Improving Liquefied Natural Gas Bunkering in Korea through the Chinese and Japanese Experiences

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Received: 9 September 2020; Accepted: 10 November 2020; Published: 17 November 2020

Abstract: The International Maritime Organization has strengthened global environmental regulations related to sulfur and nitrogen oxides contained in ship fuel oil since the beginning of 2020. One strategy to comply with the regulations is to fuel ships with liquefied natural gas (LNG) rather than with traditional heavy fuel oil. China and Japan are both developing a business structure for the bunkering of LNG through public–private partnerships to expand their leadership in the field in Northeast Asia and secure a competitive advantage. Compared to China and Japan, Korea has relatively inadequate laws, policy support, and best practices for safe and efficient LNG bunkering for ships. This article provides a comprehensive overview of the LNG bunkering regulation systems in China and Japan and addresses how these systems can be mirrored by Korea to improve the Korean system. It compares the legislative and normative rules of China and Japan regarding the complex global scenario of maritime transportation. The results show that Korea must revise its guidelines and create the advanced institutional framework required for the LNG bunkering market to support an eco-friendly shipping industry and maintain a competitive edge against China and Japan.

Keywords: LNG bunkering business; environmental regulation; IMO 2020; policy support; emission control area

1. Introduction

1.1. Overview of the History of Maritime Fuel Regulation

Since the 1972 United Nations (UN) Conference on the Human Environment, in which the issue of acid rain was raised, countries worldwide have made efforts to gradually strengthen regulations on sulfur oxide (SOx) and carbon dioxide (CO2) emissions from ships to achieve the common goal of protecting the marine environment and improving air quality [1,2]. In 1997, Chapter 6 of the International Convention for the Prevention of Pollution from Ships (MARPOL) was adopted, which took effect in May 2005. It includes regulations on SOx contained in ship fuel oil, nitrogen oxide (NOx) produced in the combustion process of diesel engines, volatile organic compounds contained in cargo oil, garbage incineration on ships, and reduction of greenhouse gases. Owing to differences in the levels of industrial development among countries, however, regulations on SOx and NOx in ship fuel oil are classified into Emission Control Areas (ECAs) and general areas by applying different standards primarily in the North Sea, Baltic Sea, and along the North American coast [3,4]. Despite strengthened application standards, to minimize the causes of air pollution from ships, the 70th Marine Environment Protection Committee of the International Maritime Organization (IMO) decided in 2016 to lower the limit on the sulfur content in ship fuel oil from 3.5% m/m to 0.5% m/m or less starting in 2020 [1,5,6]. Table 1 shows the IMO sulfur regulations.
Table 1. International Maritime Organization sulfur limit regulations by year.

| Applied Area          | Detailed Classification of Sulfur Oxide (SOx) Emissions | Change after 1 January 2020 |
|-----------------------|--------------------------------------------------------|-----------------------------|
| SOx emission control areas | Existing (2016–2020)                                  | 1.5% m/m or less            |
|                       |                                                        | 0.1% m/m or less            |
| All areas             | 3.5% m/m or less                                      | 0.5% m/m or less            |

Source: [7].

Thus, beginning in January 2020, all ships engaged in international navigation must use ship fuel oil with a sulfur content of 0.5% m/m or less [1,8]. Global marine transportation companies can adopt various strategies to comply with this regulation, such as using low-sulfur oil or mixed oil, installing scrubbers, or converting existing heavy fuel oil (HFO) engines to liquefied natural gas (LNG) engines. The choice of strategy depends on factors such as the company’s financial situation, new ordering plans, and mid- to long-term route arrangements [9,10]. LNG bunkering requires specialized infrastructure for ships and ports. Currently, global hub ports have difficulty developing such infrastructure, although progress in this area has accelerated. Early adoption of LNG bunkering is occurring in Europe, where the European Union (EU) has required a core network of ports to provide LNG bunkering by 2030. According to Directive 2014/94/EC on the deployment of alternative fuels infrastructure, EU ports should be widely available. Standards and regulations provide legal certainty to ship owners, LNG bunkering suppliers, port authorities, and other parties. As defined by Directive 2014/94/EC, the availability of LNG in EU hub ports will be available as of 31 December 2025 (maritime ports for international trading), and 31 December 2030 (inland ports for other purposes), with the same standards and regulations establishing an obligation for EU Member States to use appropriate standards, including specific technical specifications for LNG for maritime and inland waterway transport [11]. In addition, LNG bunkering in the United States currently takes place in Jacksonville, FL, and Port Fourchon, LA, with a third facility under development in Tacoma, WA. While vessel conversion to LNG fuel may increase demand for U.S.-produced shale gas, such an increase could be partially offset by reduced demand for U.S.-produced crude oil. Furthermore, the LNG industry has experienced some trials and errors, and the Coast Guard has been developing new standards to address the unique safety and security risks associated with the LNG bunkering process [12].

China’s first dual-fueled marine engine ship in inland waterways was reconstructed from a ferry named Wuhan Ferry No. 302, which completed a 25-day sea trial in the Yangtze River in 2010 [13]. In 2013, primarily through Japan’s Ministry of Land, Infrastructure, Transport, and Tourism, its Ministry of Economy, Trade, and Industry, and the Japan Coast Guard, Japan formed the “Committee for the Comprehensive Review of Measures to Promote LNG-fueled Ships” to expand the supply of LNG as ship fuel, as well as the “Standard Work Manual and Design Guidelines for High-pressure Gas Supply Systems, Including LNG Bunkering-related Safety Measures.” Furthermore, the committee recommended a cooperative network, for example, information sharing for coordination, R&D, and the expansion of LNG-fueled ships [14].

In terms of the supply chain in the case of Korea, the existing ship bunkering business and the LNG bunkering business are quite similar. This is because, unlike for general oil, Korean laws have permitted the introduction of LNG by the Korea Gas Corporation since 1983 and LNG use for power generation and industrial mass consumption since 2013. Thus, the structure of LNG bunkering contracts, supply, and payment was formed.

The report “Global Environmentally Friendly Ship Equipment Market Trends and Strategies to Enter Overseas Markets” [15], which was jointly published by the Korea Development Bank and the Korea Trade-Investment Promotion Agency, expects that as many as 1962 new LNG-powered ships will be built by 2025. The demand for LNG bunker tankers is also estimated to increase from 313,000 dwt in 2016 to 3.2 million dwt by 2030. This is because global LNG prices will remain stable not only due to changes introduced at IMO 2020 but also because of warmer winters, expanded shale gas exports in the
United States, increased supply from Australia and Qatar, and the industrial downturn caused by the COVID-19 pandemic. Moreover, as the Oxford Institute for Energy Studies report demonstrated [16], since LNG is cheaper than oil, it will emerge as an alternative that satisfies both the environmental and economic requirements of ship owners.

Worldwide, there are many types of standards and guidelines on LNG bunkering. The most representative standards and guidelines are from the International Organization for Standardization (ISO), the Society for Gas as a Marine Fuel (SGMF), and the International Association of Ports and Harbors (IAPH). First, the ISO issued guidelines covering procedures for supplying LNG bunkering to ships (ISO/TS 18683:2015) beginning in 2015. Since then, it issued ISO/DIS 20519, which includes functional requirements for LNG bunkering equipment and operations as well as aspects such as bunker connectors, hoses, risk assessment, communications, and safety distances, among many other dimensions related to the bunkering of gas-fueled ships. Second, the SGMF published the Safety Guidelines for LNG Bunkering to reflect the contributions of different industry stakeholders provided in 2015. The guidelines, issued in May 2017, include LNG hazards, safety management systems, and bunkering procedures for the various types of LNG bunkering modes, and were developed to provide the highest level of safety management in the LNG bunkering industry. Finally, the IAPH developed LNG bunker checklists for different LNG bunkering scenarios in 2015. These checklists reflect various requirements relevant to all parties involved in the LNG bunkering industry.

Currently, the three standards or guidelines and checklists mentioned above are by far the most significant references for LNG bunkering. Therefore, many countries have used them to reflect different national requirements and local/port regulations including risk assessment, bunkering/transfer equipment, and dock workers/seafarer training. In Korea, the purpose of the Harbor Transport Business Act [17] is to establish order regarding port transport and promote public welfare by encouraging the sound development of the harbor transport business. However, to legalize the domestic LNG bunkering industry, the regulations should be revised to include natural gas, as, according to Article 2 (3) of the act’s Enforcement Decree, only oil is specified among the types of harbor transport-related projects in the ship supply business.

In practice, the term “bunkering” has primarily been used to refer to the “ship oil supply industry.” However, as the range of ship fuels has expanded from oil to LNG, liquified biogas (LBG), methanol from natural gas, renewable methanol, and hydrogen fuel cells produced from natural gas, this concept has changed to the “ship fuel supply industry.” Therefore, LNG bunkering for ships refers to supplying LNG, an eco-friendly fuel, rather than traditional fuel oil such as high-sulfur or low-sulfur fuel oil, to the main and auxiliary engines of LNG-fueled ships.

Table 2 summarizes the characteristics of each type of LNG bunkering method for LNG-fueled ships. First, Truck-to-Ship involves supplying fuel to ships docked at harbors through an ISO standard 20-ton tank lorry. Second, Pipe- or Terminal-to-Ship involves supplying fuel to docked ships through a loading arm installed in an LNG terminal used for export. Third, Ship-to-Ship involves supplying LNG loaded in the cargo hold of an LNG bunkering ship through a loading arm or loading hose. Fourth, Portable Tank-to-Ship involves supplying LNG fuel using a 20-ft or 40-ft ISO standard container for LNG fuel storage.
Table 2. Characteristics of general liquefied natural gas (LNG) bunkering methods.

| Method                  | Advantage                                                                 | Characteristics                                      | Weakness                                                                 |
|-------------------------|---------------------------------------------------------------------------|------------------------------------------------------|--------------------------------------------------------------------------|
| Truck-to-Ship           | i. Low cost of construction and operation                                | i. Slow LNG bunkering speed                          | i. Limited LNG bunkering for large ships                                 |
|                         | ii. Appropriate for small-scale bunkering                                | ii. Slow LNG bunkering speed                         |                                                                          |
| Pipe- or Terminal-to-Ship| i. Quick LNG bunkering speed                                             | i. Vulnerable to natural disasters                   | i. Limits only available for dedicated port                              |
|                         | ii. Appropriate for large-scale bunkering                               | ii. Vulnerable to natural disasters                   |                                                                          |
| Ship-to-Ship            | i. Large-capacity and quick LNG bunkering                               | i. High initial investment cost for LNG bunkering ship construction |                                                                          |
|                         | ii. Simple LNG bunkering process                                         |                                                     |                                                                          |
| Portable Tank-to-Ship   | i. Quick LNG bunkering speed                                             | i. High cost to operate and maintain the portable tank |                                                                          |
|                         | ii. Simple LNG bunkering process                                         |                                                     |                                                                          |

Source: [https://ww2.eagle.org/content/dam/eagle/advisories-and-debriefs/ABS_LNG_Bunkering_Advisory.pdf](https://ww2.eagle.org/content/dam/eagle/advisories-and-debriefs/ABS_LNG_Bunkering_Advisory.pdf) (accessed on 3 October 2020).

In Korea, in line with the 2018 Harbor Transport Business Act [17], the “ship oil supply business” concept was changed to “ship fuel supply business,” and, through the partially revised Urban Gas Business Act, “marine natural gas business” and “marine natural gas business operators” were newly established, thus amending the legal grounds on a limited basis. Nevertheless, Korea has relatively inadequate research on laws and policies compared to China and Japan, who have already been promoting safe and efficient LNG bunkering for ships.

This study aims to propose guidelines for Korean LNG adoption, mirroring the examples of China and Japan. The ultimate objective is to achieve the best available standards provided by international institutions such as the IMO, EU, ISO, and other organizations that already provide benchmarking in this field. It aims to answer the following research questions (RQs):

RQ1: What can be concluded from a literature review on the perspectives of Chinese and Japanese laws and policy in terms of Korea’s advancement in LNG bunkering?

RQ2: Why has LNG bunkering been important for the Asian shipping industry since IMO 2020?

RQ3: How will improvements in Korea affect the Asian region in the global scenario of LNG bunkering?

RQ4: What are the contributions of this research to advancement in the field of clean fuels and improvement of the shipping sector’s efficiency?

1.2. General Review

Several previous studies have provided some insight into the development of LNG bunkering operation procedures, risk assessment, and technology utilization. For example, Schrooten et al. [18] proposed a methodology for comprehensive maritime transport data on activity, specific energy consumption, emission factors, and total emissions that have been developed within the European EX-TREMIS project. Lindstad et al. [19] found that emissions can be reduced by up to 30% at a negative abatement cost per ton of CO₂ by replacing the existing fleet with larger vessels. Ma et al. [20] concluded that a scrubber system for HFO has the potential to reduce SOX emissions with reduced well-to-wake energy consumption. Brynolf et al. [3] provided an environmental assessment of marine fuels comparing LNG, LBG, methanol, and bio-methanol. Holmgren et al. [21] reviewed some studies to assess the effects of their implementation and the possibility of a modal shift. Seddiek and Elghohary [4] (p. 737) observed that “ships emission reduction became one of the technical and economic challenges facing ships and operators.”

Approaches to reduce vessel emissions that neglect ecosystems and jurisdictions were criticized by Lindstad et al. [8]. They suggested combining different approaches, as damages and policies are
associated with ports and coastal areas, defined as ECAs. Tichavska et al. [22] observed the lack of connection between regulatory frameworks and atmospheric pollution. They suggested providing a pollution inventory and diversifying the type of regulation according to the scope of the pollution.

Calderón et al. [23] described alternatives for cleaner fuels for ships, such as marine oil gas (MOG), HFO with scrubbers, LNG, and methanol. They found that LNG is the most developed fuel solution in the short to medium term. Stevens et al. [24] questioned whether new emission legislation stimulates the implementation of sustainable, energy-efficient maritime technologies. These authors developed a framework that allows linking the different emission legislation initiatives in different countries with the technical energy-efficient solutions that could be used to comply with the legislation.

Sys et al. [1] examined the potential effects of environmental standards aimed at limiting greenhouse gas emissions from shipping from the perspective of competition between seaports. In a comprehensive study, Abadie et al. [25] analyzed how the shipping industry’s current fleet can adapt to the new emissions regulations following two main techniques: (i) using low-sulfur marine diesel and (ii) installing scrubbers. Gritsenko [9] examined recent literature on polycentric climate governance and suggested principles for environmental regulation in shipping based on a polycentric approach. Hua et al. [26] performed a total fuel life cycle inventory for atmospheric emissions for two ships operating between the People’s Republic of China and Taiwan. They compared the use of HFO and LNG and concluded that LNG is an alternative fuel to power ships. LNG reduced CO$_2$ emissions but increased methane emissions; the reduction of NOx was 38–39%, and that of SOx was 99.8%.

Lee and Nam [14] defined green shipping and eco-friendly vessels. They identified regulations and the current market situation related to eco-friendly vessels in major countries such as the United States, Japan, China, and South Korea, as well as in Europe. They recommended establishing a cooperative shipping network, information sharing for joint costs reduction, R&D cooperation, and an expansion of LNG-fueled shipping.

Lindstad et al. [27] highlighted that, in 2016, the IMO decided on global regulations to reduce sulfur emissions into the air from maritime shipping, starting in 2020. Similarly, Zis and Psarafits [28] pointed out that in January 2015, the sulfur limit within sulfur ECAs was lowered to 0.1%. This can be achieved only if vessels are using ultra-low sulfur levels or if they invest in abatement technologies. These authors proposed a modal split model that estimates modal shifts considering competing maritime land-based modes available to shippers.

Hansson et al. [29] recommended the assessment of seven alternative maritime fuels for the shipping sector by 2030 through the application of a multi-criteria decision analysis approach. The alternatives are LNG, LBG, methanol from natural gas, renewable methanol, hydrogen fuel cells produced from natural gas or electrolysis, hydrotreated vegetal oils, and HFO. Schnurr and Walker [2] found that SOx vessel emissions reached 10.6 million tons, and NOx emissions reached 18.6 million tons in 2014, causing 12% and 13% of global SOx and NOx anthropogenic emissions, respectively. According to these researchers, by 2050, marine transportation will be responsible for 17% of global greenhouse gas emissions.

Aneziris et al. [6] provided a systematic literature review on LNG safety and risk assessment at ports concerning the operations of storing and transferring LNG. These scholars presented regulations, standards, and guidelines for risk assessment of LNG storage at ports during bunkering. Baba et al. [30] assessed the profitability of flexible routing by LNG cargoes for a single supplier. They considered uncertainties in the medium-term dynamics of gas markets. Haehl and Spinler [31] presented real options for emissions, considering technology and capacity choices, and provided analytical solutions studying the effect of regulatory uncertainty. Lee et al. [32] analyzed willingness to pay for replacing common fuels with LNG in the case of flour imports and found that consumers accept prices up to 36% higher than the average price. Park et al. [33] studied the safety zone layout design of a floating power plant fueled by natural gas. They provided an example of a hybrid approach for LNG.

Wang et al. [34] analyzed the status of difficulties and suggestions for developing the LNG bunkering industry in China. These scholars proposed countermeasures to promote China’s LNG-fueled
ships and rebuild LNG bunkering stations. Wan et al. [36] recommended the application of LNG in the Chinese shipping industry and simultaneously provided useful information to ship owners and LNG bunkering suppliers and policymakers for decision-making regarding the development of LNG-fueled ships. Fan et al. [35] provided a literature review on China’s LNG bunkering policy to control ship ECAs in the Pearl River Delta, Yangtze River Delta, and around the Bohai Sea (Beijing, Tianjin, and Hebei). These scholars presented solutions designed to solve the fueling difficulty for LNG ships on inland waterways and suggestions for safe and reliable practices through LNG bunkering pontoons [35]. Wan et al. [36] examined the evaluation criteria established to support relevant LNG-fueled ship development policymaking in many countries. The study aimed to provide tailored insights for China policymakers for the development of LNG-fueled ships.

Lee et al. [32] analyzed the public’s willingness to pay for products imported in LNG-fueled ships using the contingent valuation method. Their study was aimed at developing useful baselines for future LNG bunkering-related policies in Korea.

Lee [37] suggested the legislative improvement plan for LNG bunkering, including clarifying the definition of LNG-fueled ships and revising the Urban Gas Business Act.

While many studies have covered LNG bunkering-related safety, risks, options, and alternative maritime fuels, studies to date have not examined the standard types of guidelines for Korea’s LNG bunkering adoption, mirroring the examples of China and Japan, as proposed in this study.

2. Materials and Methods

RQ1 will be answered with a literature review, and RQ2, RQ3, and RQ4 will be answered by assessing Korean legislation in comparison with that of China and Japan, as shown in Figure 1.

![Figure 1: Outline of research flow.](image-url)

Although it began slightly later than China and Japan, Korea has developed and implemented “Standards for Ships Propelled by Natural Gas” and “Standards for the Transportation of Dangerous Bulk Liquid Goods,” which are technical standards for LNG-fueled ships and LNG bunkering ships. In addition, reflecting the International Code of Safety for Ships Using Gas or Other Low-flashpoint Fuels (IGF), the Korean Register of Shipping provided the “Gas Fuel Ship Guidelines” on 1 July 2016, based on construction contract standards and has provided a technical and legal basis to be applied in the construction and operation stages. As such, Korea has provided technical standards and the minimum institutional framework required for the LNG bunkering market, which is distinct from the existing natural gas supply market for power generation and households.
3. Results

3.1. Description of Bunkering-Related Policies and Laws in China

3.1.1. Description

The State Council of China announced the Air Pollution Prevention Action Plan (2013–2017) in 2013, which decreases air pollution, increases the share of eco-friendly energy sources, and implements policies to improve the atmosphere; the council is also promoting policies to accelerate the LNG bunkering business by reducing the share of coal power generation. From a macrolevel perspective, starting in 2013, the Chinese Ministry of Transport has gradually expanded clusters related to the LNG bunkering business from inland waterways to coastal and deep-sea areas. Furthermore, it promotes a two-track policy that expands targets from general cargo ships to passenger ships and ships carrying dangerous goods, thus enhancing the provision and construction of LNG bunkering infrastructure, support for science and technology and management supervision, and a continuous system of innovation. Particularly, in terms of microlevel financial support, the Chinese Ministry of Finance and Ministry of Transport established a linear standardized fund management system in 2014 to support construction funds needed to build LNG-fueled ships for inland waterways [35].

In 2014, the Chinese Ministry of Transport began to establish laws to designate pilot operating areas for LNG-fueled ships and develop technologies necessary for LNG-fueled ships, LNG bunkering terminals, LNG bunkering ships for inland waterway connections, port LNG trucks, LNG-powered cruise ships for inland waterways, LNG Ship-to-Ship, and ship propulsion systems.

Ultimately, as shown in Table 3, the Chinese government established policies for LNG bunkering from a macrostructural perspective, as well as incentives to support infrastructure subsidies for the LNG bunkering business from a microscopic perspective. Moreover, it is proactively enacting laws to construct and operate LNG-fueled ships and LNG bunkering ships, thus promoting business stabilization [36].

Table 3. Land- and sea-related laws on liquified natural gas (LNG) bunkering in China.

| LNG Bunkering Location | Safety-Related Laws | Technical Laws |
|------------------------|---------------------|----------------|
| On land                | i. Safe Production Law of the People’s Republic of China   | i. Design specifications for inland river LNG bunkering terminals |
|                        | ii. Hazardous Chemicals Safety Management Regulations       | |
| At sea                 | i. Interim Provisions on the Safety Supervision and Administration of Water LNG Refueling Stations | i. Interim Provisions for the Statutory Inspection of Inland Water Filling Barges for LNG Fuel |
|                        | ii. Provisions on the Safety Supervision and Administration of Inland Water LNG Fuel-powered Ships No.3. | ii. Specification for natural gas fuel-powered ships |
|                        | iii. Notice of the Ministry of Transport on Issuing the “Requirements for the Safe Transportation of LNG Transportable Tanks on Whole Ships (Trial)” Jiaohai Regulation (2020) No. 9 | iii. Rules for the classification and construction of LNG bunkering pontoons |
|                        |                                                                 | iv. Guide for LNG bunkering operations |
|                        |                                                                 | v. The design specifications for ship LNG filling stations |

3.1.2. Limitations and Implications

Because of air pollution originating from ships, since January 2018, the Chinese Ministry of Transport mandated the use of low-sulfur fuel oil for all ships using berths in ECAs [13]. Furthermore, the ministry enforced a 0.5% limit on the ratio of fuel’s sulfur content for all regions of the Chinese coast from January 2019. In addition, it established the 2017–2025 Plan for Construction of LNG Bunkering
Terminals in the Yangtze River and the Beijing and Hangzhou Canals, approved basic drawings for standard LNG bunkering bases, and is implementing a top-down policy to establish a regional LNG bunkering infrastructure construction plan. However, given that only three of 19 LNG bunkering infrastructure construction plans are in the test operation phase as of 2019, it is evident that local governments face restrictions in acceptance and approval because the Chinese Ministry of Transport still has not included specific technical standards [34]. Ultimately, despite China establishing and promoting new energy policies (see Figure 2) at the government level beginning in 2018, the country lacks a comprehensive policy management system to share and solve detailed problems related to LNG bunkering permits and efficient policy support.

![Figure 2. Configuration of the strategy to promote the liquified natural gas (LNG) bunkering industry in China. Source: Author.](image)

3.2. Description of Bunkering-Related Policies and Laws in Japan

3.2.1. Description

At the G7 Kitakyushu Energy Ministerial Meeting in 2016, the Japan Ministry of Economy announced its “LNG strategy,” which includes various business models such as establishing a hub to respond to changes in the global LNG supply-and-demand environment, standardizing global LNG contracts, promoting the international standardization of LNG transportation ships, and developing LNG bunkering and related technologies. As an extension of this strategy, the Japanese Ministry of Land, Infrastructure, Transport, and Tourism is applying land- and sea-related laws according to the LNG bunkering method as shown in Table 4. Through this, by specifying the details of the nighttime work on LNG-fueled ships and LNG bunkering during passenger movement, the ministry has implemented improvements for safe and smooth LNG bunkering while securing flexible ship operation and supporting construction of LNG-fueled ships that satisfies international standards [38].
Table 4. Land- and sea-related laws on liquified natural gas (LNG) bunkering in Japan.

| LNG Bunkering Method | LNG Bunkering Ships | LNG-Fueled Ships | Safety-Related Laws |
|----------------------|---------------------|------------------|---------------------|
|                      | i. Ship Safety Law (Sea) | i. Ship Safety Law (Sea) | i. Ship Safety Law (Sea) |
|                      | ii. Act on Port Regulations (Sea) | ii. Mariners Act (Sea) | ii. Act on Port Regulations (Sea) |
|                      | iii. Mariners Act (Sea) | iii. Risk Management Notification by Port (Sea) | |
| Ship-to-Ship          |                      |                  |                     |
|                      |                      |                  |                     |
|                      |                      |                  |                     |
| Pipe-to-Ship          | i. High-Pressure Gas Safety Act (Land) | i. Ship Safety Law (Sea) | i. High-Pressure Gas Safety Act (Land) |
|                      | ii. Mariners Act (Sea) | ii. Ship Safety Law (Sea) |                      |
|                      |                      |                  |                     |
| Truck-to-Ship         | i. High-Pressure Gas Safety Act (Land) | i. Ship Safety Law (Sea) | i. High-Pressure Gas Safety Act (Land) |
|                      | ii. Mariners Act (Sea) | ii. Ship Safety Law (Sea) |                      |

Source: Fueling maritime shipping with liquified natural gas: The case of Japan—©OECD/ITF 2018. P. 17, https://www.itf-oecd.org/sites/default/files/docs/maritime-bunkering-lng-japan.pdf.

Particularly, through the planning of business certification and the introduction of advanced ships announced in October 2017, the Japanese government is expanding policies that allow ship owners, ship management companies, shipbuilding and marine equipment companies, and LNG bunkering companies to receive subsidies if they establish and submit plans for introducing eco-friendly ships, including those using alternative ship fuels such as LNG, LPG, methanol, biofuel, and hydrogen. Further, the Japanese Ministry of Land, Infrastructure, Transport, and Tourism established a “system that subsidizes one-third of the budget for construction and infrastructure for LNG bunkering ships as part of the 2018 LNG bunkering industry support policy” to provide financial subsidies for the construction of large initial infrastructure [39]. It is important to note that in Japan, individual business entities promote cooperation through a detailed strategy to expand to a new LNG bunkering cluster in Tokyo Port via joint ventures between general trading companies, LNG bunkering-related designers, and various port construction companies [40].

3.2.2. Limitations and Implications

As such, to form a cluster of Northeast Asia-based LNG bunkering bases, the policies established and promoted by Japan (Figure 3) ensure the initial LNG bunkering business’s competitiveness by sharing existing LNG infrastructure with the private sector and providing subsidies to private operators; thus, Japan’s approach is different than China’s top-down policies. The synergy of the Japanese LNG bunkering industry is organically combined with various government tax support policies, electricity companies’ LNG fuel conversion policies divided by region, and eco-friendly marine fuel oil-use policies of private shipping companies such as NYK, MOL, and K-Line. In particular, Yokohama Port, which represents Japan, is set to expand as a major supply base for LNG bunkering as the central port of the Asia-European and Asia-North America sailing routes in the Northeast Asia region, along with Busan Port and Shanghai Port. In addition, the Japanese government is proactively constructing LNG terminals and storage tanks to build its port as a major LNG bunkering base when the North Pole route is commercialized. Thus, Japan has built an ideal model to lead the LNG bunkering industry, centered on the private sector, which will serve as a subsidiary for the government. However, in reality, there are limitations in providing optimal, high-efficiency, and low-cost LNG bunkering services because of the lack of relevant laws and regulations, the non-standardization of LNG introductory prices and procedures, and methods for introducing LNG bunkering for each region related to excessive competition.
3.3. Recommended Policies for Korea’s LNG Bunkering Industry

The regulations defined in Korean laws on the scope of businesses are as follows.

First, the natural gas business for ships is defined in Article 2 of the Urban Gas Business Act as the use of natural gas as ship fuel (including natural gas supplied when undergoing construction inspection or ship inspection) to ships (including ships undergoing construction or repair), following Subparagraph 1, Article 2 of the Ship Safety Act. Second, under Paragraph 3, Article 2 of the Enforcement Decree of the Harbor Transport Business Act, the business of supplying ship fuel oil within harbors is defined as a bunkering business for ships and is included among harbor transport-related businesses.

Korea has been supplying LNG bunkering for ships as of 2020 through the Jeju LNG No. 2, which was built as an LNG carrier and bunkering ship. However, the government still plans to gradually expand its hardware infrastructure based on demand for additional LNG bunkering infrastructure. Without the supply of domestic LNG propulsion ships and the preparation of related statutes, industry revitalization through the government’s unilateral implementation of a project supporting LNG bunkering vessel construction is limited.

In the context of tightened global environmental regulations related to ships, the “LNG bunkering business” included under ship bunkering involves the business of loading existing “bunker C oil” and using a tanker to transport it to ships docked at other harbors, berths, and foreign ports. The phrase also refers to the business of supplying LNG fuel to LNG-fueled ships [32]. Nevertheless, there is still a lack of consensus from stakeholders and a lack of specific guidelines on technological development, work procedures, and safety standards related to LNG bunkering. In terms of hardware, Korea is well-positioned to promote the LNG bunkering industry; however, the LNG bunkering-related legislative and normative framework has not been properly established. Therefore, Korea has limitations in forming a competitive LNG bunkering market that can support the eco-friendly shipping industry compared to China and Japan. Finally, to develop the domestic LNG bunkering business, it is urgent to revise the Harbor Transport Business Act.

4. Discussion

Environmental regulations on ships have recently been strengthened in Korea and other countries to reduce SOx, NOx, and particulate matter. Therefore, the Korean Ministry of Oceans and Fisheries and Ministry of Trade, Industry, and Energy enacted the “Act on the Promotion of Development and
Distribution of Environment-Friendly Vessels” and implemented it as of 1 January 2020, to expand the targets of environmentally friendly ship-conversion policies. These policies are focused on large merchant vessels but extend to various vessel types, including inner harbor ships, passenger ships, fishing boats, and towing vessels, thus promoting the development and diffusion of environmentally friendly ships.

Furthermore, to remove the institutional uncertainty of the marine natural gas business under the Urban Gas Business Act, the Ministry of Trade, Industry, and Energy defined procedures for establishing a new business definition; notifying registration and business start, stop, and closure; notifying imports and exports; and notifying changes. Particularly, relevant disposal regulations stipulate that imported and supplied natural gas cannot be disposed of by third parties in Korea except for ships and other marine natural gas business operators. However, to maintain cost competitiveness with China and Japan, evaporation gas generated when operating gas supply facilities can be disposed of according to procedures and methods prescribed by presidential decree. Moreover, to legally supply LNG fuel before a ship is commissioned or departs a shipyard, the scope of the marine natural gas business was expanded to include ships under construction or repair, thereby supporting the development of related business.

China’s LNG bunkering policy, led by the government, provided support by forming LNG clusters comprising LNG public enterprises, power plants, equipment and materials companies, shipowners, and universities; preemptively establishing basic infrastructure by developing related technologies; establishing standard procedures; and enacting laws and systems centered on inland waterways. In the case of Japan, the private sector is at the center of LNG promotion, forming an LNG bunkering cluster specialized in the port in cooperation with LNG power plants, shipowners, and the Ministry of Land, Infrastructure, Transport, and Tourism. Using China’s and Japan’s LNG bunkering support and cooperative models as benchmarks, the Korean government has established representative laws and policies as follows. These are meant to support technology development through R&D support, tax reduction, and deregulation; to support private companies to cooperate in educating and training experts related to LNG bunkering; to standardize various technologies; and to expand new applications for LNG bunkering businesses, thereby contributing to the revitalization of LNG bunkering projects.

According to the 2018 Comprehensive Plan for Regulatory Reform Promotion, the Korean Ministry of Oceans and Fisheries selected the ship fuel oil supply industry among seven new future industries, and Article 26-3, Paragraph 1 of the Harbor Transport Business Act stipulates that ship fuel oil suppliers shall register with the head of the Regional Maritime Affairs and Port Office, which manages ports by port and sector. Particularly, as confirmed in the above definition in Article 2, Paragraph 2 of the Harbor Transport Business Act, when offshore floating LNG bunkering terminals are introduced in the future, ship fuel oil supply locations must inevitably expand to berths and seas outside harbor limits [40].

Therefore, to promote the LNG bunkering business, in addition to being considered a harbor transport-related business, measures should include it as part of the marine cargo transportation business so that ship fuel oil supply can be performed beyond harbor limits.

In terms of location, according to Article 2, Paragraph 3 of the Marine Transportation Act, LNG bunkering may be included as a sub-business of transporting goods from the sea or inland waterways in contact with the sea, or as work accompanying these activities. Therefore, according to Article 26, Paragraph 3 of the Marine Transportation Act (Registration of Business), this should be interpreted as being included within the scope of coastal cargo transportation business between Korean ports. This is because, according to existing work handling guidelines for the port transportation business, ships registered under a coastal cargo transportation business can also engage in bunkering in ports according to the Harbor Transport Business Act. Thus, according to Article 24, Paragraph 1 of the Marine Transportation Act, which differs in legal scope from the Harbor Transport Business Act’s interpretation of an LNG bunkering business for one ship, LNG bunkering ships registered under a coastal cargo transportation business can operate without being restricted by operating area.
5. Conclusions and Suggestions for Further Research

International standards related to LNG bunkering essentially consist of the IGF Code and the International Code of the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC) Code established by the IMO, and technical guidelines or checklists include those produced by the ISO, SGMF, and IAPH. However, there is still no clear international agreement on which criteria should be applied first. As a result, Europe, China, and Japan, who engage in the LNG bunkering business, have developed and standardized domestic laws and classification rules according to the individual country’s circumstances or selectively apply relevant standards. Similarly, by revising legislation such as the Urban Gas Business Act, Marine Transportation Act, Ship Safety Act, and Mariners Act, Korea has provided legal grounds at a rudimentary level for the LNG bunkering business and the construction and operation of ships. Compared to China and Japan, however, there are still insufficient revisions to maritime laws that include safety standards; operational procedures; operational standards related to berthing, training, and certification; and terminology unification in relation to LNG bunkering ships and LNG-fueled ships, which are needed to secure the LNG bunkering business's competitiveness. Accordingly, there is an urgent need for the implementation of a government-wide legal system, expansion of LNG fuel oil supply in the energy industry, the ordering and construction of LNG-related ships, and active development of an eco-friendly “green ship” market via expansion of the LNG bunkering market through close cooperation of the Korea Gas Corporation with the domestic marine transportation and shipbuilding industries as shown in Table 5.

Table 5. Definition of fuels for ships.

| Division of Ships by Fuel Type | Definition |
|-------------------------------|------------|
| Green ship                    | Made of recycled parts and uses an eco-friendly ship design, or is powered by renewable energy. |
| Cleaner fuel ship             | Uses different fuels, with low or even zero sulfur (e.g., liquefied natural gas or biofuels). |
| Renewable fuel ship           | Uses solar, wind, or aeronautic power. |

Source: [http://www.imo.org/en/MediaCentre/PressBriefings/Pages/34-IMO-2020-sulphur-limit-.aspx](http://www.imo.org/en/MediaCentre/PressBriefings/Pages/34-IMO-2020-sulphur-limit-.aspx) (accessed on 3 October 2020).

These findings suggest that there are problems not only with the cooperation of those who participate in the LNG bunkering industry but also with the legal grounds for the LNG bunkering business. Based on the findings, the following implication is confirmed, and the following recommendations are suggested.

The results of the analysis of various literature related to LNG bunkering in China and Japan are summarized as follows. To ensure the competitiveness of the initial LNG bunkering business, the Japanese government has established and promoted an LNG bunkering cluster by sharing existing LNG infrastructure with the private sector and providing subsidies to private operators; Japan’s approach can be differentiated from the top-down policies of China.

In the global shipping industry, the use of LNG fuel will inevitably expand because of the IMO’s regulation of ship fuel emissions, which is considered the strongest environmental regulation in history. Therefore, the government of Korea should actively transform international marine environment regulations into a driving force for co-prosperity between the shipping and shipbuilding industries and port areas and develop “various infrastructures for the LNG bunkering industry” to build an eco-friendly shipping system [37]. Korea must also revise its guidelines and create the advanced institutional framework required for the LNG bunkering market to support an eco-friendly shipping industry and maintain a competitive edge with China and Japan.

Korea, who aims to become a key player in the field of shipping and logistics, needs to focus on and promote LNG bunkering projects and LNG-fueled ships as a national future strategic business to become a hub port in the future. In this market environment, this study is meaningful in that it
provides the basic legal data necessary for the development of the Korean LNG bunkering industry based on the Chinese and Japanese cases. Therefore, to achieve the mid- to long-term objective of environmental friendliness, LNG bunkering-related stakeholders must continue to promote relevant laws, whereas, in the short-term, it is necessary to introduce a “pre-permit, post-regulation” method in which operators establish their safety management plans, receive approval from a classification society, and then apply the procedure that was approved by the competent port authority. In addition, based on this study, more research on eco-friendly fuel-powered ships is needed.

This study focused on the Urban Gas Business Act, the Marine Transportation Act, Ship Safety Act, and the Mariners Act for the development of the LNG bunkering industry. There is a limit to the ability to perform a precise analysis. Therefore, we have reviewed the LNG bunkering laws and standards and propose an advanced amendment. Finally, once the government and shipowners clarify the long-term objective of environmental friendliness, to strengthen the competitiveness of the Korean LNG bunkering market, which has thus far been relatively inferior, a joint strategy that increases selective and focused investments and detailed revisions to relevant laws is necessary.

Author Contributions: Conceptualization, J.D.H.; methodology, L.C.H.; validation, L.C.H.; investigation, L.C.H.; resources, L.C.H.; data curation, Y.Y.U.; writing—original draft preparation, Y.Y.U.; writing—review and editing, L.C.H.; supervision, L.C.H.; project administration, L.C.H.; funding acquisition, P.S.H. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by a grant from the National R&D Project, “Development of LNG Bunkering Operation Technologies based on Operation System and Risk Assessment,” funded by the Ministry of Oceans and Fisheries, South Korea, grant number PMS4310.

Acknowledgments: All support is gratefully acknowledged. We would like to thank Editage for editing support.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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