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NATURAL GAS: TECHNOLOGIES AND PROSPECTS FOR NIGERIA'S ENERGY FUTURE

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INTRODUCTION

The gas sector is a cornerstone of the modern energy industry, playing a vital role across all aspects of natural gas utilization, from exploration and production to processing and power generation. This sector is underpinned by diverse technologies that enable efficient extraction, refinement, and use of natural gas for energy production.

The history of natural gas as an energy resource is long and storied, with significant technological advancements occurring during the 19th and 20th centuries, which have solidified its place in the energy landscape.

Furthermore, natural gas is widely regarded as a cleaner alternative to coal and oil, producing significantly lower carbon emissions and pollutants. This positions it as a key component in the global energy transition towards more sustainable and environmentally friendly sources.

1.1. Natural Gas Technology in the 19th Century

The 19th century marked a transformative period in the evolution of gas technology, especially in the realm of natural gas. During this era, natural gas began to emerge as a critical energy resource, driven by significant advancements in exploration, extraction, and utilization methods. The commercial use of natural gas took root in the early 1800s, highlighted by the pioneering efforts of William Hart, who drilled the first recorded natural gas well in Fredonia, New York, in 1821. This milestone laid the groundwork for the broader adoption and development of natural gas as a key energy source.

1.2. Natural Gas Technology in the 20th and 21st Century

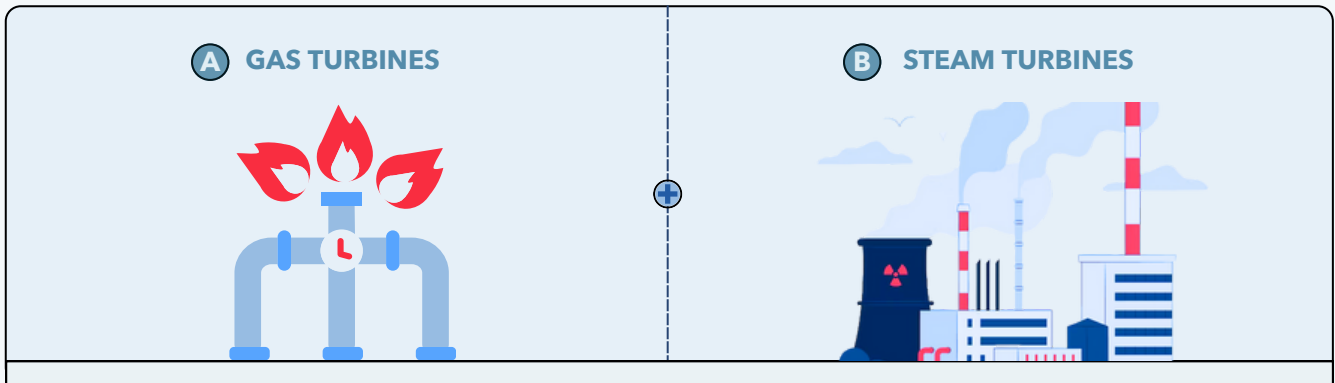
The 20th century saw a significant evolution in natural gas technology, fuelled by the discovery of vast reserves, advancements in pipeline infrastructure, and innovative extraction techniques. These developments established natural gas as a pivotal resource in the global energy landscape.

Looking ahead, natural gas is expected to play an increasingly dominant role in the electricity sector over the next two decades, surpassing coal as a primary energy source. However, experts at Imperial College London's Sustainable Gas Institute anticipate that its prominence will start to decline by 2050 as renewable energy sources gain traction and accelerate their adoption, reshaping the future energy mix.

01 Types of Gas Technologies

1.3. Types of Gas Technologies

Gas technologies employed in gas-fired power plants are primarily classified into two main categories:



A. Gas turbine:

A combustion turbine, commonly referred to as a gas turbine, is an advanced engine that transforms the energy from fast-moving, high-temperature gases into mechanical power and thrust. The process starts in the combustion chamber, where fuels like natural gas or diesel are ignited. This combustion produces high-pressure, high-temperature gases that expand rapidly. As the gases pass through the turbine, they drive the rotation of turbine blades, converting thermal energy into mechanical energy. This technology is vital for powering numerous industrial applications and plays a key role in electricity generation, enhancing both efficiency and the reliability of power systems.

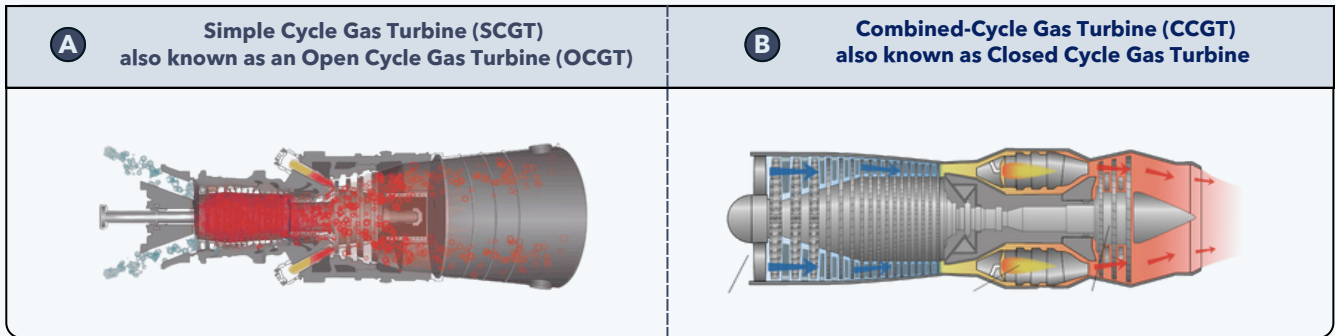
B. Steam turbine:

This machine converts the thermal energy generated by pressurized steam into mechanical work, typically by rotating a shaft. It operates by harnessing the expansion of high-pressure steam, which drives a series of blades attached to the rotating shaft, effectively transforming heat energy into kinetic energy.

01 Types of Gas Technologies

1.4. Types of Gas Powerplants

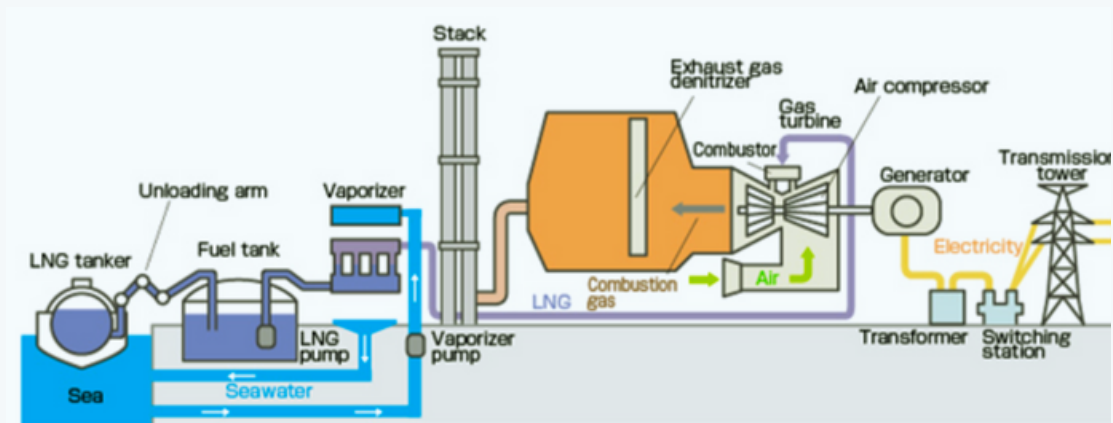
There are two types of gas powerplants in operation today, these are;



A. Simple Cycle Gas Turbine (SCGT)

This gas turbine operates on the Brayton cycle, where air is compressed, mixed with gas, ignited, and the resulting hot exhaust gases drive a turbine connected to a generator to produce electricity. Unlike combined cycle systems, this setup does not include a waste heat recovery system, meaning the heat typically expelled through exhaust gases is not captured or utilized.

Figure 1: Gas turbine power generation



Air is drawn into the plant through an intake system, where it's filtered to remove dust and other particles. The clean air then enters a compressor, where it is compressed, increasing its temperature and pressure. This high-pressure air is mixed with natural gas in the combustion chamber, where ignition occurs, producing a high-temperature, high-pressure gas stream.

01 Types of Gas Technologies

The hot gases flow into the turbine, causing its blades to spin. The turbine is connected to a shaft that drives a generator. As the shaft rotates, it turns a rotor inside the generator, creating a magnetic field that induces an electric current in the stator windings, generating electricity. The produced electricity is then either sent to the power grid or used locally. After passing through the turbine, the exhaust gases are expelled through the exhaust system at a lower temperature and pressure. This entire process efficiently produces electricity for grid distribution or local use.

Simple Cycle Gas Turbines (SCGT) are valued for their flexibility and rapid start-up capabilities, making them ideal for meeting peak demand, providing backup power, or supporting intermittent renewable energy sources. They are often maintained as "spinning reserves" to respond quickly to changes in grid demand.

Typical large SCGTs generate between 100-300 MW of power, with the most efficient models achieving up to 46% energy utilization². While SCGTs trade off some efficiency for greater operational flexibility and lower capital costs, they are well-suited for high-power demand situations. However, they are less efficient for continuous power generation compared to combined cycle gas turbines.

Due to their versatility and ability to efficiently convert chemical energy into mechanical energy, SCGTs are used in a wide range of applications, including aircraft propulsion, power generation, and various industrial processes.

B. Combined Cycle Gas Turbine (CCGT)

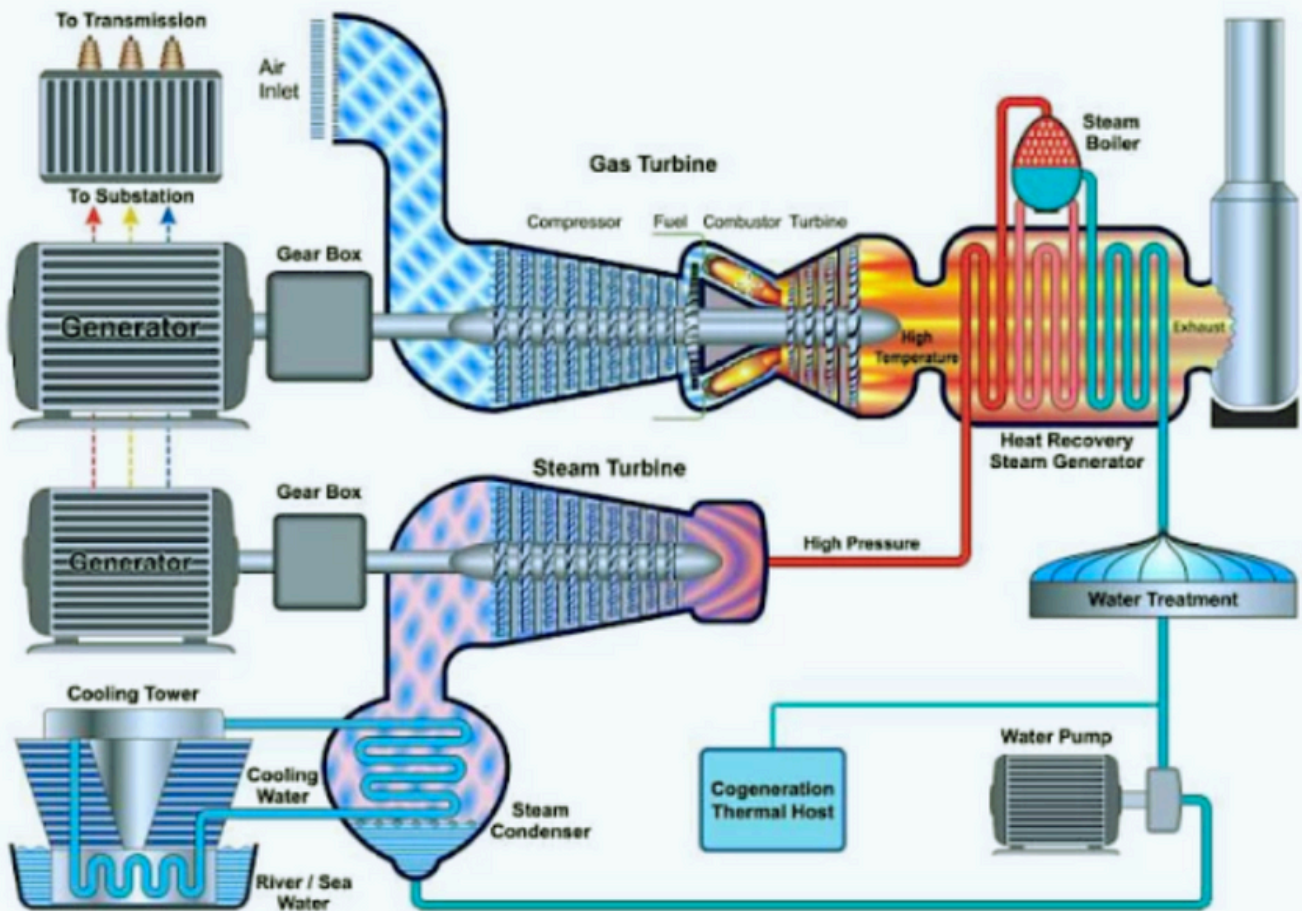
A combined-cycle gas turbine (CCGT) power generation system maximizes efficiency by integrating two energy cycles: the Rankine (steam turbine) and Brayton (gas turbine) cycles. The process begins with a gas turbine that burns natural gas in the combustion chamber, producing a high-velocity stream of hot gases. These gases drive the turbine, causing it to spin and generate electricity through a connected generator.

Instead of wasting the hot exhaust gases, they are channeled into a heat recovery steam generator (HRSG), where they are used to convert water into steam. This steam then powers a steam turbine, which drives a second generator to produce additional electricity.

01 Types of Gas Technologies

By combining the gas and steam turbines, CCGT plants can produce up to 50% more electricity compared to conventional simple-cycle plants. This integration not only boosts energy production but also reduces fuel consumption and lowers emissions, making CCGT a highly efficient and environmentally friendly option in modern power generation.

Figure 2: Combined-cycle power system using a gas turbine generator with heat recovery steam generator.



Nigeria's power generation portfolio includes a variety of gas power stations, primarily fueled by natural gas. The total installed capacity of these gas power stations amounts to 12,197 MW. Of this capacity, 15% is comprised of CCGT, while 85% consists of SCGT. Both SCGT and CCGT technologies play a vital role in the country's electricity generation, with CCGT offering greater efficiency through the use of waste heat recovery systems, and SCGT providing quicker operational flexibility.

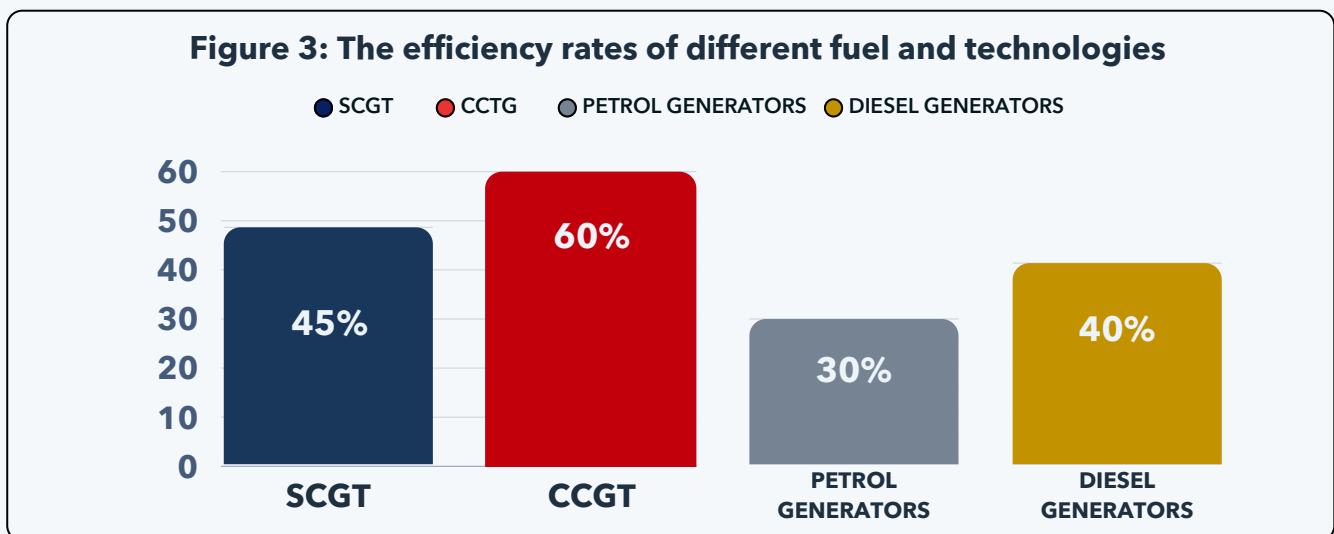
The breakdown of these gas power stations is detailed in the table below.

S/N	Name	Type	Capacity (MW)	State
1	Afam VI	CCGT	624	Rivers
2	Afam IV- V	SCGT	726	Rivers
3	Alaoji	CCGT	1,074	Abia
4	Azura	SCGT	450	Edo
5	Odukpani NIPP	SCGT	561	Cross River
6	Egbin Power Plc	SCGT	1,320	Lagos
7	Gbarain IPP	SCGT	225	Bayelsa
8	Geregu I	SCGT	414	Kogi
9	Geregu II NIPP	SCGT	434	Kogi
10	Ibom Power	SCGT	190	Akwa Ibom
11	Ihovbor	SCGT	450	Edo
12	Okpai IPP	CCGT	480	Delta
13	Olorunsogo I	SCGT	336	Ogun

S/N	Name	Type	Capacity (MW)	State
14	Olorunsogo II NIPP	CCGT	675	Ogun
15	Omoku IPP	SCGT	150	Rivers
16	Omotosho I	SCGT	336	Ondo
17	Omotosho II NIPP	SCGT	450	Ondo
18	Rivers IPP	SCGT	180	Delta
19	Sapele ST	SCGT	1,020	Delta
20	Sapele GT NIPP	SCGT	450	Delta
21	Trans Amadi IPP	SCGT	136	Rivers
22	Delta (Ughelli)	SCGT	900	Delta
23	AES Barge IPP	SCGT	270	Lagos
24	Aba Power	SCGT	140	Abia
25	Taopex	SCGT	60	Lagos
26	MEPP	SCGT	50	Borno
27	Paras	SCGT	96	Ogun
Total			12,197	

SCGT : 9,344 MW ○ **CCGT : 2,853 MW**

Efficiency: Gas power plants are typically more efficient than other types of fossil fuel-powered generators. The CCGT plants can achieve efficiencies of up to 60% or more by utilizing both gas and steam turbines, while SCGT can achieve efficiencies of 35% to 45% by using the gas turbine and it can start up quickly, making them ideal for meeting high power demands and providing backup power. In contrast, petrol (gasoline) which is typically used to backup power systems has lower efficiency of around 20-30%, diesel has efficiencies of around 30-40% for large-scale generators, and coal of about 33-37% efficiency.

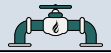


Cost-Effectiveness: Gas power plants, especially SCGT, have lower initial capital costs compared to some renewable energy projects. Specifically, building a 1 MW power station in Nigeria varies significantly depending on whether it is a gas-fired or solar power plant. Constructing a 1 MW gas-fired power plant in Nigeria typically ranges from \$800,000 to \$1 million⁵. This cost depends on several factors, including the technology used (whether it is a single-cycle or combined-cycle plant) and the location. While the cost of building a 1 MW solar power plant in Nigeria is generally higher, ranging from \$1 million to \$1.2 million⁶. This cost includes expenses for solar panels, inverters, land acquisition (typically 4-5 acres for 1 MW), and installation. Solar projects might also face additional costs related to grid connections, especially if the plant is located far from existing infrastructure.

Cleaner Burning: Natural gas burns cleaner than coal and oil, producing fewer pollutants like sulfur dioxide (SO₂) and nitrogen oxides (NO_x). In addition, burning natural gas produces about 50-60% less carbon dioxide (CO₂) per unit of energy generated than coal and oil. This makes natural gas a cleaner alternative to fossil fuels for power generation and heating.



A. Resource Limitations:



Natural gas is a non-renewable fossil fuel that faces long-term sustainability concerns due to the eventual depletion of its reserves. According to Templars, Nigeria possesses the 9th largest proven natural gas reserves globally, estimated at approximately 200 trillion cubic feet. Despite holding the largest reserves in Africa, only about 25 per cent of these reserves are currently being developed. This limited development suggests that while the depletion of these reserves is not imminent, it is a future concern that will need to be managed as the world moves towards more sustainable energy solutions.

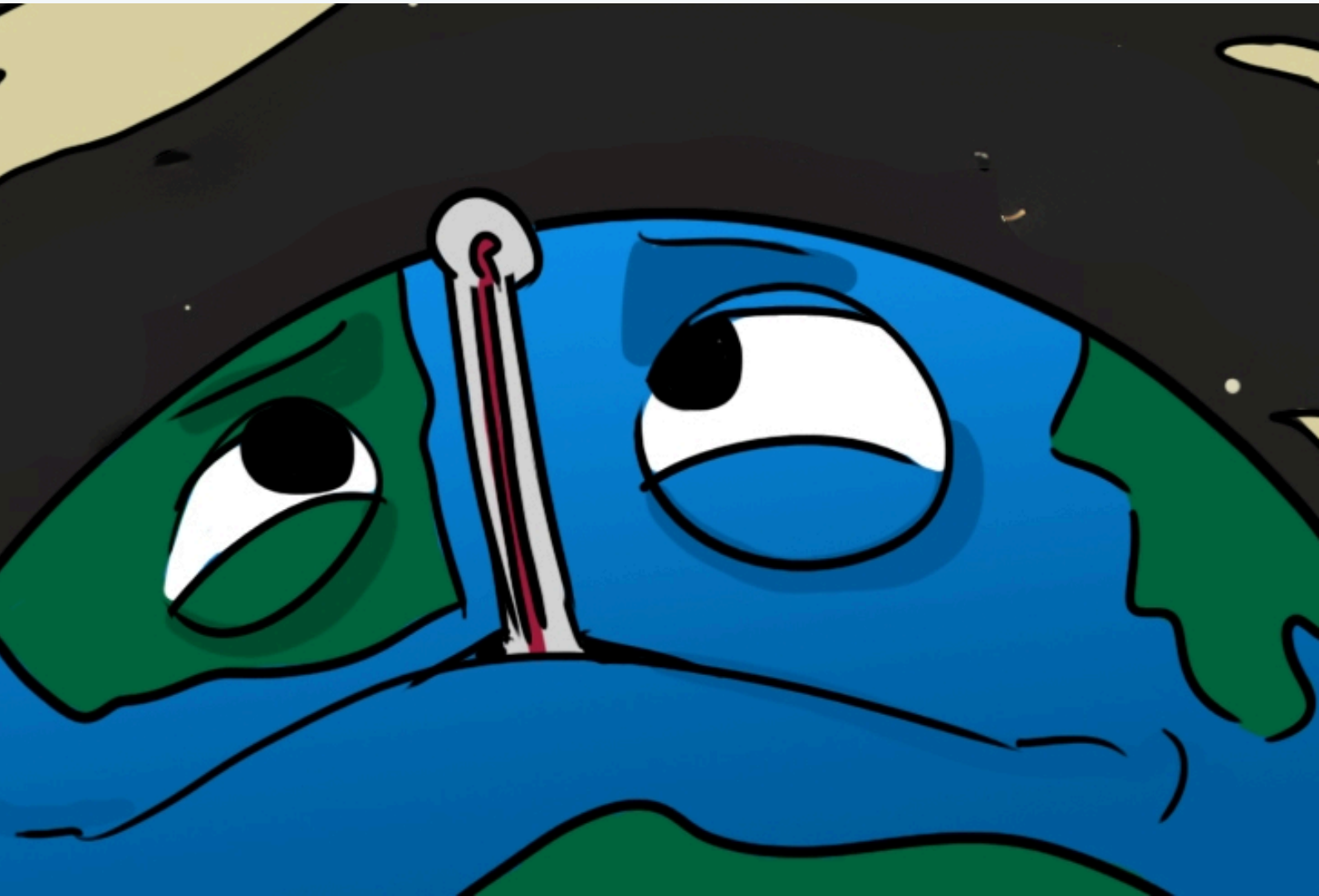
B. Sustainability:



As the global focus shifts towards reducing carbon emissions and embracing renewable energy, the future role of natural gas in the energy mix remains uncertain. Some experts have argued that the climate benefits of natural gas are often overstated, especially when accounting for methane leakage. They also warn that significant investments in natural gas infrastructure could create a lock-in effect, diverting resources from renewable energy projects and potentially hindering the transition to a low-carbon energy system. Conversely, others believe that natural gas can contribute to emissions reduction in the short to medium term as part of a diversified energy strategy. They view it as a "bridge fuel" that can support the energy transition while renewable technologies develop. However, some are concerned that continued reliance on natural gas might result in stranded assets as the energy landscape evolves, leaving its long-term role in the transition uncertain.

C. Environmental Concerns:

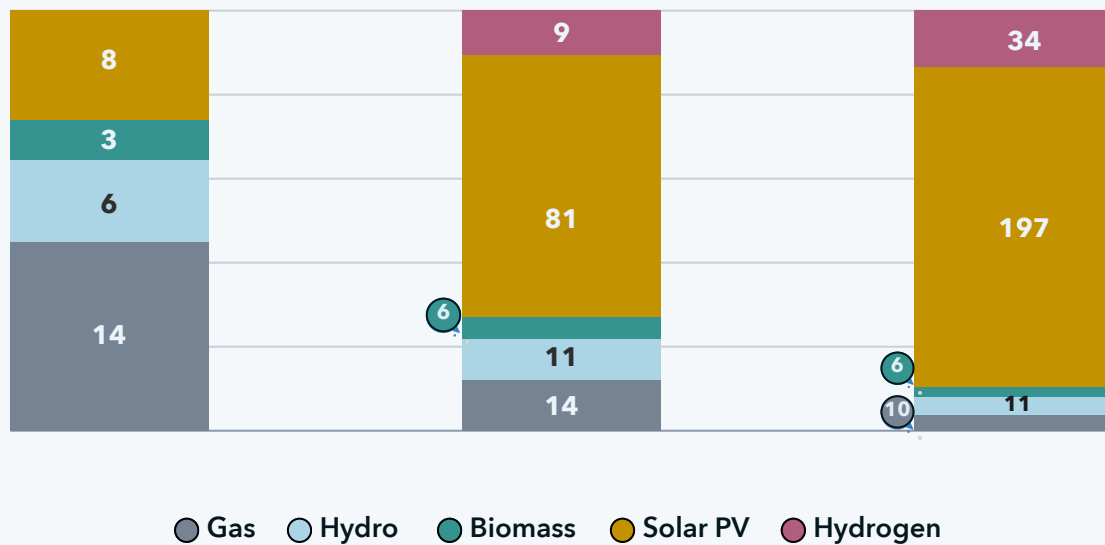
Methane, a potent greenhouse gas, can escape during natural gas extraction, processing, and transportation, significantly contributing to global warming. The extraction process often involves hydraulic fracturing, where a mixture of water, sand, and chemicals is injected at high pressure into rock formations to release trapped gas. This method not only demands substantial water use but also risks contaminating groundwater. Additionally, while natural gas burns cleaner than coal, it still emits CO₂ and other pollutants, which continue to impact the environment.



Gas and steam turbines present substantial opportunities for growth and efficiency enhancements within Nigeria's power generation sector. However, to fully realize their potential, it is imperative to address challenges such as securing adequate funding and upgrading essential infrastructure for gas supply and generation. Nigeria is committed to expanding its gas turbine capacity as a means to reduce dependence on diesel generators and meet the increasing demand for electricity. Concurrently, steam turbines are poised to play a crucial role in supporting the nation's decarbonization objectives, particularly in biomass and waste-to-energy facilities.

Nigeria's Energy Transition Plan (ETP) emphasizes the strategic utilization of gas as a transition fuel. The plan aims for a 15% increase in gas-powered generation capacity by 2030, which will create significant investment opportunities in this sector. However, the timeframe for capitalizing on these opportunities is limited, as Nigeria has set an ambitious goal of achieving full carbon neutrality by 2060.

Figure 4: Projected Centralised Energy Mix (GW) in Nigeria's ETP



According to the ETP, gas-powered plants are expected to contribute 45% of the generation mix by 2030, with an installed capacity of 14GW. Given that there is currently about 12 GW of licensed gas-powered generation on-grid which are only providing about , the focus should shift from constructing new plants to optimizing and unlocking existing gas generation capacity. This is particularly vital as projections indicate that by 2050, Nigeria's gas-powered capacity may decline to approximately 10GW, reflecting a broader transition toward cleaner energy sources.

Natural gas technology plays a crucial role in the modern energy landscape, particularly in Nigeria where vast reserves remain underutilized. The technological advancements in gas turbines, such as SCGT and CCGT, provide efficient, cost-effective, and relatively cleaner alternatives to coal and oil. These gas plants contribute significantly to Nigeria's power generation, with flexibility to meet peak demands and a growing focus on energy efficiency. However, despite its immediate benefits, the long-term sustainability of natural gas is uncertain due to resource depletion, environmental concerns, and the global shift towards renewable energy sources.

While gas technology offers short- to medium-term advantages, particularly as a bridge fuel in the energy transition, its future role must be balanced with investments in renewable energy to meet climate goals. Methane emissions and other environmental challenges must also be addressed to ensure that natural gas contributes positively to global decarbonization efforts. Ultimately, the success of gas technology in Nigeria and beyond will depend on continued innovation, supportive regulations, and an integrated approach to energy production that embraces cleaner and renewable alternatives.



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