CHAPTER 24 - Protecting the Arctic Environment: Challenges and Opportunities for Liquefied Natural Gas

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Protecting the Arctic Environment: Challenges and Opportunities for Liquefied Natural Gas

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Résumé : *De nombreux rapports scientifiques sur les indicateurs climatiques et leurs analyses statistiques approfondies témoignent que l'impact du phénomène du réchauffement planétaire est de plus en plus évident. Les modèles météorologiques ont déjà été gravement altérés dans diverses régions de la Terre, le cas de l'Arctique étant clairement visible. Comme la couverture de glace dans cette région maintient sa tendance à la baisse, la création d'opportunités d'affaires nouvelles et significatives devrait cependant être notée. Des itinéraires maritimes précédemment couverts par des banquises sont maintenant disponibles pour la navigation. La promesse de voyages plus courts en provenance d'Asie vers l'Europe et / ou les Amériques (et vice-versa) attire. En outre, la diminution de la glace dans l'ensemble de l'Arctique pourrait faciliter l'extraction des nombreuses ressources naturelles (et notamment énergétiques) disponibles dans toutes ces zones gelées, qui étaient auparavant considérées comme inaccessibles à tout type d'entreprise.*

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L'analyse conduite met brièvement en évidence le déclin de la couverture glaciaire dans l'Arctique et élabore sa principale conséquence par rapport au système de transport maritime mondial contemporain : la création des « passages arctiques ». En outre, elle fournit un résumé du cadre réglementaire actuel associé à la région étudiée, et en particulier les dispositions du Code international pour les navires opérant dans les eaux polaires (code polaire arctique). De plus, compte tenu du fait que l'utilisation du pétrole est aujourd'hui la principale source de combustibles au sein de la navigation commerciale, cette analyse permet d'élargir les efforts de recherche antérieurs visant à préserver l'environnement arctique en limitant l'utilisation de ces carburants. Par conséquent, elle examine l'utilisation de sources alternatives, notamment sous forme de gaz naturel liquéfié (GNL), afin de réduire l'impact environnemental du pétrole déversé dans les eaux arctiques vierges, en cas de déversement accidentel, mais aussi afin de réduire les polluants atmosphériques.

Abstract: *Numerous scientific records of climate indicators and in-depth statistical analyses thereof testify that the impact of the phenomenon of global warming is becoming increasingly evident. Weather patterns have already been severely altered in various regions of the Earth, with the case of the Arctic clearly standing out. As ice coverage in this region maintains its downward trend, the creation of new and significant business opportunities should, however, be noted. Maritime routes that were previously covered with ice packs are now becoming available for shipping; the promise for shorter voyages from Asia towards Europe and/or the Americas (and vice-versa) is enticing to say the least. Additionally, the reduction of ice in the wider arctic region could facilitate the extraction of the numerous natural resources (and especially energy-related ones) available in all those frozen areas, which were previously widely considered as unsuitable for any type of business.*

The analysis in hand will briefly highlight the decline of ice coverage in the Arctic and elaborate on its main consequence in relation to the contemporary global maritime transport system: the creation of the so-called "Arctic Passages". Additionally, it will provide a summary of the current regulatory framework associated with the region under discussion and especially the provisions of the International Code for Ships Operating in Polar Waters (Polar Code or PCD). Furthermore, considering petroleum is today the primary marine fuel source within commercial shipping, this analysis will expand upon previous research efforts into how to preserve the arctic environment by limiting the use of such oil fuels. Therefore, it will explore the use of alternative sources, specifically in the form of liquefied natural gas (LNG), as a way to reduce the environmental impact of petroleum spilled within the pristine arctic waters in the event of an accidental discharge, as well as to decrease air pollutants.

INTRODUCTION

Numerous agencies and institutes around the globe (e.g. National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA), both based in the United States of America, the European Space Agency (ESA), the Japanese Meteorological Agency (JMA) and the United Kingdom's Hadley Centre) monitor data such as temperatures and ice level in the Arctic by air, land and sea-based means (e.g. drifting buoys), or even images from space. Their observations and statistics strongly support the argument that the consequences of global warming are becoming increasingly evident.[5] It is no coincidence that the Arctic is used by climate scientists as an indicator for the course of events for the whole planet Earth: this region heats up with the greatest pace when compared to any other part of the world.[6] It is also important to note that the year 2016 is a milestone in Arctic history. First, it is a sequential year that the sea ice cannot recover satisfactorily. Additionally, during the previous winter season (between the years 2015 and 2016) record high air temperatures were attested by two principal research centres monitoring climate behaviour: NASA and NOAA.[7] In fact, the pace of the Arctic sea ice retreat is increasing, currently being at 13.3% per decade compared to the average of the ages 1981-2010[8]. The relevant data provided by the US's National Snow and Ice Data Centre (NSIDC) is self-explanatory (see figure 1); all these accumulated pieces of information are clearly testifying that climate change and ice retreat in the Arctic are both a reality. Therefore, it is a pressing need for the whole international community to adapt and respond to this new environmental situation.

On the other hand, this scientifically-recorded decline of ice coverage in the Arctic is creating significant new business opportunities: maritime routes that were previously no-go areas for navigation are now becoming more and more accessible. According to the latest scientific estimates, the days when navigation is possible are expected to follow an increasing trend: from around 70 days (currently) up to 125 in the year 2050 and as many as 160 in 2100.[9] As a result, ship owners are beginning to consider the use of the so called "Arctic Passages" in order to capitalise on shorter voyages,

5) Intergovernmental Panel on Climate Change, available at: http://www.ipcc.ch/, accessed June 2015.

6) Dalaklis D. & Baxevani E., (2015), "Maritime Transport in the Arctic after the Introduction of the Polar Code: A Discussion of the New Training Needs", *ShipArc 2015: Safe and Sustainable Shipping in a Changing Arctic Environment Conference*, Malmo, Sweden, 26 August 2015.

7) Dalaklis D., Baxevani E. &, Siousiouras P., (2016), "The Future of Arctic Shipping Business and the Positive Influence of the Polar Code", *International Association of Maritime Economists 2016 Conference*, Hamburg, Germany, 24 August 2016.

8) CLIMATE NASA Report: 2016 Global Climate Change & Arctic Sea Ice Minimum, available at: http://climate.nasa.gov/vital-signs/arctic-sea-ice/, accessed March 2016.

9) Cariou P. & Faury O., (2015), Relevance of the Northern Sea Route (NSR) for bulk shipping, *Transportation Research Part A*, 78, pp. 337–346.

therefore saving on time and fuel costs as well as reducing air pollution. Additionally, great interest is now more openly expressed for the extraction of the estimated natural resources available in all those (previously) isolated areas and the Arctic seabed, another possible task for maritime transport. With the understanding that arctic routes are alternatives to traditional trans-ocean routes and more specifically that these alternate routes are in their infancy (because the number of yearly crossings remains well below a hundred) there is obviously a window of opportunity for regulators to establish stiff safety measures under a pre-emptive approach in order to substantially decrease the impact of the expected increase in maritime traffic towards the extremely sensitive arctic marine environment.[10]

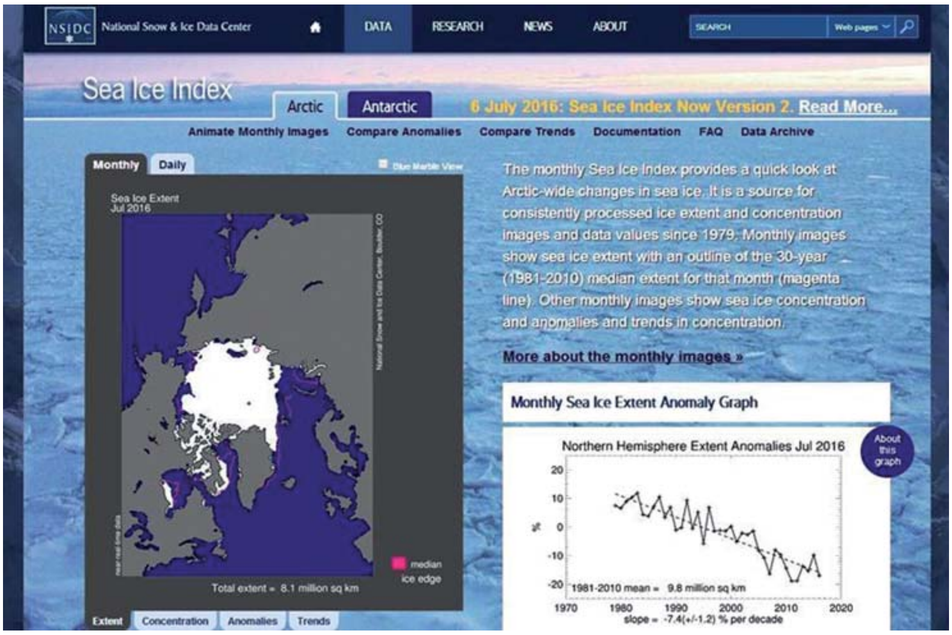

Figure 1 – Arctic Sea Ice Index

Source: The National Snow and Ice Data Center (NSIDC) (United States of America), available at: https://nsidc.org/data/seaice_index/, accessed September 2016.

Before proceeding any further, it is necessary to note that, for the purposes of the analysis in hand, the region of the Arctic contains the Arctic Ocean as well as the respective territories of the five states with a latitude higher than the Arctic Circle (66°33'46.1 N) that have (Arctic) coastlines and can therefore raise claims regarding

10) DeWitz, J., Dalaklis D., Olcer A. & F. Balini, A., (2015), "Arctic LNG: Exploring the Benefits of Alternative Fuels to Mitigate Environmental Impact Risks", *ShipArc 2015: Safe and Sustainable Shipping in a Changing Arctic Environment*, Malmo, Sweden, 26 August 2015.

the continental shelf, namely Canada, the US (via Alaska), Denmark (via Greenland), Norway and Russia, also called the "Arctic 5". There is a simple explanation why: these countries have the right to project their sovereignty seawards; in fact, Denmark, Canada, Norway, and Russia have already made submissions in relation to the Arctic seabed to the United Nations Commission on the Limits of the Continental Shelf (CLCS), which was established by the 1982 United Nations Convention on the Law of the Sea (UNCLOS).[11] In any case, the area north of the Arctic Circle is about 20 million square kilometres (7.7 million square miles) and covers roughly 4% of Earth's surface.[12] The Arctic Circle passes through the Arctic Ocean, the Scandinavian Peninsula, North Asia, North America, and Greenland. The land within the Arctic Circle is divided among eight countries that have also formulated the Arctic Council, a necessary forum of cooperation: Denmark, Norway, Sweden, Finland, Russia, the US, Canada and Iceland (where it passes through the small island of Grímsey).

Although ice coverage in the Arctic maintains its downward trend, conditions for maritime traffic today still remain harsh and perilous. On the positive side, the International Maritime Organization (IMO) has already taken a pre-emptive and very significant step toward reducing the risks of maritime accidents, any of which could devastate the regions' fragile and sensitive ecosystem: safety levels for ships that will operate in this unfriendly region for transiting vessels are strongly enhanced through the introduction of the International Code for Ships Operating in Polar Waters (the Polar Code or PCD). It must also be noted that, since August 2011, the IMO has amended the International Convention for the Prevention of Pollution from Ships (MARPOL) to include Chapter 9 of Annex I, in order to prohibit the use of heavy grade oils as fuel (as well as cargo carriage) in the sea area beyond latitude 60° south. This, along with the recent adoption of the PCD, is a very strong indicator of increased global interest in establishing safer practices in the polar regions. Apart from a very quick summary of the current regulatory framework associated with the Arctic and especially the provisions of the PCD, the analysis in hand will briefly explain the transport routes that are currently in use in the area under discussion (or even emerge in the future) and highlight their potential for commercial use. Furthermore, considering that petroleum is today the primary marine fuel source within commercial shipping, this paper will expand upon previous research efforts into how to preserve the arctic environment by limiting the use of such oil marine fuels. Therefore, it will explore the use of alternative fuels, specifically in the form of liquefied natural gas (LNG), in order to reduce the environmental impact of petroleum spilled within the pristine arctic waters in the event of an accidental discharge as well as to decrease air pollutants.

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11) Commission on the Limits of the Continental Shelf - United Nations Oceans and Law of the Sea, available at: http://www.un.org/depts/los/clcs_new/clcs_home.htm, accessed May 2016.

12) For additional details see: Marsh W.M. & Kaufman M.M., (2012), Physical *Geography: Great Systems and Global Environments*, Cambridge University Press, Cambridge.

THE ARCTIC PASSAGES

Today, shipping is by far the most international of the world's industries. Each and every day, ships of different sizes and capabilities carry huge quantities of cargo and a very large number of passengers cost effectively, cleanly and safely. Maritime transport is essential to the normal functioning the world's economy as over 90% of the world's trade is carried by sea and this mode of transport is, by far, the most cost-effective way to move goods and raw materials en masse around the world.[13] With oceans covering almost three-quarters of the earth's surface and with the vast majority of all international trade transported by sea,[14] shipping activities should be considered the backbone of globalisation and vital for all "just-in-time economies".[15] Furthermore, shipping is an industry strongly interwoven with the environment; as such it can be directly affected by the latest environmental developments in the Arctic. In this case, the retreat of the ice caps opens up new areas and routes for navigation. This is indicated by the fact that recent interest in the form of "traffic facilitated by climate change" started in 2007 for the Northwest Passage (NWP) and in 2009 for the Northern Sea Route (NSR), when their respective complete transits were made possible for the first time, spurring the debate regarding the viability of the so-called "Arctic Passages".[16] It is necessary to emphasise that the contemporary global maritime transport system can be directly affected by the opening of these new routes (see figure 2). A promise for shorter voyages from Asia towards Europe and/or the Americas (and vice-versa) is enticing; the decision, however, on whether to opt for one of these routes or not is complicated, with many varying aspects involved simultaneously.[17]

The Northern Sea Route (NSR) connects the Atlantic with the Pacific Ocean, crossing the eastern part of the Arctic Ocean. The great majority of this route runs along the northern Russian coastline and is therefore "controlled" by Russian authorities. It is regarded as an alternative to the traditional route from Asia towards Europe through the Suez Canal and is actually 40% shorter compared to the one crossing the Indian Ocean. It is necessary to note that in 2014, according to the NSR administration data, approximately 53 transits were recorded in this particular route (carrying around 630,000 tons of freight), whereas for the same year the respective number transits of

13) International Maritime Organization, http://www.imo.org/en/About/Pages/Default.aspx, accessed March 2016.

14) United Nations Conference on Trade and Development-UNCTAD, (2015), *Review of Maritime Transport 2015*, UNCTAD/RMT/2015.

15) Dalaklis D., (2012), "Piracy in the Horn of Africa: Some good news, but a lot of work has still to be done…", *Maritime Security Review-MSR InDepth*, No. 9, p. 3.

16) Dalaklis D. & Baxevani E., (2016), "Arctic in the Global Warming Phenomenon Era: Maritime Routes & Geopolitical Tensions" in: *New maritime routes: origins, evolution and prospects,* (editors: Odile Delfour-Samama, Cédric Leboeuf & Gwenaele Proutière-Maulion), A. Pedone, Paris, 2016.

17) Dalaklis *et al.*, 2016.

the Suez was 17,148.[18] These statistics clearly testify that the Suez Canal's status as a pivotal maritime corridor will not be threatened by the Arctic any time soon.[19] The second important route in the Arctic is the Northwest Passage (NWP). This passage also links the Atlantic and the Pacific Ocean, but this time through the Canadian Arctic Archipelago. Its importance lies on the idea that it can be used as an alternative for the Panama Canal. But, the geographical complexity of this route and its legal regime ambiguity (that it is outside the scope of the analysis in hand), however, do not favour its large-scale use for maritime transport. More specifically, there is a disagreement between Canada – which claims that the passage is through internal/ territorial waters – and the USA (as well as the EU as a whole and various other state entities), which hold the view that these waters are international and therefore free navigation is in place. In addition, the NWP can be less predictable due to drifting floes of ice that may block parts of the route. It is noteworthy that, when it comes to both the NWP and NSR, there is no single defined route. Vessels may be required to navigate around various natural configurations, such as small islets or ice-blocks that prevent the use of a certain maritime corridor; this could result into adding (or saving) a percentage of nautical miles per journey.

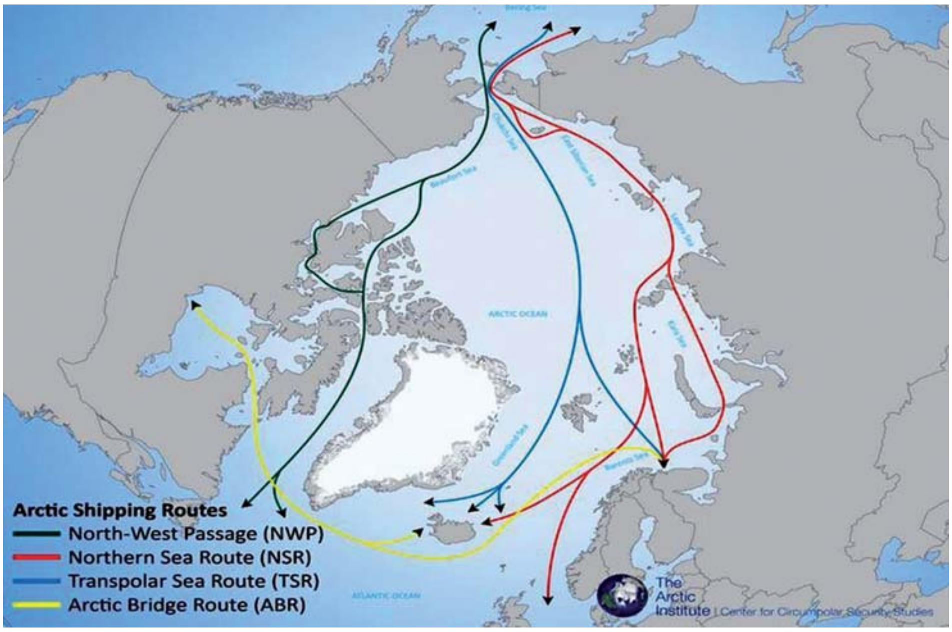

Figure 2 - The Arctic Routes

Source: ARCTIC INSTITUTE - CENTER FOR CIRCUMPOLAR SECURITY STUDIES, 2014.

18) Suez Canal Authority: Brief Yearly Statistics, available at: http://www.suezcanal.gov.eg/TRstat.aspx?reportId=4, accessed June 2015.

19) Dalaklis D., (2015), Maritime Security Energy Issues: The role of the Suez Canal, *6th NMIOTC*

Figure 2 shows the Transpolar Sea Route (TPR) (also known as Central Arctic Route or CAR). It is important to point out that, if climate change proceeds according to the latest scientific predictions, the current very infrequent use of the waters near the Pole will be transformed into a regular and rather heavily-used traffic route directly through the North Pole, even though icebreaker capacities will remain essential. This route would be the shortest possible connection between the American and Europe-Asian continents and, of course, their respective markets. But, the time scale for this prediction is much extended in the future and many factors influencing the final outcome could change. Furthermore, the Arctic Bridge (AB) is included in this summary of Arctic Passages. It is essential to clarify that this route is not referring to a crossing of the Arctic, but it is a seasonal sea (and air) connection between the Canadian port of Churchill and the Norwegian port of Narvik or the Russian port of Murmansk. Finally, it needs to be strongly highlighted that transiting through the Arctic via the above-mentioned passages is possible only for a rather limited time period (a couple of months per year, around summer). And that for the time being, it is the NSR that has attracted most attention for reasons connected with common sense, as well as political drivers. Its geomorphology is less complicated than the NWP; it also connects the Asian to the European market, with hinterland connections being far better when compared to the vast Canadian and Alaskan areas. Additionally, Russia has officially stated the goal to make its northern territories appealing; it has diverted major funds towards that region to build ports, icebreakers, enhance navigation safety as well as the associated hinterland connections.[20] It should be emphasised here that coastal infrastructure adaptation to climate change, in particular for new ports in this region, is an important consideration which needs to be factored into the strategic planning from very early design stage.[21]

REGULATORY EFFORT TO PROTECT THE ARCTIC ENVIRONMENT

A very important IMO initiative, which aims to protect the environment at the global level, is the introduction of restrictions on the air pollutants associated with shipping that came into force in 2015 for the already established Sulphur Emission Control Areas (SECAs) and in 2020 for the rest of the world. For ship owners, in order to be compliant with these restrictions, changes in the current business model are needed, with two main options are currently standing out: a) integrating an emission abatement technology, such as scrubber, in the current propulsion system of their ships; b) opting for a more environmentally friendly energy resource such as liquefied natural gas

Conference: "Current and future challenges to Energy Security in the Maritime Environment", Chania, Greece, 4 June 2015.

20) Dalaklis & Baxevani, 2015.

21) Mutombo K. & Ölçer A., (2016), Climate Change in the Arctic Region: building port infrastructure resilience, *Journal of Ocean Technology*, Volume 11, No.3, pp. 20-30.

(LNG); c) using low sulphur – but more expensive – fuel such as MGO (marine gas oil) or MDO (marine diesel oil). It is true that several technological solutions to the above-mentioned situation are currently being evaluated; however, it needs to be strongly emphasised that, for the time being, LNG has the possibility of remaining the leading candidate in order to retain a substantial share of the world bunker market. To begin with, LNG has already proven its value, since numerous ships are already running on this type of marine fuel; when LNG is used for propulsion, ship's emissions easily conform to the new regulatory requirements and less CO_2 is released in the atmosphere, a very positive contribution to dealing with the adverse overall effects of greenhouse gases. In comparison to diesel, typical emissions savings associated with natural gas are: greenhouse gas reduction of between 11% and 20%, NO_x emissions reduced by 80% and particulate matters and SO_x emissions removed by 99%.[22] In addition, economics are in many cases in favour of LNG, while a few challenges like LNG bunkering availability arise.

Shifting from the global towards the regional level, the first important initiative to preserve the pristine polar environment was related solely to Antarctica; it took place during August 2011, when the carriage of heavy fuel oils (HFO) in bulk as cargo or fuel was prohibited in the sea area beyond 60° S latitude, as prescribed in MARPOL Annex I Chapter 9. It is true that this prohibition was limited to only a few selected vessel operations, but it is self-explanatory that the protection from potential pollution by HFO should be considered a very significant milestone toward achieving a "collective global commitment" in the multi-level efforts needed to preserve polar waters. Certainly, there is no need to question the idea that for the Arctic too, collaboration at a global and/or regional level is the way to move forward. Important developments in this domain have already taken place: in May 2013, the global commitment to protect polar waters was strengthened in the North. The eight Arctic Council member states signed an Agreement on Cooperation on Marine Oil Pollution Preparedness and Response in the Arctic.[23] This was to be a set of non-binding Operational Guidelines for cooperation, coordination and mutual assistance. Most critically, these guidelines address procedures for notifications and assistance requests, command and control in response operations, joint training and exercises, administrative issues and other recommended measures in order to facilitate an effective cooperative oil pollution incident response. Again, there is a concerted effort to collectively utilise all resources available in order to ensure preservation and conservation within arctic areas as a top priority.

Another influential initiative in relation to the polar regions followed swiftly. In November 2014, the IMO member states finalised and adopted the International Code for Ships

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22) LNG Master Plan project, available at: http://www.lngmasterplan.eu, accessed May 2016.

23) Arctic Council, (2013), *Agreement on Cooperation on Marine Oil Pollution Preparedness and Response in the Arctic.*

Operating in Polar Waters (Polar Code or PCD); it will enter into force on the 1 January 2017. This Code, the most significant body of work by the international community in terms of polar regulation, covers the full range of ship design, construction, equipment, operations, training, search and rescue and environmental protection matters relevant to ships operating in the "unfriendly" and frozen waters surrounding the poles (see figure 3). The PCD is divided into two different parts: mandatory measures covering safety are included in part I-A, while pollution prevention is covered in part II-A. Finally, recommendatory provisions for both these important domains are in parts I-B and II-B respectively. Additionally, this "goal-based" Code, where the standards for ice strengthening and safe design differ depending on the risks associated with the activities, requires ships to apply for a Polar Ship Certificate in which they would then be classified as Category A, B, or C. In more detail, Category A ship refers to ships designed for operation in polar waters at least in medium first-year ice, which may include old ice inclusions; Category B ship refers to ships not included in category A, designed for operation in polar waters in at least thin first-year ice, which may include old ice inclusions; finally, Category C describes a ship designed to operate in open water or in ice conditions less severe than those included in Categories A and B. The issuance of a certificate would require an assessment, taking into account the anticipated range of operating conditions and hazards the ship may encounter in the polar waters. This assessment includes information on identified operational limitations and plans or procedures for additional safety equipment necessary to mitigate potential safety or environmental incidents.[24]

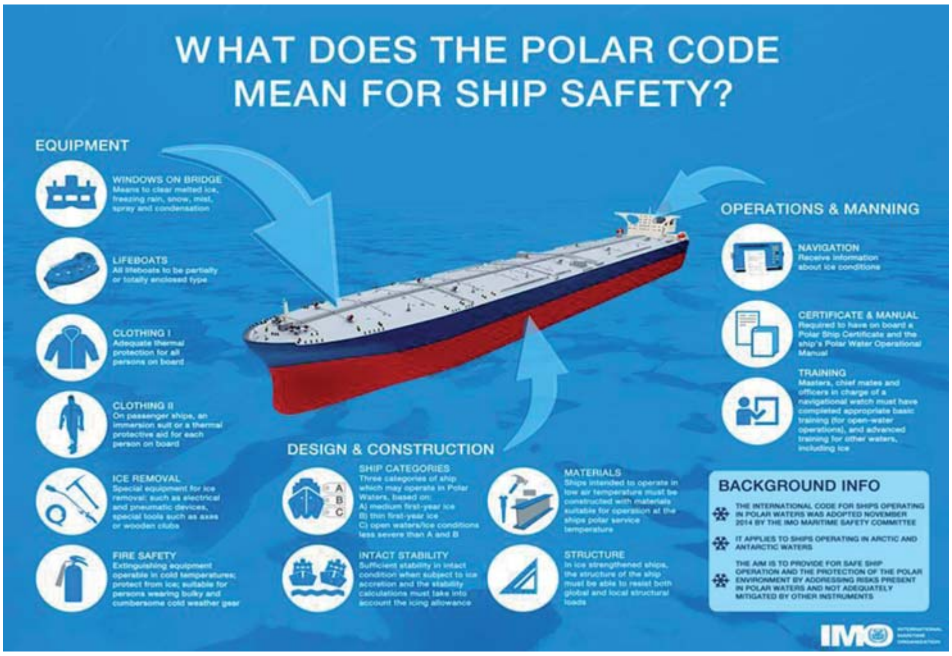

Figure 3 – The IMO Polar Code
Source: IMO website, 2015.

Finally, the IMO recently adopted the Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels (IGF Code), with amendments to make the Code mandatory under the International Convention for the Safety of Life at Sea (SOLAS); this new "toolbox"of regulations will also come into force in 2017. It is almost a self-explanatory fact that the interest in gas as a fuel, particularly liquefied natural gas (LNG), has significantly increased in the industry in recent years due to its very low sulphur and particulate matter emissions. On the other hand, gas and other low-flashpoint fuels pose their own set of safety challenges; LNG, in particular, is kept in a cryogenic state which requires skilled operators to balance tank pressures and temperatures during bunkering operations. The IGF Code aims to minimise the risk to the ship, its crew and the environment, taking into account to the nature of the fuels involved. The goal-based Code contains mandatory provisions for the arrangement, installation, control and monitoring of machinery, equipment and systems using LNG.[25] Furthermore, with a strong similarity to the respective approach of the Polar Code, the IGF Code has also established special training requirements for personnel involved in this type of operation.

LIQUEFIED NATURAL GAS

The global trade in liquefied natural gas (LNG) is growing rapidly: from an almost negligible amount in 1970 up to what is expected to be a globally meaningful amount around the year 2020. As a reference, the 2015 total "petroleum and other liquids fuel" global consumption was 93.78 million barrels per day.[26] To elaborate more on statistics, during the year 1970, global LNG trade was extremely low, around 3 billion cubic meters (bcm); by 2011, it was increased up to the level of 331 bcm.[27] If this trend is maintained until the end of this decade, the LNG market could then be roughly 10% the size of the global crude oil market and that does not count the vast majority of natural gas which is delivered via pipelines directly from the well to the consumer. In any case, it is very difficult to predict the future of energy consumption, especially when taking into consideration the recent financial crisis. But, it is a given fact that today a majority of the world's supply comes from countries with the largest natural gas reserves: Algeria, Australia, Brunei, Indonesia, Libya, Malaysia, Nigeria, Oman, Qatar, Trinidad and Tobago, as well as Russia and the US. In most cases that describe a LNG value chain commercial development, the (LNG) suppliers first confirm sales to the downstream buyers and then sign long-term contracts (typically 20–25 years)

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24) DeWitz *et al.*, 2015.

25) Kriliæ T., (2015), News from IMO, *Transactions on Maritime Science*, 4(01), pp. 54-57.

26) Energy Information Agency-EIA, http://www.eia.gov/forecasts/steo/report/global_oil.cfm, accessed February 2016.

27) Economist, available at: http://www.economist.com/node/21558456, accessed June 2014.

with strict terms and structures for gas pricing; only when the customers are confirmed and the development of the respective project is deemed economically feasible, the sponsors of an LNG project would invest their money towards development and operation. Thus, the LNG liquefaction business has been limited to players with strong financial and political resources. Major international oil companies (IOCs) such as ExxonMobil, Royal Dutch Shell, BP, BG Group, Chevron, and prestigious national oil companies (NOCs) such as Pertamina and Petronas are very active in the LNG domain, with a brief summary of actors involved in the LNG market provided in figure 4:

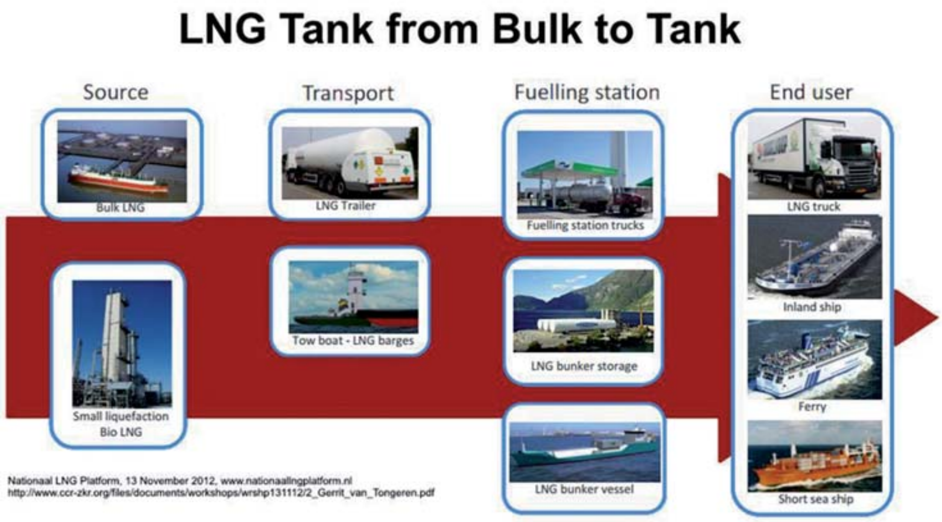

Figure 4 – Actors in the LNG market

It is important to clarify the fact that liquefied petroleum gas (LPG), liquefied natural gas (LNG) and compressed natural gas (CNG) are all fossil derived fuels. Therefore, their use can release (one way, or another) greenhouse gases into the atmosphere. As vehicle fuels, they are suitable for use in the two dominant internal combustion engine technologies: spark ignition and compression ignition. Although capable of working in either type of the above-mentioned engines, there are practical factors which limit their applications to one rather than the other. Broadly speaking LPG is compatible with petrol (gasoline) engines, such as those of cars and trucks; LNG and CNG are a better match for heavy diesel vehicles and certainly for large size seagoing vessels (see figure 5). Although, in principle, they can be used to replace diesel or petrol, LPG is better suited as a petrol alternative for smaller vehicles such as cars and small vans and LNG and CNG are appropriate for larger diesel vehicles. LNG maintains a higher reduction in volume when compared with compressed natural gas (CNG) so that the (volumetric) energy density of LNG is 2.4 times greater than that of

CNG or 60% that of diesel fuel.[28] This makes LNG cost efficient to transport over long distances where pipelines do not exist. Specially designed cryogenic sea vessels (LNG carriers) or cryogenic road tankers are used for its transport. LNG is principally used for transporting natural gas to markets, where it is re-gasified and distributed as pipeline natural gas. It can be used in natural gas vehicles, although it is more common to design vehicles to use compressed natural gas. Its relatively high cost of production and the need to store it in expensive cryogenic tanks have hindered widespread commercial use.

Figure 5 – Bunkering operation of an LNG powered vessel
Source: LNG Europe.

Focusing more on LNG properties, it is a gas kept in a liquid state through the application of cryogenic temperature (near -163 Celsius). This fuel can be stored within a high-pressure tank (10 bar or more), or within an "ordinary" atmospheric tank depending upon the fuel system demands. Currently, many coastal vessels are fitted with independent type C pressure tanks because of their small capacity needs. Ocean-going ships will certainly require much larger capacity than the coastal ones and

28) *Envocare*, available at: http://www.envocare.co.uk/lpg_lng_cng.htm, accessed February 2016.

therefore utilise membrane atmospheric tanks. Nevertheless, all types of LNG storage tanks are designed with extensive safety features, to include containment and monitoring. When LNG is exposed to the atmosphere, it will warm and return to its natural gaseous state. This is done by rapid boiling and evaporating. This evaporation process can be accelerated when LNG comes into contact with surfaces with a higher temperature, such as seawater or even ice.[29] Initially, LNG is heavier than air and settles on the water's surface while changing state. As the temperature elevates to -107°C, it will become lighter than air and begin to rise from the surface. Wave action will naturally sustain the accelerated evaporation, expediently dissipating the risk in absence of an ignition source. Vaporisation studies have been on-going for several decades; a report from 1970 conducted by the U.S. Coast Guard Hazardous Materials Division, in a controlled environment, found that the vaporisation rate was 0.037 lbs/ft sec.[30] Recognising that many variables will affect the evaporation speed, it remains safe to assume that a worst case discharge of a deep sea LNG fuelled vessel would likely evaporate long before first responders could arrive to the scene.

The flammability range, undeniably present, is only slightly higher than that of light oils and does not pose an explosion risk despite public perception. Unless a spill is trapped where vapours can accumulate over a period of time, such as a tank space or engine room, then it might be possible to build pressure and cause rapid expansion. However, the level of detection mandated by the IGF Code requires detection redundancies in nearly every phase of the fuel system, proper installation of adequate ventilation as outlined in the IGF Code, and swift response action by the crew would quickly mitigate this occurrence. LNG has a relatively low reactivity and low burning speed with a flammability range of 5-15% volume in air. Even in polar conditions, LNG would rapidly warm and turn to gas, forming an air-gas mixture well below the lower flammable range. When an ignition source is introduced, burning would not easily occur because of such a narrow flammability range. If ignited, the flame speed is slow and would therefore not produce dangerous overpressures like that of liquid petroleum gas. Although the accidental release of LNG into the Arctic marine environment would be considered a pollutant, the devastating effects like that of oil would not be present. In fact, there would be no effect to the marine water quality because the gas is neither toxic nor corrosive. Also, once the liquid turns to its gaseous state, it would rise and therefore not affect marine life.[31]

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29) DeWitz *et. all*, 2015.

30) United States Coast-Gurd, 1970, *Hazard of LNG Spillage in Marine Transportation*, Final Report Supporting Investigation: MIPR No. Z-700099-9-92317. Department of Transportation, U.S. Coast Guard Hazardous Materials Division.

31) DeWitz *et. all*, 2015.

CONCLUSION

As a result of global warming, weather patterns have already been significantly altered in various regions of the Earth. Among such cases, the Arctic is perhaps the most obvious one. In contrast with the thus-far responsive regulatory efforts of the IMO, both polar regions and especially the Arctic were approached via a pre-emptive approach. It is indicative that in 2002, the IMO published recommendatory provisions for Arctic shipping which stated in the introduction: "Ships operating in the Arctic environment are exposed to a number of unique risks. Poor weather conditions and the relative lack of good charts, communication systems and other navigational aids pose increased challenges for mariners. The remoteness of the areas makes rescue and clean-up operations difficult and costly. Cold temperatures may reduce the effectiveness of numerous components of the ship, ranging from deck machinery and emergency equipment to sea suctions. When ice is present, it can impose additional loads on the hull, propulsion system and appendages."[32] Although the ice coverage problem is better when compared with the situation roughly fourteen (14) years ago, the challenges have remained the same. Arctic shipping has now become a real opportunity and according to growing statistics showing substantial ice diminish, the shipping community will continue to pressure regulators to establish the parameters in which to reasonably operate. Nearly every area of traditional shipping must be further analysed for continued risk mitigation and it is incumbent upon Arctic nations and supporting IMO member states to put forth prudent action. Many believe this is being done. However, as profound as it may seem, the opportunity to eliminate the threat of oil spills is well within maritime governance's ability and authority. Reducing an Arctic environmental footprint of this magnitude can positively alter the future of shipping for generations to come.[33]

In early 2015, the maximum sulphur content in burnt marine fuel within SECAs was effectively reduced from 1.0% to 0.1%. In 2018, IMO member states must decide on whether to mandate a global reduction of sulphur content to 0.5% with an expected implementation in 2020. Currently, the SECA regulation allows emissions to be mitigated by either modifying the fuel specification/type or by the cleaning of exhaust gas. Owners with existing vessels operating within a SECA must choose between distillate fuels, installing exhaust gas cleaning systems (scrubbers) or replacing engines that run on clean fuels. The major obstacle for a global reduction in sulphur content in marine fuel is the availability of such fuel to meet the stringent SECA requirements. The EU has already agreed, regardless of any decision by the IMO, that a 0.5%

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32) MSC, (2002). MEPC circular on guidelines for ships operating in Arctic ice-covered waters. Annex 10 of the forty-fifth session of the Sub-Committee (DE 45/27)-reference Chapter 11 of the Circular. Draft Guidelines submitted to MSC76.

33) DeWitz *et. all*, 2015.

sulphur limit will apply to international shipping within 200 nautical miles of the coast of all EU member states for ships calling at EU ports. The International Chamber of Shipping has in this context stated: "For better or worse, the global cap is very likely to be implemented in 2020, almost regardless of the effect that any lack of availability of compliant fuel may have on the cost of moving world trade by sea." But, a solution to this rising problem is already in place: LNG-fuelled engines have very clean exhaust gases compared to traditional marine fuels. Furthermore, Northern Europe has been leading the way in LNG bunkering, mainly within the Baltic region, such as the EU funded research project, namely GoLNG;[34] Norway, Denmark and Sweden are clearly leading, but further progress is being made throughout the non-SECA regions to increase capacity and capability. Last, but not least, there are now on-going LNG bunker projects throughout the Mediterranean to include the Atlantic side of Spain, Portugal, and France. Even though these nations are not mandated to reduce emissions at the moment, they are preparing for the market shift to cleaner fuels.

It is true that the advancement of marine engines, capable of being powered by non-oil fuel sources, has truly exploded in most of the major manufacturers. Today, there is a plethora of options to consider: from hydrogen to methane, or even biofuel; many of the aforementioned are providing better efficiency or a more environmentally friendly performance. Unfortunately, many of these fuels have limited bunker availability and the purchase and installation of the related equipment or systems can be quite expensive. However, there is one fuel in particular that is being considered "a viable alternative" to marine oil; that is liquefied natural gas (LNG). The progress already made in engine design, performance and efficiency, as well as bunkering, containment and monitoring of the specific energy resource, has given the maritime industry a real solution to traditional oil alternatives. When dealing with the future of the maritime industry and creating the new necessary regulations, it is important to consider that the expected increased traffic in the Arctic can result in inherent pollution discharges associated with emissions and waterborne routine maintenance and operations, not to mention the inventory demand of sources needed to efficiently combat the effects of an oil spill.

Let us not forget that, under icy conditions, there are tremendous difficulties in operating traditional mechanical oil containment and recovery equipment. For example, containment booms are generally ineffective due to ice drifts and in a high sea state, because their positioning can quickly be compromised by even the lowest concentrations of ice. Mechanical recovery equipment, originally developed for open waters, can easily become congested with large influences of ice and slush rendering the equipment more burdensome than effective. It is no surprise that there are many alternatives to oil, in today's contemporary energy portfolio, but LNG has already earned the prestigious title of the most commercially-viable competitor. This industry

34) GoLNG project, available at: http://golng.eu/, accessed June 2016.

has grown exponentially over the last few years, with technical capabilities steadily improving. In summary, the authors envisage that further regulations strictly limiting the use of oil within the polar regions will significantly reduce the environmental impacts by encouraging the use of clean fuels such as LNG. Finally, a pressing issue that still remains unresolved is the availability of ice-breakers to accommodate the expected increase of maritime traffic. When the Danish-owned Nordic Orion became the first bulk carrier to transit the Northwest Passage, it relied on an escort for part of the route by the Canadian Coast Guard's most capable icebreaker, the Louis S. St-Laurent. The ship's voyage, completed in October 2013, revealed the importance of escort ships in order to take advantage of Arctic opportunities for maritime transport. The more than 45-year-old vessel is one of only two Canadian icebreakers capable of making sure the 1,450-kilometer (900-mile) transit can be done safely. Clearly, additional investments in new construction icebreakers are necessary in order to support the expected use of the Arctic Passages. Russia's associated infrastructure, with five nuclear-powered icebreakers, allows it to keep the NSR open year-round. Russia also has a dedicated Arctic search and rescue service, with two icebreakers containing diving equipment and oil spill response gear. This country has also made public its plans to build more ice-breaking rescue vessels with helicopter access; the respective American capabilities, for the time being, remain rather limited and this is a significant disadvantage for the NWP.

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