Mar. Sci. Tech. Bull. (2022) 11(3): 369-383
e–ISSN: 2147–9666
info@masteb.com

dergipark.org.tr/en/pub/masteb
www.masteb.com
DOI: 10.33714/masteb.1146003

Marine Science and Technology Bulletin

RESEARCH ARTICLE

LNG bunkering dynamics: An exploratory study for Türkiye

Mehmet Doymus[1*] • Gul Denktas Sakar[2]

[1] *Dokuz Eylul University, Maritime Faculty, Department of Marine Transportation Engineering, Tinaztepe Campus, 35390, Izmir, Türkiye*

[2] *Dokuz Eylul University, Maritime Faculty, Department of Logistics Management, Tinaztepe Campus, 35390, Izmir, Türkiye*

ARTICLE INFO

Article History:
Received: 20.07.2022
Received in revised form: 22.09.2022
Accepted: 22.09.2022
Available online: 28.09.2022

Keywords:
LNG Bunkering
LNG as Marine Fuel
Small-Scale LNG
Supply Chain

ABSTRACT

United Nations' decarbonization and greenhouse gas reduction targets are to be achieved through the utilization of alternative fuels globally. LNG is a viable alternative for mitigating maritime transport-related greenhouse gas emissions. This study investigates LNG bunkering supply chain development in Türkiye. Semi-structured interviews with bunkering supply chain representatives were conducted to explore phenomena. The results of the research provided a pathway to establish a new supply chain for alternative marine fuels. The research findings indicate that collaboration and setting a regulatory framework are vital for supply chain development.

Please cite this paper as follows:

Doymus, M., & Denktas Sakar, G. (2022). LNG bunkering dynamics: An exploratory study for Türkiye. *Marine Science and Technology Bulletin*, *11*(3), 369-383. https://doi.org/10.33714/masteb.1146003

Introduction

More than 80% of world trade by volume is handled by shipping and maritime transportation is considered the most fuel-efficient mode of transport. However, ships are increasingly defined as a critical source of air and water pollution. According to GHG (Greenhouse Gas) research conducted by the International Maritime Organization (IMO), CO_2 emissions from the shipping industry might increase by 50% to 250%, depending on economic development and energy demand (IMO, 2015). Shipping-related pollutants such as nitrogen oxides (NO_x), particulate matter (PM), sulphur oxides (SO_x), and unburned hydrocarbons (UHC) can deplete the ozone layer, cause acid rain, contribute to greenhouse gas (GHG) emissions and cause significant impact on climate change. The initial target set by the International Maritime Organization (IMO) for decreasing GHG emissions from ships is to reduce total GHG emissions by at least 50% by 2050 compared to 2008 (IMO, 2020). The maritime sector must address these environmental challenges over time while using

* Corresponding author
E-mail address: mehmet.doymus@deu.edu.tr (M. Doymus)

the most cost-effective fuel. Alternative fuels in shipping include LNG, ammonia, hydrogen, LPG, methanol, ethanol, fuel cells, and batteries. Compared to other clean fuel options, the LNG supply chain is already in place and ready for expansion at the bunkering stage. The LNG supply chain is extended to marine end-users through strategic collaborations between stakeholders such as ports and suppliers (Wang & Notteboom, 2015). In some context, LNG marine fuel requires to use existing supply chain in some context, and bunkering can develop where the LNG market already exists for industrial purposes or power generation (Sharples, 2019).

Türkiye already has a natural gas grid and LNG terminals serve for power generation, industrial use and domestic heating. However, as a marine fuel, it has not yet been activated commercially. Türkiye is listed in the top 20 of the world's largest economy by GDP and by port call (UNCTAD, 2019), taking advantage of being surrounded by the sea and controlling an important shipping route from the Black Sea to the Mediterranean. LNG as ship fuel has an increasing demand across the world and it's worth investigating LNG bunkering development in Türkiye. Erkmen (2018) only conducted research in the literature by studying small-scale LNG in Türkiye however this study was not focused on the supply chain development (Erkmen, 2018). This study explores different perspectives of bunkering supply chain stakeholders in the Türkiye context as the first research in this field. In this study, semi-structured interviews have been conducted with potential stakeholders of small-scale LNG supply chain and LNG bunkering. Ship owners, suppliers, port authorities, policymakers and technical service providers' opinions were explored to explore the LNG bunkering option in Türkiye.

This study aims to explore and contribute to LNG bunkering application in Türkiye based on different stakeholders' views in the supply chain. The following research questions have been formulated for this purpose:

RQ1- What are the bunkering dynamics in Türkiye? RQ1 is important to gain insight into Türkiye's present bunkering structure, supply locations and volumes.

RQ2- How is the current situation in the existing natural gas and LNG infrastructure in Türkiye? RQ2 is critical to determine potential LNG bunkering development at an optimum level.

RQ3- How can a small-scale LNG supply chain for LNG bunkering be developed in Türkiye? RQ3 is essential for gathering different stakeholders' view in the supply chain and proposing a model for LNG bunkering development.

The structure of the study is organised as follows. Section 2 explores bunkering activities in Türkiye, section 3 investigates natural gas and LNG in Türkiye. The research method and data collection have been described in section 4. Section 5 discusses empirical findings and section 6 includes the conclusion and future research.

Bunkering Activities in Türkiye

Ship supplies are critical for any shipping activity. Provision, crew change, spare parts and consumable deliveries have tremendous importance to operating a vessel effectively. Bunkering could be vital among all these supplies as vessels cannot proceed from A to B or cannot perform cargo operations without fuel on board or without convenient fuel onboard. Ship supply hubs are strategically located on busy maritime transportation routes. Straits, narrow seaways, and busy ports create demand for any type of supply, repair, or service as well as bunker (Lam et al., 2011).

Türkiye involves in significant international and domestic shipping activities. Istanbul and Çanakkale Straits are the densest nods since they connect Black Sea ports to international shipping activities. The Marmara Sea has substantial marine traffic which includes not only transit traffic from the Black Sea to the Mediterranean but also port calls such as Izmit, Gemlik and Tekirdağ. Nemrut, Aliağa and Izmir ports show high traffic density. Cabotage traffic around Türkiye's West Coast is also significant along with connection with islands although it represents seasonality. Mediterranean ports such as Antalya and Mersin have dense marine traffic activity. However, Iskenderun Gulf is observed as the busiest region as it has substantial port activities for dry bulk, containers, and oil and gas cargoes. As these ports usually handle large vessels, high traffic density not only explains the number of the vessels, but also substantial demand potential as larger vessels lift much more bunker quantity per operation.

There is important port traffic in Türkiye. Kocaeli handles the largest proportion as total GT and by the number of the vessels calling. Other Marmara Sea ports such as Ambarli, Gemlik, Tekirdağ, and Tuzla are in the top ten according to the total GT of the vessels calling these ports. On the other hand, two smaller ports Çeşme and Bodrum have significant touristic traffic between the Greek Islands and Türkiye. Çeşme also has regular Ro-Ro traffic which connects Çeşme to Italy and France. Iskenderun and BOTAŞ are under different port authorities in Iskenderun Gulf. Their total share takes the second largest part as GT (15.3%) after Kocaeli.

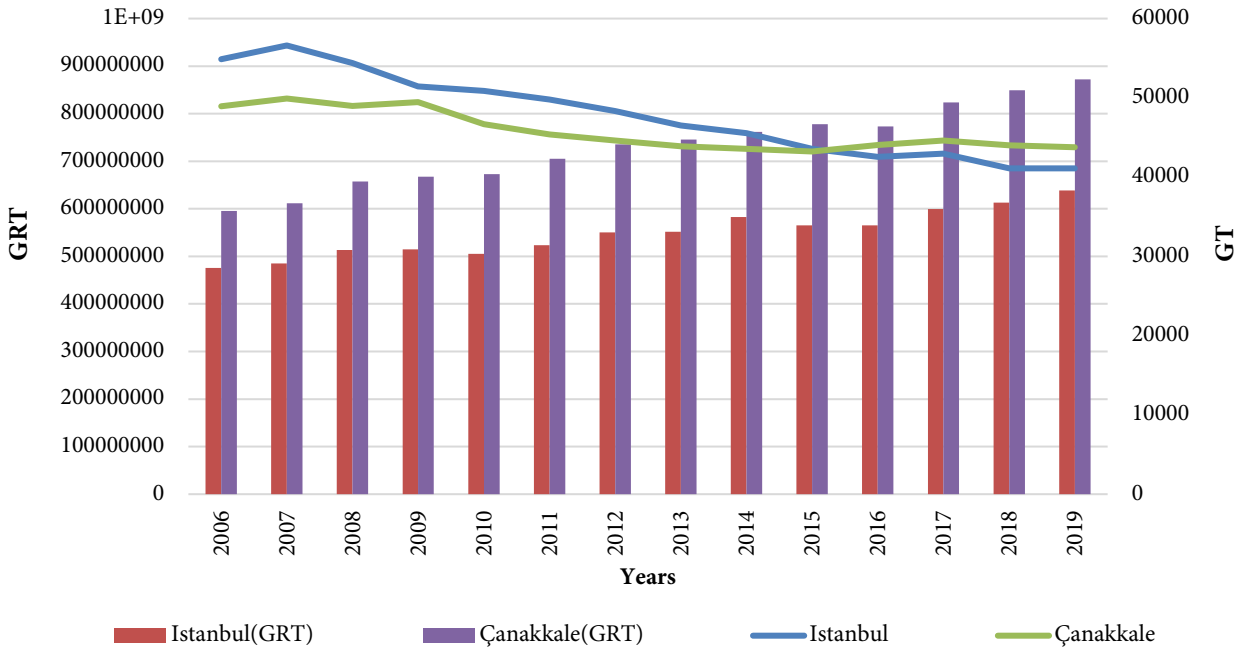

Figure 1. Istanbul and Çanakkale Straits' traffic data as number and GT (*Source*: Author, compiled from MOTI (2020b))

Table 1. Total Bunker Deliveries of Türkiye

Year	Delivery with SCT	Delivery without SCT	Delivery under Transit Regime	Total (ton)
2018	9548	34258	1999129	2036934
2017	5501	35720	1891362	1932583
2016	5629	38610	1434790	1479029
2015	234	0	324633	507332
2014	8687	36139	1279474	1324300
2013	4625	356008	688555	1049188
2012	25452	479368	1325632	1830452
2011	6879	278021	1331803	1616703
2010	11693	232343	1105909	1349945
2009	14343	266638	942064	1223045
2008	15049	266089	1109477	1390615
2007	11401	243541	1085211	1340153

Source: Author, Compiled from EMRA Annul Reports covering 2007 to 2018

To understand the shipping activities in Türkiye, Çanakkale and Istanbul Strait passages traffic provides an important indicator.

Figure 1 summarises the number of vessels passing through Istanbul Strait and Çanakkale Strait as number and GT by data obtained from the Ministry of Transport and Infrastructure database covering 2006 to 2019. The number of vessels passing through Çanakkale and Istanbul Straits is decreasing however, the total GT of the vessels are increasing in these straits -from 595,826,240GT to 872,314,222GT for Çanakkale and 475,796,880GT to 638,892,062GT for Istanbul. There are more than 40000 passages for each strait since 2006 as they are declining over the years.

Table 1 summarises Türkiye's total bunker deliveries with and without special consumption tax (SCT) and delivery under the transit regime. The table excludes 'export' figures as it does not distinguish 'cargo' and 'bunker' exports. Another reason is the explanation remark of the EMRA report which states that "Deliveries based on Cities\Türkiye have been included in transit regimes and export". However, once we calculate the data, it is observed that deliveries to the city table exclude exports and only take into account figures in Table 1.

Natural Gas and LNG in Türkiye

Türkiye's energy mix is dominated by fossil fuels and its share in the energy supply is approximately 85% (Kırlı & Fahrioğlu, 2019; Sigma, 2020). Due to lack of fossil fuel sources, Türkiye is a highly import-dependent country for energy which involves gas, oil, and coal 99.6%, 94.32%, 97.3%, respectively. This dependency has significant effect on country's trade deficit. Energy imports in 2019 was 41.18 billion dollars and it takes 20,3% of the country's total import expenditure (Sigma, 2020). Oil takes the first place as primary energy source among other alternatives with 29%. The second energy source is coal (26%) and natural gas's share is 27% and other energy sources, renewables and hydro-electric followed natural gas with 11% and 7%, respectively.

Natural gas takes a critical part in Türkiye's energy strategy. Its share in power generation is 24%, despite a significant decrease from 2018 to 2019. In addition to power generation; heating and industrial use of natural gas increased rapidly and now it accounted for more consumption than power generation (Topuz, 2019). Türkiye has LNG import terminals, Floating Storage and Regasification Unit (FSRU)s and numerous pipelines and interconnections between Asia and Europe as gas infrastructure (Topuz, 2019). However, Öge (2021) argues that Türkiye has not benefitted from its geopolitical position in terms of pipeline transit due to contractual obligations.

Natural gas takes third place as Türkiye's primary energy source following petroleum and coal. By the end of 2019, the natural gas market reached 45685.34 Sm3 total supply (production and import) and 46048.18 Sm3 total demand (domestic sales and exports) volume (EMRA, 2020). Türkiye carries out natural gas imports via pipelines and LNG import points. Pipeline imports are received from Russia, Iran and Azerbaijan with long-term purchase agreements, long term LNG agreements and LNG spot markets. Russia takes an important part in Türkiye's natural gas imports while taking over 50% share over the years, in 2019 it reduced to the lowest level of 33.61% (EMRA, 2020). These differences were compensated by increases in Azerbaijan gas imports from 14% to 21%. Total natural gas imports have decreased by 10% and lowered dependency on Russian natural gas. However, this reduction in Russian gas quantity is not reflected in the country's budget due to 'take or pay' obligations. The pipelines are the main natural gas sources of Türkiye, however, LNG investments, FSRUs are changing the pipeline gas/ LNG balance positively to the LNG side. LNG share increased from 12.92% to 28% from 2013 to 2019. In 2019, pipeline imports reached the lowest volume since 2010 (EMRA, 2020).

Natural gas takes an important part in Türkiye's energy sources and power generation. LNG is another alternative to reduce pipeline natural gas dependency and it's share in natural gas imports are gradually increasing in parallel to new FSRUs. Small-scale LNG and LNG as a marine fuel could create another market option for LNG imports and bunker suppliers.

Methodology

This study employs the interview method and the researchers can use the interviews to gather valid and reliable data that is relevant to the research questions (Saunders et al., 2009). The semi-structured interviews allow the researcher to have lists of themes and questions that may vary for different respondents. Some questions may vary depending on the interview's flow or be focused on certain topics based on the context, giving the researcher the freedom to investigate new phenomena. Researchers can perform an exploratory and explanatory study using this strategy in semi-structured interviews. Semi-structured interviews help to understand variables in the small-scale LNG supply chain and LNG bunkering in the Türkiye context. Therefore, a semi-structured interview method has been used as this study aims to explore a relatively new concept that has no operational applications in the sector in Türkiye.

By considering only data from a subgroup rather than all possible cases or components, sampling techniques allow you to minimize the amount of data you need to collect. Some research questions would necessitate sample data that will enable you to statistically generalize about all of the cases from which your sample was drawn. There are two types of sampling technic: probability and non-probability (Saunders et al., 2019). Probability sampling is usually associated with survey research strategies. The chance, or likelihood, of each case being chosen from the target population, is known with probability samples, and it is normally equal for all cases. This ensures that you can answer research questions and meet goals that include statistical estimation of the target population's characteristics from the sample. However, since the probability of each case being chosen from the target population is unknown in non-probability samples, it is difficult to answer the study questions or meet the goals that include statistical inferences about the population's characteristics (Saunders et al., 2019). Purposive sampling occurs when a researcher has a clear understanding of what sample units are needed based on the study's objectives,

and then approaches possible sample participants to see if they meet the requirements. Those who comply are employed, while those who do not are dismissed (Easterby-Smith et al., 2015). In the small-scale supply chain literature, stakeholders have been categorised. Therefore, to fulfil these requirements of the research objectives, purposive sampling strategy has been used for semi-structured interviews. This research explores relatively new topic in the maritime industry and there are limited numbers of expert in this field.

The population of the study covers shipowners, suppliers, regulatory bodies and technical service providers. The purposive sampling strategy was used to maximise the variations in the phenomenon. Interviews were conducted with six shipowners, five suppliers, four regulatory bodies and four technical service provider representatives. The number of the interviews was not determined before, rather, the size of the samples was restricted in line with theoretical saturation, in other words, till data collection generates no insight.

The first contact with interviewees has been made through email or phone call and the means of the interview have been decided accordingly as online meeting, phone conversation or email. All interviews were conducted via online meetings and phone talks due to COVID-19 restrictions. Managers are less committed to doing remote interviews since they are not required to host the interviewer or see them at a specific time. Remote interviewing, however, does not always favour the researcher for these reasons. Face-to-face interviews provide instant contextualization, depth, and nonverbal communication that mediated interviews lack (Easterby-Smith et al., 2015). However, internet-based or telephone conversation could be particularly useful in real-time and process-based research.

The themes of the questions were determined as safety (Jeong et al., 2017; Park et al., 2018), technical (Choi & Park, 2019; Kim et al., 2019a), operational (Kim et al., 2018, 2019b), regulatory framework (Xu et al., 2015; Wan et al., 2018) and commercial components (Schinas & Butler, 2016; Eise et al., 2017; Yoo, 2017) following the findings obtained from the literature review. Interviews were conducted between 16th November 2020 and 15th January 2021.

Table 2. List of Interviewees with Experts in Türkiye

Code	Title	Function	Type
R1	Director	TSP	Mobile Phone
R2	Business Development Manager	TSP	Online
R3	Planning Manager	Shipowner	E-mail
R4	Country Manager	TSP	Online
R5	Country Manager	Regulatory Body	Online
R6	General Manager	Supplier	E-mail
R7	Energy Manager	Shipowner	Mobile Phone
R8	General Manager	Shipowner	Online
R9	Senior Technical Officer	Regulatory Body	E-mail
R10	Ass. Sec. Gen.	TSP	Online
R11	General Manager	Supplier	Online
R12	GM	Shipowner	E-mail
R13	Investment Manager	Supplier	E-mail
R14	Director	Supplier	Online
R15	General Manager	Regulatory Body	E-mail
R16	Energy Specialist	Regulatory Body	Online
R17	General Manager	Supplier	Online
R18	Operation Manager	Shipowner	E-mail
R19	Operation Manager	Shipowner	E-mail

The rigor of the study is established through Wallendorf & Belk (1989) protocol. In order to establish credibility, before each interview, the aim/scope of the research and the background of the interviewer were explained. A brief summary was made after each interview in order to confirm that the understanding of the interviewee is correct. The purpose sampling method was used to achieve transferability which is achieved through variation of participants in terms of title and segments. Dependability is ensured through not restricting sample size and the data collection process was completed once theoretical saturation was assured. In order to achieve confirmability; the responses of different participants were not shared with any other, and the findings were interpreted through quotes. The integrity of the research was assured through compliance with ethical principles. Names and company details were kept confidential. Table 2 summarises the details of the semi-structured interview participants.

Shipowners' representatives run bulk carriers, tankers and container vessels. One of the tanker owners has already LNG fuelled vessels on their order list. The technical service providers include the shipbuilding industry, shipyard, ship design and leading LNG technology provider in the world. The shipyard representative has already built LNG-fuelled vessels and other alternative fuelled vessels in their shipyard. The design/consultancy firm representative has delivered numerous projects fuelled with LNG. The suppliers in the list include port/terminal representatives and bunker suppliers. Regulatory body participants are policymakers and classification society representative.

Results and Discussion

This study aims to explore the views of the experts in Türkiye related to or potentially relating to LNG bunkering. The interviewees were classified according to their fields of expertise: namely; shipowners, suppliers, regulatory body (RB) members and technical service providers (TSP). The questions, in parallel with literature findings, were organized according to environmental, safety, technical, commercial and regulatory frameworks from a Turkish perspective. As Covid-19 restrictions were in place, the interviews were conducted through online applications, mobile phone networks or e-mail. 5 shipowners, 6 suppliers, 4 TSPs and 4 RBs representatives participated in the interviews. All general and specific expertise-related questions have been answered by the interviewees. Interviews were transcribed and analysed thoroughly.

Challenges of LNG Bunkering Development in Türkiye

The use of LNG as ship fuel is seen as a positive development because it is a cleaner energy source and is economical compared to other fuels. LNG not only complies with today's emission limits but also offers various advantages over other alternatives in terms of available infrastructure and capacity.

- For this reason, LNG bunkering was considered a promising alternative marine fuel for the future by 14 participants out of 19. Two shipowners and 1 technical service provider participant do not see any future in LNG marine fuel.

Türkiye's LNG bunkering potential was evaluated in terms of transit via the Turkish Straits, large ports, the domestic fleet, the proximity to some main maritime trade routes, the existing LNG terminals and the LNG market.

- Suppliers and Technical service providers point out that Türkiye has significant potential for LNG bunkering based on the aforementioned criteria thus highlighting Türkiye's advantage. On the other hand, 2 shipowners and 1 supplier underlined that Türkiye is not in an advantageous condition due to market structure and geographical location.

The challenges for LNG bunkering in Türkiye were defined in parallel to global challenges. Its environmental advantage compared to other fossil fuels is important, but it is not sufficient to meet global targets.

- Commercial factors, LNG demand, LNG price and the LNG market were some of the keywords underlined by 19 participants.
- High capital expenditure is not affordable for shipowners is another finding that is highlighted by 19 participants.
- Infrastructure is developing rapidly but global coverage has not yet been established.
- Crew competency along with safety considerations are other key subjects that were highlighted by 6 shipowner participants. 2 of the TSP also underlined the same issue.
- Fleet type, such as container vessels in liner services, Ro-Ro fleet, and large carriers (either tankers or container vessels) were emphasised by shipowners highlighting some potential in LNG fuelled vessel applications in different segments.

Türkiye's LNG bunkering legislation and regulatory framework are important items which were emphasised by the supplier and regulatory body participants.

- To date, there is no legislation in place for LNG bunkering. This is another factor that is slowing down the LNG bunkering infrastructure development process from the supplier side as

they seek references and standards to comply with local regulations.

Technical service providers are the most optimistic stakeholders regarding LNG bunkering development. Well-known problems of LNG bunkering such as boil-off gas and methane slip can be minimised with technological improvements. The International Code of Safety for Ship Using Gases or Other Low-flashpoint Fuels (IGF Code) standard for boil-off gas (BOG) treatment in bunker barges has been set at 15 days and the industry is able to comply with these restrictions. The Turkish shipbuilding industry is already producing LNG fuelled vessels as well as other alternatively fuelled vessels. Commercial factors were again highlighted by the technical service providers, specifically that individual investment by a shipowner is unlikely due to the high capital expenditure costs.

Suppliers in Türkiye are closely monitoring developments in alternative fuels in shipping. There are investments in LNG bunkering facilities which were mentioned during the interviews.

• Collaboration was one of the keywords to advance LNG bunkering developments in Türkiye. It was emphasised by 4 suppliers.

• With regards to collaboration, 5 suppliers also highlighted government subsidies in order to encourage investment in infrastructure and develop the markets.

• Oil price, LNG price market structure and demand are the other keywords which were emphasised frequently by shipowners and suppliers. High capital expenditure and the pay-back time of the investment were defined as barriers to entering the market.

LNG Bunkering Case for Türkiye

Türkiye is an important ship-supply location in maritime traffic. The Istanbul area provides not only bunkering but also crew change, provisions, spare parts, water/oil supply and repair facilities which all contribute to Türkiye's economy. Traffic density in the Istanbul and Çanakkale Straits makes this place one of the busiest shipping routes and the total tonnage of vessels passing through has been increasing gradually over the years. In addition to transit passage through the straits, the growing shipping activities at ports are crucial to the measure of bunkering potential. By the end of 2018, Türkiye's total bunkering volume reached 3 million tonnes (Shipandbunker, 2020). It is provided by 55 bunker barges in service. However, it is argued that this is still below the potential of Türkiye as only about 1,200 ships per year receive bunker in Istanbul and this is only approximately 3% of the total transit passage of the Istanbul Strait. Another crucial item is the storage facilities which are located in the Izmit Gulf which affect the competitive price of bunker deliveries. In light of these bunkering facts in Türkiye, the LNG bunkering case was discussed.

Bunker supply chain stakeholders in Türkiye generally have a positive attitude towards utilising LNG as an alternative marine fuel. One of the regulatory body participants justified using LNG as a marine fuel as follows:

"…. LNG emerges as an important alternative fuel. Considering the operational costs, LNG is advantageous as a fuel compared to low sulphur fuel in terms of lower prices and higher energy efficiency. All these points show that LNG stands out as an alternative fuel for ships compared to other options." (R16).

The Marmara region is a highly populated area and there is significant marine traffic in the Marmara Sea. Ship-induced air pollutants such as SO_x, NO_x, and PM have a significant effect on human health and ecosystems. The positive contribution of LNG to air pollution should have great importance for the city of Istanbul, which is located around one of the busiest waterways in the world. These environmental benefits are supported by operational benefits by the supplier participants.

".. In addition, bunker LNG reduces the operational costs of ship machinery such as maintenance and creates less vibration, soot and odour in ships (especially for cruises ships), which provides important advantages" (R13).

On the other hand, one of the shipowner participants is not optimistic about LNG as a marine fuel. He argued against it as follows:

"I think it is difficult to use it as ship fuel in the short term due to current market conditions, economic crises, high costs, alternative fuels, alternative systems and challenging conditions, insufficient incentives, operational-operating costs and insufficient supply points" (R18).

These arguments are similar to other shipowners' perspectives not only in Türkiye but also in the world.

The Turkish perspective on LNG as a marine fuel seems slightly less promising than the global context. Although environmental benefits are emphasised by all participants; 2 out of 4 shipowner participants did not view LNG to be important alternative fuel, taking into account high capital expenditure. This is the primary reason why shipowners are reluctant to invest in alternative fuels. Unless forced by regulation, shipowners seek less risky and less costly alternatives in their operational and tactical decision-making processes.

Table 3. Comparative table of the LNG bunkering challenges based on experts in global and experts in Türkiye

No	LNG Bunkering Challenges in Global Context	LNG Bunkering Challenges in accordance with experts in Türkiye
1	Commercial Factors	Commercial Factors
2	Safety	Regulatory Framework
3	Sustainability/Environmental	Safety
4	Regulatory Framework	Operational Factors
5	Technical Factors	Crew Training
6	Infrastructure	Operating Region
7	Location/Operation Region	Infrastructure
8	Collaboration	Subsidies
9	Fleet type	Collaboration
10	Operational Factors	Environmental

Source: Author, compiled from (Doymus & Denktas Sakar, 2020)

Türkiye's LNG bunkering potential was usually evaluated via its geostrategic location and existing LNG handling facilities by the participants. This potential was underlined by one of the regulatory body participants as follows:

".. Considering this potential, it is important to be able to supply LNG as a bunker, which stands out as an alternative fuel in ships depending on the worldwide trend, environmental constraints and regulations, as well as the conventional bunker supply" (R15).

An existing LNG infrastructure, knowledge, and experience are the advantages for Türkiye in the East Mediterranean and the Black Sea region. This is pointed out by a supplier as follows:

"…Due to the existing LNG Terminals and an established / experienced market structure in the bunker fuel trade, it is possible to access bunker LNG from Turkish ports at competitive prices and under favourable conditions" (R18).

Türkiye has a very dynamic shipbuilding industry. LNG fuelled vessels have already been built in Türkiye. There is number of shipyards in Türkiye which have the knowledge and capability to build vessels in Green Ship concepts which are fuelled by alternative fuels such as Cemre Shipyard, Tersan Shipyard, and Sanmar Shipyard. This point was emphasised by several participants to illustrate the potential of Türkiye.

The challenges for LNG bunkering development in Türkiye have similar considerations as is the case on the global scale. Insufficient demand for LNG bunker is a major challenge for suppliers in taking the decision to invest in LNG. The long pay-back time prediction due to the infancy of the market was underlined by all supplier participants. On the shipowner side, parallel to global concerns, the high CAPEX requirement and lack of global coverage of infrastructure were defined as the main reasons to be reluctant to invest in LNG fuelled vessels. At the same time, shipowners will remain in favour of traditional solutions as long as the regulations allow, relying on economic facts. Another outstanding challenge highlighted by all shipowners is the lack of a qualified crew. It was argued that even if they made the decision to invest in LNG fuelled vessels, it would be difficult to find and employ qualified crew who are certified in LNG fuelled vessels. However, one technical service provider argued that:

"…Türkiye has had LNG handling experience with BOTAŞ and EGEGAZ over the years, crew training could be easily arranged with these companies together with the collaboration between universities and shipowners" (R4).

There are numerous training institutes in Türkiye for ship crew. These institutes are providing manpower for shipowners. On the other hand, there is not any shipowner running an LNG vessel, and LNG qualified crew requirements for the Turkish shipowners. FSRU units are equipped with foreign crew members. As it's argued by a TSP, Türkiye could develop training facilities for crew members while taking into account LNG handling experience over the years in LNG import terminals.

Technical standardisation and the regulatory framework at the global scale are almost ready. However, it is still attracting substantial criticism from the supplier participants in the Turkish case. One of the suppliers argued that:

"The technical standards are not yet ready. When making such a high-cost investment, it is necessary to know what the local rules, limitations and requirements are. Therefore, first of all, there should be legislation that we need to follow" (R17).

Another participant who represents a supplier also pointed out that:

"*…Even though we have invested in LNG bunkering, we do not have the chance to compete with foreign countries with the current customs legislation. Profit margins are very low due to the current legislation and the operational constraints it imposes*" (R6).

In addition, the RB participant points out that in terms of legislation, the Ports Regulation adopted in 2012 needs to be updated regarding LNG bunkering safety and other related issues. On the other hand, in 2019, the necessary arrangement was made in the Turkish Straits Maritime Traffic Regulation in order to regulate the passage of LNG fuelled vessels through the Turkish Straits (R15). Legislation for LNG bunkering is not yet ready in Türkiye. This has a significant effect on how stakeholders deal with uncertainties concerning high-cost investment. The legislation is crucial for defining the technical specifications and structuring limits of the investments. Moreover, as LNG transfer is not the same as conventional bunkering, current customs legislation also needs to be updated regarding operational standards and safe handling procedures for LNG. Doymus & Denktas-Sakar's (2020) study reveals LNG bunkering challenges in global context. Table 3 compares findings of LNG bunkering challenges in the global context and with experts in Türkiye.

The table includes frequently highlighted issues by the experts. It should be emphasised that there are almost two years of a time lag between two the studies. However, challenges show similarities in many contexts. Inevitably, commercial factors take the highest concern for all the experts. LNG bunkering price, LNG contracts, uncertainty, lack of transparency are important factors along with high CAPEX requirements. Participants from Türkiye pointed out regulatory concerns more than their counterparts in global. This is one of the important concerns in front of Türkiye side -missing clear legislation for LNG bunkering. Safety factors, operational consideration, collaboration, and infrastructure are the common elements almost equally emphasised in both studies. One important keyword for Türkiye side is the subsidies. This was also highlighted in a global context but for the Türkiye case, it was one of the top keywords stressed by all the participants. Environmental concerns were underlined and acknowledged as one of the most important drivers for LNG bunkering in a global context. However, in the Türkiye case, it took limited attention while justifying LNG as marine fuel but was not underlined as the main driver for LNG bunkering supply chain development. In parallel to this finding, public awareness was highlighted frequently as well. In Türkiye case, it was only mentioned by one TSP. Public awareness or public opinion is one of the strongest developments for the LNG bunkering case, when the existing small-scale LNG supply chain was investigated in NW Europe and the Baltic Sea. Public opinion also triggers green funds and government subsidies for high CAPEX investments. In the Türkiye case, public pressure on environmental issues is not strong or just parallel to daily politics. Reaching out subsidies and incentives is not easy as in developed countries.

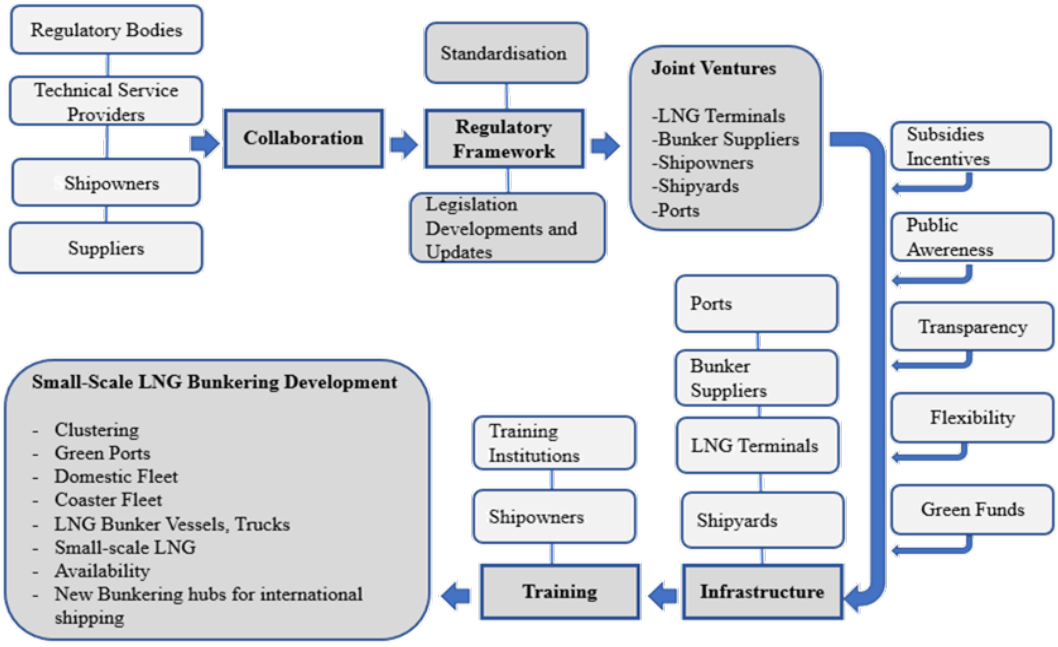

Figure 2. LNG bunkering development pathway in Türkiye (*Source*: Author)

Figure 2 summarises the LNG bunkering development pathway in Türkiye. Collaboration is a must between stakeholders. The regulatory framework needs to be updated and standards should be in place. Joint venture agreements are necessary for high CAPEX required new business. The risk of the new investment decision should be shared by the stakeholders. The organisation should be supported by subsidies and incentives. Infrastructure should be developed by joint venture participants. Crew members should be trained in cooperation with shipowners and training institutions. Small-scale LNG supply chain and LNG bunkering development should be supported by a clustering approach, renewing domestic fleet, renewing coaster fleet and green port concept. Trucks could be used firstly while the market is unmature and demand is low. Creating the demand at a small-scale scale and availability will lead to growing demand, larger ships and new hubs as it has been seen in other locations across the world.

The global coverage of the LNG bunker infrastructure on the main trade routes has been completed. Developments in the West Mediterranean region are also promising as Spain's LNG bunker deliveries increased 272% in 2020 compared to the previous year, including activities on the Atlantic Coast (Bunkerspot, 2021). Greece and South Cyprus have already invested in LNG projects and small-scale LNG not only for marine fuel but also for power production. LNG is not the ultimate marine fuel solution to meet UN decarbonization targets, but it is ready, and it has a fast-developing infrastructure across the world. Other important alternatives such as ammonia, methanol and hydrogen still need time to prepare infrastructure and overcome availability concerns. Arkas Bunker signed an agreement with Sumitomo Corporation for LNG bunkering (Arkas, 2021). One of the important Turkish shipowners has already ordered 10 LNG-ready vessels and is expecting to receive the first delivery in 2022 (R7). This is the only known Turkish shipowner who invested in LNG-fuelled ships on a large scale. Turkish shipyards have built numerous LNG fuelled, battery or hybrid driven vessels so far. For example, Tersan shipyard built 4 LNG-powered fishing vessels, 4 LNG-powered Coastal Passenger vessel, 5 battery-powered Ro/Ro Passenger vessels, 5 hybrid (gas and battery) powered Ro/Ro passenger & vehicle carrier for Norwegian shipowners so far (Tersan, 2021). Moreover, 3 battery powered passenger ships, 4 battery-driven fishing boats, 2 battery-driven renewable energy vessels were built in Cemre Shipyard. 2 fishing boats are LNG-battery driven under construction and are to be delivered in 2022 (Cemre, 2021). Other shipyards such as Sanmar, Kuzey Star, and Sefine shipyards have already built LNG-powered, battery-powered and hybrid ferryboats, tugs and fishing vessels (Portnews, 2020; Sefine, 2021; Sanmar, 2021a). Turkish shipyard built one of the largest batteries driven vessel (2000kwh) in the world as well. Türkiye is also the only country in the world that built hybrid-powered fishing boats (R2). Turkish shipbuilding industry is not only building vessels based on foreign designs; but also developing their own designs. Moreover, the Turkish shipbuilding industry is also exporting technology to Spain in electrical outfits to be used on the green concept ships (R1). Recently, Sanmar shipyard signed an agreement with Canada to build LNG fuelled 5 tug boats (Sanmar, 2021b). Despite these steps in LNG bunkering, it was observed that the LNG bunkering concept is not fully comprehended by the Turkish maritime industry. The high capital expenditure requirements for LNG fuelled vessels are the biggest barriers for shipowners. Safety concerns along with a lack of infrastructure and qualified crew requirements are also other issues to consider. Turkish bunker suppliers' demand concerns are not specific to the Turkish fleet as they provide service to all vessels conducting strait transits or calling on Turkish ports. The shipbuilding industry is able to build LNG fuelled vessels. However, they are not competitive compared to Far Eastern shipyards in this field as they still need to invest in research & development to develop tank designs and gain a competitive advantage. The big players of the world economy; Japan, Korea, China, Australia, Singapore, EU, the USA and Canada are improving their LNG bunkering infrastructure. Not only LNG but also other alternative fuels are gaining momentum globally parallel to the UN's decarbonization targets.

Conclusion

The study collects data through interviews with shipowners, bunker suppliers, ports, terminals, shipbuilders, policymakers, classification societies, and technical service providers were contacted. The key outcomes of this research have been highlighted as recommendations for the Turkish maritime industry:

- Collaboration is key for LNG bunkering development. Supply chain stakeholders; ports, terminals, shipowners, bunker suppliers, shipyards and policymakers should collaborate to overcome the current challenges of LNG bunkering development.
- Legislation to deliver LNG as a marine fuel and small/mid-scale LNG operations have to be developed, and customs requirements need to be updated to comply with safe LNG

handling operations while taking into account the competitiveness of Türkiye's bunker market. The regulatory framework, technical standards and legislation need to be ready before taking any high CAPEX required investment decision by all stakeholders.

• Global LNG bunkering supply chain development analysis indicates that high CAPEX investments have occurred via special subsidies, incentives and funds. Türkiye should seek international funds which prioritise the environmental benefits of LNG, air pollution mitigation strategies and contributions to reducing CO_2 emissions.

• The Turkish shipbuilding industry has experience in building vessels in the green concept as well as in LNG fuelled vessels. However, building LNG fuelled vessels at a competitive price is critical mainly due to LNG tank design know-how. Cryogenic container manufacturing is available in Türkiye (Aritas, 2021). Building the tanks for LNG fuelled vessels needs further research & development investment.

• Crew competency is an important barrier in LNG bunkering development not only in Türkiye but also in the world. The first LNG fuelled vessels were not even tanker and crew members conducted these operations after training in liaison with classification societies. IGF code set standards for LNG-fuelled vessels now. Türkiye already has LNG handling experience. The number of the LNG fuelled vessels or LNG bunker barge will be limited in the near future, therefore training of countable crew members problem could be solved with the cooperation of training institutes, shipowners and the LNG industry in Türkiye.

• The shipowner dimension is another critical point for small-scale LNG development. Türkiye has an ageing domestic fleet of ferries and Ro-Ro vessels (MOTI, 2021). Renewing the ageing coaster fleet is a long-lasting discussion in Türkiye, but it has not been achieved to date due to a lack of funds, collaboration or strategic level maritime policies. Supporting shipyards with new orders enables them to invest in R&D. Renewing the coaster fleet with green concept vessels enlarges the market for the Turkish coaster fleet, particularly in EU ports (Cogea, 2017).

• Bunker suppliers need to see demand in order to invest in LNG bunkering and calculate their pay-back time. Local bunker demand in small quantities plays important role in setting up a market and allows it to grow up gradually. The domestic fleet renewal project is a strategic decision and requires the collaboration of all stakeholders.

• Regulatory pressure is the main motivation for the shipping industry to take initiative and invest in new designs, new fuels or new vessels. Emission Control Areas (ECAs) are an important driver of technological improvement and investment decisions. IMO's plan to set new ECA in the Mediterranean and the Black Sea could be an important driver to shift to environmentally friendly marine fuels.

• Green incentives could support ports and shipowners in line with environmental policies and regulations. At the same time, Türkiye is an important country for tourism and the 'Green' concept is quite important for cruise shipping. Providing LNG bunkering facilities in Galataport, Istanbul, Izmir and Kusadasi could attract new-build, energy efficient and environmentally friendly ships to Turkish ports.

LNG is one of the alternative fuels for the maritime industry and it is gaining momentum across the world. Other alternative fuels will emerge in the near future as well. Türkiye should take strategic level decisions to be a leading country in shipping while using its know-how in the shipbuilding industry, manpower in shipping, fleet size and growing port activities. The findings and recommendations of this study are in the LNG bunkering concept but similar arguments could be adapted to other alternative fuel supply chain developments. Türkiye's ambition to become an energy hub, despite being a net importer, is subject to using the resources cleverly and creating new opportunities rather than being just a follower. LNG bunkering and small-scale supply chain literature is very limited as it is relatively new phenomena. The study firstly contributes to small-scale LNG supply chain literature by defining challenges and important consideration for future development. Some studies in the literature address this problem, however, researches are limited to one country, or with a one stakeholder perspective, with one segment of the shipping or limited to quantitative researches (Wang & Notteboom, 2014, 2015; Aymelek et al., 2015; Xu et al., 2015; Calderón et al., 2016; Ge & Wang, 2017; Jafarzadeh et al., 2017; Gucma et al., 2019; Doymus et al., 2022). This study encompasses different supply chain stakeholders through semi-structured interviews and bring a holistic insight to the phenomenon. Moreover, the study also contributes to knowledge by bringing real-time practitioners' experience in bunkering into this relatively new issue in shipping and provides a comprehensive framework for further research.

This study also contributes to investment decisions in LNG bunkering for shipowners and suppliers. The ports are a vital part of the small-scale LNG supply chain. Not only regulatory pressure but also public pressure takes an important role over port management. Providing service for alternative fuels is critical for the sustainability targets of the ports. Therefore, port

managements should consider investing in 'green' concepts. LNG in trucks and ISO containers could be operational in small/mid-size ports. The large ports should take into account ship-to-ship operations. Simultaneous operations supported by detailed risk assessment are crucial for LNG bunkering developments at ports. Providing service for alternative fuels is essential for cruise terminals. In Türkiye case, Istanbul, Kusadasi, Izmir and Galataport should consider LNG bunker service in order to attract 'green' concept cruise vessels and gain a competitive advantage against other alternative ports in the region. LNG terminals play a pivotal role in infrastructure developments and being part of the joint ventures should be considered to reduce the risk and invest in high CAPEX required business.

Türkiye has a very well-developed shipbuilding industry capable of adopting new technologies but struggling with a lack of finance and sustainable order lists. Bunker suppliers are working within very limited profit margins and the high CAPEX required for investment is not realistic. Shipowners are on the edge of profit margins and can barely manage the running cost of the ageing fleet. Therefore, the industry needs strong support from the government that could orchestrate stakeholders with incentives, subsidies and guarantees as part of strategic maritime and energy policies. Ministry of Energy and Natural Resources, Ministry of Environment and Urbanisation, Ministry of Trade, Ministry of Transport and Infrastructure and Energy Market Regulatory Authority are crucial regulatory bodies and policymakers in that should take part to develop a convincing structure not only for LNG bunkering but also for other alternative fuels in shipping. The regulatory body should shape its strategic plans not only from a commercial perspective but also for public welfare as shipping-related activities have substantial negative effects on public health. Eliminating air pollution over the highly populated cities by incentives provided to the shipping industry could pay back in the long-term by reducing the pressure on the public health system.

The study has some limitations. There are 19 respondents for the semi-structured interviews in Türkiye. Ship-to ship LNG bunkering operations have not been performed in Türkiye, yet. Shipowners and supply experts in Türkiye are inexperienced in this field and they shared their views based on their theoretical knowledge.

This study employed semi-structured interviews as a qualitative research method. Small-scale LNG and LNG bunkering could be explored with the Delphi method by surveying a panel of experts as well. Another data collection method could be a focus group study which brings a group of experts into a room and provide feedback on the related phenomenon. A similar study could be conducted for other alternative marine fuels such as hydrogen, methanol, ammonia and LPG. A comparative study could provide another decision tool for shipowners, suppliers and other stakeholders in the maritime industry.

Acknowledgements

The authors would like to express their gratitude to the respondents for their valuable inputs and contributions.

Compliance With Ethical Standards

Authors' Contributions

MD: Conceptualization, Methodology, Visualization, Formal analysis, Investigation, Writing - Original Draft, Data Curation, Writing – Review and Editing.
GDS: Supervision, Methodology, Writing – Review and Editing

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

Funding

The research presented in the manuscript did not receive any external funding.

References

Aritas. (2021). Company Profile | Arıtaş. Retrieved on March 14, 2021, from https://aritas.com.tr/about

Arkas. (2021). News Detail - Arkas Holding S.A. Retrieved on February 22, 2021, from http://www.arkas.com.tr/ennews_detail.html?newsId=1454

Aymelek, M., Boulougouris, E. K., Turan, O., & Konovessis, D. (2014) Challenges and opportunities for LNG as a ship fuel source and an application to bunkering network optimisation. In Soares, C. G., & Santos, T. A. (Eds.) *Maritime technology and engineering* (pp. 767–776). CRC Press/Balkema. https://doi.org/10.1201/b17494

Bunkerspot. (2021). EUROPE: LNG bunkering activity soars 272% in Spain - Bunkerspot - Independent Intelligence for the Global Bunker Industry. Retrieved on February 20, 2021, from

https://www.bunkerspot.com/europe/52268-europe-lng-bunkering-activity-soars-272-in-spain

Calderón, M., Illing, D., & Veiga, J. (2016) Facilities for bunkering of liquefied natural gas in ports. *Transportation Research Procedia*, *14*, 2431–2440. https://doi.org/10.1016/j.trpro.2016.05.288

Cemre. (2021). Cemre Shipyard. Retrieved on February 20, 2021, from https://www.cemreshipyard.com/en

Choi, J., & Park, E.-Y. (2019) Comparative study on fuel gas supply systems for LNG bunkering using carbon dioxide and glycol water. *Journal of Marine Science and Engineering*, *7*(6), 184. https://doi.org/10.3390/jmse7060184

Cogea. (2017). *Study on differentiated port infrastructure charges to promote environmentally friendly maritime transport activities and sustainable transportation*. Final Report. Retrieved on July 20, 2022, from https://www.cogea.it/sites/default/files/2017-06-differentiated-port-infrastructure-charges-report.pdf

Doymus, M., & Denktas Sakar, G. (2020). An exploratory study on the perceptions of stakeholders in LNG bunkering supply chain. *Journal of ETA Maritime Science*, *8*(1), 66–84. https://doi.org/10.5505/jems.2020.43255

Doymus, M., Denktas Sakar, G., Topaloglu Yildiz, S., & Acik, A. (2022). Small-scale LNG supply chain optimization for LNG bunkering in Turkey. *Computers & Chemical Engineering*, *162*, 107789. https://doi.org/10.1016/j.compchemeng.2022.107789

Easterby-Smith, M., Thorpe, R., & Jackson, P. (2015). *Management and business research*. 5th Ed. SAGE Publications Ltd.

Eise Fokkema, J., Buijs, P., & Vis, I. F. A. (2017). An investment appraisal method to compare LNG-fueled and conventional vessels. *Transportation Research Part D: Transport and Environment*, *56*, 229–240. https://doi.org/10.1016/j.trd.2017.07.021

EMRA. (2020). *2019 yılı doğal gaz sektör raporu*. Republic of Türkiye, Energy Market Regulatory Authority. Retrieved on July 20, 2022, from https://www.epdk.gov.tr/Detay/Icerik/3-0-94/dogal-gazyillik-sektor-raporu

Erkmen, T. (2018). The model of pricing of small scale LNG bunker terminal in Turkey. *Journal of Naval Sciences and Engineering*, *14*(2), 71–90.

Ge, J., & Wang, X. (2017). Techno-economic study of LNG diesel power (dual fuel) ship. *WMU Journal of Maritime Affairs*, *16*(2), 233–245. https://doi.org/10.1007/s13437-016-0120-x

Gucma, M., Bąk, A., & Chłopińska, E. (2019). Concept of LNG transfer and bunkering model of vessels at South Baltic Sea area. *Annual of Navigation*, *25*(1), 79–91. https://doi.org/10.1515/aon-2018-0006

IMO. (2015). *Third IMO Greenhouse Gas Study 2014*. International Maritime Organization (IMO). Retrieved on July 20, 2022, from https://www.imo.org/en/OurWork/Environment/Pages/Greenhouse-Gas-Studies-2014.aspx

IMO. (2020). *Fourth IMO Greenhouse Gas Study: Executive Summary*. International Maritime Organization (IMO). Retrieved on July 20, 2022, from https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/Fourth%20IMO%20GHG%20Study%202020%20Executive-Summary.pdf

Jafarzadeh, S., Paltrinieri, N., Utne, I. B., & Ellingsen, H. (2017). LNG-fuelled fishing vessels: A systems engineering approach. *Transportation Research Part D: Transport and Environment*, *50*, 202–222. https://doi.org/10.1016/j.trd.2016.10.032

Jeong, B., Suk Lee, B., & Zhou, P. (2017). Quantitative risk assessment of fuel preparation room having high-pressure fuel gas supply system for LNG fuelled ship. *Ocean Engineering*, *137*, 450–468. https://doi.org/10.1016/j.oceaneng.2017.04.002

Kim, K., Park, K., Roh, G., & Chun, K. (2019a). Case study on boil-off gas (BOG) minimization for LNG bunkering vessel using energy storage system (ESS). *Journal of Marine Science and Engineering*, *7*(5), 130. https://doi.org/10.3390/jmse7050130

Kim, A.-R., Kwak, D.-W., & Seo, Y.-J. (2019b). Evaluation of liquefied natural gas bunkering port selection. *International Journal of Logistics Research and Applications*, *24*(3), 213-226. https://doi.org/10.1080/13675567.2019.1642311

Kim, Y. H., Jung, D. W., Cho, S. K., & Sung, H. G. (2018). Experimental study on hydrodynamic characteristics and operational feasibility of floating LNG bunkering terminal moored side-by-side with LNG Carrier and two LNG bunkering shuttles. *Ships and Offshore Structures*, *13*(5), 504–518. https://doi.org/10.1080/17445302.2018.1430099

Kırlı, M. S., & Fahrioğlu, M. (2019). Sustainable development of Turkey: Deployment of geothermal resources for

carbon capture, utilization, and storage. *Energy Sources, Part A: Recovery, Utilization and Environmental Effects*, *41*(14), 1739–1751. https://doi.org/10.1080/15567036.2018.1549149

Lam, J. S. L., Chen, D., Cheng, F., & Wong, K. (2011). Assessment of the competitiveness of ports as bunkering hubs: empirical studies on Singapore and Shanghai. *Transportation Journal*, *50*(2), 176-203. https://doi.org/10.5325/transportationj.50.2.0176

MOTI. (2020). *Deniz Ticareti Genel Müdürlüğü İstatistik Bilgi Sistemi*. Ministry of Transport and Infrastructure. Retrieved on June 17, 2020, from https://atlantis.udhb.gov.tr/istatistik/gemi_gecis.aspx

MOTI. (2021). *Filo İstatistikleri, Filo - Denizcilik İstatistikleri*. Ministry of Transport and Infrastructure. Retrieved on March 14, 2021, from https://denizcilikistatistikleri.uab.gov.tr/filo-istatistikleri

Öge, K. (2021). Understanding pipeline politics in Eurasia: Turkey's transit security in natural gas. *Geopolitics*, 26(5), 1510-1532. https://doi.org/10.1080/14650045.2019.1687447

Park, S., Jeong, B., Yoon, J. Y., & Paik, J. K. (2018). A study on factors affecting the safety zone in ship-to-ship LNG bunkering. *Ships and Offshore Structures*, *13*(sup1), 312–321. https://doi.org/10.1080/17445302.2018.1461055

Portnews. (2020). *Russia's first LNG-powered RO-RO ferry launched in Turkey*. Available at: https://en.portnews.ru/news/300549/ (Accessed: 2 June 2021).

Sefine. (2021). Project Detail | Sefine Shipyard, NB52 - NB53 | 5700 m^3 Live Fish Carrier. Retrieved on June 2, 2021, from https://sefine.com.tr/Project/Project_Detail/40

Sanmar. (2021a). *Are you looking for a proven design and quality tug boats for sale*. Retrieved on June 2, 2021, from http://sanmartugboat.com/tugboats/

Sanmar. (2021b). *Sanmar to Build Five Technologically Advanced Tugs to Serve LNG Canada - Sanmar Shipyards*. Retrieved on June 2, 2021, from https://www.sanmar.com.tr/sanmar-to-build-five-technologically-advanced-tugs-to-serve-lng-canada/

Saunders, M., Lewis, P., & Thornhill, A. (2019) *Research methods for business students*. 8th Ed. Pearson.

Saunders, M., Lewis, P., & Thornhill, A. (2019) *Research methods for business students*. 5th Ed. Pearson.

Schinas, O., & Butler, M. (2016). Feasibility and commercial considerations of LNG-fueled ships. *Ocean Engineering*, *122*, 84–96. https://doi.org/10.1016/j.oceaneng.2016.04.031

Sharples, J. (2019). *LNG supply chains and the development of LNG as a shipping fuel in northern Europe*. Oxford Institute for Energy Studies. https://doi.org/10.26889/9781784671266

Shipandbunker. (2020). *LNG bunkering coming to Turkey in 2021 - Ship & Bunker*. Retrieved on February 1, 2021, from https://shipandbunker.com/news/emea/694360-lng-bunkering-coming-to-turkey-in-2021

Sigma. (2020). *Turkey's energy outlook – A snapshot - Sigma Turkey*. Retrieved on June 28, 2020, from https://www.sigmaturkey.com/turkeys-energy-outlook-a-snapshot/

Tersan. (2021). *Tersan Shipyard*. Retrieved on June 2, 2021, from https://www.tersanshipyard.com/projeler

Topuz, K. (2019). The missing piece in the Turkey's gas hub ambitions. IICEC Energy and Climate Research Paper, Sabancı University İstanbul International Center for Energy and Climate. Retrieved on July 20, 2022, from https://iicec.sabanciuniv.edu/sites/iicec.sabanciuniv.edu/files/2020-11/iicec_energy_and_climate_research_paper_the_missing_piece_in_the_turkeys_gas_hub_ambitions_2.pdf

UNCTAD. (2019). *UNCTAD Handbook of Statistics 2019*. United Nations Conference on Trade and Development. United Nations Publication. Retrieved on July 20, 2022, from https://unctad.org/webflyer/handbook-statistics-2019

Wallendorf, M., & Belk, R. W. (1989). Assessing trustworthiness in naturalistic consumer research. In Hirschman, E. C. (Eds.), *SV - Interpretive Consumer* Research (pp. 69-84). Association for Consumer Research.

Wan, Z., el Makhloufi, A., Chen, Y., & Tang, J. (2018). Decarbonizing the international shipping industry: Solutions and policy recommendations. *Marine Pollution Bulletin*, *126*, 428–435. https://doi.org/10.1016/j.marpolbul.2017.11.064

Wang, S., & Notteboom, T. (2014). The adoption of liquefied natural gas as a ship fuel: A systematic review of perspectives and challenges. *Transport Reviews*, *34*(6), 749–774. https://doi.org/10.1080/01441647.2014.981884

Wang, S., & Notteboom, T. (2015). The role of port authorities in the development of LNG bunkering facilities in North European ports. *WMU Journal of Maritime Affairs*, *14*(1), 61–92. https://doi.org/10.1007/s13437-014-0074-9

Xu, J., Testa, D., & Mukherjee, P. K. (2015). The use of LNG as a marine fuel: The international regulatory framework. *Ocean Development & International Law*, *46*(3), 225–240. https://doi.org/10.1080/00908320.2015.1054744

Yoo, B. -Y. (2017). Economic assessment of liquefied natural gas (LNG) as a marine fuel for CO_2 carriers compared to marine gas oil (MGO). *Energy*, *121*, 772–780. https://doi.org/10.1016/j.energy.2017.01.061