ENERGY AND CLIMATE
PANORAMA

Status of
LNG IN PAKISTAN
A Case Study

ABOUT US

Who we are

We are a dedicated team of researchers and experts who recognize the urgent need for action in addressing climate resilience and energy transition in Pakistan. Our mission is to develop and implement effective policies for cleaner, renewable energy sources like solar and wind, aligning with Pakistan's 2030 goal of 30% renewable energy in its electricity mix. As a multidisciplinary team, we leverage expertise in three key disciplines of study—Energy Systems Engineering, Thermal Energy Engineering, and Electrical Power Engineering—to drive our mission forward. We are united by a shared vision of creating a sustainable and resilient future for Pakistan, where cleaner energy sources play a pivotal role in reducing the nation's vulnerability to climate-related challenges.

What we do

We conduct in-depth, evidence-based research to analyze and improve energy policies in Pakistan. Our focus is on advancing renewable energy solutions and engaging stakeholders to ensure effective policy implementation. Our methodology involves a critical examination of current energy policies to pinpoint areas of improvement and formulate strategies for the widespread adoption of renewable energy sources across various levels.

In line with our commitment to fostering sustainable practices, we have established a fellowship program as part of our broader initiatives that aims to facilitate evidence-based research for promoting energy transition in Pakistan. Through research studies, surveys, and forecasting, we plan to assess various aspects of energy transition, including the adoption of renewable energy technologies and their impact on climate change. Our approach involves active engagement with stakeholders to address their concerns and facilitate the effective implementation of policies, fostering the growth of renewable energy manufacturing and marketing facilities.

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Exceutive Summary

This study explores the significant shift in the global and Pakistan energy landscape towards Liquefied Natural Gas (LNG) as a key energy source. Previously, Natural gas trade relied on extensive pipeline networks due to its low density. However, advancements in purification, liquefaction, and regasification technologies have made LNG an increasingly attractive and cost-effective means of transportation. The emergence of cost-effective combined cycle generation turbine (CCGT) plants has enabled nations like Pakistan, India, China, and Turkey to shift towards gas-fired power generation, promoting worldwide natural gas production and consumption. Environmental concerns and the approaches for cleaner energy sources have further boosted the appeal of LNG, due to its low sulfur content, reduced CO2 emissions, and increased energy generation. This aligns with the global pursuit of renewable energy options, positioning LNG as a favored energy source. Additionally, the LNG supply chain offers simpler solutions, including simpler liquefaction and regasification plants, making it scalable and adaptable to a wide range of customers.

In Pakistan, LNG imports commenced in year 2015, marking a significant transformation in the country's energy landscape. Imports have steadily increased, accounting for a substantial portion of total gas demand. Two key regasification stations, Engro Elengy's offshore facility and Pakistan LNG Terminal Limited (PLTL), have played vital roles in enhancing Pakistan's LNG infrastructure.The report also highlights ongoing and upcoming LNG infrastructure projects in Pakistan, which are essential to meet the country's growing energy needs. Regulatory bodies like the Oil and Gas Regulatory Authority (OGRA) look after various aspects of the LNG sector, including allocation, pricing, and safety compliance. The importation of LNG is crucial to address shortages and support electricity generation, particularly for Combined Cycle Power Plants (CPPs). Despite these efforts, Pakistan faces challenges in bridging the gap between domestic gas production and demand. The report emphasizes the need for an integrated approach to ensure energy security and reduce gas shortages. The government's pursuit of LNG imports is crucial, but it must also address issues with provinces to ensure the domestic availability of LNG. The current shortage of natural gas has had significant economic and societal impacts, underscoring the importance of securing the country's energy supply.

1. Introduction

The global demand for energy is increasing by the day with the expected addition of 1.2% per year. Despite efforts to shift towards alternative energy sources, due to their abundance and availability, fossil fuels are still projected to remain important in providing the world's energy demands. Meanwhile, 85% of the world's energy needs is fulfilled by fossil fuels. China's energy demand for power generation is predicted to more than double by the next century, exceeding US power consumption by over a third. The transportation industry, which now accounts for more than half of overall oil demand, is likewise likely to expand dramatically [1] [2] .

Despite efforts to increase energy efficiency and the use of nuclear and renewable energy sources, between 2005 and 2030, worldwide CO2 emissions are predicted to increase by about 30%. As a result, there is a push to develop alternative fuels with less CO2 emissions, it can be used to replace hydrocarbons like diesel and gasoline in order to meet increased energy requirements [3]. Wide ranges of alternative fuels have been developed, though few are widely available. Natural gas's importance as an energy resource is rapidly growing, and its global consumption share is expected to grow significantly over the next two decades because it is renewable (via biogas or bio-methane production), plentiful, and emits fewer greenhouse gases than other fuels. Natural gas is used in a variety of ways, including CNG, LNG, and hydrogen blends. Due to its environmental friendliness, higher efficiency, and cost-effectiveness it has become the preferred fuel. Natural gas liquefaction has numerous advantages over pipeline transportation, particularly for long-distance natural gas transportation.

***Figure 1**. A working FSRU (Source: Klaipėdos Nafta)*

LNG, as a natural gas, is a cleaner alternative to coal and oil. LNG is very efficient source of transporting gas over long distances, accounting for 25% of global gas movement. As a result, the use of LNG has gained widespread acceptance in the global gas market. This is an excellent opportunity to examine the current state of LNG development regarding natural gas resources, storage, transportation, and use of LNG in various sectors. Nonetheless, to be economically viable, LNG projects require significant investments and significant natural gas reserves, particularly for distances greater than 2,500 miles. In this regard, the desirability of LNG technology must be assessed [4] [5].

At the moment, local natural gas production totals 29.3 million tons of equivalent (TOE), accounting for nearly 35% of the nation's primary energy supply. This places Pakistan in the top 25 countries in terms of natural gas output. For the previous two decades, natural gas's percentage of ultimate energy consumption has stayed above 30%. Natural gas is a major feedstock and fuel source for the fertilizer industrys, as well as for thermal power producers, households, and general

ndustries. Despite significant and rising consumer demand, domestic gasoline provisions have remained unchanged since 2008. The drop in mining and exploration efforts due to security concerns in gas-rich regions, along with chronically low well-head prices, has harmed their economic viability. Meanwhile, severe underpricing of natural gas for domestic use has resulted in excessive consumption and waste of fuel resources. The aforementioned issues have all contributed to the country's growing natural gas imbalance. As a result, the government is now obliged to develop a medium- to long-term strategy to address the demand for gas imports. Consequently, in 2010, Pakistan signed two major pipeline trade agreements, the Turkmenistan-Afghanistan-Pakistan-India (TAPI) Gas Pipeline and the Iran-Pakistan (IP) Gas Pipeline. However, due to funding constraints and geopolitical conditions in the region, these projects have been delayed. To solve the acute gas deficit, Pakistan began importing large volumes of natural gas in liquefied form (LNG) beginning in FY 2015. This proactive step led to the country swiftly emerging as a significant purchaser in the global LNG market. Approximately 23% of the country's natural gas consumption is now met by LNG imports. Particularly, between 2017 and 2020, the advent of LNG imports had a critical role in lowering the overall costs of energy generation in the country, resulting in a decrease of nearly Rs 234 billion. As projected by the Ministry of Energy and the Oil and Gas Regulatory Authority (OGRA), the domestic gas production in Pakistan is anticipated to meet a mere 22.3 percent of the estimated demand by the year 2030. In the event that the long-pending I-P and TAPI gas pipeline projects do not come to fruition, there is a forecasted average annual deficit of approximately 2,593 million cubic feet per day (mmcfd) of gas for the period spanning from 2021 to 2030.

LNG is an odorless, non-flammable, non-toxic liquid that has been safely shipped around the world for over 60 years.

2. LNG: A Primer

Natural gas, which is composed of paraffinic hydrocarbons such as methane, ethane, propane, butane, and others, also contains trace amounts of carbon dioxide, hydrogen sulfide, and nitrogen. LNG is often referred to as methane and is considered the purest form of natural gas due to its high methane content of over 98%. Natural gas emits significantly less carbon monoxide than petrol because of its low Sulphur content and density (0.789 basis air).

Natural gas is converted into LNG by decreasing its temperature to -162 °C (-260 °F), producing a phase shift from a gaseous to a liquid form. This intense cooling reduces the volume of the gas significantly, decreasing it by over 600 times its original size. This process allows for transporting vast natural gas reserves worldwide on specially designed ships, giving global consumers access. When at atmospheric pressure, LNG, or liquefied natural gas, retains its properties as a translucent, odorless, non-toxic, and non-corrosive cryogenic liquid. Notably, LNG has a lower density than water, which has a density of 1.0 kg/L. The density of LNG varies from 0.4 to 0.5 kg/L depending on conditions such as temperature, pressure, and composition.. As a result, in the event of a spill on water, LNG

floats to the surface and quickly vaporizes, leaving no residue. Removing acid gases such as CO2 and H2S from natural gas before liquefaction is critical in producing pure methane.

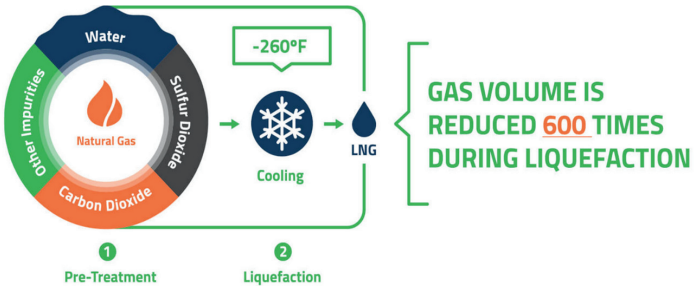

***Figure 2**. LNG Process (Source : RIO GRANDE LNG)*

2.1 Understanding the Mechanism of LNG

In contrast to the natural gas pipeline trade, the LNG trade necessitates significant expenditures at several stages of value addition. The first step in converting natural gas into LNG is to explore natural gas sources beneath the Earth's surface. Nations with an exportable surplus of natural gas reserves export this resource. It is vital to note that the exploration phase accounts for around 11% of the entire cost of LNG production. Following exploration, liquefaction is the next phase in the LNG production process, various extraneous components are removed from the natural gas during this stage, resulting in a refined product with a homogenous composition and consistent combustion properties. The liquefaction process necessitates significant investments and adds to a 42 percent increase in total LNG production costs. Following the conversion of natural gas to liquid form (LNG), the next stage is to transport it to importing countries. This transportation is made possible by specialized trucks and ships equipped to transport LNG.Transportation and shipping costs account for about 20% of the overall cost of LNG borne by the importing company. Upon arrival at the importing sites, the marine terminals commence the process of receiving, storing, and subsequently re-gasifying the LNG in the subsequent stage of the value chain. This intricate process involves specialized vessels and barges, including Floating Storage Units (FSUs), Floating Regasification Units (FRUs), and Floating Storage and Regasification Units (FSRUs), which undertake distinct functions within this framework, catering to the needs of various countries. These FSRUs provide LNG-importing countries with an immediate and cost-effective alternative, accounting for around 27% of the total landed price of LNG. Finally, LNG in its gaseous condition is transferred to final users via the country's exclusive transmission and distribution networks [6].

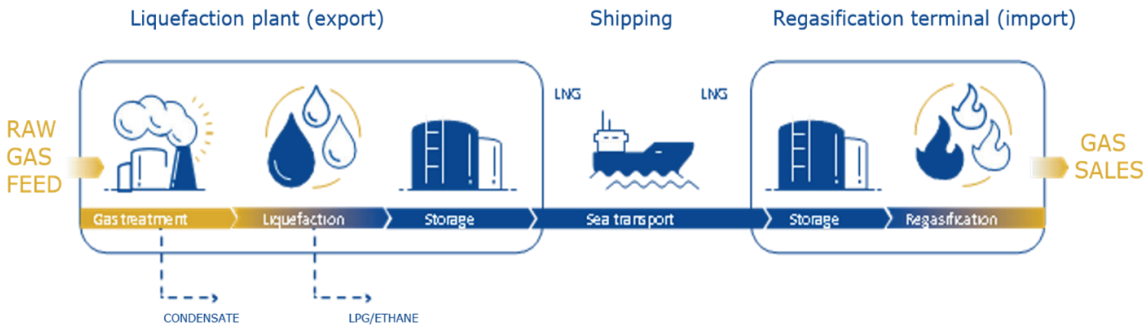

***Figure 3**. LNG Process Chain (Source: GIIGNL (2019). The LNG Process Chain. LNG Information Paper#2)*

3. LNG, CNG, LPG: Differentiating Gas Variants

When subjected to comparable temperature and pressure conditions, CNG and LPG exhibit unique properties. CNG, which is mostly composed of 80-90% gaseous methane, is colorless, non-toxic, and buoyant. It is compressed to increase its energy density, allowing for more efficient storage in cylinders. Because of this compression, CNG is becoming a more popular and cost-effective fuel option among automobile owners, exceeding traditional petroleum fuels.

LPG, on the other hand, is a clean and environmentally friendly fuel with a high octane rating. LPG is made from gases such as propane and butane and is created by refining crude oil or fractionating natural gas. While these gases remain gaseous under normal settings, they can be liquefied by applying moderate pressure or cold to -42°C. This feature is extremely adaptable, allowing for simple condensation, packaging, and storage. When pressure is released, the liquid expands to roughly 250 times its volume in gas form, allowing for the compact storage and delivery of large amounts of energy. In comparison to natural gas at room temperature, LNG occupies 600 times the volume in its liquefied state, whereas CNG experiences only a 1% drop in its original volume. In comparison to other natural gases such as CNG and LPG, the significant volume reduction in LNG makes its transportation more economically feasible for transporting large amounts of natural gas across long distances. The ability to transport and store LNG under normal atmospheric Furthermore, as compared to CNG refueling stations, LNG refueling stations have lower capital and maintenance costs, and they function without the need for energy. LNG has a significant advantage over CNG and LPG because to its simplified transportation andstorage methods, as well as its higher density as compared to gaseous methane. Notably, LNG has the potential to accelerate progress in biogas-to-biomethane conversion for automotive fuel via gas purification. This capacity stems from LNG's intrinsic ability to change from a liquefied condition to compressed natural gas, emphasizing LNG's adaptability as a feasible energy alternative (L-CNG) [4].

Quick Understanding

- LNG projected as a bridging fuel for clean energy transition.
- LNG is produced by cooling underground natural gas to a liquid state, purifying it, condensing it, and transporting it via a terminal, making it easier to transport in areas without pipelines.
- Regasification converts LNG to gaseous form at plants connected to pipeline distribution network.
- LNG, unlike LPG, is not petroleum-based and primarily consists of methane, a byproduct of petroleum processing, used for heating and powering electrical grids and stoves.
- LNG primarily consists of methane, while LPG is made from petroleum processing and primarily comes from natural gas deposits.
- LNG produces 25% less CO2, 90% less NO2, and 100% fewer sulfur compounds.

4. Why LNG? The Global and Pakistan Perspective

Natural gas trade has historically relied significantly on huge networks of inter- and intra-country pipes due to its low density, which made storage and trading via maritime routes more expensive than oil. However, the business has seen tremendous developments in technologies linked to purification, liquefaction, and regasification. These advancements have not only decreased the cost of carrying liquefied gas via specialized vessels, but have also increased the possibility for trading this commodity. The elimination of the need for capital-intensive long-distance pipelines has increased the attractiveness of LNG as a means of transportation. For a variety of reasons, LNG has gained substantial traction as a viable energy source. The emergence of cost-effective combined cycle generation turbine (CCGT) plants is the most significant technological accomplishment in power generation. These developments have allowed the move of oil-importing developing nations such as India, China, and Turkey to gas-fired power generation, allowing them to capitalize on cost flexibility. As a result, worldwide natural gas production and consumption have been steadily increasing. Furthermore, growing environmental concern has fueled a need for cleaner fuel alternatives, with LNG emerging as a leading candidate. When compared to other fossil fuels, natural gas is distinguished by its low sulfur content, fewer CO2 emissions, and increased energy generation. These characteristics are consistent with the global quest for renewable energy sources. In summary, technological advancement, environmental concerns, and the diversity of the LNG supply chain have all contributed to the change of the natural gas trading landscape from pipelines to LNG. These features, taken together, position LNG as a more popular energy source on the demand side, encouraging cleaner energy development and contributing to global energy security.

Finally, the LNG supply chain provides customised and adaptable solutions to meet the different needs of its customers. Options such as simpler liquefaction, regasification plants, and refueling systems are included. This adaptability demonstrates LNG's ability to provide scalable and efficient energy solutions to a wide range of customers. Consequently, the global LNG supply chain has seen a massive rise in participants since the early 2000s. On the export front, newcomers like Qatar, Australia, and, more recently, the United States have risen to prominence, displacing long-standing exporters like Indonesia, Malaysia, and Russia. Concurrently, countries such as China, India, and Pakistan have fueled increasing global LNG demand. Global LNG infrastructure has expanded dramatically in response to increased demand. Investment has increased at every level of the LNG cycle, from discovery to liquefaction, shipping to regasification and distribution. With increased competition in mind, Qatar has announced intentions to increase its LNG production and handling capacity by 64% by 2024, leveraging newly discovered gas reserves. Other natural gas-producing countries, notably Canada, Mozambique, and other West African countries, have declared similar development plans. Importing countries, on the other hand, have made significant expenditures in expanding their LNG regasification, storage, and pipeline capacity. For example, in 2019, India, Bangladesh, China, and Brazil all opened new LNG regasification

stations. Furthermore, new LNG importers are entering the fray, with the Philippines, El Salvador, Ghana, Cyprus, Croatia, and Vietnam all in the midst of developing their first receiving facilities. This rapid expansion in the LNG supply chain demonstrates the sector's growing importance in the global energy landscape. The dynamics of supply and demand, as well as infrastructure development, point to a key shift toward cleaner and more adaptable energy sources.

5. Current Scenario of LNG in Pakistan

In 2015, Pakistan began importing liquefied natural gas (LNG), signaling a dramatic shift in the country's energy environment. These imports have increased over time, reaching 7.4 million tonnes by 2020, with the government forecasting a significant increase in LNG demand. The amount of re-gasified LNG (RLNG) in total gas demand in Pakistan has increased significantly, going from slightly under 8% in FY2016 to 26% in FY2020.

Project Name	Location	Capacity (MMCFD)	Developer	Cost (US$m)
Tabeer LNG Terminal	Jhari Creek, Port Qasim	750-1,000	Tabeer Energy Private Ltd. (Mitsubishi subsidiary)	300
Energas LNG Terminal	Chara Creek, Port Qasim	750-1,000	Energas Consortium; Qatar Petroleum	180
Daewoo Gas Terminal	Karachi	356	Daewoo Gas and CNCEC	300
Easy LNG Terminal	Karachi	50-60	LNG Easy Pvt. Ltd.	200

Table 1. *Terminals Under construction*

Particularly, two operating regasification stations are located in the Port Qasim area. The first is Engro Elengy's offshore facility, which serves Pakistan State Oil (PSO) and can import 4.8 million tonnes of LNG per year. Pakistan LNG Terminals Limited (PLTL), created in 2017 and owned by Pakistan GasPort Consortium Ltd., has a capacity of 5 million tonnes per annum (mtpa) and operates under the auspices of Pakistan LNG Limited (PLL). These terminals are critical to improving Pakistan's LNG infrastructure and satisfying the country's growing energy demands.

5.1 Governance and Operational Structure

The natural gas sector, which includes activities ranging from exploration to distribution and even LNG importation, operates within a set of norms and policies. Various governmental ministries and regulatory entities are in charge of enforcing these restrictions. OGRA (Oil and Gas Regulatory Authority) is authorized by the government to manage the allocation, pricing, and other important aspects of LNG. OGRA also issues licenses for the construction and operation of LNG terminals and pipelines. Furthermore, these regulatory authorities are in charge of assessing and conveying to domestic users the average cost of imported LNG.

LNG terminal operators have to obtain No Objection Certificates (NOCs) from a number of different bodies. The Ministry of Energy (Petroleum Ministry), Port Qasim Authority, Ministry of Maritime Affairs, Ministry of Defense, Ministry of Industries and Production, Civil Aviation Authority, Sindh Environmental Protection Agency, and Naval Headquarters/Maritime Security are among these authorities. These NOCs are required to assure compliance with the requirements and specifications established by these authorities in sectors such as energy, port operations, marine affairs, defense, industries, environmental protection, aviation, and security.

5.2 Import of LNG

LNG shortages are expected to last the entire year (after a few years), and unless significant new gas reserves are discovered or gas importation options are implemented as planned, the shortages will worsen over time. Seasonal consumption variation in winter will be seen in the future, and LNG importation will vary with seasonal variation in petrol consumption to mitigate the winter hike challenge. The operation of 1,211 gas-based Combined Cycle Power Plants (CPPs), which consume approximately 415 million Cubic Feet per Day (MMCFD) of gas, including LNG, is driving up current demand for natural gas in Pakistan. To meet this rising demand, the electricity supplied to these CPPs must come from the national grid rather than from natural gas. This will also help to reduce the burden on domestic gas supply. However, in order for this to work, grid connectivity and reliability must be improved. To reduce the cost of Liquid Natural Gas (LNG), it should be made available at its imported cost, which is still less expensive than Liquefied Petroleum Gas (LPG) and can help meet future demand. The Government of Pakistan (GoP) must ensure its domestic availability by resolving issues with provinces in accordance with Article 151 of the constitution. Presently, the country's domestic gas production is less than 4,000 MMCFD, falling short of meeting the demand by approximately 2,000 MMCFD. Considering the unconstrained gap, the shortage exceeds 4,000 MMCFD. This shortage is causing significant hardships in people's daily lives and impeding the country's

To address this issue, the Government of Pakistan is following a global trend by pursuing the import of Liquefied Natural Gas (LNG) to mitigate the gas shortfall. Rather than adopting an integrated approach, the government has opted for an unbundled approach, employing separate contracts for LNG procurement and regasification. Before delving into the impact of imported LNG on securing Pakistan's energy supply, it is essential to emphasize the concept of energy security and its current status in the country.

Figure 4. LNG cargo ship (Source: ALAMY)

6. Barrier Influencing the Import of LNG

High transportation costs, uncompetitive pricing, restricted market activity, risk concerns, restricting contracts, and governmental trade restrictions are all examples of global natural gas trade barriers. These obstacles are currently severe, but indicators show that their impact will gradually diminish.

6.1 Geopolitical Implications: Ukraine-Russia Conflict's Impact on the LNG Market

Pakistan's persistent energy insecurity has been aggravated by the compounding effects of the pandemic, floods, and the Ukraine conflict. While some experts dismissed concerns about Pakistan's energy dependence, citing the abundance and affordability of Liquefied Natural Gas (LNG), the unfolding crisis in Ukraine has proven them wrong. Sanctions imposed in the wake of the conflict have disrupted Russia's energy supplies and led to global price hikes. With Europe's entry into the market and its willingness to bear escalating costs for limited supplies, Pakistan finds itself in an even more precarious position.

Constrained by geopolitical sensitivities preventing alignment in the Ukraine conflict, Pakistan must safeguard its national priorities, with a paramount focus on ensuring energy security.

Pakistani officials are sounding alarms about imminent gas shortages, while widespread load-shedding plagues households, subjecting many areas to daily 16-hour power cuts. The nation's crucial textile industry is also poised to suffer due to interrupted and restricted supply. This predicament persists despite Pakistan's possession of exploitable natural resources, as policy-makers have remained steadfast in their belief that achieving self-reliance through resource development is unattainable. Furthermore, insecurity and political instability in resource-rich areas like Balochistan have thwarted potential corrective measures.

Pakistan faces limited straightforward avenues for accessing Russian energy resources. The prospect of establishing a gas pipeline named Pakistan Stream from Russia is hindered by sanctions that Pakistan lacks the means to bypass. Certain Pakistani scholars have optimistically suggested that by maintaining neutrality, the country can forge energy agreements with Russia without upsetting the West by abstaining from voting on the matter at the UN. Yet, given its relatively minor role within the broader geopolitical landscape, the reality remains that Pakistan will eventually confront the necessity of aligning with one side or the other in this overarching geopolitical contest.

6.2 Impact of International Relations on Pakistan's LNG Import

To address its increasing gas requirements, Pakistan needs to prioritize gas imports from neighboring nations like Tajikistan, Iran, and Russia. Unfortunately, due to the looming risk of US sanctions, Pakistan had previously withdrawn from a collaborative gas pipeline agreement with Iran. To secure its gas demand by 2030, Pakistan must accelerate the progress of the Turkmenistan-Afghanistan-Pakistan-India Gas Pipeline Project, an extensive 1,800-kilometer endeavor. This project holds the promise of furnishing Pakistan with roughly 490 billion cubic feet of gas annually. Concurrently, exploring alternative options for imported gas pipelines is essential. Given that the northern region of Pakistan, especially during the winter season, exhibits the highest demand for gas, a north-south pipeline that can transport imported LNG from the southern port to the northern area is imperative. By implementing these strategies, Pakistan can effectively manage the escalating natural gas demand, ensuring a consistent supply of electricity without disruption. To meet the demand shortfall, nearly three times more LNG will need to be imported by 2030 than is currently imported in the country.

Currently, only two LNG terminals exist to manage imports, with a total capacity of approximately 1,200-1,400 MMCFD. As a result of the presented increase in LNG imports, the country will require additional LNG terminals to meet the import requirement of 1,900 MMCFD by 2030 [7]. This LNG is transported by cargo tanks with a capacity of 3000 MMCFD and transported to FSRU (Floating storage and regasification unit) with a capacity of 600 MMCFD, each terminal need a cargo after 5 days. In response to both internal and foreign pressures, Pakistan's Energy Managers have chosen to purchase Liquefied Natural Gas (LNG) from Qatar. This option is regarded as the most expedient and viable approach. While alternative solutions are being considered, such as the IP Gas Pipeline Project ,the TAPI Gas Pipeline Project, and the Qatar-Pakistan Undersea Pipeline/LNG import is also being considered. Potential energy sector collaborations with China and the United States are also being investigated as part of the broader discussions.

. It is important to consider the pros and cons of each option critically rather than making decisions based on emotions or fears. Strategic prioritizing of these initiatives, both short and long term, is critical for effectively addressing the energy crisis in a sustainable manner. The Pakistan government has adopted a proactive stance by beginning LNG import from Qatar, seeing it as the quickest accessible answer among alternatives with less controversies. However, the cost of importing LNG is three times higher than the domestic natural gas, and the government has not explored the feasibility of distributing this fuel effectively. The gas infrastructure in Pakistan is monopolized by SNGPL and SSGC, which are the sole managers in their respective areas within the country. However, both of these companies experience pipeline losses ranging from 10% to 13% referred to as unaccounted for gas losses (UFG losses). But according to Arshad H. Abbasi, an energy advisor at the Sustainable Development Policy Institute in Islamabad, the unaccounted-for gas (UFG) ratio in Pakistan stands at 18%. In comparison, countries like Canada, Germany, Ukraine, and New Zealand maintain ratios around 2.5%. Abbasi explained that UFG refers to gas leaks caused by deteriorating pipelines, weakening cathodic protection, underdeveloped network design, and a lack of advanced metering. He further emphasized that Pakistan's annual losses due to UFG are nearly $4 billion andsuggested that addressing this issue would require a one-time investment of $500 million to revamp the gas transmission and supply network. In current situation, domestic consumers make up 20% of total gas consumption in Pakistan, while the power sector uses 35% ,the fertilizer and general industries consume almost 30%. Losses attributed to factors beyond the control of distribution businesses are exempt from any mandated financial penalties, as outlined by the Regulatory. Several organizations have expressed worries about a variety of issues, including customer choice constraints, infrastructure deficiencies, challenges relating to unionized staff, outdated gas distribution networks, and operating capacity limitations. As a result, LNG distribution over the same gas distribution company facilities and existing pipeline network would undoubtedly incur

Effect of Cyclone Biparjoy

- Cyclone Biporjoy made landfall in Pakistan on 16 june 2023.
- The cyclone affected the LNG supply to the country from Port Qasim.
- The supply from the LNG terminal has been suspended for four hours, affecting the industrial and CNG sector.
- Authorities had already warned that the cyclone might affect the LNG supply to power plants, resulting in electricity shortage in the country.
- Shipping activity has been suspended at the two ports of Karachi.
- One LNG cargo was delayed due to Cyclone Biperjoy, affecting the industrial and CNG sectors.

osses. The question is, "Is the Pakistani Regulatory Authority (OGRA) willing to accept losses for an imported LNG fuel that is also much more expensive?" Failure to successfully distribute LNG to consumers will result in chaos for the energy sector, which is already in distress. For a long-term future, the entire activity must be financially viable. [8], [9].

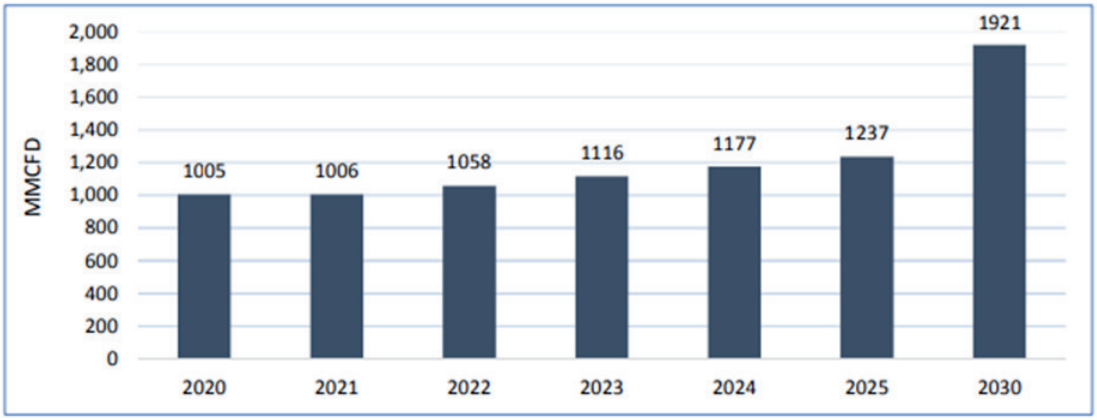

Figure 5. *Import of LNG 2020-2030 (IEP, Pakistan Energy Outlook report)*

7. Distribution of LNG

National authorities have developed plans to import LNG in order to help the faltering energy sector and improve their reputation in dealing with energy emergencies. Initially, LNG sales were made available to business clients such as Independent Power Producers and fertilizer producers. The increased cost of LNG in comparison to domestically producednatural gas, on the other hand, has elicited conflicting reactions from business clients. While some have accepted the offer due to current gas load curtailments and load shedding, others have rejected it due to the higher cost in comparison to natural gas and furnace oil. Given the extreme gas shortages, the CNG industry has voiced a strong desire to obtain LNG, particularly in areas like; Punjab and Islamabad. Various options are being considered to identify who will benefit most from LNG. The CNG Association is actively campaigning for its inclusion, despite the fact that the government is facing financial restrictions and cannot afford to endanger the project's sustainability. Distribution companies are wary about accepting culpability for associated losses and incorporating more expensive R-LNG (regasified LNG) into their pipeline networks after degasification. If they opt to proceed, the companies listed on the stock exchange will most certainly face a dismal market trend. These companies are already involved in legal battles with OGRA about modifications to benchmark UFG (Unaccounted-for Gas) losses and regulatory penalties for losses.

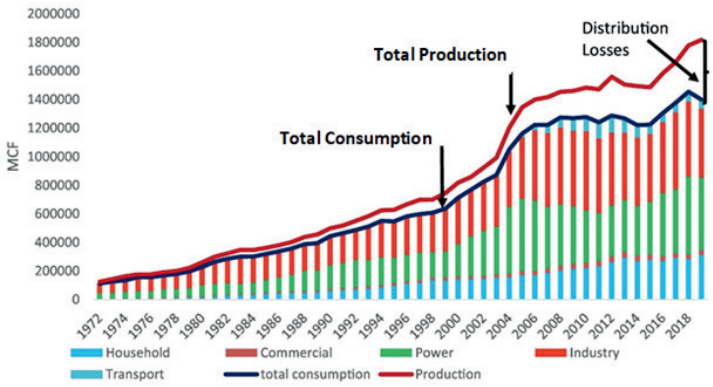

Figure 6. *Natural Gas Consumption in Pakistan by different sectors [10].*

LNG importers chose to use the current network of gas distribution companies rather than considering any alternatives for the LNG infrastructure. With the exception of corporate clients who could access gas via the Sales Metering Station (SMS) or Consumer Metering Station (CMS) located at the transmission network's terminus, thereby avoiding distribution network losses, companies were initially hesitant to extend LNG sales to all customers. For SNGPL, the distribution network consists of a sizable, interconnected pipeline system that spans approximately 95,000 KM and serves customers in every market segment who are situated there. Control over the distribution network depends on a variety of variables, from those that can be controlled to those that cannot. But in order to sell LNG to CNG stations, it must be transported through the same distribution network, which also caters to customers in every category and is battling low pressures. The CNG stations are dispersed throughout the major cities and on the highways without any prior planning for minimally required standard distances. As a result, the LNG would not change the situation and would instead get lost in the network of distribution pipelines. Due to a variety of factors such as inadequate development efforts, engineering designs influenced by political considerations for the pipeline networks, and limitations in terms of accommodating operational demands while upholding stringent standards, there is a lack of willingness to assume the financial burden associated with gas distribution network losses. When talking about the distribution company, SNGPL can be used as a reference because it has a larger infrastructure as well as a network than SSGC. However, following a contentious corporate debate, SNGPL and SSGC have recently decided to distribute LNG. Even though the distribution is currently confined, there are future plans to scale up the project, and work is already underway to create a specific LNG pipeline for SNGPL. SSGC is now providing its system with regasified LNG imported onshore, while temporarily trading domestic gas allocation with SNGPL. It is vital to remember that the calorific values of domestic natural gas and LNG are not the same. Customers who are prepared to comply with the prescribed terms and conditions for LNG distribution and are not in default have been chosen from among SNGPL's existing customers.

8. User Domain of LNG

The OGRA has established four main consumer categories, which are classified according to operational and tariff considerations [11]. These categories include

- Industrial Consumers
- Commercial Consumers
- Domestic Consumers
- Special Domestic/Bulk Consumers

The OGRA has also provided detailed sub-categories for consumers, which include

- Domestic Sector/Special Domestic
- Commercial
- Special Commercial (Roti Tandoors)
- Ice Factories
- Industrial
- Compressed Natural Gas (CNG) Stations
- Cement, Fertilizer Companies
- Power Stations (WAPDA's and KESC's Power Stations)
- Independent Power Producers
- Captive Power

Based on the quantity of gas required by consumers and the nature of their business, these categories can be further classified into

- Corporate Consumers (Power, Fertilizers & Cement),
- Bulk Consumers (Industry, Bulk Commercial & Bulk Domestic),
- Retail Consumers

Corporate customers are preferred by gas distribution companies due to low theft and simple monitoring. Due to possible measurement errors and the need for resources to rectify them, bulk consumers rank second and retail consumers last.

9. Economic Analysis of LNG Usage on Pakistan

Pakistan's growing reliance on imported liquefied natural gas (LNG) is exacerbating the country's energy insecurity and budgetary difficulties. While natural gas has historically played an important part in Pakistan's economic landscape, the fall in domestic production has pushed policymakers to increasingly rely on LNG imports to compensate. As a result, Pakistan exhibits several features consistent with optimistic scenarios for LNG demand growth: rising demand, a wide range of gas customers from various economic sectors, and a complex and increasing network of transmission and distribution pipelines. Nonetheless, efforts to increase LNG's import in the country's primary energy supply have deteriorated, resulting in a situation that straddles economic troubles and energy security worries. LNG providers have frequently failed to fulfill volumes specified in contracts, leaving the country without fuel or power. These electricity and fuel shortages have had a direct impact on the economic productivity of local businesses and industries. Furthermore, LNG purchased from global markets is currently priced 5 to 10 times higher than domestically produced gas. The significant volatility in LNG prices over the last few years has degraded the efficacy of energy sector planning and exposed the government to ongoing fiscal uncertainty. Despite being marketed as a "bridge fuel" to cleaner and more cost-effective energy options, LNG has increased Pakistan's reliance on more environmentally damaging fuels. whenever natural gas prices rise. As a result of growing pricing, several businesses, such as cement plants, have resorted to importing coal from Afghanistan. LNG prices are expected to remain elevated and volatile for the foreseeable future, according to projections. The high cost of gas has revealed various previously hidden faults in the country's gas architecture. These include disparities in final tariffs that do not reflect actual gas expenses, an inefficient cross-subsidization method for gas tariffs, and significant losses of unaccounted-for gas (UFG) along the transportation process. These concerns are expected to worsen as Pakistan's gas system accepts more LNG.

Circular debt, which has long been a problem in Pakistan's power sector due to the accumulation of unpaid bills between buyers and sellers, has now penetrated the gas sector. The significant financial burden created by LNG, reinforced by mandated payments in US dollars, is likely to reverberate throughout the economy. These effects include the government's fiscal budget, home energy bills, investor confidence in the energy sector,

and the efficiency of critical economic fields such as textiles and fertilizers. The complex interplay of energy sourcing, financial complexities, and general economic stability highlights the various problems Pakistan faces in managing its energy landscape [12].

HOME TRUTH

LNG offers certain advantages over natural gas (NG), but it cannot be considered a complete alternative due to the potential increase in our country's dependency on foreign sources.

- *Increased Dependency: Relying heavily on LNG imports would make the country vulnerable, as it would further amplify our reliance on other nations for energy supply, affecting our energy security.*
- *Higher Consumer Prices: Although the import price of LNG may be lower, the cost for consumers is likely to be around three times higher than domestic gas prices.*
- *Price Volatility: LNG prices are subject to fluctuations based on factors such as political crises, market demand, distance, and other variables. This volatility adds uncertainty to long-term planning and economic stability.*
- *Infrastructure Investment: Utilizing LNG requires additional infrastructure and substantial investment. However, this infrastructure may become burdensome if there are significant policy changes or shifts in the energy sector in the future.*
- *Missed Exploration Opportunities: Overreliance on LNG can divert attention and resources from exploring and harnessing the potential of our own natural gas reserves, resulting in missed opportunities for economic growth and resource utilization.*
- *Compromised Energy Security: Depending heavily on LNG undermines the country's long-term energy security, as it can expose us to supply disruptions and geopolitical risks associated with foreign energy sources.*

It is crucial to carefully consider these factors and strike a balance between utilizing LNG and developing domestic energy resources to ensure sustainable and secure e nergy supply.

10. Environmental Impact of LNG

It is critical to transition from oil to gas in order to pave the way for a cleaner future. Gas is gaining popularity because to its inherent benefits, which include lower carbon emissions, low sulfur content, high energy density, and widespread availability. Liquefied natural gas (LNG) has emerged as a fast rising worldwide energy alternative as demand for numerous carbon-based fuels declines. The emission of carbon dioxide (CO2) from the combustion of liquefied natural gas (LNG) is determined by the composition of the natural gas as well as the efficiency of the LNG production and transportation operations. Natural gas, particularly LNG, has the reputation of being a more environmentally friendly fossil fuel than coal and oil, emitting less CO2 when burned. However, it is worth noting that methane, a major component of natural gas, has an 87-fold greater climate impact than CO2 during a 20-year period. Methane emissions account for around 30% of the total observed global warming thus far. This highlights the ambiguity of natural gas, which serves as a cleaner option while simultaneously raising worries about methane emissions. Striking a balance between cleaner solutions and minimizing greenhouse gas emissions remains a critical problem in managing the developing energy landscape.

Natural gas combustion produces roughly 50-60% lower CO2 emissions than coal and approximately 25-30% fewer CO2 emissions than oil. However, it is critical to recognize that the precise CO2 emissions from LNG can vary depending on variables such as the composition of the natural gas, the efficiency of the energy-intensive LNG production and regasification facilities, and the possibility of methane leaks at various stages of the LNG supply chain.

Methane emissions can occur during natural gas extraction, production, transportation, and distribution, including the LNG value chain. Efforts to minimize methane leakage and control emissions throughout the LNG supply chain are crucial to reducing LNG's overall greenhouse gas impact.

To mitigate the environmental impact of LNG, countries and companies are implementing measures such as advanced technologies for methane leak detection and control, investing in infrastructure upgrades to reduce losses, supporting international agreements and initiatives to promote sustainability in the LNG industry. Stakeholders in the LNG sector need to prioritize environmental considerations and work towards minimizing CO2 and methane emissions to achieve a more sustainable energy future.

When liquefied natural gas (LNG) is converted into its gaseous form and utilized as fuel, it greatly diminishes particulate emissions to nearly negligible levels. Furthermore, when compared to heavier hydrocarbon fuels, LNG can reduce carbon dioxide (CO2) emissions by up to 70 percent. The environmental benefits become even more significant when LNG is used for power generation, as it virtually eliminates sulfur dioxide (SO2) emissions and significantly reduces CO2 emissions in comparison to other hydrocarbon fuels.

10.1 Impact of LNG Terminals on Nearby Environment

Pakistan's existing and future LNG terminals are strategically positioned in environmentally sensitive areas. Notably, LNG operations at Port Qasim have resulted in the loss and degradation of mangrove habitats. This has a direct impact on coastal towns that rely on a healthy natural ecology. These populations may encounter difficulties as a result of unfavorable changes in fishing circumstances, increased water contamination, and the shifting of mud and debris. As a result, these shifts pose significant challenges to their sustenance and livelihood.

These terminals are responsible for the cooling and loading of natural gas onto barges, have the potential to release over 90 million tons of greenhouse gases annually. This amount of pollution is equivalent to the emissions generated by approximately 18 million combustion-engine cars in a year. LNG terminals also release harmful pollutants and negatively affect marginalized communities in climate "sacrifice zones."

Environmental friendliness of LNG

- LNG is non-toxic, non-corrosive, non-explosive, and non-flammable.
- LNG has a colorless and odorless appearance similar to water.
- LNG does not contaminate soil or water, and any accidental spills quickly vaporize without leaving residue. LNG shipping has a long history of safe transportation worldwide since the first cargoes in 1964.

Degradation of mangrove habitats. This has a direct impact on coastal towns that rely on a healthy natural ecology.

In short, LNG terminals have far-reaching impacts on their surrounding environments, affecting air quality with the release of pollutants like VOCs, NOx, and SOx, as well as causing noise pollution from loading and unloading activities. Also, they pose risks to water quality and marine life due to the potential for spills and chemical contamination. These terminals disrupt local ecosystems, changes the visual landscape, and destroy local infrastructure, potentially offsetting economic benefits with disruptions to other industries. Regulatory measures and community engagement are crucial for mitigating these adverse effects and minimizing harm to the nearby environment.

10.2 Impact of LNG Terminal on Air Quality

LNG is often considered a cleaner alternative to traditional fossil fuels like coal and oil due to its lower carbon dioxide (CO2) emissions when burned for energy. However, it is essential to recognize that LNG combustion is not entirely without environmental consequences, specifically regarding air quality. The combustion of LNG can still release pollutants, including nitrogen oxides (NOx) and particulate matter (PM), which can have significant impact on air quality and public health.

10.1.1 Nitrogen Oxides (NOx)

LNG combustion produces nitrogen oxides (NOx), primarily nitric oxide (NO) and nitrogen dioxide (NO2). These pollutants are generated when the high temperatures of combustion cause nitrogen in the air to react with oxygen. NOx is a major contributor to the smog and ground-level ozone that can irritate the respiratory system and lead to various health

issues, including asthma, bronchitis, and other respiratory diseases. In real time examples, Lahore, Pakistan has highest level of smog and that is increasing day by day.

10.1.2 Particulate Matter (PM)

LNG combustion also emits fine particulate matter (PM), which consists of tiny airborne particles. These particles can be inhaled into the lungs and have health risks.
PM can originate from incomplete combustion, impure fuel, or the lubrication oil used in LNG engines. It can contain harmful substances such as heavy metals and organic compounds.
Exposure to PM is associated with respiratory and cardiovascular problems, including lung cancer, heart attacks, and aggravated asthma.

10.1.3 Methane Emissions

Although methane (CH4) is the primary component of natural gas but it is also a potent greenhouse gas. Methane leaks during the production, transportation, and use of LNG can contribute to climate change. While methane is not a direct air quality pollutant, its indirect impact on air quality and public health is through its role in climate change, which can exacerbate extreme weather events, air quality issues, and the spread of vector-borne diseases also a major cause of global warming.
In conclusion, while LNG is often touted as a cleaner energy source, it is not entirely safer for environment. The combustion of LNG can release pollutants like NOx and PM, which contribute to smog formation and respiratory health problems. It is crucial to implement stringent emissions controls and monitoring systems to mitigate these adverse effects and ensure that the environmental benefits of LNG are realized while minimizing its negative impacts on air quality and public health.

11. Calculation of CO_2 emissions

The emissions of carbon dioxide from a vehicle are directly linked to both the quantity of fuel consumed and the carbon content present in the fuel. Exhaust emissions, specifically carbon dioxide emissions, represent a significant contemporary concern. While it is a contentious and extensive subject, the fundamental calculation of vehicle CO2 emissions is relatively uncomplicated. It primarily relies on two factors: fuel consumption and the carbon content within the fuel variant. The following equation can be used to calculate CO2 emissions.

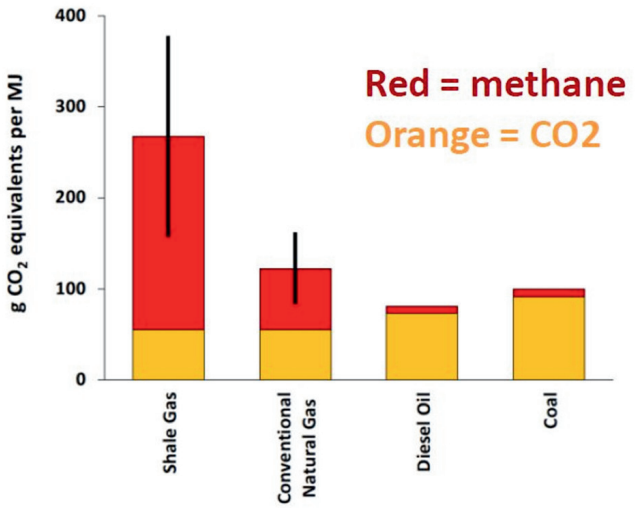

Figure 7. *Methane and CO2 Emission comparison [13]*

$$Average\ CO_2\ Emissions = \frac{Combined\ Combustions\left(\frac{liter}{100km}\right)}{100} \times CO_2\ produced\ by\ 1\ liter\ of\ fuel_{(g)}$$

11.1 CO2 Emission for CNG

When 1 kilogram of Compressed Natural Gas (CNG) is burned, it contains 72.7% carbon, which is equivalent to 727 grams of carbon. The combustion process requires 1939 grams of oxygen. As a result, the total carbon dioxide produced is the sum of 727 grams of carbon and 1939 grams of oxygen, which amounts to 2666 grams of CO2 emitted from the burning of one kilogram of CNG.

So for an average consumption of 10 kilograms per 100 km, the CO2 emissions will be 10/100 x 2666 = 266.6 grams of CO2 /km

11.2 CO2 Emission for LPG

When 1 litre of Liquefied Petroleum Gas (LPG) is burned, it weighs 550 grams and contains 82.5% carbon, which is equivalent to 454 grams of carbon. The combustion process requires 1211 grams of oxygen. Consequently, the total carbon dioxide produced is the sum of 454 grams of carbon and 1211 grams of oxygen, resulting in 1665 grams of CO2 emitted from burning one litre of LPG. So for an average consumption of 10 litres per 100 km, the CO2 emissions will be 10/100 x 1665 = 166.5 grams of CO2 /km.

Pollutant	Natural Gas	Oil	Coal
Carbon Dioxide	117,000	164,000	208,000
Carbon Monoxide	40	33	208
Nitrogen Oxides	92	448	457
Sulfur Dioxides	0.6	1122	2591
Particulates	7	84	2744

Table 2. *Comparison of different pollutants by different fuels, values in lbs/Billion Btu.*

Fuel	Emissions in g CO_2/kWh_{PE}	Emissions in g CO_2/MJ_{PE}
Wood	367.6	102.1
Lignite	398.7	110.8
Peat	366.5	101.8
Hard coal	338.2	93.9
Liquid petroleum gas	238.8	66.3
Natural Gas	200.8	-
Gasoline	263.9	73.3
Fuel oil	263	73.3
Diesel	266.5	74.0
Crude oil	266.5	74.0
Kerosene	263.9	73.3

Table 3: *Carbon Dioxide emissions of Various fuels in comparison to LNG (Source: Umweltbundesamt 2022)*

12. Suggested Approaches

In this critical juncture, the implementation of comprehensive, timely, sustainable, and well-calibrated policies is of paramount importance. To realistically achieve success, the following measures are imperative:

- **Fostering Political Unity**: Politicians must transcend partisan divides and collaborate to establish an era of political stability. Minimizing disputes and disagreements can redirect valuable time towards the development of energy security.
- **Strategic Energy Agreements:** Pakistan should enter into energy investment and infrastructure development agreements with China, Russia, and other willing nations while safeguarding its national interests. The lessons gleaned from prior adverse experiences with LNG intermediaries should be kept in mind.
- **Nationwide Energy Conservation Drive:** Initiate a comprehensive energy conservation campaign, coupled with a public relations effort to portray energy as a finite resource. Immediate actions must be taken to curtail energy wastage in
- **Nationwide Energy Conservation Drive**: Initiate a comprehensive energy conservation campaign, coupled with a public relations effort to portray energy as a finite resource. Immediate actions must be taken to curtail energy wastage inwastage in households and industries, prioritizing efficiency. Should also apply off-Peak and on-Peak hour strategies for energy savings.
- **Clean Energy Advancement:** Encourage the adoption of clean energy technologies, including incentivizing solar power adoption for households and industries, as well as the establishment of wind power facilities.
- **Emphasis on Domestic Resources:** Promote the development and investment in domestic energy resources to diminish reliance on imports, thereby enhancing energy security.
- **LNG Import Strategy Optimization**: Reevaluate previous LNG import plans, such as the Qatar LNG project in 2015, and consider refined approaches like the Qatar LNG project in 2022.
- **Enhanced LNG Tender Process:** Implement improvements to the LNG tender process to optimize its efficiency and effectiveness.

- **Diversifying Energy Sources:** To begin the process, it is wise to begin by reducing gas demand in the power sector. This goal can be reached through advancing utility-scale and behind-the-meter renewable energy projects, as well as targeted battery storage initiatives.
- **Transition to Non-Gas Sectors:** It is critical to have the ability to move non-power sectors away from their reliance on gas and LNG. This includes accepting alternate renewable energy sources like biogas and hydrogen to power these industries.
- **Expert Engagement:** Facilitate regular roundtable discussions involving non-partisan economic, energy, and environmental experts. Such dialogues should critically evaluate proposals' contributions to energy security and national interests.By thoughtfully implementing these measures, Pakistan can take significant strides towards addressing its energy challenges while fortifying its energy security and sustainability.

13. Conclusion

In the context of the environmental and economic crises outlined in the report it is imperative to underscore that liquefied natural gas (LNG) should not be perceived as an environmentally clean solution. The adoption of LNG to address Pakistan's energy challenges brings with it a host of significant drawbacks and potential hazards that must not be overlooked. LNG, often touted as a cleaner-burning fossil fuel, still contributes to greenhouse gas emissions, thereby exacerbating climate change. Moreover, the methane leakage associated with LNG extraction and transportation poses an immediate and potent threat to the environment. Furthermore, the environmental impact of natural gas drilling, including habitat disruption and water contamination, cannot be underestimated. From an economic standpoint, the substantial capital costs required for LNG infrastructure development can burden the nation's finances. Additionally, relying excessively on LNG imports exposes Pakistan to energy security risks tied to global market fluctuations. Consequently, it is crucial to consider alternative, more sustainable energy sources, such as renewables, and weigh the economic and environmental trade-offs associated with LNG adoption. Addressing these concerns in a balanced manner is paramount to making informed decisions about Pakistan's energy future.

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