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EPA Coalbed Methane Outreach Program Technical Options Series

COAL MINE METHANE AND LNG

Example of a small scale LNG plant
(built by a predecessor company to Prometheus Energy)

Primary Benefits of Using Coal Mine Methane for Producing LNG…

- Can operate on methane from mine pre-drainage and medium quality gob gas
- Uses methane at near atmospheric pressure, avoiding compression costs
- Can use methane diluted with up to 30 percent nitrogen
- Reduces emissions of methane (a potent greenhouse gas)
- Easily transportable by rail or road in absence of pipeline
- Advancements in small-scale refrigeration technologies make CMM to LNG projects feasible in remote areas without pipelines
- Mines that produce LNG on site using gob gas can use it to operate mine vehicles and equipment, or may sell to a local consumer

Why Consider Coal Mine Methane for Liquefied Natural Gas?

The growth in natural gas prices in the United States in recent years has triggered a boom in the liquefied natural gas (LNG) market. In 2007, a record-setting 771 billion cubic feet (22 billion cubic meters) of natural gas in gaseous form (15 million metric tons of LNG) was imported into the U.S. and billions more were produced domestically. The U.S. exported 48.5 billion cubic feet (1.4 billion cubic meters or 946 thousand metric tons), primarily to Japan.

Because of technology constraints and economies of scale considerations, conventional natural gas to LNG plants are typically constructed large - on the order of 4 to 15 million tonnes of LNG production capacity per year. Construction costs average $1.5 to $2.0 billion per plant in this size range. Recently, however, small-scale purification and refrigeration techniques have succeeded in efficiently downsizing gas liquefaction units. Smaller LNG facilities are now becoming more economically feasible, creating new opportunities in the form of both non-traditional markets and non-traditional gas sources.

Coal mine methane (CMM) could be a low-cost and small-scale alternative to conventional natural gas for LNG production in some areas. Gob areas (collapsed rock over mined-out areas) release large quantities of gas, which mines remove with ventilation fans and sometimes by supplemented drainage systems. Air from mine ventilation contaminates the gob gas, usually making it unsuitable for pipeline injection. However, recovering and using gob gas to make LNG can reduce the amount of methane that mines emit to the atmosphere while producing fuel for vehicles, machinery, heating, industry or other local uses.

CMM to LNG Projects and Smaller Scale LNG Technologies

CMM to LNG projects operate at a much smaller scale than conventional projects. For example, the two largest CMM recovery projects operating in the United States in 2006 produced 23.4 and 17.0 billion cubic feet (660 and 480 million cubic meters) of methane respectively, which would equate to approximately 460 and 330 thousand metric tons of LNG production. In addition, CMM may contain high concentrations of nitrogen, oxygen, carbon dioxide and water that need to be removed before liquefaction; while conventional natural gas typically contains different quantities and types of contaminants. As a result of these size and purification constraints, CMM to LNG projects must choose from a unique set of liquefaction technologies.

There are a number of smaller scale LNG solutions appropriate for CMM projects. Both Prometheus Energy (with LNG – Silesia of Poland) and Idaho National Laboratory (INL) have embarked on LNG plant designs that can produce as little as 3 thousand metric tons of LNG per year. In addition to these LNG-specific technologies, the Nitech™ Nitrogen Rejection Unit manufactured by BCCK Engineering, Inc. produces LNG as part of its cryogenic purification process before it is regasified for pipeline sales which can be used at smaller applications.

<u>Prometheus Energy/LNG – Silesia Technologies</u>
The U.S. company Prometheus Energy and the Polish company LNG – Silesia are currently implementing CMM to LNG projects. In addition to large scale LNG growth, LNG – Silesia is working on gaining methane from marginal sources such as CMM, CBM, and nitrogen rich natural gas sources. The technology developed is applicable to small scale operations on the order of 8 to 40 metric tons of LNG production per day. The process results in an LNG product of 97% methane.

The upcoming CMM to LNG installations will involve the following process:

- removing particulate matters from the gas;
- removing the moisture and trace amounts of sulfur, chlorine, and mercury compounds;
- removing oxygen with a thermal oxidizer;
- removing CO_2 using a vacuum pressure swing adsorber (VPSA);
- cooling and generating a homogeneous solution of N_2 and CH_4 using the turbo-Brayton refrigeration cycle or a low pressure mixed refrigerant cascade;
- removing N_2

These installations are modified to handle CMM concentrations as low as 40%. Installations may also include a flare to burn off gas produced from CO_2 and N_2 removal. Additional equipment installed onsite

includes LNG storage tanks to provide 3-4 days buffer storage, a genset to provide power, and a truck scale to weigh loaded trucks.

New Compact High Efficiency Natural Gas Liquefier Fit for CMM Applications

Another technology for small scale LNG processes developed by Idaho National Laboratory (INL) is a compact high efficiency natural gas liquefier that does not require costly pretreatment to remove water and carbon dioxide contaminants. The secret of INL's highly efficient technology is that it uses "free" energy from pipeline pressure letdown to liquefy the natural gas. INL liquefaction technology is designed to draw natural gas from a transmission pipeline at a point where the pressure is dropped to accommodate commercial distribution. The plant is powered mainly by the energy created through this pressure drop. As the gas enters the plant, some of it is allowed to expand, and as it expands, it cools. This allows the process to use the natural gas as a coolant in the liquefaction process.

A pilot plant, installed in Sacramento, California, removes contaminants from the methane stream as it progresses through the plant. The stream is injected with methanol, which bonds to the water. When the temperature drops to the point where the methanol vapor becomes liquid – the water and methanol are separated out of the methane stream. During the final cooling of the LNG product, solid CO_2 is formed and separated by incorporating a patented centrifugal solids separation step to remove frozen carbon dioxide that could clog the system.

This significantly decreases the work involved with pre-cleaning the methane. The water/methanol mix and solid CO_2 are vaporized into the distribution line without significantly changing the BTU of the line. The natural gas is liquefied and moved into a storage tank where it stays until used, trucked away, or re-injected into the pipeline. The pilot plant is designed to liquefy 10-20% of the gas entering the plant. Other plant models are being designed to adapt to higher CO_2 concentrations, nitrogen content, higher and lower pressure distribution lines, connections at non letdown points, and to liquefy a higher percentage of incoming gas. No gas is consumed by the plant during this process.

INL reports that the compact high efficiency natural gas liquefier can fit in a cargo container and costs less than two million dollars. The technology has generated worldwide licensing interest from 36 countries. Due to its compact size, relatively low cost, and advances in purification, the INL technology could be applicable for smaller-volume CMM applications. The liquefier could be expected to produce between 8 and 70 metric tons of LNG per day.

BCCK Engineering, Inc.'s Nitech™ Nitrogen Rejection Unit

BCCK's Nitech™ technology allows for profitable recovery of gas resources, regardless of nitrogen content, and is thus ideal for unconventional gas resources such as CMM. BCCK plants are presently operating at three CMM projects. The Nitech™ process integrates the removal of the four most common coal mine methane contaminants – nitrogen, oxygen, carbon dioxide and water – and renders a sellable methane stream. As part of the Nitech™ process, the gas stream is liquefied; however, at present applications, the LNG is regasified for pipeline sales. BCCK's Nitech™ technology has not been used for LNG production yet, though a BCCK plant may provide a turnkey solution to a CMM to LNG project by including purification with liquefaction. BCCK's current CMM projects produce approximately 4 billion cubic feet (113 million cubic meters) of pipeline quality gas per year which would equate to about 85 thousand metric tons of LNG production per year (233 metric tons per year). BCCK's plants may be used on as little as about 1 billion cubic feet per year (28 million cubic meters) of CMM.

Other Technologies

Although the technologies featured here are applicable to CMM to LNG projects in their purification abilities and scale, other technologies may be suitable as well. A number of technologies exist for purification and upgrade of CMM (see the CMOP's Network Contacts at www.epa.gov/cmop/networkcontacts.html) which could be used in conjunction with natural gas liquefaction technologies provided the appropriate conditions. For information on additional LNG technologies and companies, visit the LNG Journal's Industry Directory at www.lngjournal.com.

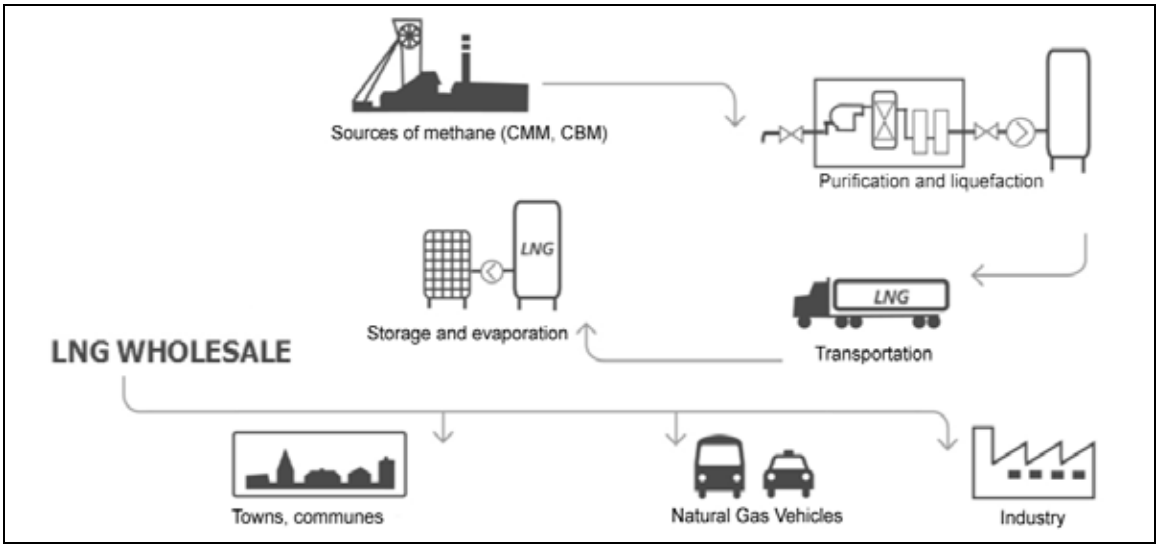
Current Markets for LNG

LNG is well positioned to serve several energy market niches. First, LNG can be practical if the gas production or utilization site is far from a gas pipeline. Liquefying natural gas provides a means of moving

it long distances when pipeline transport is not feasible. One specific, small-scale example of this application is the growth of LNG in the propane market. LNG can serve as a substitute for propane in areas where low population density and the absence of pipeline infrastructure make direct connection of small gas utilities to the pipeline grid impractical. LNG also has replaced propane or other fuels in certain isolated industrial sites such as mineral extraction and forest product facilities. A CMM to LNG plant could be economical in areas where other gas storage options are limited.

Another emerging use of LNG in North America is for seasonal gas storage. In regions where pipeline capacity can be very expensive and natural gas use is seasonal, LNG plants store natural gas during the warmer months, then vaporize and inject the gas into local pipelines during cold weather months; thus reducing expensive pipeline capacity commitments during peak periods. This concept can be applied at a smaller-scale regasification plants, often called "peakshaving plants." Alternatively, LNG may be transported in special tanker trucks to small facilities where it is stored and regasified as needed. Such facilities are called "satellite plants." The U.S. has about 100 satellite and peak shaving plants.

LNG is becoming increasingly popular as an alternative fuel for vehicles or to be sold directly to end users. Vehicles can store more liquid gas than compressed gas, making it well-suited for high fuel comsumption vehicles. In addition, substantial federal and state gas tax credits are available in the U.S. for converting and using alternative fuel vehicles.



Representation of the LNG Chain
(courtesy of LNG – Silesia)

Worldwide, the largest market for LNG is fuel for electric power plants. LNG demand in the Asia-Pacific region is highest in the world with Japan and South Korea being the major importing nations. In the future, China and India are expected to be major LNG markets. With abundant CMM resources, the expanding LNG market in Asia offers opportunities for coal mine gas use. With advancements in smaller-scale LNG technologies, opportunities for CMM use are broadened worldwide

Facts about CMM to LNG Projects…

- Plant designs for CMM to LNG projects must accommodate smaller gas flows than conventional natural gas to LNG applications, keeping in mind the largest U.S. CMM project produced 23.4 billion cubic feet (660 million cubic meters) in 2006.
- CMM to LNG projects must also consider additional purification issues specifically for nitrogen, oxygen, carbon dioxide and water removal as part of the plant design.
- End uses for LNG may include vehicles, even heavy trucks; transport and storage for peak shaving or satellite plants; and transport to industrial customers for power or vehicle operation.
- LNG plants are ideal for remote collection sites where pipeline access or capacity is not available.

For more information…

New technologies for liquefying natural gas are expanding the options for using methane recovered from coal mines. Use of LNG derived from coal mine methane can increase mine profits while reducing methane emissions to the atmosphere.

To obtain more information about technologies for liquefying coal mine methane contact:

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The LNG Journal's Industry Directory:
www.lngjournal.com

Or contact EPA's Coalbed Methane Outreach Program for information about this and other profitable uses for coal mine methane:

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