The Development of Alternative Fuel Infrastructure in Irish Ports

A Feasibility Study

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1.0

Executive Summary

Transportation across the European Union is almost entirely dependent on fossil fuels. To help reduce this dependency and the associated harmful environmental effects, the EU Commission established an alternative fuels strategy. The strategy identified the lack of supporting infrastructure as a key obstacle to the uptake of alternative fuel technology. As a result, EU Directive 2014/94/EU was developed to address these issues and was published in November 2014.

In the maritime sector, the directive obliges Member States to install shore-side electricity (SSE) for seagoing ships in the ports of the TEN-T Core Network[1] . In addition, Member States must ensure that an appropriate number of liquefied natural gas (LNG) refuelling points are put in place at maritime ports to enable vessels using LNG to circulate throughout the TEN-T Network. These objectives are to be met by 31 December 2025, unless there is an absence of demand or the relevant costs are disproportionate to the benefits. Motivated by the EU directive, this report has two distinct aims. First, to conduct a feasibility study of SSE for seagoing ships in TEN-T Irish ports and secondly, to assess the market demand for LNG fuelling facilities in major Irish ports.

To accomplish the report's objectives, it is important to understand where best practice has occurred in terms of Alternative Fuel Infrastructure (AFI) deployment. The report examines the factors that determine locational or sectoral concentrations in the deployment of AFI, and discusses the applicability of these factors to the Irish context. The report reaches conclusions about the feasibility of the deployment of AFI in Irish ports.

Our research finds that successful AFI deployment has been achieved where geographic, economic, technological and regulatory factors align. These conditions are present in large trading ports such as Rotterdam, Antwerp, Los Angeles, and Vancouver, as well as geographic clusters in Scandinavia that include the ports of Oslo and Gothenburg. Each location has developed effective installations of both shore side power technology and LNG fuelling facilities.

From an economic standpoint, the ports listed benefit from favourable economic environments, within which the per unit cost of electricity and/or natural gas falls below European averages (Eurostat, 2019). For example, the per KWh cost of electricity to industry in Norway and in British Columbia is approximately half that of Ireland, which was among the five most expensive countries in Europe in 2017 (Government of Canada, 2019; Eurostat, 2019). A lower per unit cost of electricity allows shore side power provided by the port to become more competitive relative to traditional auxiliary fuel sources used by ships while at berth.

Many economic advantages however, are derived from natural resources available to these and other ports with successful AFI installations. The Netherlands and Norway have significant reserves of natural gas. Norway supplies one third of all natural gas imported from outside the EU, while The Netherlands is the second largest supplier inside the bloc (Eurostat, 2019). Such abundant natural resources allow both countries greater flexibility in terms of price and installation when considering LNG infrastructure at ports. Regarding electricity production, two thirds of all electricity production in Canada and Norway is from renewable sources (Statistics Norway, 2019; Government of Canada, 2019). Hydroelectricity is a significant source of power in both countries, with Canada the second largest producer of hydroelectric power in the world (Government of Canada , 2019). Similar to large natural gas resources, significant renewable electricity production capacity allows countries to drive down per unit costs, increasing the likelihood of successful AFI development.

Favourable economic and geographic environments are necessary but not sufficient to stimulate the successful development of AFI. A regulatory environment that demands and/or incentivises AFI is commonplace in ports that have successful developments. The IMO and EU have been the most active bodies in the imposition of stringent regulation geared towards

[1] Trans-European Transport Network (TEN-T): This is an EU policy that aims to build an effective, EU-wide transport network of roads, railways, airports and waterways.

the abatement of harmful emissions. The most significant stimulus came from the IMO – in the form of the International Convention for the Prevention of Pollution from Ships (MARPOL) – labelled Annex VI (IMO, 2014; DNV GL, 2019). Coming into force in 2005, it targeted reductions in nitrogen (NO_X) and sulphur (SO_X) oxides and created Emission Control Areas (ECA's) wherein ships must adhere to stricter emission standards. All of the ports listed above, as well as any significant cluster of ports with AFI installations, lie within these ECA's. Ireland currently lies outside of these areas.

Outside of favourable economic and geographic conditions and a stringent regulatory environment, scale of operations was found to be a common influence in the successful deployment of AFI. Rotterdam and Antwerp were the two largest ports in Europe in 2017 (Eurostat , 2019), while L.A. is the largest container port in North America (U.S. Dept of Transportation, 2018). The scale of operations in these ports gives rise to a significant number of vessel calls each year, increasing the likelihood of demand for alternative fuelling facilities such as LNG. In addition, ports of such scale are often located in close proximity to large urban centres. This proximity often results in easy access to an electricity grid capable of handling shore side power facilities for ships.

Such scale is closely correlated with successful deployments of AFI, allowing ports to generate predictable, forecastable demand, which is a prerequisite for any form of large capital investment. Scale also allows ports the opportunity to undertake trial installations to establish underlying demand. Both provide ports with the opportunity not only to become champions of alternative fuels, but market leaders in their provision. This potential to create market change improves the likelihood of capital investment in AFI.

Taking the aforementioned drivers into account, the report considered the demand for, and feasibility of, AFI in Irish ports. The report found that many of the characteristics evident at current AFI locations are not present at Irish ports. Ireland does not gain from geographic conditions favourable to local natural gas production or to renewable energy production on the scale outlined in previous examples. Therefore, Ireland's price competitiveness is relatively low in the market for alternative and renewable energy. In addition, Ireland currently falls outside the Emission Control Areas, wherein the most stringent regulatory standards are applied. Lastly, the scale of operations in Irish ports and the number of ships calling to them does not generate sufficient demand to justify the capital investment that AFI requires. As a result, forecasted demand for alternative fuelling facilities or SSE in Irish ports is low.

In reaching these findings, the IMDO undertook an assessment of market demand for AFI in Irish ports, as well as an analysis of the financial viability of potential investments in such infrastructure. In addition to this quantitative research, the IMDO engaged extensively with industry stakeholders to gain clarity on the barriers which they see to investing in AFI. The findings from these consultations follow the pattern of assessment outlined above. Many industry leaders highlight their concerns that the forecasted demand does not justify large scale capital investment in AFI, and that the Irish regulatory environment is not a barrier to current methods of operation.

Irish ports expressed the view that because the debate in relation to the future usage of alternative fuels remains unsettled, prudence demands that large scale capital investment should be avoided until stable demand conditions are established.

2.0

Introduction

There is a pressing need for research into the development of Alternative Fuel Infrastructure (AFI) for the maritime industry. Ambitious objectives for the reduction of harmful emissions have been set in national and international policies. Some of the most far-reaching emissions targets affecting the maritime industry have been set within the last five years, including, but not limited to; The 2015 Paris Climate Agreement, the International Maritime Organisation's (IMO) 2018 Greenhouse Gas (GHG) reduction target of 50% versus 2008 levels by 2050, as well as the IMO's 2020 Sulphur Cap requiring an 85% reduction in sulphur oxide (SO_X) emissions. Compliance with these policies and regulations requires ship owners and ports to invest in low carbon alternatives.

However, as DNV GL's[2] Maritime Forecast to 2050 report shows, these stringent emissions regulations are being advanced in an era of significant growth in the maritime industry (DNV GL, 2018). The report forecasts a 32% rise in seaborne trade[3] up to 2030, which will coincide with a commensurate increase in capacity (DNV GL, 2018 p.10-12). The challenge for the maritime industry will be to meet the new standards for emissions without compromising trade growth. The forecasts outlined in the report however, are optimistic, predicting that by 2050, 39% of shipping energy will come from carbon-neutral fuels and 34% will come from liquid fossil fuels (DNV GL, 2018 p.38). Notably, the report specifically highlights the challenges associated with the provision of adequate AFI (DNV GL, 2018 p.96).

In Ireland, the Climate Action Plan (CAP) 2019 outlines the government's plans to reduce GHG emissions, setting targets out to 2050. The report finds that transport accounts for approximately 20%[4] of all Irish GHG emissions. This is roughly in line with EU averages, however, the carbon intensity of this sector – standing at 2.6 $MtCO_2$eq. per capita, - is higher than the EU average, with Ireland emitting 40% more CO_2eq. per capita (CAP, 2019). It is notable that 96.7% of all transport energy in Ireland was generated from fossil fuels in 2017, and that overall Irish GHG emissions are set to rise by 25% by 2040 in the absence of corrective measures.

Like the Maritime Forecast to 2050, the CAP highlights that Ireland will have to tackle these challenges in a period of significant growth. The report acknowledges that there is a close correlation between transport emissions and economic activity. As a result, the forecasted increase in the Irish population of 1 million by 2040, coupled with a forecasted economic growth rate of 8.2% in 2018, increases the decarbonisation challenge in maritime transport. To tackle these issues, Ireland's CAP recognises that the most efficient avenue for Irish transport would see a 45-50% reduction in emissions by 2030, an increase in electric alternatives for heavy freight transport and the development of an electricity grid capable of improving the utilisation of offshore renewable energy around Ireland's coasts.

The research carried out by the IMDO reaches conclusions that are directly relevant to Ireland's transport decarbonisation challenge. The increased use of LNG in the maritime sector can mitigate some of the harmful NO_X and SO_X emissions, and is regarded as a stepping stone towards lower carbon emissions. SSE can provide significant improvements in local air quality, an issue which the CAP says "cannot be ignored" (CAP, 2019 p.85). In addition, designated emission reduction zones can be a significant driver of SSE provision, and the CAP calls for increased discretion for local authorities in the designation of these zones (CAP, 2019 p.87).

Our research has shown that the use of alternative fuels in the maritime industry is influenced by many factors that raise questions as to the economic feasibility of AFI in Ireland. It is important to understand the relevant technologies, or combination of technologies, that are available in greater detail. The technology underpinning the AFI focused on in this report is well established. Studies aimed at assessing the economic feasibility of SSE can be found as far back as

[2] DNV GL provide consultation & expertise on energy infrastructure and technical standards for the shipping industry.
[3] As measured in trillion tonne-nautical miles per year for 2016– 2030 (DNV GL, 2018)
[4] Transport accounted for 19.8% of Irish GHG emissions in 2017 (CAP, 2019).

MariTermAB's 2004 report for the North Sea Commission. Similarly, academic investigations into the adoption of natural gas as a fuel source can be found as far back as the 1980's, with Fallen Bailey & Moreno's 1989 study of compressed natural gas in domestic vehicles.

The reasons behind our failure to achieve widespread adoption of alternative fuels in ports and in shipping are multi-faceted, but Von Rosenstiel et al (2014) argue that;

> *"If the evolution of a market depends on the presence of another market, failure of coordination between both can inhibit their respective development"* (p.93).

Such could be said of the complimentary relationship between the market for alternative, cleaner fuels and the associated port infrastructure required to support it. For a given level of clean fuel demand, too many bunkering terminals and/or overinvestment in shore side facilities, will reduce the profitability of both shipping companies and ports, whereas too few create queues and inconvenience, also leading to reductions in profitability. Both situations cause investment to stall, as coordination failure prevents demand and supply side factors from being reconciled (Von Rosenstiel, et al., 2014). Finding the optimal balance is not straightforward and continues to be a barrier to large scale adoption today, even in the face of increasingly stringent regulation;

> *"Conversions are being stalled due to a lack of options for LNG bunkering. What owners require more than anything else is confidence that they can obtain fuel when they need it – and today that isn't there."*
>
> -Andrew Pickering, CEO Avenir LNG Ltd (Tutturen, 2019).

Government intervention may therefore be required. Collantes & Melaina (2010) studied the co-evolution of AFI and vehicles in Argentina and found that government intervention is most effective when in the form of promotion and the assurance of credibility of the infrastructure, rather than its provision. The authors argue that provision is often more effective when undertaken by the private sector. Furthermore, Yeh (2007), in an empirical analysis of alternative fuel adoption across several countries, finds that government *"at all levels"* is one of five essential stakeholders involved in AFI adoption (p.5868). The author finds that market creation policies and price/tax specific incentives - targeted towards the vehicles and the fuel suppliers - were the most commonly used policy tools employed for AFI adoption across eight countries (Yeh, 2007).

Overall, research surrounding AFI points to a significant role for government, wherein a matrix of policy tools is employed targeting not only tax and regulation issues, but market creation through the provision of necessary infrastructure. This research is important because it has the potential to identify the factors that must change to achieve feasibility and the tipping points that must be reached in order to stimulate investment from the private sector or from government.

The report is structured as follows;

- Section 2 outlines the research methodology employed by the authors.
- In section 3, explanations of the technology behind Liquefied Natural Gas as a marine fuel and SSE infrastructure at ports is provided. A brief description of emerging marine fuel technologies designed for the reduction of harmful emissions is also provided. These include battery powered engines, hydrogen fuel and Exhaust Gas Cleaning ('Scrubber') Systems.
- Section 4 provides an illustration of where AFI is currently in operation, broken down by industry sector and geographic location. Following this, an investigation into the drivers of demand for AFI in the regions identified is undertaken. In doing so, this section outlines the macro-environmental characteristics of regions with successful AFI development from an economic, political and regulatory perspective.
- Section 6 employs the preceding research into AFI best practise and applies the information to an Irish context. A financial viability assessment is undertaken to illustrate the likely conditions necessary for AFI development at Irish ports. Lastly, findings and recommendations are presented.

3.0

Methodology

In order to achieve the reports two distinct objectives - a feasibility study of SSE adoption and an assessment of market demand for LNG infrastructure at Irish ports - the authors used a mixed-methods approach. This approach was decided upon because the above objectives cannot be addressed by relying exclusively on either quantitative or qualitative methods.

With regard to the feasibility of SSE and the assessment of market demand for LNG, quantitative financial analysis is undertaken. However, this approach has limitations. First, it is unclear how relevant existing data is in the context of the Irish market. Second, as the industry for alternative shipping fuels is a nascent one, historic data is not always readily available, making time series analysis relatively unreliable. Lastly, quantitative techniques cannot adequately capture the views and attitudes of stakeholders towards the use of alternative fuels in shipping, mainly because of the uncertainty that exists in relation to the evolution of science and technology in this emerging area.

To address these methodological limitations, qualitative research - in the form of semi-structured interviews - was carried out with industry stakeholders. The objective was to go beyond quantitative analysis in understanding the views and concerns that exist within the shipping and ports sectors in relation to the demand for alternative fuels and the infrastructure that will be needed to service that demand.

The IMDO engaged directly with industry at the Norshipping Conference and Trade Show in Oslo (1-4 June 2019). The event attracted over 900 exhibitors from 48 countries. Our researchers conducted interviews and discussions with international port companies, shipping companies, engine manufacturers, scrubber manufacturers, classification societies and national administrations. In order to understand the Irish context, semi-structured interviews were also conducted with Irish Ports, as well as shipping companies operating in Irish waters[5]. At the end of this report, seven vignettes are presented which provide additional insight into this consultation process.

A systematic literature review was also carried out using the Business Source Complete and Google Scholar databases. Extant literature relevant to the study was integrated into the report. Finally, the DNV Alternative Fuel Insights Platform was used extensively for quantitative information regarding market demand for alternative fuels.

[5] For further information on the industry stakeholders whose views were personally consulted throughout the process, see *Appendix A*.

4.0

Alternative Fuels Explained

The shipping industry is under increasing pressure to reduce emissions. Developments in fuel propulsion and berthing technology are currently focused on eliminating Nitrogen Oxide (NO_X) and Sulphur Oxide (SO_X) particulate emissions, although reductions in greenhouse gas (GHG) emissions remain a priority for the near future.

Alternatives to the sustained use of traditional, oil based fuels include, but are not limited to; Liquefied Natural Gas (LNG) and Shore Side Electricity (SSE). SSE allows ships to shut off oil based engines while at port, instead providing electricity on board by way of a port-side grid connection. Some propulsion fuels emerging as cleaner options include Hydrogen and Battery power, though further development is ongoing to enable wide scale application across different vessel types and sizes in the world's shipping fleet.

In addition, Exhaust Gas Cleaning Systems (ECGS) - also known as scrubbers - offer a competitive alternative to the aforementioned propulsion fuels in meeting emission requirements. Scrubbers allow vessels to continue to use conventional oil based fuels, as the scrubber systems capture and store harmful emissions that can be disposed of at suitable locations. While strictly not a fuel option, the growing use of scrubber technology influences market transition from conventional oil based fuels, to alternative fuels.

i) Liquefied Natural Gas (LNG)

LNG is a globally recognised, commercially viable fuel option and is available worldwide in quantities capable of meeting the fuel demand of ships over the coming decades. LNG technology enables ships to meet existing and upcoming emission requirements. The International Maritime Organisation (IMO) specifically encourages and incentivises LNG as a means of meeting its emission standards - particularly its upcoming 2020 Sulphur Cap, whereby sulphur emissions from fuel oil must be reduced by approximately 85% within designated emission controlled areas (IMO, 2019).

Replacing conventional oil based fuels (heavy fuel oil or marine gas oil) with LNG provides improvement in local air quality primarily through the reduction of SO_X and NO_X emissions, as well as carbon dioxide, particulate matter (PM) and black carbon. Specifically, LNG fuel provides for the complete removal of SO_X and PM emissions, a reduction of NO_X emissions of up to 85% and a potential reduction of CO_2 emissions of 20% (Anderson, et al., 2015). As a result, the case for conversion to LNG propulsion is strong, especially in coastal areas and sensitive ecosystems.

However, studies have highlighted that emissions of carbon monoxide and hydrocarbons (e.g. unburnt methane known as "methane slip") could result in *higher* greenhouse gas emissions from LNG ships (Anderson , et al., 2015). Gas carriers around the world have been using LNG as part of their fuel source for decades and as a result, many of the associated risks are long understood. Methane slips have been reduced in many cases, and eliminated in others. The development of engine tanks - the largest expense involved in the conversion process - is still underway (DNV GL, 2019).

With regard to government led involvement, centralised funding from the Connecting Europe Facility (CEF) for Motorways of the Sea actions has included LNG under its environmental pillar. By way of example, there was a successful funding application for *RealNG*, an EU initiative to provide LNG infrastructure in the North Sea – Baltic Corridor (See *Appendix B*).

ii) Shore Side Electricity (SSE)

Shore side electricity (SSE) enables ships to shut down their engines while berthed and plug into an onshore power source. The ship's power load is transferred to the shore side power supply without disruption to onboard electricity provision. SSE is also known as Shore Connection, Shore-to-ship Power or Cold Ironing.

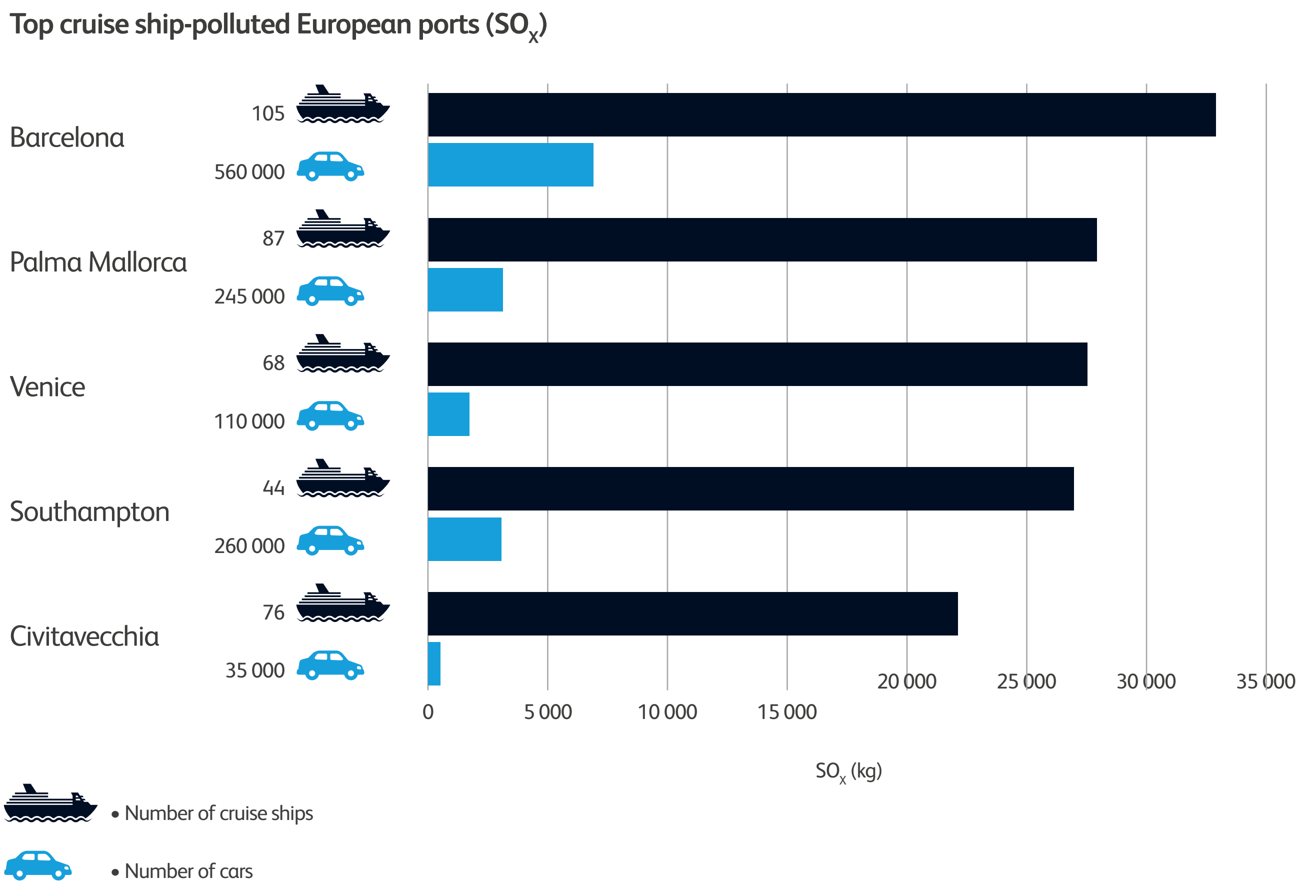
The reductions in emissions is dependent on how the SSE is generated, but harmful emissions in the port locality can be reduced significantly. In Europe, the increased use of renewable energy and phase out of coal fired power stations means that overall emissions can be significantly reduced when compared to ships using their engines while berthed in ports. As well as reducing harmful emissions, the use of SSE also reduces noise and vibrations from ships while in port, benefitting the surrounding port community. Since ports are often located in environmentally sensitive areas, close to major conurbations, the use of SSE can have many beneficial effects.

For example, Transport & Environment's (2019) report claims that a cruise vessel berthed for 8 hours and requiring 12MW of power can emit 1.2 tonnes of NO_x from its engines, which is equivalent to 10,000 cars. Similarly, in terms of NO_x emissions in Denmark;

> *"107 cruise ships analysed emitted as much NO_x in the Danish maritime economic exclusive zone as half the passenger cars operating in the country itself "* (Transport & Environment , 2019).

In Figure 1 below, the same report outlines the extent to which Europe's busiest cruise destinations face harmful sulphur (SO_x) emissions.

Figure 1: Top European cruise ship ports exposed to highest SO_x emissions in 2017



Source: Transport & Environment (2019)

SSE therefore has the potential to mitigate a significant amount of harmful oxide emissions. The technology for SSE is well established and deployed in ports worldwide.[6] The commercial benefits, however, depend on total demand and the associated per unit cost of electricity relative to that of the traditional oil based energy used while at port. It is worth noting that the total number of cruise vessels that called to Irish ports in 2018 was circa 300 (IMDO,2018). Although the number of vessel calls has increased in recent years, the total number of calls represents a small percentage of the traffic moving through Irish ports. This, along with regulatory factors, impact heavily on the uptake of SSE in ports worldwide, and this issue is dealt with in detail in Section 3 of this report.

iii) Emerging Fuel Technology

Battery Propulsion Technology

The use of electric propulsion systems has the potential to greatly reduce emissions from shipping, in particular if the electricity used to charge the on-board batteries comes from renewable energy sources. Battery technology is under development but journey times and distance capabilities are relatively short at present . As a result, battery powered propulsion is only in use over relatively short distances, or in conjunction with traditional propulsion systems as part of a hybrid solution. Short ferry routes therefore represent viable opportunities for existing battery technologies. In an Irish context, the vast majority of shipping routes from the island of Ireland are maintained by RoRo vessels on relatively short journeys to Great Britain through the Central, Northern and Southern corridors. Ireland may therefore be in a geographically advantageous position to avail of battery propulsion on short sea journeys, as the technology develops.

Hydrogen

Hydrogen powered fuel cells are also being developed as clean fuel options. If the hydrogen is produced from renewable energy sources, then this technology could provide a scalable option to reduce greenhouse gases from shipping. Given the embryonic stage of the development of this technology, it is not surprising that market uptake is relatively slow. There is a discernible sentiment in the shipping industry, however, that recognises the long-term potential of this energy source and sees LNG as a bridging technology.

Scrubbers

Exhaust gas cleaning systems (EGCS), or scrubbers, are becoming a more frequently used technology for ships to achieve compliance with emissions regulations. Scrubber systems are being used in new builds but can also be retrofitted to older ships to comply with emissions regulations.

A scrubber sprays seawater or fresh water mixed with a caustic chemical into the exhaust gas stream in several stages. The pollutant – mainly sulphur dioxide – reacts with the alkaline water, forming sulphuric acid. In the case of an open-loop system, the resulting wash water is discharged back into the sea. In areas and ports where open-loop scrubbing is prohibited, ships can use closed-loop systems and collect the accumulated sludge on board for subsequent disposal at a suitable in-port facility. Hybrid scrubber systems can operate either in closed-loop or in open-loop mode (DNV GL, 2019).

[6]The feasibility of SSE is understood at EU level, and has been included in studies of ports that have been supported by Connecting Europe Facility (CEF) funding – See *Appendix C.*
[7] The CEF has been used to fund projects on "Zero Emission Ferries" - see *Appendix D.*

5.0

Where are Alternative Fuels used?

i) Geographic Concentrations of Alternative Fuel Infrastructure

This section provides geographic and sectoral analysis of where AFI has, and is, presently being deployed. Once the locations and sectors of AFI concentration are established, it is possible to comment on the economic, market and regulatory environments which drove their development. In doing so, the report can consider causality between these variables and the development of AFI. The relevance of these variables is then considered in an Irish context.

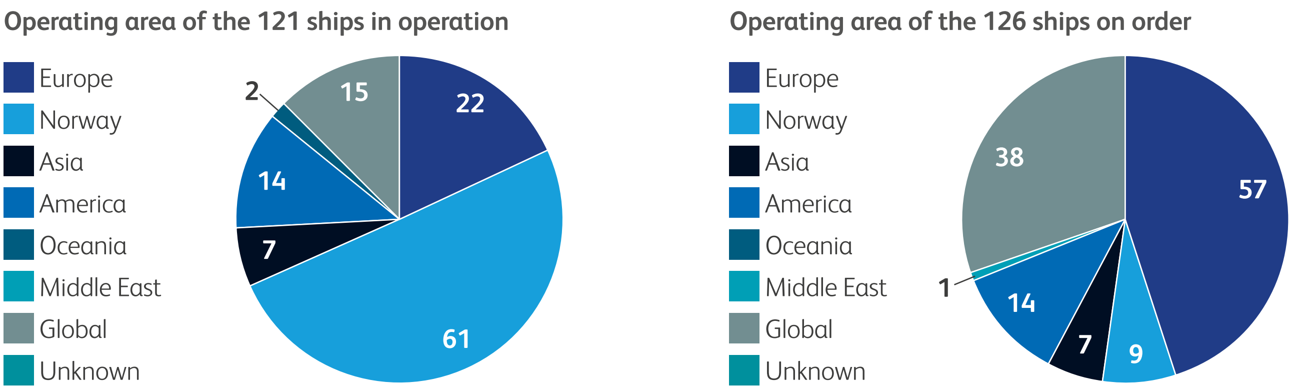
Figure 2 below is a geographic representation of the IMO's Emission Controlled Areas (ECA) across Northern Europe. Much stricter emission standards are enforced within ECA's – specifically for NO_x and SO_x emissions (DNV GL, 2019; DNV Alternative Fuel Insights, 2019).

Figure 2: Northern Europe Emission Controlled Areas

Source: *DNV* Alternative Fuel Insight (2019)

Figures 3 is a representation of the geographic concentrations of LNG worldwide. It illustrates that approximately half of all LNG ships currently in operation are in Norway. It also shows that Europe will have the largest growth rate of LNG ships in the future, with 57 ships on order and 22 currently in operation.

Figure 3: Areas of operation of LNG fuelled vessels worldwide



Updated 1 April 2018. Excluding LNG carriers and inland waterway vessels

Source: DNV Alternative Fuel Insights (2019)

Figure 4 is a geographic representation of SSE infrastructure across Europe[8]. Similar to concentrations of LNG ships, there is a concentration of SSE infrastructure in Northern Europe, particularly in Norway.

Figure 4: **Northern European SSE Infrastructure**[9]

Source: DNV Alternative Fuel Insights (2019)

[8] Additional maps of SSE & LNG concentrations, as well as ECA's are provided in Appendices *F to J*.
[9] In *Figure 4* the green markers indicate the existence of SSE services. These represent locations where ships at berth in these ports have the opportunity, or are often required by law, to shut off engines and instead provide hotel services for the ship using the SSE service.

ii) Sectoral Concentrations of Alternative Fuel Infrastructure

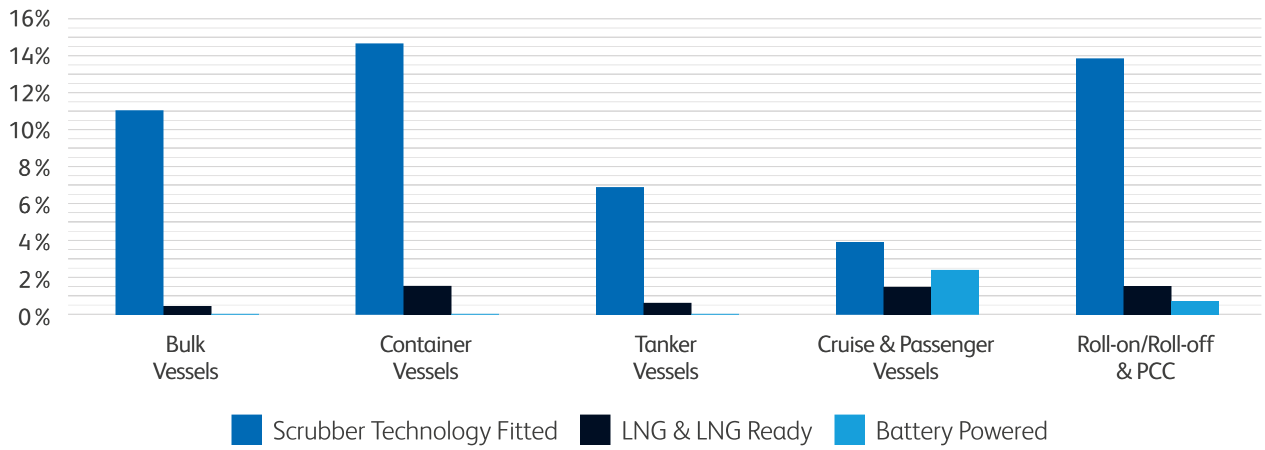
Figure 5 below represents the percentage uptake of alternative propulsion fuels and emission reduction technology among the world's fleet of commercial vessels. As expanded upon in Section 3 of this report, scrubber technologies are not an alternative to traditional diesel fuels, but rather an Exhaust Gas Cleaning System (ECGS). As noted by DNV GL (DNV GL, 2019), demand for such technology has grown rapidly since 2010, with almost 1,300 scrubber systems fitted across the world fleet. The rise has been heavily influenced by the International Maritime Organisation's stringent 2020 Sulphur Cap regulations, which demands that;

> *"the limit for sulphur in fuel oil used on board ships operating outside designated emission control areas will be reduced to 0.50% m/m (mass by mass), from 3.50% m/m"* (IMO, 2019).

The IMO also suggests and incentivises ship owners to take certain actions to comply with the new regulations. To do so, the IMO explicitly suggests using ECGS technology, alternative propulsion fuel such as LNG, as well as onshore power supplies while at berth. Figures 5 and 6 below are graphical and numerical representations (respectively) showing the percentage of alternative fuel technology uptake by sector. Both make clear how ECGS technology has been the most successful avenue for ship owners in complying with existing regulations.

Figure 5

Sectoral Concentrations of Alternative Fuel Technology



Source: Adapted from Clarksons Shipping Intelligence Network (2019), & DNV Alternative Fuel Insights (2019)

Figure 6

Ship Type	Total in Operation	Conventional Oil Based Fuel	Scrubber Technology Fitted	LNG & LNG Ready	Battery Powered
Bulk Vessels	**11,353**	88.51%	11.02%	0.46%	0.02%
Container Vessels	**5,266**	83.78%	14.62%	1.58%	0.02%
Tanker Vessels	**14,675**	92.38%	6.87%	0.66%	0.09%
Cruise & Passenger Vessels	**8,055**	92.15%	3.90%	1.53%	2.42%
Roll-on/Roll-off & PCC	**1,620**	83.89%	13.83%	1.54%	0.74%
Gas tankers	**1,997**	94.89%	4.26%	0.85%	0.00%
General cargo ships	**18,055**	99.48%	0.47%	0.04%	0.01%
Other activities (Excl fishing)	**5,982**	98.76%	0.07%	0.35%	0.82%
Offshore	**9,153**	98.90%	0.01%	0.40%	0.69%
Tugs	**19,525**	99.86%	0.00%	0.08%	0.06%
Total	**95,681**	**95.22%**	**3.91%**	**0.50%**	**0.36%**

Source: Adapted from Clarksons SIN (2019), & DNV Alternative Fuel Insights (2019)

6.0

Drivers of Alternative Fuel Development

In this section we undertake a PESTLE Analysis to identify and categorise the macro-environmental factors that will influence the roll-out of alternative fuel infrastructure in Irish Ports.

i) Political Factors

Policy

There is an increasing interest in green maritime ship technologies due to the growing emphasis being placed on reducing harmful emissions from transport. The driving force behind this development are the policy decisions taken by the International Maritime Organisation (IMO) and the European Union (EU) to reduce harmful emissions from maritime transport (Stevens, et al., 2015).

EU Directive 2014/94/EU recognises the unsustainable dependency that exists within the EU on energy generated from fossil fuels and the correlated harmful effects on the environment and human health. In response, the EU Commission developed a sustainable alternative fuels strategy. This strategy identified establishment of supporting infrastructure, along with a lack of associated common technical standards, as major obstacles to market uptake of alternatively fuelled vehicles. This Directive represents current EU policy on the adoption of alternative fuels and places a responsibility on Ireland to respond. In the maritime sector, under Directive 2014/94/EU, Member States must ensure that the need for SSE supply for seagoing ships is assessed and installed as a priority in ports in the TEN-T Core Network, and in other ports, by 31 December 2025. Furthermore, Member States are obliged to ensure that, taking into consideration market needs, an appropriate number of refuelling points for LNG are put in place at maritime ports, to enable LNG seagoing ships to circulate throughout the TEN-T Core Network by 31 December 2025.

At a national level, the Climate Action Plan (CAP) identifies specific actions to be taken and the need to consider the use of alternative fuels in the transport sector. The plan states that we must:

> *Develop an overarching charging infrastructure strategy with a target to be set for the supply of infrastructure to stay ahead of demand. Review and update the targets (currently set out in the National Policy Framework for Alternative Fuels Infrastructure for Transport in Ireland 2017-2030) for the supply of public charging infrastructure for electric vehicles, taking into account the proposed uptake of electric vehicles set out in this plan* (CAP, 2019 p.44).

Industry Regulation

The regulation surrounding the provision of alternative fuel infrastructure at ports is not well developed in Ireland. International regulations in relation to emissions have had an effect on the Irish shipping industry and brought about changes in attitudes and behaviors, but domestic regulation has had no discernable impact on the roll-out of AFI in Ireland. In countries with more progressive environmental policies, such as Norway and the Netherlands, domestic regulation has been more impactful and resulted in the accelerated roll-out of AFI. However, since the successful deployment of AFI depends on a variety of factors, it cannot be asserted that regulation alone will result in investment in AFI. Regulation makes a necessary, but insufficient contribution, to ensure successful deployment. Factors such as the scale of demand, and the distribution of demand across industry sectors are equally, if not, more important.

Government Spending and Tax Policies

Unlike other European countries, Ireland has no specific plans to increase Government expenditure in the area of AFI, or to incentivize private sector investment through supportive tax policies. Given the anticipated level of demand for alternative fuels in the Irish maritime industry, it is questionable as to whether or not such actions would have any appreciable impact on demand or on the appetite of the private sector to invest. The combination of factors needed to drive AFI deployment are not currently present in Ireland, and this is a problem that cannot be resolved by regulation alone.

ii) Economic Factors

Demand for fuel in the maritime industry is a function of the volume of international trade. The Irish economy is small, open and vulnerable to fluctuations caused by many external factors including global economic growth, oil prices, exchange rates and disruptive events such as Brexit or the collapse of financial markets, as occurred in 2007. Notwithstanding the openness of the Irish economy, Ireland's international trade is expected to grow for the foreseeable future in a manner that is highly correlated with economic growth. In short, international trade will grow incrementally in line with economic growth, with no reasonable basis for believing that there will be a seismic change in the growth patterns experienced in the past. On this basis, it is unlikely that demand for alternative fuels will change to any appreciable extent as a result of dramatically increased volumes of international trade. This assumption underpins the conclusions reached in this study.

The scale of the Irish maritime industry must also be taken into account in any economic assessment of the viability of AFI in Irish ports. There are approximately 12,000 vessel calls annually at Ireland's five main ports at Dublin, Cork, Shannon Foynes, Rosslare and Waterford. By way of comparison, the Port of Singapore, which has over 160,000 vessel calls each year, will deliver its first LNG refuelling facility in 2021. AFI is a capital intensive investment that is difficult to justify in a relatively small economy such as Ireland. There is a secondary consideration that relates to the connectivity that Irish ports enjoy with larger ports, such as Liverpool, Antwerp and Rotterdam. The scale of operations in these larger ports make investments in AFI a more viable proposition and it is likely, as is the present case, that vessels trading with Ireland will avail of bunkering facilities at these larger ports rather than in Irish ports. Put simply, the economies of scale do not exist at Irish ports to justify the significant capital investment involved AFI. This is less likely to be a problem in bigger ports.

iii) Social Factors

There is a growing awareness of the ramifications of climate change and the need to take action to mitigate its effects. At a societal level, this is reflected in the growing support for political parties that advance a green agenda and to the increased activism in civic society towards furthering environmental issues. Such awareness is likely to result in greater political interest in climate change issues. This will include changes to regulation and increased investment by government in solutions targeting a reduction in environmental damage caused by harmful emissions. In short, social pressure is likely to accelerate action to mitigate the effects of climate change. We take cognizance of this trend in the recommendations that follow at the end of the report.

iv) Technological Factors

Technological developments will affect the types of fuels that we use and the means by which we deal with harmful emissions. Research is ongoing to reduce the harmful emissions of fossil fuels by altering their chemical composition. In addition, research is ongoing into the use of alternative forms of energy in maritime transport, ranging from electricity to hydrogen and ammonia. The shipping industry has not arrived at a settled position in relation to these alternative fuels, an issue which significantly restricts investment in them.

As best, LNG is regarded as a bridging mechanism between conventional fuels and the "super fuels" of the future, whatever they may be. The shipping industry has expressed this view through its actions, by continuing to build ships that burn marine diesel. At the time of writing this report, less than one percent of the world's merchant fleet uses alternative fuels. Although the percentage of new builds using alternative fuels has increased, the rate of conversion to alternative fuels has now plateaued, and in the absence significant policy changes, is unlikely to increase.

v) Legal Factors

The legal issues that arise have been dealt with under the heading of Political Factors, which encompasses the range of regulations, policies, laws and directives that will emerge from national and international systems.

Regarding the development of AFI however, ports will need to be mindful of the complicated planning processes that surround port development, as well as the lengthy lead-in times associated with such projects.

vi) Environmental Factors

The need to deal with climate change in order to protect the global environment - and the ecosystems within it - is well established and supported by scientific research. Although the contribution that Ireland can make to solving the global problem is small, there is an obligation on Ireland to play a part, proportionate to its size, in resolving the problem of climate change. While it is important that Ireland exhibits a readiness to act, it is equally important that efforts are targeted on initiatives that will have the greatest impact.

It is by no means clear how investment in AFI in Ireland will have any meaningful effect on emissions or on decarbonisation, given the relatively small scale of the maritime industry in Ireland and the reluctance of the shipping industry to transition in any substantial way to using alternative fuels.

There is a case to be made that the scarce resources available to deal with climate change should be directed towards investments that deliver the greatest impact in terms of emissions abatement. Investment in AFI for the maritime industry in Ireland are unlikely to deliver such impact.

7.0

Irish Market Analysis

The demand for alternative fuels in Ireland is a function of the number and type of vessels calling to Irish ports. CSO statistics for 2018[10] show that Ireland had 12,025 vessel calls at its 5 main ports (CSO, 2019). Around two-thirds of the calls were RoRo vessels, split between Dublin (over 7,000 calls), Rosslare (approx. 1,600 calls) and Cork (approx.1500 calls).

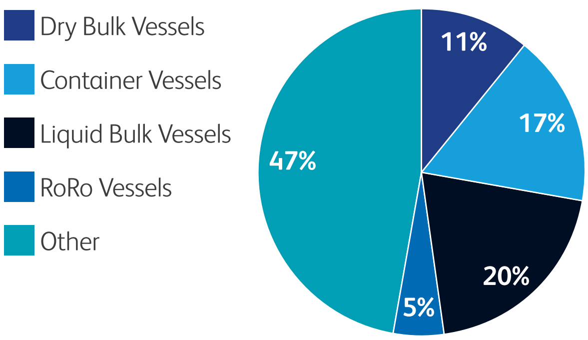
There were 300 cruise vessel calls in Ireland in 2018, with 264 of these calls at the main ports -predominantly Dublin Port, which had 150 cruise vessel calls.

i) Irish Market Demand for LNG

From global market analysis, there are currently 479 ships in operation that are fuelled with LNG or can be fuelled with LNG (i.e. 'LNG ready') (DNV Alternative Fuel Insights , 2019). This represents less than 1% of the world fleet (Clarksons SIN, 2019). Close to half of the current LNG fuelled fleet is *not* associated with trade cargoes (Cruise, fishing vessels, passenger ferries, offshore supply vessels and Tugs), as shown in Figure 7 below.

Figure 7

Sectoral Breakdown of LNG & LNG Ready ships



Source: Adapted from DNV Alternative Fuel Insights (2019).

[10] For a graphical representation of vessel calls at Irish ports, see *Appendix E*

If the market trends outlined above are applied to Irish ship traffic, then less than 20 of the approximately 12,000 vessel calls (less than 0.2%) at Ireland's main ports would be LNG propelled ships that *may* seek to be refuelled. As discussed earlier in the report, there is a strong probability that ships serving the Irish market will decide to refuel in larger ports where prices are lower and service levels higher.

The majority of vessel calls in Ireland are RoRo vessels, with approximately 20 vessels currently employed on routes to the UK and Europe. Based on global fleet statistics, combined with the uptake of alternative fuel development in this sector, approximately 2 of these vessels will be LNG propelled. From our consultations with RoRo operators, no vessels are currently using LNG as a means of propulsion. However, one new build vessel that is currently in service could be retrofitted with LNG equipment if this became a commercially viable alternative in the future.

Financial Viability Assessment of LNG in the Irish Maritime Industry

The cost associated with establishing the LNG refuelling capabilities in ports is significant, as indicated by the Connecting Europe Facility (CEF) funded projects to date. For example, the *Helsingborg & Klaipeda LNG Infrastructure Facility Deployment* – (HEKLA) included the construction of an LNG liquefaction plant in the Port of Helsingborg, as well as an LNG Reloading Station at Klaipedos. The total project cost was €28 million and over €10 million was provided from the EU CEF programme (CEF, 2014). The project was part of a wider global initiative to expand the LNG bunkering network throughout the Baltics, understanding that the commercial viability of the project would benefit from previous LNG investments elsewhere in the region. There are currently no existing investments in LNG infrastructure in Ireland. Large fixed investment costs, combined with the relatively low level of demand from LNG propelled vessels at Irish ports, means that an investment on this scale is not economically feasible in Ireland.

There is a less expensive alternative to infrastructural investment, which involves transporting LNG from locations outside the state in bunkering barges, thus limiting the shore-side infrastructure involved. Although the quantum of capital investment involved in this type of bunkering operation is reduced, the level of demand and the frequency of orders would not justify such investment. If AFI cannot be justified in Dublin Port, which currently handles almost 90% of the State's RoRo trade and more than 70% of its Lo/Lo trade, it is clear that the conditions do not exist at other smaller ports that would justify such investment.

ii) Irish Market demand for SSE

An ECOFYS study for the EU Commission in 2014 (Winkel , et al., 2015) quantified the capacity of electricity required to provide shore side power across Europe at 3,343 GWh per year, representing 0.1% of Europe's entire electricity market -see figure 8 below. This would represent the mitigation of 800,000 tonnes of CO_2 emissions. Around one third of this SSE demand would come from Cruise vessel calls. RoRo, which has the highest level of vessel calls to Ireland, makes up around 3% of the total.

Source: RSM/ Pure Marine Gen

Figure 8: Calculation of total GWh consumption at berth

Type of Ship	Transport in 2020 (Gt)	Average Ship Gt	Number of berths	Annual Fuel Consumption for Electricity (tonnes)	Annual GWh
Oil Tankers	1,400 m tonnes	46,135	30,346	135,800	760
Bulk Carriers	1,000 m tonnes	52,430	19,073	80,000	448
Containers (including reefers)	2,200 m tonnes	28,855	76,243	103,400	579
General Cargo	211 m tonnes	3,458	61,018	18,779	105
RoRo	250 m tonnes	26,171	9,553	20,750	116
Cruise		83,650	16,119	260,232	1334
			Total	618,961	3,343

Source: Winkel, et al. (2015).

Applying these metrics to Irish traffic, the potential electricity demand if all vessels were connected to SSE at berth would be around 149GWh. This would represent less than 0.5% of Ireland's electricity consumption (SEAI, 2018). The potential mitigation of CO_2 emissions would be 36,000 tonnes per year, which represents 0.06% of Ireland's annual emissions. While all reductions in CO_2 emissions are of benefit in achieving climate change targets, this represents a relatively low level in reductions compared to other areas. Consultation with Irish ports, conducted by the IMDO as part of this study, indicated that there were no recent requests for SSE from shipping companies calling at their facilities.

Financial Viability Assessment of SSE in the Irish Maritime Industry

The financial viability of SSE is dependent on the ability of the port to recover the costs of installing the new electrical infrastructure required. As a result, a high utilisation factor is required to increase the likelihood of viability. However, in the absence of any binding regulation, ship owners will only make use of shore side power if it is less costly than burning oil based fuel to provide electricity services to ships while at berth.

Analysis in an ECOFYS study (Winkel , et al., 2015) concluded that cruise, RoRo and container ships exhibit the best financial case for SSE. In an Irish context, the busiest RoRo berths in Dublin port have around 1,500 vessel calls per year (CSO, 2019). The power capacity requirement for RoRo vessels while at berth is roughly 2MW. A facility capable of providing this level of electricity would cost approximately €500,000 to install (Winkel , et al., 2015). Expanding to annual consumption requirements, the electricity required for Irish RoRo vessel calls is estimated to be 12,140MWh per year. Therefore, the port would have to charge an additional mark-up of €8.20 per MWh to the electricity supplied in order to recoup the investment costs over a 5-year period. Regarding costs to the ship owner, it is estimated that providing electricity through main engines, which are powered by marine fuel oil, would cost approximately €90 per MWh. The current cost of electricity to consumers in Ireland is between €150 - €200 per MWh (Howley & Barriscale, 2017), therefore it is unlikely that a ship would choose to use SSE unless mandated to do so by local legislation. As a result, the cost to ships of shore side power relative to that of conventional, oil based fuel renders the project financially unsustainable. The per MWh cost of electricity remains the greatest barrier, particularly in the absence of any binding regulation that may mandate the internalisation of pollution costs to ship owners.

8.0

Findings and Recommendations

Findings

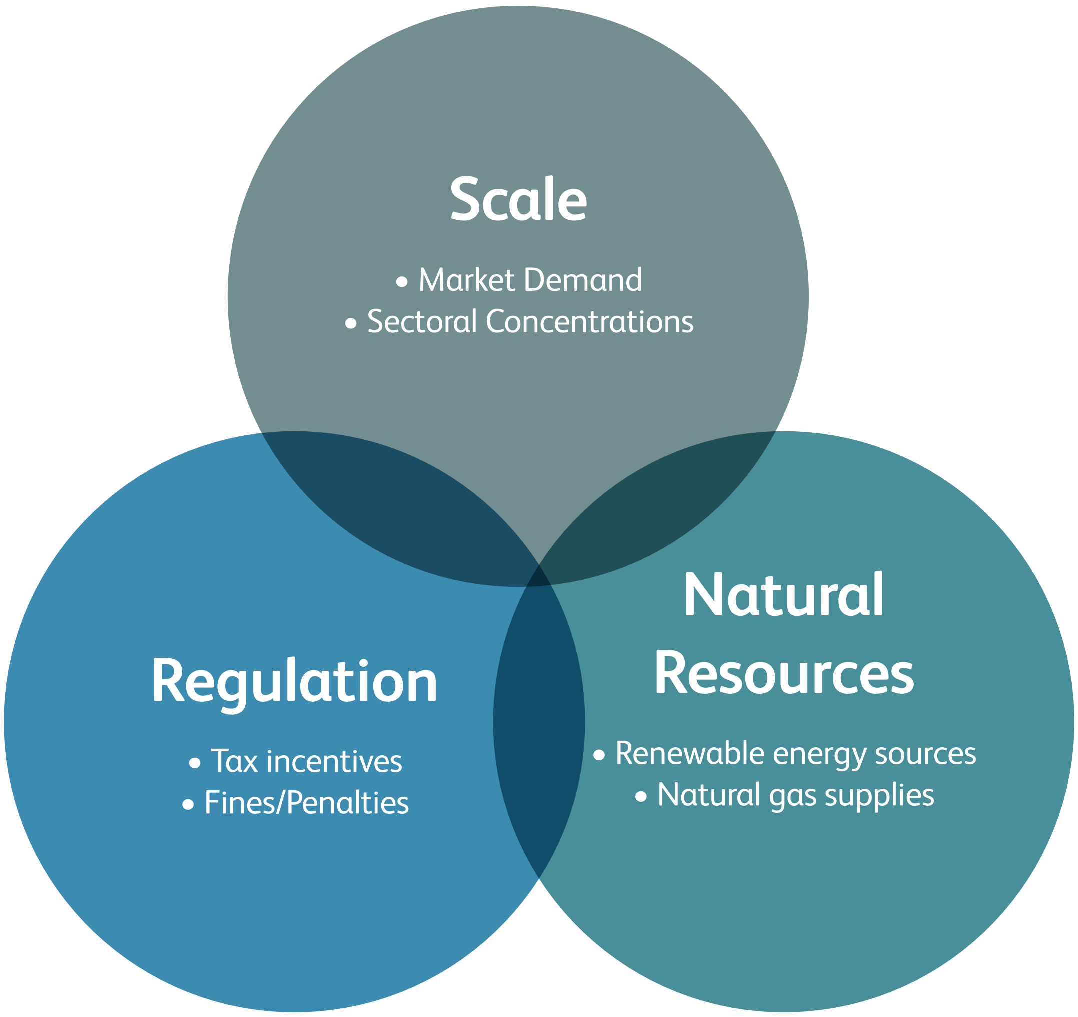
The key findings from the research carried out are summarised below:

1. Ambitious targets aimed at improving the environment and addressing climate change are in place for the maritime transport sector. However, 99% of the world's shipping fleet - comprising circa 95,000 vessels (Clarksons SIN, 2019) – currently use oil based fuel.
2. The use of alternative fuels can play a role in achieving these targets, though other options exist such as Exhaust Gas Cleaning Systems (scrubbers). Scrubber technology has been the preferred solution deployed by ship owners, in new builds and in retrofitting, to meet new regulations on environmental emissions, with around 4% of vessels in operation or on order fitted with these systems (DNV Alternative Fuel Insights , 2019; Clarksons SIN, 2019).
3. The LNG fuelled fleet currently represents approximately 0.5% of the global vessel fleet (DNV Alternative Fuel Insights, 2019). Consultations with industry indicated that, under current conditions, rapid growth is unlikely over the next 5-10 years. The uptake of LNG as an alternative fuel is greatest where international and national policies targeting reductions in environmental pollution overlap with favourable market demand conditions, the availability of natural gas resources, and an existing LNG supply chain.
4. Similarly, growth in the use of SSE is evident where there is an overlap between policy and available resources, such as cheap energy from renewable resources. In Europe, the areas where these conditions exist are predominantly in the Baltic and Scandinavian regions, where existing gas reserves and cheap electricity from hydro resources are available.
5. Investments in infrastructure for LNG fuelling facilities for ships has been supported by funding from the Connecting Europe Facility (CEF), though projects have been developed where other LNG infrastructure for supplying the broader energy market already exist. In addition to a geographic concentration in the Baltics, these facilities have been developed in large ports where the scale and number of vessel calls is many times larger than the demand that could be generated within Ireland's entire ports system.
6. In Ireland's maritime sector, approximately twenty RoRo vessels are currently employed on the routes to the UK and Europe from Dublin and Rosslare. None of these ships are LNG fuelled, though some of the new builds have been designed as "LNG ready" and could convert to using LNG in the future, if it becomes commercially viable to do so. There is no current demand for LNG refuelling at Irish ports. Based on the types of vessels operating on routes to/from Ireland, if the use of LNG were to grow in line with the global averages, approximately 20 (0.2%) of the vessels calling at Irish ports would be LNG propelled. There is no existing LNG infrastructure in Ireland and an investment in facilities dedicated to maritime transport would not be commercially viable given the low demand and uncertainty about the long term deployment of LNG in the global shipping fleet.
7. The deployment of SSE at Irish ports could play a role in reducing greenhouse gas emissions, if the electricity supplied comes from renewable energy sources. However, the high cost of electricity in Ireland, compared to the option of using the ships own engines which are powered by marine fuel oil, is a barrier to conversion to SSE.
8. There are several overlapping issues from transport and energy sectors that impact the viability of investments in LNG or SSE in Ireland. These need to be addressed as there may be synergies within plans for the development of LNG storage facilities and smart grid systems for renewable energy. These synergies could provide opportunities to develop alternative fuel options for the maritime transport sector in Ireland.

9. There is a widely held belief within the shipping industry that LNG represents a short-to-medium term solution to what is a long term problem. The innate conservatism and risk aversion of the industry make investment in LNG unlikely because of the potential obsolescence of LNG technologies through the development of alternative fuels such as hydrogen.

10. The drivers of AFI deployment are not prevalent in the Irish shipping industry. As illustrated in Figure 9 below, an overlap of three essential factors must be present for AFI development to be successful and sustainable. First, Ireland's shipping industry lacks the scale and demand required to make investment in LNG or SSE facilities commercially attractive. Second, in the absence of significant changes in environmental regulation, as well as the introduction of supportive policies to encourage or compel change, little action will be taken by market actors. Third, in the absence of cheap natural resources sufficient to drive down the per unit cost of natural gas and/or electricity, there is no incentive to switch to a fuel option that is relatively costly. In short, the conditions do not exist in the Irish shipping industry for market-led change in the use of alternative fuels.

Figure 9



Recommendations

1. There should be continued monitoring of market trends to assess the level of convergence in solutions to achieve the ambitions for the maritime transport sector set out in the Alternative Fuels Directive. The IMDO will report annually[11] to the Department of Transport, Tourism and Sport regarding changes in market trends and emerging issues.

2. The IMDO, supported by SEAI and other state agencies, will engage with key stakeholders and industry contacts across the maritime transport and energy sectors to ensure that up to date market intelligence that informs investment decisions is made available to policy makers, ports and the wider business community.

3. The IMDO should facilitate discussions between the maritime industry, and other industries currently using LNG, to surface opportunities to exploit synergies and to generate a cross-industry demand to increase the viability of investments in alternative fuels in transport.

4. Statistics on the use of alternative fuels should be collated and reported annually by the IMDO, in particular through the use of the DNV GL "Alternative Fuels Insight" platform.

5. Stakeholders in Ireland's maritime transport sector should seek opportunities to get involved in wider European projects related to alternative fuels in order to gain experience and insights into this emerging area. This will be supported by the IMDO and other state agencies.

6. In the absence of marked changes in environmental regulation or significant incentives, particularly at an international level, through organisations or institutions such as IMO or the EU, which have the effect of making such investments commercially viable, the targets for the development of AFI in Irish ports by 2025 should be set at zero.

7. Investments in AFI should be assessed in the context of the broad range of climate change mitigation measures available, and resources should be directed towards the measures that deliver the greatest impact.

[11] This report will be released in April of each year.

9.0

Appendices & Vignettes

Appendices

Appendix A: Shipping industry stakeholders whose views were consulted by the IMDO

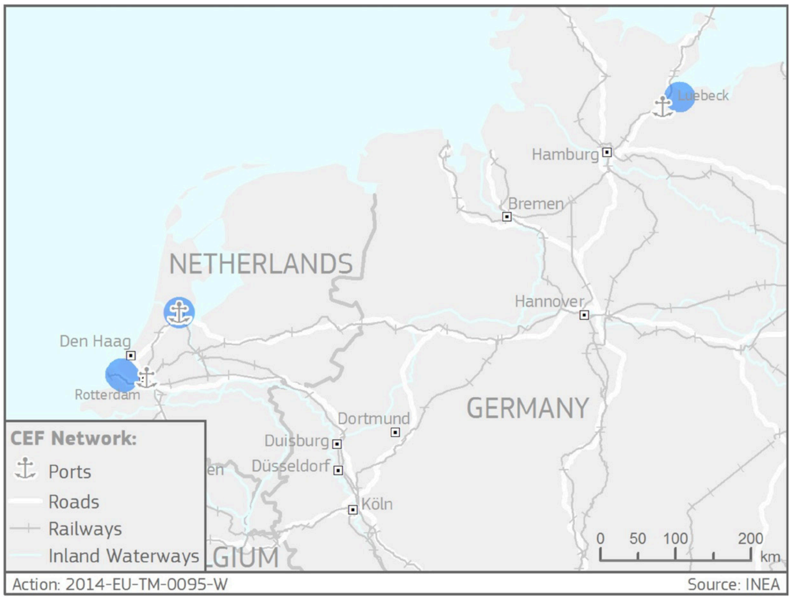
	Ship Builders	Equipment Suppliers	Ports	Shipping Companies	Other
1	Damen	Kongsberg	DP World	Arklow Shipping	DNV
2	VARD (Fincantieri)	MAN	Singapore	ICG	NOAA
3	HSG*	Andritz	Algeciras	Stena Line	Lloyd's Registry
4	Eaglestar	WIN GD	Malta	CLdN	Clarksons
5	Ulstein	Liebherr	Cyprus	Cruise Lines	Nordic Energy
6		Faiveley	Irish Ports		ABB
		Wartsila			

Source: IMDO (2019)

Appendix B: ReaLNG: Turning LNG as marine fuel into reality in the North Sea-Baltic region

Programme: CEF Transport
Call year: 2014
Location of the Action: Germany, Netherlands
Implementation schedule: January 2014 to September 2017
Maximum EU contribution: €12,581,818
Coordinator: Shell Western LNG B.V. (Netherlands) https://www.shell.com/
Transport corridor: North Sea - Baltic, North Sea - Mediterranean, Rhine - Alpine, Scandinavian - Mediterranean
Transport mode: Maritime

Source: (CEF, 2014)

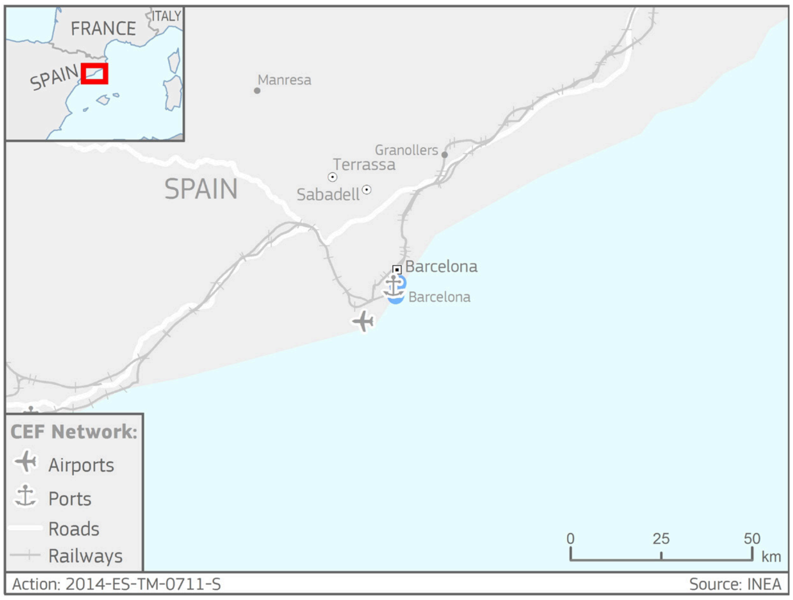


As of January 2015 a new sulphur regulation entered into force, limiting sulphur emissions from ships in the Sulphur Emission Control Area (SECA) area. The aim of the Action was to ensure deployment of LNG in the area and upgrade the maritime link in the North Sea–Baltic Sea region by providing a bunkering vessel and LNG-related infrastructure in the Port of Rotterdam and the Port of Lubeck. This is a horizontal wider benefits Action, under Motorways of the Sea. The ReaLNG Action consisted of designing, building and operating a maritime LNG bunker vessel as well as all the necessary port investment for LNG bunkering. It also included the implementation of training courses and pilot trainings rolled out in the field of LNG operations based on the specific needs of ports and the maritime operators. The Action contributes to the implementation of the SECA and MARPOL regulations by promoting an environmentally beneficial fuel for short sea shipping.

Appendix C: Cleanport - Alternative Fuels and Solutions for Port's Cold Ironing

Programme: CEF Transport
Call year: 2014
Location of the Action: Spain
Implementation schedule: January 2014 to December 2018
Maximum EU contribution: €3,174,529
Total eligible costs: €6,349,058
Percentage of EU support: 50 %
Coordinator: NATURGY ENERGY GROUP S.A (Spain)
Transport corridor: Mediterranean
Transport mode: Maritime

Source: (CEF, 2014)



The Action aims to overcome the barriers for the harmonisation and standardisation of the supply of alternative fuels (LNG and natural gas) in maritime ports. It will demonstrate new operations and alternatives to traditional energy services by allowing electricity generation on-board during arrival, departure and port permanence. The Action includes a real life trial consisting of 3 elements: the installation of a dedicated auxiliary natural gas engine on the Abel Matute ferry to generate electricity; a small scale LNG bunkering facility (truck to ship); and a natural gas bunkering facility both located in the core port of Barcelona. Pilot operations and results will be analysed and disseminated. The Action will also promote regulatory improvements and further standardization, where necessary.

Appendix D: Zero Emission Ferries - a green link across the Oresund

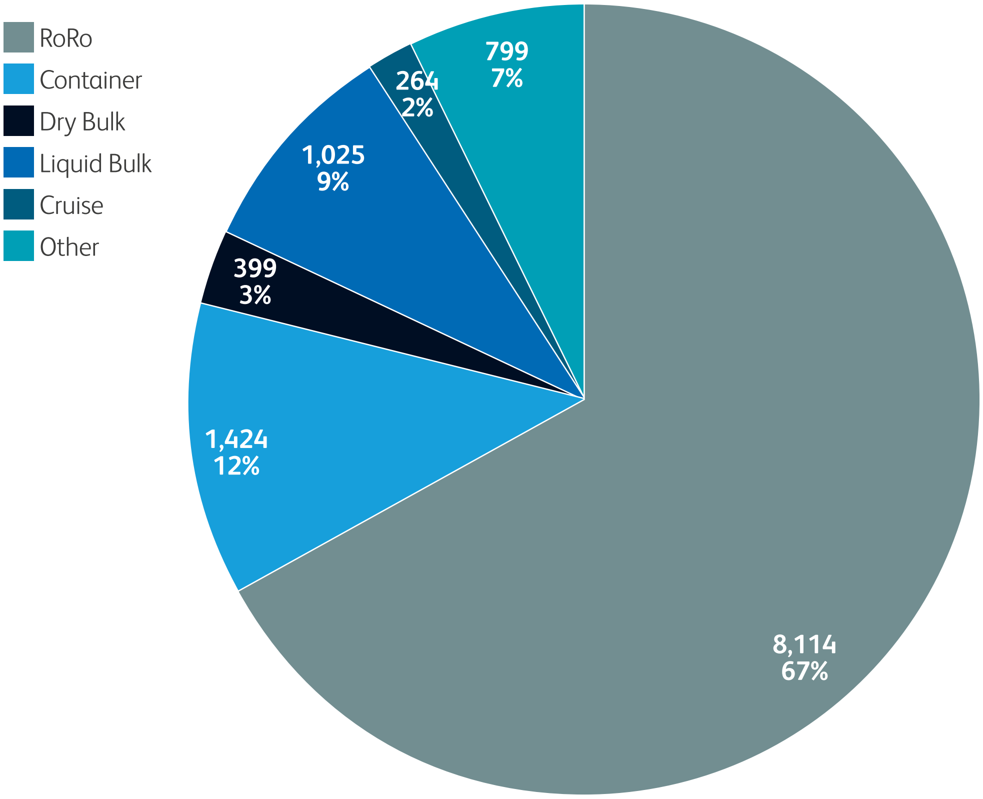
Programme: CEF Transport
Call year: 2014
Location of the Action: Denmark, Sweden
Implementation schedule: January 2014 to December 2017
Maximum EU contribution: €13,150,000
Coordinator: Forsea Helsingør ApS (Denmark) http://hhferriesgroup.com
Transport mode: Maritime

Source: (CEF, 2014)

The Action covers the introduction of new and innovative concepts and technology by converting two existing complex RoPax ships - originally fuelled by heavy oil - to plug-in all electric powered operation using exclusively batteries. The Action brings a more environmentally friendly solution to a very busy maritime link, connecting the comprehensive TEN-T network ports of Helsingör (Denmark) and Helsingborg (Sweden). In conjunction with the ship conversion, the required power provision and charging installations in the ports/ferry terminals were realised. Both ferry terminals are located in densely populated areas, so the Action contributes to significant improvements of air quality. The project supported the development of clean Motorways of the Sea by testing and deploying new technological solutions in real operational conditions.

Appendix E: Vessel Calls at Irish Ports

Vessel Calls at Irish Ports in 2018

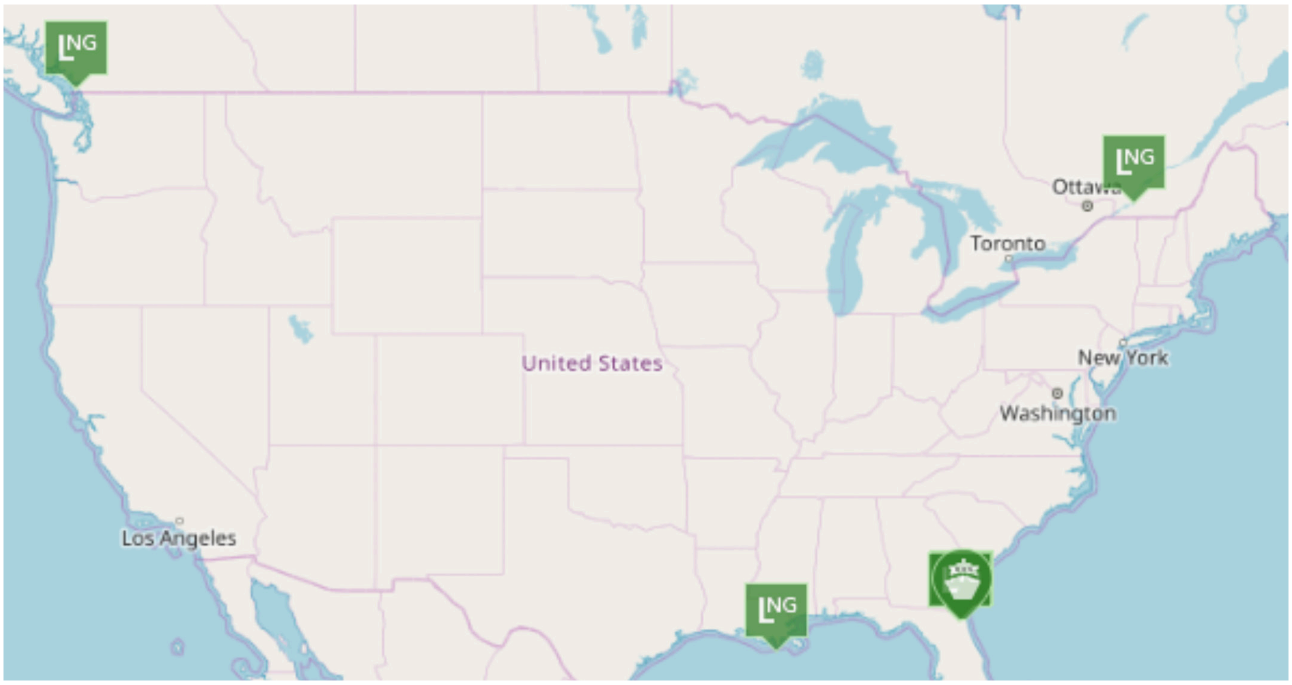


Source: (CSO, 2019)

Appendix F: North American Emission Controlled Areas

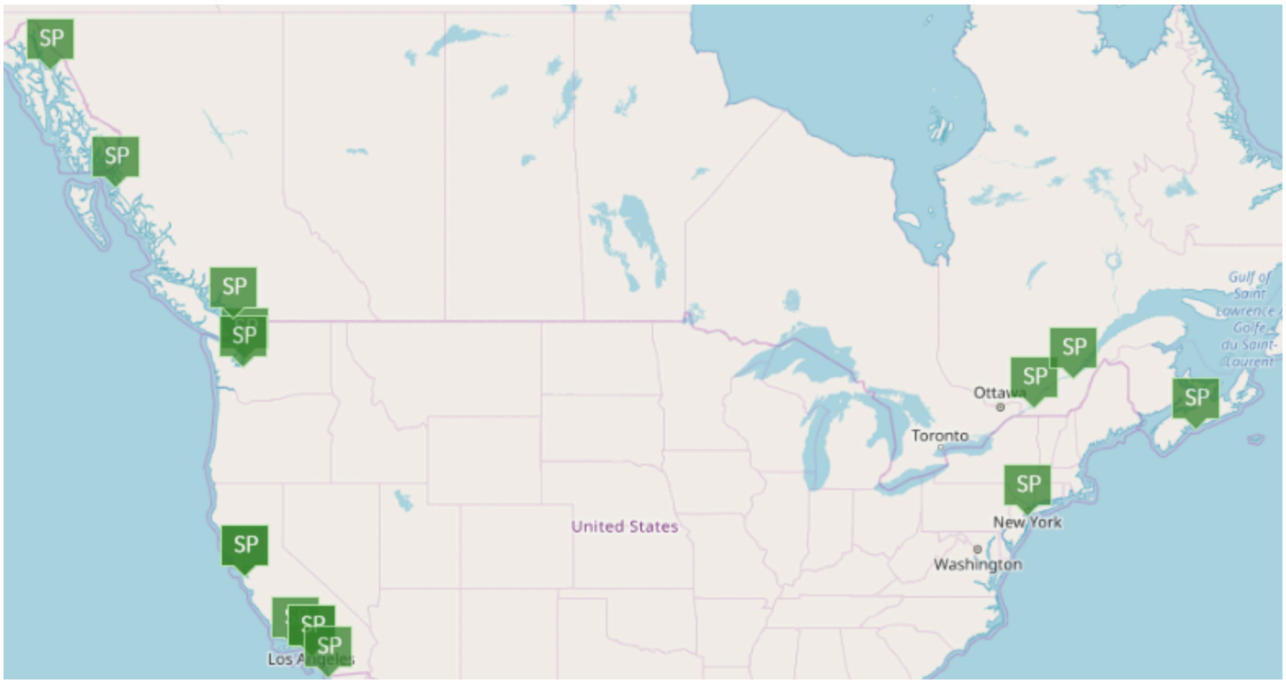
Source: (DNV Alternative Fuel Insights, 2019)

Appendix G: North American LNG Infrastructure



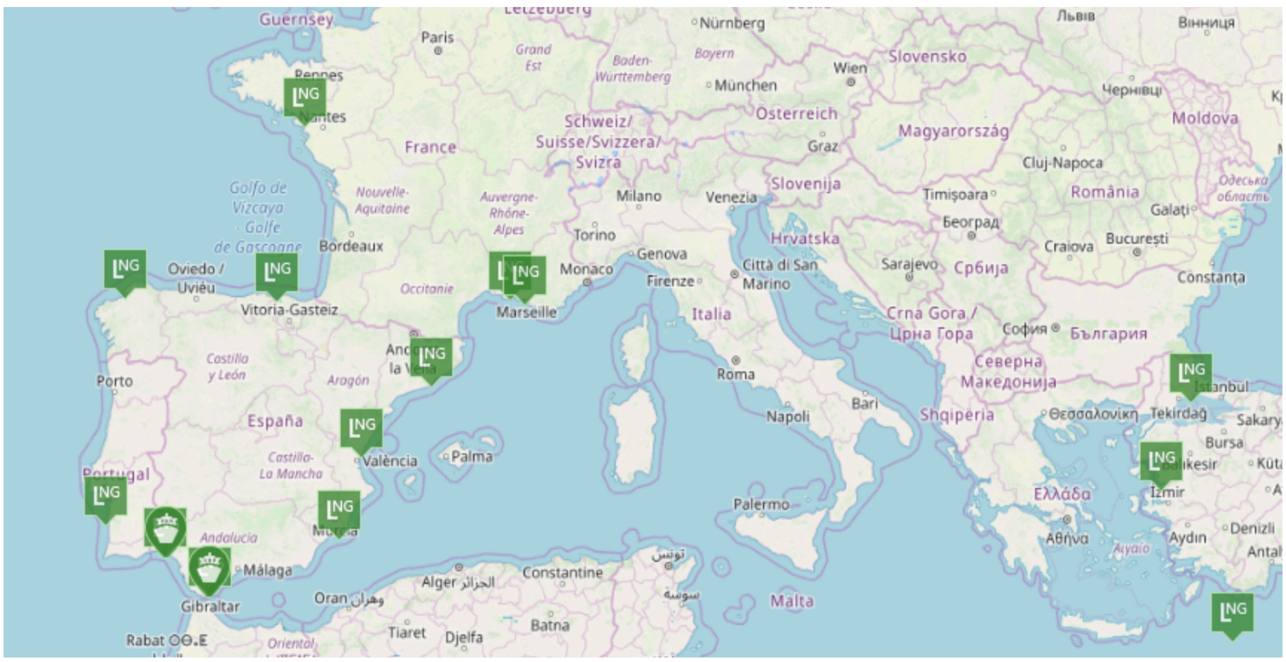
Source: (DNV Alternative Fuel Insights, 2019)

Appendix H: North American SSE Infrastructure



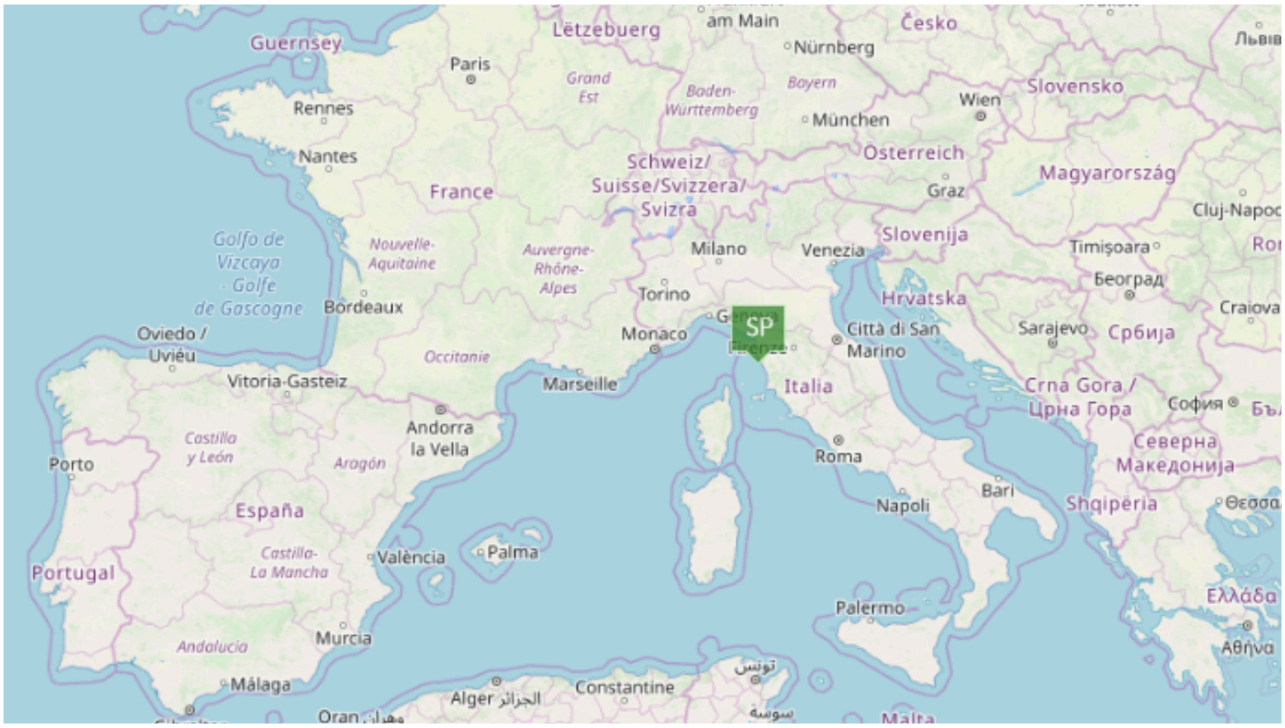
Source: (DNV Alternative Fuel Insights, 2019)

Appendix I: Southern Europe LNG Infrastructure



Source: (DNV Alternative Fuel Insights, 2019)

Appendix J: Southern Europe SSE Infrastructure



Source: (DNV Alternative Fuel Insights, 2019)

Appendix K: Terms of Reference

Transport in Europe is almost entirely dependent on oil. To help reduce this dependency and the correlated harmful effects on the environment, the EU Commission developed a sustainable alternative fuels strategy, which identified the slow establishment of supporting infrastructure, along with a lack of associated common technical standards, as major obstacles to market uptake of alternatively fuelled vehicles across the EU. Directive 2014/94/EU was subsequently developed to address these issues and was published in November 2014.

The Directive outlines the fuel options that could provide alternatives to oil in transport (both road and maritime) and obliges Members States to establish targets for a minimum level of infrastructure for clean fuels, particularly electricity and natural gas, along with common EU wide standards for the equipment needed. The Directive also requires Member States to implement measures to ensure such targets are reached. Member States were required to adopt and publish a National Policy Framework (NPF) to support the provision and use of refuelling infrastructure for alternative fuels. Ireland's NPF was published in 2017; in 2018 corresponding regulations were published that fully transposed the Directive (Irish Statute Book, 2018).

In the maritime sector, under Directive 2014/94/EU, Member States must ensure that the need for shore-side electricity supply for seagoing ships is assessed and installed as a priority in ports of the TEN-T Core Network, and in other ports, by 31 December 2025, unless there is no demand and the costs are disproportionate to the benefits, including environmental benefits. Shore-side electricity facilities can serve maritime transport as clean power supply, in particular where air quality or noise levels are poor.

Furthermore, Member States are also obliged to ensure that, taking into consideration market needs, an appropriate number of refuelling points for liquid natural gas (LNG) are put in place at maritime ports, to enable LNG seagoing ships to circulate throughout the TEN-T Core Network by 31 December 2025. LNG can assist vessels in meeting their requirements to decrease the sulphur content of their fuels in SOx Emission Control Areas (which affect half of the ships sailing in European short sea shipping). Member States can cooperate with neighbouring Member States where necessary to ensure adequate coverage of LNG in the TEN-T Core Network, which can take the form of LNG terminals, tanks, mobile containers, bunker vessels and barges. While the initial focus for LNG is on the core network the possibility of availability at ports outside the core network should be considered. The decision on the location of the LNG refuelling points at ports should be based on a cost-benefit analysis including an examination of the environmental benefits while applicable safety-related provisions should also be taken into account.

Ireland did not propose any infrastructural targets for the maritime sector in the NPF, instead it was concluded that a review of the market needs of the Sector was required in advance of setting targets for 2025. The NPF states that no targets will be set in the interim in the absence of any market demand; however, subject to the outcome of the review, Ireland will commit to setting targets for shore-side electricity and LNG facilities at the three TEN-T ports (at a minimum) in 2019, thus adhering to the requirements of the Directive.

Vignettes

Vignette 1

Ferry Company

Chief Executive

The company took delivery of a new ferry in 2019 at a cost of €150m. The vessel burns marine diesel and the company declined the opportunity to use alternative fuels. The CEO, who heads a company that has been at the forefront of the shipping industry for more than 30 years, gave careful consideration to using alternative fuels. The vessel referred to above has been acquired at a particular point in the company's investment cycle. The ability to use alternative fuels, will have a profound effect on the residual value of vessel, particularly over the 20-year life cycle of modern vessels. Notwithstanding the implications for residual values and the mounting pressure on the shipping industry to reduce harmful emissions, the CEO opted against the use of alternative fuels. The reasons put forward included:

- The higher operating cost of alternative fuels
- Supply difficulties, which will not be resolved because there is no return to be made on the provision of the infrastructure, unless the investment can exploit opportunities in other industry sectors, through connection to the national grid or commercial applications in road transport.
- A belief that LNG is at best a stop gap solution, pending technological developments that will make the use of hydrogen, or other carbon neutral fuels, feasible.
- The relatively small size of the market in which the company operates, which will not be able to generate a return on the capital investment needed to deliver alternative fuel infrastructure

The CEO was more positive about the use of flat-ironing in ports, that can generate appreciable benefits in terms of noise and air quality for residents in the locality of busy ports.

Vignette 2

Bulk Shipping Company

Operations Director

The company is privately owned and operates a fleet of over 45 bulk carriers through Europe. The company has a further 15 vessels on order. There are no vessels in the fleet using alternative fuels and all of the vessels on order will use marine diesel. The company's decision to decline the opportunity to use alternative fuels in its fleet was driven by:

- The relatively high cost of alternative fuels. On average, vessels equipped to burn alternative fuels cost 20% more to build. Operating costs are more difficult to assess, because of the volatility of fuel prices, but based on current prices and factoring in other operating costs, are about 20% higher than those of a conventional vessel of similar size.
- The amount of space occupied by alternative fuel storage tanks on seagoing vessels
- The increased safety risk associated with LNG
- The increased engine maintenance costs associated with alternative fuels, such as LNG
- The uncertainty that exists in relation to the longevity of LNG as an energy source – LNG does not address the problem of carbon emissions
- The company views LNG as an interim solution that will be overtaken by developments in other fuels such as electricity and hydrogen.
- The scarcity of engineers with experience in using alternative fuels
- Supply chain difficulties in relation to LNG
- The relatively low interest in LNG within the shipping sector (exceptions were recognised in certain geographic regions (such as Scandinavia), and in certain sectors of the industry (such as cruise vessels). The director estimated that about 1% of the world fleet uses LNG and the demand has not reached a plateau, but the growth rate is slowing.

Given the levels of risk and uncertainty that exist in relation to LNG, the company expressed the view that it was not in its interest to "lead the way". Strategically, the company is better served by keeping a close watch on developments in LNG and by being flexible and adaptable in following changes in the industry.

The Operations Director was more open to using shore based electricity, which would have significant benefits in terms of air quality in ports. He offered the opinion that cold-ironing initiatives would have to be subsidised by ports or national governments, in order to offset the high capital cost of the infrastructure and grid connections, and the higher Opex involved for shipping companies.

The Operations Director noted the financial supports and tax breaks being offered to Norwegian shipping companies that use LNG. He also noted the lower harbour dues that are charged in French ports on vessels that use shore-side electricity.

Note: Marine diesel engines can be converted to LNG, but at considerable cost. It requires the installation of different valves and treatment plant for the storage and preparation of the fuel for use in diesel engines.

Vignette 3

Tanker Company

Fleet Manager

The company is a world leader in maritime transport. It manages a fleet of more than 50 ships, comprising product tankers, bulkers and container vessels. The company's mission and strategy makes specific reference to the protection of the environment. Notwithstanding its environmental policies, the company does not use alternative fuels, it does not use shore-side electricity and it has no immediate plans to alter its position. The Fleet Manager explained the company's stance:

- There is insufficient global demand to warrant widespread capital investment in alternative fuel infrastructure, with less than 1% of the world fleet using LNG.
- The availability of LNG facilities at international ports will be piecemeal at best.
- There is no settled position within the shipping industry in relation to fuels of the future.
- Since LNG does not resolve the decarbonisation issue, the shipping industry expects further development in fuels technology and will not invest in LNG powered vessels at present.
- It would be imprudent of the company to risk significant investment in vessels powered by alternative fuels, at this point in time.
- The cost of grid connections in smaller ports will make the provision of shore-side electricity uneconomic.
- For the foreseeable future, the company will rely on marine diesel, using scrubbers to reduce NOX and SOX emissions.

The fleet Manager regards LNG as a short-term solution only that does not justify a long-term capital commitment.

Vignette 4

Chief Operations Officer

International Tanker Operator

The company, which is based in Europe, is engaged in the ownership and operation of product and chemical tankers in worldwide trade. The company has a fleet of 19 vessels and charters in additional tonnage as the demand arises.

The COO, in a recent interview, expressed the view that although it is not economically viable to operate vessels with alternative fuels now, the economics of the argument will change in tandem with increased environmental awareness and a desire by shipping companies to live up to their corporate social responsibilities. Although the economic case for alternative fuels is not yet persuasive, the COO is of the opinion this will change as environmental regulations become more stringent. For the moment, the COO believes that long term investments in untested alternative fuel technologies are inconsistent with the uncertainty that surrounds their use. The company will not convert to alternative fuels under present circumstances.

Vignette 5

Vice President Sales

European Shipyard

The Group is a fully integrated shipbuilding enterprise, part of the strong maritime cluster which has specialized in state-of-the-art offshore and fishing vessel technology. The Group specializes in ship design, shipbuilding technology, ship equipment and systems. The Group is a market leader in the construction of vessels that use alternative fuels and in December 2018 received a grant to develop a hydrogen powered propulsion system for cruise ferries.

The VP is a proponent of the use of alternative fuels in the shipping industry. He accepts that the conditions in the market his company serves are conducive to the use of alternative fuels, referring specifically to the strong environmental policies and supports for the development of the industry that exists. The prominence of cruise tourism in the market, in addition to the abundance of short-distance ferry services are strong drivers of the use of alternative fuels. Notwithstanding the favourable regulatory framework and prevalence of alternative fuel use in the cruise and short-sea sectors, the VP estimated that only 10% of vessels operating in the market use alternative fuels. He accepted that the rate of conversion to alternative fuel usage across the shipping industry had slowed.

The Group has positioned itself to take advantage of the increased usage of alternative fuels in the shipping industry in the future, which the VP considers inevitable, as environmental regulation enforces increased usage of greener fuels in response to climate change.

Vignette 6

Sales Director

Shipyard

The Group is engaged in shipbuilding and engineering in Northern Europe, doing business in 120 countries. It operates more than 50 shipyards, repair yards, and related companies - as well as numerous partner yards. Its interests in all areas of the shipping industry give the company unique insights into how demand for vessels that use alternative fuels is changing across different sectors, from cruise to container ships.

The Sales Director confirmed that less than 1% of the world fleet is powered by alternative fuels. He recognized a concentration of interest in alternative fuel vessels in the cruise sector and commented on the environmental policies and tax incentives that have given rise to increased market demand in countries in Northern Europe. On average, vessels that use alternative fuels cost more than conventional vessels (higher Capex + 20%) and have higher running costs (higher Opex + 25%). He concluded that without incentives, the market will not opt for alternative fuels.

The Sales Director offered the view that scrubbers technology is accepted across the shipping industry and is seen as a viable solution that involves an acceptable risk/reward profile to the shipping industry.

Vignette 7

Port Engineer

Core Port within Europe

The Port is in the process of transferring a significant part of its trades to a purpose built terminal, down river from its existing location. The provision of AFI was considered as part of the new development, but was rejected as unviable because of the low level of demand that exists within the shipping industry for alternative fuels. The Port Engineer expressed the view that the decision not to provide AFI was justified on the basis of:

- Low demand for AFI in the Port (currently no demand)
- Risk that demand will never reach a level that will generate a return on the significant capital investment involved
- Superior demand for AFI at other ports that give them greater economies of scale than those that can be generated in smaller ports. He expressed the view that not every port needs to have AFI
- High risk that LNG is a bridging solution that will be replaced by fuels that contribute more significantly to decarbonization

He made it clear that the port had no immediate plans to reconsider its decision in relation to AFI.

10.0

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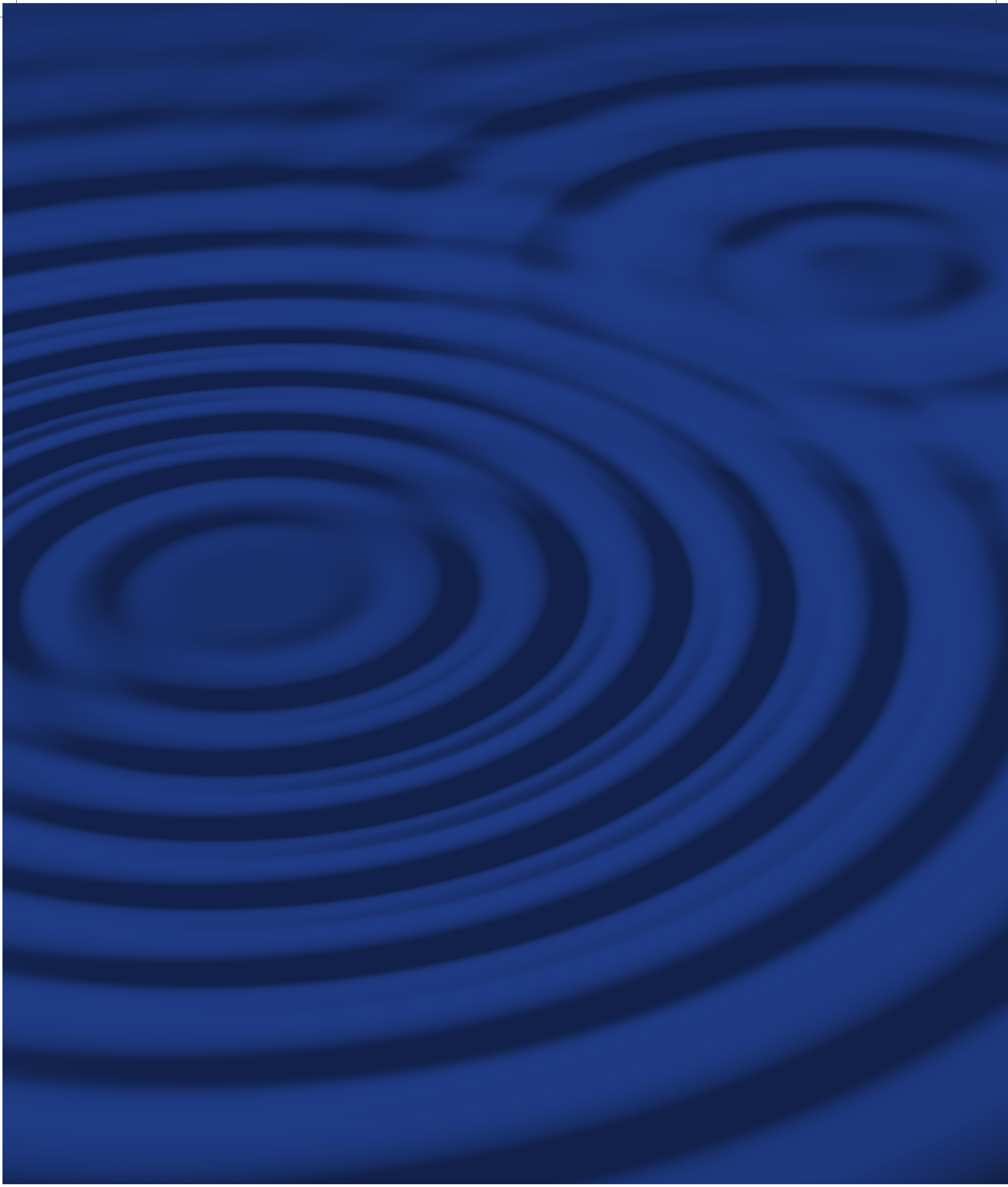

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