LNG-Fueled Vessels – Environmentally friendly ships for the Arctic

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A Symposium on
Environment in the Courtroom:
Protection of the Marine Environment
October 13, & 14, 2016
Dalhousie University

Canadian Institute of Resources Law Institut canadien du droit des ressources

UNIVERSITY OF CALGARY
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This project was undertaken with the financial support of:
Ce projet a été réalisé avec l'appui financier de :
Environment and Climate Change Canada
Environnement et Changement climatiq

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I. Introduction

For many years, liquefied natural gas (LNG) has been carried as cargo aboard vessels. However, it is a relative novelty in international shipping to use LNG as fuel for the vessels themselves. Offering clear advantages over traditional fuel both in terms of costs and environmental protection, LNG is arguably the most revolutionary change in international shipping in decades. For the Arctic, this means a complete rethinking of oil-spill preparedness and prevention.

II. Background: what is LNG and why are we talking about it now?

LNG is essentially methane gas, which is liquefied and cooled down to a temperature of -162 degrees Celsius. In its liquid form, it may be transported in specially designed storage tanks. In the early 2000's, optimistic projections about future LNG demand spurred an investment boom to build new import facilities across North America. However, many planned LNG import terminal projects were cancelled on account of low natural gas prices and weak industrial demand. The 2008 financial crisis proved to be the definitive turning point.

There are two main drivers behind the shift: (1) incrementally strict air pollution regulations at the international level; and (2) massive U.S. shale gas production capacity and structurally lower prices for LNG than for traditional crude (diesel) oil. Finally (3), there is now a legal framework in place that regulates the use of LNG as a marine fuel. As a result, today's conditions are very favorable to LNG, inciting the global shipping industry to expand the use of LNG as the fuel of choice for many newbuildings.

(1) Air Pollution Restrictions: MARPOL, ECAs and the EU

MARPOL 1973/78, with its 1997 Protocol, includes Annex VI on Prevention of Air Pollution from Ships.[1] Annex VI sets limits on sulphur oxide ("**SOx**"), nitrogen oxide ("**NOx**") and particulate matter emissions from ship exhausts and prohibits deliberate emissions of ozone depleting substances. It was revised by IMO's Marine Environment Protection Committee ("**MEPC**") with effect from October 1, 2008.[2]

This 2008 revision installed a global progressive reduction in emissions of SOx and NOx, and introduced so-called emission control areas ("**ECAs**") to further reduce emissions of those air pollutants in designated sea areas. Under the revised Annex VI, the global SOx limit of ship fuel was reduced from 4.5% to 3.5% effective January 1, 2012, then progressively, year by year, to 0.5% effective worldwide from January 1, 2020, subject to a feasibility review to be completed no later than 2018. The limits applicable in ECAs for

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[1] MARPOL Annex VI, Regulations for the Prevention of Air Pollution from Ships, Regulation 14 re sulphur oxide emissions**,** in force as of May 19, 2005 and Regulation 13 on nitrogen oxide emissions (or the associated NOx Technical Code 2008), which entered into force on 1 July 2010.

[2] See MEPC 176 (58), adopted in July 2005 and in force October 2008. See also generally IMO, "Air Pollution from Ships"; online at:
http://www.imo.org/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Air-Pollution.aspx .

SOx and particulate matter have been reduced to 0.10% effective from January 1, 2015 onwards. Tight Tier III restrictions on NOx emissions are in force since January 2016.

A North American ECA was designated by the IMO on March 26, 2010. This ECA runs along the eastern and western coasts of Canada and the USA (including southeast Alaska and the main Hawaiian islands) and extends some 200 nautical miles from the coastline, but below 60 degrees north latitude. The ECA came into force in Canada on April 18, 2013, pursuant to the *Regulations Amending the Vessel Pollution and Dangerous Chemicals Regulations*,[3] adopted under the *Canada Shipping Act, 2001*.[4]

In the European Union ("**EU**"), Council Directive 1999/32[5] as amended by Council Directive 2005/33,[6] had already imposed a 0.1% sulphur limitation on vessel fuel emissions for ships within EU ports for longer than two hours and on EU inland waterways. On November 21, 2012, the European Parliament and the Council further adopted Directive 2012/33/ amending Council Directive 1999/32,[7] in order to give full effect to MARPOL's Annex VI in the EU.

At present, the Arctic Region is not designated as an ECA. There have been calls for the expansion of the mandatory air quality regime north of 60, however to date, industry, through the IMO, has remained focused on the higher traffic areas of the south to focus their efforts on improving emission standards for vessels.

2. Oil prices

For decades, crude oil was the ocean vessel fuel of choice – it was abundantly available and inexpensive. While LNG was always recognized as having both financial and environmental benefits, there was never a real incentive to invest in its wider use. This has changed since the financial crisis of 2008.

The ready availability of natural gas, amongst others because of the booming natural gas production through the use of hydraulic fracturing (so-called *fracking*) in the US, has shifted the focus from importing LNG into North America to exporting it – and using it as a cheap alternative to crude oil as a marine transportation fuel. No less than seventeen proposed LNG export facilities in Canada have entered the regulatory review process – sixteen in British Columbia and one in Nova Scotia. Canada's only operational LNG terminal is Canaport LNG's regasification terminal located in Saint John, New Brunswick.[8]

Moreover, until recently crude oil prices have been at a historically high level in recent years. Demand for crude oil is still on the rise, but the marginal production costs have

[3] SOR/2013-68, *Canada Gazette*, Part II, Vol. 147, No. 10, May 8, 2013, p. 919.
[4] S.C. 2001, c. 26, subsects. 35(1), 120(1) and (2), sect. 190 and paragraphs 207(2)(a) and 244(a).
[5] Council Directive 1999/32 of April 26, 1999 on Sulphur Content of Liquid Fuels.
[6] Council Directive 2005/33 of July 6, 2005.
[7] OJEC 27.11.2012, L. 327/1. For full text, see: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:327:0001:0013:EN:PDF.
[8] See Natural Resources Canada, at http://www.nrcan.gc.ca/energy/natural-gas/5683.

gone up significantly. As a result, investments in less volatile and cheaper alternatives, such as LNG, have increased over the last several years. The fallback of the oil prices during the last year will not hamper this evolution, as economic experts expect prices to rise again within the next two to five years.[9]

3. Legal framework

Through its Sub-Committee on Bulk and Liquid Gases ("**BLG**"),[10] the IMO, with the input from classification societies, has developed and eventually adopted in 2015 the so-called IGF Code – the "*International Code for Safety for Ships Using Gases or Other Low Flashpoint Fuels*".[11] The IGF Code has been adopted it as an amendment to the Safety of Life at Sea Convention (SOLAS),[12] and permits ships using LNG to meet the 2015 ECA emission standards. In the past internationally agreed safety requirements were missing and therefore each national administration had to set their own requirements. This also related to the operation range of such vessels to national waters because individual permits from each administration involved were required. This was one reason to propose the development of the IGF-Code in 2004. The adoption of the IGF Code therefore also has immediate positive effects on the viability of international LNG-fueled sea-going vessels and their operation range.

The IGF Code contains mandatory provisions for the arrangement, installation, control and monitoring of machinery, equipment and systems using low-flashpoint fuels, focusing initially on LNG. The Code addresses all areas that need special consideration for the usage of low-flashpoint fuels, taking a goal-based approach, with goals and functional requirements specified for each section forming the basis for the design, construction and operation of ships using this type of fuel.[13]

The MSC also adopted related amendments to the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), and STCW Code, to include new mandatory minimum requirements for the training and qualifications of masters, officers, ratings and other personnel on ships subject to the IGF Code. The amendments also will enter into on January 1, 2017, in line with the SOLAS amendments related to the IGF Code.

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[9] See for instance the US Energy Information Administration, "Short-term energy outlook", at https://www.eia.gov/forecasts/steo/report/prices.cfm.

[10] This "BLG" Sub-Committee is a sub-committee of the IMO's Marine Environment Protection Committee.

[11] The SOLAS convention used to permit only fuels with flash points above 60°C to be used as vessel fuel. This meant that gas is not permitted to be used as vessel fuel - with the exception of LNG tankers. The IGF Code changes this. Among the topics addressed by the IGF Code are: A safety assessment to be done by ship owners and designers and submitted to the national maritime administration; Ship design and construction standards; Equipment for LNG-fueled vessels; Crew training (especially re the safe handling of LNG and bunkering procedures); Bunkering procedures.

[12] See http://worldmaritimenews.com/archives/163680/imo-adopts-new-code-for-gas-fuelled-ships/.

[13] IMO, "Gas and low-flashpoint fuels code adopted by IMO", online at http://www.imo.org/en/MediaCentre/PressBriefings/Pages/26-MSC-95-ENDS.aspx.

At present Canada's *Marine Machinery Regulations*,[14] which are in force pursuant to the *Canada Shipping Act, 2001*,[15] limit ship engines, with few exceptions, to (diesel) fuel having a flash point of 60 degrees C.[16] Canada has no specific statute or regulations governing LNG-fueled ships. Transport Canada is, however, presently reviewing the issue and has prepared a report on the feasibility of LNG as the primary fuel for marine transportation in Canada. [17] Nevertheless, it seems clear beyond doubt that that subject, relating as it does to "Navigation and Shipping" within the meaning of sect. 91(10) of the *Constitution Act, 1867*, would lie within the exclusive jurisdiction of the federal Parliament and government, and outside the sphere of legislation of the provinces and territories.

III. Advantages and challenges for using LNG as vessel fuel

The main advantages of LNG, compared to traditional oil-based fuel, are clear:[18]

- LNG emits significantly less SOx, as much as 90 to 95 percent. NOx emissions are cut by about 80% using LNG as fuel.[19] LNG also reduces carbon dioxide (CO_2) emissions, by an estimated 20 to 25 percent, depending on the type of engine and the measures applied to reduce the release of unused methane, as well as particulate emissions.

- When it leaks, LNG evaporates into the air or on the surface of water. The risk of marine pollution is thus substantially diminished in cases of spills. This is advantageous especially in light of growing concerns for the protection of the fragile Arctic marine environment because of increased shipping activity and the opening of Arctic sea routes.

- Prices for LNG make it the more affordable fuel for ship owners, costing clearly less than traditional diesel fuel, giving LNG the necessary commercial appeal it lacked before.

Given the stringent international IMO regulations in force, LNG provides an easy cap on vessel emissions and may be marketed as a green choice – not unimportant in a globalized setting where consumers are increasingly aware of climate change and hold companies accountable for their contributions to the perceived solutions.

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[14] SOR/90-264,
[15] S.C. 2001, c. 26, in force July 1, 2007.
[16] *Marine Machinery Regulations*, sect. 4 and Schedule XII, item 1.
[17] https://www.tc.gc.ca/eng/innovation/tdc-projects-marine-1579.html
[18] See Germanischer Lloyd, "Why LNG as Ship Fuel?" at http://www.gl-group.com/en/group/lng_benefits.php and Bloomberg Business, "Why shippers are turning to LNG-powered vessels", at http://www.bloomberg.com/news/articles/2015-09-23/lng-powered-ships-gain-as-rising-output-answers-oil-price-tumult.
[19] See Oskar Levander, "The Green Answer", World Cruise Network, September 1, 2006, online at: http://www.worldcruise-network.com/features/feature687/.

The Danish government, in a study conducted in cooperation with the EU, has concluded that LNG is the most cost-effective solution whereby ship owners can meet coastal emission controls, even considering the high costs of building LNG terminals to facilitate bunkering.[20] LNG as fuel may also prove more economical than installing exhaust gas cleaning systems (so-called scrubbers) on vessels to reduce emissions from traditional diesel oil.[21]

While LNG is here to stay and will fundamentally transform international shipping as we know it[22], there are at least three (regulatory) challenges linked to the use of liquefied natural gas as fuel for vessels: (1) ship design; (2) bunkering facilities; and (3) training of crew members.

1) Ship design

In marine transportation, maximizing a vessel's cargo carrying capacity is key. However, because LNG is less dense than petroleum, the specially designed LNG tanks take up significant space on vessels. An equal energy content of LNG requires about 1.8 times more volume than traditional diesel oil. Adding tank insulation, and noting the maximum filling ratio of 95%, the required volume increases to about 2.3 times that of traditional diesel oil.[23] The overall volume occupied for all LNG facilities on board a vessel is between 3 to 4 times higher than for conventional fuels – representing a significant loss of cargo space.[24]

The main issue connected with this storage question is where the LNG tanks should be located, and, in particular, whether they should be placed under accommodations. This is an issue of special relevance to cruise ships, although it also is a source of concern for container vessels. Moreover, LNG-fueled vessels are about 10 to 25% more expensive to build than comparative vessels running on traditional diesel fuel – meaning that the LNG-fueled vessels take about 5 to 8 years to earn back the difference in costs. Especially the specifically designed storage tanks, which require special insulation, contribute to the higher price.[25]

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[20] See "Danes back LNG as fuel", Trade Winds, January 13, 2012 at p. 56.

[21] In the U.S., Washington State Ferries, operating 21 ferries out of Seattle, has studied using LNG-powered ferries, finding them both practical and cost-effective, offering the prospect of savings of some US $870,000 a year based on 2010 prices. See http://www.ship-technology.com/features/featurecontainer-shipping-is-lng-the-fuel-of-the-future-4645479/. See also Germanischer Lloyd's "LNG as ship fuel – Will it be cost-effective?" at http://www.gl-group.com/en/group/lng_cost.php.

[22] See for instance Greg Knowler, "LNG-powered ships predicted to be game changer", at http://www.joc.com/maritime-news/no-avoiding-move-develop-lng-powered-ships-ship-manager-says_20151028.html.

[23] See Oskar Levander, "The Green Answer", at http://www.worldcruise-network.com/features/feature687 .

[24] TOTAL, Pablo Semolinos, Gunnar Olson and Alain Giacosa, "LNG as Marine Fuel: Challenges To Be Overcome", 2013, available online at http://www.gastechnology.org/Training/Documents/LNG17-proceedings/7-2-Pablo_Semolinos.pdf

[25] BloombergBusiness, "Why shippers are turning to LNG-powered vessels", at http://www.bloomberg.com/news/articles/2015-09-23/lng-powered-ships-gain-as-rising-output-answers-oil-price-tumult.

2) Bunkering facilities

The potential financial viability of LNG-propelled vessels in both national and international trade will depend, to some degree, on whether supply of the fuel can be arranged effectively.

Norway is by far the most advanced country in the use of LNG-propelled vessels and the bunkering facilities that must necessarily accompany that evolution. Norway has built a network of points along its coast where such ships can refuel. Other countries are gradually expanding their bunkering facilities for LNG-fueled ships.

Small LNG bunkering vessels are being built and put into service[26]. Another solution is delivery of LNG by tanker trucks or bunkering via pipelines. Bunkering procedures will have to be regulated, so as to lessen the danger of fire if some of the gas escapes during the process and encounters a source of ignition.

The Danish and EU report mentioned above, however, expresses the view that even if it were necessary to build special terminals to facilitate bunkering, the long-term economic benefits of using LNG as fuel would amply justify the capital costs of such infrastructure.[27]

3) Training of crew members

For the same reason, the training of crew members in the proper handling of LNG as fuel is essential. LNG, if spilled at -163 degrees C. can cripple steel structures and then evaporate, producing an inflammable gas cloud liable to catch fire if ignited.[28] Crew training therefore needs to be stringently regulated. It is therefore unsurprising that the IMO adopted amendments to the STCW and the STCW Code, to include new mandatory minimum requirements for the training and qualifications of masters, officers, ratings and other personnel on ships subject to the IGF Code. The amendments will enter into force on January 1, 2017, in line with the SOLAS amendments related to the IGF Code.

IV. LNG-fueled vessels in operation[29]

A growing number of LNG-powered vessels are cruising the world's oceans. They include oceangoing ships of significant tonnage to be used in international trade.

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[26] See for instance the World Ports Climate Initiative, at http://www.lngbunkering.org/lng/vessels.

[27] See "Danes back LNG as fuel", TradeWinds, January 13, 2012 at p. 36. The Port of Hamburg developed an LNG-bunkering facility in time for Euro Marine Day in May 2012, to show the potential of small-scale LNG distribution for bunkering, as well as a safety analysis. See TradeWinds, "Calls for a safety code governing LNG as fuel", December 16, 2011 at p. 43.

[28] See Germanischer Lloyd "LNG Bunkering" at http://www.germanlloyd.org/en/snb/lng_bunkering.php and http://www.gl-group.com/en/14832.php?country=/de/index.php.

[29] See Wendy Laursen, "The Week in Review: The LNG-As-Fuel Revolution", online at http://www.maritime-executive.com/article/the-week-in-review-the-lng-as-fuel-revolution ; DNV-GL, "Highlight Projects in the LNG as fuel history", at https://www.dnvgl.com/Images/LNG%20as%20fuel%20highlight%20projects_new_tcm8-6116.pdf.

By the end of 2016, forty-three LNG-fueled ships are scheduled for delivery or conversion. At the same time, infrastructure for LNG bunkering of ships will be developed. As a result, opportunities for new LNG-fueled ships will continue to emerge.

Of the LNG-fueled ships currently in operation, 69% are operating in Norway, however vessels operating on LNG as fuel is expanding beyond Scandinavia. Of confirmed new orders, we see 58% of the ships heading elsewhere in Europe and 26% of the ships heading to North America.

As bunkering facilities expand, LNG-fueled ships will follow, in Europe and North America in particular. Australia will also see the first LNG-fueled ship on the water, demonstrating the technical and operational feasibility of LNG fuel. With this expansion will inevitably come an increase in LNG bunkering infrastructure.

The expansion of LNG-powered vessels is primarily focused on routes with dedicated trades, where planned bunkering is easily made. The Arctic, in particular for the dedicated trade of community resupply, can accommodate well-positioned bunkering facilities, either shore-based or by way of bunker barge.

A study published on March 21, 2016 by DNV-GL[30] shows that there are currently 76 LNG-fueled vessels in operation worldwide (excluding LNG carriers and inland waterway vessels). It is expected that the next couple of years will show an exponential growth in the number of LNG-fueled vessels operating worldwide – in Europe and North-America especially – with no less than 79 new LNG-fueled vessels under construction and existing vessels being outfitted to be LNG ready. Here are a few examples:

- The Harvey Power, the second LNG-fueled OSV operating in the United States, entered service in October 2015. The vessel is working for Shell Upstream America's deep water operations in the Gulf of Mexico. Harvey Power is the second of six LNG OSVs being built for Harvey Gulf International Marine by Gulf Coast Shipyard Group, and like its sister ship, Harvey Energy, Harvey Power is capable of operating on LNG or diesel fuel. When operating on LNG, these vessels exceed the new Tier IV emissions regulations requiring lower sulfur oxides and nitrogen oxides emissions as part of the North American ECA.

[30] Available at https://www.dnvgl.com/maritime/lng/ships.html.

- In October 2015, Crowley Maritime announced that construction of the first of two LNG-powered, combination container (ConRo) ships reached an important milestone with the installation of three LNG fuel tanks. The double-walled, stainless steel tanks – which are 110 feet in length and 20.6 feet in diameter – weigh 225 tons and will hold more than enough LNG fuel for two round-trip voyages between the vessel's future ports of call, Jacksonville, Florida, and San Juan, Puerto Rico.

- General Dynamics NASSCO has christened its first 610-foot-long ECO tanker for American Petroleum Tankers (APT). The ECO tanker, the Lone Star State, is the first of a five-tanker contract between NASSCO and APT, which calls for the design and construction of five 50,000 deadweight ton, LNG-conversion-ready product carriers with a 330,000 barrel cargo capacity.

- General Dynamics NASSCO delivered the world's first LNG-powered container ship, the M/V Isla Bella, to TOTE Maritime. It began operations in January 2016. As part of a two-ship contract signed in December 2012 with TOTE, the 764-foot long Marlin Class container ships will be the largest dry cargo ships powered by LNG. Its DWT is 45000t and its dimensions are 233x32m.

  - Closer to home, the NM F.-A.-Gauthier offers ferry services between Matane, Baie-Comeau and Godbout since July 2015, with a capacity of 180 vehicles and 800 passengers.[31] The NM Jos-Deschenes and the NM Armand Imbeau are under construction.

  - In British Columbia, BC Ferries will be introducing its Salish Class of vessels. The Salish Orca, the Salish Raven and the Salish Eagle will be introduced into service on the Southern Gulf Islands routes starting in 2017. These new vessels will be capable of running as dual-fuel on either LNG or ultra-low sulphur diesel.[32]

  - Deltamarin, Arista Shipping, ABS and GTT have announced Project Forward, a joint development project to equip the dry bulk carriers of the future with LNG propulsion. The aim of the project is to develop a commercially feasible LNG-

[31] Société des traversiers du Québec, https://www.traversiers.com/en/a-propos-de-la-societe/les-navires/nm-f-a-gauthier/.
[32] http://www.bcferries.com/about/intermediatevessel.html

powered dry bulk carrier design capable of complying with the IMO's Energy Efficiency Design Index 2025 standards, NOx Tier III and Marpol Annex VI SOx emission levels. The concept design will be based on the highly-optimized Deltamarin B.Delta design suitable for ships between 82,000 and 210,000dwt. It will employ GTT's membrane-type LNG tanks for fuel containment.

V. Conclusion

Industry continues to study the prospect of LNG becoming the fuel of choice in the marine industry in Canada [33]. As a clean-burning fossil fuel, natural gas is expected to play an ever more important role in meeting worldwide energy demand. Energy demand is expected to increase over the long-term and global LNG production is also expected to grow.

LNG-powered ships and dual-fuel ships featuring LNG as one of their power sources are here to stay. They offer the promise of keeping the air over our oceans and rivers cleaner, and perhaps also of saving considerable money for their owners and operators. With a new robust regulatory regime in place and continued investment, LNG-propelled vessel may prove to be a game-changer for the shipping industry.

National adaptations of that framework will probably follow, hopefully in versions consistent with the international regime, so as to avoid conflicts of law and secure multilateral legal harmony in this new and exciting domain of world maritime law.

DNV predicts that LNG will dominate ship fueling by 2050.[34] LNG fuel for vessels would appear to be an idea whose time has come. From an environmental perspective, this is only good news. Canada should prepare proper regulation for these vessels and enact the rules that their safe and environmentally-beneficial operation will demand.

[33] http://www.mmdonline.com/technology/marine-use-of-lng-being-examined-105142/

[34] See Alaric Nightingale, in Bloomberg, "LNG to Dominate Ship Fueling Within 40 Years", November 19, 2010. See also "Is LNG the Fuel of the Future?", at: http://www.ship-technology.com/features/featurecontainer-shipping-is-lng-the-fuel-of-the-future-4645479/.