Alaska LNG could have right heat content for Asia buyers

Alaska North Slope gas exported to Asia could hold a key attraction over other U.S. LNG exports: The Alaska gas would burn hotter.

To adopt the gas industry's jargon, Alaska's liquefied natural gas would be somewhat "wet" or "rich" compared with the "dry" or "lean" gas other U.S. liquefaction plants will process into LNG.

And many Asian buyers love wet gas — which is laced with gas liquids that raise the heat content. Especially in key markets such as Japan, South Korea and Taiwan, power-plant turbines, industrial furnaces and household appliances are calibrated to burn rich gas.

A gas-fueled kitchen stove built for a Japanese home could not be used in the United States without modification, and vice versa.

Gas out of the ground comes in as many varieties as Starbucks has blends of coffee. Try to feed raw natural gas through your household furnace or your patio propane grill and you risk a miserable stay in a hospital burn unit.

Even LNG, which undergoes robust processing before heading to sea, is not a singular, uniform product. Some blends are wetter than others, making them unsuitable for certain markets without further processing. Some are drier, making them unsuitable for other buyers without extra cost.

The absence of a homogenized natural gas commodity on the world market might seem less surprising when one realizes that the natural gas business is a relatively young industry.

Unlike its glamorous big brother — crude oil —

LNG content from Asia-Pacific plants in 2012

	Methane	Ethane	Propane	Butane+
Australia - North West Shelf	87.3%	8.3%	3.3%	1%
Australia - Darwin	87.6%	10%	2%	0.3%
Brunei	90.1%	5.3%	3%	1.5%
Indonesia - Arun	91.9%	5.7%	1.6%	0.8%
Indonesia - Badak	90.1%	5.5%	3%	1.4%
Indonesia - Tangguh	96.9%	2.4%	0.4%	0.2%
Malaysia	91.7%	4.6%	2.6%	0.9%
Oman	90.7%	5.8%	2.1%	1.2%
Peru	89.1%	10.3%	0.1%	0%
Qatar	90.9%	6.4%	1.7%	0.7%
Russia - Sakhalin	92.5%	4.5%	2%	1%
Yemen	93.2%	5.9%	0.8%	0.1%
Alaska - Nikiski	99.7%	0.1%	0%	0%

Source: International Group of Liquefied Natural Gas Importers which has been a high-octane business since the late 1800s, the modern natural gas industry got legs only in the 1950s, starting in North America, coming of age with the Cold War, suburbia and rock 'n' roll.

The overseas LNG trade arrived a generation later, ripening into adolescence in the late 1970s, coinciding with Mideast nationalization of oil production, runaway inflation and disco dancing.

As the gas industry expanded by pipeline and by LNG tanker, different regional systems developed in isolation from one another, sort of how different languages emerged around the world. Each new gas system was a unit unto itself, based on the quality of local or regional gas supplies. In industrialized North America, dry gas was amply available, so that's what is piped to U.S. furnaces. Japan, South Korea and Taiwan built their systems on the wet-gas LNG blends from nearby Indonesia, Malaysia and Brunei.

Only in the past 10 years or so — as some gas brewed for one market got served to other customers — has the market difference between dry gas and wet gas even begun to matter much.[1]

The global gas trade that arose over the past 50 years is a story of resource haves and have-nots, of oil-price shocks and degrees of industrialization, of stranded gas reserves and entrepreneurial risk taking.

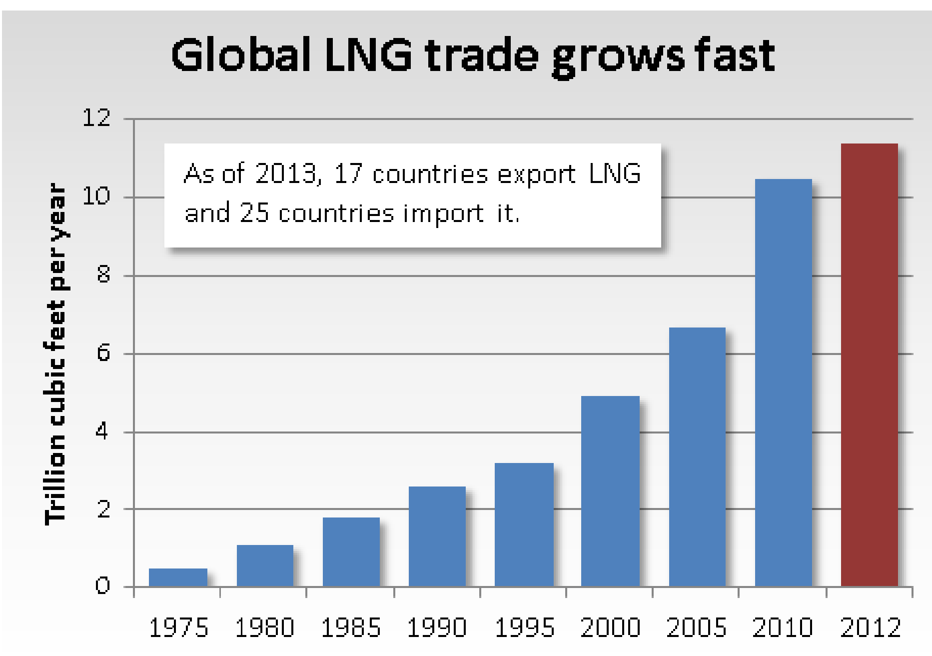
Elements of this story have worked against Alaska gas, stranding the state's North Slope reserves in a harsh environment distant from major markets. But the gas under Alaska's Arctic has its advantages, too. It is wetter than some dry-gas resources of Eastern Australia's coal-bed methane fields, British Columbia shale plays and East Africa offshore deposits — gas that could compete with Alaska for Asian LNG buyers in the 2020s.

The blend of Alaska Arctic gas that ExxonMobil, BP and ConocoPhillips might superchill into LNG could be almost ready-made for the Asian market.

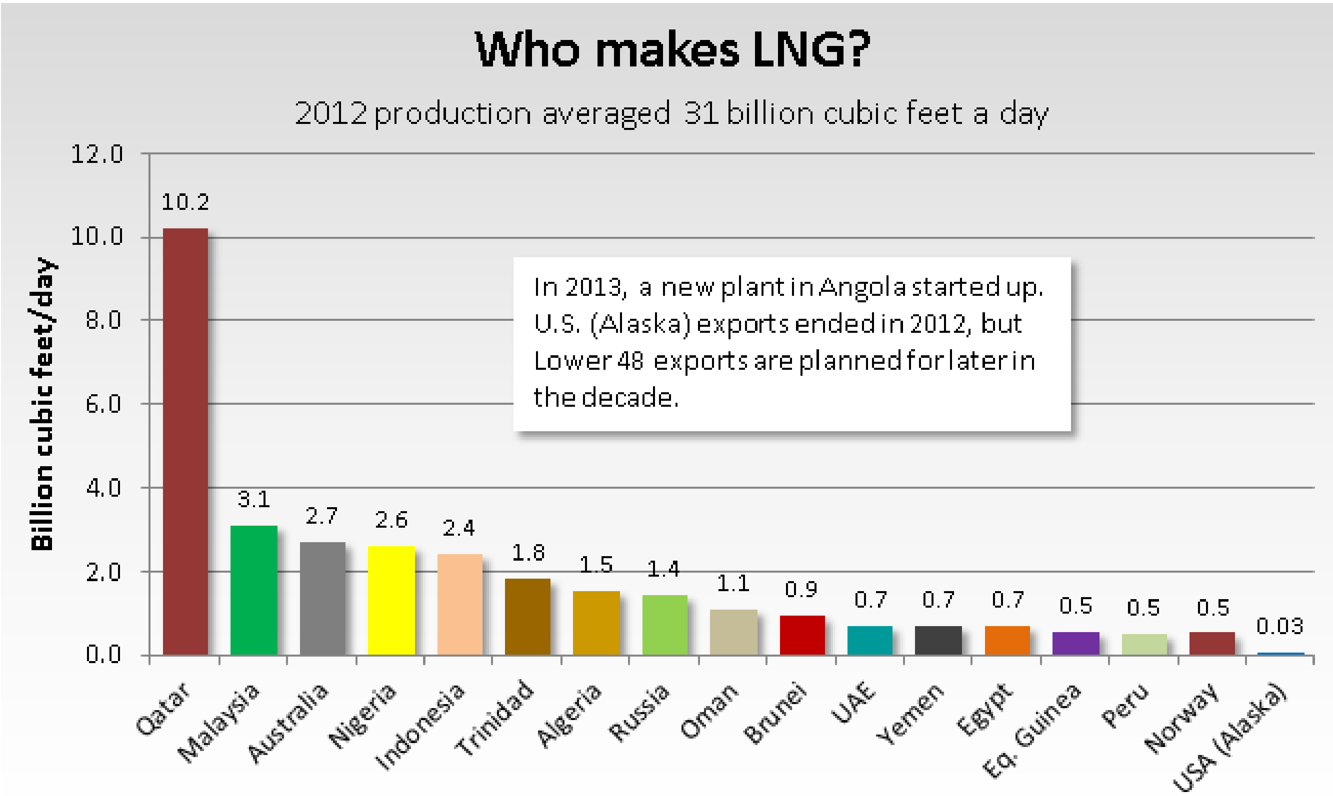
CALORIES OF ENERGY

For starters, let's put some numbers on the table to help explain wet gas vs. dry gas:

- 1.01 million British thermal units, or Btu — This is the heat content of 1,000 cubic feet of methane, a standard measure of methane. Energy content is reported in Btus so that different fuels — gas, oil, coal — can be compared. Natural gas usually is priced in units of 1 million Btu.
- 1.022 million Btu — The average heat content per thousand cubic feet of U.S. pipeline gas, the gas that goes to power plants and home furnaces. This pipeline gas is almost pure methane.[2]
- 1.06 to 1.13 million Btu — The heat content that Japanese and South Korean utilities expect from the gas they burn.[3] (Some sources will show different ranges based on different assumptions about the



Source: BP Statistical Review of World Energy



Sources: BP Statistical Review of World Energy, U.S. Department of Energy

temperature and pressure of the gas. The range given here serves to show that Japan and Korea use a higher-Btu gas than found in pure methane or U.S. pipeline gas.)

Liquefied North Slope Alaska gas should fall within the Btu window of Japan and Korea, with likely about 1.1 million Btu of energy per thousand cubic feet. Certain decisions by the gas producers, their customers and others could move this Btu number around.

More poetic members of the gas industry refer to the Btu content as "gross calorific value." In other words, higher Btu gas serves up more "calories" of energy.

Gas industry engineers, poetic or otherwise, have a say in this, too. They note that not all Btus are created equal. Gas supplies with identical Btu measures might have different densities, because different mixes of methane, ethane, propane, etc., can result in identical Btus. Density can matter a lot as gas passes through a burner nozzle on its way to ignition. For example, a gas that combusts inefficiently can emit lots of dangerous carbon monoxide — just as an ice-cold auto engine releases more carbon monoxide than normal when started.

As the International Gas Union, a trade group, put it in a 2011 report, "All gas-fired equipment is designed and built for a particular gas specification. This will include a range of gas qualities within which the appliance will function correctly. If gases outside this range are combusted, this can lead to a range of problems from poor quality combustion through to equipment damage and ultimately dangerous operation."[4]

So engineers crafted a formula that adjusts the heating value to account for gas density, putting different gas blends on the same footing. This formula results in the Wobbe Index for gas, a term we'll drop from this discussion because Btu differences tell the story well enough.

WHY CARBON ATOMS ARE IMPORTANT

Raw natural gas is a combustible cocktail of hydrocarbons.

Hydrocarbons — because hydrogen and carbon atoms compose the parts of gas that produce energy.

One carbon atom plus four hydrogen atoms equal methane.

Ethane has more heat content per unit than methane because it has two carbon atoms, not one, to fuel the burning process. A natural gas blend of methane with a taste of ethane burns hotter than just methane.

Propane has three carbon atoms and more heat content yet. Butane four. Pentane five. And so on. With enough carbon atoms you get crude oil.

Methane is considered dry gas. Over time, the other components became known as natural gas liquids because with a change in temperature or pressure these can become liquid and separate from the vaporous methane.

Methane laced with enough gas liquids is known as wet gas — a synonym for high-Btu natural gas.

The oldest natural gas market — North America — has built industries around each hydrocarbon within raw natural gas.[5]

Methane fuels household furnaces and power-plant turbines. Ethane is a petrochemical feedstock and is transformed into ethylene to make such products as plastic bags. Propane also is a petrochemical feedstock as well as a fuel for heating rural homes and broiling steaks on backyard grills. Butane helps make synthetic rubber for tires and is cigarette-lighter fuel.

TURNING LEFTOVERS INTO MONEY

Each component of natural gas originally was regarded with disdain, a nuisance byproduct of oil production.

But one by one over many decades, North American industries developed around each component, tracing their births to entrepreneurs who found cash in what others considered waste. Today, in a textbook feat of capitalism, profit is gained from the entire spectrum of natural gas components, in much the same way that slaughterhouses and butchers carve a whole hog into different products.

The gas liquids industries came first. Plants got built that could "fractionate" the gas stream — separating the gas into its various components. Until World War II, liquids — particularly propane and butane — comprised pretty much the whole U.S. gas industry. Methane, if it was produced at all, was vented or flared to get rid of it, or piped short distances from fields to nearby towns.[6]

As long-distance gas pipelines were laid in the 1950s — and these pipelines connected to each other over time — standards developed so that pipeline gas was pretty much the same across North America. It was a triumph of efficiency. Anybody's gas could travel through any pipeline system to any customer.

Because North America gas liquids already had their own markets, pipeline gas for home furnaces, power plants and industrial uses became what was left over — essentially pure methane with perhaps traces of liquids that raise the Btu content a tad.

This pipeline gas — dry, low-Btu methane — is what proposed Lower 48 liquefaction plants would superchill into LNG for export.[7]

HOT GAS IN ASIA

A different story unfolded as the global LNG industry set sail outside North America in the

Energy content of different fuels

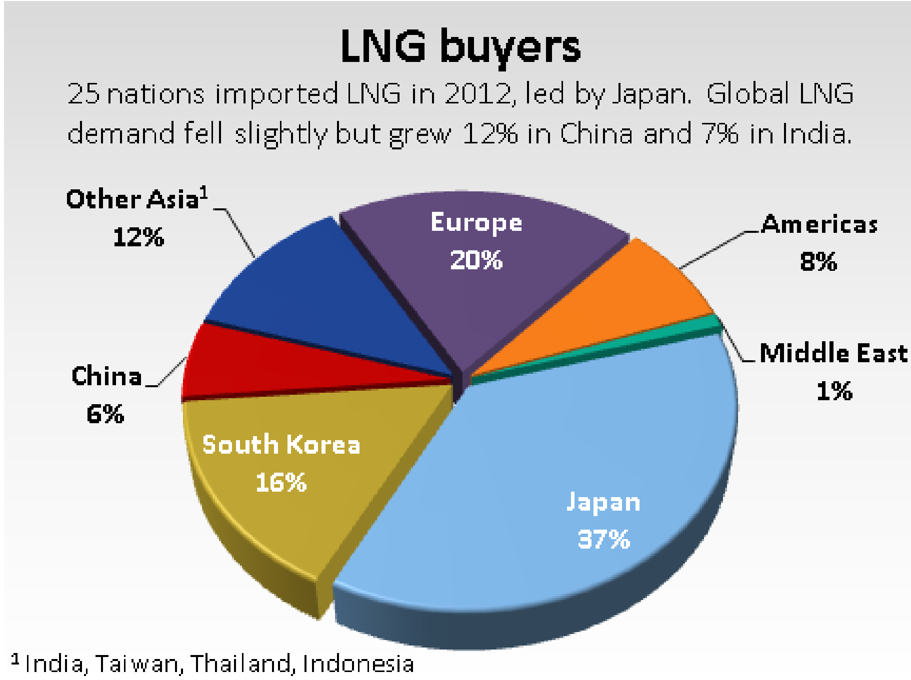
Thousand cubic feet methane	=	1.01 million Btu
Thousand cubic feet ethane	=	1.77 million Btu
Thousand cubic feet propane	=	2.52 million Btu
Thousand cubic feet n-butane	=	3.25 million Btu

Source: U.S. Energy Information Administration

1960s and 1970s.

In the Asia-Pacific market, Japanese utilities were the first buyers. They targeted huge stranded gas reserves in Brunei, Indonesia and Malaysia. These countries had no petrochemical industries, no internal markets for propane and butane. They had no economic reason to strip liquids out of their methane.

So the liquids stayed in the LNG.



Source: International Gas Union

At the time, Japan was weaning itself off oil-based fuels after global oil prices soared in the 1970s.[8] Japan built its natural gas use around high-Btu gas. Brunei LNG packs about 1.13 million Btu per thousand cubic feet. Much Indonesian LNG comes in at about 1.12 million Btu. Today LNG from Indonesia's legacy plants is about 90 to 92 percent methane and 5 to 6 percent ethane, with a smattering of propane and butane.

South Korea began LNG imports in 1986 and Taiwan in 1990. They bought from the same plants supplying Japan, and high Btu became their standard, too.

Today these three countries, plus China and India, consume about two-thirds of the world's LNG. They buy from plants across the globe, some of which sell rich gas and some — such as the Caribbean's Trinidad and Tobago — relatively lean gas.

To ensure the consistency of LNG, a utility can boost the Btu measure by juicing the gas with propane, or lower the Btu count by stripping gas liquids or injecting inert nitrogen. However, the machinery of all that spiking or diluting adds cost to the LNG value chain.

Tokyo Gas modifies the different blends of imported LNG so that the heating value of its gas is almost constant, the IGU said in its 2011 report.

Osaka Gas deals with diverse LNG cargoes by supplying customers with gas within a range of heating values. The utility "detuned users' appliances to operate over the defined range," the IGU said.

One Japanese utility — Tokyo Electric Power — has taken note that substantial volumes of lean LNG could hit the market within 10 years from U.S. Gulf Coast terminals and three Eastern Australian plants under construction that will liquefy low-Btu coal-bed methane. TEPCO is planning to install expensive storage tanks and other infrastructure in Japan to segregate lean gas from its other LNG imports.[9]

China's story is different. Its first LNG imports arrived in 2006, and more comes in every year. The country also has substantial domestic gas production — unlike Japan, South Korea and Taiwan. China has yet to develop uniform standards that apply to the gas Btu hodgepodge delivered to its industries, the IGU said.

In a June 2012 report, global financial services company Credit Suisse downplayed the lean-gas/

rich-gas challenge for buyers, calling it a "manageable issue" for Japan, South Korea and Taiwan.[10] As for China and India, the issue is less important because they already are coping with a motley mix of gas supplies.

(A quick aside: ConocoPhillips' low-Btu LNG exports from its Nikiski, Alaska, plant were a historical aberration in Asia-Pacific trade. This plant pioneered exports to Japan in 1969, but its output soon was dwarfed by LNG shipments from Brunei, Indonesia and Malaysia. The Alaska plant's low Btu count — about 1.014 million per thousand cubic feet — resulted from feed gas that was almost pure methane straight out of the ground. The plant produced the driest LNG in global trade until shipments ended in fall 2012. Buyers in Japan spiked the Alaska LNG with gas liquids.)

ALASKA GAS IS GETTING DRIER

The Alaska North Slope's roughly 33 trillion cubic feet of proven gas reserves are wet.

But not as wet as when they were discovered 45 years ago.

The main field is Prudhoe Bay, the nation's largest oil producer and one of its largest gas reservoirs. Prudhoe would be the anchor source of gas for a large-scale Alaska LNG project.

When oil production was about to start back in 1977 and a gas pipeline project was being planned, Exxon, one of the producers, estimated the gas was 73 percent methane, 6.9 percent ethane, 3.72 percent propane, 3.23 percent butane or heavier gases (more carbon atoms).

Oh yes, plus a nuisance ingredient: 12.71 percent carbon dioxide. CO_2 is a nuisance gas because it doesn't burn and it can corrode pipelines. So gas producers strip out most CO_2 before piping the gas to market and essentially all of it before making LNG.

Prudhoe's 12 percent carbon dioxide is a big proportion. Gas in the other big North Slope gas field — Point Thomson — is about 4 percent CO_2, according to ExxonMobil. But 12 percent isn't off the scale. Australia's Gorgon LNG project under construction will process some gas that is 14 to 16 percent CO_2.[11] Gas at the proposed East Natuna LNG project in Indonesia is an estimated 70 percent CO_2.

So, through a muscular process, carbon dioxide and other impurities would be stripped from the North Slope's gas stream. The plant handling this scrubbing chore would be one of the largest of its kind in the world — removing as much as 500 million cubic feet of CO_2 each day from about 3.5 billion cubic feet a day of raw, produced gas.

Nobody will buy LNG loaded down with CO_2. It would be like buying a holiday turkey loaded with water to boost its weight. The water adds no benefit, just cost. Besides, during cooling CO_2 would become solid — think dry ice — and clunk up the LNG machinery well before the methane vapors get cold enough to become liquid.

In 1977, Exxon estimated that Prudhoe's gas composition would be as follows after cleaning:

- 85.11 percent - Methane.
- 7.7 percent - Ethane.
- 3.99 percent - Propane.
- 1.23 percent - Butane.
- 0.22 percent - Pentane and heavier.

At the time, a project was being planned to pipe Prudhoe gas to the U.S. Lower 48 states. (Economics killed that project in the 1980s.)[12] Federal gas regulators estimated the gas heat content per thousand cubic feet at 1.139 million Btu.

That would have been a rich gas indeed. Only Libya's LNG is comprised of a higher percentage of high-Btu gas liquids today, according to the International Group of Liquefied Natural Gas Importers.[13] Back in the early 1980s, the gas liquids carried with the Alaska pipe's methane would have been extracted somewhere along the pipeline route, probably in Alberta, Canada, where

Composition of Prudhoe Bay gas over time

	Raw gas		Gas after treatment		
	1977	2012	Pipeline proposal 1977	LNG proposal 1995	Potential LNG 2013[1]
Methane	72.92%	80%	85.11%	89.87%	91%
Ethane	6.90%	5%	7.70%	5.94%	5.9%
Propane	3.72%	2%	3.99%	1.88%	1.9%
Butane+	3.23%	0.3%	1.45%	1.61%	0.2%
CO_2	12.71%	12%	1%	0%	0%
Nitrogen	0.51%	0.6%	0.75%	0.7%	0.6%

[1] *Percentages could change by time project is built.*

Sources: 1977 - Federal Power Commission; 1995 - Yukon Pacific Corp.; 2012 - State of Alaska; 2013 - Office of the Federal Coordinator estimates

a petrochemical industry was sprouting up and in need of gas liquids feedstock.

But as was mentioned, Prudhoe's gas is less wet today than in 1977. The gas stream that would support an LNG export project likely would boast a Btu content of around 1.1 million Btu per thousand cubic feet, according to those connected to the project.

WHAT HAPPENED?

When the proposed 1970s-era gas pipeline got shelved as a loser, Exxon and the other producers devised a new strategy. This Plan B was straight out of Economics 101: Turn the heaviest gas liquids into money by sending them to market down the oil pipeline.

They anticipated doing this early on. In October 1977, four months after the first oil flowed from Prudhoe Bay, an Atlantic Richfield (now ConocoPhillips after a series of mergers) executive told a congressional committee, "The most efficient way of getting natural gas liquids from Prudhoe is by blending them into the crude stream."

In 1986, the producers executed that idea. They christened the world's largest gas processing plant at Prudhoe Bay. The plant extracts butanes and heavier gases — the high-Btu liquids that will blend with crude oil and stay liquid in the trans-Alaska oil pipeline.

Through 2011, they produced over 635 million barrels of gas condensate and gas liquids. Only two of the North Slope's two dozen oil fields have yielded more barrels of liquid product over the years: Prudhoe Bay and Kuparuk River, according to state of Alaska statistics. The state profited by collecting tax and royalty on those gas liquids.

Gas liquids production peaked in 1997 at 95,000 barrels a day. Because so much of the heavier liquids are gone and the oil flow is lower, the plant produces about 30,000 barrels a day of gas liquids now, according to BP, which runs the plant.

An ExxonMobil executive explained the removal of heavier gas liquids during a February 2013 presentation to legislators in Juneau, Alaska.

Prudhoe Bay's gas "has been cycled for 30 years," said Steve Butt, ExxonMobil senior manager for the proposed Alaska LNG project. "When you talk about Prudhoe, the Prudhoe Bay operators have done an excellent job of managing an oil field in the way one manages an oil field. Keeping the reservoir pressure up [by reinjecting produced natural gas], so that the oil will move and can be produced and all the stakeholders in that project may enjoy those benefits.

"In doing that, however, that gas has been cycled, almost three times — meaning it's been produced out of the ground, taken to a compression facility, the liquids can be removed, and put back in the ground. Every time you move that gas you remove the liquids, which means you no longer have those liquids to sell. The good news is you've already sold them and already generated all the benefits

Photo courtesy of BP

Prudhoe Bay's Central Gas Facility removes heavier gas liquids from the produced gas and sends them to the trans-Alaska oil pipeline.

that those liquids have."

Selling the heavy liquids means they're not available to help pay for new gas pipeline infrastructure, because they won't use that infrastructure.

Selling them also is part of the reason the gas stream's Btu content has declined. But the stream is still rich.

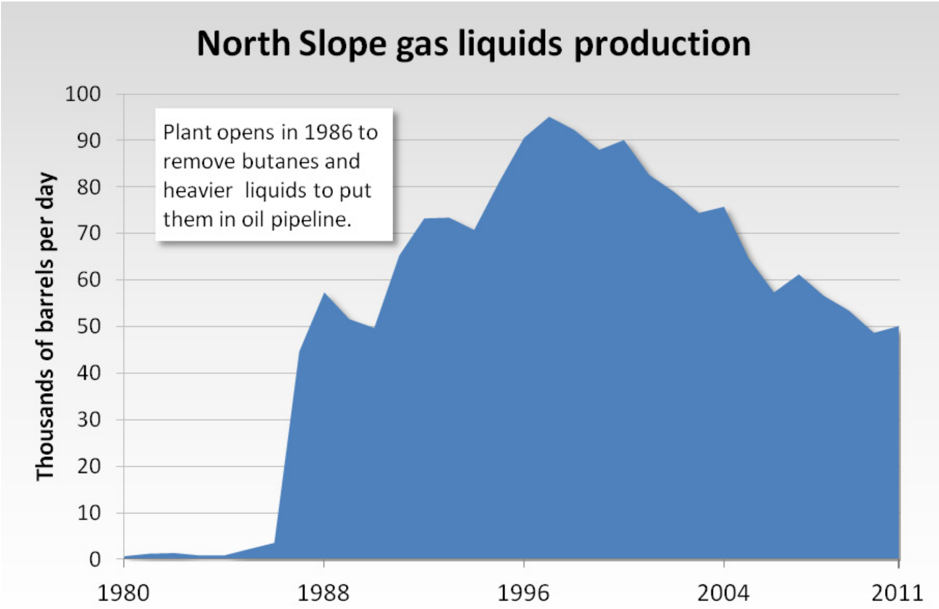
ALASKA'S RICH GAS

The North Slope producers considering an LNG export project have divulged little detail about the makeup of gas that would be piped from the North Slope to a liquefaction plant. Other than to say the gas stream would contain some ethane and a little propane, and that the Btu content would be about 1,100 per thousand cubic feet.

Those lighter liquids would make the gas piped from the North Slope too rich to use in existing Alaska or U.S. gas systems without modifying the gas to dilute the Btu content.

"It would be too hot to burn in a traditional residential environment because of the ethane," Butt of ExxonMobil said in his Juneau presentation. "You'd have to blend it with something like air."

Would the Prudhoe Bay producers continue diverting some gas liquids to make a cocktail called miscible injectant that helps scour more oil from Prudhoe Bay and nearby fields? Propane, ethane, methane and carbon dioxide are the main ingredients of miscible injectant. Would state oil-



Sources Alaska Department of Natural Resources, Alaska Oil and Gas Conservation Commission

Fast forward to today. The raw, out-of-the-ground gas production that enters Prudhoe's Central Gas Facility has 1.002 million Btu per thousand cubic feet, according to data from the U.S. Energy Information Administration.

After the central gas plant removes butane, pentane and heavier liquids for shipment in the oil pipeline, the heat content drops to about 0.955 million Btu per thousand cubic feet, according to BP, the plant operator.

field regulators allow a rolling back of the miscible program?

The declining richness of Prudhoe Bay's gas stream over time is evident in changing state estimates of the heat content.

In 1996, four state department heads, in a memo to their boss, Gov. Tony Knowles, said LNG from an export project conceived back then would be steeped in gas liquids.[14] The North Slope producers estimated the heat content would be about 1.17 million Btu per thousand cubic feet for the first 10 years, then average 1.1 million Btu for the remainder of the project's life, the department heads said.

In 2004, a state petroleum manager said the heat content of pipeline gas — with small amounts of CO_2 — leaving Prudhoe Bay for North America markets would range between 1.067 million and 1.119 million Btu per thousand cubic feet.[15] The higher number would occur if the miscible injectant program was scaled back or ended, leaving more ethane and propane for the gas stream. (With no CO_2, as would be the case for an LNG export project, the Btu range would have been a little higher.)

This low-Btu gas — carbon dioxide and all — is what gets burned to power the Prudhoe Bay field and a couple of nearby utilities. This gas is about 81 percent methane, 5.3 percent ethane, 1.7 percent propane and traces — about 0.12 percent — butanes and heavier.

Scrub carbon dioxide from this field gas would lift its energy content to about 1.08 million Btu per thousand cubic feet.

Other factors could tweak the Btu content of Alaska LNG exports.

That said, the methane, ethane and propane blend comprising Alaska export LNG likely would be comparable to the rich-gas LNG that plants in Indonesia, Malaysia and Brunei ship to utilities in the key markets of Japan, South Korea and Taiwan.

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