ALASKA NATURAL GAS TRANSPORTATION PROJECTS
OFFICE OF THE FEDERAL COORDINATOR

Small-scale LNG: Niche business with room to grow

The famous face of LNG involves multibillion-dollar developments rescuing stranded treasures of natural gas, shipping it across oceans aboard tremendous tankers to distant cities where customers crave a less polluting alternative to oil or coal to make electricity and heat homes.

But running in the background is a more mundane facet of liquefied natural gas.

This facet, unlike its globe-trotting brother, doesn't involve multinational lending consortia, trade-balance considerations and national-interest debates. It involves consuming LNG in sips not gulps, deliveries by trucks not tankers.

This part of the industry might be considered niche LNG.

The cast of characters includes local gas utilities that want a small cache of gas compactly warehoused for quenching demand spikes during cold snaps.

And pipeline companies that need a spurt of extra gas to maintain pressure and reliability at times of high consumption.

And off-the-pipeline-grid industrial sites — a mine, perhaps, or a small community — that need a fuel that can be trucked in affordably.

This small side of LNG mainly encompasses the original commercial use of liquefied natural gas — as a so-called peak-shaving fuel for utilities — a use of natural gas that started 70 years ago, well before the launch of international trade in LNG.

LNG timeline

1941	Cleveland, Ohio, local gas company opens first commercial LNG plant.
1947	Peak-shaving LNG plant starts up in Moscow, Soviet Union.
1964	First commercial LNG export, from Algeria to United Kingdom.
1969	Japan imports its first LNG, from Alaska.
1971	First U.S. LNG import terminal opens.
1973	Boil-off gas used in an LNG tanker.
1991	Burlington Northern Railway commissions two experimental LNG locomotives.
1994	First U.S. plant to service transportation market opens.
2000	First use of LNG to fuel a ship entirely.
2005	Natural gas fueled drilling rigs begin to be used in the U.S.
2005-2006	India and China begin LNG imports.
2010	First LNG mining truck in U.S.

Sources: Encana, International Group of Liquefied Natural Gas Importers, OFC research

But money also is getting invested and plans are being drawn to find other niche markets for LNG.

Small-scale LNG champions dream of small power plants on isolated islands burning LNG not oil-based fuels.

They want to extend the reach of natural gas into transportation fuels — a domain oil dominates — with heavy-duty trucks powered by LNG not diesel, and ships burning natural gas not oily bunker fuel.

They want oil fields powered by LNG not diesel. And remote oil fields liquefying associated gas production rather than burning or venting it.

"Small-scale LNG is ... increasingly being used as a means of monetizing early gas from fields distant from infrastructure, reducing the need to flare," a Shell executive wrote in "LNG 2012," a Petroleum Economist publication.

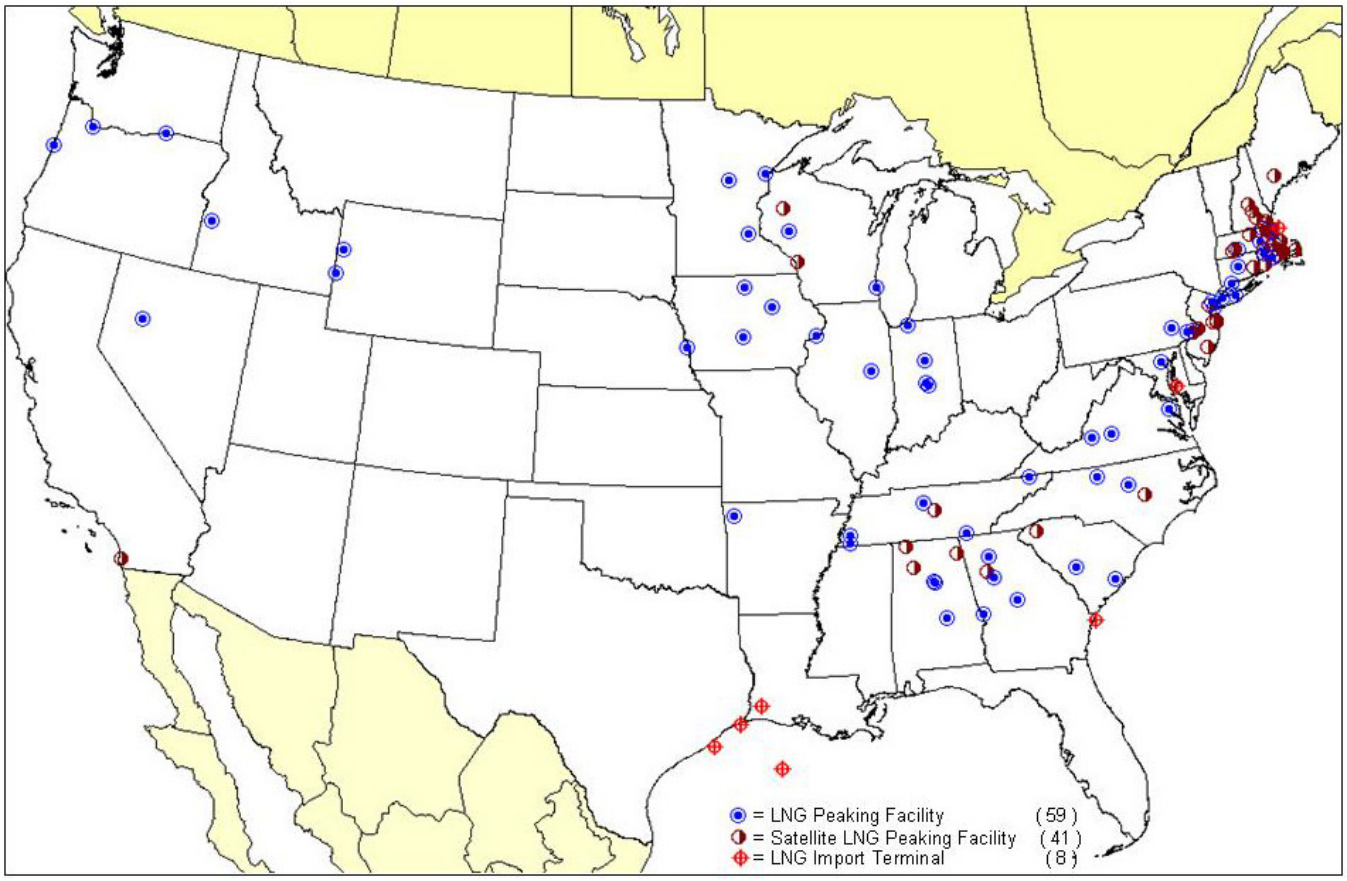
Much R&D effort is getting channeled to niche LNG, trying to minimize the disadvantages of small economies of scale in an industry defined by megaprojects.

If costs can be wrung from the machinery of small-scale liquefaction, transportation, storage, regasification or how engines consume LNG, the resulting efficiencies can make niche LNG an important growth sector for the industry.

"On the back of innovations in small-scale liquefaction and engine technology, the spread of gas to transport may yet have the potential to become a second wave of the LNG business," as Ajay Shah, head of strategy and portfolio in Shell's Global LNG business, put it in "LNG 2012."

TWO FORCES — ECONOMIC, ENVIRONMENTAL

It's almost impossible to draw a sharp line separating natural gas liquefied for export from LNG made for niche uses.

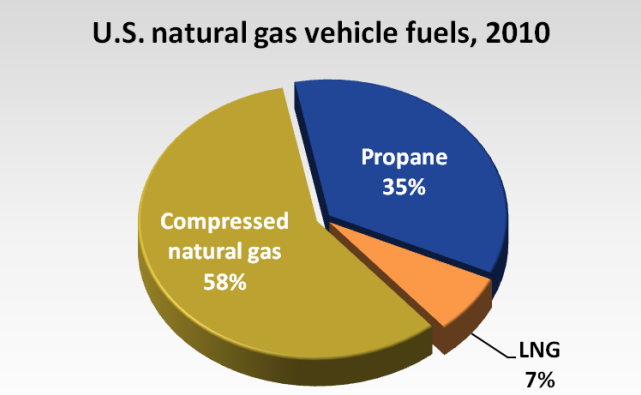


Source: U.S. Energy Information Administration

Some LNG stored to slake utility demand spikes — called peak-shaving gas — is homemade and some is imported. Some homemade LNG is trucked across the border as exports.

Still, certain information is available that sketches an outline of the industry:

- In the United States, one plant made LNG for export — in Nikiski, Alaska — and 59 made LNG for peak shaving, according to Energy Information Administration 2008 figures. In addition, the United States had 41 other sites where LNG was trucked in and stored for peak shaving, but where no LNG making occurred.
- Worldwide, about 260 peak-shaving and storage sites exist, according to the University of Texas Center for Energy Economics. That compares with 26 plants in 19 countries that make LNG for export and about 90 plants worldwide that receive, store and regasify large volumes of imported LNG.
- But equating number of plants with LNG production would be misleading, like assuming convenience stores outsell supermarkets because there are more of them. A typical U.S. LNG-for-peak-shaving plant can process 5 million to 20 million cubic feet of gas per day, according to Black & Veatch, a global engineering and construction firm involved in developing LNG projects. (That's not much; a typical house might consume 50,000 cubic feet of gas per year for heat; much more in Alaska, less in Alabama.) But the world's LNG-for-export plants range in size up to 5.4 billion cubic feet a day; the average processing capacity is about 1.5 bcf, roughly 100 times larger than the typical peak-shaving LNG plant.
- In other niche markets, LNG has barely a toenail hold. In the United States natural gas provides just 0.2 percent of vehicle fuel, and almost all of that gas is compressed methane or propane, not LNG.
- As of last year, only 29 of the tens of thousands of ocean-going vessels used LNG as their main fuel. Most were ferries serving the seas around Norway. However, many of the world's 370 LNG tankers use boil-off, or vaporized, gas from their cargo for some of their energy needs.



LNG comprised 26 million of the 362 million gasoline-equivalent gallons.

Source: U.S. Energy Information Administration

The drive to grow small-scale demand for LNG stems from two potent forces.

One is economic. A gap has opened between oil and natural gas prices in parts of the world. In an era when oil prices have averaged a lofty $90 a barrel for the past five years, pained consumers of oil are hunting for less-expensive fuels.

In North America the price gap is acutely wide, making fuel switching more alluring. Oil is sold in increments of 42-gallon barrels and natural gas in increments of 1,000 cubic feet. Because a barrel of oil packs about six times more energy than 1,000 cubic feet of gas, on a pure energy basis oil should be priced about six times higher than gas. But in North America today, amid a shale-gas supply glut, oil is priced 25 times higher than gas. That kind of gap shortens the break-even moment of switching fuels.

The other force at play is environmental. Natural gas burns more cleanly than other fossil fuels, and governments are demanding fewer toxic and greenhouse-gas emissions from power plants, ships, trucks and other fuel users.

The most beaming optimists see a glorious future for LNG, one in which LNG-powered engines guzzle 31 bcf a day of the fuel in North America alone, as one consultant predicted at a Canadian energy conference this fall. Or the ocean's ships burning 4 bcf a day worth of LNG in their boilers, as executives

with GDF Suez, a major European energy company, predicted in "LNG 2012."

Others think that's crazy talk.

Below we look briefly at some niche uses of LNG.

PEAK SHAVING BY UTILITIES

In the chain of events that routes methane from deep underground in some faraway place to the pilot light on your furnace, storage is a key link.

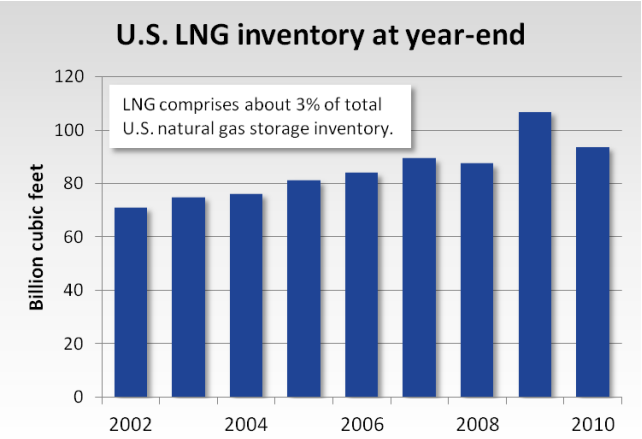
Storage balances the wild swings in natural gas consumption during the year — high demand for heat during winter, high demand for air conditioning during summer — with the steady flow of gas production year-round. Excess production gets stored during slack demand so utilities can use the gas later, sort of like canning the fall harvest to eat during winter and spring.

The U.S. Energy Information Administration calls gas storage and peak shaving "a risk-management calculation" by the utility or pipeline company. It's costly to install storage and peak-shaving plants. "However, the cost of a service interruption, as well as the cost to an industrial customer in lost production, may be much higher" if they don't have gas when they need it.

In addition, storing gas means a local utility avoids reserving tremendous — and expensive — space on supply pipelines, space the utility would use only rarely during demand spikes. "The objective is to maintain sufficient local underground natural gas storage capacity and have in place additional supply sources such as LNG and propane air to meet large shifts in daily demand, thereby minimizing capacity reservation costs on the supplying pipeline," the EIA says.

In the gas-storage game, LNG plays a bit part.

Most gas storage occurs in large volumes, with gas as a vapor piped underground into depleted gas fields, salt caverns or aquifers. Heading into this winter, U.S. utilities, producers, traders and pipeline companies had almost 4 trillion cubic feet of gas packed into underground storage — a record amount. With gas production of about 67 billion



Source: U.S. Energy Information Administration

cubic feet a day in the dead of winter and gas consumption of perhaps 90 bcf a day, this stockpile, plus imported Canadian gas, will help keep the lights on and furnaces warm.

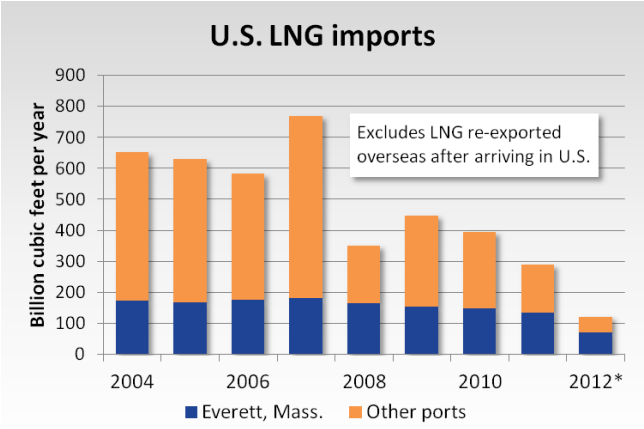
By contrast, LNG stored in above-ground tanks totals a mere 90 bcf or so, not all of it for peak shaving. The big disadvantage of LNG storage for peak shaving is that it's expensive relative to underground storage. The big advantage is the LNG is close by and can be put to use quickly.

New England is a hotbed of gas liquefaction for peak shaving because the area hosts no underground storage sites and pipeline capacity into the region is either limited or non-existent in rural areas. At year-end 2010, 17 of the nation's 67 sites where LNG was stored largely for peak shaving were in New England, according to EIA data.

TRUCKING, NOT PIPING, LNG

LNG is either made at peak-shaving sites or trucked there in special insulated tanks — commonly 40-foot -long thermos bottles on wheels. LNG is too cold — minus 260 — to be piped anywhere; steel pipe exposed to the frigid LNG would shatter.

The United States doesn't import much LNG, but the lion's share of it arrives at a receiving terminal in Boston harbor. That terminal can warm the gas back into a vapor and inject it into two interstate natural gas pipelines and the local gas utility's pipes. The terminal also features four truck-loading bays that can send out 100 million cubic feet a day. The



* January - September

Source: U.S. Department of Energy

terminal operator, GDF Suez, boasts its customers include local gas distribution companies throughout New England, power plants, gas marketers and industrial users.

China is another cradle of trucked LNG.

Black & Veatch and its Chinese partner Chemtex International have built or are building 16 LNG distribution plants across China, according to "LNG 2012." A 4-year-old plant called Erdos in remote Inner Mongolia has four loading stations that fill 33 trucks a day on average.

"The model for Chinese developments is a central LNG plant which distributes LNG to multiple gas users in industrial and residential markets," Black & Veatch executives wrote in the article.

One of the executives, Shawn Hoffart, presented this fall at a London conference about the latest innovation: a new northern China plant that uses coal from a nearby mine as the feedstock to make LNG and methanol. He estimated the plant will make 78 truckloads a day of LNG.

On a very small scale, some U.S. LNG gets trucked to remote users in Mexico.

A U.S. company called Applied LNG Technologies has been trucking LNG to Mexico since at least 1998 from a liquefaction plant in Topock, Ariz.

Last year the company trucked 1.6 bcf across the border, according to the Energy Department. It's a niche business, to say the least. Last year the U.S. piped 500 bcf of gas to Mexico.

Applied LNG plans to double the capacity of its Arizona liquefaction plant so it can sell more LNG as vehicle fuel in California, another market it serves.

LNG gets trucked in small quantities elsewhere around North America to users off the gas pipeline grid. For example, since 1998, Fairbanks Natural Gas LLC has trucked LNG from its small liquefaction plant served by Alaska's Cook Inlet gas fields to customers 300 miles north in Fairbanks. Last year it delivered about 900 million cubic feet to 1,100 customers, mostly commercial accounts eager to avoid high-cost fuel oil. Fairbanks Natural Gas, and separately the Fairbanks-area electric utility and a nearby oil refinery, are considering trucking larger volumes of LNG about 350 miles south from Alaska's North Slope fields.

Hawaiian utilities also are moving to import LNG instead of burning more costly and dirtier oil-derived fuels. Because Hawaii's demand would be so small, the gas utility looks to start with a pilot project of LNG delivered in insulated containers loaded aboard cargo ships that call on the state. In time, the gas and electrical utilities might work together to expand the imported volume enough to justify tanker deliveries rather than truckloads.

Among pending applications at the U.S. Department of Energy for permission to export LNG is one from a business eying the market of Caribbean utilities that burn oil. Florida-based Carib Energy wants permission to export 3.44 bcf a year "to any country located within Central America, South America or the Caribbean which has or in the future develops the capacity to import LNG" stored in containers that cargo ships would carry.

"Carib ... will transport the LNG within the United States over highways, using approved 40-foot ... LNG containers," its application says. The project anticipates loading no more than 11 trucks a day. The exports could occur from any of a variety of southern U.S. ports.

The buyers would include power plants, industrial and commercial customers that need small amounts of LNG "and would not otherwise be served by very large suppliers of LNG," Carib's application says.

Source: Natural Gas Vehicles for America

Trucks tank up on LNG fuel at the Port of Long Beach.

LNG FOR HEAVY-DUTY TRUCKS

LNG is a niche fuel for vehicles, too.

Only 3,354 vehicles in the U.S. use LNG as a fuel, according to the EIA.

Many of them are trucks that move cargo around the huge neighboring ports of Los Angeles and Long Beach, California. To cut air pollution, those ports prohibit drayage trucks from burning dirty fuels.

Most of the trucks now burn clean diesel, but some — 8 percent of the Los Angeles port fleet — use LNG. The ports have LNG fueling stations to make sure the gas is available to truckers.

Some city and regional buses, garbage trucks, heavy-duty tractors also use LNG.

Putting more LNG-fueled vehicles on North American roads might be confined to heavy-duty vehicles, even though natural gas is priced so much lower than oil-based fuels. Big fuel-guzzling trucks that are on the road all day can recoup faster the higher up-front cost of LNG vehicles.

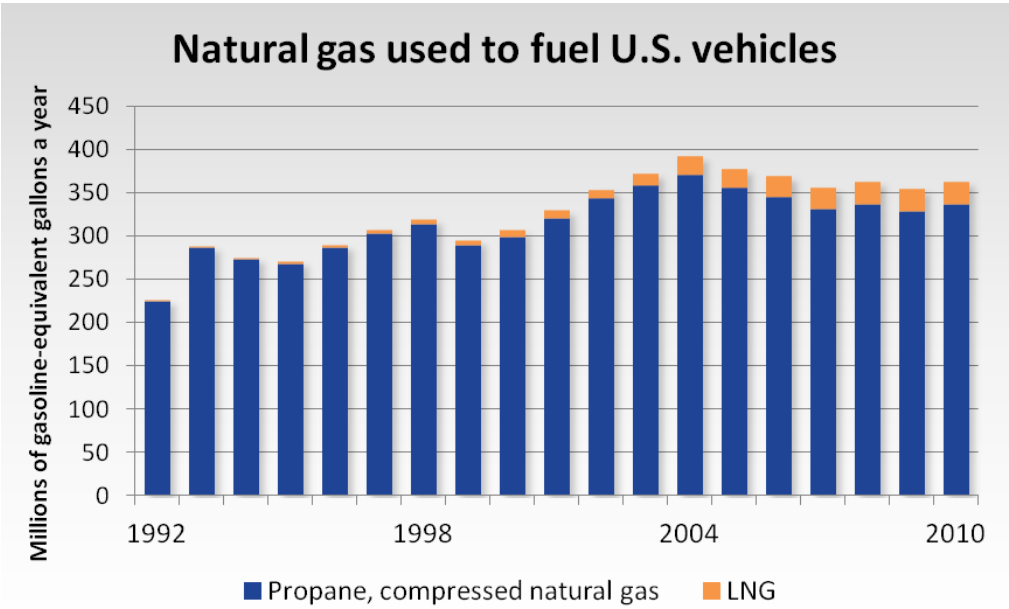
Still, LNG vehicles will remain a rare sight until the industry surmounts some formidable barriers:

LNG vehicles are much more expensive. "While emission reductions are comparable ... there is a much greater cost associated with the purchase of LNG trucks versus new clean diesel trucks," says a white paper from the Port of Long Beach. The report pegged the cost of an LNG truck at $100,000 above the cost of a diesel truck.

LNG vehicles need refueling sooner. A gallon of LNG packs less energy than a gallon of diesel. An Energy Information Administration report said a 150-gallon diesel tank will take a heavy-duty truck about 1,000 miles compared to about 300 to 400 miles for a similar size tank of LNG.

Few places exist to refuel. It's the classic chicken-and-egg riddle. "Unless more natural gas vehicles enter the market, there will be little incentive to build more natural gas fueling infrastructure nationally or in local or regional corridors," the EIA said in 2010.

Of the nation's 3,820 natural gas fueling stations, only 59 serve up LNG; the rest provide compressed natural gas or propane, according to the Department of Energy. However, that was 21 more stations than three years earlier. Two-thirds of the stations are in California, providing little geographic range for a long-distance trucker.



Source: U.S. Energy Information Administration

Source: Natural Gas Vehicles for America
LNG truck refueling station in East Valley, Calif.

Some efforts are afoot to make LNG fuel more available. A database kept by Zeus Intelligence lists 27 stations planned or under construction in the U.S. and Canada. Only some will be open to the public; the rest will fuel private fleets.

An organization called Clean Energy Fuels hopes to develop a chain of LNG fueling stations across the country. For now, the focus is on a couple of high-traffic corridors in California and Texas.

Natural Gas Vehicles for America, another advocacy group, has laid out its own roadmap for wider use of LNG-powered trucks.

A similar effort is under way in Canada, called the Canadian Blue Corridor, which would space LNG fueling stations every few hundred miles along major trucking corridors.

The fine print of such ambitions typically seeks government assistance to help the LNG-fuel industry refine its technology and build itself to a point where economies of scale lower costs and let it stand on its own.

In China, a nation plagued by air pollution, the government has rolled out a policy designed to boost use of natural gas as a vehicle fuel, especially LNG.

Buses, taxis, trucks and ships should be preferred users of natural gas as China moves to increase gas use while keeping supply and demand under control. "The policy push would lead to the world's biggest fleet of LNG-fuelled vehicles," according to a news account.

FUEL FOR SHIPS

The chicken-and-egg riddle restrains widespread use of LNG fuel for ships as well. The world has only a few places where ships can top off their LNG tanks.

A new Lloyd's Register report on LNG's prospects as a marine fuel foresees widespread use by shipping fleets only far into the future, especially if LNG can be priced much lower than competing oil-based fuels.

Lloyd's is one of the big international organizations that establish technical standards for ship construction and operations. In its report, Lloyd's predicted just 4 percent of new ships delivered by 2025 — 653 ships total — would use LNG fuel. These ships most likely will be container ships, cruise ships or oil tankers, Lloyd's says.

Driving the ship industry's embrace of LNG are new International Maritime Organization rules on pollution emissions. Most deep-sea vessels are powered by oil-based bunker fuel steeped in sulfur — with high emissions of harmful sulfur dioxide.

The IMO is a United Nations' arm set up to bring consistency to worldwide shipping oversight. The new rules impose tight limits on sulfur content of shipping fuels, especially along busy shipping corridors, including the U.S. coast. Those limits get tighter over time. (International ships likely will continue burning heavy fuels in open waters then switch to cleaner fuels near coasts.)

LNG has virtually no sulfur. It can meet the new pollution standards. But that also is a feature of low-sulfur diesel — though distilling 'clean' diesel from crude oil is costly.

Another advantage: Diesel refueling is widely available around the globe. Not so for LNG refueling. A couple of European ports and Singapore do hope to establish themselves as LNG refueling stations.

Lloyd's predicts LNG fuel will start picking up market share around 2019, before even-stricter IMO standards kick in. But by 2025 LNG will fill just a small

fraction of global bunker-fuel demand and comprise a likewise small portion of LNG production, Lloyd's says. Constraints on LNG as a fuel include the high cost of outfitting ports and ships, and the lack of investors willing to pay these costs.

A small U.S. cargo line announced in August that it will convert to LNG its two 9-year-old ships that haul cargo from Washington state to Alaska. Totem Ocean Trailer Express got a waiver from meeting the IMO standards while it converts its ships.

"The comprehensive project will also lead to the establishment of long-term supplies of LNG for use by other sectors of the transportation industry" in the Seattle-Tacoma region, a Totem executive noted.

A group called American Clean Skies Foundation hopes other U.S. boat owners follow Totem's lead. Clean Seas envisions a way for LNG fuel use to rise among some ships in U.S. waters, but the price gap between gas and oil must remain wide.

In a new report, Clean Skies says new liquefaction plants and storage would be needed to supply ports where no LNG exists today. Further, the cost of converting a ship from oil fuels to LNG ranges from $7 million for a medium-sized tug to $24 million for a Great Lakes bulk carrier.

Even if the gas remains much cheaper than oil, a vessel that's running almost nonstop — thus burning a lot of fuel — would need 10 years or more to recoup its upfront investment in LNG, Clean Skies concluded.

"Despite low natural gas prices, some vessels will not generate high enough annual fuel cost savings to provide a reasonable payback period for the high vessel conversion costs," Clean Skies said.

"Successful projects will require both a motivated vessel owner and a motivated LNG supplier."

For more information, please visit our website: www.arcticgas.gov

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