Analysis of the elements of the LNG terminal’s location in Dalian Port under the background of carbon neutrality in China

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Abstract. As the issue of climate change is always attracting widespread attention and China had fulfilled its commitment on emission reduction, the proportion of traditional energy consumption such as coal in China's energy consumption structure will gradually decrease in the future, and the use of clean energy such as LNG will become the latest trend to replace the use of traditional resources, and the future increment of LNG would be mainly borne by sea transportation. Dalian City has a single source of natural gas by sea, which is highly dependent on offshore imports. In addition, it is predicted that the LNG throughput of Dalian Port will reach 8-12 billion m³ by 2050, so it urgently needs to build new LNG terminals to ensure the safety of natural gas supply. This paper statistically analyzed not only the operation status and construction progress of LNG terminals in northern China, but also the characteristics of natural gas consumption in the three North-Eastern Provinces of China and Dalian City. Based on the above situation, the principle and preliminary scheme of LNG terminal site selection were proposed.

1. Introduction

As climate change issues have attracted widespread attention and China has implemented emission reduction commitments, new types of market transactions under the emission reduction concept are gradually entering people's field of vision. For example, "Carbon-Neutral LNG", which means that the carbon emissions generated during the upstream extraction, processing, liquefaction, transportation, regasification, and final use of natural gas are completely offset by other forms of carbon reduction activities, thereby realizing the full life cycle of natural gas' net-zero emissions. According to Shell's official information, its two "carbon-neutral LNG" ships signed with CNOOC in June 2020 were through Shell's tree planting projects in Qinghai and Xinjiang, China, to offset the carbon emissions value of the entire life cycle of the ship's LNG.

Greenhouse gas emissions in China have been increasing in line with its energy consumption and economic growth. Major means for energy-related greenhouse gases mitigation in the foreseeable future are transition to less carbon intensive energy supplies and structural changes in energy consumption[1]. The carbon-neutral or Green LNG market is an emerging prospect whereby "Green" indicates either the reduction of GHG (Greenhouse Gas), or the offset of GHG emissions, linked to some, or all elements of the LNG value chain, better urban and transport planning can lead to carbon neutral, more liveable and healthier cities[2-5]. Modal shift is effective for a faster and cheaper pathway to carbon neutrality[6]. Since June 2019, East Asia has completed several " Carbon-Neutral LNG" spot transactions.
International suppliers such as Shell and Total have already sent to Japan (Tokyo Gas), South Korea (GS Energy), and mainland China (CNOOC) and other markets had delivered several "Carbon-Neutral LNG" shipments. CNOOC had also cooperated with the Shanghai Petroleum and Natural Gas Trading Center to list "Carbon-Neutral LNG" for bidding transactions with downstream customers.

According to China's relevant plans, the proportion of traditional energy consumption such as coal in China's energy consumption structure will gradually decrease in the future. The use of clean energy such as LNG to replace traditional resources such as coal has become the latest trend, and the proportion of clean energy such as LNG will increase significantly, which consumption proportion will be about 10%. According to the domestic LNG production and pipeline construction plan, the pipeline oil supply and domestic oil supply will remain at a stable level, and the future increase will be mainly borne by sea shipping. Dalian Port has excellent conditions for port construction. As the most competitive alternative port location for LNG terminal layout in the Bohai Rim region, no matter whether to implement the China's natural gas transportation and supply targets in the Bohai Rim region, or to ensure the gas demand of residents and industries in Dalian and surrounding areas, the layout of LNG terminals in the port area should be further optimized, and in-depth study the feasibility of the new layout and LNG terminal site selection should also be conducted.

2. LNG terminal construction and operation in northern China

2.1. Progress of LNG terminal construction
By the end of 2020, a total of 5 LNG terminals had been built in the Bohai Rim, which are located in the Nianyu Bay Area of Dalian Port, the Nanjiang Area and Dagang Area of Tianjin Port, the Caofeidian Area of Tangshan Port, and the Dongjiang Area of Qingdao Port[7]. The above-mentioned LNG terminals have a designed annual unloading capacity of 31.73 million tons and a system receiving capacity of 28.75 million tons of LNG, as shown in Table 1. In recent years, under the guidance of relevant LNG terminal layout plans, the construction of regional LNG terminals and storage and transportation facilities have been accelerated. At present, Tianjin, Yantai, Tangshan and other ports are advancing another 5 LNG receiving station projects, which are expected to be put into operation around 2022[8].

| Port                  | Terminal numbers | Year of first production | LNG receiving station unloading capacity (10,000 tons/a) |
|-----------------------|------------------|--------------------------|----------------------------------------------------------|
| Total                 | 5                |                          | 2875                                                     |
| Dalian Port           | 1                | 2011                     | 400                                                      |
| Tianjin Port (Nanjiang)| 1                | 2013                     | 600                                                      |
| Tianjin Port (Dagang)| 1                | 2018                     | 625                                                      |
| Tangshan Port         | 1                | 2014                     | 650                                                      |
| Qingdao Port          | 1                | 2014                     | 600                                                      |

2.2. Development of arrival LNG ship types
In recent years, the density of arrival LNG ships in China's coastal ports has increased rapidly[9]. In 2019, the number of ships arriving at China's coastal large-scale LNG receiving stations reached 859, with a year-on-year increase of 17%. Among them, LNG ships were mainly of the ship type of 150,000 to 200,000 m3, accounting for more than 50% of the total number of ships arriving at the ports.

In 2019, there were 339 ships arriving at LNG receiving stations in the Bohai Rim region, with a year-on-year increase of 19.8%, and the growth rate was higher than that of China's coastal areas. The distribution pattern of arrival ship types is basically the same as that of the coastal areas of China, with 15,000-200,000 m3 being the dominant type, accounting for 74%; LNG ships below 145,000 m3 accounted for 19%, and Q-FLEX and Q-MAX ship types accounted for 7%, as shown in Figure 1.
3. Natural gas consumption and supply in the hinterland

The consumption of natural gas in Liaoning Province showed fluctuant growth, which has certain seasonal unbalance. Before 2010, natural gas consumption in Liaoning Province had a distinct characteristic of “consumption determined by production”. Between 2011 and 2014, the supply capacity of natural gas resources increased significantly. Around 2015, due to the adjustment of regional energy policy, there was a trend of first decline and then rise, as shown in Figure 2.

The proportion of natural gas consumption in Dalian is low, the total amount is small, and the growth rate is lower than the average level of Liaoning Province, as shown in Figure 3. In 2018, Dalian's natural gas consumption was 400 million m³, accounting for 6.3% of the province's natural gas consumption, and only about 1.1% of Dalian's energy consumption, which didn’t match the level of Dalian's economic and social development. Since 2015, the average annual growth rate has been 15.4%, which is 0.9 percentage points lower than the province's growth rate.

At the same time, Dalian has a single source of natural gas, which is highly dependent on sea imports, mainly from the LNG terminal in Nianyu Bay Dalian Port. The consumption structure is mainly for urban gas, and consumption in industries, power generation and chemical industries is still in its infancy. Due to the overall shortage of regional natural gas supply, more than 90% of the LNG unloaded in Dalian Port does serve the other provinces and cities, and the abundant gas sources have not effectively driven the development of the Dalian’s natural gas consumption market.
4. Research on the development forecast of Dalian Port's LNG throughput and the new site selection

4.1. Forecast of LNG throughput of Dalian Port

In 2019, Dalian Port's LNG export volume was 3.27 million tons, with an average annual growth rate of 29.1% since 2015. The total number of ships arriving at the port is 45, and the type of ships arrived was mainly 1.5-17.9 million m3. Taking the natural gas supply and demand situation in Northeast China, Liaoning Province and Dalian City into account, the natural gas throughput of Dalian Port would be 4.5-9 billion m3 in 2035, which would be equivalent to 3.2-6.4 million tons of LNG throughput. It is predicted that in 2050, the natural gas throughput of Dalian Port serving the region will be 8 to 12 billion m3, equivalent to the LNG throughput of 5.7 to 8.5 million tons.

4.2. The new LNG terminal’s site selection

N. Zhou, F.L. Shen, H.Y. Qin, Z. Fang, B.L. Yang, K. Liu, et al. had successively studied the site selection of LNG terminals and put forward general site selection points, especially considering safety, construction cost and other factors[10-15]. This paper combined the characteristics of Dalian City and the latest related policy research, claimed that LNG terminal’s site selection should comprehensively consider the LNG consumption demand in the hinterland, which should also reduce carbon emissions as much as possible under the development concept of carbon neutrality, and examine whether the supply of terminal construction resources meets the demand for LNG receiving stations and pipeline resource layout. The focus of LNG terminal site selection should follow the principles and elements below:

1) Spatial consideration is comprehensive

Taking into account the balanced layout of the Bohai Sea side and the Yellow Sea side, the space layout of the LNG terminal should be covered at multiple points to meet the needs of local emergency peak shaving and supplementary supply guarantee.

2) Better conditions for port construction

The port site should have excellent conditions for port construction such as water depth, wind waves, and bottom quality, which would meet the basic conditions for building an LNG terminal, not only the technical feasibility, but also to minimize construction and operating costs.

3) Good navigation environment

A good navigable environment is necessary, which should meet the requirements of LNG ship navigation safety regulations, and cannot seriously affect the operation of existing port areas. If LNG dedicated waterways and emergency anchorages can be set up, it will be better.

4) Abundant land space
Relatively sufficient land space and pipeline interfaces are also important, which can meet the requirements of the layout of the terminal tank area and the connection of the rear pipeline to the pipeline network, and give full play to the system capabilities of the LNG station site.

(5) Complete conditions for external cooperation
LNG transportation function should be effectively coordinated with relevant planning, and sensitive areas such as ecological and environmental protection zones and military adjacent zones can be avoided as far as possible.

Based on the forecast of Dalian Port's LNG throughput, Dalian Port needs to add 1-2 new LNG receiving stations. Among which, a large-scale LNG terminal can be built in Changxing Island on the Bohai Sea side, as the main body of energy supply at the national and regional levels, to undertake the main LNG transportation service tasks in the hinterland. On the Yellow Sea side, a small or medium-sized LNG terminal can be built to undertake local LNG storage and emergency peak shaving tasks, as a supplement at the regional and municipal levels. Further research can be carried out at three port sites: Dengshahe, Heidao and Haiyang Hong. One of the port sites can be selected to determine the specific berth layout plan.

5. Discussion
The performance of the processing capacity of the LNG receiving station depends on multiple links such as storage tanks, gasification equipment, pipeline capacity, etc. The relevant preliminary work and specific project implementation need to be carried out simultaneously. Generally, the reliable terminal of Q-MAX LNG ships can complete the annual unloading capacity of 5 ~ 6 million tons of LNG, but the capacity of LNG receiving stations is affected by the terminal, storage tanks, gasification devices, export pipelines, truck transportation, etc. It is recommended to reasonably arrange the relevant facilities’ construction, and form the capacity at the same time to promote the full play of the LNG receiving station system’s capacity.

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