- IDEALFUEL -

Lignin as a feedstock for renewable marine fuels

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Publishable summary

The maritime industry, contributing 12% of global transport energy demand and 940 million tonnes of CO2 emissions, faces challenges despite an 8% CO2 reduction from 2008 to 2015. Without intervention, emissions are projected to rise 50-250% by 2050. Decarbonization is crucial, with advanced drop-in biofuels, meeting Renewable Energy Directive II criteria, identified as effective for immediate greenhouse gas reduction. However, less than 1% of marine fuel is bio-based due to cost and sector reliance on cheap residual fuel oil.

The EU H2020 project IDEALFUEL addresses these challenges, aiming to produce cost-competitive Bio-HFO from lignin. Legal, regulatory, and pre-normative frameworks are evaluated, providing recommendations to overcome obstacles and enhance market preparedness. Success relies on factors like legislation, mandates, emission performance, and biofuel compatibility. Recent regulatory frameworks, among them FuelEU Maritime, impact fuel choice and competitiveness. IDEALFUEL's Bio-HFO, with political and strategic advantages, addresses low SOx, GHG, and NOx emissions but could face challenges between production costs and market pricing without proper regulatory frameworks.

Contents

1 Introduction

The maritime industry contributes significantly to global energy demand and CO2 emissions, accounting for 12% of total transport energy demand and 940 million tonnes of CO2 emissions globally. Despite a previous 8% reduction in CO2 emissions from 2008 to 2015, further improvements are needed. Without intervention, emissions are projected to increase by 50% to 250% by 2050, according to the International Maritime Organization (IMO).

Decarbonizing the shipping industry is challenging but crucial. Advanced "drop-in" biofuels, defined by the Renewable Energy Directive II, are considered effective for immediate greenhouse gas (GHG) reduction, aligning with 2030 targets. These biofuels, derived from Annex IX part A feedstocks, play a vital role in the European decarbonization roadmap, reducing fossil fuel dependence and utilizing non-value residues.

Currently, less than 1% of marine transportation fuel is bio-based due to the lower cost of fossil fuel alternatives and the shipping sector's reliance on cheap residual fuel oil. Advanced biofuels face challenges, including higher costs (2 to 5 times more than crude-based fuels) and insufficient production capacity to meet global demand.

In response to these challenges, the EU H2020 project IDEALFUEL aims to produce an advanced and cost-competitive biofuel, Bio-HFO, from lignin. The project involves developing a process to extract lignin from lignocellulose, which, when upgraded, becomes a suitable marine fuel. Although lignin is available in the market, its chemical characteristics need modification for efficient biofuel production. IDEALFUEL's approach aligns with the circular economy by utilizing the residual stream of lignocellulosic biomass, adding overall value to the project.

This document outlines the evaluation of the existing legal, regulatory, and pre-normative framework, which may not always align with the introduction of a new (bio)fuel, such as Bio-HFO. Legal concerns will be tackled at the EU level. Recommendations will be provided with a focus on addressing the primary legal and regulatory obstacles identified in the assessment. Additionally, the recommendations will explore measures to enhance market preparedness. Another aspect scrutinized and incorporated into the list of recommendations is the existing standardization processes for commercializing a fuel.

2 Lignin based Bio-HFO as a fuel

The transition from fossil to renewable fuels in the maritime sector is essential for reducing greenhouse gas (GHG) and other pollutant emissions like particulate matter, NOx, and SO2. Liquid renewable drop-in fuels are considered the most viable option for the mid-to-long term (30-40 years) in the maritime industry. Currently, there is minimal production of maritime biofuels in the EU. While this transition presents clear and significant benefits, meeting the extensive criteria set out in various regulatory frameworks for a new renewable fuel, particularly in the initial stages, poses challenges. Table 1-1 provides an overview of key performance, sustainability, and technology-readiness indicators for conventional fossil bunker fuels and existing biofuel alternatives.

The IDEALFUEL project focuses on utilizing lignocellulosic biomass for fuel and high-value chemicals production, with lignin being a key component. Lignin serves as a source for biofuels and biomaterials. The complex structure of lignin is depolymerized through various methods in the IDEALFUEL project, resulting in two lignin-based feedstocks: ex-softwood Crude Lignin Oil (CLO) and lignin oligomers from hardwood. The CLO undergoes hydrodeoxygenation (HDO) to reduce oxygen content and achieve physical properties compatible with Heavy Fuel Oil (HFO). The existing global regulatory framework and the maritime sector's familiarity with alternative fuels primarily center around methane (LNG) and ammonia.

Table 2.1: Overview of key features of selected biofuels vs conventional HFO.

Fuel	TRL (2019)	CO_2 reduction potential[a]	Compatible current engines	Combust. efficiency	Availability & sustainability of source[b]	Cost competitive with fossil[c]	Efficient production process
Bunker fuel oil (HFO)[f]	**9**	**0-5%**	---	---	---	---	---
Bio-LNG[d]	**5-7[1]**	**70-85%[2]**	✗	✓	✓	✓	✓
Bio-MeOH[e]	**7-9**	**60-95%[3]**	✗	✓	✓	✗	✓
BTL-diesel[f]	**5-6**	**70-90%[2]**	✓	✓	✓	✗	✓
Bio-DME[g]	**5-6[4]**	**60-95%**	✗	✓	✓	✗	✓
SVO[h]	**9[5]**	**60-80%**	✗	✗	✗	✓	✓
FAME[i]	**9**	**40-80%[2]**	✗	✓	✗	✓	✓
HVO[j]	**9**	**45-70%[2]**	✓	✓	✗	✓	✓
HTL products[k]	**6-8[1]**	**50-70%[2]**	✓	✓	✓	✗	✗
Bio-HFO (IDEALFUEL)	**3**	**60-90%**	✓	✓	✓	✓	✓

[a] Potential in well-to-propeller (WtP) reduction in CO_2 GHG emissions based on Life Cycle Analysis, taking an average value of 750 gCO_2-eq/kWh for fossil-based HFO as reference. [b] Only biofuels which can be produced from a wide range of non-edible lignocellulosic biomass feeds, which would not entail issues associated to land use or competition with the food industry, are considered to fulfill this criterion. [c] Criterion based on projection estimates to 2030 and a current cost of 450-550 €/ton for fossil ULSFO. [d] Biogenic liquefied synthetic natural gas. [e] Biogenic methanol. [f] Synthetic diesel produced via Biomass-to-Liquids process based on the Fischer-Tropsch synthesis from biosyngas. [g] Biogenic dimethylether. [h] Straight Vegetable Oils. [i] Fatty Acid Methyl Esters. [j] Hydrogenated Vegetable Oils. [k] Products from Hydrothermal Liquefaction processes.

1 http://artfuelsforum.eu/wp-content/uploads/2018/12/2018_PDB_Grijpma_Sustainable-Marine-biofuel-for-the-Dutch-Bunker-Sector.pdf

2 P. Balcombe et al. *Energ. Cov. & Managm*. 182 (2019) 72-88.

3 J. Hansson, et al. *Biomass & Bioenergy* 126 (2019) 159-173.

4 https://www.koersenvaart.nl/files/Framework%20CO2%20reduction%20in%20shipping.pdf

5 https://platformduurzamebiobrandstoffen.nl/wp-content/uploads/2018/12/2018_E4tech_Master-plan-for-CO2-reduction-in-the-Dutch-shipping-sector-Biofuels-for-shipping_Final-Report.pdf

3 Legislation framework

3.1 RED

The Renewable Energy Directive (RED) was established in 2009 to promote renewable energies within the EU. Initially, it mandated that 10% of energy in the transport sector should be sourced from renewables. In 2015, the EU Indirect Land Use Change Directive amended RED, imposing a 7% limit on fuels from resources that might compete with food production, such as soy. Subsequently, a 0.5% target for advanced biofuels was introduced. In 2018, RED underwent a revision, leading to the implementation of RED II. RED II, for the first time, outlined specific sustainability criteria and targets for biofuels. The revised directive raised the target for total renewables to 14% and set a 3.5% goal for advanced biofuels by 2030, introducing the double counting approach, wherein the contribution of advanced biofuels is accounted for twice in the greenhouse gas (GHG) balance. The use of fuels from feedstocks posing risks to food security or potential land use change will be phased out by 2030, with some EU member states committing to avoid traditional feedstocks before 2030. The Delegated Regulation (EU) 2019/807, supplementing RED II, encourages the use of low-risk resources for Indirect Land Use Change (ILUC) and those promoting improved agricultural practices. Annex IX of RED II pertains to edible feedstock for advanced fuel production. Advanced biofuels, primarily derived from residual streams, are crucial for sustainable biofuels production. The sustainable use of lignocellulosic material depends on its derivation, considering direct or indirect land use change (LUC), potential GHG emissions, and biodiversity loss.

Regarding IDEALFUEL, the feedstock material is lignocellulosic material for fuel production, as such it is essential to consider agricultural residues. The valorisation of agricultural and forestry residues is critical to increasing bioenergy capacity and adding value to feedstock without expanding land areas, thereby addressing concerns related to agricultural practices and land use change. Annex IX of RED II, Part A, lists certain lignocellulosic feedstocks available for advanced biofuels production, such as straw, bagasse, husk, nutshells, cobs, forestry residues, and non-food cellulosic material. Feedstocks outside this list are not considered for advanced fuel production, and emissions during the production phase are accounted for. EU Member States are expected to incorporate EU directives into their national frameworks, accommodating relevant national specifics. RED establishes criteria that Bio-HFO must meet to be deemed an advanced biofuel. Recognition by the EU and a certification scheme are necessary for Bio-HFO to benefit from market incentives related to sustainability performance.

3.1.1 REDIII

The revised Renewable Energy Directive (RED III), part of the Fit for 55 package, sets new targets for the EU's renewable energy share by 2030. Adopted on October 9, 2023, and in force since November 20, 2023, the directive impacts the transport sector by offering member states two options: a binding target of a 14.5% reduction in greenhouse gas intensity from renewables in transport by 2030 or a binding share of at least 29% renewables in the sector's final energy consumption. An additional sub-target of 5.5% by 2030 is set for advanced biofuels and renewable fuels of non-biological origin (RFNBOs), with a minimum requirement of 1% for RFNBOs. The share of biofuels and biogas from specific feedstocks will be considered twice its energy content. For shipping, member states with ports should aim for a 1.2% share of renewable fuels of non-biological origin in maritime transport energy from 2030. The directive's implementation requires member states to transpose it into national legislation within 18 months of its entry into force.

3.1.2 Hernieuwbare brandstofeenheden (HBEs)

As a directive, the Renewable Energy Directive (RED) needed to be incorporated into national legislations. In the Netherlands, a renewable energy unit system (HBEs: hernieuwbare brandstofeenheden) was established to ensure compliance with the annual renewable energy obligation and greenhouse gas (GHG) emissions reductions in transportation. Each HBE represents 1 gigajoule (GJ) of renewable energy delivered to the Dutch transport market, generated by claiming deliveries of renewable energy. The Dutch government utilizes a trading system under the Energy for Transport compliance system, allowing participants to collaboratively fulfil their mandatory share of renewable energy in a cost-effective manner. Various types of HBEs exist based on the raw material used for fuel production. The mandatory prioritization of advanced HBEs over conventional ones and the preference

for high-value applications (over heat) are advantageous for advanced biofuels production (Rijksdienst voor Ondernemend Nederland, n.d.).

While the shipping sector was not initially subject to the GHG emissions reduction obligation, it was included in the system through the creation of voluntary HBEs, known as "opt-ins." This inclusion aimed to stimulate the development of sustainable solutions in the shipping sector. In 2020, approximately 19 million HBEs were generated in the shipping sector. Since the beginning of 2021, only advanced biofuels (produced from feedstocks listed in Annex IX Part A of RED II) are eligible to create HBEs. In the Netherlands, double counting is applied to advanced biofuels to further incentivize their usage. It's important to note that this trading system is currently specific to the Netherlands, as other EU countries do not have implemented a similar system or mandatory legislation for the use of advanced biofuels in the maritime sector.

3.2 European Green Deal (EGD)

In December 2019, the European Commission unveiled the European Green Deal (EGD), outlining a transformative agenda. All 27 EU Member States endorsed the roadmap toward a climate-neutral economy. The EGD aims to achieve a minimum 55% reduction in emissions by 2030, relative to 1990 levels, progressing towards carbon neutrality by 2050. Operating as a catalyst for change, the EGD introduces the "Green Oath: Do No Harm" policy principle, requiring alignment with other EU initiatives (Sikora, 2020). The Fit for 55 Package, announced in July 2021, implements the EGD's objectives (European Commission, 2021b).

3.3 FITFOR55

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Fit for 55 comprises a comprehensive set of legislative proposals targeting a 55% reduction in emissions across various sectors by 2030, compared to 1990 levels. Notably, the shipping industry is incorporated into these proposals through specific policies:

1. **Revision of the Renewable Energy Directive II:**

Aims to progressively increase the use of renewable and low-carbon fuels in the EU. The previous targets, such as the 14% share of renewable energy for transport and the 3.5% sub-target for advanced biofuels (subject to double counting), are replaced by a 13% greenhouse gas (GHG) intensity reduction target for transport, with a sub-target of 2.2% for advanced biofuels by 2030. Certification of fuels, such as IDEALFUEL's Bio-HFO, plays a crucial role in compliance. The ongoing revision of Annex IX aims to enhance the feedstock list's clarity and potential inclusion of new materials.

2. **Introduction of the Fuel EU Maritime Initiative:**

Aims to decarbonize the shipping industry by increasing the use and production of renewable and low-carbon maritime fuels. Targets a fleet-wide reduction in GHG emissions, starting with 2% by 2025 and progressing to 75% by 2050. Biofuels meeting sustainability criteria are considered, and IDEALFUEL's Bio-HFO must adhere to Directive (EU) 2018/2001 for certification. The initiative initiates market-based measures wherein shipping companies must purchase and surrender emission allowances for their reported CO2 emissions.

3. **Revision of the Alternative Fuels Infrastructure Directive:**

Aims to enhance the development of infrastructure for renewable and low-carbon fuels. IDEALFUEL needs to assess how these developments align with its Bio-HFO infrastructure requirements.

4. **Gradual Inclusion in the EU Emissions Trading System (EU-ETS):**

Fit for 55 envisions the gradual inclusion of the maritime sector into the EU-ETS starting in 2023. This system establishes a cap on maritime GHG emissions, requiring a 61% reduction by 2030 compared to 2005 levels. The reduction will be implemented gradually, and ships over 5,000 gross tonnages must purchase and surrender

emission allowances for their CO2 emissions. This market-based measure aims to make emissions reduction cost-effective (European Commission, n.d.).

5. **Revision of the Energy Tax Directive:**

Involves a reassessment of tax exemptions for conventional fossil fuels used in intra-EU shipping. The potential introduction of carbon taxes and a minimum tax level on fossil fuels across EU countries can indirectly impact IDEALFUEL's Bio-HFO market position.

Proposals from the aviation sector, such as Emissions Trading System (ETS) for aviation, ETD tax rates for aviation, and ReFuelEU Aviation, may also influence the shipping sector, affecting feedstock availability due to competitive use for fuel production.

3.3.1 ReFuelEU (Maritime initiative)

The FuelEU Maritime Initiative is a crucial component of the Fit for 55 package, introduced by the European Commission in July 2021 to achieve a 55% reduction in net greenhouse gas emissions by 2030 and climate neutrality by 2050. Following negotiations between the Transport Council and the European Parliament, a provisional agreement was reached on March 23, 2023.

The initiative's primary goal is to boost demand for renewable and low-carbon fuels, thereby reducing greenhouse gas emissions in the shipping sector. The legislation aims to align maritime transport with the EU's climate targets for 2030 and 2050. Key provisions include a gradual reduction in the greenhouse gas intensity of shipping fuels, incentives for renewable fuels of non-biological origin, exclusion of fossil fuels from certification, a requirement for on-shore power supply for passenger ships and containers in major EU ports from 2030, a voluntary pooling mechanism for compliance, and exceptions for specific regions and economically dependent areas. The regulation also outlines the utilization of revenues (FuelEU penalties) for decarbonization projects in the maritime sector, with enhanced transparency, and emphasizes monitoring through the Commission's reporting and review process.

Key provisions of the regulation include a gradual reduction in the greenhouse gas intensity of shipping fuels from 2% in 2025 to 80% by 2050, a special incentive regime for high-decarbonization potential renewable fuels of non-biological origin, exclusion of fossil fuels from certification, and a requirement for passenger ships and containers to use on-shore power supply at major EU ports by 2030 to reduce air pollution. The regulation applies to vessels above 5,000 gross tonnes, responsible for 90% of CO2 emissions from the maritime sector. Revenues from the regulation will fund projects supporting maritime decarbonization, with monitoring conducted through the Commission's reporting and review process.

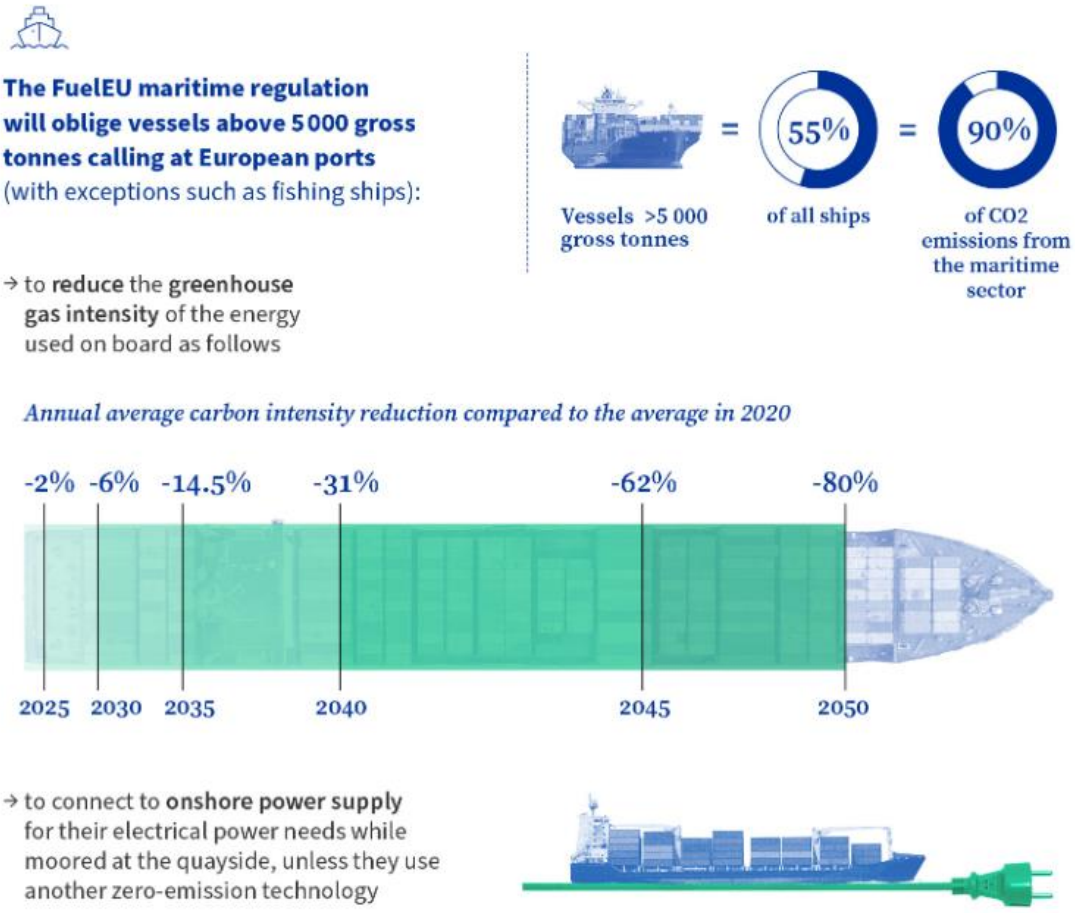

Figure 3.1: Infographics on ReFuelEU Maritime.

3.3.1 Energy Taxation Directive (ETD)

The Fit for 55 proposal by the EU extends decarbonization measures to the maritime industry, incorporating a revision of the Energy Taxation Directive (ETD). The update aims to align with current climate objectives, incentivize clean technology investment, and eliminate favoritism towards fossil fuels. The revised ETD is set to take effect in January 2023, with a minimum exemption period for alternative fuels until 2033. The European Parliament's Economic and Monetary Affairs Committee has temporarily suspended work on the proposal until March 2023. The ETD may tax bunker fuels sold and used within the EU, with transitional exemptions for sustainable fuels during the initial ten years. Options under discussion include intra-EU shipping, minimum rates for intra-EU operations, and potential inclusion in the EU Emissions Trading System. The proposal is subject to ongoing discussions and may undergo changes during deliberations by the EU Parliament and Council. Considerations include a comprehensive assessment of the Fit for 55 package, a heavy fuels tax for the maritime sector, tax exemptions for 'clean' energy sources in shore-side electricity, and the possibility of basing taxation rates on energy content rather than volume

3.4 EU Sulphur Directive (Directive (EU) 2016/802)

Directive (EU) 2016/802, commonly known as the 'Sulphur Directive,' regulates sulphur emissions from ships within the EU. Since January 1, 2010, the directive mandates that ships, regardless of their flag, berthed in EU ports must use fuels with a sulphur content limit of 0.1%. Fuel changeovers should be initiated upon berthing and as close to departure as feasible. Exemptions apply to ships with berthing times less than two hours according to a published timetable and those transitioning entirely to shoreside electricity supply. The term 'berthed' includes securely moored or anchored ships in an EU port during loading, unloading, or hotelling, even during periods without cargo operations (Directive (EU) 2016/802).

4 International Regulatory Framework

The international regulatory frameworks play a crucial role in establishing targets and imposing constraints, serving as the foundation for defining the criteria that fuels must meet and exerting significant influence in the market. Despite the substantial potential of advanced biofuels in reducing CO2 emissions, their production is often more costly than their fossil counterparts due to lower technological maturity and scale. Consequently, market interventions become imperative to promote the utilization and acceptance of advanced fuels. In the context of IDEALFUEL's Bio-HFO, the international regulations set by the International Maritime Organization (IMO) and EU directives will profoundly shape market opportunities.

4.1 SOLAS Convention

The use of fuels is regulated by the International Maritime Organization (IMO) through the International Convention for the Safety of Life at Sea (SOLAS). The regulations for conventional fuel oils are prescriptive and based on decades of experience. Utilizing fuels with a flashpoint below 60°C (defined as Low Flashpoint Fuels) has generally been prohibited to prevent tank explosions and fires. In 2015, the SOLAS Convention was amended to allow the use of low flashpoint fuels for ships complying with the International Code of Safety for Ships Using Gases or Other LowFlashpoint Fuels (IGF Code).

Recent amendments to Regulation 4.2.1 of Chapter II-2 of SOLAS are set to take effect on January 1, 2026. These amendments address the lack of regulatory control in the bunker industry by ensuring the safety of bunkers. Key provisions include determining flashpoints in accordance with ISO standard 2719:2006, accreditation of test laboratories with ISO/IEC 17025:2017, bunker suppliers providing a declaration and delivery note specifying flashpoints, and notification requirements for bunkers supplied below a flashpoint of 60˚C. Contracting states must take appropriate action against non-compliant bunker suppliers, with specific measures left to their discretion. Stakeholders are advised to prepare for these amendments and align their practices with the new requirements.

4.2 IGF Code

The IGF Code provides an international standard for the safety of ships using low-flashpoint fuel, other than gas carriers which have to comply with separate requirements in the IGC Code (see 4.3). The IGF Code requires that the safety, reliability and dependability of the systems shall be equivalent to that achieved by new and comparable conventional oil-fuelled main and auxiliary machinery. The IGF Code specifies a set of functional requirements applicable for all fuel types covered by the Code, but only contains specific design requirements to LNG. Specific design requirements for other low-flashpoint fuels will be added as, and when, they are developed by the Organization. Until such regulations are in place, approval of ships using other fuels than LNG will be based on first-principle analysis demonstrating that the design complies with the basic functional requirements of the IGF Code. This risk-based approval process is referred to as the 'alternative design' approach, where an equivalent level of safety needs to be demonstrated. The alternative design approach can be a time-consuming process with a high degree of uncertainty and therefore potentially higher business risk than the prescriptive experience-based rules that the maritime industry is used to working with. This must be considered as a barrier against uptake of alternative fuels in the industry.

4.3 IGC Code

The IGC Code establishes a global standard for the secure maritime transportation of liquefied gases in bulk. While it features a dedicated chapter addressing the utilization of cargo as fuel, it explicitly prohibits the use of cargoes classified as toxic products, such as ammonia, for this purpose. Consequently, the current version of the Code does not authorize gas tankers to employ ammonia as a fuel source. Notably, ammonia is transported as cargo in substantial quantities via gas carriers. Nevertheless, the stipulations outlined in the IGC Code can offer valuable guidance on designing fuel storage systems especially when the IDEALFUEL Bio-HFO contains significant amounts of methanol.

4.4 IMO MARPOL

The responsibility for governing greenhouse gas (GHG) emissions from international shipping falls under the United Nations Framework Convention on Climate Change (UNFCC), particularly through the International Maritime Organization (IMO). The IMO's main objective is to establish a comprehensive regulatory framework for shipping, covering safety, environmental concerns, and efficiency. The International Convention for the Prevention of Pollution from Ships, adopted in 1973 and modified in 1978, addresses marine pollution through technical Annexes with regulations to prevent and minimize pollution. The most important policies under MARPOL Annex VI affecting GHG emissions and biofuel adoption are the **Energy Efficiency and Design Index**, the **Ship Energy Efficiency and Management Plan** and the implementation of **Emission Control Areas.**

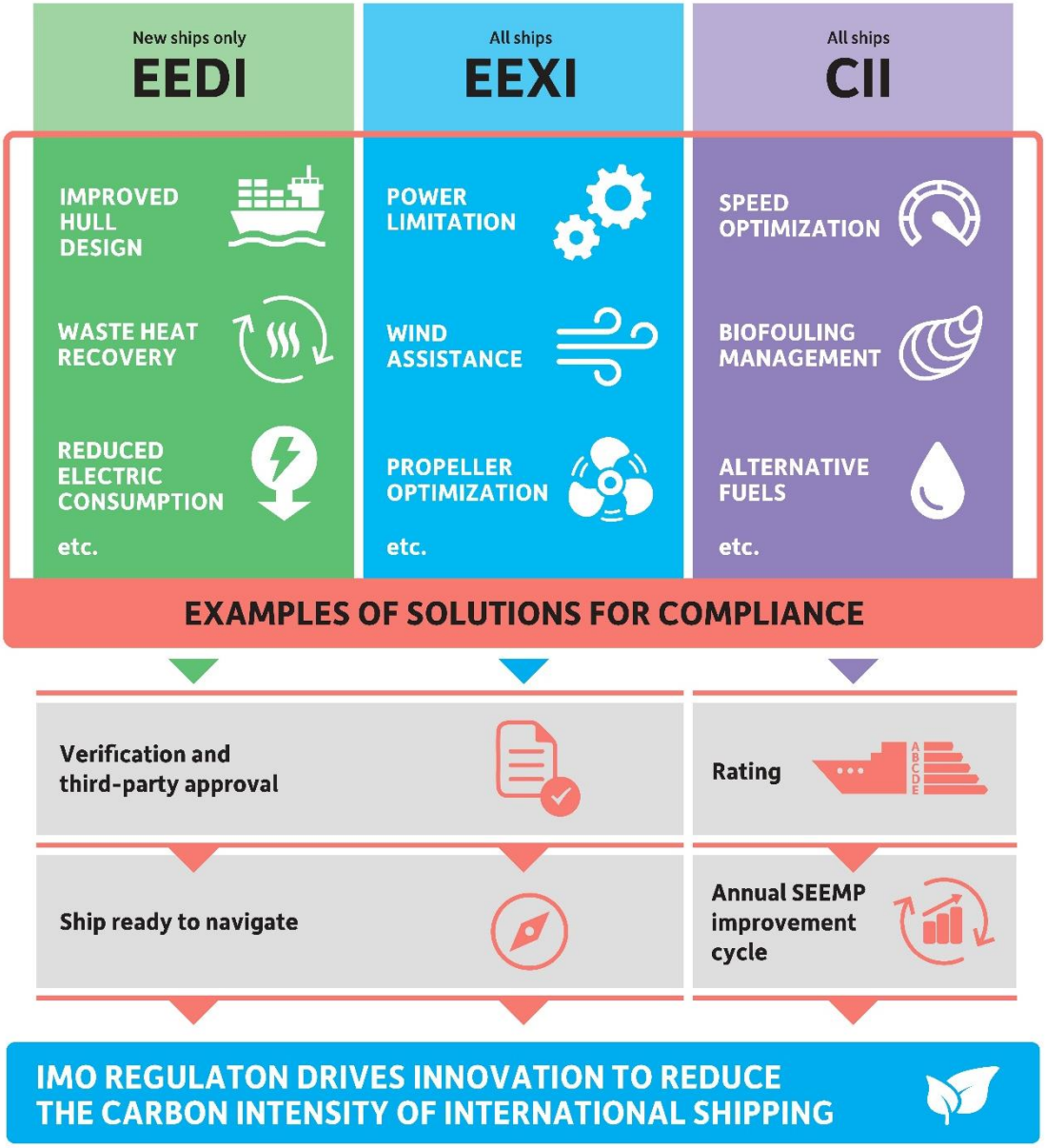

Figure 4.1: IMO strategy on reduction of GHG emissions from ships [1]

4.4.1 Energy Efficiency and Design Index (EEDI)

The Energy Efficiency Design Index (EEDI) is a technical measure promoting the use of more energy-efficient equipment and engines in newbuild ships, measured in grams of carbon dioxide per ship's capacity-mile. It applies to ships of 400 gross tonnage and above, engaged in international voyages, excluding certain types like platforms and non-mechanically propelled vessels. The EEDI sets a minimum energy efficiency level for various ship types, requiring a CO2 reduction of 30% for newbuilds in 2025, calculated from a reference line based on the average efficiency of ships built between 2000 and 2010. Shipyards calculate the EEDI, verified by classification societies, and the CO2 reduction levels will be tightened every five years starting in 2025. The European Union aims to publish the technical efficiency (EEDI or EIV) for each ship calling at EU ports as part of its Monitoring, Reporting, and Verification (MRV) regulation on emissions from maritime transport.

4.4.2 Ship Energy Efficiency and Management Plan (SEEMP)

The Ship Energy Efficiency Management Plan (SEEMP) is a ship-specific plan designed to enhance a ship's energy efficiency. Ships of 400 gross tonnage and above engaged in international voyages must develop and maintain a SEEMP, following IMO guidelines. The SEEMP focuses on monitoring and improving energy efficiency by estimating current energy consumption, implementing measures like hull and propulsion improvements, automated engine management, voyage planning, and speed optimization. Establishing an efficiency goal, such as annual fuel consumption or the Energy Efficiency Operational Indicator (EEOI), is crucial for incentive. Part II of the SEEMP, applicable to ships 5,000 GT and above, addresses fuel oil consumption data reporting. Part III, introduced in 2023, focuses on the ship's operational carbon intensity under short-term MARPOL measures, requiring calculations, reporting processes, future CII plans, self-evaluation, improvement, and corrective actions. The IMO approved 2022 Guidelines for SEEMP development, including the newly added Part III to record information related to the short-term greenhouse gas reduction measure.

4.4.3 Emission Control Areas (ECA)

Emission Control Areas (ECAs) were established in 2005, imposing stricter limits on nitrogen oxide (NOx), sulfur oxide (SOx), volatile organic compounds (VOC), and particulate matter (PM). In 2018, the IMO adopted a strategy to reduce GHG emissions by 40% in 2030 and 50% in 2050 compared to the 2008 baseline. This has led to increased investment in research and development, infrastructure, and trials to support new technologies and fuels. Approximately 70% of current fuels in the market may need to be replaced with sustainable fuels to meet these targets. European targets and goals for the maritime sector are still under definition, with ongoing legislative developments that may impact renewable fuels.

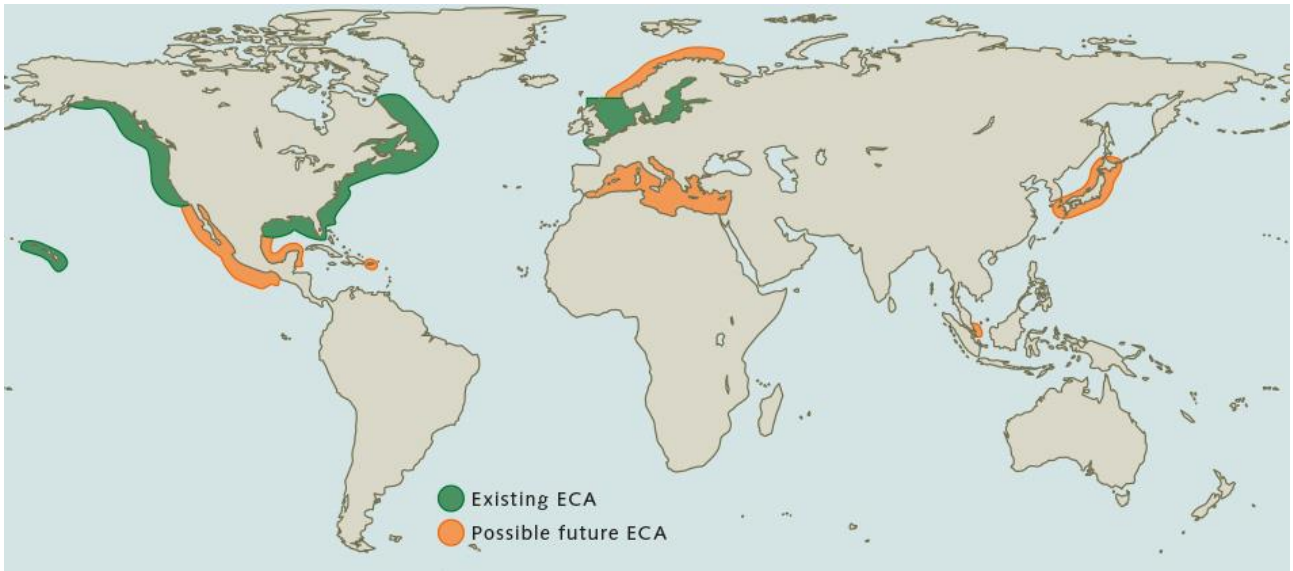

Figure 4.2: Existing and possible future ECA.

5 Conclusions and Recommendations

The success of IDEALFUEL's Bio-HFO in the market hinges on various variables, among them legislation, mandates, and incentives; emission performance. Existing and upcoming legislation provides a favorable market environment for biofuel adoption, necessitating compliance with norms and directives. For Bio-HFO to be deemed an advanced fuel, the raw material must be classified as waste, with lower compliance risks if lignin is a secondary residue within the process. However, this requires careful consideration of engineering, process design, and political factors. This report delved into the regulatory landscape concerning the European Economic Area (EEA). Legislative mandates emerge as pivotal drivers shaping the trajectory of advanced biofuels in the market, potentially influencing their share. However, as presented above, the impact of legislative mandates on the maritime sector remains a subject of ongoing discourse. Presently, these mandates serve as valuable guidelines for the future but are subject to continuous reassessment.

Over the years the European Commission and IMO have proposed and implemented various regulatory frameworks to reduce emissions in the maritime sector. Classification Societies tend to have a faster rule development cycle than IMO and EU. When a Classification Society has developed a set of rules covering the use of a fuel where specific design requirements are not included in the IGF Code, a Flag Administration may accept the application of this rule set to ease the alternative design approach. A set of class rules may also form a basis for developments of international regulations in IMO and EU.

Recently design options have been implemented in the FuelEU Maritime framework, each impacting the choice of renewable low-carbon fuels for compliance by ships. Despite potential cost increases, the competitiveness of ocean-going shipowners is expected to remain unaffected, as the regulation applies to all ships visiting EU ports. However, in coastal shipping, where short-sea shipping competes with land and inland transport, the relative cost increase is larger.

Advanced bioenergy is seen as a catalyst for emission reduction and enhancing energy supply security. The diversification of feedstock ensures the fulfillment of these demands. Given these potential impacts political regulatory measures play a substantial role in shaping the bio-based market's evolution. It is essential to recognize that the development of the biofuel market is intricately linked to both technological advancements of the IDEALFUEL project and the (socio-)political and environmental context. The mission performance of the Bio-HFO is expected to be a political and strategical marketing advantage, particularly in addressing SOx, GHG, and NOx emissions, with a focus on GHG emissions linked to feedstock classification. Fuel compatibility, crucial for uptake, depends on a broad blending range, necessitating attention to specific tests and achieving product characteristics equivalent to fossil counterparts. In the end a balance of fossilization and product quality poses a trade-off between production costs and market pricing, requiring careful consideration as more information about the IDEALFUEL Bio-HFO becomes available.

6 References

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7 Risk Register

Risk No.	What is the risk	Probability of risk occurrence[1]	Effect of risk[1]	Solutions to overcome the risk
1	Feedstock cannot be considered as waste according RED.	2	1	Engage on lobbying discussion. Marketing of cellulose stream must be prioritized.
2	Lower regulation targets and carbon price .	3	2	Reduction in production cost must compensate a lower carbon price and decreased demand.
3	Low stability or compatibility with HFO or fossil-based fuels.	2	1	Process design working together with product testing.
4	Low oil prices	1	2	Minimize production costs and GHG emission to benefit from the carbon market.
5	Quicker market uptake of other lignocellulose-based fuels	2	1	Accelerate end user tests. Cost optimization.
6	Market tendency towards other alternative fuel: Methanol, LNG.	1	2	Accelerate end user tests. Cost optimization. Lobbying.

[1)] Probability risk will occur: 1 = high, 2 = medium, 3 = Low

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Project partners:

#	Partner short name	Partner Full Name
1	TUE	Technische Universiteit Eindhoven
2	VERT	Vertoro BV
3	T4F	Tec4Fuels
4	BLOOM	Bloom Biorenewables Ltd
5	UNR	Uniresearch B.V.
6	WinGD	Winterthur Gas & Diesel AG
7		(Formerly SeaNRG, is now GOODFUELS #12)
8	TKMS	Thyssenkrupp Marine Systems GMBH
9	OWI	OWI – Science for Fuels gGmbH
10	CSIC	Agencia Estatal Consejo Superior De Investigaciones Cientificas
11	VARO	Varo Energy Netherlands BV
12	GOOD	Goodfuels B.V.

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