Alaska's frigid climate could give state an edge in LNG

What is it that brings misery, numb toes and frozen pipes to Alaska residents but warms the hearts of people designing a liquefaction plant?

The state's cold weather.

Low temperatures would make the natural gas liquefaction process and related systems more energy-efficient for the Alaska LNG project. Higher efficiency and lower operating costs are an important advantage in an intensively price-competitive global market for liquefied natural gas sales.

Besides reducing fuel costs, the improved efficiency can cut capital costs as some of the equipment doesn't need to be as big and powerful.

The Alaska LNG project as currently envisioned would include:

- A giant North Slope treatment plant to purify the gas as it comes out of the ground.
- 800 miles of pipeline and eight compressor stations to move the gas to Nikiski, on the Kenai Peninsula.
- An equally giant liquefaction plant at Nikiski to supercool the gas, along with storage tanks and marine shipping terminal.

Oil producers on the North Slope have long benefited from the same cold-weather phenomenon that would boost the bottom line of an LNG project. The huge compressors used at the oil production facilities are more efficient in cold weather, sending thousands of barrels of additional oil down the line each day during the winter.

The general colder-temperature-efficiency principles are the same throughout the LNG project, from the gas treatment plant to the pipeline compressor stations to the LNG plant. But the liquefaction plant will cost the most to build of any of the project components and will benefit the most from Alaska's low temperatures.

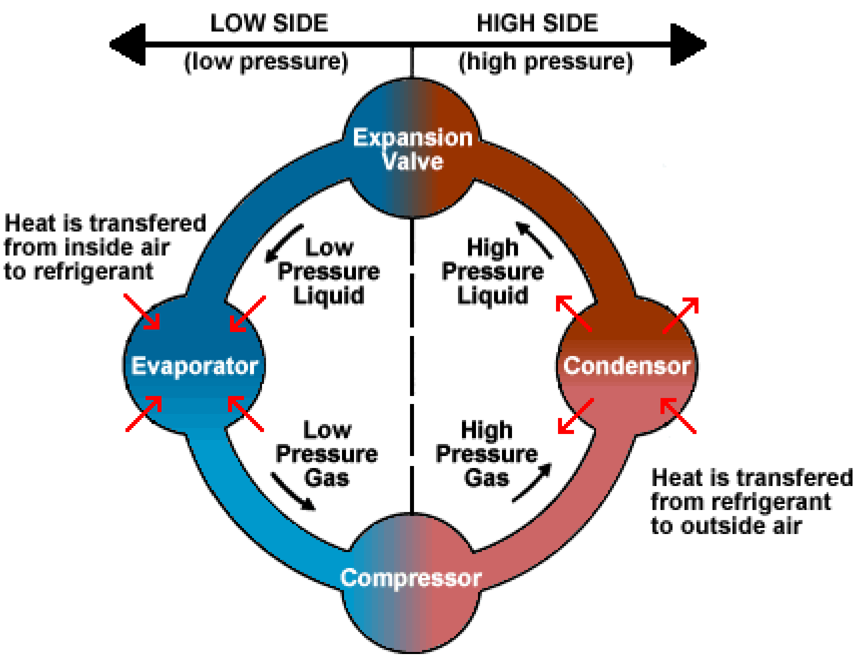
JUST LIKE AT HOME

A liquefaction plant works a lot like the refrigerator in your home, except on a vastly larger scale — imagine Godzilla versus a gecko. The plant's assignment is simple, but brutal: Take vaporous natural gas coming out of a pipeline at ambient temperatures — somewhere between 0 degrees and 100 degrees Fahrenheit over most of the Earth's surface — and chill it until it condenses and liquefies at minus 260 so it can be shipped on tankers to overseas customers.

In the end, the liquefaction plant and your refrigerator are both affected by the surrounding temperature. When it's cold in your house, the refrigerator doesn't use as much power to keep your lettuce crisp. Similarly, the lower the temperature outside, the less power needed to run a liquefaction plant.

How much difference does temperature make?

Quite a bit, as it turns out. A detailed analysis of temperature effects on energy use was done in 2012 for Snohvit, an LNG plant in the Norwegian Arctic.



Source: Southwest Tech, Fennimore, Wisc.

The liquefaction process at an LNG plant is similar to home refrigerators — coolants circulating in a closed system draw the heat out of the natural gas and transfer that heat to the outside air

The analysis[1] concluded that Snohvit — operating in an ambient temperature of 39 degrees — was 11 percent more efficient than if the temperature had been 68, and 20 percent more efficient than if it had been 97.

"That heat removed from the natural gas has to go somewhere," said Jim Wilkins, a senior technical professional and process engineer with ExxonMobil in Houston. "And that typically goes into a heat sink, and ultimately the heat sink is ambient conditions."

(A heat sink is an environment that absorbs heat from a higher-temperature source. In the case of a gas liquefaction plant, the receiving environment for the heat is normally air or water. The substance giving up heat is a liquid coolant the plant uses to chill natural gas until it liquefies. A device that actually transfers heat from a source to the heat sink is called a heat exchanger.)

How much of a break might a big liquefaction plant at Nikiski get from low-temperature energy efficiencies?

Steve Butt, an ExxonMobil employee managing the Alaska LNG team, has said that liquefaction equipment in Nikiski would be 10 percent to 15 percent more efficient than the same piece of equipment working in the Middle East. That means more LNG at a lower energy cost.

Still, a lot of design and engineering work remains for Alaska LNG before selecting specific equipment for the plant, filing plans with regulatory agencies, pinning down costs and making a final investment decision to go ahead with construction.

There is a rule of thumb for energy efficiency based solely on temperature differences, Wilkins said. The improvement at an LNG plant ranges from 0.5 percent to 1 percent each time the ambient temperature drops by 1.8 degrees.

This makes it possible to form some estimate of how much edge an Alaska plant might have over a rival in a representative Middle East LNG port with an average year-round temperature — typical of the region — of 80 degrees. At Nikiski, the favored LNG plant site for the Alaska project, it's 36 degrees.

That's a difference of 44 degrees.

Thus, Alaska's efficiency advantage over the Middle East could range from 12 percent to 24 percent, in the same ballpark as the figures from Butt and from the Norwegian analysis for Snohvit.

WHY IT'S COOL TO BE COLD

Some energy benefits arise inside the gas turbines that provide power to an LNG plant. These turbine engines draw in outside air to burn some of the incoming gas to produce heat. Then they convert the heat to either mechanical power or electric power, as needed. Using colder air makes any turbine a little more efficient.

The first step in running a gas turbine is to compress the incoming air so that it can be mixed with natural gas and burned in the combustion chamber. The hot combustion gases then expand through the turbine blades, spinning them to produce power. Because cold air starts out denser than warm air, less work is needed to compress the flow of cold air to the conditions required for combustion. That is, the turbine consumes less power doing its job, which translates into more power being available for useful work and higher efficiency.

Source: Oil Search Ltd.

The large number of rack-mounted fans at the Papua New Guinea LNG plant are part of the process that cools the refrigerants used to superchill natural gas into a liquid. The plant was under construction in this photo; it loaded its first cargo in May 2014.

However, the energy gain at this stage is not as pronounced as across the LNG plant as a whole — only 0.1 percent or so for every 1.8-degree drop in air temperature.

The big energy savings come at the heart of the plant, in the liquefaction process.

Because it takes less power to liquefy gas in cold weather, the turbines that drive the process don't need to burn as much gas to produce LNG at minus 260 degrees. And that's the definition of higher energy efficiency.

Details matter all through the process. The plant's efficiency benefits from both the low temperature of the incoming gas and the low temperature of the surrounding air.

How cold would the incoming gas be at Nikiski?

The temperature of the gas in the buried pipeline from Prudhoe to Nikiski will be managed with one chief goal in mind: Making sure it is compatible with the temperature of the soil through which it passes. It'll be kept below 32 in frozen soil and above 32 in non-frozen soil.

To do otherwise would invite disaster. In frozen soil, particularly permafrost, a warm pipeline would risk thawing the soil and causing the line to sag and possibly rupture. In un-frozen soil, a below-freezing pipeline would risk accumulating an ice bulb that could push it upward, possibly causing it to split or crack.

Thus, the gas is likely to show up at the Nikiski plant at a year-around average temperature in the neighborhood of 35 degrees, in sharp contrast to the Middle East, where soil temperatures can reach 86 degrees. So Nikiski could have something like a 50-degree head start in cooling its gas to minus 260.

COLDER AND COLDER

At Nikiski, the gas would be chilled by passing it through a chain of several coolants, each colder than the one before. The final coolant is so good at its job that the natural gas liquefies as it passes through.

And how are the coolants kept cool?

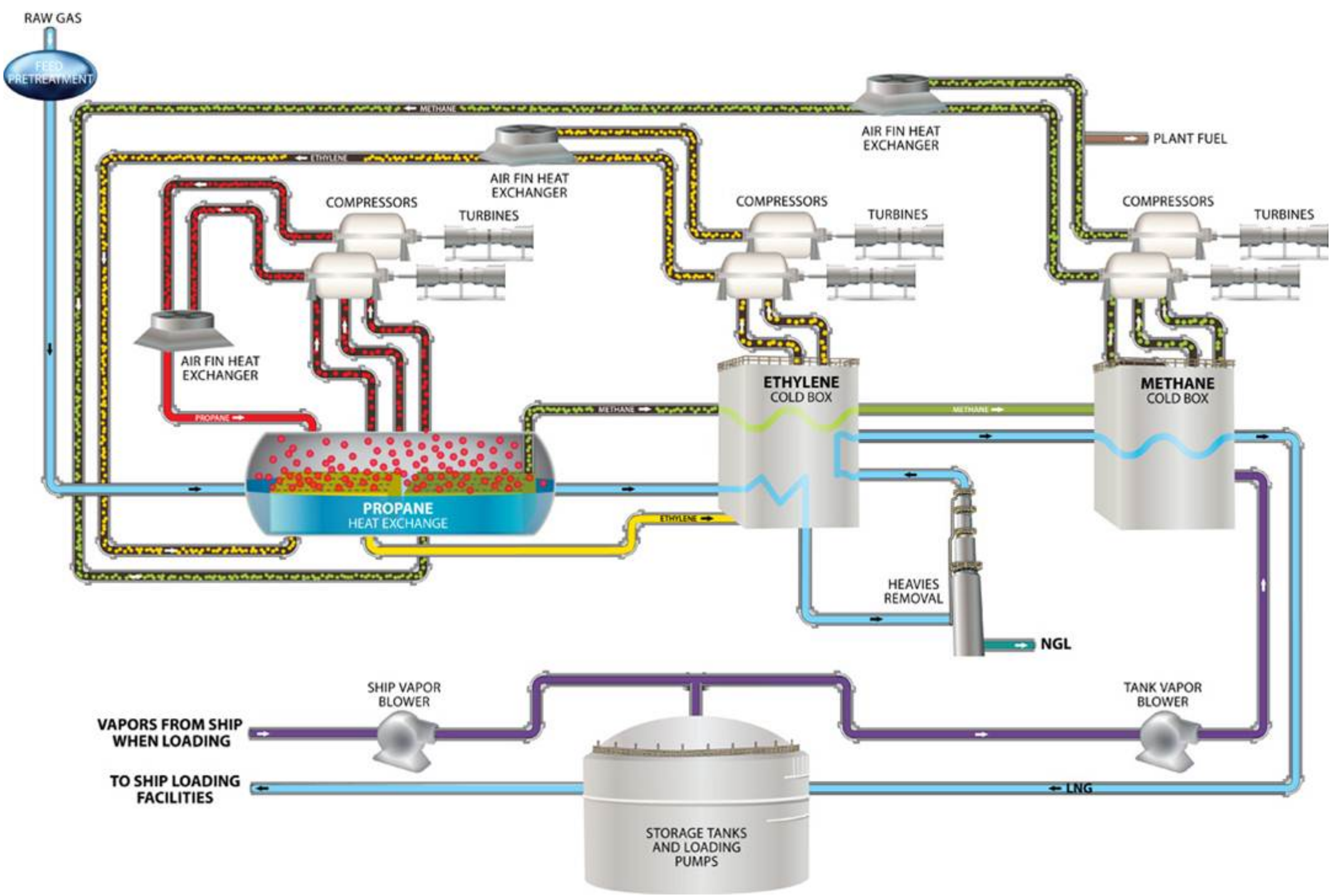
The coolant refrigeration cycle starts with each coolant in a relatively warm gaseous state. It's compressed to a fraction of its original volume, which heats it further. Next, the hot, pressurized gaseous coolant passes through a condenser — or heat exchanger — here heat is transferred away and the coolant becomes a high-pressure liquid. The coolant is then allowed to expand, which further reduces its temperature.

Now a cooler low-pressure liquid, it passes through an evaporator — another type of heat exchanger — where it absorbs heat from the natural gas and then evaporates back to its original relatively warm gaseous state, ready to start the cycle over.

It's similar to the refrigeration cycle of the coolant — Freon, usually — inside your kitchen fridge. It, too, starts out as a relatively warm gas. Then it's compressed and run through a condenser — that assembly of fins and tubing on the back of the refrigerator. There, it cools and condenses into a pressurized liquid and gives up its heat to the air within your house.

Then it's run back into the refrigerator and through an expansion valve, which cools it to a low-pressure liquid. Then it's circulated through a heat exchanger as the refrigerator's warm interior air — warmer than the Freon, at any rate — is blown through the heat exchanger. The interior air cools off to keep that lettuce crisp, the Freon heats up and evaporates back to a gaseous state inside the tubing, and the cycle beings anew.

In a multi-coolant LNG plant, all coolants may not be treated alike. In many installations, only the



Source: ConocoPhillips

ConocoPhillips' Optimized Cascade Process is one of several options available for LNG plant developers worldwide. The Conoco process uses three separate steps to draw the heat out of the natural gas and supercool it to minus 260 until it condenses and becomes liquid.

condenser for the first coolant transfers heat to the outside air. For subsequent coolants in the chain, the heat exchangers are inside the reservoir of that first coolant. In such cases, the first coolant is the sole medium for transfer of heat from natural gas to outside air — the essence of the liquefaction process.

After the natural gas leaves the final coolant reservoir in the desired liquid state, it is pumped into storage tanks to await shipment to market on LNG carriers.

Most of the efficiency benefit in this complex and interlooping process comes as the initial coolant passes from the compressor to its air-cooled condenser. The colder outside air means less pressure in the line to the condenser, and that means the turbine-driven compressor doesn't have to work as hard to push against it.

With ambient air at 36, rather than 80, the Alaska plant's 44-degree advantage comes into play not just on the first pass, but also during each subsequent loop the initial coolant makes through the system.

Finally, there are efficiencies connected with the huge, insulated LNG storage tanks. Because no insulation system is perfect, the liquefied gas absorbs some heat from the surrounding environment and as a result part of it evaporates. This gas is called boil-off gas.

If, as at Nikiski, the surrounding environment is colder, less of the gas boils off.

What gas does boil off must be reliquefied so that it can be returned to the tanks. And reliquefaction of boil-off gas, as with incoming gas, is more efficient at lower air temperatures.

Source: Alaska LNG

An Alaska LNG export plant could look something like this conception provided by the Alaska LNG project sponsors: ExxonMobil, BP, ConocoPhillips and TransCanada.

Ultimately, the higher output of gas turbines, the higher effectiveness of the air-cooled condensers, and the fuel gas savings that all result from Alaska's colder ambient temperatures produce lower costs and improved energy efficiency.

MORE ADVANTAGES FOR ALASKA PROJECT

There are some savings on capital expenditures because less-powerful equipment can be used in some places in the production chain, though that is offset at least to some extent by the higher cost of building and running things in cold climates.

For example, some of the plant's equipment would need to be toughened and specially designed to work in very cold temperatures. And any space where people need to work must be enclosed, insulated and heated; in the Middle East and other warm regions, some of that same work can take place in open-air sheds.

Moreover, some aspects of an LNG plant's construction and operation don't much depend on temperature. A storage tank big enough to hold a given amount of LNG must be the same size, whether in Nikiski or the Middle East. And the sizes of pumps and pipes big enough to move a given amount of LNG per day from liquefaction to storage or from storage to tanker don't change with temperature.

Even though colder temperatures don't reduce costs for every piece of the project and its construction, it's one of the quantifiable advantages for Alaska LNG.

The project has another big advantage, as well. The liquefaction site is closer to Asian markets than much of the competition.

Nikiski is about 3,800 miles from Yokohama, a major port in central Honshu, Japan's main island, and home to Tokyo and several LNG import terminals. The proposed Kitimat project in British Columbia is almost 4,500 miles from Yokohama, and Russia's huge Yamal project in the Arctic is not only about 7,800 miles away from Yokohama but also ice-locked for much of the year.

On the other side of the ledger are the disadvantages of the cost and difficulty of building and running facilities in a cold, remote locale like Alaska. Another issue is the fact that the Alaska project — unlike many of its competitors around the world — would need an 800-mile pipeline to get gas from the fields to the liquefaction plant.

Calculating the financial implications of those advantages and disadvantages will go a long way toward helping the North Slope producers — ExxonMobil, BP and ConocoPhillips — determine if they have a project that can compete on price per million Btu of delivered gas.

LONG ROAD AHEAD

The sponsors of the $45 billion to $65 billion Alaska LNG project will take a few years for engineering, design, environmental work and all the other tasks that come with such an enormous undertaking.

First, a lengthy process of engineering and design has to take place, as does a complicated permitting process with federal and state agencies. The project would then be ready for a final investment decision, after which, if the sponsors proceed, construction could begin. The earliest LNG deliveries could start would be 2023-2024.

But if that day does come, it could mean billions of new dollars for the state of Alaska, a longer life for the North Slope oil fields, and a major bump in oil-industry employment in the state.

And, for once, the fact that Alaska is colder than most of the rest of the world could actually help a little.

Notes

[1] "Exergy Evaluation in the Arctic Snohvit Liquefied Natural Gas Processing Plant in Northern Norway — Significance of Ambient Temperature." Anne Berit Rian and Ivar S. Ertesvag, Department of Energy and Process Engineering, Norwegian University of Science and Technology, 2012.

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