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NATURAL GAS – AN ENERGY AND ENVIRONMENTAL SAVIOR DURING THE 21ST CENTURY

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Abstract: Climate change is inevitable. Contributing to this change are (i) natural effects, which include the Earth in an interglacial period and (ii) various other effects such as anthropogenic effects, which include the release of non-indigenous gases into the atmosphere. However, the exact contribution of each effect to global climate change is not known with any degree of certainty. Natural gas has been proposed as a savior for the environment insofar as it released less carbon dioxide during combustion that crude oil or coal. This paper examines the properties of natural gas and how this fuel might affect the environment.
Keywords: climate change, natural gas, anthropogenic activity

INTRODUCTION

The most general definition of climate change is a change in the statistical properties of the climate system when considered over long periods of time, regardless of cause. Accordingly, fluctuations over periods shorter than a few decades, such as El Niño, do not represent climate change. The term sometimes is used to refer to climate change caused by human activity, as opposed to changes in climate that may have resulted as part of Earth's natural processes. In this sense, especially in the context of environmental policy, the term climate change has unfortunately and incorrectly been associated with anthropogenic (human activities) global warming as the causative factor. Within scientific journals, global warming refers to an increase in the surface temperature of the Earth while climate change is amore all-inclusive term that includes global.

The issue of global climate change is often associated with the use of fossil fuels as sources of energy. Of most concern is the increase in emissions of carbon dioxide (CO2) due to emissions from fossil fuel combustion:

$$C_{\text{fossil fuel}} + O2 \rightarrow CO2 \quad (1)$$

Natural gas produces carbon dioxide when it is burned for energy but the combustion of natural gas produces considerably less carbon dioxide per unit of usable energy than combustion of other fossil fuels such as coal or crude oil, and their respective products. However, carbon dioxide emissions are not the main cause of observed atmospheric warming and there are several other causes that contribute to the global warming phenomenon [1]. The focus solely on carbon dioxide as the is due to.

Human activity produces vastly more carbon dioxide than all other greenhouse gases put together. However, this does not mean it is responsible for most of the earth’s warming. Many other greenhouse gases trap heat far more powerful than carbon dioxide [2].

Thus, the focus of this paper is the properties of natural gas and how this fuel might affect the environment.

NATURAL GAS

Natural gas, which includes shale gas, gas from tight formations, and coalbed methane (Speight, 2018), is predominantly methane, occurs in underground reservoirs separately or in association with crude oil [3,4,5]. The principal types of hydrocarbons produced from natural gas are methane (CH4) and varying amounts of higher molecular weight hydrocarbons from ethane (CH3CH3) to octane [CH3(CH2)6CH3]. Generally the higher molecular weight liquid hydrocarbons from pentane to octane and collective referred to as gas condensate.

While natural gas is predominantly a mixture of combustible hydrocarbons (Table 1), many natural gases also contain nitrogen (N2) as well as carbon dioxide (CO2) and hydrogen sulfide (H2S). Trace quantities of helium and other sulfur and nitrogen compounds may also be present. However. Raw natural gas varies greatly in composition and the constituents can be several of a group of saturated hydrocarbons from methane to higher molecular weight hydrocarbons, especially natural gas that has been associated with crude oil in the reservoir, and non-hydrocarbon constituents (Table 1). The treatment required to prepare natural gas for distribution as an industrial or household fuel is specified in terms of the use and environmental regulations. Briefly, natural gas contains hydrocarbons and non-hydrocarbon gases. Hydrocarbon gases are methane (CH4), ethane (C2H6), propane (C3H8), butanes (C4H10), pentanes (C5H12), hexane (C6H14), heptane (C7H16), and sometimes trace amounts of octane (C8H18), and higher molecular weight hydrocarbons. Some aromatics [BTX – benzene (C6H6), toluene (C6H5CH3), and the xylene isomers (o-, m-, and p-CH3C6H4CH3)] can also be present, raising safety issues due to their toxicity. The non-hydrocarbon gas portion of the natural gas contains nitrogen (N2), carbon dioxide (CO2), helium (He), hydrogen sulfide (H2S), water vapor (H2O), and other sulfur compounds (such as carbonyl sulfide (COS) and mercaptans (e.g., methyl mercaptan, CH3SH) and trace amounts of other gases. In addition, the composition of a gas stream gas from a source or at a location can also vary over time which can cause difficulties in resolving the data from the application of standard test methods [6,7].

Table 1. Composition of Natural Gas from a Petroleum Well

Category	Component	Amount (% v/v)
Paraffins	Methane (CH_4)	70-98
	Ethane (C_2H_6)	1-10
	Propane (C_3H_8)	Trace-5
	Butane (C_4H_{10})	Trace-2
	Pentane (C_5H_{12})	Trace-l
	Hexane (C_6H_{14})	Trace-0.5
	Heptane and higher molecular weight (C_{7+})	Trace
Cycloparaffins	Cyclohexane (C_6H_{12})	Trace
Aromatics	Benzene (C_6H_6) + other aromatics	Trace
Non-hydrocarbons	Nitrogen (N_2)	Trace-15
	Carbon dioxide (CO_2)	Trace-1
	Hydrogen sulfide (H_2S)	Trace-1
	Helium (He)	Trace-5
	Other sulfur and nitrogen compounds	Trace
	Water (H_2O)	Trace-5

However, prior to use, natural gas must be processed to remove the non-methane constituents [3,5,8]. Gas processing (also called gas cleaning or gas refining) consists of separating all of the various hydrocarbons and fluids from the pure natural gas [3,5,8-14]. While often assumed to be hydrocarbons in nature, there are also components of the gaseous products that must be removed prior to release of the gases to the atmosphere or prior to use of the gas in another part of the refinery, i.e., as a fuel gas or as a process feedstock.

Gas processing involves the use of several different types of processes to remove contaminants from gas streams but there is always overlap between the various processing concepts. In addition, the terminology used for gas processing can often be confusing and/or misleading because of the overlap [10]. Gas processing is necessary to ensure that the natural gas prepared for transportation (usually by pipeline) and for sales must be as clean and pure as the specifications dictate. Thus, natural gas, as it is used by consumers, is much different from the natural gas that is brought from underground formations up to the wellhead.

OTHER SOURCES OF METHANE

— Natural sources

The main natural sources of methane are wetlands, termites and oceans. Wetlands are by far the largest source with methane being produced from the anaerobic decomposition of organic matter covered by water. Because this process involves the action of bacteria, the rate of methane production is strongly temperature dependent. Maximum methane production is experienced at temperatures between 37 and 45ºC (100 and 112ºF) and so future increases in global temperature may enhance methane production from wetlands, thereby reinforcing the greenhouse effect.

Methane is also produced by the digestive processes of termites, resulting in approximately 5% of world methane emissions. This value is unlikely to change as termite populations are not expanding despite greater availability of biomass due to deforestation.22 Methane emissions from termites should be treated as a significant, but background, source that is likely to remain constant.

Oceans contribute approximately 2% to global methane emissions. The methane is produced by methanogenic bacteria within sinking particles in surface waters. The production of methane from oceans is spatially dependent, with much methane arising from methanogenesis in marine sediments, particularly in nutrient rich areas such as estuaries. There is also an anthropogenic component to ocean emissions, with bacterial populations being increased by high nutrient levels from agricultural fertilizer run-off and waste treatment effluents.

— Anthropogenic sources

The key anthropogenic sources of methane include fossil fuels, agriculture, landfill and the burning of biomass. Methane emissions arising from the fossil fuel industry form the largest anthropogenic source of methane. The main sources of fossil fuel-related methane emissions are the release of natural gas from coal mining and leakage from gas processing and distribution pipes [15-17]. Pockets of methane that have been trapped between layers of coal during its formation and methane within the coal itself are released once the coal is mined. Agricultural practices also result in significant methane emissions, the two major sectors being rice production and the rearing of livestock [18,19]. Thus, the relative lifecycle carbon intensity of a range of potential natural gas sources must be more fully understood, particularly methane leakage.

Methane is produced as part of the natural digestive processes of ruminant animals such as cattle, sheep and goats. Food is broken down by bacteria in the rumen, aiding digestion, since stomach enzymes are insufficient to break down plant polymers. However, the action of these bacteria yields methane, carbon dioxide and ammonia as gaseous by-products. With an increasing global population, coupled with higher living standards, livestock numbers are increasing world-wide.

Landfill sites also provide an anaerobic environment where methanogenic bacteria break down waste organic materials. Somewhere between 40 and 60% of landfill gas is methane, depending on the composition of the waste. The remainder is mainly carbon dioxide with other trace gases. The amount of methane emitted to the atmosphere from a landfill site is strongly dependent on the design and operation of the site. Unchecked, the landfill gas will simply permeate through the waste or along cracks in the compacted waste or bedrock. Modern landfill sites use impermeable liners and a capping layer to control the movement of the gas, which may then be collected. However, even the best caps are only 85% efficient25 with the remaining 15% of methane escaping through the cap.26. This is offset by breakdown of up to 90% of the methane in the capping layer by methanotrophic bacteria.

The burning of biomass releases substantial quantities of methane into the atmosphere each year. Biomass burning results mainly in the production of carbon dioxide, but if fires smolder and combustion is incomplete, methane and other volatile organic compounds are released. The extent of methane emissions is dependent on the completeness of combustion and the carbon content of the fuel used.

— Methane hydrates

Although currently neither a source nor a sink, methane hydrates are by far the largest store of methane on the planet and account for 53% of all fossil fuels on earth. They are a crystalline solid mixture of water and methane (essentially methane trapped in ice) and are found in ocean floor sediments and arctic permafrost.

The methane in ocean sediment hydrates is trapped by the high pressure deep in the ocean but is released above a depth of 400m as the pressure drops. The energy industry is keen to take advantage of this and mine these deposits.29 Methane contained in arctic tundra, trapped within the frozen solid structure of the hydrate, is a more serious issue. Should temperatures rise, the methane hydrate will melt, releasing methane gas to the atmosphere. There is concern that, if rising global temperatures due to anthropogenic climate change cause the arctic permafrost to melt, massive quantities of methane would be released into the atmosphere, causing a catastrophic run-away greenhouse effect beyond even the upper 5.8ºC estimate postulated by the IPCC. Such a process is believed to have occurred in the Paleocene-Eocene Thermal Maximum, which occurred approximately 55 million years ago, when global temperatures increased by 5ºC (90F) average and which lasted for 150,000 years.

GASES IN THE ATMOSPHERE

The atmosphere (excluding moisture) consists of nitrogen (78%) and oxygen (21%) as well other gases, including greenhouse gases such as carbon dioxide, are collectively classified as trace gases due to their low concentrations. There is the belief that human activity is altering the composition of the atmosphere by increasing the concentration of greenhouse gases. Greenhouse gases occur naturally in the atmosphere and their presence results in what atmospheric scientists call the greenhouse effect. It is important to remember that the greenhouse effect is what keeps the earth warm enough to be habitable. The current concern is directed at an enhanced greenhouse effect, one that would put more heat-absorbing gases into the atmosphere, thereby increasing global temperatures.

The recent attention given to the greenhouse effect and global warming is based on the recorded increases in concentrations of some of the greenhouse gases due to human activity. Of particular interest are water vapor, carbon dioxide (CO_2), methane (CH_4), nitrogen oxides – such as nitrous oxide (N_2O) nitric oxide (NO), and nitrogen dioxide (NO_2), and ozone (O_3) – and all of these gases occur naturally and/or are also produced by anthropogenic activity [20].

Carbon dioxide (CO_2) is considered the most important human-influenced greenhouse gas. Scientific measurements reveal an unmistakable global increase in the amount of carbon dioxide, which arises primarily from the burning of fossil fuels (motorized vehicles, electric power plants, and homes heated with gas or oil) and the burning and clearing of forested land for agricultural purposes. But is carbon dioxide the real culprit for global climate change?

Methane (CH_4) is the major constituent of natural gas and it is also a product of natural biologic processes, but its output can also arise from anthropogenic activity. This gas is emitted from the decay of organic matter in waterlogged soils (for example, wetlands and rice paddies) and from the digestive tracts of grazing animals (for example, ruminants). The additions from human activities include:

emissions from livestock,
emissions from landfills, and
leakage from natural gas during production and transportation [21,22].

Methane, the principal constituent of natural gas, is a much more effective greenhouse gas than carbon dioxide and has adverse effects on the atmosphere [23]. The infrared absorption of a methane molecule is almost 30 times that of a carbon dioxide molecule. However, the effective lifetime of methane in the atmosphere is much shorter. Nevertheless, an increase in the concentration in the atmosphere could result in a major change in the effects on the climate. Moreover, substitution of natural gas for crude oil and coal can be an important interim strategy to moderate carbon dioxide emissions while better non-fossil sources are developed and deployed.

The emissions of methane during the lifecycle of natural gas may be much higher than conventional estimates and the total greenhouse gas emissions may, as a result, be close to, or even higher than, those from the lifecycle of coal – particularly in the case of shale gas [24]. Clearly, there is a need for research to quantify much more reliably the methane emissions associated with natural gas. This can result in in findings that are unfavorable to the use of natural gas and there is need for serious quantification of any derived data.

It is therefore important to reduce global emissions to such a level that they are outweighed by methane sinks, so that the concentration of methane in the atmosphere decreases and its subsequent warming effect is reduced.

CONCLUSIONS

Natural gas has been promoted as a fuel that will allow society to continue to use fossil energy over the coming decades while emitting fewer greenhouse gases than from using other fossil fuels such as coal and crude oil. It is a fact that less carbon dioxide is emitted per unit of energy released during combustion when burning natural gas is compared to coal or crude oil, natural gas is composed largely of methane which is an extremely potent greenhouse gas. In fact, methane is responsible for nearly as much global warming as all other non- carbon dioxide greenhouse gases put together. Methane is twenty-one times more powerful a greenhouse gas than carbon dioxide.

The current information for global climate change points to global warming/climate change being influenced by the sum of all effects with no one effect (such the anthropogenic effect) being the major contributor from a multi-component group of effects, one of which is methane emissions. However, sound policies must be in place to make certain that natural gas is used to replace coal and minimize methane emissions.

Note:
This paper is based on the paper presented at VIII International Conference Industrial Engineering and Environmental Protection – IIZS

2018, organized by University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, SERBIA, in Zrenjanin, SERBIA, October 11-12th, 2018.

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ISSN: 2067-3809