Global LNG market: supply-demand and economic analysis

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Abstract. The transition to clean and low-carbon energy is an irresistible trend globally that drives the scale of trade in the global LNG market to grow continuously. The paper reviews the global LNG trade in 2020 and forecasts the future LNG supply and demand. On this basis, the costs in segments of a LNG project are analysed from the perspective of the LNG industry chain. The feasibility of export from LNG projects and the preferred target markets are determined by calculating the economic index of projects. It is concluded that the possibility of future rebound in oil prices and the demand growth in the incremental market in emerging Asian countries are most likely to determine the capacity scales of new LNG projects around the world and contribute to a dynamic balance in the LNG market in the medium- and long-term. The costs in different segments of the LNG industry chain vary greatly with the availability of resources and markets. The economics of LNG export depend on the demand for LNG imports in end markets, the cost plus in different segments of the industrial chain, and the affordability of end consumers. Through the cost and economic analysis on typical LNG Projects, Qatar is found still the most economical and highly profitable country in the global LNG export market nowadays. Unsatisfactory economic performance is a common reason for delayed investments in many large LNG projects in Australia and other countries.

1. Introduction

In the critical period when the challenge of climate change goes in parallel with the transformation and upgrading of the energy industry in the world, natural gas, as a clean and efficient energy source, has become a sure choice for international oil companies as they make the transition to low-carbon and sustainable energies. Compared with pipeline natural gas (PNG), LNG has increasingly become the most active form of gas supply due to its advantages such as ease transportation, flexibility, safety, and efficiency. As LNG liquefaction and shipping technologies advance continuously, production costs have been significantly reduced and the global LNG trade has developed rapidly. In 2020, despite the dual impact of the COVID-19 and plunging oil prices that dragged down the demand for natural gas by 2.5% from the level in 2019, the LNG trade volume still managed to increase by 1.6% year-on-year [1]. As the global LNG production capacity and trade scale expand, the flexibility and liquidity of LNG trade will be further enhanced to facilitate rebalancing in the market. Scholars have tracked the international prices and volumes of LNG trade year by year based on statistics from consulting agencies and yearbooks, and made outlook on the basis of statistical data [1-3]. The research focuses have gradually shifted from fundamentals, regional pricing and trade policies at the macro-level to project feasibility analysis at the micro-level. This paper discusses the trend of the global LNG market from the perspectives of LNG demand and production capacity, and project costs and economics.
2. Analysis on supply and demand of global LNG market

2.1. Global LNG trade in 2020

As shown in Table 1, global LNG exports in 2020 amounted to 356 million tons (MMt). As two traditional large LNG exporters, Qatar and Australia were the biggest exporters and together accounted for 43.4% of the global exports, with little gap between them. The United States and Russia, which have rapidly increased their liquefaction capacity in recent years, were the third and fourth largest emerging LNG exporters that accounted for 12.6% and 8.3% of global LNG exports, respectively, followed by Malaysia, Nigeria and Indonesia.

In terms of trade market, LNG imports in the Asia-Pacific amounted to 254 MMt, accounting for 71.4% of global imports. The largest three importers were Japan, China, and South Korea, which together took 72.3% of the total LNG imports in the Asia-Pacific. In addition, India has witnessed rapidly growing demand in recent years. LNG imports in the Asia-Pacific were supplied by Australia, Qatar, Malaysia, and the United States, which accounted for 30.5%, 20.6%, 9.4% and 7.6% of the LNG imports in the Asia-Pacific, respectively. LNG imports in Europe amounted to 82 MMt, accounting for 22.9% of global imports, and they were supplied mainly by Qatar, the United States and Russia, which took 26.8%, 22.7% and 15.4% of the LNG imports in Europe, respectively. The Americas had relatively moderate LNG imports that accounted for only 3.7% of global imports. Latin American countries mainly imported LNG from the United States and Trinidad and Tobago [4].

| Region          | 2020 LNG imports | Global proportion | 2050-Optimistic Forecast LNG imports | Global proportion | 2050-Conservative Forecast LNG imports | Global proportion |
|-----------------|------------------|-------------------|-------------------------------------|-------------------|----------------------------------------|-------------------|
| Asian-Pacific   | 254.4            | 71.4%             | 582.6                               | 72.5%             | 409.3                                  | 68.8%             |
| Europe          | 81.6             | 22.9%             | 90.6                                | 11.3%             | 102.3                                  | 17.2%             |
| America         | 13.2             | 3.7%              | 52.9                                | 6.6%              | 34.2                                   | 5.7%              |
| Middle East & Africa | 6.9    | 1.9%              | 77.8                                | 9.7%              | 49.3                                   | 8.3%              |
| Total           | 356.1            | 100%              | 803.9                               | 100%              | 595.0                                  | 100%              |

Source: Wood Mackenzie, IHS Markit, similarly hereinafter

2.2. Supply and demand forecast

Over the past three decades, the global natural gas consumption has been increasing year by year. The annual demand had doubled from 69 tcf in 1990 to 139 tcf in 2019, with an annual growth rate of 2.4%. The current global LNG trade volume meets 12% of the gas demand and will continue to account for more of the demand in the future. IHS has provided global LNG demand (Figure 1) and supply (Figure 2) forecasts under two scenarios [5].

Figure 1. Forecast of global LNG demand.
2.2.1. Optimistic scenario. Some emerging consumers, such as China and India, maintain robust demand for LNG, requiring a plenty of infrastructure investments and supporting domestic price reforms. It is estimated that by 2050 the global demand for LNG will grow by 2.7% annually to 800 MMt, and LNG will take a proportion increasing to 22% in natural gas consumption. In the global demand for LNG, the proportion of the Asia-Pacific will rise to 72.5%, while that of Europe will drop to 11.3%. By 2050, the global LNG production capacity will reach 970 MMtpa. In the future, LNG production areas will be concentrated in the Atlantic-Mediterranean, Pacific, and the Middle East regions. The Pacific region will demonstrate the fastest growth of total LNG volume, with a proportion rising to 50% by 2050, compared with 46% in 2020.

2.2.2. Conservative scenario. Due to the impact of COVID-19, the global gas demand declines significantly, and final investment decisions on upstream investments and LNG projects are postponed. In China, increased domestic shale gas supply drags down the growth of LNG imports. The competition between coal and renewable energy also limits the demand for gas. In the following ten years, the global LNG will continue to be oversupply, and incremental LNG projects will be mainly low-cost projects in certain regions. It is estimated that by 2050 the global demand for LNG will grow by 1.7% annually to 595 MMt, and LNG will take a proportion increasing to 17% in natural gas consumption. In the global demand for LNG, the proportions of the Asia-Pacific and Europe will decline to 68.8% and 17.2%, respectively. By 2050, the global LNG production capacity will reach 740 MMtpa. The Atlantic-Mediterranean region will experience the fastest growth in the total LNG volume, with a proportion of 30% by 2050, compared with 28% in 2020.

The forecasts of third-party energy consulting agencies are changing dynamically. In spite of data differences, those forecasts have been made on the same ground. There is no doubt that the low LNG prices caused by COVID-19 have further delayed investment in new projects in the medium- and long-term. The future growth rate of LNG trade volume will mainly depend on changes in the incremental markets of emerging Asian countries and the price competition with pipeline natural gas and alternative energy sources.

![Figure 2. Forecast of global liquefaction capacity (left: optimistic scenario; right: conservative scenario).](image)

3. Costs in segments of the LNG industry chain
The supply costs of an LNG project mainly consist of natural gas exploitation cost, purification and liquefaction cost, transportation cost, and regasification cost. The LNG industry chain is divided into upstream, midstream and downstream. Depending on the availability of resources and market, the costs account for varying proportions [6], as shown in Table 2.
3.1. **Upstream**
The upstream mainly includes exploration, development, purification, separation, and liquefaction segments. After natural gas is exploited from the gas field, the raw gas will be transported to the LNG plant where it will be liquefied into LNG products through the treatments such as removing impurities and NGL and condensing the raw gas into liquid products with refrigerant [7]. Upstream natural gas developers usually require a minimum return on investment at around 8–10% for such projects [8]. Given country-/project-specific fiscal terms, an economic evaluation model is needed to forecast the cash flow throughout the life cycle of the project after it is completed and put into production by deducting capital expenditures and operating expenses (e.g. operating costs and administrative expenses) from expected revenues, minus taxes or profit share taken by the host country. The breakeven cost of the LNG project, or the floor price that delivers the market value of products, can be forecast through inverse calculation according to the lowest return on investment. For natural gas projects with separate ownership of exploitation and liquefaction, the breakeven prices of the two parts must be measured separately.

3.2. **Midstream**
The midstream includes the storage and transportation of LNG and the construction of receiving terminals and gas supply (trunk and branch) pipelines [7]. LNG transportation costs mainly include the depreciation costs of LNG tankers, fuel costs, as well as labor and management costs. At the receiving terminal, LNG products are unloaded from the tanker for storage and then gasified into ordinary PNG to be transported to power plants or end users as fuel gas. This process mainly involves the depreciation costs of the receiving terminal and pipeline facilities, regasification energy costs, as well as labor and management costs.

3.3. **Downstream**
The downstream serves end users, including power stations, gas companies, industrial parks, and distributed energy stations, as well as gas station users, users of chemical raw materials, and all further downward LNG-related sectors [7]. The cost in each downstream segment off the port is relatively stable and, depending on the demand of the downstream consumer market, is related to the profit requirements of the LNG project company and the preferential policies and tax breaks that support LNG projects in different countries.

| Industry Chain | Upstream | Midstream | Downstream |
|----------------|----------|-----------|------------|
| Item           | Exploitation | Liquefaction | Transportation | Regasification |
| Percentage     | 15-20%    | 30-45%    | 15-45%     | 15-25%       |

4. **Cost analysis on major LNG projects**
The price of LNG in the international market, be it spot price, futures price, or long-term contract price, is usually free-on-board (FOB) cost. Like international crude oil prices, FOB cost is sensitive to several factors such as geopolitics, economic and trade relations, and climate. The sum of FOB cost plus shipping cost is the delivered ex ship (DES). The sum of DES plus the regasification cost is the post-regasification delivered price. Upstream development costs are related to the availability of resources, development and operation costs, fiscal and taxation systems, and the profit requirements of developer. Purification and liquefaction costs are related to the development of processing technology, while transportation cost is related to shipbuilding cost and transportation distance. As liquefaction and shipping technologies continue to progress, the production cost, transportation cost, and regasification cost have been significantly lower, driving the rapid development of global LNG business. The purification and liquefaction costs of natural gas have decreased by 35%–50%. The transportation cost of LNG per unit has declined by 40%.
Statistics on the production costs of representative major LNG projects in the world [9] shows that the costs of LNG projects vary greatly. As shown in Table 3, the average construction cost of a LNG plant is $600–1,100/ton. In the Middle East, the construction cost of a LNG plant is relatively low at about $500–800/ton, and the lowest cost appears in Qatar. However, the construction cost of a special LNG plant project can be up to $1,500/ton. For example, projects in Norway, Australia, and the United States report an FOB cost more than $10/MMBtu, with clearly poor economic benefits.

The upstream unit costs of LNG projects range generally between $2–7/MMBtu. The Middle East has relatively lower costs at $1.96–4.18/MMBtu, and the lowest cost appears in Qatar at $1.96–2.20/MMBtu. The unit costs of certain projects in Norway and Australia reach $10–14/MMBtu. The unit upstream cost of a LNG project in the Middle East can be as low as less than $0.5/MMBtu, while higher upstream costs can be found in the United States, Australia, and Mozambique at $3–5/MMBtu. Globally, the unit costs of LNG liquefaction range between $2–4/MMBtu. Except that special projects in Australia and Norway cost $6–9/MMBtu, the liquefaction costs of other projects are close. In addition, some projects in the United States and Canada report higher FOB costs because they include pipeline transportation costs in the upstream segment.

Table 3. Cost statistics of representative LNG projects in the world.

| No. | Project                 | Basin-Country               | Liquefaction Capacity | Time of Operation | Upstream Cost | Pipeline Transportation Cost | Liquefaction Cost | FOB Cost | LNG Plant Unit Investment |
|-----|-------------------------|-----------------------------|-----------------------|-------------------|---------------|-------------------------------|-------------------|----------|---------------------------|
| 1   | Sabine Pass LNG T1-2    | Atlantic-Mediterranean United States | 9 MMtpa | 05/2016 | 3.37 | 2.08 | 5.46 | 607 |
| 2   | Golden Pass LNG T1-3    | Atlantic-Mediterranean United States | 15.6 MMtpa | 03/2024 | 4.1 | 2.31 | 6.41 | 610 |
| 3   | Corpus Christi LNG T1-2 | Atlantic-Mediterranean United States | 13.5 MMtpa | 08/2019 | 3.61 | 2.21 | 5.81 | 592 |
| 4   | Corpus Christi LNG T3   | Atlantic-Mediterranean United States | 10.5 MMtpa | 02/2019 | 3.47 | 3.07 | 6.53 | 937 |
| 5   | Snovhit LNG T1          | Atlantic-Mediterranean Norway | 4.20 MMtpa | 02/2008 | 3.63 | 6.30 | 9.93 | 1930 |
| 6   | Yamal LNG T1-3          | Atlantic-Mediterranean Russian Arctic | 16.50 MMtpa | 03/2018 | 0.32 | 4.01 | 4.33 | 1443 |
| 7   | Qatargas II T2          | Middle East-Qatar | 7.8 MMtpa | 09/2009 | 0.21 | 1.75 | 1.96 | 510 |
| 8   | RasGas I                | Middle East-Qatar | 6.6 MMtpa | 04/1999 | 0.22 | 1.98 | 2.20 | 614 |
| 9   | Yemen LNG T1-2          | Middle East-Yemen | 6.9 MMtpa | 02/2010 | 0.50 | 3.68 | 4.18 | 809 |
| 10  | Alaska LNG T1-3         | Pacific -United States | 20 MMtpa | 04/2040 | 1.5 | 3.26 | 7.56 | 900 |
| 11  | Gorgon LNG T1-3         | Pacific - Australia | 15.6 MMtpa | 10/2016 | 2.65 | 9.66 | 12.32 | 2760 |
| 12  | Ichthys LNG T1-2        | Pacific - Australia | 8.9 MMtpa | 12/2018 | 5.15 | 8.39 | 13.55 | 2389 |
| 13  | LNG Canada T1-2         | Pacific - Canada | 14 MMtpa | 09/2024 | 2 | 3.97 | 6.9 | 1131 |
| 14  | MLNG Satu T1-3          | Pacific - Malaysia | 8.1 MMtpa | 04/1983 | 1.78 | 0.99 | 2.77 | 1248 |
| 15  | Mozambique LNG T1-2     | Pacific - Mozambique | 12.88 MMtpa | 02/2025 | 2.12 | 2.12 | 4.24 | 558 |
| 16  | Rovuma LNG T1-2         | Pacific - Mozambique | 15.2 MMtpa | 02/2029 | 3.15 | 2.75 | 5.9 | 712 |
| 17  | Sakhalin-2 T1-2         | Pacific -East Coast of Russia | 10.8 MMtpa | 04/2009 | 1.58 | 4.12 | 5.69 | 1164 |

5. Economic analysis on typical LNG projects
The export economics of LNG projects means that the profits from LNG exports should not be lower than the profits from domestic direct sales of natural gas; otherwise, the motive to maintain long-term export will be gone from the production line. From the perspective of international and regional
options for importing LNG, the price of importing LNG from a given place should not be higher than
the price of importing natural gas from other sources in the world. Economics depends on the LNG
import demand in the end market, the cost plus in each segment of the industry chain, and the
affordability of end users. Stable export price and supply of LNG will in turn affect the import demand
in the end market [10].

The cost plus level and marginal price requirements at the resource side, the affordability at the
sales side, and the impact on the market selection of LNG projects in the world are comprehensively
considered by comparing the FOB cost estimated according to the breakeven cost with the sales prices
in the target markets. The export economic analysis and market selection process are as follows.

1) Calculate the economic index of a given LNG export project.

\[ E_i = \frac{\text{Upstream breakeven price} + \text{Liquefaction plant breakeven price} + \text{Shipping cost}}{\text{Actual delivered cost at end market}} \]

2) If \( E_i < 1 \), then the project is economically feasible.

3) Once the project is confirmed with economic feasibility, compare the economic indexes of N
end markets for the project. The market with the smallest \( E_1 - E_N \) is the best economical choice.

It should be noted that at the operational level, the selection of the end market for a LNG export
project is affected not only by economic factors, but also by the potential in demand growth, the
competitiveness of alternative projects and alternative fuels, as well as geopolitical and commercial
factors in the importing region, which will influence the trade flow of LNG projects globally.

Under the assumption that the Brent long-term oil price is $70/bbl, the Russian Yamal LNG T1-3
and the Australian Gorgon LNG T1-3 are selected as typical projects for economic analysis.

### Table 4. Economic analysis on the export of Russian Yamal LNG project.

| Project component economics (USD/MMBtu) | End Market |
|----------------------------------------|------------|
|                                        | Grain (UK) | Bahia Blanca (Argentina) | Dahej (India) | Rudong/Jiangsu (Mainland China) |
| Upstream Breakeven (IRR=8%)             | 0.32       | 0.32                     | 0.32          | 0.32                       |
| Liquefaction Breakeven (IRR=8%)         | 4.01       | 4.01                     | 4.01          | 4.01                       |
| FOB cost (Reference Case)               | 4.33       | 4.33                     | 4.33          | 4.33                       |
| Shipping Cost                           | 0.65       | 1.63                     | 1.81          | 1.90                       |
| Delivered Cost                          | 4.98       | 5.96                     | 6.14          | 6.23                       |
| Delivered Sales Price [11]              | 8.76       | 7.84                     | 9.70          | 9.24                       |
| Economic Index                          | 0.57       | 0.76                     | 0.63          | 0.67                       |
| Economically Best Market                | Yes        | Yes                      | Yes           | Yes                        |

As shown in Table 4, the upstream breakeven price (IRR=8%) of the Russian Yamal LNG T1-3
project is $0.32/MMBtu, and the breakeven price of the liquefaction plant (IRR=8%) is $4.01/MMBtu.
The sum of the upstream and liquefaction plant breakeven prices is the FOB cost of $4.33/MMBtu.
Shipping costs are higher and, depending on terminal port, range from $0.65/MMBtu (UK) to
$1.90/MMBtu (China). The sum of the FOB cost and the shipping cost is the CIF cost of $4.98–
6.23/MMBtu. The end market sales prices range from $7.84/MMBtu to $9.70/MMBtu. The economic
index of export from the project is the CIF cost divided by the end market sales prices, which is 0.57–
0.76. Because \( E_i \) is greater than 1, export is an economically feasible choice for the four sales markets,
four sales markets are economically feasible for export, among which the best market is the United
Kingdom according to the economic index. The profit is the sales price minus the CIF cost. The profit
calculated from the weighted average price based on the actual sales market share is $3.16/MMBtu
(Figure 3).

As shown in Table 5, the upstream breakeven price (IRR=8%) of the Australian Gorgon LNG T1-3
project is $2.65/MMBtu, and the breakeven price of the liquefaction plant (IRR=8%) is $9.66/MMBtu.
The sum of the upstream and liquefaction plant breakeven prices is the FOB cost of $12.32/MMBtu. The end markets are all located in the Asia-Pacific. The three destination countries are close, except India, and the shipping costs are almost the same, ranging from $0.59/MMBtu to $0.68/MMBtu. The sum of the FOB cost and the shipping cost is the CIF cost of $12.91–13.00/MMBtu. The sales prices in the end markets are $9.87–11.67/MMBtu. The economic indexes are all greater than 1, and all the sales markets are not economically feasible for export. The project is now operating at a loss. The net loss is the sales price minus the CIF cost. The average loss calculated based on the actual sales market share is $1.49/MMBtu (Figure 4).

**Table 5.** Economic analysis on the export of Australian Gorgon LNG project.

| Project component economics (USD/MMBtu) | End Market                          |
|----------------------------------------|------------------------------------|
|                                        | Himeji (Japan)                     |
|                                        | Incheon (Korea)                    |
|                                        | Kochi LNG (India)                  |
|                                        | Dalian (Mainland China)            |
| Upstream Breakeven (IRR=8%)            | 2.65                               |
| Liquefaction Breakeven (IRR=8%)        | 9.66                               |
| FOB cost (Reference Case)              | 12.32                              |
| Shipping Cost                          | 0.67                               |
| Delivered Cost                         | 12.99                              |
| Delivered Sales Price [11]             | 11.67                              |
| Economic Index                         | 1.11                               |
| Economic Feasibility                   | No                                 |

6. Conclusions
The transition to clean and low-carbon energy is an irresistible trend globally, and LNG will play an increasingly important role in the international energy structure. Several major natural gas suppliers in the world have managed to seize the industry opportunities to go all out for the dominant position in global LNG supply. Under the impact of force majeure events (e.g. plunging oil prices, increasing downward pressure on the global economy, and COVID-19), the global LNG market will see an oversupply in the short term. The possibility of future rebound in oil prices and the demand growth in the incremental market in emerging Asian countries are most likely to determine the capacity scales of new LNG projects around the world and contribute to a dynamic balance in the LNG market in the medium- and long-term. In the future, emerging producers such as the United States and Russia, which have considerable potential for LNG exports, are likely to surpass traditional producers such as Australia to hold more shares in the LNG market.
By analyzing the costs of the entire LNG industry chain and building the economic index of export from LNG projects, it is indicated that Qatar is the most economical and highly profitable country in the global LNG export market, due to its extremely low construction and liquefaction costs for LNG projects and moderate distances to end markets. Unsatisfactory economic performance is a common reason for delayed investments in many large LNG projects in Australia and other countries.

The pricing mechanism of LNG trade still needs to be improved and the global LNG trade flexibility and demand elasticity will continue to enhance. To maintain competitiveness, LNG export projects should not only lower investments and operating costs by applying new technologies, new processes, and new concepts, but also gain sufficient insights into the supply and demand in the market, pricing models in long-term contracts, and project benefits and risks. The export potential of LNG projects, economic changes, and challenges in key host countries are notable topics for future discussion.

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