The Benefits and Downsides of Methane

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Introduction

Energy is essential for survival for all living things on Earth. We use it almost every day to power our automobiles, the buildings we work in, and our smart phones when we need to send a message to a friend. Fossil fuels have largely been our main source of energy, accounting for 86% of US energy consumption in the form of petroleum, coal, and natural gas. [1] Alternative sources of energy have improved in the hopes of meeting the energy needs in a more environmentally friendly way, including solar, wind, and hydroelectric energy with greater success over the past few years. [2] Despite great progress, they still greatly lag behind the rate at which we consume fossil fuel resources, where there is a large amount of evidence pointing towards their deleterious effect on the environment ranging from global warming to the very habitat that supports life.

Recent developments spearheaded by multiple countries with harnessing methane have made it a promising source of energy that could overtake other fossil fuel energy sources (Fig.1). It is considered to be a cleaner alternative to oil and coal, is richer in carbon, and found abundantly in nature. However, methane is considered a more potent greenhouse gas than carbon dioxide and can be hazardous to store and manage. [3] Here we highlight both the benefits and downsides of increasing our efforts to harvest methane and what might be best moving forward to support our energy needs while minimizing damage induced on our environment.

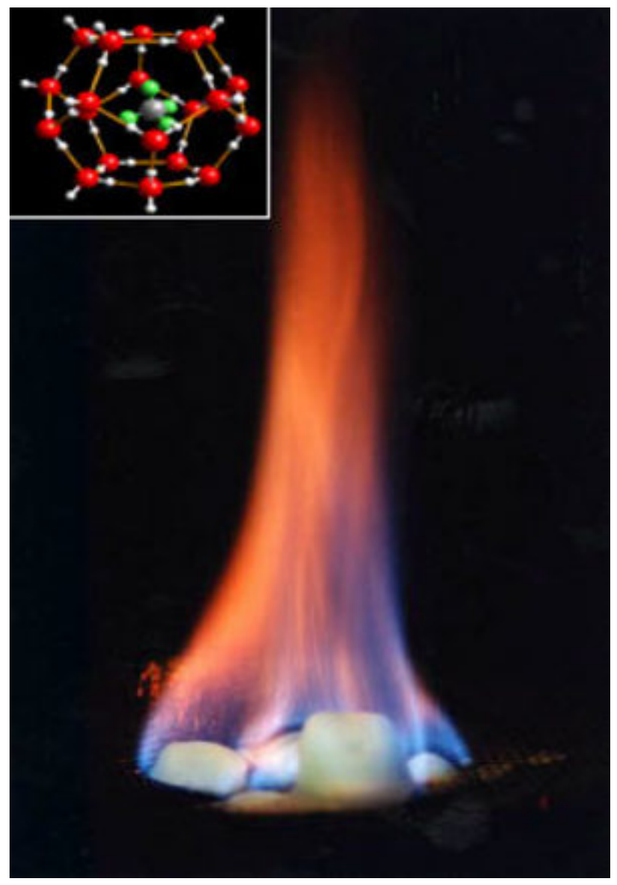

Fig. 1: Methane clathrate burning with inset showing molecular structure. Wikimedia Commons

Benefits of Methane

Methane is produced through a variety of sources. Human activity has been known to produce copious amounts of methane through rice farming, livestock farming, landfills, biomass burning, and even coal mining. Natural sources include cellulose-disgesting bacteria, or methanogens, in the gut of termites or in the wetlands. Methane is produced through two major pathways under anaerobic conditions, where (1) carbon dioxide is reduced with hydrogen, fatty acids, or alcohols as hydrogen donors and (2) transmethylation of acetic acid (CH_3COOH) or methyl alcohol (CH_3OH). Although this phenomenon is well understood, calculating the actual net amount is a bit complicated since methane can be consumed in overlying aerobic layers. Nevertheless, current estimates put methane production on the order of millions of tonnes. [4]

One source in particular has gained much attention over the past few years. Methane clathrate, or more colloquially known as "fire ice", is found as an ice crystal with natural methane gas locked inside, formed through the combination of low temperatures and high pressure. One cubic meter of the compound releases about 160 cubic meters of gas, making it a highly energy-intensive fuel. [5] A large portion of methane can be found distributed primarily within permafrost regions and in continental slode sediments. [6] Evidence shows that these deposits are enormous, with more energy stored in methane hydrates compared to the world's oil, coal and gas combined. Methane produces energy in the form of heat when ignited through oxidative pyrolysis. The following reaction equations describe this process: [4]

$$CH_4 + O_2 \rightarrow CO + 2\,H_2O \quad \text{(oxidative pyrolysis)}$$
$$2\,H_2 + O_2 \rightarrow 2\,H_2O + \text{ENERGY} \quad \text{(heat)}$$
$$2\,CO + O_2 \rightarrow 2\,CO_2 + \text{ENERGY} \quad \text{(heat)}$$
$$CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O + 891\text{kJ/mol (STP)}$$

Recent efforts especially by Japan have proven to be fruitful, where there is an estimated 6 trillion cubic meters of methane hydrate in sedimentary basins nearby. [7]

Downsides of Methane

Storing and utilizing methane can be tricky and poses potential problems that may exacerbate the global warming issue we are currently facing today. It is highly flammable, which increases the risk of combustion given ideal conditions. [3] In addition, methane is considered to be 20-30 times more potent as a greenhouse gas compared to carbon dioxide. [4] Therefore, with the impending rise of temperature around the world, it is not too difficult to imagine a scenario when permafrost and methane hydrates will begin to thaw, releasing trillions of cubic meters of methane into the atmosphere and consequently accelerating global warming. Another source of methane from agriculture and ruminants also makes it difficult to figure out how these sources can be curtailed when the demand for meat and crops will not subside anytime soon. [8] Landfills within developing worlds are not entirely equipped to be able to contain methane that is being produced in the presence of methanogens. Combined with the current lack of resources for collecting methane in a reliable manner and its ability to trap heat within the earth's atmosphere makes methane a lot more difficult to handle and potentially unwieldy and dangerous.

Future Directions

Despite environmental concerns, methane is still considered to be a better alterative to other fossil fuel sources and efforts are certainly underway to make it a leading source of energy in the future. Experts believe that the release of methane from clathrates are believed to be slow and chronic rather than catastrophic, and much of it may never reach the atmosphere. [8] However, it is probably for the best if we could minimize the amount of energy we all use over time, which could then alleviate demand and furthermore preserve whatever fuel sources we still have on Earth. Unfortunately, we don't have an infinite amount of resources and our ability to be frugal with what we have may be what saves us in the coming decades.

References

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