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Industrial Energy Efficiency to Curb Bangladesh's Short-term LNG Demand Growth

Imported fossil fuel dependence and fiscal strains call for more efficient use of energy

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Key Findings

Bangladesh's plan to power its economic development with LNG imports was not designed to cope with extreme global fuel market volatility, depreciation of the local currency and weak fiscal conditions.

Greater efficiency in gas-fired captive power generation and productive use of waste heat can reduce LNG imports by 50.18Bcf and save Bangladesh US$460 million a year.

This study finds that the average efficiency of industrial gas-fired captive generators is 35.38%, which can be improved to 45.2% with high-efficiency generators.

The high dependence on gas is raising import bills and with it, the tariffs paid by consumers. Bangladesh must urgently re-evaluate its energy strategy and take steps to improve energy efficiency to contain the growing demand for gas.

Executive Summary

Even as global fuel prices stabilise, Bangladesh struggles to import sufficient liquefied natural gas (LNG) to satisfy escalating demand. So rather than import more LNG, the country can save almost half a billion dollars a year by reducing demand for this highly volatile fossil fuel. The solutions do not lie offshore but closer to home, such as in replacing the nation's vast stock of ageing, inefficient captive gas-fired power generators. Replacing these with efficient models, which are readily available, may incur an upfront cost, but this study shows that the capital outlay for this is recouped between 1.5 and five years. The return on investment in waste heat recovery is only about one year. Weaning Bangladesh off its LNG imports will take time but decision-makers must plan and act now, lest the country is left exposed to the next global shockwave.

Cheap and subsidised natural gas has been the centrepiece of Bangladesh's energy system since the early '70s. Used extensively in power generation, industrial processes and other applications, gas has powered the country's economic progress.

However, the insatiable demand for gas outpaced local production, directly affecting the country's energy supply system. With limited success in renewable energy, spiralling gas demand in different sectors and concerns about long-term energy security, the government frontloaded efforts to import liquefied natural gas (LNG) to supplement local gas production.

Bangladesh entered the LNG market in 2018 with a modest import of 31.45 billion cubic feet (Bcf) of LNG. In 2023, imports swelled to 238.72Bcf, more than seven times the 2018 figure. Over the six years since 2018, rapidly rising imports in a volatile global market exposed Bangladesh's energy sector's weak financial health earlier than anticipated. This is a clarion call to listen and respond accordingly.

As we stand today, there is a need for policy-level intervention to assess the benefits of improving energy efficiency to contain increasing LNG demand in the short- to medium-term instead of only enhancing regasification capacity and increasing imports. There is also concern about the inefficient use of gas, for example, in captive power generation, which provides uninterrupted electricity supply to industries amid the lack of reliable grid electricity.

Bangladesh is unlikely to abandon LNG imports in the foreseeable future. However, to curb demand growth, it will need to draw on all available avenues, such as enhancing energy efficiency in captive power generation.

This report builds on available evidence and a survey conducted by IEEFA of 51 industries with 124 gas-fired captive generators with a combined generation capacity of about 250 megawatts (MW).

We find that the average efficiency of these generators is 35.38%, having improved from 30% identified in a previous assessment a decade earlier.[1] However, as 45.2% efficient generators are available in the market, there is scope for further improvement and an associated gas consumption reduction.

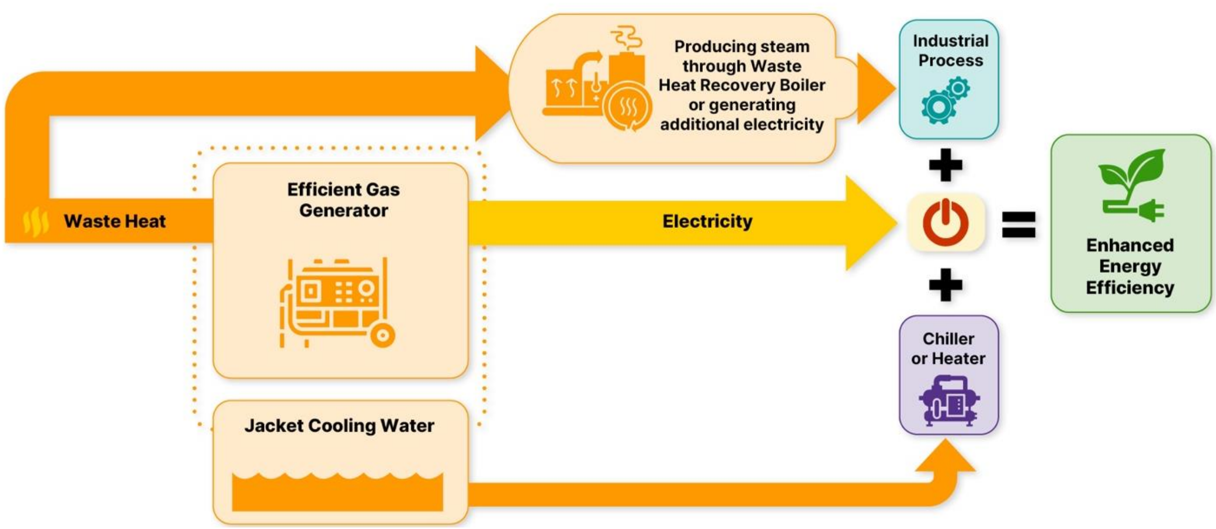
Moreover, this study finds that 54.28% of the sample generators have an operational age of more than eight years. Although age is not the only parameter affecting generator efficiency, when industries procured the old stock of generators, the rated efficiency was not as high as the efficiency of newly purchased generators. For this study, we ran a regression model to check the association between the age of generators and efficiency and found a strong correlation.

The payback of replacing inefficient generators is also quick (see Annexure 6).

This study further finds that 44.22% of industry samples do not use waste heat released by generators, while 79.6% do not use jacket cooling water in productive applications. By using the waste heat recovery boiler/plant and jacket cooling water in a chiller or heater, a substantial amount of gas can be saved. The return on investment for both interventions is lucrative.

This study, therefore, recommends replacing old and inefficient generators with 45.2% efficient generators and utilising both waste heat available in the exhaust gas and jacket cooling water to significantly enhance efficiency in captive generation (Figure 1).

Figure 1: Enhancing Energy Efficiency in Captive Power Generation



Source: IEEFA

The proposed energy efficiency measures can help Bangladesh reduce LNG imports by 21% and save US$460 million a year (see Annexure 5).

[1] Tetra Tech ES. Industrial Energy Efficiency Opportunities and Challenges in Bangladesh – Final Report. May 2014. Page 35.

Energy efficiency improvement in captive generation is highly expedient as the capacity of gas-fired captive generators exceeds 3,000MW. In some scenarios of the Integrated Energy and Power Master Plan (IEPMP), gas-fired captive generation will have an important role in the country's energy system right through to 2050.

The technical energy efficiency potential in captive power generation is attractive. Yet, the lack of credit facilities has often hampered the uptake of energy efficiency measures, despite their convincing financial returns. Low-cost financing vehicles available in Bangladesh can derisk investment in energy efficiency and mobilise private capital, but the pool of funds is limited.

Bangladesh Bank may consider establishing a dedicated low-cost revolving funding facility for industrial energy efficiency with support from multilateral development banks (MDBs), similar to the previous Financing Brick Kiln Efficiency Improvement Project.[2] With the rising demand for finance, Bangladesh may also look into bonds to raise funds, particularly for large energy consuming industries wanting to reduce energy consumption and minimise their environmental footprint.

With regulations for manufacturing environment-friendly products tightening around the world, any complacency in undertaking energy-saving measures will likely erode the competitiveness of industries. As the era of cheap energy comes to an end, and the government makes pricing more competitive in the foreseeable future, enhancing energy efficiency will be financially more rewarding.

While the path to limiting energy price spikes and import dependence has narrowed, it is still possible – if Bangladesh harnesses its strong energy efficiency potential and deploys renewable energy with greater ambition. Without decisive action, the window of opportunity may close sooner if all planned infrastructure for imported fossil fuels is built, and the country is locked into even greater dependence on imports, at the mercy of volatile global markets.

Bangladesh can accelerate the promotion of energy efficiency by building on policy foundations that are already in place. For instance, energy efficiency and conservation rules require mandatory energy auditing of designated consumers, including industries. The Sustainable and Renewable Energy Development Authority (SREDA), established to accelerate the deployment of clean energy, may design measures to swiftly scale up energy efficiency, both in captive power generation and industrial processes. Likewise, it may stimulate renewable energy deployment in the country by surmounting barriers. The government would also need to expedite investment in modernising the grid to attract industrial consumers to shift to grid electricity gradually. Such a comprehensive approach will reduce the country's dependence on gas far more than efficiency improvements in captive generation alone.

The country's highly import-dependent energy sector is prone to challenges, but a sense of urgency and firm commitment by policymakers can drive it towards a more secure and sustainable future.

[2] Bangladesh Bank. Quarterly Review Report on Green Banking Activities of Banks & Financial Institutions and Green Refinance Activities of Bangladesh April – June 2019. 2019. Pages 4-5.

Background

Bangladesh's energy and power sector disruptions are symptomatic of a high dependence on imported fossil fuels. The goal to ensure 100% electricity access and uninterrupted energy supply amid diminishing local gas production brought about a paradigm shift in the country's energy system. To enhance energy security, the country started importing liquefied natural gas (LNG) in addition to its huge reliance on foreign oil and coal in the energy mix.

While the plan to import energy for development hinged on the country's anticipated financial capacity, it was not designed to cope with the high level of volatility in the international fuel market, depreciation of the local currency and weak fiscal conditions. This is evident from the difficulty that Bangladesh experiences in importing fuel even when the international fossil fuel market has cooled.

> **Despite much discussion and enhanced ambition, progress in key areas, such as renewable energy deployment, has been limited.**

The outlook is dire as the energy sector has been overwhelmed by the turbulence in the global fuel market. Despite much discussion and enhanced ambition, progress in key areas, such as renewable energy deployment, has been limited. Installing solar home systems in off-grid areas improved the lives of rural people. However, since the country achieved 100% grid coverage in 2022, solar home systems have almost become stranded. Insufficient investment in local gas exploration has left Bangladesh with a hefty shortfall between demand and supply. The country is at a fundamental disadvantage as it does not produce enough energy apart from gas. Full energy independence may be a utopian dream, but the country must find ways to rein in its import dependence.

As gas is used extensively in different sectors and often inefficiently, assessing the avenues to reduce consumption and curb the increasing demand for LNG imports is timely.

A low-efficiency gas-fired captive power generator consumes a significant amount of gas annually. Despite a paucity of available data, this study assesses the existing level of efficiency at which different gas-fired captive generators operate in industries and to what extent their waste heat is recovered for productive applications.

We survey selected industries to collect operational data on energy production in generators and corresponding natural gas consumption to derive efficiency. We analyse what proportion of the industries are applying waste heat released by generators and the heat available in jacket cooling water in their processes. We then calculate the potential gas savings (equivalent to LNG import reduction) if old and inefficient generators are replaced with efficient ones and if industries use waste heat and jacket cooling water in other applications.

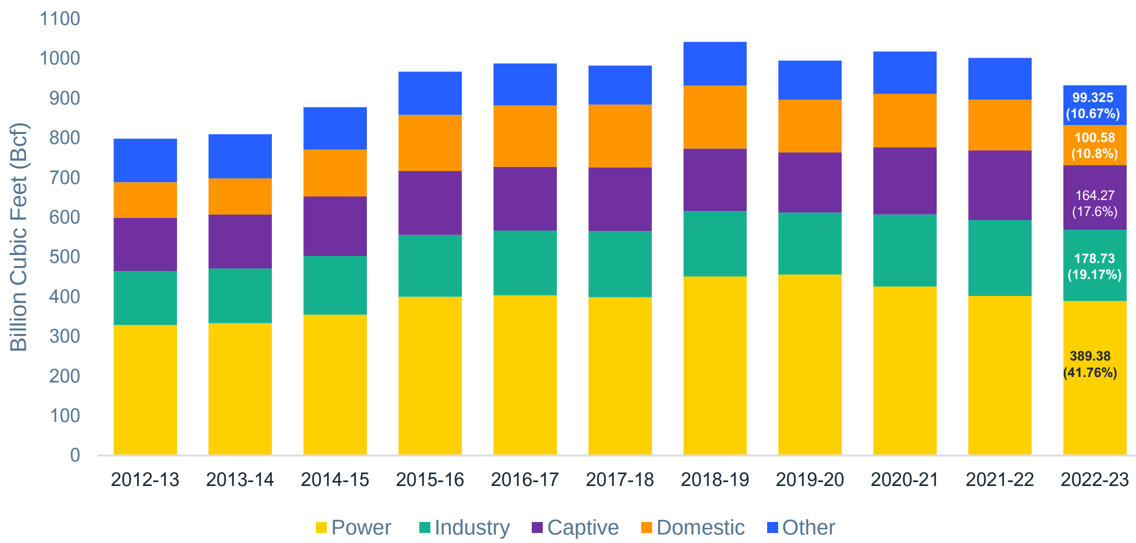
We identify key areas to be addressed on priority for a faster take-up of energy efficiency and to curb increasing LNG demand in the short-term. Finally, we provide a broader outlook for reducing LNG consumption in the long-term and the internal adjustments Bangladesh must make in the face of a volatile international energy market.

Brief Overview of Bangladesh's Natural Gas Sector

Sectoral Consumption Pattern

Bangladesh's economy relies considerably on natural gas, with no sign of abating in the foreseeable future. The power sector is the single largest contributor to national gas consumption, with a 41.76% share (389.38Bcf) in the fiscal year (FY) 2022-23. During FY2022-23, industrial processes, excluding fertiliser and tea production, and captive power generation consumed 19.17% and 17.6%, respectively. The remainder is used in sectors such as domestic, commercial, transport, and tea and fertiliser production.[3,4]

Figure 2: Sectoral Gas Consumption Pattern (FY2013-FY2023)

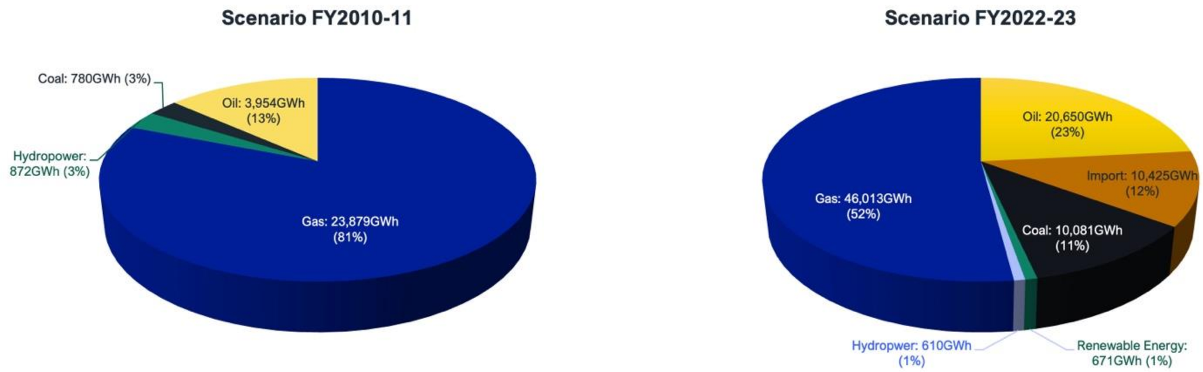


Source: Hydrocarbon Unit Annual Report 2022-23

Despite the government's strategy to diversify fuels, gas continues to dominate grid-based power generation in the country. A comparative evaluation indicates that Bangladesh diversified its fuel mix in power generation during the 12 years from FY2010-11 to FY2022-23, but the overall contribution of gas almost doubled in that time. Gas-fired energy production surged to 46,013 gigawatt hours (GWh) in FY2022-23 from 23,879GWh in FY2010-11, a 92.7% rise. Grid-connected renewable energy, however, increased only marginally while all fossil fuel-fired generation had a drastic uptick (Figure 3).[5,6]

[3] FY2022-23 means July 2022 to June 2023. As FY2022-23 is often written as FY2023 in Bangladesh, we use the same.
[4] Ministry of Power, Energy and Mineral Resources (MPEMR). Hydrocarbon Unit. Annual Report on Gas Production, Distribution and Consumption 2022-23. 26 November 2023. Page 36.
[5] Bangladesh Power Development Board (BPDB). Annual Report 2010-11. 1 August 2011. Page 16.
[6] BPDB. Annual Report 2022-23. 1 January 2024. Page 14.

Figure 3: Fuel Mix in National Electricity Grid (FY2011-FY2023)

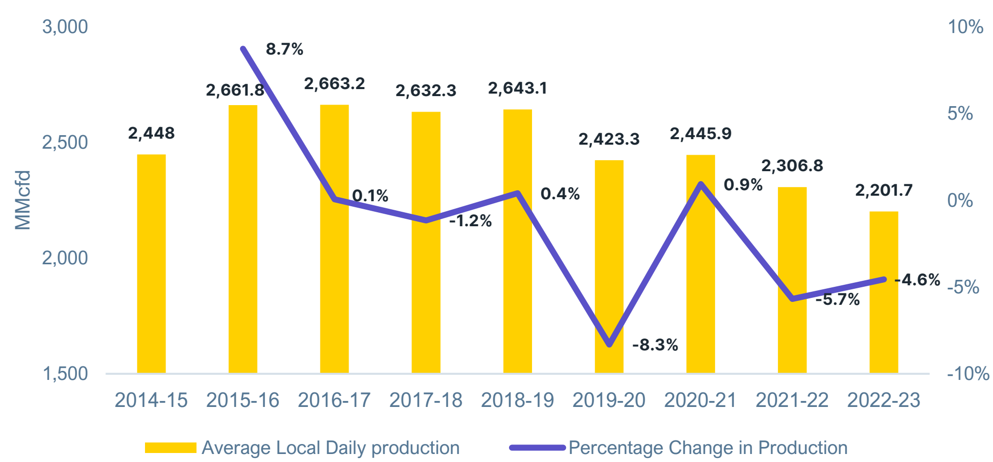


Sources: BPDB Annual Reports

Local Gas Production Waning

While optimism about the discovery of a huge quantum of local gas had encouraged the government to supply it to different sectors at a cheaper rate, insufficient investment in onshore gas exploration depleted local production.

Figure 4: Decreasing Trajectory of Local Gas Production (FY2015-FY2023)



Sources: Hydrocarbon Unit Annual Reports 2014-15 to 2022-23; IEEFA Analysis

Peak gas production, hovering around 2,600 million cubic feet per day (MMcfd), only sustained for four years from FY2015-16 to FY2018-19, declining gradually afterwards. Data demonstrates that local gas production in FY2022-23 contracted by 17.33% compared with FY2016-17 (Figure 4).[7] The delay in exploring onshore gas has further affected the sector and the country's energy security.

[7] MPEMR. Hydrocarbon Unit. Annual Reports on Gas Production, Distribution and Consumption 2014-15 to 2022-23. June 2017 – November 2023.

Bangladesh's Exposure to LNG

Drivers of Imports and Likely Future Dependence

Without any immediate solution to its energy sector challenges, Bangladesh saw LNG as the answer to its rising energy demands. Systemic challenges may make the country dependent on LNG imports well into the future (Table 1).

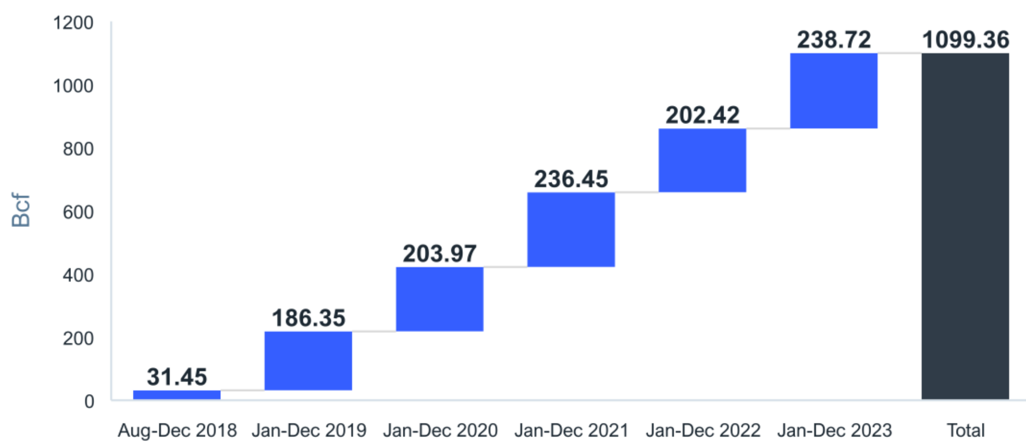
Table 1: Bangladesh's LNG Dependence

Drivers	
Economic	High and sustained economic growth in the pre-COVID era increased energy demand, tempting policymakers to shift to LNG as an alternative fuel.
Energy Use Pattern	Natural gas has shaped the country's energy and power sectors for decades, contributing considerably to the nation's development. The role of natural gas can be best understood from its use in important sectors of the economy and the energy mix of the power sector (see Figures 2 and 3).
Energy Security Concern	With shrinking local gas supply, investment and efforts to ramp up local production were inadequate. Fears of a drastic fall in local gas supply, compromising economic growth, prompted policymakers to import LNG. Although Bangladesh is home to one of the largest solar home systems programme in the world, overall success in renewable energy is limited (Figure 3). Uncertainty over renewable energy deployment at scale and the high cost of battery energy storage also influenced the decision to import LNG.
Systemic	Industries use gas extensively in processes and captive power generation. Grid power should have replaced gas-fired captive generation in the industry. But the reliability of grid power remains a concern, and captive power is still cheaper, incentivising export-oriented industries to use it for their cost competitiveness in external markets. These will likely prolong Bangladesh's LNG dependence.

LNG Import Trend

The completion of the first floating storage regasification unit (FSRU), with 500MMcfd capacity in August 2018, marked Bangladesh's entry into the LNG import era.[8] While it imported a modest 31.45Bcf of LNG that year, the trend rose steadily the following year as total regasification capacity reached 1,000MMcfd.[9,10] However, due to elevated spot market prices and tight fiscal conditions following Russia's invasion of Ukraine, Bangladesh reduced LNG imports in 2022. With falling prices, the country's LNG imports surged to 238.72Bcf in 2023, a 17.9% increase year-on-year (YoY) (Figure 5). Imported LNG comprised 23.57% of the country's total gas consumption in 2023.[11,12]

Figure 5: Annual LNG Import Trend



Sources: Petrobangla Annual Report 2018, Hydrocarbon Unit Monthly Reports January 2019 – December 2023; IEEFA Analysis

Growing Burden of Imported LNG

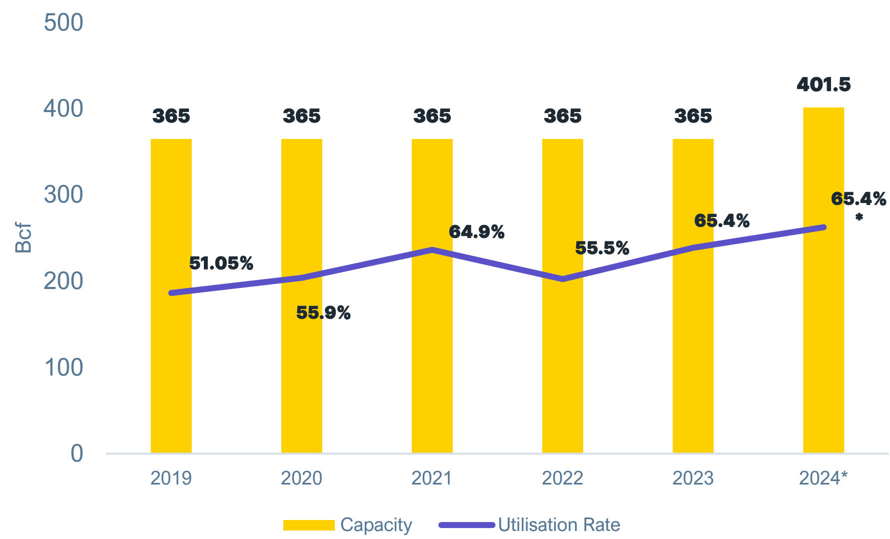
An analysis of the import trend shows that the highest capacity utilisation of FSRUs was 65.4% in 2023, followed by 64.9% in 2021.[13,14] However, high LNG prices had severe knock-on effects in the country's energy sector in 2022, compelling the government to reduce LNG imports to 55.5% that year. Bangladesh experienced over 1,000MW day-peak load shedding in eight of the fifteen months from August 2022 to October 2023.[15] After a brief spell of relief, load shedding reportedly soared to 3,196MW on 29 April 2024.[16] The unreliable supply of power and gas deterred industries from operating at full capacity, thereby affecting the economy.

[8] Petrobangla (Bangladesh Oil, Gas and Mineral Corporation). Annual Report 2018. 15 October 2019. Page 5.
[9] Ibid. Page 23.
[10] Petrobangla. Annual Report 2019. 28 December 2020. Page 7.
[11] MPEMR. Hydrocarbon Unit. Monthly Reports on Gas and Coal Reserve & Production - January 2022 to December 2023. March 2022 – March 2024.
[12] Calculated based on annual consumption and imports.
[13] In 2023, the LNG import was 238.72Bcf against the LNG terminal capacity of 365Bcf.
[14] In 2021, the LNG import was 236.75Bcf against the LNG terminal capacity of 365Bcf.
[15] IEEFA. Towards a Rooftop Solar Transition in Bangladesh. 18 December 2023. Page 16.
[16] United News of Bangladesh (UNB). Record Load Shedding of 3200 MW as Mercury Hits 43ºC Amid Heatwave. 29 April 2024.

Since the capacity of one FSRU has been increased by 100MMcfd, the country will be able to regasify 401.5Bcf of LNG onboard compared with 365Bcf in 2023 (Figure 6).[17,18&19]

As such, Bangladesh will incur an additional cost of US$219 million in 2024 if it regasifies imported LNG at the same rate as 2023.[20]

Figure 6: LNG Terminal Capacity vs Utilisation



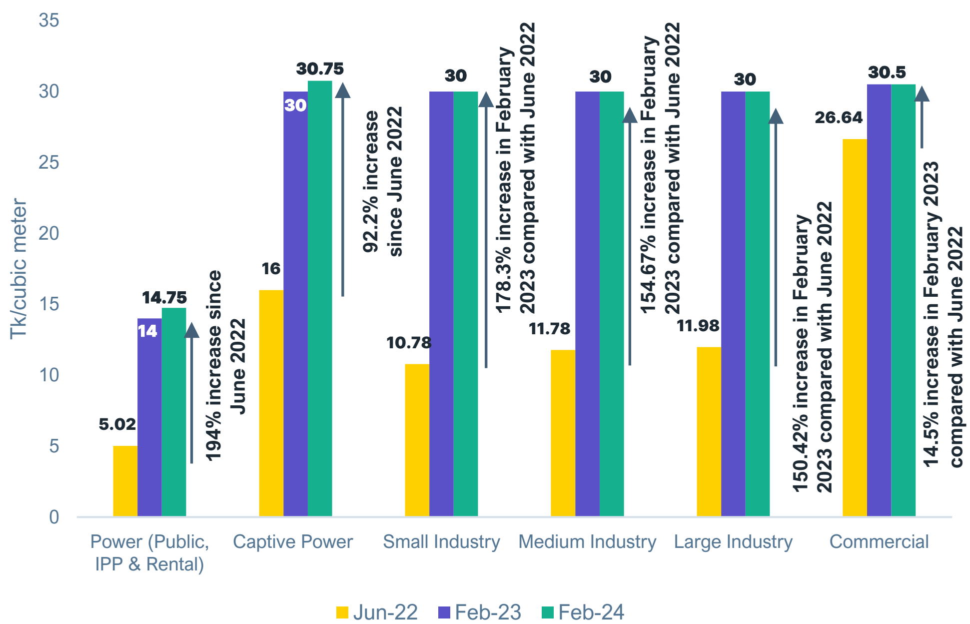
Sources: Petrobangla and The Daily Star; IEEFA Analysis.
**Assumed capacity utilisation of 65.4% (same as 2023) to calculate additional cost of LNG imports in 2024.*

Having been awarded a contract to build a new LNG terminal and a contract for another terminal likely to be approved soon, Bangladesh may have significant unused LNG capacity in 2026 and beyond. The situation calls for policy-level intervention to assess whether additional LNG terminal capacity will help in the short- to medium-term or whether measures such as energy efficiency to contain increasing LNG demand are more economical. As the private sector will mostly deal with the investment in energy efficiency without obligating the government to spend on imports or pay capacity charges, it will free up government resources.

Imported fossil fuel dependence has become an anathema to many consumers exposed to high energy costs. The government raised gas prices for selected sectors by 14.5% to 194% from February 2023 to February 2024 in two stages (Figure 7).[21,22&23]

[17] Petrobangla. Annual Report 2019. 28 December 2020. Page 7.
[18] The Daily Star. Govt to Buy LNG from Excelerate under 15-year Pact. 26 October 2023.
[19] Using conversion from MMcfd to Bcf.
[20] Additional LNG imports = (401.5Bcf * 65.4% - 238.72Bcf) = 23.86Bcf; 1Bcf = 0.966 trillion metric million British thermal units (MMBtu). Assuming a conservative price of US$9.5/MMBtu, the cost = US$219 million.
[21] Bangladesh Energy Regulatory Commission (BERC). Gazette on Prices of Gas at Consumer Level. 4 June 2022.
[22] MPEMR. Gazette on Gas Prices for Consumers of Different Distribution Companies under Bangladesh Oil, Gas and Mineral Corporation (Petrobangla). 18 January 2023.
[23] MPEMR. Gazette on Gas Prices for Power Plants and Captive Power Plants. 25 February 2024.

Figure 7: Rising Gas Tariffs in Selected Sectors



Sources: MPEMR & BERC; IEEFA Analysis

Reducing Short-term LNG Demand Growth

Raising tariffs is not the only solution to the unaffordability and/or fiscal burden of imported fossil fuels, as it affects people's living conditions and industries' competitiveness. Instead, Bangladesh should find ways to reduce its exposure to imported fossil fuels, which, if not addressed, will likely prolong the country's vulnerability to spiralling costs and energy insecurity.

While Bangladesh cannot move away from LNG imports in the foreseeable future, it can minimise increasing demand. Gas-fired captive power generation, which is often criticised for its inefficiency, is one area that can help contain gas demand, i.e., equivalent LNG consumption.

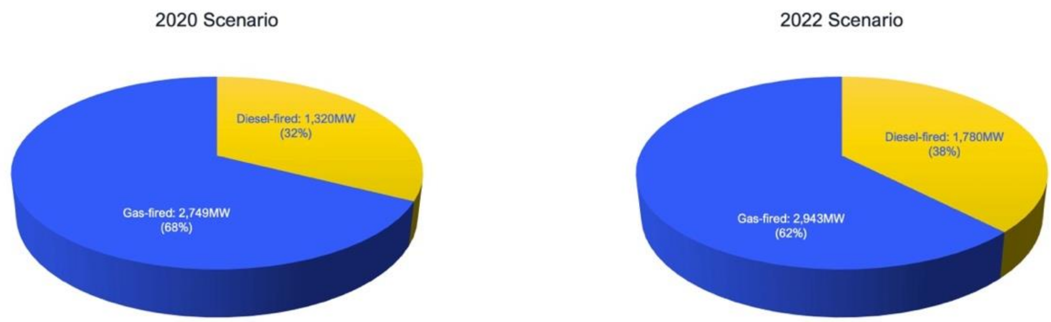
Gas-fired Captive Power Generation in Bangladesh

The Bangladesh government approved onsite captive power generation against the backdrop of electricity shortfalls and the urgency to support industries in the growing economy. However, the aggregate power capacity of captive generation units and corresponding energy consumption are jaw-dropping. Data from the Bangladesh Energy Regulatory Commission (BERC) shows that the total gas-fired captive generation capacity was 2,749MW in January 2020, representing 68% of the combined captive systems (Figure 8).[24] Despite the gas supply crunch in 2022, gas-fired captive

[24] BERC. Request for Expression of Interest for 'A Comparative Study on Grid versus Captive Power for Export Oriented Industry in Bangladesh – Past, Present and Future'. 28 January 2020.

systems increased, reaching 2,943MW in September 2022 against the total captive capacity of 4,723MW.[25] As such, gas-fired captive system capacity has likely crossed 3,000MW since then.[26] These generators consumed 164.272Bcf of gas in FY2022-23.[27]

Figure 8: Composition of Bangladesh's Captive Power Generation Units



Sources: BERC, 2020 and Prothom Alo, 2022; IEEFA Analysis

The Integrated Energy and Power Master Plan (IEPMP 2023) projected no role for conventional gas-fired captive systems in 2050 under a Net Zero greenhouse gas (GHG) emissions scenario and a minimal role in an Advanced Technology scenario. However, captive power generation plays a significant role in other forecasts. The PP2041 (Perspective Plan 2021-41) and In-Between scenarios estimated that gas consumption in captive generating would decline in 2030 from FY2022-23 levels and rise again until 2041 before touching a new low in 2050. [28,29,30&31] The Adjusted Gas Outlook, however, anticipated that gas consumption in the sector would jump in 2030 and then gradually decrease. In this outlook, demand for gas will be 32.5% and 15% higher in 2030 and 2041, respectively, compared with FY2022-23. Demand will decrease in 2050 but will still be at 80% of the FY2022-23 level.[32]

Therefore, gas-fired captive generation is likely to play an important role in 2050 in these scenarios (Figure 9).

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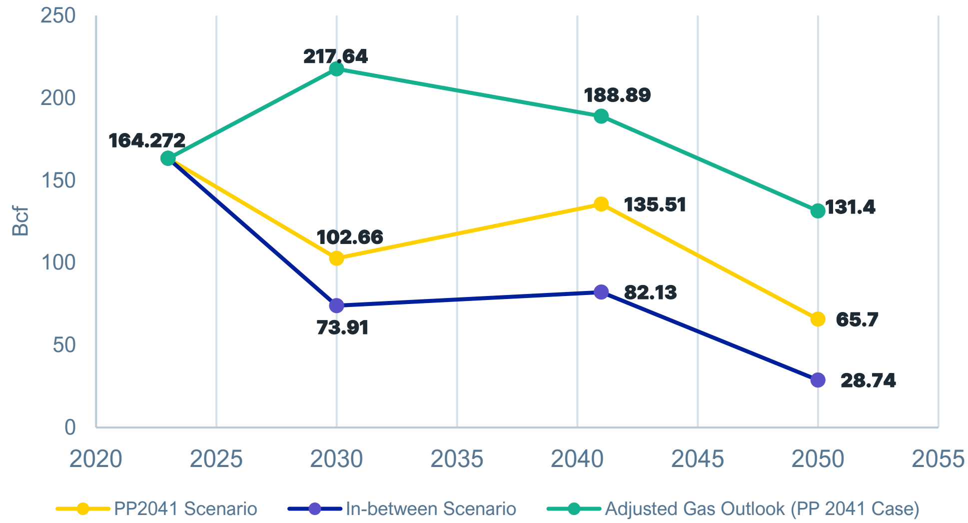
[25] Prothom Alo. Factory Owners Nevertheless Want Captive Power Plants. 25 September 2022.
[26] Due to the scope of the study, only gas-fired captive power generation is considered.
[27] MPEMR. Hydrocarbon Unit. Annual Report on Gas Production, Distribution and Consumption 2022-23. 26 November 2023. Page iv.
[28] PP2041 assumes growth rates compatible to transform Bangladesh into a developed country in 2041.
[29] In-Between scenario means the economic growth rate between the PP2041's projection and the IMF estimate.
[30] MPEMR. Hydrocarbon Unit. Annual Report on Gas Production, Distribution and Consumption 2022-23. 26 November 2023. Page iv.
[31] MPEMR. Integrated Energy and Power Master Plan (IEPMP) 2023. July 2023. Page 116.
[32] Ibid. Page 117.

Figure 9: Future Gas Outlook for Captive Power Generation



Sources: Hydrocarbon Unit Annual Report 2022-23; IEPMP 2023; IEEFA Analysis[33]

Inefficiency in Captive Power Generation

There are widespread concerns that captive power generation plants operate at a very low efficiency. Investment-grade energy audits carried out from December 2012 to November 2013 in 120 industries concluded that gas-fired captive power plants were operating at 30% efficiency. Few industries were using waste heat recovery boilers/plants to tap the benefits of heat released by captive generators. The study further demonstrated that no industries undertook measures to use jacket cooling water in a vapour absorption chiller or heater.[34]

However, new gas generators are more efficient and consume significantly less energy than older plants. For instance, gas generators with 45.2% efficiency are available in the local market.[35] Additionally, waste heat from generators, if utilised in suitable applications, can produce a combined energy efficiency of more than 90%.[36,37]

This study, therefore, attempts to analyse operational captive generation units to determine the gas-saving potential (equivalent LNG consumption) by enhancing energy efficiency.

The assessment of efficiency in gas-fired captive generation holds significance, given that several of IEPMP's projections show that gas-fired captive generation will continue in the foreseeable future.

[33] Gas demand in captive power generation = 2.5 million tonnes of oil equivalent (MToE) in 2030 under PP2041 scenario; 2.5MToE = 2.5*1000*365/(8.8887*1000) = 102.66Bcf (as per IEPMP)
[34] Tetra Tech ES. Industrial Energy Efficiency Opportunities and Challenges in Bangladesh – Final Report. May 2014. Page 85.
[35] Discussion with local suppliers.
[36] Applied Sciences. Model Investigation of Natural Gas Engine Performance to Achieve Variable Heat/Electricity Ratios for a CCHP System by Varying Spark Ignition Timings. 27 July 2022.
[37] 90% efficiency includes efficient generator with a waste heat recovery system and a chiller unit to use jacket cooling water.

Measures to Reduce LNG Demand Growth

This study delves into efficiency enhancement measures in captive power generation to reduce gas consumption (equivalent LNG imports) in the industry sector. Table 2 provides a summary of the scope and objective of the assessment.

Table 2: Interventions to Contain LNG Demand Growth and Methods for Analysis

Intervention	Methods for Analysis
Enhance energy efficiency of gas-fired captive generators	Comparative assessment of the efficiency of existing generators with the most efficient generators available in the market.
	Estimate the gas-saving potential of replacing the existing stock of generators with more efficient generators.
	Conduct a brief feasibility study of replacing inefficient generators based on operational years and the cost of procuring new generators.
Use waste heat of gas generators	Estimate the percentage of industry sampled that does not use waste heat.
	Calculate the potential to reduce gas if industries with gas-fired captive generators install waste heat recovery boilers or generate additional electricity by using waste heat.
	Assess the feasibility of a waste heat recovery system.
Utilise jacket cooling water in chiller and/or heater	Determine the proportion of industries not utilising jacket cooling water.
	Evaluate gas-saving potential if industries with gas-fired captive generators can use jacket cooling water.
	Examine the viability of using jacket cooling water in a chiller or heater.

Survey of Industries

A comprehensive energy audit of 120 industries, conducted from December 2012 to November 2013, estimated the efficiency level of captive generators at 30%.[38] However, it is likely that many industries have replaced their old generators in the past decade. Similarly, industries may have adopted energy-efficiency measures, such as waste heat recovery boilers/plants, and are utilising jacket cooling water in a chiller or heater. This is due to growing awareness of energy inefficiency in industries. Energy audit programmes supported by multilateral and bilateral agencies continue to

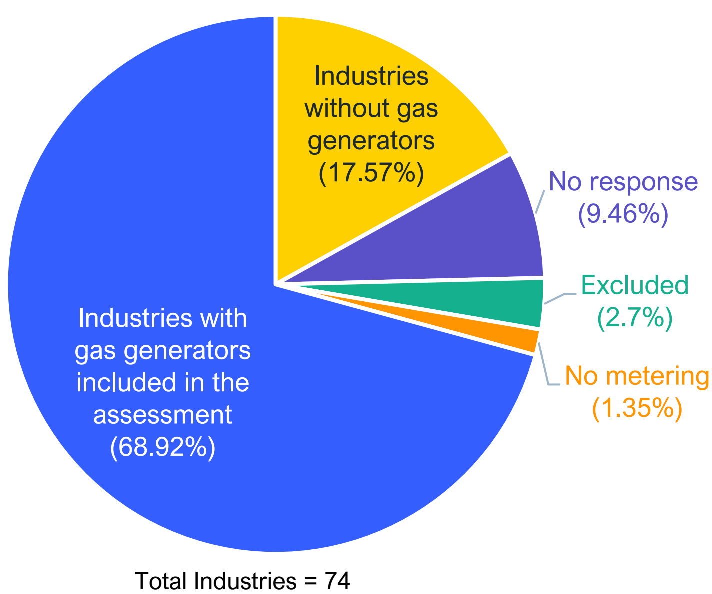
[38] Tetra Tech ES. Industrial Energy Efficiency Opportunities and Challenges in Bangladesh – Final Report. May 2014. Page 35.

promote opportunities and economics of energy efficiency in industries. Additionally, the government increased energy prices drastically and in quick succession in the past two years, which means the financial return from energy efficiency improvements is more convincing today.

Therefore, to assimilate accurate information and data on the efficiency level of gas generators with minimal error, this study surveys 74 industries from the garment, textile, steel, pharmaceutical, chemical and fertiliser sectors (see Annexure 1 for an overview of the information collected in the survey).

Of the 74 industries surveyed, 17.57% have diesel generators only and, as such, are excluded from further analysis. The 68.92% of industries that have gas generators and metering systems in place are included in the study (Figure 10). The remaining samples have either not responded or lack suitable meters to monitor gas consumption. A few of these samples, which have provided inflated electricity production data or reduced gas consumption data, are not included in the assessment.[39]

Figure 10: Summary of Industries Surveyed



[39] In a few cases, calculations show that the efficiency of electricity generation crosses even 48% whereas the generators with the highest efficiency in the local market are at 45.2%. Such samples have been excluded from the assessment.

Below is a summary of the eligible industries:

Table 3: Snapshot of Industry Samples

Industry Samples with Gas generators	**51**
Type of Industries	Garment, textile, steel, chemical, fertiliser, pharmaceutical etc.
Total Operational Gas Generators in Surveyed Industries	124
Total Gas Generators Considered as Samples (some industries have common gas meters for multiple generators and, as such, multiple generators with a common meter are considered one sample)	73
Combined Gas-fired Captive Generation Capacity of the Sample Industries	~250MW[40,41]

Gas-fired captive generation capacity of approximately 250MW considered in this study represents about 8% of the sector's capacity. Since collecting data from industry poses challenges, the study contemplates that 250MW power generation capacity of 124 generators from 51 industries provides an excellent overview of the level of efficiency in gas-fired captive power generation and the status of using waste heat recovery boiler/plant and jacket cooling water.

As different industries have common meters for multiple generators, the sample size of generators becomes 73 (Table 3). However, a sample size of 73 is acceptable at 90% confidence interval. This is because the minimum sampling requirement here is 68.[42,43]

Efficiency of Operational Captive Generators

Despite the speculation about the very low efficiency of gas-fired captive plants, this assessment finds that the average efficiency of the sample generators is 35.38%. However, their efficiency ranged from a low of 27.08% to as high as 45.2%.[44]

The improved average efficiency level of 35.38% compared with the previously identified 30% demonstrates the strong commitment of industries to strive for enhancing energy efficiency. Notably, the managements of some sample industries have already taken decisions to change their inefficient

[40] Some industries have not provided data of total generation capacity. That number would have increased total generation capacity of the sample industries.

[41] Total gas-fired captive generation capacity was 2,943MW in September 2022 and it has already crossed 3,000MW. This is because some industries have recently received gas connections for their generators.

[42] Sample size = $Z^2 * p * q / e^2 = (1.645^2 * 0.5 * 0.5 / 0.1^2) = 68$ (the Cochran's formula is used for unknown population size); Here Z is 1.645 for 90% confidence level, p = 0.5, q = 1 – p = 0.5, e is 10%

[43] International Journal of Economics, Commerce and Management. Sampling Techniques & Determination of Sample Size in Applied Statistics Research: An Overview. Volume II, Issue 11. November 2014.

[44] Efficiency is calculated from the gas consumption to produce 1 unit of electricity. See Annexure 2 for details.

gas generators. Several sample industries have realised the cost-saving potential of replacing inefficient generators.

The generator efficiency dataset shows an almost normal distribution (Figures 11 and 12).[45]

Figure 11: Distribution of Efficiency of Sample Gas-fired Generators

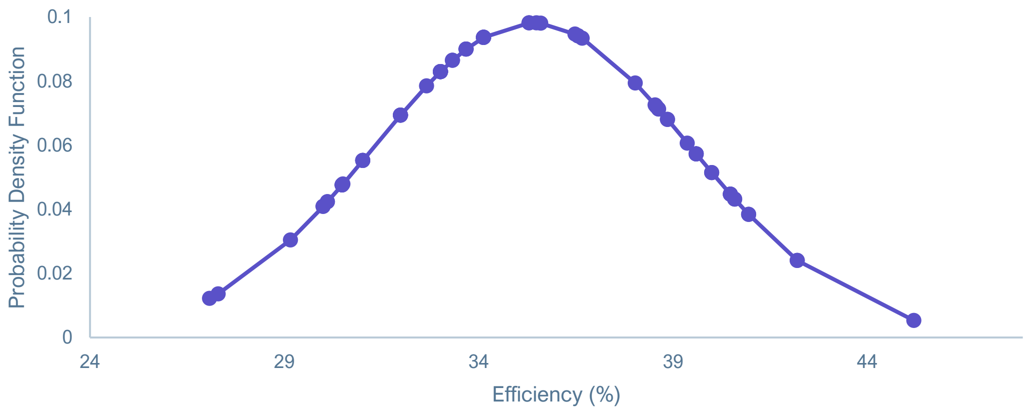
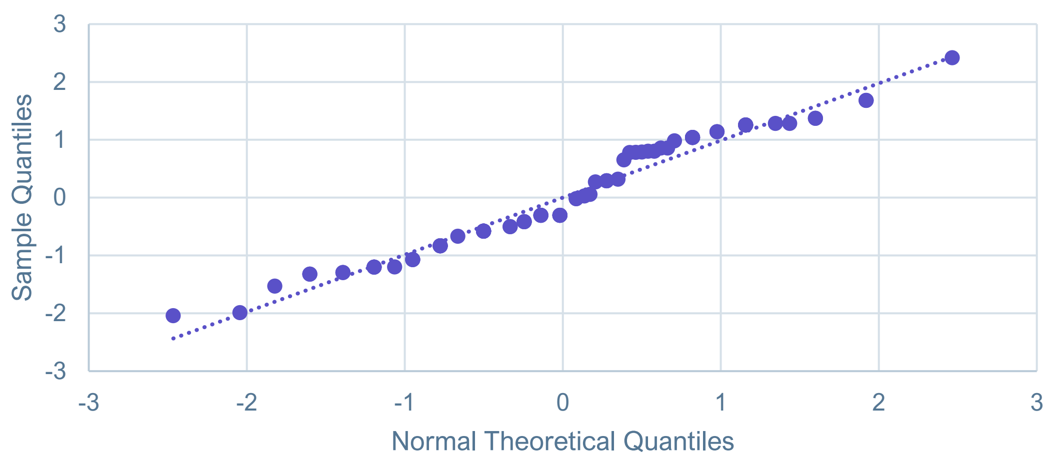


Figure 12: Quantile-Quantile Plot[46]

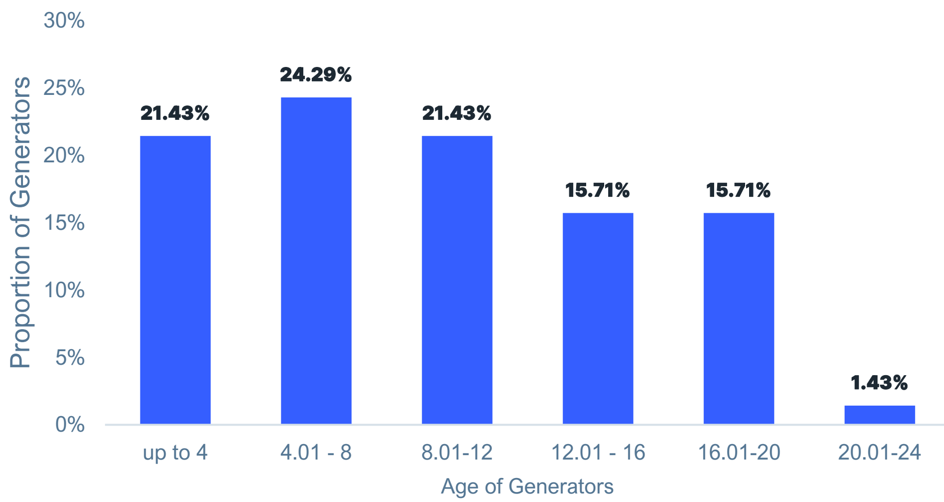


As such, the chance of mean efficiency of 35.38% to represent the sample generators is more.

Replacing inefficient generators involves capital investment, and is not always financially viable if the existing ones are new. The survey finds that 54.28% of the sample generators have been operational for more than eight years (Figure 13).

[45] Skewness and kurtosis of 0.12895 and -0.8578 indicate that the efficiency of generators is almost normally distributed (see Annexure 3 for descriptive statistics)
[46] A Q-Q plot helps assess whether a set of data is normally distributed or not. See Annexure 3 for examples of data used.

Figure 13: Age Distribution of Sample Generators



A regression model is run to gauge to what extent age (operational years) affects the level of efficiency within the samples. The regression shows that with increasing age, the energy efficiency of a generator decreases (note: age is not the only parameter that affects efficiency).[47] The relation between efficiency and age is found to be statistically significant (Table 4 and Annexure 4).

Table 4: Summary of Regression

Output	Value	Interpretation
Coefficient (of age)	-0.524	The slope is negative. This indicates that with increasing age, efficiency of a generator decreases.
Correlation Coefficient (R)	0.749	It shows a strong correlation between efficiency and age of a generator.
P	7.9E-14	The assessment is statistically significant.

Therefore, the industry sector may attempt to gradually improve the average captive power generation efficiency of 35.38% to the level of the highest efficient generators.

Use of Waste Heat Released by Generators

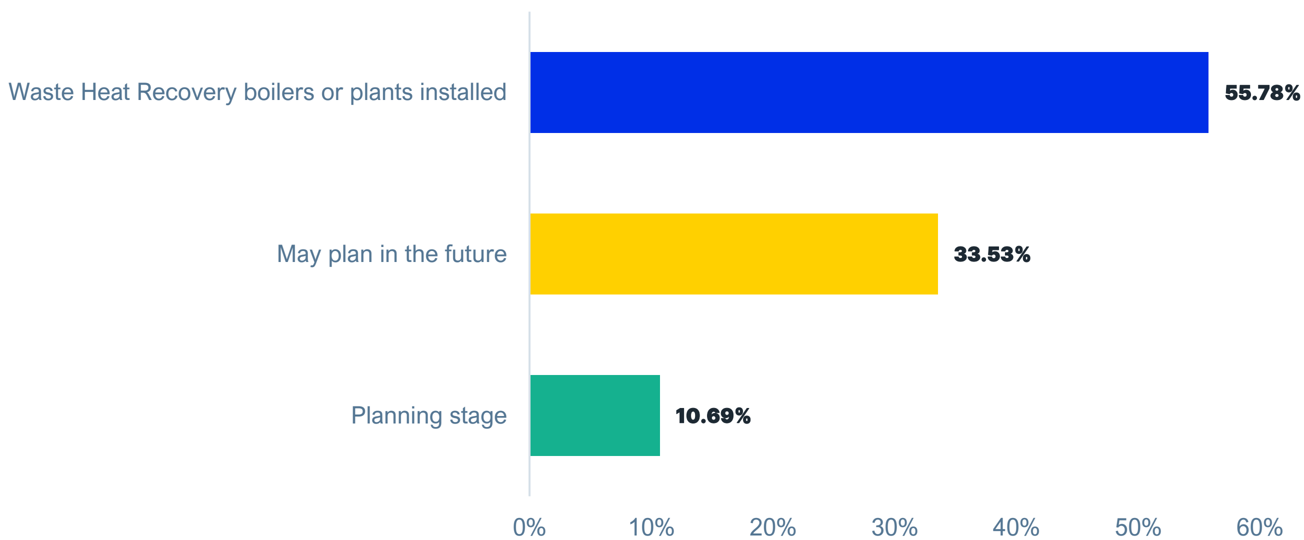
The survey results provide an impression of the present status of waste heat recovery in different industries. A thorough analysis reveals that 55.78% of the sample industries have either installed

[47] Parameters, such as how well generators are maintained, load factor etc., also affect efficiency. However, it is likely that very old generators are less efficient due to wear and tear. Also, the latest version of generators has higher efficiency.

waste heat recovery boilers to use heat in their processes or waste heat recovery plants to generate additional electricity. This is a significant improvement in the decade as a previous study conducted from December 2012 to November 2013 concluded that the use of waste heat in industries was limited.[48] Increasing awareness, rising energy costs and the goal to reduce GHG emissions, particularly for the garment and textile sectors, catalysed this transformation.

While 10.69% of the industries sampled would like to install waste heat recovery boilers or plants in the foreseeable future, 33.53% have not made any concrete plans. The utility sections of the industries report that their energy savings from utilising waste heat range from 20% to 22%. As waste heat of generators can reduce a significant amount of energy, and 44.22% of the industries still can tap into the benefit, this area deserves more attention.

Figure 14: Status of Waste Heat Application in Boiler or Plant

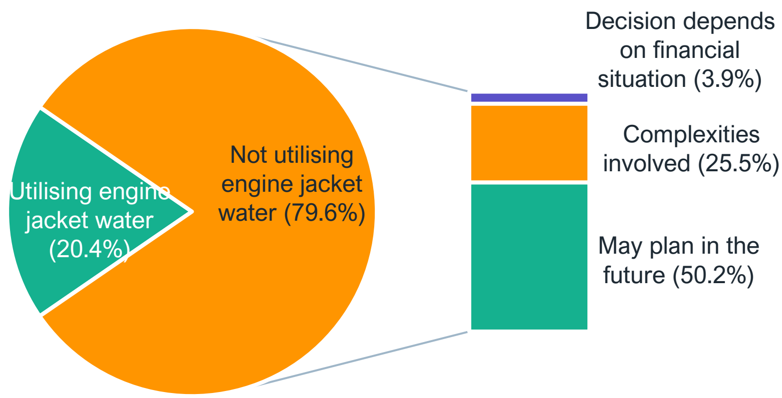


Application of Jacket Cooling Water

Despite the notable progress in recovering waste heat released by gas generators in the last decade, using jacket cooling water in a chiller or heater has changed little. Only 20.4% of the industries sampled are utilising the benefits of jacket cooling water by operating a vapour absorption chiller. Although more than a quarter of the samples experience complexities in using jacket cooling water, more than half may consider using jacket cooling water in the future.

[48] Tetra Tech Es, Inc. Industrial Energy Efficiency Opportunities and Challenges in Bangladesh – Final Report. May 2014. Page 85.

Figure 15: Status of Utilising Jacket Cooling Water in Industries



Industries that are benefiting from jacket cooling water have shared that the intervention can save energy by up to 22%.

Estimating LNG Consumption Reduction Potential

During FY2022-23, the combined gas consumption in captive power generation was 164.272Bcf.[49] This study sheds light on three areas – replacement of inefficient generators, installation of waste heat recovery boilers/plants and utilisation of jacket cooling water – to reduce gas consumption and thus help limit LNG demand growth.

Energy Saving and Import Bill Reduction Potential

This study assumes that sample industries and generators examined for assessing energy efficiency are representative of the industry sector. As the average efficiency level of gas generators is 35.38%, based on the samples, a gradual shift towards replacing them with 45.2% efficient generators would lead to a reduction in annual gas consumption, i.e., equivalent LNG import. Other measures, such as the installation of waste heat recovery boilers/plants and the productive use of jacket cooling water, would save energy too. The combined LNG saving potential would reach 50.18Bcf a year, providing Bangladesh an opportunity to cut imports by 21% a year. This is equivalent to an annual reduction of imports worth US$460 million (Table 5 and Annexure 5).

[49] MPEMR. Hydrocarbon Unit. Annual Report on Gas Production, Distribution and Consumption 2022-23. 26 November 2023. Page iv.

Table 5: Estimated Savings[50]

Measures	Natural gas or equivalent LNG saving potential per year (Bcf)
Replacing inefficient gas generators with high-efficiency generators	35.5
Installation of waste heat recovery boilers/plants	9.11
Using jacket cooling water	11.15
Subtotal	55.76
Assuming 10% error	- 5.58
Total	50.18 This saving potential is 21% of the total LNG imported in 2023[51]
LNG saving potential: 48.47 x 10^6 metric million British thermal units (MMBtu) a year	
Total import bill reduction: US$460 million	

Feasibility of Investment in Energy Efficiency

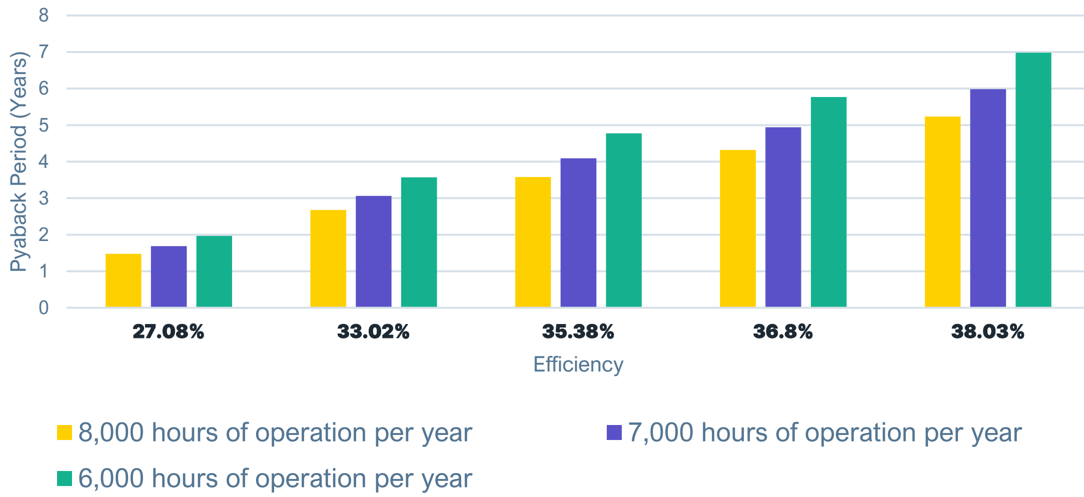
Energy efficiency requires upfront capital investment. Often, a lack of concrete assessment deters highly convincing energy efficiency investments. This section provides a brief overview of the feasibility of investment in three energy efficiency measures considered in the study.

The financial analysis substantiates that industries with generators of up to 36.8% efficiency and operational hours of 7,000 hours a year will recover the investment in 45.2% efficient generators in less than five years (Figure 16 and Annexure 6). This could be achieved even earlier as many industrial gas generators operate up to 8,000 hours a year. Notably, if an industry operating a 38% efficient generator for 8,000 hours a year installs a 45.2% efficient generator instead, the payback period at current tariffs will be about five years.

With rising gas prices, the replacement of even 39% efficient generators would be a good investment.

[50] See Annexure 5 for details.
[51] In 2023, Bangladesh imported 238.72Bcf of LNG; The country can reduce imports by (50.18Bcf * 100 /238.72Bcf) = 21%.

Figure 16: Payback Periods of Replacing Existing Generators with Efficient Ones



Therefore, replacing inefficient generators with 45.2% efficient ones is an economically prudent decision.

Installing a waste heat recovery boiler is also financially rewarding. The payback period is up to 1.3 years (see Annexure 7). Likewise, energy savings from jacket cooling water will help recover the investment in chiller or heater very quickly (see Annexure 8).

Implications of Enhancing Efficiency

Economic

Efficiency enhancement in captive power generation and tapping heat for productive use, which otherwise is wasted, can offer a multitude of benefits at the micro level. As energy bills soar, industries can contain per-unit production costs through energy efficiency and thus improve their competitiveness.

Amid increasing pressure from buyers for clean energy to be used in garment manufacturing and tighter international regulations, such as the carbon border adjustment mechanism, industrial energy efficiency will remain relevant. Notably, energy efficiency is the cheapest way to mitigate GHG emissions.

At the macro level, energy savings will boost the economy by reducing import bills by US$460 million a year and relieve growing strains on foreign currency reserves. Estimated annual natural gas savings of 50.18Bcf represent 21% of the LNG imported in 2023 (Table 5 and Figure 5).

Energy Security

Despite achieving the commendable feat of 100% grid electricity coverage, energy-supply disruptions have plagued Bangladesh's power sector in recent years. Likewise, gas rationing to vital sectors, such as industries, is rampant with no sign of any immediate relief. With grid-scale renewable energy capacity still at a low level and a major boost in local gas production in the short-term unlikely, reducing LNG demand growth, backed by energy efficiency, will help Bangladesh enhance its energy security.

Policy

The energy efficiency and conservation master plan stipulates that Bangladesh will reduce 20% of primary energy consumption per gross domestic product (GDP) in 2030 compared with 2013.[52] The country has also pledged to double its energy efficiency rate by 2030.[53] Hence, enhancing efficiency in captive power generation and utilising waste heat will be vital to achieving these goals.

However, the take-up of energy efficiency and its sustainability depend heavily on policy and monitoring. SREDA would need to motivate industries to deploy energy-efficiency measures on the ground. SREDA should further ensure the mandatory reporting of industries on annual energy consumption, based on energy audit reports. This reporting is a fundamental tenet of the revised energy efficiency and conservation rules.[54]

Furthermore, the crisis triggered by imported fossil fuel dependence and price volatility in the international energy market in 2022 offers Bangladesh an opportunity to rectify its energy course. It calls for policy-level intervention to gauge whether expanding LNG terminal capacity and thereby intensifying import dependence will help the country in the short- to medium-term or undertaking prudent measures such as energy efficiency to contain the increasing LNG demand is more compelling.

Finance

Despite attractive financial returns, energy efficiency projects are often under-implemented due to challenges in investment. Discussions with industry representatives highlight that low-cost financing vehicles could garner more interest to quickly realise energy efficiency opportunities.

Low-cost financing schemes available include Bangladesh Bank's refinancing scheme, which is open to environment-friendly projects in 70 categories. The competition for the Bangladeshi taka (Tk)4 billion (US$36.4 million) facility is so high that many projects with excellent credit reports may miss out due to limited funds.[55]

[52] SREDA. Energy Efficiency and Conservation Master Plan up to 2030. May 2016. Page 6.
[53] COP28, United Nations Climate Change. Global Renewables and Energy Efficiency Pledge. December 2023.
[54] MPEMR. Revision of The Energy Efficiency and Conservation Rules, 2016 (S R O No. 10-Act/2023). 1 February 2023.
[55] IEEFA. Towards a Rooftop Solar Transition in Bangladesh. 18 December 2023. Page 40.

Bangladesh Bank also has a refinancing facility, known as the Green Transformation Fund, including US$200 million, €200 million and Tk5 billion (US$45.45 million) for export-oriented industries to implement green measures. The Euro component of the fund also covers raw material imports.[56]

Additionally, Bangladesh Bank offers a refinance facility of Tk10 billion (US$90.9 million) for technological development/upgrades of export-oriented industries.[57]

Energy efficiency is one of the key financing avenues of the Infrastructure Development Company Limited (IDCOL). Among other schemes, it has a US$256.5 million facility to finance energy-efficient equipment in garment and textile industries under a green climate fund project.[58]

The Bangladesh Infrastructure Finance Fund Limited (BIFFL), supported by international agencies, provides debt finance to improve energy efficiency in industrial enterprises.[59] However, none of the refinancing schemes on offer from Bangladesh Bank are dedicated to industrial energy efficiency enhancement.

While these low-cost financing facilities can derisk investment in energy efficiency and mobilise private capital, the size of the pool is dwarfed by the volume of finance needed to foster industrial energy efficiency in Bangladesh.

Also, interest rates for commercial loans in the local market have soared from single to double digits with Bangladesh Bank's monetary tightening policy for price and macro stability, making clean energy investment with a commercial loan harder. Notably, energy-efficient technologies, which have relatively higher frontloaded investments, are lucrative when interest rates are low.

Therefore, the role of multilateral development banks (MDBs) will remain important. Bangladesh Bank may consider establishing a dedicated low-cost revolving funding facility for industrial energy efficiency with support from MDBs similar to the previous Financing Brick Kiln Efficiency Improvement Project to move towards the rapid deployment of energy-efficient technologies in industries.[60]

As demand increases, Bangladesh may also look to the bond market to raise funds, particularly for large energy-consuming industries. As a sustainability-linked bond has already been issued for electric mobility, this can work for large industries intending to reduce energy consumption and thus reduce their environmental footprint.

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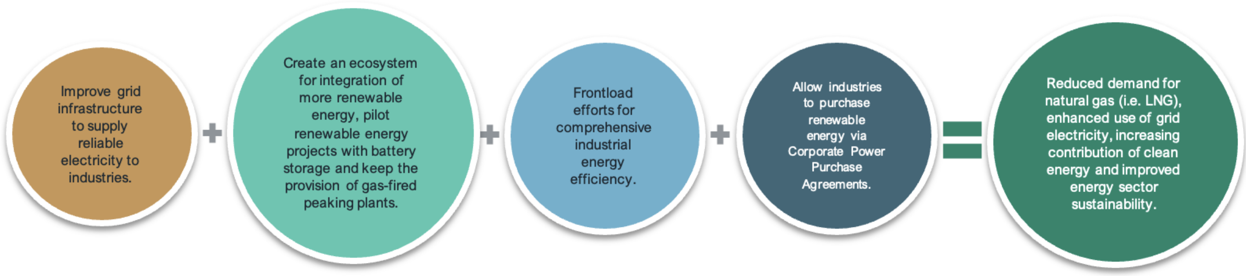
[56] Bangladesh Bank. Quarterly Review Report on Sustainable Finance of Banks & Financial Institutions April – June 2023. 2023. Pages 15-16.
[57] Ibid. Page 16.
[58] IEEFA. Revised Tariffs Make Clean Energy Compelling for Bangladesh. 22 April 2024.
[59] Bangladesh Infrastructure Finance Fund Limited (BIFFL). What We Do. 2024.
[60] Bangladesh Bank. Quarterly Review Report on Green Banking Activities of Banks & Financial Institutions and Green Refinance Activities of Bangladesh April - June 2019. 2019. Pages 4-5.

The Bigger Picture

Bangladesh's energy landscape is changing – albeit at varying speeds – and exposing different challenges of the sector while also identifying opportunities to help the country in the short- and long-term. This is where a well thought out approach is highly expedient. This study proposes a four-step approach to curb Bangladesh's long-term LNG demand, and enhance the energy sector's sustainability.

Figure 17: Pathway to Reduce LNG Demand and Enhance Power Sector Sustainability



Source: IEEFA

Tellingly, the Perspective Plan 2021-41 (PP2041) and interim gas outlooks under the IEPMP show a reduced role of natural gas-fired captive power generation in 2050 compared with 2023. Although the adjusted outlook predicts a greater contribution of gas in captive generation, Net Zero and Advanced Technology scenarios project a minimal role of gas-based captive power in 2050. Understandably, the country will not move away from gas-fired captive generation quickly but likely plan for a decreasing gas supply to captive power generation in the future. As such, to align the gas outlook for captive generation with the power sector development plan, Bangladesh would need to focus on improving the reliability of grid electricity to encourage industries to shift to the grid gradually. The measure is also imperative in view of the country's subdued power demand growth vis-a-vis its projected power system capacity. This will require grid modernisation by the government.

The challenge is also evident from the country's ongoing import dependence, which puts energy and power sector institutions at risk of further financial strain. Slowing the business-as-usual transition and reshaping the energy landscape to create an ecosystem for renewable energy expansion and sustainability are essential. Given the high existing and projected excess in baseload power capacity, power sector planning must recognise that excessive baseload capacity will limit the growth of renewables without battery backup. The government may consider some simple cycle gas-fired plants in lieu of all combined cycle plants to allow renewable energy use during peak hours. Alternatively, while phasing out the old combined cycle gas-fired plants in the foreseeable future, the government may only keep the gas turbine for meeting peak demand. This will help the country increase variable renewable energy and cater to peak demand when renewable energy is not available. Additionally, piloting some renewable energy projects with battery backup for a couple of hours would generate cheaper electricity than oil-fired peaking power plants.

The industry sector is a big gas consumer at the aggregate level. In addition to captive power generation, gas is used in production processes, providing further energy efficiency opportunities. While industries pursue energy efficiency in different areas, frontloading efforts in both captive power generation and processes will help to significantly reduce gas consumption in the long-run. The amended energy efficiency and conservation rules stipulate the timeline of mandatory energy auditing of different designated consumers, including industries.[61] Bangladesh can build on this to accelerate the momentum of comprehensive industrial energy efficiency.

Finally, the apparel and textile manufacturing industries of Bangladesh are the first to feel the pressure of mitigating their GHG emissions but they are not likely to be the last. Growing requirements for environmental, social and governance (ESG) across the globe and rising awareness of stakeholders on reducing environmental footprints may compel other export-oriented industries to follow suit. Stringency of future international regulations similar to the carbon border adjustment mechanism may have knock-on effects for other industries in Bangladesh. The existing threshold for implementing rooftop solar of up to 70% of an industry's sanctioned load and energy efficiency measures are unlikely to help meet the mitigation target. For instance, the apparel industry is in an improbable situation to achieve a 30% mitigation goal by 2030 with rooftop solar and energy efficiency. However, to remain on track to attain the 30% goal, the apparel and textile industries may need to procure renewable energy through corporate power purchase agreements as implemented in other countries. The government will need to be more open to allowing private sector renewable energy projects to sell electricity to industries, using the relevant distribution lines of the utilities by paying the agreed fees.

The four steps, outlined above, will not only reduce long-term increasing LNG demand but also help ailing public sector utilities to reduce their vulnerabilities and transition towards sustainability.

Recommendations and Way Forward

The volatile and elevated international energy market in 2022 had serious knock-on effects for Bangladesh's energy system due to the unaffordability of importing enough fossil fuels, including LNG. Although LNG imports surged by 17.9% in 2023, following affordable prices in the spot market, the capacity utilisation of LNG terminals only reached 65.4%. As regasification capacity has increased by 10%, the country will incur an additional cost of US$219 million in 2024 to maintain the previous year's capacity utilisation rate. Notably, the government has awarded a contract for new LNG capacity expansion in light of the uncertainty over local gas production and the rising need for fuel in gas/LNG-fired power plants.

As Bangladesh's dependence on LNG raises import bills, consumers are feeling the impact of higher gas prices. The country must heed the warnings of the global supply disruptions that exposed the weak financial health of Bangladesh's energy sector and re-evaluate its energy strategy.

[61] MPEMR. Revision of The Energy Efficiency and Conservation Rules, 2016 (S R O No. 10-Act/2023). 1 February 2023.

Increasing LNG regasification capacity may help in the short- to medium-term. However, undertaking energy efficiency measures, particularly in captive power generation, to contain increasing LNG demand makes more sense.

Building on evidence and a survey, this study proposes efficiency-enhancement measures in captive gas-fired power generation units to curb the country's trend of increasing LNG demand (Figure 18).

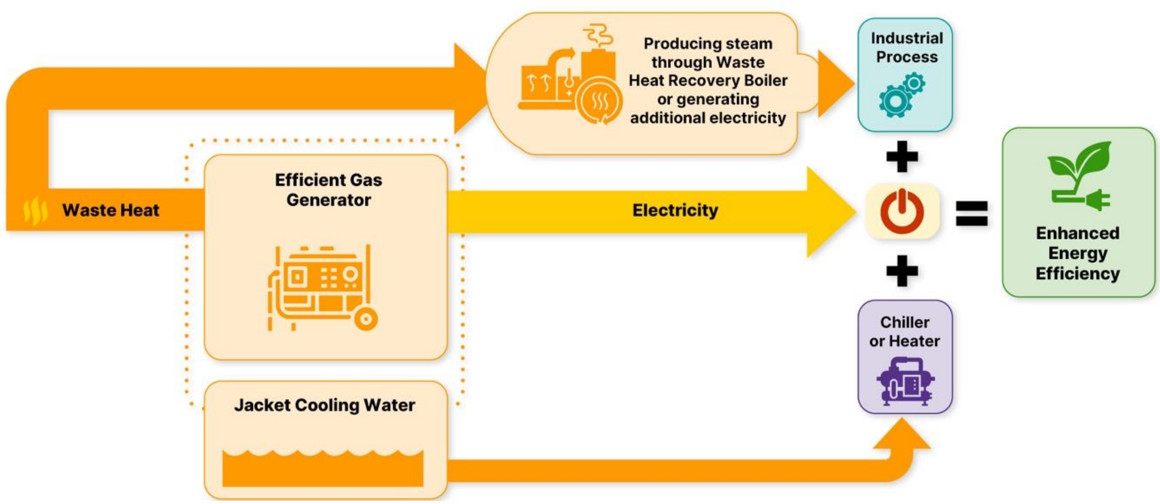
Despite a decade of improvement, this study finds that the average efficiency of gas-fired captive generators is 35.38% as opposed to the availability of 45.2% efficient generators in the market.

Waste heat released by gas generators and the heat available in the jacket cooling water also offer significant gas saving potential.

Therefore, IEEFA recommends replacing old and highly inefficient generators with 45.2% efficient generators and utilising waste heat and jacket cooling water.

Industries would face the upfront costs of installing efficient generators, waste heat recovery boilers/plants and chillers/heaters, but these investments will deliver long-term savings. Financial analysis shows that these investments have a quick payback period.

Figure 18: Enhancing Energy Efficiency in Captive Power Generation



Source: IEEFA

The upside is that energy efficiency interventions, if implemented prudently, will create a better economy, by reducing import bills and helping stabilise foreign currency reserves.

On a conservative estimate, Bangladesh can reduce up to 50.18Bcf of LNG imports a year through energy efficiency in captive power generation. This represents an opportunity to minimise LNG consumption by 21% and save up to US$460 a year.

The study holds significance as different outlooks of IEPMP, excluding Net Zero and Advanced Technology scenarios, show a vital role for gas-fired captive generation until 2050.

With international regulations on producing environment-friendly products likely to become more stringent, delays in undertaking measures to save energy will likely erode the business competitiveness of Bangladesh's industries. As the era of cheap energy comes to an end, with the government likely to make energy pricing more competitive in the foreseeable future, enhancing energy efficiency will be financially more rewarding.

While the low-cost financing facilities available in Bangladesh can derisk investment in energy efficiency and mobilise private capital, the size of the pool is tiny compared with the volume of finance needed to foster industrial energy efficiency. Furthermore, interest rates for commercial loans have soared from single to double digits with Bangladesh Bank's tightening monetary policy for price and macro stability, making clean energy investment harder.

Therefore, Bangladesh Bank may consider establishing a dedicated low-cost revolving funding facility for industrial energy efficiency with support from MDBs. With rising demand, Bangladesh may also look to bonds to raise funds, particularly for the large-energy consuming industries intending to reduce energy consumption and thus minimise their environmental footprints.

The study further recommends a comprehensive approach, including:

- Enhancing the reliability of the electricity grid to encourage industries to shift to grid power from captive generation.
- Increasing renewable energy capacity and piloting renewable energy with storage.
- Building some gas-fired peaking power plants instead of only base-load plants to allow integration of more renewable energy. Alternatively, retaining the gas turbines of old combined-cycle gas-fired plants, which are due to be phased out, as a source of power when renewable energy is not available.
- Addressing inefficient energy use in industrial processes in a holistic way.
- Facilitating the purchase of renewable energy by industries through corporate power purchase agreements.

These measures will help Bangladesh reduce its dependence on gas far more than efficiency improvements in captive power generation alone. However, in the absence of a longer-term plan, high power and energy prices could be the new normal for Bangladesh. While the path to limiting energy price spikes and import dependence has narrowed, it is still possible – if Bangladesh harnesses its strong energy efficiency potential and deploys renewable energy with greater ambition. Going ahead with building the planned infrastructure for imported fossil fuels may lock the country into even greater import dependence and uncertainty.

Yet, Bangladesh can accelerate the momentum, building on policy foundations already in place. For instance, the energy efficiency and conservation rules already require mandatory energy auditing in selected designated energy consumers, including industries. SREDA, established to help aid clean energy expansion, can design measures to swiftly scale up energy efficiency. Likewise, it can stimulate renewable energy deployment in the country. However, delay means losing the opportunity itself.

Annexure 1: Information Collected in Survey

1. Number of gas generators being used in electricity generation and their capacities in MW.

2. Energy generated in kilowatt hours (kWh) in 2023 using gas generators and the corresponding gas consumption (cubic metres); Alternatively, amount of gas needed (m^3) to produce 1kWh of energy in 2023.

3. Age of existing gas generators.

4. Status of utilising waste heat of the gas generators.

5. To what extent energy is saved due to the installation of waste heat recovery boiler(s) or plants?

6. If not utilised, what is the plan to harness waste heat recovery?

7. Status of utilising jacket cooling water in chiller or heater.

8. How much energy is saved if jacket cooling water is used?

9. If not utilised yet, what is the plan to take the advantage of jacket cooling water?

10. What are the factors that influence investment in energy efficiency?

Annexure 2: Calculation of Gas Generator Efficiency

Formula Used

Efficiency = 860*100 / (Lower Calorific Value of Natural Gas*Gas Consumption/ kWh of electricity)[62]

Lower Calorific Value Used = 8,400 kcal/m^3

Efficiency of one of the sample generators = 860*100 / (8,400*0.28065) = 36.48%

Justification of Using 8,400kcal/m^3 as lower calorific value

Average Gross Calorific Values of gas produced in gas fields in FY2022-23: [63]

Gas Field	Gross Calorific Value (Btu*/cubic feet)	Gross Calorific Value (kcal/m^3)[64]	Lower Calorific Value (kcal/m^3)[65,66]
Sylhet	1,056.878	9,406	8,465.4
Rashidpur	1,017.234	9,053.2	8,147.9
Kailashtila	1,042.726	9,280.1	8,352.1
Titas	1,032	9,184.6	8,266.1
Habiganj	1,014	9,024.4	8,122
Bakhrabad	1,057	9,407.1	8,466.4
Semutang	1,037.08	9,229.8	8,306.8
Begumganj	1,045.61	9,305.7	8,375.2
Beanibazar	1,086.418	9,668.9	8,702
Fenchuganj	1,018.39	9,063.5	8,157.1
Jalalabad	1,056.066	9,398.8	8,458.9
Narsingdi	1,044	9,291.4	8,362.3
Meghna	1,050	9,344.8	8,410.3
Shahbazpur	1,044.57	9,296.5	8,366.8
Saldanadi	1,029.86	9,165.6	8,249
Bibiyana	1,060	9,433.8	8,490.4
Bangura	1,049.2	9,337.7	8,403.9
Moulavibazar	1,020.22	9,079.8	8,171.8
Sundalpur	1,013.52	9,020.1	8,118.1
Srikail	1,041.05	9,265.1	8,338.6

Arithmetic mean of lower calorific values of all gas fields: 8,336.6kcal/m^3

Value considered in this study: 8,400kcal/m^3 [67]

**Btu = British thermal unit*

[62] BERC. Regulatory Energy Audit of Generation Facilities Regulations, 2017. January 2017.
[63] Petrobangla. Annual Report 2022. 14 October 2023.
[64] BP. Approximate Conversion Factors – Statistical Review of World Energy. July 2021.
[65] Plant Engineer's Reference Book. Chapter 13 – Gas. 2002.
[66] Lower Calorific Value = 90% of Higher Calorific Value.
[67] This value is used in different energy audit reports.

Annexure 3: Normality Test – Descriptive Statistics and Q-Q Plot

Descriptive Statistics

Efficiency (%)	
Mean	35.37990411
Standard Error	0.475558203
Median	34.13
Mode	33.02
Standard Deviation	4.063171067
Sample Variance	16.50935912
Kurtosis	-0.857863432
Skewness	0.128951151
Range	18.12
Minimum	27.08
Maximum	45.2
Sum	2582.733
Count	73[68]

Data for Q-Q Plot

Efficiency (%)	Rank	Percentile	Normal Theoretical Quantile	Sample Quantiles
27.08	1	0.006849	-2.465	-2.0427
27.3	2	0.020545	-2.0425	-1.9885
…	..	…..	…..	…..
…	..	…..	…..	…..
45.2	73	0.99315	2.465	2.4168

[68] Some industries have common meters for their generators. Therefore, if one industry has three generators but a common meter, it is considered one generator in normality test.

Annexure 4: Regression Analysis – Generator Age and Efficiency

Regression Statistics	
Multiple R	0.74999
R Square	0.562497
Adjusted R Square	0.556
Standard Error	2.716
Observations	70 [69]

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	645.01	645.01	87.427	7.9E-14
Residual	68	501.68	7.377		
Total	69	1146.69			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	40.14209412	0.63352	63.363	3.3E-62	38.8779	41.406	38.877	41.4
Age	-0.523823	0.05602	-9.35	7.9E-14	-0.6356	-0.412	-0.6356	-0.412

[69] Some industries did not share the operational ages of their generators. Additionally, a sample size of 70 is statistically significant as the requirement is to have at least 68 samples according to Cochran's formula for confidence interval of 90% and error of 10%.

Annexure 5: Gas (equivalent LNG) Saving Potential

Annual savings due to replacement of inefficient generators:
% Change in fuel consumption per kWh of electricity due to increased efficiency = {(fuel consumption$_{@35.38\%}$ - fuel consumption$_{@45.2\%}$) * 100}/ fuel consumption$_{@35.38\%}$

= {(0.28894 – 0.2265) * 100} / 0.28894 = **21.61%**

Total gas consumption in captive generation in the FY 2022-23 = 164.272 Bcf[70]

The potential gas savings from replacing generators with 45.2% efficient generators

= annual sectoral gas consumption * 21.61% = 164.272 * 21.61% = **35.5Bcf** a year

Annual savings due to the utilisation of waste heat:

Status: 44.22% of the samples have not installed waste heat recovery boiler/plant.

Assumptions: Samples are representative of industries. 80% of the remaining industries will use waste heat in the future.

Energy saving value considered for waste heat recovery: 20% of the gas consumption in generator[71]

Total gas consumption of the sector after replacement of old generators

= 164.272 – 35.5 = 128.772Bcf a year

Potential savings from waste heat recovery

= 44.22% * 80% * 128.772 * 20%

= **9.11Bcf a year**

Savings from using jacket cooling water:

Status: 79.6% of the samples are not using jacket cooling water. 25.5% samples have different challenges in using jacket cooling water in productive applications, i.e., chiller and heater. 54.1% of the samples can still utilise this and save energy.

Assumptions: Samples are representative of industries. 80% of the 54.1% samples will utilise jacket cooling water.

Energy Saving value considered: 20% of the gas consumption in generator[72]

Total gas consumption of the sector after replacement of old generators

= 164.272 – 35.5 = 128.772Bcf a year

Potential savings due to valuable use of jacket cooling water

= 54.1% * 80% * 128.772 * 20% = **11.15Bcf a year**

[70] MPEMR. Hydrocarbon Unit. Annual Report on Gas Production, Distribution and Consumption 2022-23. 26 November 2023. Page iv.
[71] Sample industries with installed waste heat recovery boilers/plants are saving more than 20% energy.
[72] Sample industries using jacket cooling water are saving more than 20% energy.

Combined annual savings potential:

Overall annual savings potential = (35.5 + 9.11 + 11.15) = 55.76Bcf of gas

Taking a 10% margin of error, the savings will be = 55.76 * (1 – 0.1) = 50.18Bcf of gas

= 50.18 * 0.966 trillion Btu of LNG [73]

= 50.18 * 0.966 * 1,000,000 million metric British thermal units (MMBtu) of LNG

= 48,473,880 MMBtu of LNG

= **48.47 million MMBtu of LNG**

Some LNG pricing samples:

Long term LNG price$_{\textbf{Excelerate}}$ = 13.35% of Brent crude oil/barrel on the day + US$0.3/MMBtu[74]

= (0.1335 * US$87 + US$0.3)[75]

= US$11.91/MMBtu

Long term price$_{\text{Qatar}}$ = up to US$11/MMBtu (approximately on 26 December 2023)[76]

Long term price$_{\text{RasGas}}$ = 12.65% of three month-average price of Brent crude oil per barrel + US$0.5/MMBtu[77]

= (0.1265 * US$85 + US$0.5)[78]

= US$11.25/MMBtu

LNG spot purchase$_{\text{23 January 2024}}$ = US$10.88/MMBtu[79]

LNG spot purchase$_{\text{31 January 2024}}$ = US$9.93/MMBtu[80]

LNG spot purchase$_{\text{March 2024}}$ = US$9.23 to US$9.79[81]

On a conservative estimate, taking a price of US$9.5/MMBtu, the combined annual cost savings from reduced LNG purchase will be = 48.47 million MMBtu a year * US$9.5/MMBtu[82]

= **US$460 million a year**

[73] BP. Approximate Conversion Factors – Statistical Review of World Energy. July 2021.
[74] The Daily Star. Govt to Buy LNG from Excelerate under 15-year Pact. 26 October 2023.
[75] Brent crude oil price was hovering around US$87-88 a barrel during the third week of April 2024. Future price fluctuations are not considered.
[76] The Financial Express. BD Eyes 24 LNG Cargoes from Spot Market in 2024. 27 December 2023.
[77] Ibid.
[78] Brent crude oil price was hovering around US$82-88 a barrel during February-April 2024. As such, US$85 a barrel is considered.
[79] The Daily Star. Govt Importing LNG at Lower Price. 1 February 2024.
[80] Ibid.
[81] The Financial Express. Three Spot LNG Cargoes to be Imported in May. 29 March 2024.
[82] While the spot market price continues to trend lower, the average price of US$9.5/MMBtu is considered as Bangladesh's long-term contract price is higher.

Annexure 6: Financial Analysis of Installing an Efficient Gas Generator

Cost of a 1MW gas-fired generator with 45.2% efficiency = US$425,000 = Tk46,750,000

Efficiency of a sample gas generator = 33.02%

Reduction in gas consumption per kWh of electricity for replacing 33.02% efficient generator with a 45.2% efficient generator = 0.0835 m^3 [83]

Load factor = 85%

Price of gas = Tk30.75/m^3 [84]

$\text{Payback}_{\text{@8,000 hours of operation per year}}$ = 46,750,000 / (1,000*8,000*0.85*0.0835*30.75) = 2.7 years

$\text{Payback}_{\text{@6,000 hours of operation per year}}$ = 46,750,000 / (1,000*6,000*0.85*0.0835*30.75) = 3.6 years

Note: Operations and maintenance costs are not included as such costs will be needed in existing generators too.

[83] BERC. Regulatory Energy Audit of Generation Facilities Regulations, 2017. January 2017.
[84] MPEMR. Gazette on Gas Prices for Power Plants and Captive Power Plants. 25 February 2024.

Annexure 7: Financial Analysis – Waste Heat Recovery Boiler

Assumptions

Average load of gas generator: 1,500 kilowatts (kW)

Probable Steam Generation = 750kg/hour

Steam can be used **m** = 750*0.75 = 562.5kg/hour[85]

Enthalpy of steam **h1** = 658.7kcal/kg (from steam table at a pressure of 6kg/cm^2)

Enthalpy of feed water **h2** = 60kcal/kg

Heat available for generating steam **Q** = 562.5kg/hour * (658.7 – 60) kcal/kg

= 336,769kcal/hour

Annual natural gas saving$_{\text{@8,000 hours of operation a year}}$

= 336,769kcal/hour * 8,000hour * 0.8 / 8,400kcal/m^3 (taking a conversion factor of 0.8)

= 256,586m^3

Annual monetary savings = 256,586m^3 * Tk30/m^3 (gas price =Tk30/m^3 for industrial processes)

= Tk7,697,580

Price of 1 tonne/hour waste heat recovery boiler = Tk4,000,000

Payback = Tk4,000,000 / Tk7,697,580 per year = 0.52 year

However, waste heat recovery boilers imported from the US or Europe may cost about Tk10 million

Hence, **payback** will be = 1.3 years.

[85] Assuming that 75% of the steam can be realised.

Annexure 8: Financial Analysis – Jacket Cooling Water Application

Assumptions

Generator capacity: 1MW

Water flow rate **v**: 36m^3/hour

Jacket water outlet temperature: 88°C

Jacket water inlet temperature: 80°C

Available heat **Q** = m * Cp * ∆T

m = þ * v = 1,000 kg/m^3 * 36m^3/(60*60 second)

= 10kg/second

Available heat **Q** = 10kg/second * 4.18kJ/kg/K * {(88 + 273.15)K – (80 +273)K}

= 334.4kW

Cooling capacity of chiller = 334.4kW * 1.2 (taking a 20% safety margin)

= 401.28kW

= 114.097 tonnes of refrigeration (TR) (1TR = 3.517kW)

= ~114TR

Equivalent electrical load = 1.2kW/TR * 114TR

= 136.8kW

Annual energy savings due to using jacket cooling water to run chiller = 136.8kW * 6,000 hours

= 820,800kWh

Annual monetary savings = 820,800kWh * Tk10.88/kWh (flat rate tariff for a medium industry) [86]

= Tk8,930,304

Investment in chiller = 114TR * Tk60,000/TR = Tk6,840,000

Payback = Tk6,840,000/Tk8,930,304 per year = 0.77 year

[86] MPEMR. Gazette on Retail Tariffs for Electricity. 29 February 2024.

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