Challenges in the LNG Industry: Megaproject Management of Qatar's LNG Value Chain Expansion

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Abstract
Megaprojects have been increasingly developed during the last decades. Megaprojects have unique particularities in the liquefied natural gas (LNG) industry. They are significantly different from projects in other industry types since LNG requires a precise match of production, processing, transportation, and consumption, from strategic to operational decision-making. This introduces additional difficulties, risks, and challenges for proper and efficient project development and management. These challenges are mostly related to the highly complex, risky, and uncertain environment of the LNG value chain, particularities and complexities of LNG processes and projects, contractual and spot market trends, novel business models in the LNG industry, and the transition to renewable energy sources. They demand to identify opportunities for improvement, trends, challenges, and gaps for achieving breakthroughs towards improved and more successful management of LNG megaprojects, which is especially important given the current expansion of the LNG value chain in Qatar. The information and discussion provided herein are fundamental for adequately understanding and handling the complex, challenging environment within the LNG industry towards enhanced megaproject management capabilities. This work aims to provide information on the current scenario of the LNG expansion, discuss the importance of megaproject management within the LNG industry and the main challenges faced within this environment, and stimulate further studies on the topic.

Keywords
Megaproject, LNG, natural gas, value chain, project management.

1. Introduction
Over the past decades, there has been a significant increase in the development and implementation of megaprojects in many diverse fields and areas worldwide to supply the economic growth required by the Industry 4.0 age (Soderlund et al. 2017). This leads to an emergent field of study focused on megaproject management systems, which aims to cover multiple vital aspects and elements of the topic (Wang et al. 2020). Recently, significant industrial investments have led to an increasing need to improve the current capabilities employed in developing, executing, and implementing megaprojects. This is particularly important for the liquified natural gas (LNG) industry, given the current expansion of the LNG value chain, mainly driven by the recent investments in the Qatar LNG industry. Moreover, this highlights the importance of further studies on LNG megaproject management to achieve enhanced industrial capabilities.

Megaprojects play a crucial role in social and economic development in the oil and gas industry. They are critical, mainly because of their social and environmental concerns, sizeable economic value, and improvement provided

towards the Industry 4.0 and Society 5.0. Given their complexity, they often experience substantial cost overruns, prolonged schedule delays, and many uncertainties, risks, and challenges to be addressed (Olaniran et al. 2015; Jo et al. 2018).

Despite the urgent need to enhance the current management capabilities of LNG megaprojects, only a few studies have addressed such a topic. Megaprojects within the LNG industry have characteristics that make them unique and impose difficulties for incorporating knowledge/experience from other projects. For example, they are the only project requiring handling, transporting, and storing cryogenic hydrocarbon molecules. Such particularities and unique aspects are closely associated with the LNG industry's multiple (and highly impactful) challenges over the development and management of megaprojects. That is especially important given the recent expansion of the LNG value chain in Qatar, which significantly increases the investments in multiple areas of LNG megaprojects. Over their development, multiple (and complex) challenges are expected to arise, which may bring risks, uncertainties, and disruptions over the project's lifetime. Consequently, that may compromise the successful management and execution of projects.

Within this context, it is fundamental to investigate and understand the main challenges often existent in LNG megaprojects for providing better management capabilities. This can adequately mitigate adverse events and overcome potential issues, especially given the recent advances in the Industry 4.0 era, which can potentially enhance industrial capabilities. This work aims to discuss the most impactful challenges in the LNG industry and provide meaningful insights to be considered the development, management, and execution of LNG megaprojects. Although the ideas presented herein are specific to the LNG industry, the overall discussion also applies to other types of industries and fields. We believe such discussion is critical given the complexity and importance of the topic. The main contributions of this work rely on presenting meaningful information on the current scenario of the LNG industry, especially given its recent expansion, and discussing key megaproject management challenges closely related to the LNG value chain. This will hopefully highlight the importance and impact of such topics and stimulate further studies.

The outline of this paper is as follows. Section 2 addresses the LNG value chain expansion in Qatar. While Section 3 discusses LNG megaprojects in Qatar. Section 4 discusses the critical challenges in the LNG industry with an emphasis on LNG megaprojects. Section 5 highlights this work's conclusion and final remarks that introduce an outlook on industrial megaproject management systems for the LNG industry.

2. LNG Value Chain Expansion in Qatar

According to Exxon Mobil's Outlook for Energy (2018), the world expects an energy transition over the following decades, whereby cleaner alternatives will continuously replace heavy fossil fuels such as crude oil. The world needs to pursue multiple energy sources to keep up with the considerable demand growth. Oil and gas energy sources will be nearly 60 percent of global supplies in 2040. Nuclear energy and renewables will grow about 50 percent, approaching a 25 percent share of the world's energy mix (ExxonMobil 2018). Given that the amount of energy produced from renewables still cannot supply the global energy demand for a complete replacement of fossil fuels, the natural gas and liquefied natural gas industry play a vital role in this context.

Natural gas is a low carbon-intensive fossil fuel, representing a cleaner, environmentally friendly, and more sustainable alternative for the energy transition that aims to continuously reduce the consumption of carbon-intensive fossil fuels such as coal and petroleum. Moreover, natural gas increases energy efficiency by providing the highest energy released per mass during the combustion process among fossil-based and biomass-based fuels (Mac Kinnon et al. 2018). The LNG value chain is comprised of exploration and production assets; processing stages for the refrigeration, stabilization, treatment, and liquefaction processes; loading and transportation operations; receiving terminals for unloading, storage, and regasification processes, and distributions to the end-users (Lee et al. 2018). Figure 1 illustrates a typical LNG value chain.

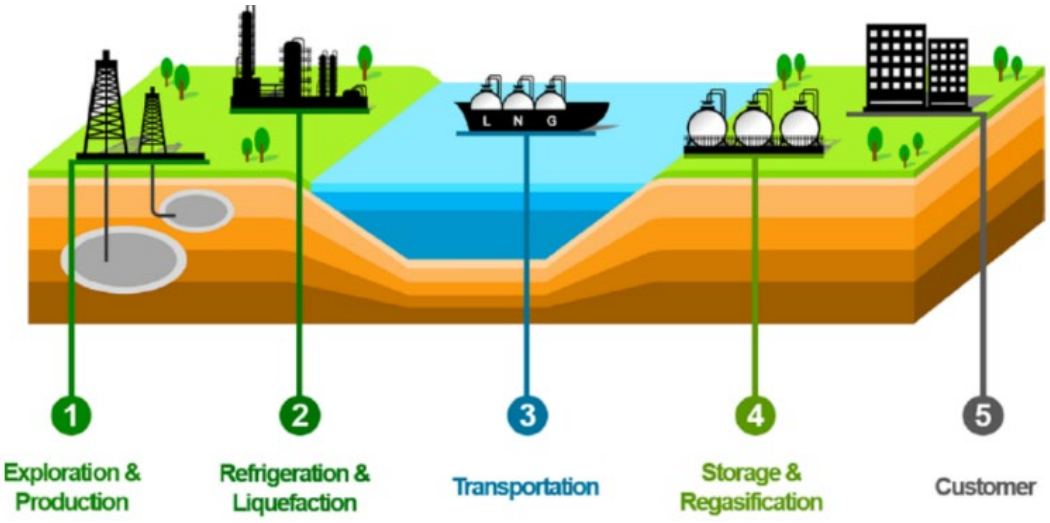

Figure 1. LNG value chain (adapted from Lee et al., 2018).

The LNG global market demand is expected to significantly rise from 356.06 million tons in 2019 to 560.19 million tons by 2027, with expanding growth rate of 5.8% from 2020 to 2027 (Grand View Research 2019). Within a highly competitive LNG market, Qatar is one of the largest LNG exporters in the world, at 77.8 million tons in 2020 (British Petrolum, 2021). Part of its strategic decisions involves massive investments over the entire LNG value chain to preserve its role as the leading global player. This includes the expansion of LNG production and processing facilities. This entire supply chain is expected to increase production by 64% by 2027, from 77 million tons to 126 million tons per year (The Peninsula Qatar 2019). With such strategic investment, Qatar aims to be the world's largest LNG producer and exporter, with investments throughout the entire LNG value chain. This provides competitive advantages and enhanced resilience to manage all supply chain segments and handle risks, disruptions, and unexpected events. However, that also demands proper planning, development, management, implementation, and execution of megaprojects over their entire lifecycle and throughout the process network.

3. LNG Megaprojects in Qatar

The oil and natural gas sectors in Qatar's upstream, midstream, and downstream segments include an integrated value chain with all facilities controlled by the state-owned QatarEnergy. This provides a suitable environment for developing and implementing LNG megaprojects, which is especially important given Qatar's leadership position in the LNG exports market, which accounts for 25% of the worldwide trade in 2018 (British Petrolum 2019). Moreover, Qatar has recently started the construction of four mega LNG trains for H2S removal, natural gas liquid recovery, helium extraction, and liquefaction processes.

The LNG industry plays a crucial role in Qatar as it represents the primary economic income of the country. The LNG megaprojects currently developed in Qatar involve investments of over US$ 29 billion (Bloomberg 2021). The development of projects with such complexity, scope, and magnitude is novel and unique, and it is driven by the recent increase in the worldwide LNG demand. Their key characteristics include huge economic investments; technical, operational, economic, and environmental risks; high technological capabilities; and many complexities and uncertainties. They comprise several complex sub-projects and involve stakeholders with differing interests, concerns, objectives, and demands.

Moreover, they are highly complex and large-scale with multi-scope impacts, affecting social, environmental, economic, and technological sectors. Given the enormous economic value associated with such investments and many other social, political, and environmental factors, studies on project management for LNG megaprojects are fundamental for improved practices and more efficient systems. This is especially important within the Industry 4.0 age, in which social, environmental, economic, and technological advances provide the proper capabilities for further breakthroughs in industrial megaprojects.

In this context, effective and efficient project management capabilities are fundamental over the project stages and all value chain segments. With the recent increase in LNG production and demand in the circular economy society for

more efficient and less carbon-intensive energy resources, there has been a meaningful opportunity for research and development in that area. Nevertheless, the literature on management systems for LNG megaprojects is still premature and needs to be further addressed. Given the dimension, scope, and complexity of such megaprojects, multiple management challenges must be further understood, developed, and enhanced to achieve more efficient capabilities for megaproject management systems. Carrying out proper and efficient research on this topic may provide enhanced management capabilities with higher quality, fewer risks and issues by acting proactively instead of reactively, and better social, environmental, economic, and technical megaproject outcomes.

4. Challenges in the LNG Industry with an Emphasis on Megaproject Management

Qatar has been developing an integrated, resilient, and efficient LNG supply chain to achieve a unique and significant competitive advantage within a highly competitive LNG business landscape. This requires developing large-scale and complex-scope megaprojects, which introduce novel and unique challenges that are incredibly impactful and must be carefully considered in the planning stage and over the execution of the projects.
There are multiple factors associated with the complexity of megaproject management systems. Such a complex environment often introduces multiple challenges prior to and during the project execution (Schoenhardt et al. 2014; Caldas and Gupta 2018). There are no clear guidelines for achieving a complete and conclusive LNG project management system and enhancing future megaprojects' management capabilities.

Megaprojects face several challenges because of their complexity, size, uniqueness, and technological and innovation requirements. The most common and impactful challenges in industrial megaprojects include schedule and budget updates, change orders, multiple sources of uncertainties, poor management and organizational structure, stakeholder alignment and engagement issues, lack of training or experience, poor monitoring and control, lack of transparency, and a high potential for corruption (Delatte Jr. 2017; El-Sabek and McCabe 2018; Bahadorestani et al. 2020; Tashidavhu et al. 2020). In addition, Flyvbjerg (2007) argues that the budget and schedule challenges are the most common and relevant within industrial environments, mainly because of the long planning horizon, planning operations, frequent change orders, and misinformation or poor estimations about costs and risks. Specifically for LNG megaprojects, there is a high risk of environmental impacts and high uncertainty in the LNG market, which may compromise the entire megaproject's expectations and outcomes. Despite the multiple risk management methodologies employed in the last decades, the increasing complexity of megaprojects imposes difficulties in achieving risk mitigation strategies. It often leads to significant issues and failures of megaprojects (Ashkanani and Franzoi, 2022).

Only a few works have addressed management systems for LNG projects. Andeobu et al. (2015) investigate issues and challenges of managing LNG projects in Australia and Nigeria. While the rapid development of large-scale LNG projects is essential within the Industry 4.0 age, these projects face multiple issues that significant investments and enhancements can only overcome across the entire project lifetime. That includes several social, environmental, technical, and political challenges. Zakir et al. (2020) discuss challenges in the LNG supply chain, including extraction, processing, and transportation processes, cost escalation and underestimation, complicated and limited storage, and market fluctuations in prices and demands. For example, there are significant opportunities for optimizing the design of LNG processes, but such characteristics should be considered when planning and implementing LNG megaprojects.

In the following, we discuss some of the most impactful challenges that directly or indirectly affect the development and management of LNG megaprojects. They involve the supply and demand processes in the LNG value chain, particularities and unique features associated with the LNG processes and projects, the LNG contractual and spot market, new business models, and the transition to renewable energy sources. Many of these features significantly impact the economic feasibility of LNG megaprojects and should be carefully considered. Given that such complex projects take years to be completed, changes in the demand and supply, market fluctuations, business models, and energy transitions are critical within this dynamic environment. Figure 2 illustrates some of the main challenges currently faced by the LNG industry that is closely related to the LNG expansion and LNG megaprojects.

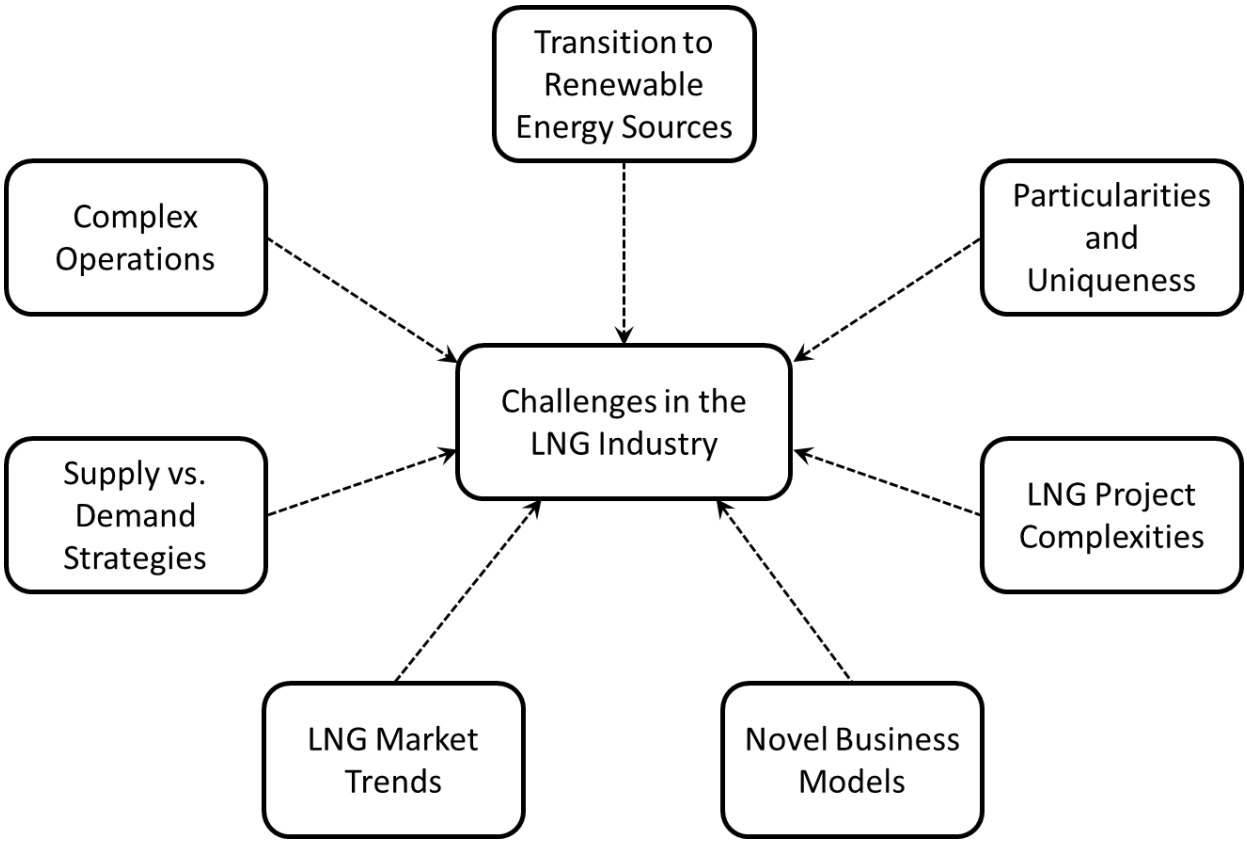

Figure 2. Main challenges faced by the LNG industry.

4.1 Supply and Demand in the LNG Value Chain

The complexity of the LNG industry leads to several challenges to both the supply and demand sides of the value chain. On the supplier side, producers negotiate agreements for the development, joint venture, sale and purchase, shipping, transportation, and receiving terminal operations. Many LNG producers have raised their interest in buying capacity in the regasification terminals around the world to ensure their plants run at full capacity and to have an outlet for their products to avoid tank top-ups in case the maximum capacity is not met. On the demand side, LNG buyers have acquired equity in LNG liquefaction plants to achieve better conditions on sales and purchase agreements (SPAs). For example, a typical feature of long-term LNG contracts is the fixed destination, in which the buyer commits to receive the products at specific ports throughout the contract. The rationale is that buyers cannot re-sell LNG, which would, in effect, be competing with the LNG producers. Then, buyers are pushing for spot purchase and free destination, which allows them to re-sell LNG in case they have overbought it in a particular period.

4.2 Particularities and Unique Features of the LNG Product

The LNG supply and value chains are unique compared to other hydrocarbon products in the oil industry. For many reasons, natural gas is not in the liquid phase at the standard pressure and temperature conditions. Hence, once LNG plants have started their operations, it is very costly to stop, store products, and re-start the production network. Moreover, the number of LNG vessels is typically lower than oil tankers, so there are higher costs for the transportation of LNG. This leads to unique and complex contracting structures and requirements for the LNG industry.

4.3 Complexity of LNG Megaprojects

Projects within the LNG industry are typically complex-scope and large-scale, demand innovative and state-of-the-art technology, and huge investments. Management of LNG megaprojects is unique and highly critical given its enormous economic investment, so efficient, tailored engineering management is fundamental. Traditional project management

systems focus on the three-dimensional approach, including cost, schedule, and scope (Remenyi et al. 1997; Ashurst et al. 2008; Gransberg and Jeong 2015). However, LNG megaprojects require customizable management strategies to minimize risks and provide proper development and implementation capabilities. Thus, they require proper management, synchronization, and coordination over the entire project lifetime (including planning, procurement, engineering, construction, commissioning etc.) to achieve successful development.

Moreover, they have particularities concerning the processing, handling, and transportation operations and are significantly different from projects in other industry types. The receiving terminal consists of unique cryogenic storage tanks for maintaining the LNG at very low temperatures to avoid premature regasification. There is high energy consumption in such a process, so the planning and procurement of LNG in megaprojects must ensure sufficient demand over a reasonable lifetime (i.e., decades) to ensure economic feasibility. This introduces several risks, difficulties, and challenges to achieving efficient project management, especially given the recent market fluctuations in the LNG price. Thus, the LNG value chain becomes even more challenging, significantly increasing the need for further improvements in the current industrial capabilities to develop LNG megaprojects.

4.4 Contractual and Spot Market Trends

The global demand for gas as a source of energy is increasing. The main propelling factors for the LNG market are the expansion and development of gas pipeline infrastructures and the rising demand for LNG across downstream industries. This trend could accelerate if gas becomes more widely accepted as a cleaner transitioning fuel until renewables become a more reliable energy source to fully supply global energy needs.

Recent changes in the worldwide gas model and overall supply and demand patterns have transformed the LNG market. On the supply side, the growth in the number of LNG projects has led to an oversupply of products, increasing the amount of LNG available in the spot market. On the demand side, due to the higher prices in the term cargos against spot prices in the last few years, buyers have been concerned about committing to the standard 25-year deals. Instead, they prefer shorter deals of 5 to 10 years to enhance reliance against market changes. Short contracts also allow them to avoid contractual obligations or to adjust their committed purchase volumes whenever changes in the LNG price negatively affect their business.

Such sudden market changes result from the volatility of hydrocarbon prices and worldwide trends toward renewables and cleaner energy sources. Besides the surge of new suppliers and consumers, the spot market purchases of LNG have also become a common practice. Indeed, spot and short-term LNG trades account for 20% of the overall import volumes in 2017 and 32% in 2018, which are expected to rise over the coming years (Abreu, 2018). Therefore, dominating the entire LNG supply chain seems to be a good and resilient strategy for LNG producers, where they can be less susceptible to market changes and perhaps even further increase their production and processing of natural gas. Examples of such strategies have been adopted by LNG producers such as Qatar, including acquiring their LNG carriers and receiving terminals.

4.5 Small-scale LNG Market

A further challenge regards the small-scale LNG market. The logistics operations to supply small-scale buyers differ utterly from the existing market. For example, producers currently use large ocean-going vessels to deliver large quantities of LNG to a few regasification terminals. Depending on the direction in which the small-scale market moves, smaller vessels may become necessary to deliver smaller quantities to many smaller buyers. This leads to multiple challenges and changes in the logistics and transportation segments of the LNG supply chain, which may significantly impact how the supply network should be designed to meet the requirements for this transition.

Such a challenge could become an opportunity for LNG producers. They could choose between continuing to supply the existing LNG buyers, adapting to start delivering to the smaller buyers or adding another layer of intermediaries to the LNG supply chain. The critical question is whether such a strategy would be economically viable for the LNG producers as the geographical distribution of the smaller LNG buyers may be broad and sparse.

4.6 Novel Business Models

Business models have also been updated over the last decade, posing extra pressure on long-term contracts. For example, the Cheniere Energy business model is based on processing and liquefying natural gas from third parties, even the LNG buyers. LNG buyers pay Cheniere a fee to process and liquefy the natural gas and store and load the

LNG. That protects Cheniere from fluctuations in the market as even if buyers cancel cargos, they are still liable to pay Cheniere's processing fees. In addition, it also allows buyers to cancel cargos if it is more economical to pay Cheniere's processing fees rather than lift the cargo and sell it at a loss.

In this business model, Cheniere offers destination-free contracts to the LNG buyers and adds to the higher number of spot cargos available in the market. It also allows the buyers to explore arbitrage opportunities in different markets. As a result, it can be argued that the LNG market is moving now closer to a liquid market, where LNG producers and buyers, based on sensitivity analysis and their preferred strategy and expected demand, aim to reduce the market risks by diversifying their portfolio among long-term contracts (10+ years), medium-term contracts (2 to 5 years), and spot sale agreements. However, a corollary of the reliance on the short-term market is that the LNG buyers become exposed to the risk of higher-than-expected prices. Since late 2020, this has impacted buyers who have opted to rely on the spot market to complement their gas requirements. LNG spot prices have detached from the link to oil prices and reached prices multiple times greater than the prices paid by long-term buyers with oil-linked contracts. The problem is compounded by a shortage of LNG cargos available for spot purchases. This may lead buyers to review their reliance on the spot market and increase the share of long-term contracts in their portfolio again.

4.7 Transition to Renewable Energy Sources

The growth in the production and demand of renewable energy sources and their price to the end-users are vital factors that affect the LNG value chain. LNG producers need accurate market estimations of other energy sources, as it significantly impacts the demand and price of LNG. That could lead to stranded assets or a drop in the prices as the demand for LNG may decline in favor of renewables. This complicates decisions on whether to pursue new LNG projects as they typically take 5 to 10 years to be completed. Financing such projects may also become more complex as banks reduce their involvement in the oil and gas industry.

There are many challenges and issues related to the LNG industry. Table 1.0 summarizes the LNG industry's main challenges and findings related to each challenge. There are no clear guidelines to overcome and mitigates the challenges; it depends on specific condition such as supply/demand and political situation.

Table 1. Challenges in the LNG industry with main findings

Main Challenges in LNG Industry	Findings
Supply and Demand in the LNG Value Chain	• LNG producers are interested in buying capacity in the regasification terminals worldwide. • LNG buyers have acquired equity in LNG liquefaction plants. • Long-term LNG contracts are the fixed destination, and buyers cannot re-sell LNG
Particularities and Unique Features of the LNG Product	• LNG plants, if it starts their operations, it is costly to stop, store products, and re-start the production network. • Higher costs for the transportation of LNG. • Complex contracting structures requirements for the LNG industry.
The complexity of LNG Megaprojects	• Complex-scope and large-scale demand innovative and state-of-the-art technology and huge investments. • Management of LNG megaprojects is unique and highly critical given its enormous economic investment. • Require customizable management strategies and coordination over the entire project lifetime

	• Processing, handling, and transportation operations are unique. The receiving terminal with unique cryogenic storage. • Planning and procurement must ensure sufficient demand over a reasonable lifetime to ensure economic feasibility. • Market fluctuations.
Contractual and Spot Market Trends	• LNG is widely accepted as a cleaner transitioning fuel. • The global demand for gas as a source of energy is increasing. • Preference for shorter contracts of 5 to 10 years to enhance reliance against market changes. • Spot and short-term LNG trades is expected to rise over the coming years.
Small-scale LNG Market	• The logistics operations to supply small-scale buyers are different from the existing market. • Smaller vessels become necessary to deliver smaller quantities. • New supply network/logistics should be designed to meet the requirements of small buyers.
Novel Business Models	• Business models have been updated, posing extra pressure on long-term contracts. • Cheniere Energy's business model is introduced (buyers pay Cheniere a fee). • Cheniere offers destination-free contracts/cancellations with paying processing fees. • LNG spot prices have detached from the link to oil prices. • Shortage of LNG cargos available for spot purchases.
Transition to Renewable Energy Sources	• The growth in the demand for renewable energy sources has a vital impact on LNG prices. • LNG producers need accurate market estimations of other energy sources. • Complicates decisions on whether to pursue new LNG projects (5 to 10 years to be completed). • Financing LNG projects become more complex as banks reduce their involvement in the oil and gas industry.

5. Conclusions and Future Work

Due to the dynamic and complex environment, LNG megaprojects often face multiple challenges and risks throughout their lifetime and even after completion. Moreover, they are challenging to be efficiently planned, managed, implemented, and controlled towards providing the expected outcomes and accomplishing the desired targets and objectives. LNG megaproject management challenges are mostly related to accomplishing the project goals given multiple requirements, expectations, and desired objectives within a highly complex, risky, and uncertain environment. Such challenges demand identifying opportunities for improvement, trends, challenges, and gaps for achieving breakthroughs towards improved and more successful management of LNG megaprojects.

This work addresses the main challenges currently faced in the LNG industry, affecting the development and management of LNG megaprojects, which is especially important given the current expansion of the LNG value chain in Qatar. That includes the supply and demand in the LNG value chain, particularities and complexities of LNG processes and projects, contractual and spot market trends, novel business models in the LNG industry, and the transition to renewable energy sources. Many of these features significantly impact the economic feasibility of LNG megaprojects and should be carefully considered. An inimitability in LNG megaprojects is the uniqueness of the LNG contracting structure. The current changes in the worldwide supply and demand of LNG lead to the transformation of market conditions with new trends and business models that focus on duration (short, medium, and long), price mechanism, cargo size, and an integrated value chain of LNG. Increased availability and reduced price of renewable energy sources is one of the main challenges of LNG producers as it leads to a reduction in the LNG price and impacts the decision to pursue new LNG projects (especially given that the project execution takes a large amount of time and huge investment), and leads to hesitation in such investments from the financial institutions.

The information and discussion provided herein are fundamental for adequately understanding and handling the LNG megaproject's complex, challenging environment towards enhanced management capabilities. This work intends to highlight the importance of such topics and stimulate further studies.

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Biography

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