METHANE HIDRATES

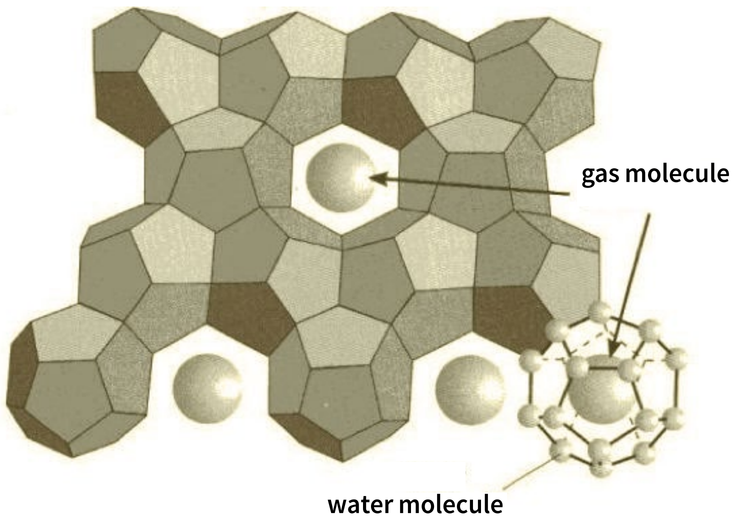
METHANE (NATURAL GAS) AND WATER TRAPPED AS AN ICY SUBSTANCE UNDER THE SEA FLOOR AND IN THE ARCTIC PERMAFROST.

VAST STORE OF CARBON, **WHICH IF RELEASED WOULD HAVE DEVASTATING CONSEQUENCES FOR CLIMATE CHANGE.**

WHAT IS IT?

Methane hydrate, also known as methane clathrate or "fire ice", occurs when methane molecules are trapped in an ice-like form of water. At certain temperatures and pressures the water molecules surround the methane in a cage which forms a slushy icy substance.

A diagram of methane hydrate molecular structure



There are huge amounts of methane hydrate around the world, mostly occurring on and under the sea floor on the continental shelves, with smaller amounts found in other marine and deep fresh water lake locations and also on-land, underground in Arctic regions. Methane hydrates may also trap large methane deposits (in gas form) beneath them.[1]

Methane hydrate deposits can be either biogenic in origin, created by microbes in sediment, or thermogenic, created by geological heating of organic material at great depths. The characteristics of the deposits vary significantly due to differences in origin, their structure, temperature and pressure conditions, and their association with different geological formations.

Methane hydrates were first created in labs in the 1800s and were found forming in and clogging up natural gas pipelines in the 1930s. It wasn't until the 1960s that they were found to occur naturally, and later still, in the 1980s, that people started to consider methane hydrates as a potential fuel source. However, methane hydrates have since remained 'a fuel of the future' due to serious technical obstacles to their extraction.

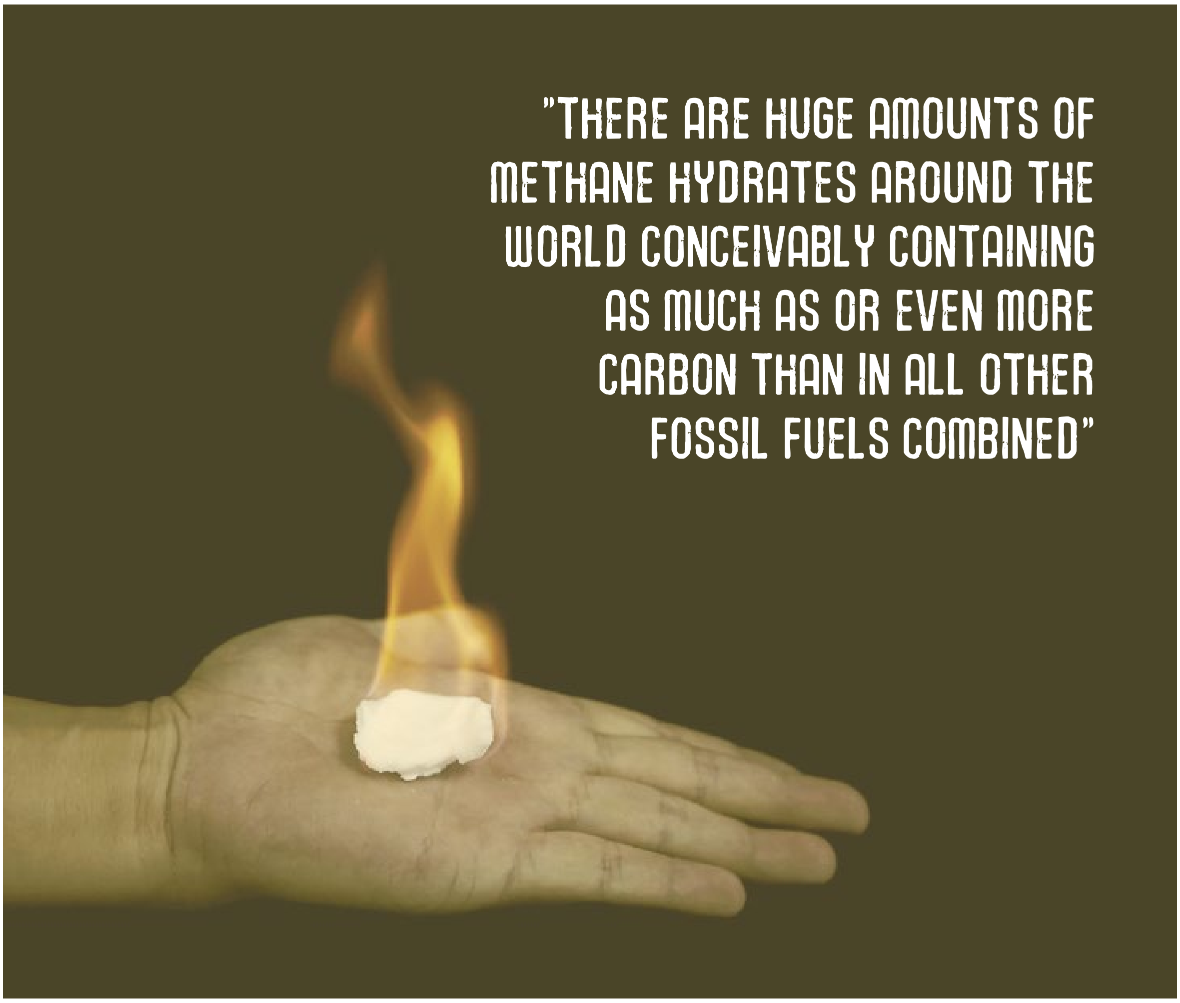
As well as a potential fuel source, methane hydrates are also of interest due to their role in the global climate system (see climate change section below).

Methane hydrate resources are extremely large. While estimates still vary significantly,[2] the total amount in the oceans is likely to be around 1000 to 5000 trillion cubic metres (about 500–2500 gigatonnes of carbon (GtC)),[3] with the amount in Arctic regions around 400 GtC.[4] An amount similar to that in the Arctic may also occur in the Antarctic.[5] Another recent study made a conservative estimate of the total amount of carbon in methane hydrates as 1800 GtC.[6]

Some estimates are much higher, putting the total carbon in methane hydrates as similar to or even more than the total carbon in all the other fossil fuels in the world combined (about 5000 gigatonnes).[7,8,9,10]

A large proportion of the world's methane hydrates are found at depths of several hundreds of metres below the sea floor in very fine-grained marine sediments. They are essentially mixed with mud, making their recovery and exploitation very difficult, and there are no current proposals for technologies to recover these deposits. The first assessments of potential technically-recoverable resources give an estimate of around 300 trillion cubic metres or around 150 GtC).[11] This is still a very large amount, much more than the total estimated global natural gas reserves (around 190 trillion cubic metres).[12]

If methane hydrates are exploited as a fuel source it would add a massive amount of carbon to the atmosphere, with dire consequences for the climate. However, despite recent completed test projects, some predict that methane hydrates will never be an economical fuel source.



Japanese drilling ship used for methane hydrate extraction

HOW IS IT EXTRACTED?

As the methane is trapped in the ice-like hydrate structure, the gas cannot be extracted using the same methods as conventional natural gas extraction. Also, if methane hydrates are removed from their natural environment the change in pressure and temperature makes them unstable and releases the methane. These factors, combined with the fact that they are mainly found below the sea bed on the continental shelf (or underground on-land in polar regions), pose significant problems for developing methane hydrates as a fuel source.

Extraction is still at the experimental stage. However, there are a number of methods that have been suggested and several test projects have been carried out. One proposed method involves pumping hot water down a drill hole to melt the hydrates and release the methane which could then be pumped away in pipelines along the sea bed.[13] One drawback with this method is the large amount of energy required to heat the hydrates.

A de-pressurisation method has been experimented with which involves drilling into the deposit, and pumping out excess fluid. This lowers the pressure and releases the methane. This method had some success at the Mallik Gas Hydrate Research Well in northern Canada,[14] and was used in Japan's recent test project, the first to successfully extract methane hydrates from marine deposits (see below).

There are also proposed techniques that involve using a combination of thermal and de-pressurisation methods. A further method, inhibitor injection, involves injecting chemicals (usually salts, alcohols or glycols) that lower the temperature at which the hydrates are stable, and thus release the methane. These inhibitors are regularly used to prevent methane hydrates forming in pipelines and during undersea drilling operations.

Another method involves injecting CO_2 into the deposit. The idea is for the CO_2 to replace the methane in the hydrate and become trapped there instead.[15] This is intended as a way of extracting methane from the hydrates and storing the CO_2 at the same time. The replacement of methane with CO_2 in hydrates has been demonstrated experimentally,[16] and a test project using this method in Prudhoe Bay, on Alaska's North Slope has been carried out.[17] The project, a collaboration between Conoco Philips, the US Department of Energy (US DOE) and Japan Oil, Gas and Metals National Corporation (JOGMEC), claims to have successfully injected a CO_2/Nitrogen mixture and extracted methane (along with large volumes of water, mud, Nitrogen and CO_2). However, a US Department of Energy spokesperson said, "Ongoing analysis of the extensive datasets acquired at the field site will be needed to determine the efficiency of simultaneous CO_2 storage in the reservoirs".[18] The Prudhoe Bay test is a very long way from proving the feasibility of this method and it is still far from certain whether or not this will be viable technology, especially at the scale and efficiencies that would be required for both commercial methane extraction and CO_2 storage.

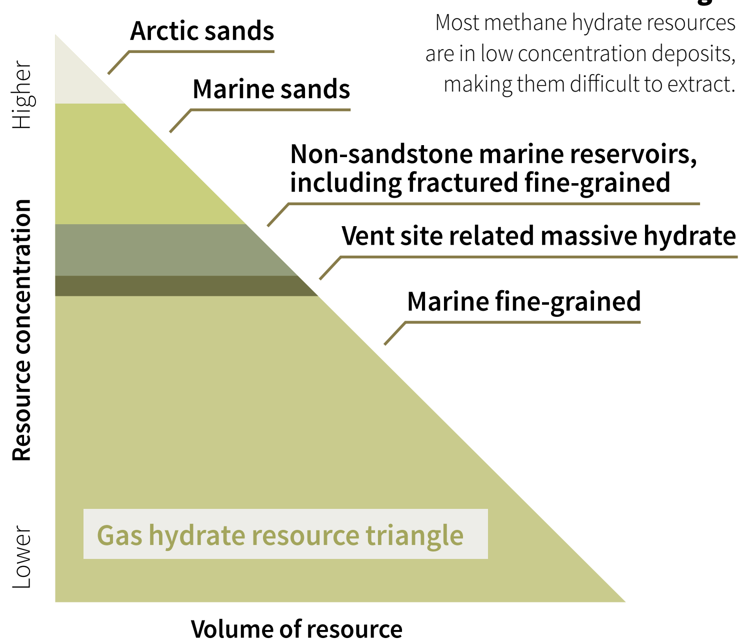
It has been suggested that methane hydrates could be mined from the sea-floor and transported to the surface in pressurised containers, but the technical difficulties mean this is highly unlikely in the near future.

Despite the completion of the recent test project in Japan (see below), there remain significant obstacles to methane hydrate extraction on a commercial scale. As well as difficulties with extraction technologies, a potential problem is in the dispersal of the deposits, if they are too widely distributed it may be uneconomical to extract them. In addition the variation in the types of deposits (the kind of structures they have, the geological formations they are associated with etc.) could make it difficult to find commercially exploitable deposits and extraction technologies may only be appropriate for very specific types of deposit. The vast majority of the world's methane hydrates are found in low concentration marine deposits, where the hydrates are spread over wide areas and mixed with lots of mud. There are currently no proposed technologies for extracting methane from these 'low grade' sources.

The extreme difficulties with methane hydrate extraction have led some to conclude it will never be a viable fuels source.

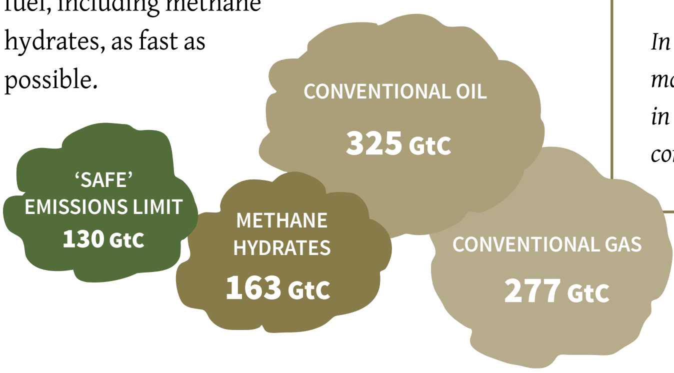
Methane hydrate resource triangle

Most methane hydrate resources are in low concentration deposits, making them difficult to extract.



CLIMATE CHANGE

Despite the variation in global resource estimates, it is clear that there are huge amounts of methane hydrates around the world, representing a vast store of carbon, conceivably as much as or even more than in all other fossil fuels combined. If we are to reduce carbon emissions to anything like the levels required to maintain a reasonably habitable planet we must move away from all forms of fossil fuel, including methane hydrates, as fast as possible.



If we are to reduce carbon emissions to anything like the levels required to maintain a reasonably habitable planet we must move away from all forms of fossil fuel as fast as possible. Measuring from the start of the industrial revolution (around 1750), a maximum of 500 Gigatonnes of carbon (GtC) can be emitted to the atmosphere while still avoiding most serious impacts and the risk of irreversible and uncontrollable changes to the climate.[19] *Between 1750 and now (2014), we have already emitted about 370 GtC leaving a limit of 130 GtC that could be further added.*[20]

In order to stay within this limit we have to leave the vast majority of the remaining conventional oil, coal and gas in the ground. Estimates vary significantly, but remaining conventional coal reserves alone are well over 500 GtC.[21]

Exploiting the estimated 163 GtC[22] of extractable methane hydrates is absolutely incompatible with staying below the limit outlined above.

Methane hydrates and the climate

As well as being a possible form of unconventional fossil fuel, methane hydrates are of interest to climate scientists from the perspective of the climate system. It has been suggested that methane hydrates might induce a positive feedback mechanisms (a process in which an initial change will bring about an additional change in the same direction i.e. *A produces more of B which in turn produces more of A*). First, rising temperatures warm and change the pressures surrounding the hydrates, releasing some of the methane they contain to the atmosphere. As methane is a powerful greenhouse gas, it increases temperatures further, which further warms the hydrates releasing yet more methane, which then further warms the atmosphere. This is referred to as the "clathrate gun" hypothesis. It has been suggested that it may have been the cause of periods of rapid warming in earth's history and could be an immediate cause for concern if it is triggered by man-made climate change. However, while there remains debate among scientists over the timescales at which methane release would occur, it is likely to be a matter of centuries rather than decades.[23]

There are also concerns that hydrate extraction may result in the sudden release of large amounts of methane, either as a result of sea-floor destabilisation causing landslides, or uncontrolled destabilisation of the hydrates, where extracting methane changes the pressure in the surrounding hydrates, leading to a chain reaction spreading throughout the deposit.

Carbon Capture and Storage (CCS)

Proponents of unconventional fossil fuels often argue that with CCS technologies, these new energy sources could be exploited at the same time as reducing GHG emissions. However, even if the huge problems with CCS technology are overcome (and this currently looking extremely unlikely), it would not change the fact that we need to move away from all forms of fossil fuel, conventional and unconventional, as soon as possible.

In the most optimistic (and highly implausible) scenario, CCS could be used to reduce a small proportion of emissions from fossil fuels. In reality, the promise of CCS being implemented in the future is being used to allow the continued expansion of fossil fuel production, to prevent alternatives from being developed, and to deflect attention away from approaches which tackle the underlying systemic causes of climate change and other ecological crises. Ultimately CCS is a smokescreen, allowing the fossil fuel industry to continue profiting from the destruction of the environment. (see 'Carbon Capture Storage' factsheet for more information).

A method of extraction that replaces methane in the hydrates with carbon dioxide as a means of CCS has been experimented with in labs and at a test site, but it is far from clear that this could ever be a viable technology (see 'extraction methods' above). The long-term (and even short-term) instability of CO_2 hydrates, the substance that would replace the methane hydrates, raises serious concerns about the reliability of using them as a trapping mechanism for holding captured CO_2.[24]

OTHER SOCIAL AND ENVIRONMENTAL ISSUES

The methane hydrates in marine sediments beneath the seafloor are often thought to be in a "precarious" state. Methane hydrate is a very low-density compound and in principle would float in sea-water if not held in place by the weight of the overlying sediments. The presence of methane gas bubbles sometimes held beneath the methane hydrate layer makes the situation even more unstable. If the mixture of solids (sediment and methane hydrate), methane gas bubbles and sea-water becomes unstable and starts to rise up the gas bubbles expand, separating the sediment further, causing it to rise even faster. This could happen in response to a small temperature increase, a physical shift or settlement of the marine sediments. Methane naturally and regularly escapes from the sediments into the ocean in this way, leaving behind explosion craters on the seafloor called pockmarks.[25]

However, there are also examples where the methane hydrate instability described above is believed to have caused or contributed to large under water landslides. The 'Storegga Submarine Landslide' is generally believed to be an instance of this. The slide occurred 8000 years ago off the Norwegian coast. It caused massive amounts of sediment to slide down the continental slope, creating an enormous tsunami, perhaps 25m high, that struck Norway and Scotland. The landslide may have been caused by rapid decomposition of hydrates due to temperature and pressure changes and the end of the last ice age.[26]

It is not clear how much of a risk methane hydrate extraction would pose in terms of causing landslides and tsunamis, but it is obviously a cause for concern. Geir Erlsand from the University of Bergen in Norway warned, "Extraction increases the risk of large-scale collapses, which might have catastrophic consequences".[27] Even small scale pressure changes or subsidence could cause problems at extraction sites, potentially leading to methane being lost to the sea and atmosphere.[28]

If methane hydrate extraction starts to take place on a significant scale, it would involve the deployment of large amounts of industrial infrastructure, which could have a serious impact on marine and Arctic environments. There are also unique ecosystems on and below the sea floor that include organisms which depend on methane hydrates as a food source.

The race to secure methane hydrate resources may also lead to conflict between countries, particularly as some deposits are found in disputed territories such as the South and East China Seas.

WHERE, HOW MUCH AND WHO?

The vast majority of the world's methane hydrates are found on the edge of the continental shelf, beneath the sea bed, mixed with fine-grained mud. Methane hydrates also occur in much smaller amounts in other marine locations (including the floor of the Caspian Sea and the Gulf of Mexico) and onshore, in and beneath the polar permafrost. It is most likely that deposits in the permafrost and marine deposits in sand (rather than mud) on the sea bed will be targeted first as they are significantly easier to extract.

Several countries have active methane hydrate research programmes or are investigating the possibilities of extraction, including the US, Japan, China, Germany, Norway, India, South Korea, the UK,Taiwan, New Zealand, Brazil and Chile.

Notable Research groups/projects include:

- The National Methane Hydrates R&D Program, US Department of Energy.[29]
- Japan's national methane hydrates R&D program (MH21). The Ministry of Economy, Trade and Industry (METI) is funding the JOGMEC methane hydrate research (see below).[30]

- German Submarine Gas Hydrate Reservoirs (SUGAR) project. A project to develop marine methane hydrates as an unconventional fuel and to combine their production with CO_2 sequestration.[31]
- Chinese Ministry of Land and Resources (MLR) methane hydrate research project, collaborating with Shenhua Energy.[32]
- India's National Gas Hydrate Programme (NGHP), a collaboration between the Indian Government, national energy companies and research institutions.[33]
- The Gulf of Mexico Joint Industry Project (JIP) is a cooperative research program between the US DOE and an industry consortium led by Chevron. It aims to investigate methane hydrate accumulations in the deep water Gulf of Mexico.[34]
- United Nations Environment Program, Global Outlook on Methane Gas Hydrates, evaluating methane hydrate as a potential energy resource for future development.[35]
- Canada recently ended its 15 year research programme saying that methane hydrate research was "not a current priority" (probably due to existing shale and tar sands projects).[36]

Around the world a number of test projects have either been completed or are currently being carried out, usually involving a collaboration of national governments, research institutes, and energy companies. These include:

- Completion of the first off shore extraction test project in March 2013 by the national resource company, Japan Oil, Gas and Metals National Corporation (JOGMEC). The test took place in the Nankai Trough off the coast of Japan using the specialised drilling ship the Chikyu Hakken. Extraction used a depressurisation method and successfully produced an average of 20,000 cubic metres of gas per day over six days. On the sixth day sand clogged a pump and extraction had to be halted early.
- CO_2 /methane exchange project in Prudhoe Bay, on Alaska's North Slope (mentioned in extraction methods section above). The project, completed in 2012 was a collaboration between Conoco Philips, the US Department of Energy (US DOE) and Japan Oil, Gas and Metals National Corporation (JOGMEC).[37]
- An international consortium, led by Japan and Canada and including the US, conducted short-duration production testing in 2002 at the Mallik site in Beaufort Sea, Canada. It demonstrated, for the first time, that methane could be produced from hydrate.
- There are also various other current and past US DOE methane hydrate projects.[38]

Notable companies involved in methane hydrate extraction include BP, ConocoPhillips, Anadarko Petroleum, Chevron, Shenhua Energy, Japan Oil, Gas and Metals National Corp. (JOGMEC) and Mitsui Engineering and Shipbuilding Co.

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