Natural Gas: A Cleaner Energy Solution and Bridge Fuel or Just Another Fossil Fuel?

Read the passage below. Use the Cornell Note Taking worksheet to organize your notes.

The Natural Gas Boom and Preparing for Climate Change
In 2013, the White House issued an executive order entitled "Preparing the United States for the Impacts of Climate Change." The order requires federal agencies to begin "undertaking actions to enhance climate preparedness and resilience," including reductions to the sources of climate change. In his February 2014 State of the Union address, President Obama described natural gas as a "bridge fuel that can power our economy with less of the carbon pollution that causes climate change." He called on Congress to "build fueling stations that shift more cars and trucks from foreign oil to American natural gas." U.S. consumption of natural gas for the generation of electricity has been steadily increasing since 2009. Due to the dramatic increase in the use of natural gas for meeting our energy demands, we must ask ourselves: Is natural gas really a cleaner energy solution and "bridge fuel," or is it just another fossil fuel?

What is a Bridge Fuel?
Bridge fuel is a commonly-used term for a fuel that will power society with the least environmental cost while we deploy non-polluting, renewable energy. The goal of using a bridge fuel is to replace the bulk of today's fossil-fuel-dependent energy sources as we transition to a cleaner and more renewable energy economy that is free of greenhouse gas emissions. The length of the bridge and the energy source used to build the bridge are both topics of debate. Many people consider natural gas a bridge fuel because it produces less greenhouse gas during the combustion process. However, additional considerations for a bridge fuel include whether it increases national energy independence while reducing pollution-related costs. A systems-based approach allows us to consider multiple elements in the energy production of natural gas. This gives us a clearer view of all the factors that must be considered. Examining energy transformation and transfer from "cradle to grave," or extraction to end use, helps us determine if natural gas is in fact a bridge fuel to a cleaner, renewable energy economy.

What is Natural Gas?
Natural gas is a fossil fuel. Like all fossil fuels, it is a nonrenewable resource. Natural gas is classified as a nonrenewable resource because it cannot be replenished at the same rate it is consumed.

Natural gas is a colorless and odorless gas composed of 70-90% methane (CH_4). Its other ingredients include ethane (C_2H_6) and propane (C_3H_8). Possible impurities include carbon dioxide (CO_2), hydrogen sulfide (H_2S), and nitrogen (N_2). The amount of impurities in a fossil fuel source determines the amount of pollutants released during the combustion process. Natural

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gas has fewer impurities compared to oil and coal, and it produces less kilograms of pollution per unit of energy created through the combustion process.

Natural gas is formed from layers of buried plants and ocean microorganisms exposed to intense heat and pressure over millions of years. The energy in natural gas comes from the energy that producers such as plants, algae, and cyanobacteria captured from sunlight millions of years ago. The percentage of methane and other ingredients in natural gas can vary based on how much temperature and pressure the geology of an area experienced over time.

Uses for Natural Gas

Natural gas is primarily used to produce electricity, but it can also be used in the industrial sector in the production of steel, glass, brick, paper, and even clothing. Natural gas is used in almost half of all the homes in the United States for heating, cooking, hot water heaters, and clothes dryers. Additionally natural gas is used in the production of paints, fertilizer, plastics, antifreeze, dyes, photographic film, medicines, and explosives.

The industrial and electric power sectors lead the U.S. in consumption and use of natural gas. Power companies most often use natural gas to generate electricity by burning the natural gas in a boiler to produce steam for a steam turbine and/or burning the gas in a combustion turbine. The industrial sector uses natural gas in a similar way, in order to create its own heat and electricity directly on-site, saving industries money by not having to purchase power from a utility company.

Natural gas can also be used in vehicles and for residential heating needs. There is particular interest in natural gas as a substitute for foreign and domestic oil in our transportation sector. Cities from Los Angeles to New York have been increasing their fleets of buses that run on natural gas. By 2011, the Los Angeles Metro had converted its entire fleet to natural gas and retired its last diesel bus. Not only municipalities but also industries are increasing the use of natural gas in transportation fleets. Initially this was done to reduce particulate matter pollution, but more recently to address emissions of greenhouse gasses. The United Parcel Service (UPS), the world's largest package delivery company, also owns the largest private fleet of natural gas vehicles in the country. In 2014, all new UPS tractor trailer purchases will use natural gas. American automakers are also beginning to increase the availability of public options for natural gas vehicles; for example Honda Civics, Chevrolet Silverado 2500, Dodge Ram 2500, and Ford F-250 all have a model that runs on natural gas.

What We Need to Know About Combustion

To understand whether or not natural gas is a cleaner burning fossil fuel requires an understanding of the combustion process. Combustion is best understood as the act or

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Natural Gas, continued

process of burning. In chemistry terms, it is an exothermic chemical reaction between a fuel (hydrocarbon-based in this case) and an oxidant (oxygen).

Combustion of different hydrocarbons produces varying amounts of carbon dioxide (CO_2). As shown in the balanced equations below, complete combustion of the hydrocarbons methane (CH_4) and octane (C_8H_{18}) produce different amounts of CO_2. Different hydrocarbons also produce varying amounts of energy. Natural gas is mostly methane.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

$$2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$$

There are different ways of looking at the amounts of carbon dioxide released by various fuels in relation to the energy they produce. One method is to evaluate the mass of CO_2 emitted per amount of energy released when each type of fuel is combusted.

Fuel Type	**Average Kg of CO_2 emitted per million British Thermal Units of Energy (Btu)**
Coal (bituminous)	95.3
Diesel fuel and heating oil	73.2
Gasoline	71.3
Propane	63.1
Natural Gas	53.1

Data Source: U.S. Energy Information Administration

As shown in the table above, the type of hydrocarbon fuel and the efficiency of the combustion process affects the quantity of CO_2 produced when burning a hydrocarbon-based fuel. These fuel types can be compared to energy sources like wind, hydroelectric, and nuclear power that directly emit zero CO_2, because there is no associated combustion process. However, it is also useful to measure the CO_2 released in the process of developing and maintaining the technology over its lifetime. This released CO_2 is significantly less over the entire lifetime of the renewable technologies' energy production than the burning of fossil fuels.

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Additionally, the amount of energy released by different hydrocarbons varies.

Fuel Type	Energy Content in (kJ/g)
natural gas	51.6
Petroleum	43.6
Coal	39.3

Data Source: Western Oregon University

The above tables show that the combustion of natural gas produces more energy and less CO_2 per gram than both petroleum and coal.

Looking through a Systems-Based Lens
Understanding the combustion of a fossil fuel may not fully capture all environmental impacts, including impacts related to total carbon dioxide and/or other greenhouse gas emissions. Even technologies that emit no carbon directly, like renewable energy sources, emit greenhouse gasses in the technology production and maintenance. Therefore it is important to look at the production and transportation of fossil fuels to determine the total contribution of greenhouse gasses for each fuel type. This is a systems-based approach to assessing climate impact and greenhouse gas emissions.

One important consideration for evaluating natural gas as a bridge fuel is to understand that the main constituent of natural gas is methane (CH_4). Methane is more potent as a greenhouse gas than carbon dioxide (CO_2). The Intergovernmental Panel on Climate Change (IPCC) notes: “Pound for pound, the comparative impact of CH_4 on climate change is over 20 times greater than CO_2 over a 100-year period.”

The global warming potential (GWP) of a gas is the measurement of how much a given mass of a chemical contributes to global warming over a given time period compared to the same mass of carbon dioxide. Carbon dioxide’s GWP is the standard by which all other greenhouse gasses are measured. The table below shows the 20, 100, and 500 year global warming potentials of some greenhouse gasses.

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Natural Gas, continued

Greenhouse Gas	20-year GWP	100-year GWP	500-year GWP
CO_2 Carbon Dioxide	1	1	1
CH_4 Methane	72	25	7.6
N_2O Nitrous Oxide	289	298	153
SF_6 Sulfur Hexafluoride	16,300	22,800	32,600

Data Source: Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (Forster, et al., 2007)

Methane is a potent greenhouse gas, so it is critical to identify any leakage of methane into the atmosphere during any phase of the energy production process from extraction to production, including transportation-related losses. This systems approach with all greenhouse gas emissions is necessary to truly assess whether or not natural gas should be used extensively as a bridge fuel.

The initial round of scientific studies and analysis by different groups—including the National Oceanic and Atmospheric Administration, U.S. Environmental Protection Agency, U.S. Department of Energy, and multiple universities—indicated widely varying accounts for how much methane is released into the atmosphere during the extraction process of natural gas. Differing scientific analysis of methane leakage, or "fugitive methane" as some call it, is due in part to the variety of techniques employed in the studies. The variability of locations sampled for natural gas also matters. The most recent reports on "fugitive" natural gas indicate that previous reports may have underestimated by as much as 50% the amount of natural gas leakage. Our current state of knowledge has a significant degree of uncertainty at best. The science of calculating methane leakage during the natural gas process from extraction to energy delivery is incomplete, and the methods for determining the complete efficiency and impact of any particular fossil fuel from beginning to end, or "cradle to grave," are complicated. Scientific knowledge of fugitive methane increases with each new study. This is an area of ongoing research.

Further complicating the systems-based evaluation is that we must consider that, as a gas, natural gas is inherently more challenging to transport long distances than liquid oil. Gas must be compressed multiple times at stations along natural gas pipelines, many of which siphon off some of the natural gas to run a compressor, resulting in energy loss.

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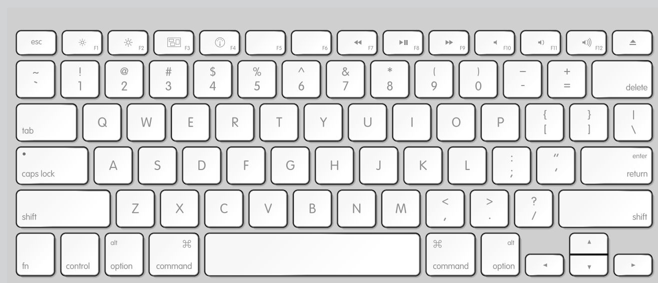
Natural Gas, continued

Final Analysis

So is natural gas a cleaner energy solution and a logical bridge fuel or is it just another fossil fuel? The answer lies not in the combustion process, but rather in a systems-based analysis. A bridge fuel by definition is a cleaner option that primarily reduces our greenhouse gas emissions as new renewable technologies gain in market share. That means that in the process of extracting, transporting, and generating energy a particular fuel choice releases fewer greenhouse gasses throughout the entire cycle than our current energy economy. To be a cleaner option, one must consider more than just one part of a complex system. If the sum of all the parts when calculated proves to reduce greenhouse gas emissions, reduces associated pollution, and increases national energy independence more than our current energy choices, then we may choose to label it a bridge fuel. However, it's important to note that a bridge fuel today will eventually become a greenhouse gas problem to solve in the future.

Our Choices Today May Affect our Ability to Make Future Decisions

When one technology has acquired an overwhelming market share, as is the case for fossil fuels, the perceived cost of switching to another technology seems daunting. Take for example the standard computer keyboard layout, called the "QWERTY" layout, where q,w,e,r,t,y, are the first letters on the top row. The QWERTY keyboard has been the standard to which people become accustomed for over 30 years. Imagine how difficult it would be for consumers to accept and investors to create a different format and layout for the keyboard, even if there was compelling reason to attempt such a change.



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The "QWERTY" example helps to illustrate that if one focuses solely on the short-term costs in making choices, they are more likely to choose to stay with the standard technology that is currently in use and has considerable demand. Future innovations may be more effective and better suited to meeting consumer demands, but oftentimes will not be able to break into the market because we are locked into these past decisions. These decisions based on solely short-term costs often prove to be more expensive over time. While difficult to do, encouraging decisions that focus on longer-term time frames allows more options to be considered when trying to accomplish a particular goal.

The American energy system has long been dominated by a select few types of energy resources and energy distribution designs. This has created the current environment where we are partially locked into our past decisions. The choices we make today about whether to invest in natural gas or renewables may have a significant effect for future generations.

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Natural Gas Glossary

balanced equation *noun.* chemical equation in which there are equal numbers of each type of atom on each side of the equation.

bridge fuel *noun.* fuel that will power society with the least environmental cost while we deploy non-polluting, renewable energy.

British Thermal Unit *noun.* amount of heat or energy required to raise the temperature of one pound of water by one degree Fahrenheit, or 251.997 calories.

byproduct *noun.* substance that is created by the production of another material.

carbon emission *noun.* carbon compound released into the air through the burning of fossil fuels such as coal or gas.

climate change *noun.* gradual changes in all the interconnected weather elements on our planet.

combustion *noun.* burning, or the process of a substance reacting with oxygen to produce heat and light.

consumption *noun.* process of using goods and services.

dry natural gas *noun.* natural gas that is almost pure methane, having had most of the other common hydrocarbons (ethane, butane, propane, pentane) removed. Dry natural gas comes from a reservoir that does not also have large amounts of liquid petroleum.

electrical energy *noun.* energy associated with the changes between atomic particles (electrons).

electrical energy *noun.* energy made available by a flow of electrical charge, through a conductor. Electrical energy is measured in Joules.

emission *noun.* discharge or release.

energy *noun.* capacity to do work.

energy consumption *noun.* use of power, usually defined as power produced by human beings in plants run on electricity, fossil fuels, or nuclear fission.

fossil fuel *noun.* coal, oil, or natural gas. Fossil fuels formed from the remains of ancient plants and animals.

fugitive *noun, adjective.* escaped from the law or another restriction.

global warming *noun.* increase in the average temperature of the Earth's air and oceans.

Global Warming Potential (GWP) *noun.* measure of how much a given amount of greenhouse gas is estimated to contribute to global warming, relative to the same amount of carbon dioxide.

greenhouse gas *noun.* gas in the atmosphere, such as carbon dioxide and ozone, that absorbs solar heat reflected by the surface of the Earth, warming the atmosphere.

hydrocarbon *noun.* chemical compound made entirely of the elements hydrogen and carbon.

impurity *noun.* minute substance that differs from the chemical composition of the main compound in which it is found.

megawatt *noun.* unit of electrical power equal to one million watts.

megawatt hour *noun.* equal to 1,000 kilowatt hours (Kwh), or 1,000 kilowatts of electricity used continuously for one hour. One megawatt–hour equals one million (1,000,000) watt-hours or 3,600,000,000 joules.

natural gas *noun.* type of fossil fuel made up mostly of the gas methane.

potent *adjective.* very powerful.

steam turbine *noun.* machine driven by the movement of steam passing over blades or rotors.

turbine *noun.* machine that captures the energy of a moving fluid, such as air or water.

wet natural gas *noun.* natural gas that includes common hydrocarbons (ethane, butane, propane, pentane) other than methane. Wet natural gas comes from a reservoir that also has large amounts of liquid petroleum.

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