

Natural Gas Brief

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As Japan moves toward a second pilot test of natural gas production from offshore methane hydrates during 2017, the Stanford Natural Gas Initiative examines the potential for this future natural gas resource and similarities to the North American shale gas revolution.



Credit: U.S. Geological Survey, photo by J. Pinkston and L. Stern

Can Methane Hydrates Spark Another Natural Gas Revolution?

Bradley D. Ritts

The North American shale gas revolution of the past 10 years has demonstrated how rapidly and profoundly the introduction of a major new natural gas supply can impact choices about energy and fuels, the economy, and the environment. In the case of shale gas, technological advancements such as horizontal drilling and multi-stage hydraulic fracturing, combined with robust market signals in the form of high and rising natural gas prices, to inspire investments and activity that unlocked new natural gas resources and dramatically expanded natural gas production in the United States and Canada. Growth in production and size of the underlying natural gas reserve base has led to falling energy costs, new opportunities for U.S. manufacturing and exports, and falling greenhouse gas and pollutant emissions from the electrical generation sector as coal is replaced by natural gas.

Such fundamental energy market shifts have occurred elsewhere in the past and would be expected in the future whenever discovery and development of a new resource disrupts existing energy markets and economies. However, the experience with North America's shale gas is particularly striking because the

U.S. is such a large energy consumer and few predicted any chance of the U.S. departing from its long-term decline in oil and gas production or understood the size of a new resource that could be unleashed with the right technological advances.

ABOUT THE AUTHOR

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Bradley Ritts is the managing director of the Natural Gas Initiative at Stanford University, where he oversees the Stanford natural gas research portfolio, and develops partnerships between Stanford, industry, government, and other organizations. Together with



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natural gas, energy, and the environment has real-world impact.

With expertise in oil and gas exploration, natural gas commercialization, and regional geological sciences, Dr. Ritts has authored dozens of articles and book chapters related to oil, gas, and other geological resources. Dr. Ritts has experience working in the oil and gas industry in a variety of exploration and new ventures positions focused on Eurasia and the Asia-Pacific region, including several years living in Singapore as a new ventures manager for a major international oil and gas company. He has also previously served on the geological sciences faculty of Utah State University and Indiana University. Dr. Ritts holds a Ph.D. from Stanford University, an M.S. from the Massachusetts Institute of Technology, and a B.S. from the University of Rochester.



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After watching the North American shale gas revolution, one can't help but look around the world for the next resource-driven natural gas or broader energy market disruption. Predictably, an early reaction to the success in North America was an attempt to identify similar shale gas plays elsewhere in the world. Undeniably, similar shale-driven growth in gas production in another major energy consumer, like China, would be transformational in expanding energy access, shifting the economics of coal versus gas, and leading to moderation of carbon dioxide emissions. However, while many basins have been identified around the world with potential shale gas resources, and some success has been seen internationally, so far the North American shale gas revolution has not been replicated elsewhere.

One resource that may hold the potential for similar revolutionary impact in future years or decades, given the right technological innovation and market signals, are methane hydrates. Methane hydrates are solid ice-like deposits that contain large amounts of methane (the primary

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component of natural gas) and are found within the seafloor in oceans greater than about 500 m water depth. Estimates of the amount of methane within gas hydrate deposits vary widely, but researchers universally agree that the volume dwarfs

that available in conventional natural gas reservoirs. While technologies to tap these resources are currently undeveloped, some countries, most notably Japan, are progressing efforts to develop and demonstrate the technology necessary to produce gas from these hydrate deposits.

Japan is notable not just for its efforts to develop the new technology and knowledge necessary to exploit methane hydrates, but also for the commercial and economic opportunity it represents. Japan is currently a major gas importer (it is the world's largest liquefied natural gas importer) and its corporations are prized natural gas purchasers, historically paying some of the highest natural gas prices in the world. Japan has no significant natural gas production or reserves (by virtue of its geological history) and is thus dependent on liquefied natural gas (LNG) imports from Australia, the Middle East, and elsewhere. However, Japan is richly endowed with methane hydrate deposits. Therefore, if Japan is successful in developing its own methane hydrate resource, it could rapidly grow domestic production, displace costly LNG imports,

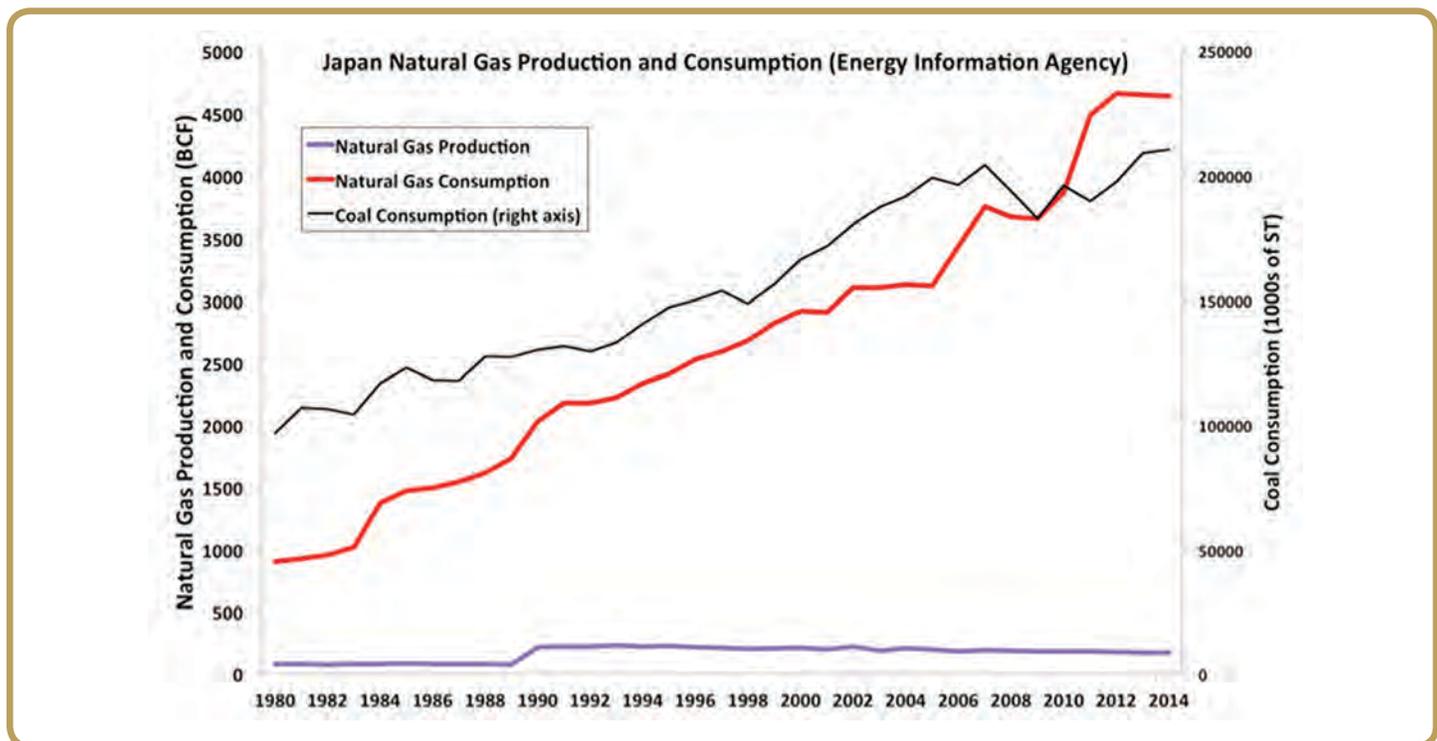


Figure 1: The gap between Japan’s natural gas consumption and production is met by imports, and coal consumption provides added opportunity for switching to lower-carbon energy sources (data from U.S. Energy Information Agency)

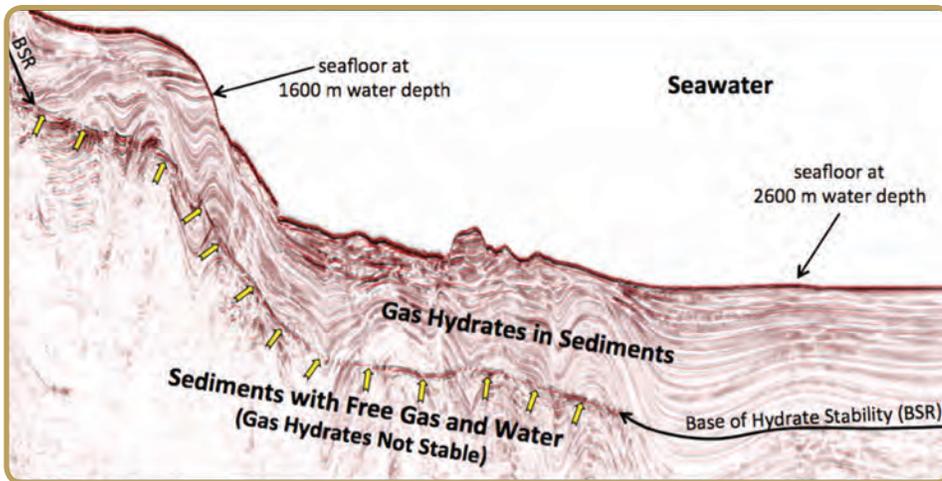


Figure 2: Seismic reflection image of the deep marine continental margin of New Zealand (water depths in image range from more than 1000 m to more than 2600 m), showing the presence of gas hydrates marked by a bottom-simulating reflector (data from New Zealand Petroleum and Minerals)

and thus remove a major buyer from the lucrative Asia-Pacific LNG market.

Methane Hydrates

Methane hydrates are ice-like solids composed of methane trapped in a cage-like crystalline lattice of water molecules. Methane hydrates form under a specific set of low temperature and high pressure conditions that are found naturally in permafrost regions as well as in deep oceans along continental margins. The conditions for marine methane hydrates are well defined, requiring cold water at the seafloor and sufficient water depth (greater than about 500 m) to create the pressure necessary for hydrates to form and remain stable. In addition to the right pressure-temperature

conditions, a source for methane must also be present.

In areas where gas hydrates are present they can fill pore spaces in the sediment below the seafloor, creating the methane hydrate deposit that is a possible energy source. Methane hydrate deposits can extend downward into the sediment column from the seafloor for hundreds of meters. The base of the methane hydrate deposit occurs where temperatures become hot enough due to geothermal heating from below to make hydrates unstable, which is at about 15 Celsius in deep marine settings. An example of this occurrence is shown in the accompanying cross-section, which shows a seismic (acoustic) image of the seafloor and the underlying sediments off the southeast coast of the North Island of

New Zealand. At this location, with water depths in excess of 1000 m, gas hydrates are stable in the shallow sedimentary column. The seismic data clearly show the base of the hydrate stability zone, indicated by the bright reflector that is emphasized with yellow arrows on the image. That reflector, called a bottom-simulating reflector because it parallels the seafloor, is caused by the change in geologic properties between the sediment above the surface, where hydrates fill some or all of the pore-space, and the water- or gas-saturated sediment below. Below the bottom-simulating reflector the temperature, which increases with depth below the seafloor, is high enough to prevent hydrates from forming or to cause their dissociation into free gas and water.

Because hydrates are found in deep marine settings with a source of methane, they are commonly encountered in exploration and development activities associated with conventional deep-water oil and gas projects in places like the Gulf of Mexico and Indonesia. They are also known from scientific studies, including drilling and dredging projects around the world. The United States Geological Survey, among other organizations, has compiled maps that show locations around the world where hydrates have been recovered or where they are inferred by other methods like seismic imaging. As shown on the map below, where stars indicate areas of known or inferred methane hydrate occurrence, these resources can be found worldwide on most continental margins, including in many areas, like Japan, which currently lack their own domestic gas resources.



Figure 3: Worldwide occurrences of methane hydrates (adapted from the U.S. Geological Survey)

Natural Gas Production from Methane Hydrates

Because marine methane hydrates are known to trap large amounts of gas and their distribution around the world is known, it is reasonable to ask why they have not been used as energy resources. The answer lies in the cost, risk, and technical complexity of developing and producing these resources.

Successfully producing methane from

hydrate deposits will rely on developing drilling and production technologies that allow wells to be placed shallowly below the seafloor within the hydrate deposits and then affect the dissociation of the methane from the hydrate in a controlled fashion that does not destabilize the reservoir, the overlying seafloor, or the well and production systems. There are few examples of commercial production of even conventional natural gas or oil reservoirs at these shallow subsurface depths, and no sustained production from a hydrate deposit at any depth. Thus, producing hydrate reservoirs will rely on technical innovation and, until these technologies are developed and demonstrated, uncertainty in the ability to access methane from hydrate reservoirs will remain.

In 2013 Japan took an important step to demonstrating the ability to produce methane from marine hydrate deposits. Japan Oil, Gas, and Metals National Corporation (JOGMEC) achieved a significant, sustained flow of gas (about 700,000 cubic feet per day) from a well offshore eastern Japan for six days before problems with equipment and sand production forced termination of the test. These results, announced by JOGMEC, provided a clear test of years of research and development into the ability to dissociate methane from a hydrate deposit as a result of depressurization and produce the resulting gas through a well. Recently, JOGMEC and Japan Methane Hydrate Operating Company have announced plans for a longer production test in the same area in 2017 that will seek to control sand production and other operational issues that shortened the first test.

Along with development of drilling and production techniques necessary to access methane hydrate resources, new research is also needed into the kinds of sediments that host methane hydrates and how different sedimentary deposit types may impact successful production of hydrates. While the conditions necessary for hydrate formation are controlled by pressure (water depth), temperature, and methane presence, the sediments in which hydrates reside will exert a major control on the ability for any

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technology to successfully dissociate the methane through depressurization and produce the resulting gas through a well to the surface. Specifically, deep marine sediments along continental margins can range from fine-grained muds and ooze that may not have the necessary permeability to coarse-grained sand and gravel deposits that provide large, interconnected pore networks and high permeability that would be expected to allow better reservoir performance. However, the occurrence of hydrate itself within the reservoir is an added factor that impacts effective permeability and porosity, and one that would change over time as the reservoir is produced. This highlights the reality that, although the vast amounts of methane locked in gas hydrates is known, a great deal of geologic work is needed to identify high-quality resources that are likely to allow production at the highest rates, lowest costs, and greatest volumes.

Deep-water drilling and resource development of any kind is an expensive endeavor. Individual well costs for conventional deep-water oil and gas drilling commonly exceed \$100 million. According to IHS Markit, even with lowered costs as a result of the ongoing low oil price environment, day rates for deep-water drillships and semisubmersible drilling rigs are in the

\$200,000–\$300,000 range. The high costs of deep-water drilling and other development activities challenge the economic viability of deep marine methane hydrate resources, even if technological obstacles to their production are resolved.

Will the world see a methane hydrate natural gas revolution?

It’s too early to know with any confidence whether methane hydrates will ever be produced as a commercial energy resource, but it’s interesting that methane hydrates share two key similarities with shale gas prior to its boom. First, both shale and hydrates are known to contain large amounts of natural gas. The presence of the energy resource is not in doubt in either case; the challenge lies in the ability to extract the resource from its geological reservoir. Second, both resources have or had high gas prices to motivate parties to develop the technologies necessary for their production. In the case of shale gas, the resulting production growth led to the price collapse of natural gas in North America, but in some other parts of the world high gas prices remain (or are expected to return) to encourage development of lower-cost, domestic resources, possibly including hydrates.

Any future production of hydrates as a commercial energy resource will first require years of continued technology development, testing, and pilot production projects. A range of operational, economic, and geological obstacles and uncertainties could prevent success anywhere along the way. Production will also depend on the ability to lower costs of methane hydrate production to levels where it can compete with LNG or pipeline imports. Over the years or decades that effort will require, changes to the global energy system could either raise the urgency for development of new natural gas resources or eliminate their need entirely. However, the lesson of North America’s shale gas revolution cautions against discounting the potential for innovation and economics to drive development of new, unexpected energy resources.



The Natural Gas Initiative at Stanford

Major advances in natural gas production and growth of natural gas resources and infrastructure globally have fundamentally changed the energy outlook in the United States and much of the world. These changes have impacted U.S. and global energy markets, and influenced decisions about energy systems and the use of natural gas, coal, and other fuels. This natural gas revolution has led to beneficial outcomes, like falling U.S. carbon dioxide emissions as a result of coal to gas fuel switching in electrical generation, opportunities for lower-cost energy, rejuvenated manufacturing, and environmental benefits worldwide, but has also raised concerns about global energy, the world economy, and the environment.

The **Natural Gas Initiative (NGI) at Stanford** brings together the university's scientists, engineers, and social scientists to advance research, discussion, and understanding of natural gas. The initiative spans from the development of natural gas resources to the ultimate uses of natural gas, and includes focus on the environmental, climate, and social impacts of natural gas use and development, as well as work on energy markets, commercial structures, and policies that influence choices about natural gas.

The objective of the Stanford Natural Gas Initiative is to ensure that natural gas is developed and used in ways that are economically, environmentally, and socially optimal. In the context of Stanford's innovative and entrepreneurial culture, the initiative supports, improves, and extends the university's ongoing efforts related to energy and the environment.

JOIN NGI

The Stanford Natural Gas Initiative develops relationships with other organizations to ensure that the work of the university's researchers is focused on important problems and has immediate impact.

Organizations that are interested in supporting the initiative and cooperating with Stanford University in this area are invited to join the corporate affiliates program of the Natural Gas Initiative or contact us to discuss other ways to become involved.

More information about NGI is available at ngi.stanford.edu or by contacting the managing director of the initiative, Bradley Ritts, at ritt@stanford.edu.

