Frozen fuel: The giant methane bonanza

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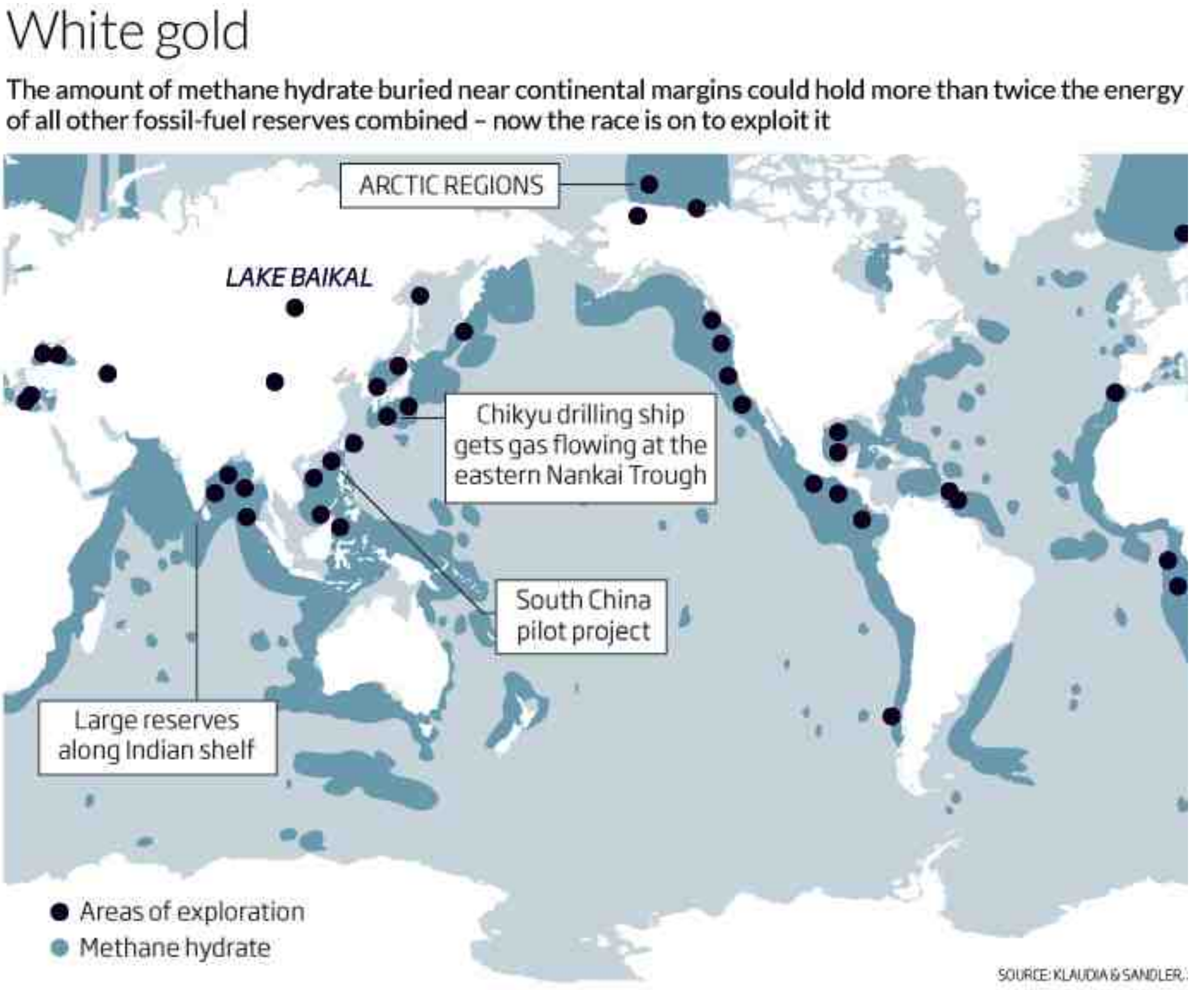

White gold

The amount of methane hydrate buried near continental margins could hold more than twice the energy of all other fossil-fuel reserves combined – now the race is on to exploit it

Chikyu drilling ship gets gas flowing at the eastern Nankai Trough

South China pilot project

Large reserves along Indian shelf

SOURCE: KLAUDIA & SANDLER.

The race is on to tap the world's biggest and most unusual fossil fuel supply – methane trapped in frozen hydrates in permafrost and at the bottom of the ocean

CROWDED around a hole in the ice, the dozen or so people clad in thick jackets could be local fishermen. But the rope winch, carefully lowering a long, fat pipe into the frigid Siberian water, hints that it is not dinner they are here to catch.

The men on the ice are researchers from the Limnological Institute in nearby Irkutsk, and the treasure they are after, hidden at the bottom of Lake Baikal, is a trove of white, ice-like chunks called methane hydrates. Put a flame next to them and they'll ignite, burning what may be the cleanest fossil fuel currently known.

For over a decade, scientists have trekked to this remote corner of the Russian wilderness from around the world, funded by governments eager to understand how to exploit these peculiar accumulations. "We've hosted scientists from everywhere – Japanese, Belgian, Indian and others," says Oleg Khlystov, a geologist at the Limnological Institute. They make the journey to Baikal because the lake's combination of storm-free waters, and – in the winter – a 1-metre-thick ice platform, provide ideal conditions for studying the icy crystals below. This year, the effort finally paid off, and a race is now on to harness them. Whoever succeeds could usher in the world's next energy bonanza, and redraw the world energy map in the process.

You wouldn't have thought that these odd little compounds held such promise. When hydrates were first discovered at the beginning of the 19th century, their weird structure made them little more than curiosities in a chemist's lab: cage-like structures of frozen water entrapping an inner "guest" molecule.

Outside of the lab it takes a unique set of conditions to form these compounds. Organic matter makes its way into a body of water, sinks to the bottom and decomposes. As microbes feed on the tasty snack, they excrete methane. This gas usually bubbles up to the surface, but at sufficient depths, the high pressure and low temperature of the surrounding water lock the methane molecules into the water cages and trap them in the sediment. The result looks like muddy sorbet.

Find a way to unlock those little cages, however, and what comes out is no different from the stuff we pry from conventional wells and shale reservoirs: flammable, odourless natural gas – methane.

Despite its reputation, in hydrate form it may well be the greenest of the fossil fuels. True, unburned methane has a far higher greenhouse impact than carbon dioxide, but it lingers in the atmosphere for less time. When burned, it also releases smaller amounts of CO_2 than coal and oil, almost no ash, and zero mercury. Even its other problems may be overstated (see "A greener shade of fuel").

And methane hydrate accumulations exist in quantities that dwarf all other fossil fuel reserves. There is an estimated 10^{15} to 10^{17} cubic metres of methane stored in this way globally, on a par with the total volume of the Greenland ice sheet. And it contains twice as much energy as all the world's other fossil fuel reserves combined, according to estimates by the US Geological Survey.

So why has the exploitation of this fuel bonanza been stuck on the drawing board for so long? In theory, prying the methane out of its cage is easy enough. Add heat or reduce the pressure, and methane hydrates "melt like sugar in a cup of tea", says Khlystov.

But in practice, accessing them is a tangle of political, economic and logistical factors. For one thing, the exact properties of undersea hydrates are still poorly understood. The right conditions for trapping methane in its watery cage exist in three kinds of geographical "sweet spots": the permafrost of Siberia and North America, on the sea floor near cold shorelines, and in sediments 100 to 300 metres beneath the ocean floor (see map). Locating them precisely requires extensive measures including seismic imaging.

Finding methane hydrates is only the first of many problems, though. Extracting them is also challenging. For example, the gas expands to 160 times its initial volume by the time it reaches the surface, which can blow standard drilling equipment to bits.

These issues point to a deeper reality: myriad government and academic programmes have investigated methane hydrates since the early 1980s, but no country has been particularly aggressive in developing the resource. Exploiting the deposits has to make sense economically. And that depends on production cost and demand, says Christian Besson, a senior analyst with the International Energy Agency. The availability of lower-hanging fruit – shale gas, conventional wells, tar sands – means it has not been worth the trouble to develop the equipment, infrastructure and other technology necessary to make methane hydrate competitive.

All that changed this year. On 12 March, a flare lit up on the stern of the Chikyu, a research drilling ship positioned about 50 kilometres south-east of Japan's main island. The team on-board – working on behalf of state oil company Japan Oil, Gas and Metals National Corporation (JOGMEC) – had become the first to successfully get gas flowing from Japan's methane hydrate deposits, in part thanks to lessons learned at Lake Baikal.

Japan had a strong reason to pursue methane hydrates. Since shutting down most of its nuclear reactors two years ago, after an earthquake and tsunami caused a meltdown at the Fukushima power station, the country has relied on liquefied natural gas imported from countries like Qatar and Brunei. Last year, after energy imports sent Japan into record financial deficits, the country accelerated its decades-old methane hydrate programme.

The resource available to Japan is enormous. JOGMEC researchers estimated in 2008 that 1.1 trillion cubic metres of the methane hydrate lurk beneath the eastern Nankai Trough – enough to offset at least a decade's worth of foreign gas imports.

Research at Baikal had already helped Japan determine the seismic signatures of different kinds of methane hydrate deposits. Even tucked into sediments hundreds of metres beneath the bottom of the ocean, hydrates can be located by their characteristic high acoustic velocities – making hidden reservoirs easier to hunt down.

Methane fishing

To extract the gas, the Japanese team used conventional methods. That involved first lowering a drill about 1000 metres to the bottom of the eastern Nankai Trough. Then they had to drill another 300 metres into the rock and drain the water out of the hydrate layer to lower the pressure in the deposit and free the methane gas. They could then pump it to the surface.

The JOGMEC researchers acknowledge that they "need to know much more" before starting commercial-scale production, but their initial success – 20,000 cubic metres a day for six days – leads them to speculate that production could start as soon as 2018.

Not everyone believes in that timeline. "They have the gas, but there's no infrastructure yet," says Basel Asmar, an oil and gas analyst with IHS, an energy consultancy based in Englewood, Colorado. "There are no pipelines in that area of the ocean." He thinks that it will be at least two decades until methane hydrates make an impact.

However, a different kind of methane hydrate could change the equation. In 2000, the Canadian fishing vessel Ocean Selector made a strange catch near Vancouver Island. The surprised crew found that the trawler had "caught" more than a tonne of ice-like chunks that turned out to be methane hydrate.

Not all deposits are locked into permafrost or sediments deep at the bottom of the ocean. In some places, they are abundant at or near the sea floor, strewn about like snowdrifts. Unlike sedimentary hydrates – which are microscopic in size, but plentiful – these do not require drilling into the sediment. They can simply be scooped up, which makes them easier, in theory, to turn into usable fuel.

It was these hydrates that caught the attention of Shinya Nishio, a scientist at Japan's Shimizu Corporation who was working on JOGMEC's deep-drilling programme. Previous research at Lake Baikal had determined that the deposits occur in "cold seeps" where gas-saturated water seeps up from faults. What was less clear was whether they contained usable amounts of methane.So in 2008 Nishio led an expedition to find answers at the bottom of Baikal.

Using a research ship borrowed from the Limnological Institute, the Russian-Japanese team began their scan of the lake's depths. At a depth of about 420 metres, they found their mother lode: big snowy chunks of snow-white hydrates. To test their methane content, the team lowered what was essentially a giant straw with a scoop attached. "We collected about 1.5 cubic metres of methane in 40 minutes," says Khlystov. "It's not much, but what surprised the Japanese was that they were seemingly not doing anything, they just turned the pumps on and the gas began to flow." No drilling required.

On his return to Japan, Nishio began prospecting for these cold-seep hydrates and Shimizu Corporation found some in the Sea of Okhotsk and the Sea of Japan. "These must also be the target of resources development," Nishio says, adding that the tests in Siberia will pave the way for further studies back home.

The claim is controversial, not least because the scooping method poses ecological concerns. Scooping is cheaper than drilling, Khlystov says, but collecting the deposits from Baikal itself is out of the question, because scooping could harm the sea life in this World Heritage Site. Would it also harm the ecosystems around Japan? "It is hard to see how mining the sea floor would be approved in any part of the world," says Timothy Collett of the US Geological Survey.

No matter which resource they tap, it is not unrealistic to expect that Japan will have major commercial operations within the decade, says Collet. The speedy timeline is not without precedent. "Five, six years ago shale gas was also barely appreciated as a potential resource," he says. "Now it's dominating and controlling the price of gas." Domestic shale gas now accounts for more than 20 per cent of US gas production, which has changed the nation's relationship with energy-exporting countries. "That can also happen with hydrates," he says.

Other countries are interested in methane hydrate. India, which is also keen to gain energy independence, has offshore gas hydrate deposits of about 1.9 trillion cubic metres, and has logged several visits to Baikal. Bandaru Ramalingeswara Rao of the National Institute of Oceanography in Goa visited the lake in 2004. "The geophysical mapping we did there helped us identify gas hydrates deposits back home in India," he says. Shortly after, he was recruited by India's state gas hydrate research project. Based in part on his findings, India decided to begin drilling subsurface sedimentary hydrates in the Bay of Bengal. South Korea and China are also pursuing methane hydrate research.

Not everyone will be inspired by Japan to develop their methane hydrate resource. Thanks to the shale gas boom, Canada, Russia and the US have scaled back their programmes. However, if even a single country successfully commercialises operations, the reverberations will change the map of world energy, says Kimball Chen, who runs the international Energy Transportation Group, which advises governments on natural gas geopolitics. "If Japan started mining gas hydrates, Russia would lose export markets for liquefied natural gas in the Far East, and then all they'll have left is China." And if China follows Japan's lead, the situation will quickly snowball. The new energy source would probably dash Australia's nascent attempts at becoming a geopolitically secure energy supplier to nations like India and China.

What's more, Japan may not even need to commercialise its resources – the mere threat of energy independence could be enough to cause these global ripple effects. "Just the physical capability to mine hydrates will give Japan negotiating power," says Chen. "If the Middle Eastern nations know that Japan can mine hydrates at a certain cost, that becomes the new price."

The global energy markets, ever susceptible to influences, are balanced on a knife edge. Everything could be changed by two Russian research ships floating idly on the glittering summer water of Lake Baikal, awaiting their next assignment.

This article appeared in print under the headline "Buried treasure"

Correction: *When this article was first published online on 28 August 2013, the superscript styling was omitted from the estimate of global methane hydrate reserves.*

A greener shade of fuel

There are concerns that focusing on methane hydrates might divert Japan's attention away from green technologies. Likewise, India, where wind is now competitive with coal, might be lured from a greener path.

But Euan Nisbet, an earth scientist at Royal Holloway, University of London, thinks the story is more complicated. Right now, Japan relies on liquefied natural gas (LNG) imported from the Middle East. "Making LNG and then regasifying it for transport by ship is energy-expensive, so as a very rough rule of thumb, imported LNG is comparable to oil in greenhouse terms," he says. "If Japan gets its gas from a very local offshore hydrate deposit, rather than burning LNG or coal, then that's probably a plus," he says. "In India the gas will compete with coal." Because methane burns cleaner than coal, this could offset coal emissions there.

Another problem that receives a lot of attention is the leaks of unburned methane in shale-gas production. But again, methane hydrate stacks up well. Such leaks will do far less harm underwater. In deep-water offshore regions, any leaked methane would be oxidised by microbes before it can reach the surface. "They love methane, and they oxidise it to gain energy," says marine geologist Klaus Wallmann of Kiel University in Germany. For example, in the BP Deepwater Horizon spill in the Gulf of Mexico, huge amounts of methane were released, but didn't make it to surface.

Perhaps methane hydrate production could even help the environment. Last year, in a trial on Alaska's North Slope, the US Department of Energy and JOGMEC, a Japanese energy company, demonstrated that it is possible to store carbon dioxide in the icy cages that normally hold methane. To make the switch, the team forced the water out of the porous methane hydrate layer. Next, they injected waste CO_2, leaving it in place for several days to ensure the CO_2 successfully took the place of the methane. Once that was done, the methane was pumped to the surface.

The swap was accomplished in permafrost, but Wallmann believes that the same process can be applied to store CO_2 in tapped offshore hydrate deposits after drilling.

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