MODULE 1

Jennifer Okeke

DOOWE

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- **Outline the benefits and drawbacks of natural gas in comparison to other energy sources in a climate where low-carbon energy policies are in place.**
- **Determine how current natural gas transmission and storage infrastructure could be used to manage non-fossil energy.**
- **Pick the main arguments that a decarbonizing world makes natural gas superior to other fossil fuels.**

WHAT IS FOSSIL FUEL?

The components of fossil fuels are decaying plants and animals. These fuels may be burned to provide energy and can be found in the crust of the Earth. Fossil fuels include coal, oil, and natural gas.

WHAT IS NON-FOSSIL FUEL?

This is also known as an alternative fuel, non-conventional or advanced fuel. Apart from conventional fuels such as petroleum (oil), coal, and natural gas, nuclear materials such as uranium and thorium, as well synthetic radioisotope fuels produced in nuclear reactors, are also materials or substances that can be used as fuels.

WHAT IS NATURAL GAS?

Natural gas is the least harmful, colourless, odourless, and low-carbon hydrocarbon. It warms food for cooking and heating, and it fuels power plants that supply homes and businesses with energy. It serves as a fuel for numerous industrial processes that create everything from glass to textiles, and it is a key component of items like paints and plastics. Converting gas at our gas-to-liquids plants into fuels and other products that burn cleaner. It is cooled to -162 ^{o}C (-260 ^{o}F), which transforms it into a liquid that is simple to transport to energy-starved regions of the world. As a lower-emission fuel, liquefied natural gas (LNG) is used in trains, buses, trucks, and ships.

BENEFITS OF NATURAL GAS

- Natural gas burns cleaner than other fossil fuels, making it the most environmentally friendly one. Natural gas doesn't have as many toxic combustion by-products as other fossil fuels.

Natural gas will glow blue when burned under ideal combustion conditions and produce little to no hazardous chemicals. One of the easiest energy sources to store and transfer is natural gas. It can be transported by tankers or international pipelines (in LNG form). Unlike other fossil fuels, it is safer and easier to store. One of the best non-renewable energy sources is natural gas. What about clean energy, though?

- Natural gas is quite dependable. Electricity is fantastic until a storm arrives. During a storm, it might be knocked out, and thereafter, our electrical equipment might break down. Natural gas cannot lead to a similar issue.

- Better transportation and storage than with renewable energy. Compared to sustainable energy, transportation is substantially more efficient across vast distances (less network loss). We cannot properly store renewable energy, which is one of their main drawbacks.

- Vehicle Efficiency
  In terms of power, acceleration, and cruising speed, natural gas vehicles (NGVs) are comparable to cars powered by gasoline or diesel. Because less overall energy can be stored in a tank of the same size as natural gas, NGVs often have a shorter driving range than equivalent gasoline and diesel cars. For larger cars, adding more natural gas storage tanks or using LNG can assist extend their range.
- Compression-ignited dual-fuel engines are marginally more fuel-efficient than spark-ignited specialised natural gas engines in heavy-duty vehicles. However, because a dual-fuel engine needs to store both types of fuel and include diesel after-treatment equipment, the fuel-storage system becomes more complex.

DRAWBACKS OF NATURAL GAS

- **A Fossil Fuel is Natural Gas.**
  Compared to other fossil fuels, gas has lower carbon emissions. It is still a fossil fuel, though. Except in very limited conditions, natural gas cannot be renewed. In both cases, it generates more carbon dioxide than renewable energy. It is a bridging fuel because of this. It bridges the gap between the widespread expansion of renewable energy and the decommissioning of larger fossil fuel plants.

- **Leaking Methane**
  Natural gas is available worldwide and is simple to transfer. At every stage of the supply chain, these processes nevertheless release methane, a strong greenhouse gas. Methane has 28 to 34 times more potential to cause global warming than carbon dioxide. Because methane leaks are difficult to prevent, natural gas is a dirtier energy source than first assumed. This emphasises natural gas' status as a fossil fuel even more, along with the fact that it is a greenhouse gas.

- **Price Sensitivity**
  The market for natural gas in Europe and, to a lesser extent, Asia is mostly under Russian control. Natural gas prices have fluctuated in both regions as a result of transportation problems and political unrest. Infrastructure that will be operational after 2023 is being developed in Europe and Asia to maintain prices stable and supply constant. Prices are lower in the United States, where natural gas supply systems are wholly domestic.

- **Natural Gas Sourcing and Processing**
  Natural gas can be extracted in several ways, but fracking is one of the most popular. To bring a subterranean gas deposit closer to the surface, fracking entails injecting water into the deposit. It has been connected to numerous serious health problems, environmental harm, and significant gas leaks. Fracking accounts for 67 per cent of gas sourcing in the US. Fracking continues to be a viable and affordable source of energy, even while new initiatives emphasise a shift toward a more sustainable extraction method.

- **Natural Gas is Risky**
  Natural gas is a combustible and highly flammable liquid. If natural gas spills, the harm might be worse.

DO THE BENEFITS OF NATURAL GAS OUTWEIGH THE DRAWBACKS?

Natural gas has several substantial benefits and drawbacks, some of which might sometimes balance one another out. It is a solid contender for a transition fuel because of its large energy capacity, simplicity of transportation, and minimal carbon dioxide emissions. However, concerns are raised about methane due to supply chain leaks, sourcing challenges, and its classification as a fossil fuel.

On the other hand, natural gas is adaptable, making it perfect for economies that are growing. Once infrastructure projects are finished later in the decade, price volatility will probably start to decrease. Natural gas will undoubtedly play a significant part in the global transition to a low-carbon future, notwithstanding the ongoing discussion regarding its potential as a bridge fuel.

NATURAL GAS INFRASTRUCTURE

- **Supplying more. The pace and magnitude of change in the US natural gas sector are unparalleled. Between 2005 and 2013, the US produced 3 per cent more natural gas. Manufacturing has changed in favour of onshore shale gas regions as opposed to traditional areas like the Gulf of Mexico. most crucial for the output in the Marcellus and Utica Basins has increased quickly, a pattern that is anticipated to last till 2030 (the time horizon under consideration for the Quadrennial Energy Review). Production has migrated to plays with abundant liquids, which also yield crude oil and natural gas liquids (NGL).**

- **A rise in demand. The rate of midstream infrastructure investment is influenced by long-term gas demand since shippers must enter into contracts to finance the expansion of new pipelines. The economics and use of natural gas for electric generation and industrial uses have altered considerably as a result of the increased supply at historically low prices. From 15.8 billion cubic feet per day (Bcf/d) in 2005 to 22.2 Bcf/d in 2013, gas demand for electricity generation increased. Significant new investments in industrial facilities, cheap capital costs, and proposed laws that would encourage fuel switching in some regions are further factors driving demand growth.**

- **Brand-new infrastructure Latent pipeline network capacity and system flexibility already in place are likely to reduce the size of future investment needed. Current policy and investment mechanisms are, in the majority of regions, addressing obstacles as they arise, according to recent investment trends and projects that are currently in development.**

According to analysis, the system won't be put under undue strain by the surge in demand brought on by the export of liquefied natural gas.

- Electric and gas are interdependent. The interdependence between the gas and electricity sectors might provide problems for regional reliability as the usage of gas for power generation rises. The two industries' coordination, including, for instance, the alignment of gas and electricity bidding and scheduling days, still needs more attention. Gas-fired power plants in some areas lack incentives to buy gas in the quantities and at the times that would signal the market to invest in infrastructure for the gas industry. The reliability and resilience of natural gas delivery can be ensured by maintaining and enhancing the flexibility of the natural gas system through high-deliverability gas storage or gas-electricity system flexibility solutions (such as electric demand response, adding natural gas pipeline capacity, dual-fuel capability, and end-use energy efficiency, and adding electric transmission capacity).

- Processing. More natural gas processing capacity and NGL transportation capacity are needed for wet gas production. In the Bakken, tight oil demand has been the main driver of associated gas extraction, which has led to severe flaring when takeaway capacity and local usage of associated natural gas and NGL are surpassed by production (for further information on NGL, see Appendix A (Liquid Fuels)). New laws have been put in place by the State of North Dakota to cut back on gas flaring, and this will probably encourage the construction of more infrastructure for gathering and processing energy in the region. By the end of 2017, the nation's processing capacity, which is currently 83 Bcf/d, is anticipated to reach 95 Bcf/d. This anticipated growth is anticipated to ease processing bottlenecks already in place.

- Environmental and Climate Impacts. Carbon dioxide and other pollution emissions from power generation can be decreased by the increase in gas-fired power generation. Nearly one-fourth of the methane emissions in the United States—or 2.5% of all carbon dioxide-equivalent emissions—were produced by natural gas systems. Methane emissions made up about 10% of the total gross greenhouse gas emissions (on a carbon dioxide-equivalent basis) from anthropogenic sources in the United States. The transmission, storage, processing, and distribution of natural gas account for more than two-thirds of all methane emissions from natural gas networks.

- Public Protection The bulk of serious gas pipeline safety accidents involve natural gas distribution networks. These occurrences frequently take place in heavily populated places. Although equipment failure, improper operation, and pipeline corrosion are also significant and preventable contributions, excavation damage is the primary factor in serious events along natural gas pipelines. b Natural gas distributors, who mostly serve residential and commercial loads, must improve their systems or replace deteriorating pipes that are prone to leaks. Although it is predicted that replacing these pipes will cost several billions of dollars, doing so results in significant risk reduction and emissions mitigation.

- Government function. To safeguard both public and private interests in terms of dependability, safety, and environmental performance, the government plays a crucial role in all energy systems. These objectives are supported by several government organisations operating at the federal, state, and local levels. These organisations carry out activities like facility permitting, safety inspections, and market oversight, all of which are crucial to the responsible design and operation of systems.

COMPARING FOSSIL FUEL AND NON-FOSSIL FUEL

One of the biggest issues of our day is climate change. However, the requirement to guarantee access to energy for improving both economic development and quality of life is equally crucial. Therefore, the sustainable development agenda must include addressing climate change. The continued advancement of new technologies has given rise to optimism and confidence that these goals for the energy system will be achieved. These discoveries have generally led to the belief that fossil fuels have reached the end of their useful lives across the energy system, that no new resources need to be discovered, and that we must stop using them as soon as possible. This presumption has also contributed to a perception of "good" renewables-based technologies and "bad" fossil fuels-based technologies in today's global energy systems. The truth is that this argument is considerably more complex and calls for a more in-depth analysis. While fossil fuels are still a part of the energy system, carbon capture and storage (CCS) technology and regulating methane emissions along the fossil energy value chain can assist achieve ambitious CO2 emission reduction targets. As a result, fossil fuels will be able to stop being "part of the problem" and start being "part of the solution". Every technology has a place in an energy system that is driven by sound economics. 80 per cent of the world's primary energy demand is currently met by fossil fuels, and the energy system is responsible for about two-thirds of all CO2 emissions in the world. Given that emissions of methane and other SLCPs are thought to be greatly understated, it is likely that an even bigger proportion of emissions are caused by the production and consumption of energy. Additionally, a large portion of biomass fuel is used on a modest scale for cooking and heating throughout the world. Particularly about indoor air quality in many less developed countries, these are incredibly inefficient and polluting. Sustainable development is hampered by the utilisation of renewable biomass in this manner. Although using fossil fuels is not prohibited by the need to reduce emissions, doing business as usual is incompatible with reducing emissions in the world's energy systems. Renewable energy and energy efficiency are frequently presented as the only ways to achieve climate goals in the energy system, yet they are insufficient. It will be crucial to increase the usage of CCS because, by 2050, this technology is predicted to reduce emissions by 16% annually. The Fifth Assessment Synthesis Report of the Intergovernmental Panel on Climate Change, which calculates that restricting emissions from the energy sector without CCS would increase the cost of climate mitigation by 138%, lends weight to this argument. The inability of diverse energy subsectors to convert from fossil fuels to renewables is the main reason why renewables cannot be employed uniformly across the energy system to replace the usage of fossil fuels today. To increase the cost-effective penetration of the largest variety of low-carbon technologies and increase the resilience of the energy system, the development of smart energy networks with common operating rules is a significant opportunity. Whether we like it or not, fossil fuels will continue to play a role in the world's energy system for years to come. It will continue to support global social and economic progress. In light of this, we must have an honest conversation about how fossil fuels fit into the world's sustainable energy systems to develop workable climate change policies. In the context of the twenty-first session of the Conference of the Parties (COP21) to the United Nations Framework Convention on Climate Change, it is crucial to involve emerging economies and developing nations. This might alter the political landscape and influence the creation of a solid climate agreement.

NATURAL GAS IS THE SUPERIOR FOSSIL FUEL

In general, extracting and using natural gas is more environmentally benign than doing the same with coal. While the extraction of natural gas through hydraulic fracturing has numerous additional negative environmental effects, other fossil fuels can occasionally be more harmful and destructive.

Acid Mist

In contrast to natural gas, emissions from coal and oil can result in acid rain, which is created when hydroxyl radicals in the atmosphere combine with sulphur dioxide and nitrogen oxides.

Air Toxicity

Natural gas burns cleaner than other fossil fuels and creates hardly any sulphur, mercury, or particles during combustion. Nitrogen oxides (NOx), which are precursors to smog, are produced during the burning of natural gas, albeit in lower quantities than during the burning of gasoline and diesel. According to DOE calculations, every 10,000 houses in the United States that use natural gas as opposed to coal would prevent the annual emissions of 1,900 tonnes of NOx, 3,900 tonnes of SO2, and 5,200 tonnes of particulates. As these pollutants have been related to issues including asthma, bronchitis, lung cancer, and heart disease for hundreds of millions of Americans, reductions in these emissions translate into benefits for public health. Unconventional gas development, however, can have an impact on local and regional air quality despite these advantages. The EPA regulates particulate matter and ozone plus its precursors as two of the six "criteria pollutants" because of their detrimental impact on human health and the environment. Concentrations of hazardous air pollutants have increased in some drilling regions. Cancer, cardiovascular disease, and respiratory symptoms are just a few of the negative health effects that can result from exposure to high amounts of these air pollutants. According to a recent study, those who live closer to unconventional gas well sites—less than half a mile away—are more at risk of experiencing negative health consequences from air pollution from natural gas production than people who live farther away.

Wildlife and land usage

Oil and gas drilling require building and land disturbance, which can change how land is used and damage nearby ecosystems by creating erosion and disrupting wildlife habitats and migratory routes. The building process can lead to the erosion of dirt, minerals, and other dangerous contaminants into surrounding streams when oil and gas companies clear a site to create a good pad, pipelines, and access roads.

Potential environmental effects from hydraulic fracturing in Michigan were found to be "significant," and they included increased erosion and sedimentation, a higher risk of aquatic contamination from chemical spills or equipment runoff, habitat fragmentation, and a decrease in surface waters as a result of lower groundwater levels.

Use of water and pollution

Through the contaminating of drinking water sources with dangerous chemicals used in drilling the wellbore, hydraulically fracturing the well, processing and refining the oil or gas, or disposing of wastewater, unconventional oil and gas development may pose health concerns to nearby communities. From inadequately cased wells, naturally occurring radioactive elements, methane, and other subsurface gases have occasionally spilt into drinking water sources. Methane is not linked to immediate health consequences, but substantial amounts may raise concerns about flammability. Concerns about the availability of water in some communities are heightened by the significant amounts of water utilised in unconventional oil and gas operations.

- **Groundwater**

  There are reported instances of fracking fluids and gases, such as methane and volatile organic compounds, contaminating groundwater close to oil and gas wells. Inadequately built or failing wells that allow gas to escape into groundwater are a major source of gas contamination. In Pennsylvania and Ohio, there have been reported cases of contamination. Natural or artificial subsurface fissures could allow stray gas to travel directly between an oil and gas formation and groundwater supplies, providing yet another possible route for groundwater pollution. In addition to gases, hydraulic fracturing fluid can contaminate groundwater. In several instances, fracturing fluid spills and surface leaks impacted groundwater. Additionally, fracture-induced fractures, failing wastewater pit liners, poorly sealed and constructed wells, abandoned wells, and fluid migration may all be caused by wells.

- **Finished Water**
  In addition to spills and leaks of chemical additives, spills and leaks of diesel or other fluids from on-site equipment, and leaks of wastewater from storage, treatment, and disposal facilities, unconventional oil and gas development also puts surface waterways at danger of pollution. Contrary to hazards associated with groundwater contamination, surface water contamination concerns are mostly associated with land management, as well as with the management of chemicals and wastewater both on- and off-site.
  More than 1,000 chemical additives, including acids (particularly hydrochloric acid), bactericides, scale removers, and friction-reducing compounds, have been identified by the EPA as being used in hydraulic fracturing. Each well only requires about a dozen chemicals, but the selection of those compounds is well-specific and dependent on the geochemistry and requirements of that well. The chemical additives are trucked to and kept on a good pad in large quantities—tens of thousands of litres for each well. If not handled correctly, the chemicals may leak or spill during transit or from subpar storage containers.
  Additionally, fluids like drilling muds, fuel, and others can leak at the surface. Leaks and spills may result from improper handling of produced or flow-back wastewater. Additionally, the deliberate inappropriate disposal of wastewater by bad actors poses a risk to surface water.

- **Use of Water**
  Growing hydraulic fracturing and its high water consumption per well could put a strain on the nearby ground and surface water supplies, especially in places with limited water resources. Due to variations in formation geology, well design, and the type of hydraulic fracturing procedure employed, the amount of water used to hydraulically fracture a well might vary. According to the EPA's estimation, 35,000 wells were reportedly fractured countrywide in 2011 using 70 billion to 140 billion gallons of water. The majority of the water needed for unconventional oil and gas exploration is not recoverable, in contrast to other

energy-related water withdrawals, which are frequently returned to rivers and lakes. A single well with horizontal drilling can require 3 million to 12 million gallons of water when it is first fractured, which is hundreds of times more than what is required in traditional vertical wells. This depends on the type of well as well as its depth and location. To maintain well pressure and gas production, enormous amounts of water are required each time a well gets a "work over" or further fracturing later in its life. Throughout its productive life, a typical shale gas well will undergo roughly two workovers.