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◆ **Later this year the first** of as many as 12 sleek service vessels will throttle up and churn from Port Fourchon on the Louisiana coast, speeding to offshore rigs miles out in the Gulf of Mexico. The scene plays itself out daily in the Gulf oil fields, but this sailing will be different. The ship will be powered by liquefied natural gas, the vanguard of an effort by service providers to exploit historically low prices and meet stricter marine emissions standards.


Natural gas may be on its way to become the darling of alternative fuels. On land, truck manufacturers are looking at LNG's greater carrying capacity to fuel fleets of heavy duty trucks. Already, service companies such as United Parcel Service are moving to take advantage of lower costs and emissions, powering a new fleet of trucks with natural gas instead of gasoline or diesel. Construction and other off-road equipment is being fitted for natural gas and railroads are

working with two locomotive manufacturers to bring LNG-fueled engines to the rails.

All of this activity flows back to a bonanza being extracted from previously impenetrable shale formations scattered throughout the U.S. Producers are now pulling volumes of natural gas and oil once thought beyond reach.

As producers fine-tune drilling techniques into unconventional formations to extract more gas faster and cheaper, the burgeoning market is trying to find outlets for it. Delivery companies are converting fleets of trucks from diesel to gas, and engine manufacturers are producing a wider range of natural-gas and dual-fuel engines. After Russia's annexation of Crimea, lawmakers have noticed too, proposing the U.S. start exporting liquefied natural gas to Europe, which is heavily dependent on Russian supplies.

Until now, the U.S. has never been a player in



*A tanker is docked at the Golden Pass LNG terminal in Sabine Pass, Tex. The terminal has approval to export liquefied natural gas overseas.*

exporting natural gas. But the “shale gale” may change that, having pushed the U.S. ahead of Russia as the world’s top producer of natural gas. Many in Western Europe may prefer to buy their natural gas from the U.S. “Europe and others will see it’s good to have more sources from political friends, from where you import your energy,” said Torstein Hole, Statoil’s vice president of onshore services in North America. The Norwegian energy giant has stakes in U.S. shale formations producing natural gas and oil.

◆ **Much of the jump** in production tracks back to the Marcellus shale formation running under Appalachia. Within five years, the formation went from near zero gas output to supplying about 20 percent of the total volume produced in the U.S., according to the U.S. Energy Information Administration.

As a result, natural gas in the U.S. costs a quarter to a third of the energy equivalent of oil. In Europe, imported LNG costs \$8 to \$12 per MMBtu and in Japan the cost hovers around \$17,

**Advanced drilling and production techniques have given the United States more natural gas than its markets can handle. Converting that bounty into liquefied natural gas promises to transform the U.S. gas industry into a global energy power.**

BY JOHN KOSOWATZ



spinning  
liquid  
gold



*A driver wears insulated gloves and a face shield as he transfers LNG from a terminal to a tanker truck.*

roughly the same as oil. With oil still pricing at \$103 per barrel, power, industrial, and manufacturing operations are looking to convert to gas.

“This is one of the most exciting times in energy in the U.S.,” said Roger K. Rodiek, business development manager for U.S. power with global engineering firm Parsons Brinckerhoff. “I’ve been in the business since 1991 and I’ve never seen anything like it.”

Domestic distribution of natural gas is generally conducted through pipelines, which transport compressed and pressurized gas. To prepare it for the international energy market, that gas must be converted to LNG in expensive and energy-intensive liquefaction trains that chill the gas to -260 °F. Gas turbines are commonly used to drive the cryogenic compressors that liquefy the gas. The resulting liquid, shrunk to 1/600 of vaporized volume, is held at 3 1/2 psig in insulated tanks for transport by pipeline or tanker.

Export facilities with liquefaction units, compressors, pipelines, and berths are not cheap, and the time needed to get from licensing, design, and construction to actual production can be as much as ten years. LNG plants require licenses from the U.S. Federal Energy Regulatory Commission for construction and from the Department of Energy for export.

“It’ll cost at least between \$2 billion and \$4 billion or more for an export facility,” Rodiek said. “If it is a brownfield, you can get to the \$1 billion to \$2 billion range. A few years ago we were looking to build import structures for gas from the Middle East. That has changed overnight.”

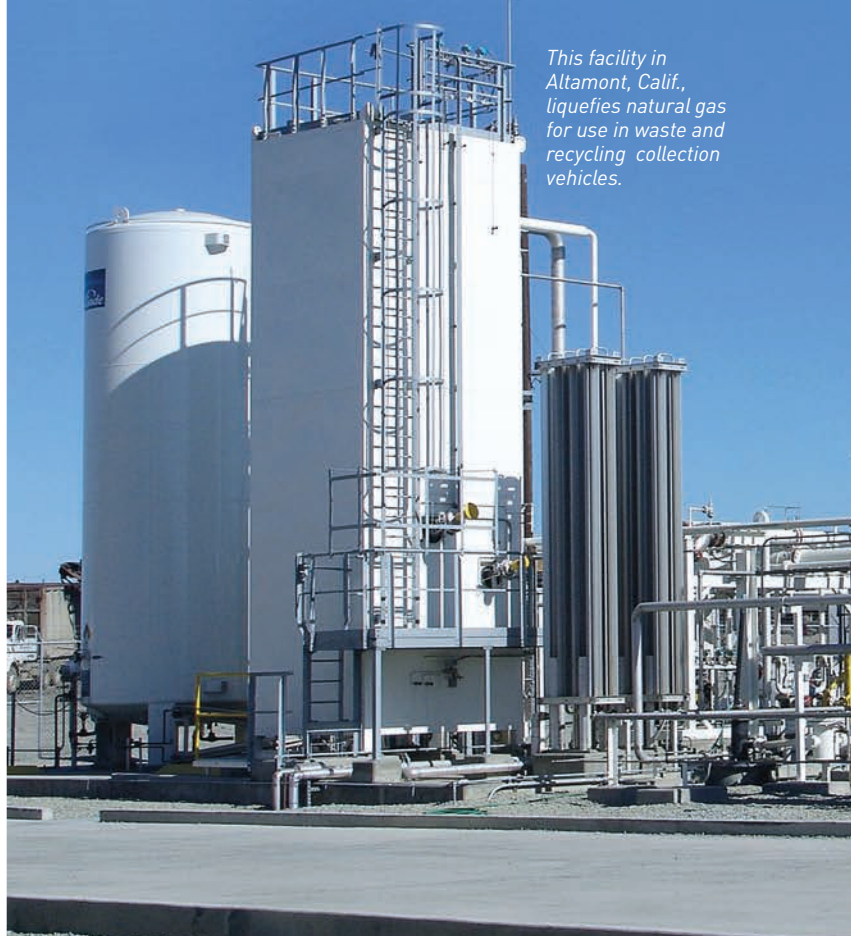
Multibillion-dollar export facilities in Louisiana and Oregon are moving forward, and another in British Columbia, to be fed by gas from Canadian shale formations, is under construction. These projects are backed by supply contracts with South Korea, the world’s second-largest importer of natural gas, and Japan, which has increased its demand for LNG since a 2011 earthquake and tsunami disrupted that country’s nuclear industry.

Cheniere Energy Inc. is adapting its Sabine Pass import terminal in Louisiana to make it “bidirectional.” The company can use the site’s five storage tanks and two berths for deepwater ships for either import or export, and the 94-mile Creole Trail Pipeline will be reconfigured to handle gas coming and going. The company is spending almost \$8 billion on four liquefaction trains, each of which can handle up to 4.5 million tons per year.

The terminal’s location near unconventional gas plays in Texas and Louisiana and interconnections to interstate and intrastate pipelines improve the site’s economics, company officials say.

In nearby Hackberry, La., Cameron LNG is in final permitting to build three liquefaction trains capable of treating 12 million tons a year of LNG. Cameron said its cost is expected to be between \$9 billion and \$10 billion, and includes a new 21-mile pipeline, compressors, and modifications to existing pipeline interconnections. Construction is expected to begin later this year.

Cameron is adding the liquefaction capacity to its import facilities. There are two berths capable of handling Q-Flex type LNG ships, the second-largest LNG carriers, capable of carrying 210,000 to 217,000 cubic meters. The “Q” is derived from Qatar, where in 2007 Qatar Gas commissioned the first of 45 giant ships to transport LNG from new production facilities to Europe.



*This facility in Altamont, Calif., liquefies natural gas for use in waste and recycling collection vehicles.*

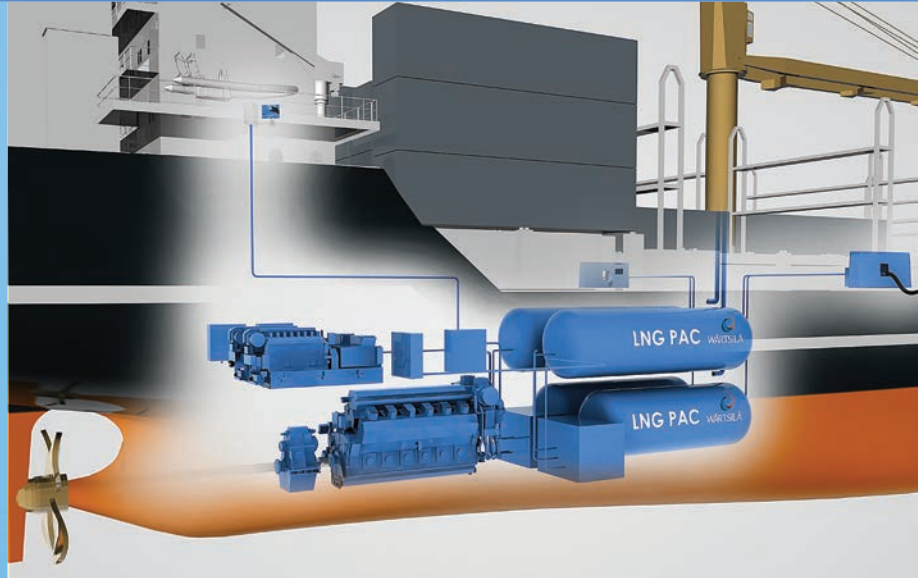
**This is one of the most exciting times in energy in the U.S. I've been in the business since 1991 and I've never seen anything like it.**

*Wärtsilä has developed fuel storage and propulsion systems (shown in diagram) to enable service boat engines to run on LNG as well as diesel.*

◆ **East of Hackberry** and Sabine Pass, there is construction of another kind at Port Fourchon. Harvey Gulf International Marine decided earlier this year to build an LNG fueling facility at its Port Fourchon terminal. The \$25 million first phase is the first of its kind in the U.S., and is being built in conjunction with the company's \$350 million program to build a fleet of dual-fueled service boats for the offshore industry in the Gulf and elsewhere. Harvey Gulf will use two sites, each with 270,000 gallons of LNG storage capacity and capable of transferring 500 gallons of LNG per minute.

Harvey Gulf's executive vice president for Alaska and LNG operations, Chad Verret, said low gas prices tied to the boom in shale recovery and stricter offshore emissions standards are pushing LNG into the marine and offshore industry. Harvey Gulf contracted with Finland's Wärtsilä Diesel to provide LNG/diesel-fueled service boats. Wärtsilä is fitting the boats with a package similar to one already working in the North Sea oilfields, integrating the engine and mechanical package into the vessels.

Verret said the first of six vessels under construction will be delivered later this year. Harvey Gulf charters them to oil companies. Building the liquefaction



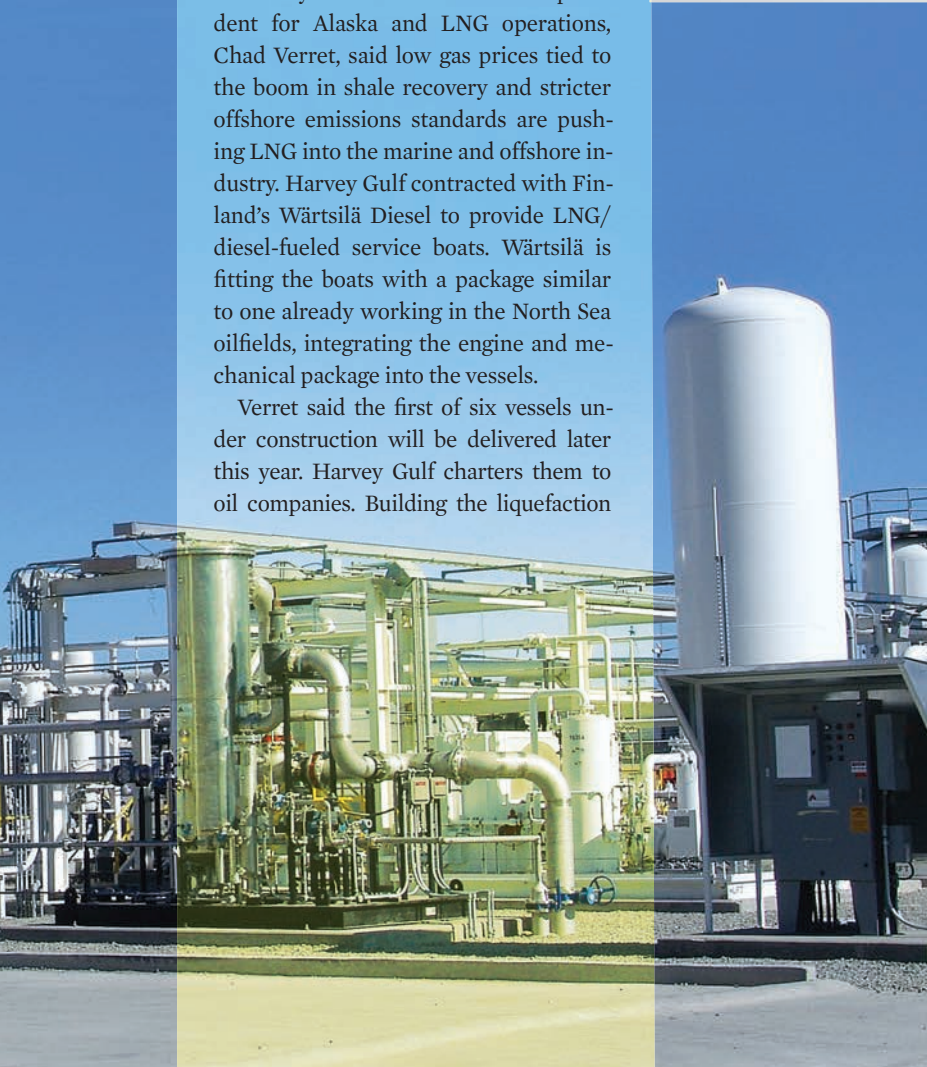
trains “guarantees fuel availability” and helps customers meet emissions requirements, he said.

The general marine and rail market remains “about five to ten years out,” said Srikanth Balasubramaniam, director of Cummins Inc.'s high horsepower natural gas business. Cummins, in Columbus, Ind., has been manufacturing natural-gas-fueled engines since the mid-1960s for off-highway vehicles and since the mid-1980s for on-highway vehicles.

On land, Cummins and others are seeing movement away from diesel engines toward either dual-fuel or gas-fueled engines. “All traditional diesel markets are showing interest,” Balasubramaniam said. “Economics is the primary motivation but there are emissions advantages there too.”

According to Roe East, Cummins' general manager for heavy duty/mid-range business, “The drivers for all of our customers are the three ‘E’s: economics, environment, and energy policy. In the U.S. now, growth is focused on economics.”

The economic motive is a recent development, East said. Until recently the



market was “mostly things like urban buses faced with stringent emissions limits,” he said.

Within the past year, United Parcel Service has announced plans to expand its fleet of LNG-capable heavy 18-wheel rigs to 800 by the end of this year, from 112. The UPS rigs will be fitted with Cummins engines, produced in joint venture with Westport Innovations of Vancouver, British Columbia.

The engines can run on liquefied or compressed natural gas. “The engine doesn’t care,” East said.

LNG is the generally preferred form of natural gas for use in long-haul heavy duty trucks because liquefying it reduces volume. More fuel can be loaded into the tank. Local-use vehicles, which operate from a central yard, often use CNG. Refuse trucks, for instance, commonly travel a designated route and return to the yard at the end of the day. Because refuse trucks get extremely low mileage, only 4 to 6 mpg, natural gas allows the firm to realize significant savings in fuel costs, East said.

Waste Management Inc. two years ago announced it will convert its entire fleet of 18,000 refuse collection vehicles to natural gas. More than 3,000 of its heavy-duty trucks are now fueled by natural gas and the company is buying 800 natural-gas-fueled vehicles per year. Officials also report the firm has built 58 fueling stations around the U.S., many of them open to the public.

Natural gas-fueled trucks cost about \$30,000 more than their diesel counterparts, but at current fuel prices will make up almost the entire difference in a year, Waste Management’s executives say. They estimate that each truck will save \$27,000 in fuel costs annually.

◆ **Heavy-duty LNG-fueled** highway trucks could jump to 10 percent of the market in five years, East believes, up from 1 percent today. One challenge is the lack of refueling infrastructure. At present, most LNG fueling stations are in California, but companies are working to expand the availability of the



*The Wärtsilä 46DF engine can produce as much as 1,145 kW running on LNG aboard a ship or offshore platform.*

fuel. Clean Energy Fuels, the largest natural gas provider for transportation fuel in North America, is installing fueling equipment at about 500 locations throughout the country.

GE Oil & Gas is moving into the market with its “LNG in a Box,” a small-scale, self-contained fueling unit aimed at service centers. The unit is designed to produce 10,000 to 50,000 gallons, or 16 to 18 tons, per day of LNG, and includes a gas pretreatment system, cold box assembly, and compressors. Typical fuel tanks for heavy-duty vehicles hold between 70 and 150 gallons (110 to 240 kg). GE believes one 10,000-gallon-per-day system could fuel up to 100 trucks per day. Its first modular-constructed units were delivered to Europe through Luxembourg-based Gasfin.

Trucking isn’t the only land transport system that could benefit from LNG. As long ago as the 1980s, the old Burlington Northern Rail-

*GE and Caterpillar have developed a locomotive (right) that can run on liquefied natural gas. Many heavy-duty vehicles, such as the garbage truck below, are converting to LNG to cut emissions.*



*LNG fueling infrastructure, such as this gas station in Long Beach, Calif., is built along busy trucking and shipping corridors.*



road used LNG-powered locomotives on some routes. Now GE and Caterpillar are both working to revive the concept by developing dual-fuel or dedicated LNG locomotives. Three major freight railroads—Burlington Northern Santa Fe LLC, Union Pacific Corp., and Norfolk Southern Corp.—are interested.

BNSF is beginning a pilot program. According to its executive chairman, Matthew K. Rose, the pilot program is “an important first step that will allow BNSF to evaluate the technical and economic viability of the use of liquefied natural gas in through-freight service.”

Savings could be huge. In 2012 Union Pacific reportedly spent \$3.6 billion on fuel, and natural gas promises to reduce those costs considerably. Railroads expect retrofit kits to convert diesel locomotives to dual fuel will come to market first. Rail executives expect retrofits to be cheaper than the cost of a new locomotive, about \$2 million.

One retro item is a fuel car to store LNG and feed it into the locomotive, a 21st-century take on coal tenders that fed steam locomotives. The American Association of Railroads has already put together a task force to review safety standards as well as to ensure that LNG-fueled engines can be used across rail networks.

The railroads will have to bring along partners

to provide fuel infrastructure, and some companies are stepping in. GE also provides what it calls MicroLNG units, a larger version of LNG in a Box. The modular liquefaction plant can produce between 50,000 and 450,000 gallons per day of LNG. The company has already sold two units to Clean Energy Fuels Corp. to supply its growing California fueling network.

◆ **For LNG, the only serious limits** that people are talking about today are related to infrastructure costs, particularly in the development of exports. Even if the international demand for LNG stays high, exports from the United States can't happen for a few years because of the time needed for plant construction.

Pierre Bechelany, senior vice president of pipelines and LNG for Fluor Corp., said, “I think we're looking at forty to fifty million tons being exported eventually by the U.S. Globally, we're told energy will grow at 5 percent per annum until 2025, and [in North America] in a little over ten years to double capacity.” Bechelany adds that meeting the demand to build new energy projects will challenge the engineering, procurement, and construction industry, and not every export facility now in the planning and permitting stages will be successful.

“The U.S. is well positioned,” he said. “Certainly four or five plants will go forward,” although he sees difficulty in obtaining capital for some projects lagging behind the leaders.

Still, optimism reigns among players throughout the natural gas industry. According to Statoil's Thorstein Hole, “For the bigger picture, you have to be open to all possibilities for product. And I am very encouraged by the attempts we're seeing for developing LNG.” **ME**