Iraqi Journal of Oil & Gas Research, Vol. 05, No. 01 (2025)

Iraqi Journal of Oil & Gas Research

Journal homepage: https://ijogr.uotechnology.edu.iq/

# Review of Natural Gas and Diesel Usage in Gas Turbines for Enhanced Efficiency and Technological Adaptation

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## Article information

**Article history:**
Received: February, 09, 2025
Revised: April, 04, 2025
Accepted: April, 05, 2025
Available online: April, 08, 2025

**Keywords**:
Gas turbine,
performance,
diesel,
natural gas Fuel,
efficiency,

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## Abstract

The choice of fuel in gas turbines is a critical decision for power plant operators, as it directly impacts factors such as fuel economy, operating expenses, efficiency, emissions, and environmental sustainability. When comparing natural gas, and diesel as fuels for gas turbines, several important factors come into play. This comparison aims to provide insights into the key considerations associated with each fuel option and their implications for power generation. Natural gas stands out as a favorable choice due to its notable advantages. It offers improved fuel economy, resulting in cost savings and cheaper operating expenses compared to diesel. The higher efficiency of natural gas combustion in gas turbines contributes to enhanced power generation capabilities. Moreover, natural gas emits fewer pollutants, including lower levels of nitrogen oxides (NOx) and greenhouse gases, making it a cleaner and more environmentally friendly option for power generation. However, the specialized handling and storage requirements of natural gas can limit its usage in certain applications, particularly in marine gas turbines where alternative fuel options may be more suitable. On the other hand, crude oil remains an affordable fuel in some regions, but its adverse environmental impacts, such as carbon emissions and pollution, make it less desirable from a sustainability standpoint. Gas turbines offer fuel flexibility, allowing them to utilize a range of liquid and gaseous fuels. This flexibility enables power plant operators to consider alternative options such as kerosene, naphtha, biofuels, and syngas, with appropriate adjustments to meet operational requirements and environmental regulations. The choice of fuel depends on various factors, including availability, cost, infrastructure, environmental regulations, and specific operational requirements. Power plant operators must carefully evaluate these factors to determine the most suitable fuel option, striking a balance between economic considerations and environmental impact. Overall, understanding the effectiveness and outcomes of different fuel options in gas turbines is crucial for informed decision-making in power generation, considering both economic and environmental aspects.

DOI: http://doi.org/10.55699/ijogr.2025.0501.1085 , Oil and Gas Engineering Department, University of Technology-Iraq

## 1. Introduction

The impact of fuel composition on gas turbine engine performance is a critical aspect that influences power output, operability[1,2], and emissions. Different fuels with varying hydrogen-carbon ratios can significantly affect the characteristics of industrial gas turbines. Fuels with higher hydrogen-carbon ratios offer benefits such as higher operating efficiencies and lower pollutant emissions[3]. The study emphasizes the importance of fuel properties, specifically the hydrogen-carbon ratio, in determining the output characteristics of gas turbines [4].Various research papers and studies have explored the influence of alternative fuel compositions on gas turbine ignition performance, combustion instabilities, and the operability of lean premixed gas turbine combustors[5]. Additionally, the selection of fuel types, such as natural gas, gasified biofuels, and synthetic gas blends, plays a crucial role in gas turbine performance and efficiency. Understanding the physical properties of fuels, including heating value, dew point, Joule-Thompson coefficient, and Wobbe index, is essential for determining their suitability for gas turbine operation[6,7]. The Wobbe index, in particular, affects engine power output, with engines providing slightly more power when the Wobbe index is reduced. Fuel gas pressure, fuel handling, and the impact of fuel properties on combustion performance are key considerations in optimizing gas turbine performance. IN summary, the composition of fuel used in gas turbine engines has a profound impact on their performance[8], efficiency, and emissions. Research and studies continue to explore ways to optimize fuel composition to enhance the overall operation of industrial gas turbines[9]. The performance of gas turbine engines is significantly influenced by the fuel composition used, which plays a crucial role in combustion efficiency, emissions, and engine durability[10]. As the aviation industry expands, optimizing fuel composition becomes essential to reduce environmental impact and ensure reliable engine operation. Gas turbine engines consist of a compressor, combustion chamber, turbine, and nozzle, and the combustion process involves fuel-air mixing, ignition, and expansion through the turbine to generate power[11]. Fuel composition can be categorized into hydrocarbon composition, chemical additives, and impurities/contaminants. Higher hydrocarbon fuels enhance combustion efficiency[12], while additives affect flame stability and ignition. Impurities can impact emissions production. Higher hydrocarbon fuels lead to increased power output[13], while additives influence engine durability. Experimental studies have explored fuel composition effects on gas turbine engine performance through fuel blending, additive testing, and engine trials. Fuel standards and regulations are vital for ensuring fuel quality and engine performance. Optimizing fuel composition for gas turbine engines involves strategies like fuel blending, additive development, and engine design optimization[14]. From 2014 to 2024, research on the use of natural gas and diesel in gas turbines has significantly grown, with a notable focus on dual-fuel technologies. This field emphasizes the potential benefits of using both natural gas and diesel in gas turbine systems to improve efficiency and reduce emissions, especially NOx and particulate matter.

Key research areas include:

- The dynamics of fuel-switching between diesel and natural gas in gas turbines, which can help optimize combustion processes for better performance and lower emissions[16†source].
- Advances in dual-fuel gas turbines that can operate on both fuels interchangeably, enhancing the flexibility and reliability of power generation systems [17†source].
- Efforts to address the challenges associated with emissions at low loads, where the performance of dual-fuel engines can degrade, particularly in terms of fuel efficiency and carbon emissions[17†source].

The studies published during this period, with much of the research aiming to reduce reliance on diesel by increasing the use of cleaner fuels like natural gas in gas turbines. You can explore specific studies through technical journals like the ASME Digital Collection and the SAE database for in-depth information The aim of this study is to compare and evaluate the effectiveness and outcomes of using different fuels, specifically natural gas, and diesel, in gas turbines for power generation. The study seeks to provide insights into the key factors that come into play when considering these fuel options, including fuel economy, operating expenses, efficiency, emissions, and environmental sustainability.

## 2. The Basic Cycle

This optional section should be used only if more extensive theoretical derivations are needed. Simpler theories and methods should be a part of either Introduction or Experiment, respectively. All equations, including those describing chemical reactions, must be written in separate lines and numbered. The symbols of quantities should be explained immediately below the equation if they were used for the first time. Theoretical part should be Times

New Roman, justified, regular; font size: 11 single. If you have any figures or tables in this section, please use the same format that will be mentioned in the “Results and discussion” part.

A gas turbine is a type of heat engine that transforms some of the chemical energy of fuel into mechanical energy that can be used. Though the labor is done sporadically, it functions similarly to an internal combustion engine running on four strokes[15].

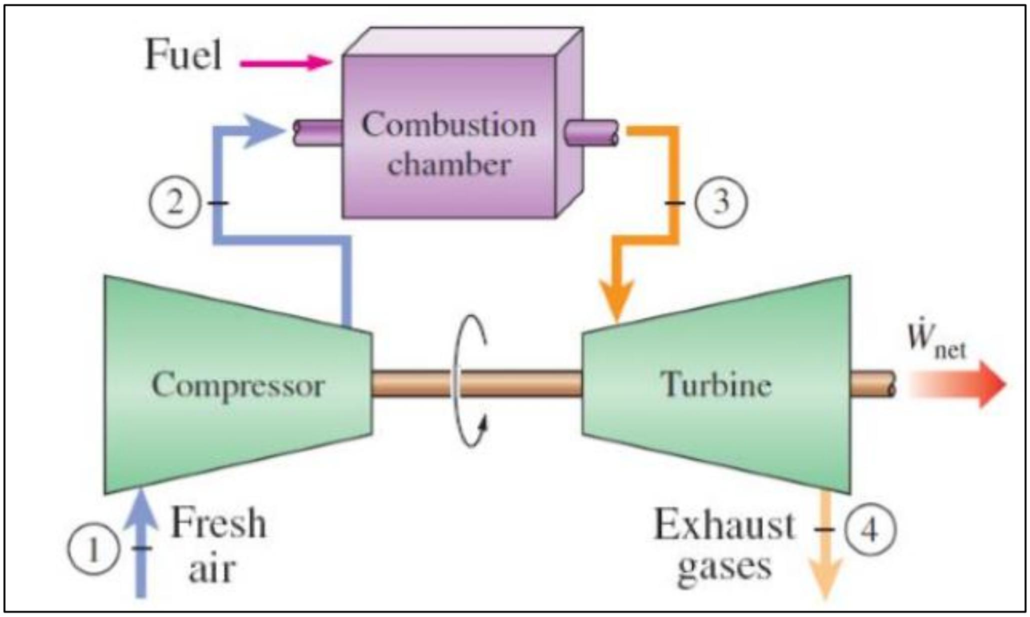

**Figure 1:** Gas Turbine Cycle [16]**.**

In a gas turbine cycle, air is drawn into the compressor, where it is compressed and then sent to the combustion system. By injecting fuel into the compressed air, more energy is added, and the air is heated to a temperature between 2500 and 3200 degrees Fahrenheit[17]. To reduce the heat to a usable level[18]. Additional air is introduced into the combustion chamber. The energy extracted from the compressed, hot gas powers compressors, auxiliary motors, and load systems.[19]. After being used, the hot gas enters the exhaust system, where it can be utilized for various purposes such as drying, heating water or air, or providing hot air to another operational boiler. The spent gas is eventually released through the exhaust chimney system, and any remaining heat can be recovered for additional processes, increasing the overall efficiency of the system[20]. Gas turbines are increasingly being used for power generation, especially in the distributed power sector. They are preferred over diesel engines and steam turbines due to their higher waste heat, dual-fuel capability, compact size, low maintenance lower emissions, high efficiency, and reasonable operating costs. Gas turbines operate based on the Brayton cycle principle[21].Gas turbine systems are divided into three main types: open cycle, closed cycle, and semi-closed cycle. In open cycles[22], air is used as the working fluid and is expelled after passing through the turbine[22], while closed cycles use condensers and recycle the working fluid[24]. Open cycle gas turbines are used for large-scale power generation, whereas closed cycle turbines are suitable for smaller-scale applications. [25], Combined cycle gas turbines offer excellent performance for large-scale power generation, but their mechanical complexity may not be suitable for smaller operations.[26].

The figure 2 shows the forecasted additional generation capacity from gas turbine electrical power generation between the years 2018 and 2027, measured in megawatts (MW). Here's an explanation:

- **X-axis (Years)**: Represents the timeline from 2018 to 2027.
- **Y-axis (Megawatts)**: Represents the total additional electrical generation capacity in MW, ranging from 0 to 60,000 MW.

1. **2018-2023**: There is a relatively stable or slight variation in generation capacity, fluctuating around the 36,000 to 40,000 MW range. These years represent slower growth in gas turbine power generation.
2. **2024-2027**: Starting from 2024, there is a noticeable increase in gas turbine power generation capacity. By 2025, the additional capacity rises significantly, reaching approximately 48,000 MW and continuing upward to 54,000 MW by 2026 and 2027. This suggests that the forecast predicts a substantial rise in gas turbine installations and their contribution to electricity generation in the latter part of the decade.

The forecast shows a stable contribution from gas turbines between 2018 and 2023, followed by an acceleration in additional capacity from 2024 to 2027, indicating the increasing importance of gas turbines in future electricity production

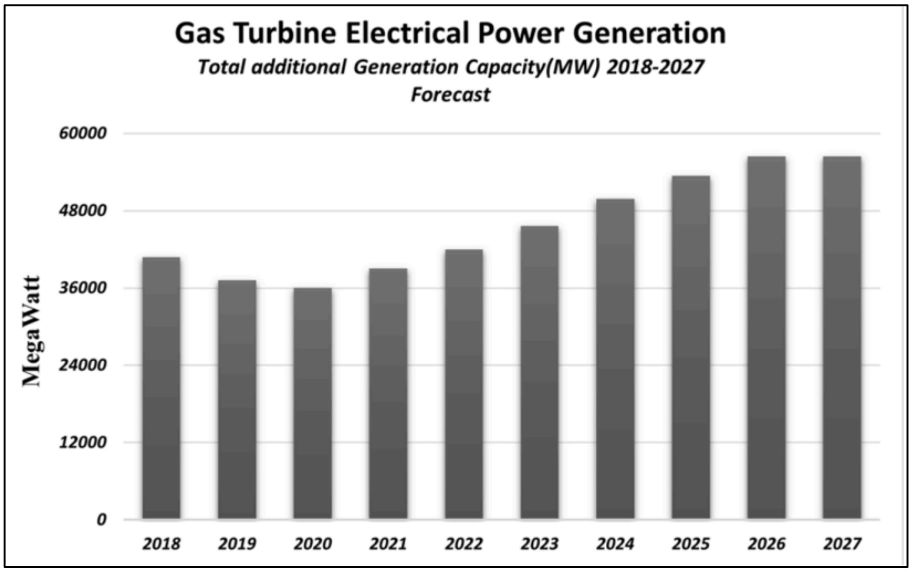

**Figure 2**: The evolution of gas turbines' contribution to the production of electricity[21].

The figure 3 shows a simple depiction of the parts and flow route for transporting liquid fuel to a gas turbine. Typically, you see a fuel tank, pump, filter, flow control valves, and injectors. This helps describe the simple approach to maintaining adequate fuel flow and pressure for efficient combustion.

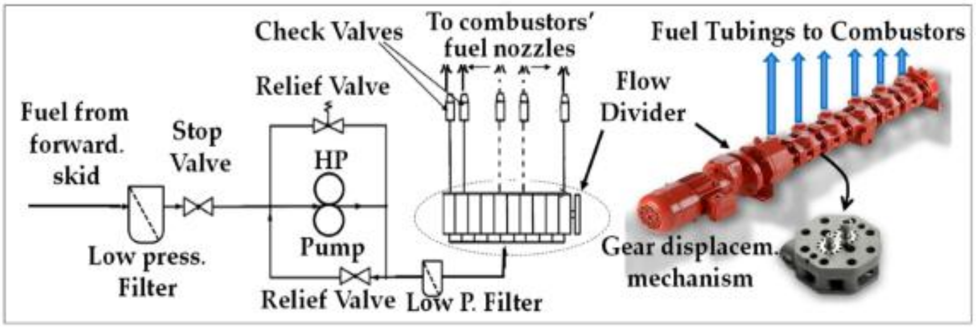

**Figure 3**: Diagram of the liquid fuel line simplified [27]

## 3. Diesel fuel

Diesel power generators come in a range of sizes and are used for off-grid, decentralized, and centralized power generation the power plants can be used for a variety of tasks, such as peak load generation, central power generation, standby power generation, emergency power generation, black start generation, and mobile power generation in different field applications[28].

## 4. Design and construction of Diesel Engine power plant

A diesel engine power plant's performance is affected by a number of variables, such as its size, load profile, engine condition, mode of operation, and maintenance schedule[29]. It is advisable to select various generator sets of varying sizes because demand is dynamic and the ideal design plan is to have a generator with a rating equivalent to the current demand. In diesel power plants, diesel engines are mostly employed as prime movers, turning electric generators and alternators to produce energy[30]. The engine, fuel storage supply system, engine charge air intake system, engine exhaust system, engine cooling system, lubricating system, engine starting system, speed governing and control system, instrument, and control air system are the main parts of a diesel power plant[31]. Inline, V-, four-, and two-stroke engines are examples of dynamic engines. Engines with four strokes are better because they are more balanced and efficient[32] . Before atomized fuel is introduced to start combustion, air in diesel engines is compressed adiabatically, raising the air temperature. Warm temperatures cause the diesel to ignite on its own, moving the pistons and rotating the crankshaft[33].

## 5. Natural Gas fuel

Methane (CH4) is the primary component of natural gas, which is the most common gaseous fuel used in power plants. Natural gas is composed of numerous gaseous carbohydrates (CnH2n+2). It is a fossil fuel that has developed over millions of years from biomass that has been heated and compressed to extreme temperatures, turning the biomass into kerogen first, then oil, and finally NGL[34]. Only deep subterranean reservoirs containing oil and natural gas can contain high-pressure natural gas trapped beneath sedimentary rocks. It can also be found in sand layers, coal as coal-bed gas, and gas-rich shale strata[35].

In conventional reservoirs, raw natural gas is typically recovered by vertical gas wells drilled deeper than a thousand meters[36]. Natural gas naturally flows up to the well head for piping to gas processing facilities where higher hydrocarbons are recovered and processed to remove impurities such carbon dioxide, hydrogen sulfide, water, SO2, mercury, and others due to the high pressure of subterranean natural gas. The type, location, and local geology of the gas field are the primary determinants of the composition of natural gas[37].

A naturally occurring mixture of hydrocarbons, natural gas is frequently found in coal fields, petroleum, and as hydrate on the seafloor. Natural gas is cooled to -162oC at atmospheric pressure to make liquid natural gas[38]. Methane (CH4) makes up the majority of natural gas, with trace amounts of ethane, hydrogen sulfide, nitrogen, propane, helium, carbon oxide (CO2), and moisture or water vapor. About 90% of the constituents are usually CH4[39].

A natural gas engine is a mechanical engine that generates mechanical or electrical power using natural gas as fuel[40]. Gas-fired turbines, dual fuel gas engines, and spark-ignition reciprocating internal combustion engines are the three fuel-based types of natural gas engines[41].

Natural gas has several key advantages over other fossil fuels that make it a desirable fuel for power generation and other engine applications[42]. These advantages include affordability, accessibility, environmental friendliness, compatibility with both compression and spark ignition engines, and low operating costs[43].

**Table 1.** Typical composition of compressed natural gas [44]

| | Element | Symbol/Formulae | Volumetric % |
|---|---|---|---|
| 1 | Methane | CH4 | 94.42 |
| 2 | Ethane | C2H6 | 2.27 |
| 3 | Propane | C3H8 | 0.03 |
| 4 | Butane | C4H10 | 0.25 |
| 5 | Nitrogen | N2 | 0.44 |
| 6 | Carbon dioxide | CO2 | 0.57 |

| | | | |
|---|---|---|---|
| 7 | Others | - | 2 |
| | Total | | 100% |

## 6. Natural gas's thermodynamic characteristics

Table 2 illustrates the variations in thermodynamic parameters between CNG, diesel, and gasoline. Diesel has the largest molecular weight and is denser than the other two fuels. On the other hand, CHG is more combustible and has a higher auto ignition point[49][50]. CNG is a better fuel for spark ignition applications than compression ignition engines since it has the highest octane value[45].

Table 1 shows that the main organic gas in compressed natural gas (CNG) is methane, which makes up the largest portion of the fuel. Carbon dioxide, ethane, butane, propane, nitrogen, and carbon dioxide are other typical components of CNG.

- The energy density of natural gas is higher than that of hydrogen. In British Columbia, the average energy content of natural gas is 40.9 MJ/m$^3$, whereas the energy content of hydrogen is just 12.7 MJ/m$^3$ at the same pressure and temperature[46].

A 20% volume replacement of natural gas with hydrogen results in a blend that only receives 2.54 MJ/m$^3$ from the hydrogen (12.7 MJ/m$^3$ * 0.2) [4]. Natural gas accounts for 80% of the remaining 35.26 MJ/m$^3$ (40.9 MJ/m$^3$ * 0.8) [45].

- Therefore, the energy content of the 20% hydrogen blend is 7.2% lower than that of pure natural gas (2.54 MJ/m$^3$ / 35.26 MJ/m$^3$ = 0.072) [47].

- 7.2% more of the 20% hydrogen blend must burn than pure natural gas in order to provide the same quantity of heat[48].

Because natural gas still makes up 80% of the blend, the reduction in carbon emissions is just approximately 7.2%, not 20%. [49].

**Table 2.** Thermodynamic properties of compressed natural gas [45]

| | Property | Unit | Gasoline | Diesel | CNG |
|---|---|---|---|---|---|
| 1 | Stoichiometric Ratio | Ratio | 14.2 | 15 | 15.7 |
| 2 | Cetane number | Unit | N/A | 40-55 | N/A |
| 3 | Octane number | Unit | 96 | N/A | 120-130 |
| 4 | Lower calorific value | Mj/kg | 42.2 | 43.5 | 45.9 |
| 5 | Higher calorific value | Mj/kg | 45 | 45.6 | 50.3 |
| 6 | Density at 25$^{\circ}C$ (DIN 51757) | Kg/m$^3$ | 749 | 837 | 2.52 |
| 7 | Molecular weight | Kg/kmol | 106.2 | 186 | 16 |
| 8 | Minimum ignition energy | Mj | 0.33 | 0.5 | 0.26 |
| 9 | Lamilar flame speed | cm/sec | 30 | - | 37.5 |
| 10 | Flammability unit | Vol% in air | 5.2 | 1 | 15.6 |
| 11 | Adiabatic flame temp | K | 2227 | - | 2266 |
| 12 | Vaporization energy | Mj/m$^2$ | 293 | 192 | 215-276 |
| 13 | Flash point | K | 266 | 325 | 124 |
| 14 | Combustion Energy | Kj/m$^3$ | 32.6 | 36 | 24.6 |
| 15 | Auto ignition point | K | 505-755 | 477-533 | 900 |

## 7. Economics and Life Cycle of LNG

Figure 4 shows the worldwide LNG price as of June 2019. South Korea and China had the highest landed price of LNG in the world. The price received at the regasification plant is referred to as the landed price. Netback price is taken into consideration for the determination of these prices, which is based on the effective price for a seller and producer at a definite location.

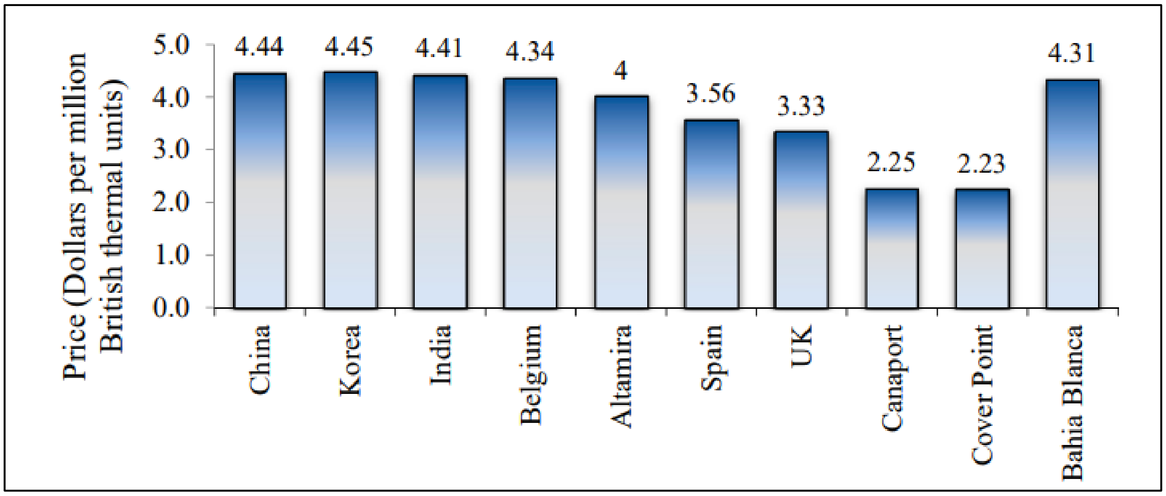

**Figure 4:** Global landing price of natural gas (LNG)[50]

This figure 5 compares the life cycle greenhouse gas emissions of heavy-duty vehicles powered by diesel and LNG across four different studies. Overall, diesel vehicles tend to have lower greenhouse gas emissions during the combustion phase compared to LNG vehicles. However, LNG vehicles may have higher emissions during the pre-combustion phase, depending on the study. The analysis suggests that, in general, diesel engines demonstrate superior performance in terms of overall life cycle emissions when compared to LNG, particularly in the combustion stage.

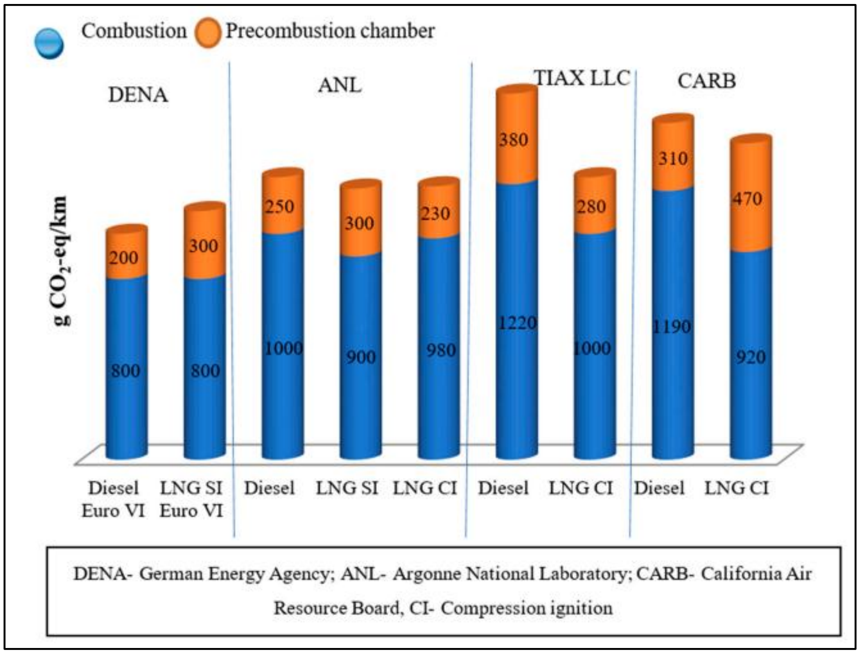

**Figure 5:** Comparison of the life cycle greenhouse gas emissions of heavy-duty diesel and LNG vehicles ,[51].

This figure 6 shows the effect of varying amounts of natural gas addition on brake thermal efficiency (BTE) in an engine. Brake thermal efficiency measures how effectively an engine converts fuel into mechanical energy.

- **Natural Gas Energy Fraction (0%)**: When the engine runs on 100% diesel, the brake thermal efficiency is at its highest, around 25%.

- **Natural Gas Energy Fraction (15%)**: Adding 15% natural gas reduces the brake thermal efficiency by 29%, indicating a significant drop in efficiency.
- **Natural Gas Energy Fraction (40%)**: At 40% natural gas, the efficiency drop is less severe, at 22%, showing some recovery in efficiency compared to the 15% fraction.
- **Natural Gas Energy Fraction (75%)**: When the natural gas fraction is increased to 75%, the brake thermal efficiency shows a smaller reduction of 8%, indicating that at higher natural gas fractions, the efficiency loss is minimized.

The initial addition of natural gas (up to 15%) significantly reduces engine efficiency. However, as the proportion of natural gas increases to 75%, the efficiency loss becomes less pronounced, potentially indicating a stabilization or adaptation in the engine's performance with higher natural gas use.

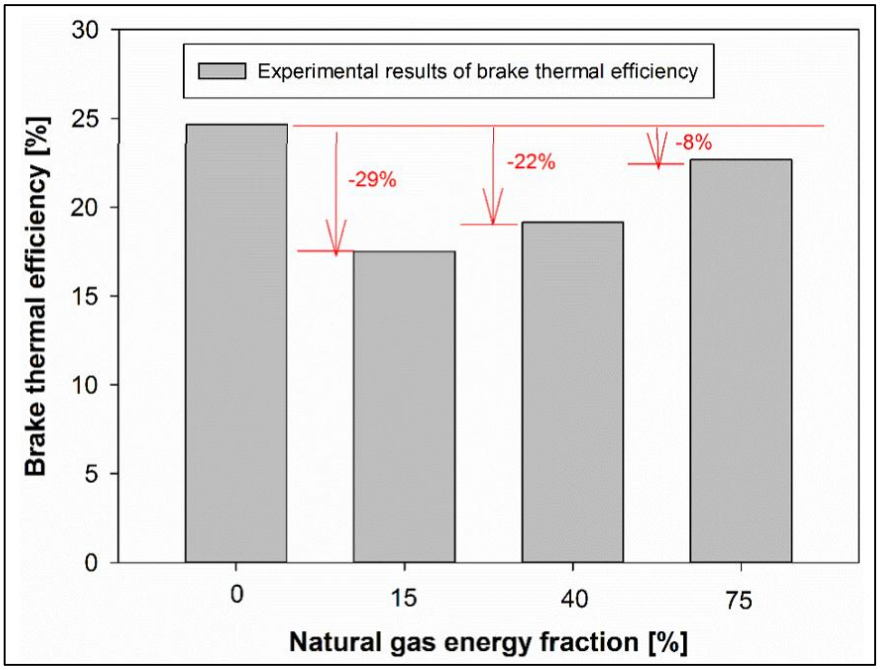

**Figure 6:** Impact of varying natural gas injection amounts on brake thermal efficiency[52]

Gaseous fuels have a higher stoichiometric air to fuel ratio than diesel. As can be seen in Fig. (7), in internal combustion engines, the efficiency and performance of the engine are significantly influenced by the type of fuel used. Gaseous fuels, such as natural gas, have a higher stoichiometric air-to-fuel ratio compared to diesel. This means that for a given amount of fuel, more air is required for complete combustion.

Here's a breakdown of the key points:

1. **Stoichiometric Air-to-Fuel Ratio**: The stoichiometric ratio is the ideal ratio of air to fuel for complete combustion. For natural gas, this ratio is higher than for diesel, meaning that more air is needed to burn the same amount of natural gas compared to diesel fuel.
2. **Air Flow Rates**: Due to the higher stoichiometric air-to-fuel ratio of natural gas, the air flow rates into the engine are higher when using gaseous fuels. This is evident in the observed data (Fig. 7), where natural gas cases require more air than diesel.
3. **Excess Air Factor**: The excess air factor is a measure of how much additional air is supplied beyond the stoichiometric requirement. For gaseous fuels, this factor is typically higher, meaning that more air is used to ensure complete combustion and to control the combustion temperature.
4. **Impact on Efficiency**: The increased amount of air required leads to higher heat dissipation. This is because the excess air absorbs some of the heat produced during combustion, which lowers the

maximum temperature within the engine. Consequently, this partial loss of heat reduces the overall efficiency of the engine.

While gaseous fuels provide cleaner combustion, the need for a higher air-to-fuel ratio and excess air results in a loss of heat and reduced efficiency compared to diesel engines.

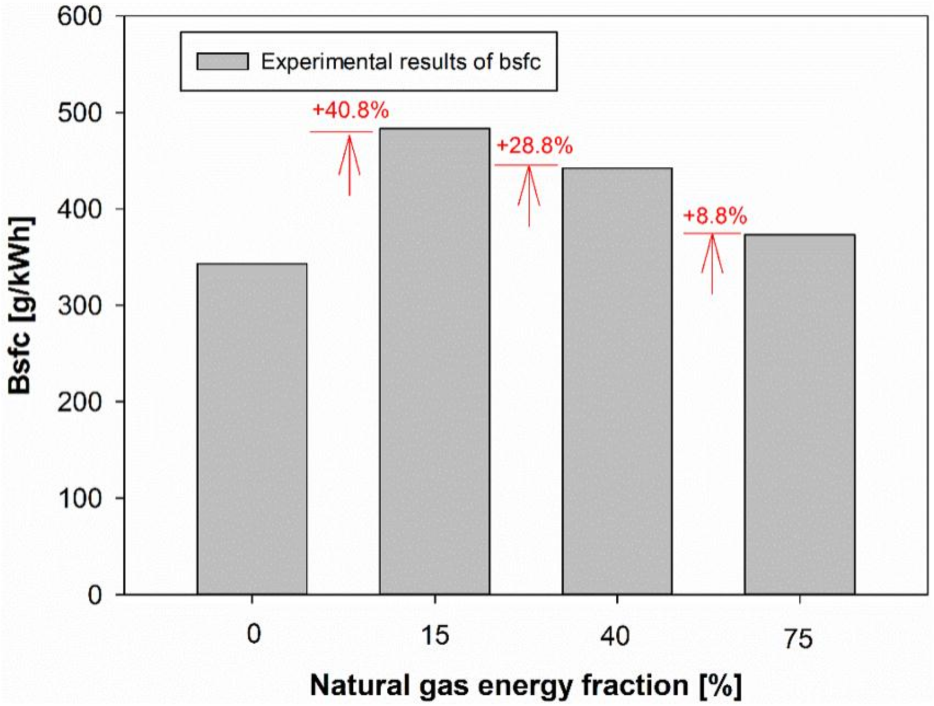

**Figure 7:**Effect of varied amount of natural gas addition on BSFC. [53]

The experimental results of brake specific fuel consumption (BSFC), measured in grams per kilowatt-hour (g/kWh), at different fractions of natural gas energy. BSFC is a measure of the fuel efficiency of an engine in terms of the fuel amount consumed per unit of power generated.

The x-axis represents the percentage of natural gas energy fraction in the fuel mix, ranging from 0% to 75%. The y-axis shows the BSFC in grams per kilowatt-hour. As the fraction of natural gas in the fuel mix increases, there is a trend of increased BSFC. This indicates that higher amounts of natural gas lead to higher fuel consumption per unit power, which might imply lower efficiency under these specific conditions. Here's a breakdown:

- At 0% natural gas (pure diesel or another base fuel), the BSFC is the lowest among the tested configurations.
- At 15% natural gas, BSFC increases by 40.8% compared to the base level.
- At 40% natural gas, there's a further increase in BSFC, totaling 28.8% from the previous level.
- At 75% natural gas, the increase in BSFC slows down to 8.8% from the previous level.

This pattern suggests that while increasing natural gas fraction may be beneficial for reducing emissions or other factors, it decreases the thermal efficiency of the engine as observed through the rising BSFC values. This can be influenced by factors such as engine design, the calorific value of the fuel mix, and how well the engine processes different fuel types.

To compare in figure (8) the cycle efficiency between diesel and natural gas as fuels, we can look at various factors:

**Diesel Fuel:**

- **Higher Compression Ratio:** Diesel engines generally have higher compression ratios than natural gas engines, which leads to higher thermal efficiency.
- **Energy Density:** Diesel has a higher energy density than natural gas, meaning more energy per unit volume, which contributes to its overall efficiency.
- **Efficiency Range:** Diesel engines typically operate with cycle efficiencies ranging from 30% to 40%.

**Natural Gas:**

- **Lower Compression Ratio:** Natural gas engines usually have lower compression ratios, resulting in lower thermal efficiency compared to diesel.
- **Clean Combustion:** Natural gas burns cleaner than diesel, reducing energy losses associated with incomplete combustion.
- **Efficiency Range:** Natural gas engines generally have cycle efficiencies ranging from 25% to 35%.

- **Diesel Engines:** Generally, more efficient due to higher compression ratios and energy density.
- **Natural Gas Engines:** Slightly less efficient but cleaner and potentially more sustainable.

This comparison highlights the trade-offs between efficiency and environmental impact when choosing between diesel and natural gas as fuels.

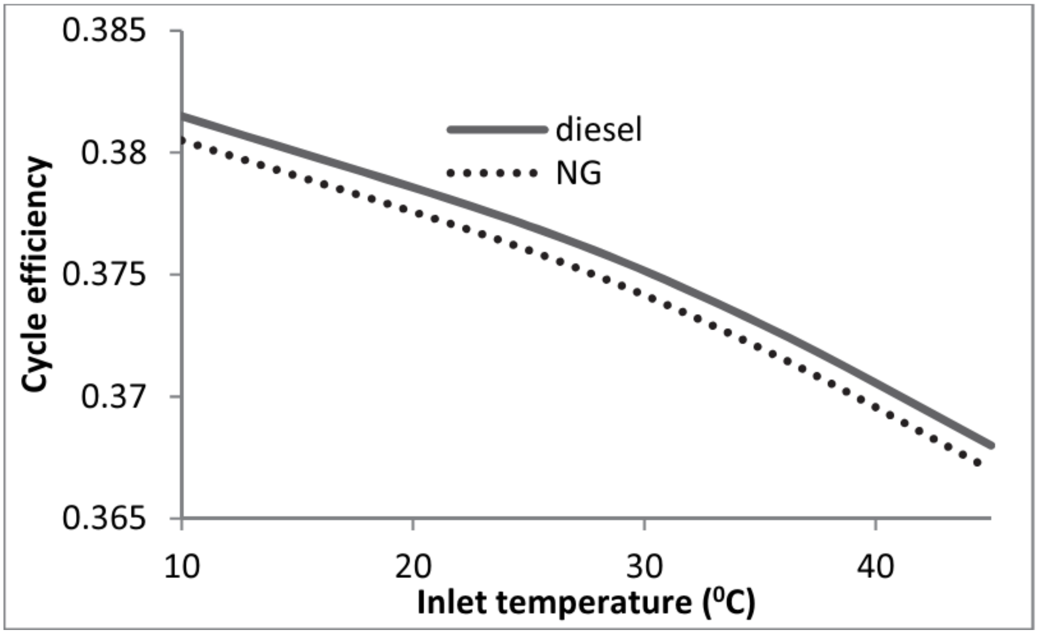

**Figure 8:**shows the various fuels' cycle efficiency [53]

Figure (9) compares the specific fuel consumption (SFC) of **diesel** and **natural gas (NG)** as a function of inlet temperature. Specific fuel consumption, measured in kilograms per kilowatt-hour (kg/kWh), is plotted on the vertical axis, while the inlet temperature, in degrees Celsius, is on the horizontal axis.

1. **Diesel** (represented by the solid line) consistently shows a higher specific fuel consumption (SFC) than **natural gas (NG)** (represented by the dotted line) across all inlet temperatures.

2. Both fuels exhibit a slight increase in specific fuel consumption as the inlet temperature rises. However, the rate of increase for diesel is more gradual, indicating it is less sensitive to changes in inlet temperature compared to natural gas.
3. The gap between the SFC values for diesel and NG remains fairly consistent across the temperature range, suggesting that natural gas is more fuel-efficient in converting energy into power.

The graph shows that **natural gas (NG)** has a lower specific fuel consumption compared to **diesel**, making it the more fuel-efficient option, especially as the inlet temperature increases. This could imply that using natural gas may lead to better energy efficiency and lower operating costs in applications where fuel efficiency is critical.

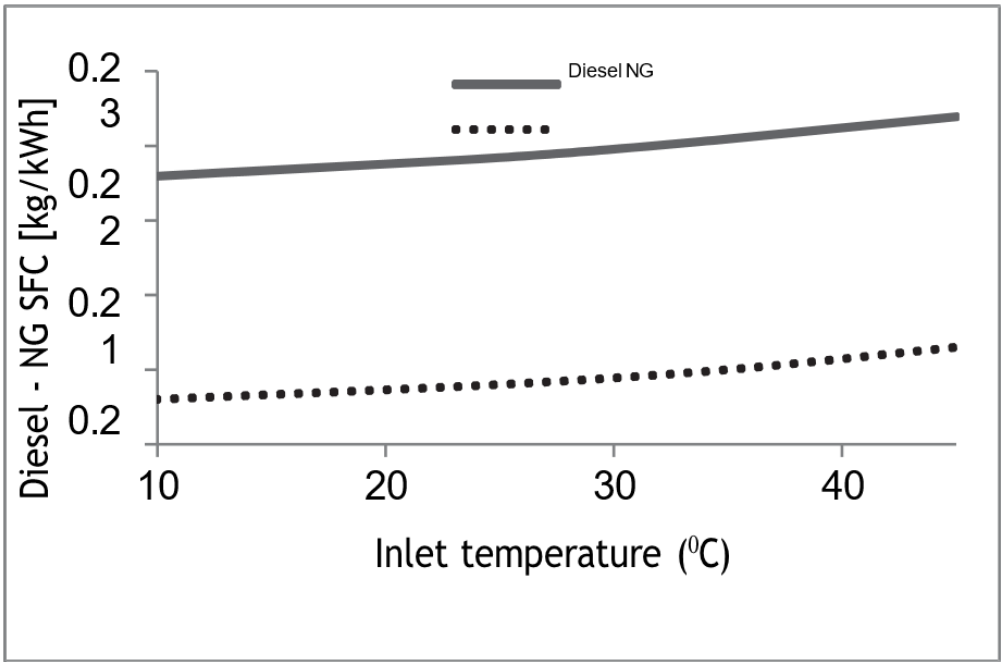

**Figure 9:** Comparison of the various fuels' specific fuel usage[54].

From figure (10), we can observe the following:

1. **Diesel** (represented by the red line) consistently achieves higher maximum temperatures than **natural gas (NG)** (represented by the blue line) across the entire range of inlet temperatures.
2. As the inlet temperature increases from 10°C to 50°C, the maximum temperature for both fuels rises. However, the rate of increase appears slightly steeper for diesel, indicating that it is more sensitive to changes in inlet temperature.
3. The gap between the maximum temperatures for diesel and NG widens as the inlet temperature increases, suggesting that diesel's thermal performance outpaces that of natural gas under higher inlet temperature conditions.

**Diesel** is shown to reach higher peak temperatures compared to **natural gas (NG)**, particularly as the inlet temperature increases. This could imply that diesel fuel is better suited for applications requiring higher thermal outputs, though this may come with different considerations regarding efficiency and emissions.

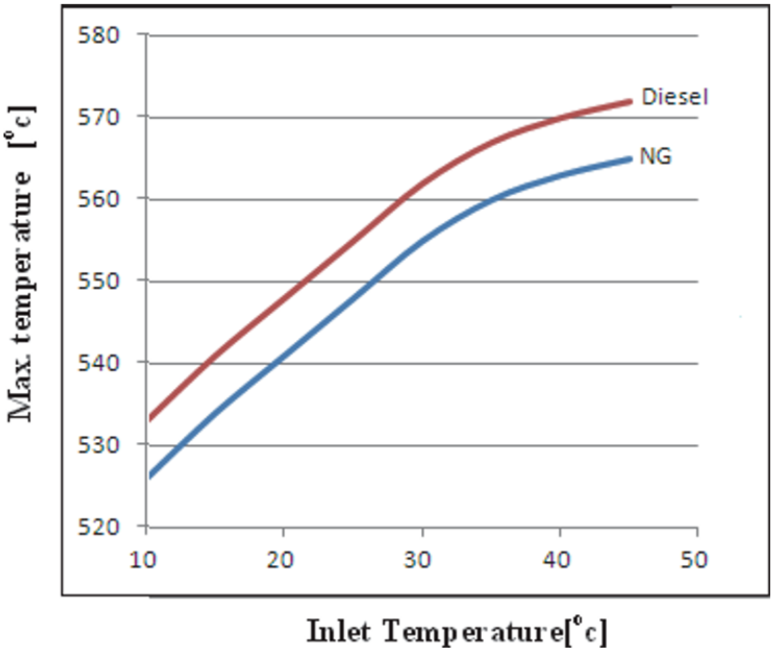

**Figure 10:**shows a comparison of the fuels' peak temperatures[55].

## 8. Assessment of Performance

Combustible and inert gases, such as methane, hydrogen, and carbon monoxide, and inert gases, such as nitrogen, carbon dioxide, and water vapor, make up gas fuels for gas turbines. Contaminants such as particulates, water, liquid heavy gases, compressor oils, hydrogen sulfide (H2S), hydrogen (H2), carbon monoxide (CO), carbon dioxide (CO2), and siloxanes can all have an impact on the quality of these fuels[15]. These impurities may affect the gas turbines and its combustion system's longevity and performance. In addition, variables like specific gravity, heating value, fuel temperature, and ambient temperature affect how well the turbine or combustion system works and how long it lasts. Problems with gas fuels could be related to each other. For example, when water joins forces with other molecules to create hydrates, this can have an impact on temperature, pressure, composition of the gas, and pressure drops in the fuel system. Liquid hydrocarbon gases can cause operational issues and safety risks, including over fueling, unstable fuel control, hot streaks in the combustor, and internal injector obstruction over time. Depending on the state equations employed, different prediction techniques for dew point temperatures for water and hydrocarbons may have different levels of accuracy[56]. The Joule-Thompson effect, which is generated by pressure decreases from valves and orifices, lowers the temperature of unheated fuel lines. Fuel heating is used downstream of knockout drums and coalescing filters to guard against heavy gasses and liquid water. The study emphasizes the significance of fuel quality and composition in gas turbines, highlighting the need to determine physical parameters such as heating value, dew point, Joule-Thompson coefficient, and Wobbe index to assess its suitability for gas turbine operation. Natural gas is a common fuel for gas turbines due to its low cost[50], availability, and low emissions. However, the composition of fuel gas can vary significantly, ranging from heavier hydrocarbons to predominantly methane or noncombustible gases. Gas turbines can also operate on liquid fuels like diesel, kerosene, and natural gas liquids. Its importance of evaluating the fuel delivery system, including fuel selection, sources, transmission, handling, storage, conditioning, and seasonal variations[57]. It's operating characteristics of gas turbines, such as pressure and flow changes with load and ambient conditions, and the relationship between emissions and fuel. the use of variable geometry to optimize gas turbine operating points for different loads and ambient conditions[58]. Nemitallah (2018) et al. [59]Possibility of various combustion techniques in gas turbines • Wider flammability limit and reduced NOx emissions can be achieved with enhanced-vortex (EV) burners. One of the primary disadvantages of oxy-combustion is the increased expense and energy needed for oxygen separation during oxy-fuel combustion. In 2019, Portillo et al.[60]Oxygen separation in oxy-combustion systems using membrane technology:  Low-emission oxy-combustion power systems can save up to

0.5–9% and 10.5–17.5% more energy and money than conventional gas turbine combustion; Oxygen-selective membrane technology can lower the higher cost of producing oxygen from cryogenic air separation units (ASU). The Nemitallah et al. (2019)[61]- Gas turbine combustion approaches - Gas turbine burner designs premixed oxy-fuel combustion can offer more stable flame and emission control than lean premixed (LPM) combustion. H2-enrichment in the combustion zone increases fuel economy and combustion efficiency. The micromixer (MM) burner exhibits greater stability close to blowout limits, whereas the Advanced Enhanced-vortex (AEV) burner has the widest flame stability overall. The Khallaghi et al. (2020)[62]. Oxygen production, exhaust gas recirculation, and the impact of operating pressure in GT oxyfuel combustion systems - Oxycombustion economics using gaseous fuels Compared to a traditional gas turbine cycle, the Oxy-Combustion Cycle (Allam Cycle) can achieve a net efficiency gain of about 50%. A smaller combustion chamber is necessary when the exhaust gas recirculation ratio is lower, indicating that membrane separation may be a feasible substitute for ASUs in the production of O2. Using staged combustion can reduce the need for exhaust gas recirculation; conversely, higher operating pressure can enhance cycle efficiency at the expense of increased pressure drop[13].

## 9. Conclusion

The study provides an analytical comparison between natural gas and diesel as fuel options for gas turbines, emphasizing the various aspects that influence their performance, operational costs, and environmental impact. Natural gas emerges as the superior choice due to its enhanced fuel economy and efficiency in combustion, which translates into reduced operational costs and lower emissions. These attributes make natural gas a more environmentally sustainable option, as it emits significantly fewer nitrogen oxides and greenhouse gases compared to diesel. The evaluation also highlights the adaptability of gas turbines to different fuel types, underscoring the importance of the hydrogen-carbon ratio in fuel compositions, which directly affects efficiency and emission levels. Moreover, the document discusses the specialized handling and storage requirements of natural gas, which, despite posing some logistical challenges, do not overshadow its benefits. With the growing emphasis on environmental sustainability and cost efficiency in power generation, natural gas is recommended as the optimal fuel choice for gas turbines, balancing economic benefits with environmental considerations. This comprehensive analysis serves as a guide for power plant operators in making informed decisions regarding fuel selection, aiming to optimize both operational performance and environmental impact.

## 10. References

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