ENERGY LOCKED IN ICE

Natural gas found beneath the Arctic tundra and on the ocean floor could be a greener alternative to coal and oil. Are methane hydrates the next big thing in fossil fuels?

Trapped beneath the Arctic tundra and the world's oceans lies a fossil-fuel source with enough energy to rival our entire known reserves of coal, oil and traditional natural gas. Although most of us have never heard of methane hydrates—icy combinations of methane gas and frozen water that burn when ignited—that may soon change.

Governments around the world, along with the energy industry, have been studying naturally occurring methane hydrates since their discovery in a Siberian oil field in the 1960s. Today, commercial exploitation is finally on the horizon, with several nations, including the U.S., hoping to introduce hydrate-sourced natural gas to the market.

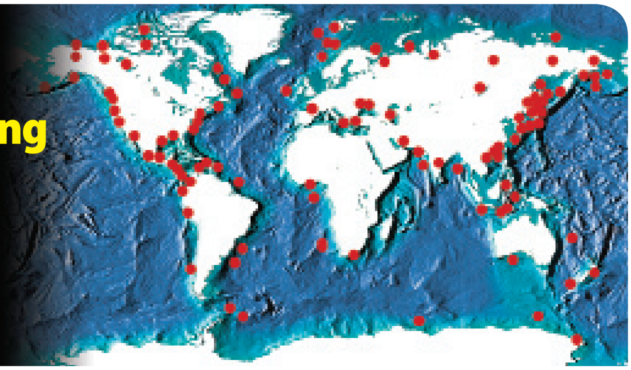
"We will see commercial-gas production from hydrates on a very limited basis within a decade, and it will continue to grow slowly through the 21st century," predicts Art Johnson, the president of Hydrate Energy International, a Louisiana-based consulting firm. Others have estimated that hydrates could become a more than $200-billion industry.

Nature Makes Methane

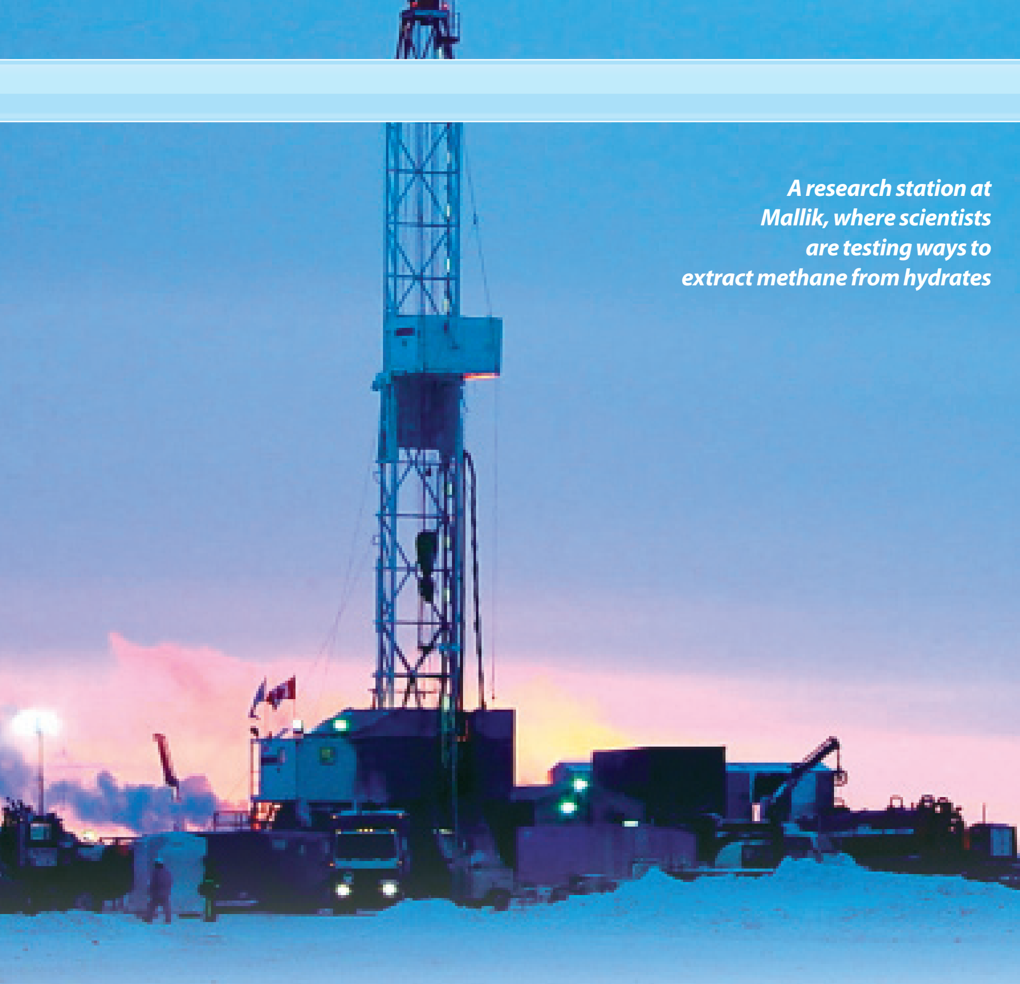
Methane hydrates are found under the permafrost in Canada, Alaska and Siberia and in the sediments on the seafloor at the margins of continents around the world. At these depths, low temperatures and high pressure

Researchers at the Mallik site in northwestern Canada retrieve drilling cores containing methane hydrates.

Deposits Common along the Coasts



● Areas on the continental margins expected to contain large deposits of methane hydrates



A research station at Mallik, where scientists are testing ways to extract methane from hydrates

cause water to freeze, and the resulting ice contains a unique cagelike structure of water molecules. Methane, formed by the breakdown of organic material by bacteria and heat, gets trapped in the ice, forming solid structures of varying size known as methane hydrates.

The methane is densely packed within the ice—a cubic foot of methane hydrates can yield from 150 to 170 cubic feet of gas. It can be freed from its icy prison by heating the hydrates or depressurizing them, or by adding a hydration inhibitor (a substance such as alcohol that prevents the formation of hydrates). Traditionally extracted natural gas is mostly composed of methane, so the gas from hydrates will be similarly used—for residential and industrial heating, electricity generation and automobile fuel, for example. The amount of natural gas stored in the world's methane hydrates is thought to be enormous. Geologist Timothy Collett with the U.S. Geological Survey says that estimates range from 100,000 trillion to 280,000,000 trillion cubic feet. If even the lower number proves true, methane hydrates could provide more energy than all other fossil fuels combined.

Like other fossil fuels, burning methane produces carbon dioxide, the major contributor to anthropogenic global warming. But natural gas is the cleanest of the fossil fuels, producing half as much CO_2 as coal, for the same energy output. "If we can replace coal with natural gas for power generation, greenhouse-gas emissions would drop substantially," Johnson says. While we're switching to non-carbon-based renewable energy sources, methane hydrates may offer a cleaner way to continue to meet our energy needs.

And for nations with limited traditional energy resources, such as Japan, India and Korea, methane hydrates offer an attractive alternative to expensive fossil-fuel imports.

Getting at the Gas

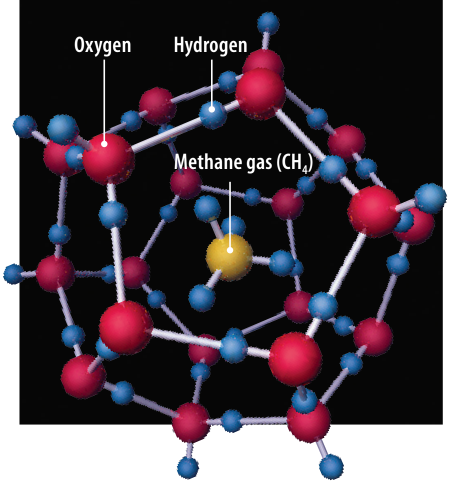
Before anyone can cash in on the untapped potential of methane hydrates, they will have to figure out how to extract and transport the gas affordably. The Canadian Arctic has been

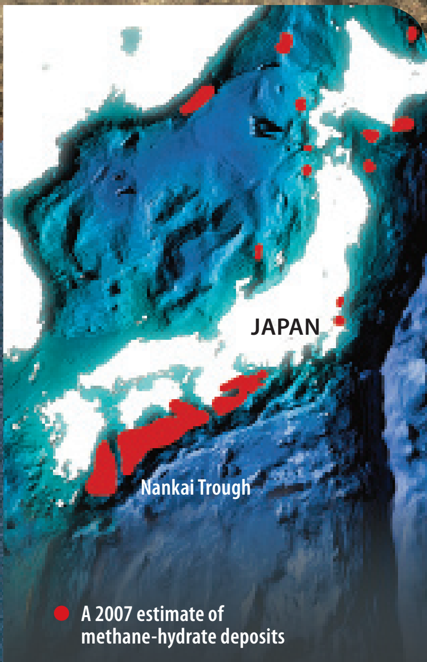
The hydrates burn when ignited.

What Are Methane Hydrates?

Naturally occurring methane hydrates have been discovered deep beneath Arctic ice and at the ocean floor, where temperatures are low and pressure is high. Here, water freezes in the sediments, forming ice that contains a characteristic cagelike structure of water molecules. Methane gas formed by the breakdown of organic material can get trapped within these ice crystals. If the temperature rises or the pressure falls, the hydrates melt, releasing the gas.

Under certain conditions, ice crystals can trap methane molecules.





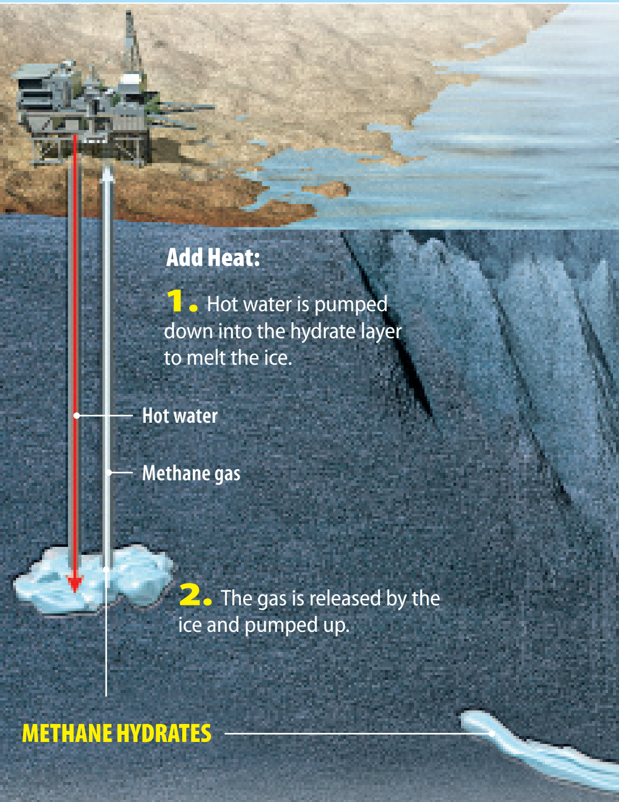
Japan's Coast Is Hydrate-Rich

Japan imports 99 percent of the oil, coal and natural gas it uses, so a domestic energy source has been a top priority for generations. Since 1995, Japanese scientists have explored the rich deposits of methane hydrates off the nation's coastline, and last year the government approved a plan calling for commercial exploitation by 2016.

By far, Japan's largest methane-hydrate deposits lie in the Nankai Trough, off the southeastern coast of the island, at locations more than 3,000 feet below sea level. Over the years, the Japanese government has carried out more than 30 research drillings in the area and has determined that about 20 percent of the ice-containing layers consist of methane hydrates, with the rest being sand and rock. As much as 40 trillion cubic feet of gas may be stored within the gas hydrate deposits of the Nankai Trough. These ample reserves alone could cover all of Japan's natural gas needs for about a century.

How to Extract Methane from Hydrates

Scientists have studied two ways to release the gas frozen in methane hydrates. One melts the ice by introducing heat; the other, a more promising technique, involves reducing the pressure around the hydrate reservoirs. Either method could be used on land or at sea.



an important area for research and development. In 2002, an international consortium, including energy-industry representatives, the U.S. Geological Survey, the U.S. Department of Energy, and researchers from Canada, Japan, India and Germany, conducted test drilling at a hydrate-rich research site called Mallik, located in the Canadian Mackenzie Delta about 1,400 miles north of Vancouver.

Scientists pumped hot water into underground layers containing methane hydrates. They successfully melted the ice and extracted the gas but found that the process was slow and that heating the water consumed too much energy. Another method—drilling a hole into the hydrate reservoirs to simultaneously lower their pressure and draw up the methane produced—appeared to hold more potential.

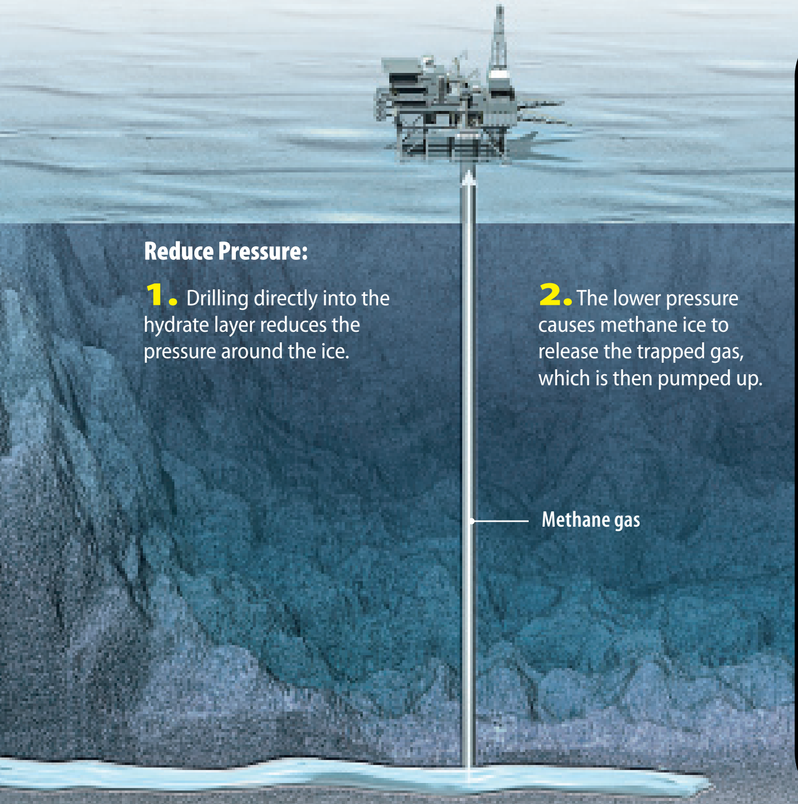
That drilling technique was tested at Mallik in 2007 and 2008 by Natural Resources Canada (NRCan), the Japan Oil, Gas and Metals National Corporation (JOGMEC), and Canada's Aurora Research Institute. The researchers eventually established a continuous gas flow of 70,000 to 140,000 cubic feet per day for six days. Scott Dallimore, NRCan's lead scientist on the project, says the testing demonstrated that conventional oil-and-gas-extraction drilling methods could be adapted to the unique properties of methane hydrates. Today, depressurization looks to be the future of methane-hydrate extraction. Two major sites of hydrate deposits, Mallik and the Nankai Trough off the southeastern coast of Japan, are two of the most promising candidates for future depressurization study and commercial extraction, says Koji Yamamoto, JOGMEC's chief researcher at Mallik.

The next step is a longer pressure-reduction trial that might span several months. Further testing to improve the recovery and production rates of methane from hydrates will also have to take place, Yamamoto says—not to mention more research and technology to narrow the estimates of the scale of potential methane-hydrate resources.

Travel Expenses

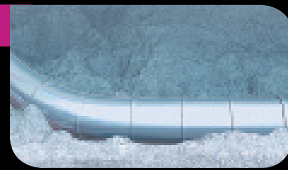
Once production models are in place, the next challenge will be to transport the gas to consumers. Hydrate-sourced

PRECEDING PAGES: USGS (3)



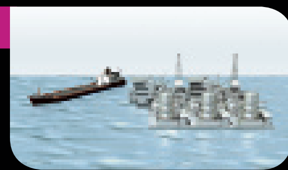
Three Ways to Get It to Land

NEW PIPELINES



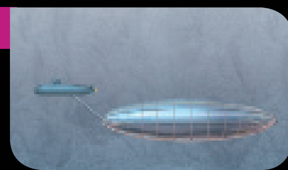
Pipelines are built on the seafloor.
ADVANTAGE: The technology is well-known from existing natural-gas fields.
DISADVANTAGES: Expensive to lay and vulnerable to undersea landslides.

CONVERSION TO LIQUID



Converted to liquid fuel on drilling platforms and transported by ship.
ADVANTAGE: Ship transport is cheap.
DISADVANTAGES: Processing is costly and consumes part of the energy.

RUBBER CONTAINERS



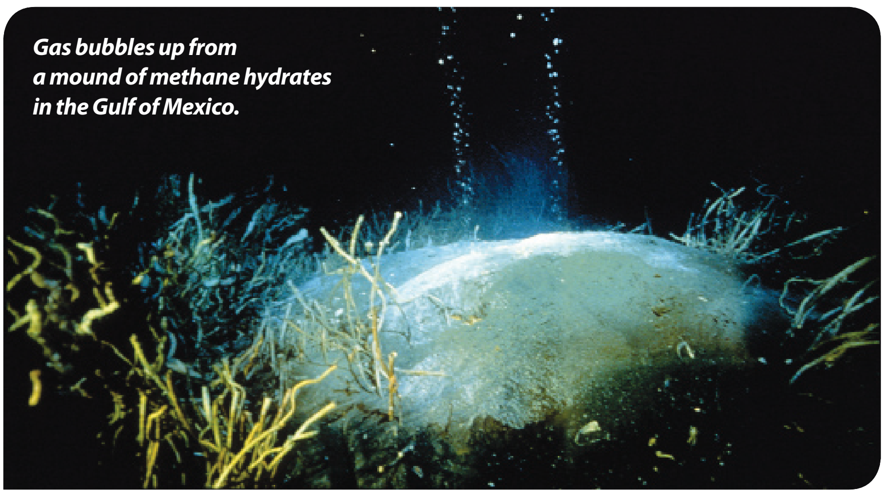
Towed to land in submarine-like bladders.
ADVANTAGE: A cheap and safe way of transporting methane.
DISADVANTAGE: The necessary technologies have not yet been developed.

methane can be moved through pipelines just like conventional natural gas. The industry could tap Arctic sources first, making use of existing pipelines or building new ones. But the majority of hydrates lie along the ocean floor, and transporting methane from there may prove a much tougher task.

One option could be to convert the methane into a diesel-like fuel on a drilling platform; the liquid product could then be hauled cheaply and easily by ship. There are drawbacks, though: Processing fuel at sea can be costly and would consume part of the methane's energy content.

Geochemist Roger Sassen of Texas A&M University suggests harnessing methane that escapes from natural vents on the ocean floor. The gas rises from sediment or along faults, often from hydrates melted by heat from the Earth's interior. He wants to convert this escaping methane into fresh hydrates and tow them to shallow water in submarine-like rubber bladders. There, the hydrates could be decomposed into water and methane. "The volume of energy, mainly methane, that vents into the water column of basins such as the Gulf of Mexico Slope is enormous—as much energy per day as a good oil and gas well," Sassen says. But for now, his idea is just that. The focus for making use of hydrates remains on drilling in sediments and permafrost.

Despite the many development hurdles that remain, Ray Boswell at the DOE's National Energy Technology Laboratory is hopeful: "We believe gas hydrate has the potential to be an important option for meeting future energy supplies." The DOE is looking to establish a safe, environmentally friendly method of extracting the gas and aims to develop the resource beginning in 2015 in the Arctic. Underwater exploitation is slated to follow in 2025 in the Gulf of Mexico. It's an ambitious goal, considering that it now costs more to produce methane from hydrates than the gas is worth. Only time will tell if burnable ice is the future of fossil fuels. ■



Gas bubbles up from a mound of methane hydrates in the Gulf of Mexico.

IAN R. MacDONALD