Turning Natural Gas to Liquid

Until recently, there were only two practical ways of transporting natural gas: flow it through a pipeline in gaseous form or chill and transport it as liquefied natural gas (LNG). A third alternative, gas-to-liquid technology, chemically converts natural gas into clean-burning liquid products that can be easily shipped to market.

^ Sasol Synthetic Fuels, Secunda, South Africa. Sasol operates two such plants, applying gas-to-liquid (GTL) technology to convert coal-derived natural gas to liquid fuels. (Photograph copyright of Sasol Limited.)

When it comes to describing natural gas, the numbers give new meaning to the word *big*. The world's proven gas reserves are estimated at an average of 5500 trillion cubic feet (Tcf) [156 trillion m^3].[1] Factoring in potential reserves brings the total to about 13,000 Tcf [372 trillion m^3].[2] Adding reserves from unconventional sources, like coalbed methane, and highly speculative sources, like naturally occurring gas hydrates, gives a dizzying grand total of about 700,000 Tcf [20,000 trillion m^3].[3]

Of the proven and potential conventional gas reserves, up to 80% are too far from large markets to be transported by pipeline.[4] Examples are the large gas reserves in Qatar, Iran, the United Arab Emirates, Russia, Saudi Arabia, Canada and Alaska, USA, that await development of new transport technology to bring their reserves to market.

Some remote gas reserves are produced and sent by pipeline to liquefied natural gas (LNG) plants, where they are cooled to –162°C [–259°F], transferred to expensive insulated and pressurized LNG vessels, and shipped to terminals where they are returned to their natural gaseous state. From these terminals, the gas is used to generate electricity or distributed by pipeline for cooking, heating or industrial use. Economic viability of the LNG method of transportation depends on low-priced incoming

^ Shell GTL plant in Bintulu, Malaysia, in operation since 1993. Using a patented Shell process, the Bintulu plant converts natural gas piped in from Sarawak to 12,500 B/D [1990 m^3/d] of clean diesel, kerosene and naphtha. (Photograph courtesy of Shell Chemicals Singapore.)

natural gas, cost-effective installation and operation of liquefaction and condensation infrastructure, affordable fleets of specialized vessels for transport, and high-priced gas at the end market.

A different kind of technology for converting hydrocarbon gas to hydrocarbon liquid—called gas-to-liquid (GTL)—is on the verge of changing the world of natural-gas transport and usage. Many large oil and gas companies are developing expertise in this promising business; a few already have commercially operating plants, and many have initiated pilot programs. This article describes the GTL process, the way companies are using it, and its potential benefits.

Invention of Necessity

The GTL process, in which a chemical reaction converts natural gas to liquid hydrocarbon products, is not a new invention. Following World War I, economic sanctions drove German scientists to explore ways to synthesize liquid petroleum from the country's abundant coal supplies. One of the successful methods, the Fischer-Tropsch process, developed in 1923 by Franz Fischer and Hans Tropsch at the Kaiser-Wilhelm Institute for Coal Research in Mülheim, Germany, converted methane obtained from heated coal into high-quality diesel fuel, lubricating oil and waxes (see "Gas-to-Liquid Chemistry," *page 34*). The diesel fuel burned cleanly, producing emissions with negligible particulates and sulfur content. By 1945, German chemical companies had constructed nine Fischer-Tropsch plants for generating clean, synthetic liquid fuels.[5]

After World War II, several countries began investigating the generation of synthetic fuels based on the Fischer-Tropsch technique. The German plants were disassembled and moved to Russia, where they formed the foundation for industrial efforts to produce waxes and chemicals.[6] Amid concerns about future security of hydrocarbon imports, work was begun in the USA and South Africa to assess the efficiency of the Fischer-Tropsch reaction at different pressures and temperatures, with different catalysts—iron, cobalt or nickel, and with different methods for flowing the gases and liquids through the reactor. By 1953, one concept was put into operation in South Africa, and since then, largely driven by restrictions on oil imports, Fischer-Tropsch fuels have met 36% of that country's liquid-fuel needs.[7]

Today, South Africa is the world's leading producer of liquid fuel from natural gas. Sasol, the country's synthetic-fuel company, produces about 160,000 B/D [25,400 m^3/d] from coal-derived gas at two huge plants near Johannesburg, South Africa (previous page). (For more information on coalbed methane, see "Producing Natural Gas from Coal," *page 8*.) Using conventional natural gas piped in from Mozambique, PetroSA produces an additional 30,000 B/D [4800 m^3/d] at a third plant.[8] It is this aspect of GTL technology, the production of easily transportable liquid fuels from conventional natural gas, that intrigues the world's large oil and gas companies.

Worldwide Interest in GTL

After the South African companies, Shell was the first, and so far, the only other oil and gas company to operate a GTL plant to produce commercial fuels. After investigating the subject for nearly 20 years, Shell opened a GTL plant in 1993 in Bintulu, Malaysia (left). With gas from fields offshore Sarawak, the Bintulu plant produces 12,500 B/D [1990 m^3/d] of clean diesel, kerosene and naphtha using the patented Shell Middle Distillate Synthesis (SMDS) process.[9] Shell committed to test operations at the Bintulu plant knowing that it would not be economic, but hoping to establish an early lead in GTL technology. Today, service stations in Bangkok, Thailand, sell synthetic diesel supplied by the Shell GTL plant in Bintulu. In the summer of 2003, Volkswagen launched a five-month test of Shell GTL fuel in Berlin, Germany. Further trials are planned in the state of California, USA, and in London, England and Tokyo, Japan.[10]

Shell has learned from its early investments in Malaysia, and is considering several locations—Argentina, Australia, Egypt, Indonesia, Iran, Malaysia, Qatar and Trinidad—for its first large-

1. *BP Statistical Review of World Energy 2003.* London, England: BP (June 2003): 20.
2. US Energy Information Administration, International Energy Outlook, Report no. DOE/EIA-0484 (May 1, 2003), http://www.eia.doe.gov/oiaf/ieo/nat_gas.html
3. Kvenvolden K: "Gas Hydrates—Geological Perspective and Global Change," *Reviews of Geophysics* 31, no.2 (May 1993): 173–187.
4. Estimates on the volume of stranded gas vary between 30% and 80% of proven and potential natural gas reserves. For one estimate see: Thackeray F and Leckie G: "Stranded Gas: A Vital Resource," *Petroleum Economist* (May 2002): 10.
5. Stranges AN: "Germany's Synthetic Fuel Industry, 1927–45," presented at the American Institute of Chemical Engineers Spring National Meeting, New Orleans, Louisiana, USA, April 2, 2003.
6. Jager B: "The Development of Commercial Fischer-Tropsch Reactors," presented at the American Institute of Chemical Engineers Spring National Meeting, New Orleans, Louisiana, USA, April 2, 2003.
7. "Energy Industry Critical to SA," http://www.safrica.info/doing_business/economy/key_sectors/energy.htm
8. Cottrill A: "Gas-to-Liquids Makes Move to Step Up a League: World-Scale Proposals Start to Drive Forward," *Upstream* (March 8, 2002): 26.
9. "Stepping on the Gas," *Shell Chemicals Magazine* (Spring 2003) http://www.shellchemicals.com/chemicals/magazine/article/1,1261,116-gen_page_id=856,00.html
10. Watts P: "Building Bridges—Fulfilling the Potential for Gas in the 21st Century," speech delivered at the World Gas Conference, Tokyo, Japan, June 3, 2003, www.shell.com/static/media-en/downloads/speeches/PBWwgc03062003.pdf

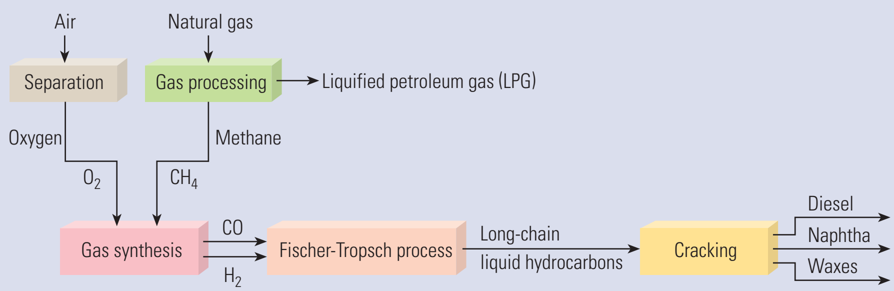
scale plant.[11] The current plan is to build a plant capable of producing 75,000 B/D [11,900 m^3/d] from 600,000 scf/D [17,200 m^3] of gas feedstock by 2007, and to commit to four such plants by the end of 2010. Each plant could cost $1.5 billion.

Other companies have invested years of research into gas-to-liquid technology, and may complete their first large-scale GTL plants before Shell constructs its second-generation plants. ChevronTexaco and Sasol have created a joint venture to build a plant in Escravos, Nigeria, with GTL production scheduled to begin in 2005 (right).[12] Initial production will total 34,000 B/D [5400 m^3/d], but the plant may be expanded to output 120,000 B/D [19,000 m^3/d]. The joint venture expects to spend about $5 billion by 2010 on a total of four GTL projects around the world.

^ Visualization of GTL plant near the ChevronTexaco oil and gas facility at Escravos, Nigeria, planned by the ChevronTexaco-Sasol joint venture. Initial production of 34,000 B/D [5400 m^3/d] is scheduled to begin in 2005 and may be expanded to 120,000 B/D [19,000 m^3/d]. (Photograph copyright of Sasol Limited.)

Gas-To-Liquid Chemistry

Converting gas to liquid using the Fischer-Tropsch method is a multistep, energy-consuming process that takes apart molecules of natural gas, predominantly methane, and reassembles them into long-chain molecules. The first step requires input of oxygen [O_2] separated from air. The oxygen is blown into a reactor to strip hydrogen atoms from the methane [CH_4]. The products are synthetic hydrogen gas [H_2] and carbon monoxide [CO], sometimes called syngas (right).



^ Converting natural gas to liquid fuels. In the first step, oxygen [O_2] separated from air is blown into a reactor with methane [CH_4]. The products are synthetic gases—hydrogen [H_2] and carbon monoxide [CO]. These pass into a Fischer-Tropsch reactor where catalysts help reform the gases into long-chain hydrocarbon molecules. The long-chain hydrocarbons are fed into a cracking unit and fractionated into diesel or other liquid fuels, naphtha and waxes. Cracking uses heat and pressure to decompose long-chain hydrocarbons and produce lighter hydrocarbons.

The second step uses a catalyst to recombine the hydrogen and carbon monoxide into liquid hydrocarbons.[1] In the last stage, the liquid hydrocarbons are converted and fractionated into products that can be used immediately or blended with others. The most well-known product is extremely pure diesel, sometimes known as gasoil. Diesel from the Fischer-Tropsch process, unlike diesel derived from distillation of crude oil, has near-zero sulfur- and nitrogen-oxide content, contains virtually no aromatics, burns with little or no particulate emissions, and has high cetane value.[2] Kerosene, ethanol and dimethyl ether (DME) can also be produced. Another product of the reaction is naphtha that is high in paraffin content. Waxes derived from GTL processes can be pure enough to use for food packaging and cosmetics.

The GTL processes in operation today convert 10,000 cubic feet [286 m^3] of gas into slightly more than 1 barrel [0.16 m^3] of liquid synthetic fuel.

1. A catalyst is a substance that increases the rate of a reaction. The Fischer-Tropsch process typically uses iron, cobalt or nickel catalysts.
2. Cetane is the diesel equivalent of octane, a measure that quantifies combustion in gasoline. Cetane index measures the ignition qualities of diesel. A high number indicates higher quality and a cleaner burning fuel. GTL diesels have a cetane index around 75, while most diesels derived from distilled petroleum have a cetane index between 42 and 51.

Country	Company	Capacity, B/D
Australia	Sasol, ChevronTexaco	50,000
Australia	Shell	75,000
Bolivia	GTL Bolivia	10,000
Bolivia	Repsol YPF, Syntroleum	103,500
Egypt	Shell, EGPC	75,000
Indonesia	Pertamina, Rentech	16,000
Indonesia	Shell	75,000
Iran	Shell	75,000
Iran	Sasol	110,000
Nigeria	ChevronTexaco, Sasol, NNPC	34,000
Malaysia	Shell	12,500
Peru	Syntroleum	40,000
Qatar	Shell, QPC	75,000
Qatar	ExxonMobil, QPC	100,000
Qatar	Sasol, QPC	34,000
South Africa	PetroSA	30,000
United States	ANGTL	50,000
Venezuela	PDVSA	15,000
Total		**980,000**

^ Locations and estimated capacities of existing and potential commercial GTL plants in operation by 2010. Pilot plants and plants that convert coal-derived gas are not included. (Adapted from LNG Center data at http://gmaiso.free.fr/lng/index.php3?suj=gtl&page=gtlsearch and from Thackeray, reference 26.)

^ The ConocoPhillips GTL demonstration plant in Ponca City, Oklahoma, USA. The plant was completed in March 2003, and is designed to convert 4 MMcf [114,600 m^3] per day of natural gas into 400 B/D [64 m^3/d] of sulfur-free diesel and naphtha. (Photograph copyright of ConocoPhillips.)

^ BP GTL test plant in Nikiski, near Kenai, Alaska, USA. The plant produced its first synthetic oil in July 2003. BP plans to produce about 250 barrels per day [40 m^3/d] in a program that is planned to last 6 to 12 months. (Photograph courtesy of Eagle Eye Helicopter.)

Leveraging catalyst and reactor research conducted by Conoco parent company DuPont, ConocoPhillips has made rapid advances in GTL technology. Since 1997, ConocoPhillips has designed, manufactured and tested more than 5000 catalysts for gas-synthesis Fischer-Tropsch processes. The company completed a GTL demonstration plant in 2003 in Ponca City, Oklahoma, USA (above right). The plant will convert 4 MMcf [114,600 m^3] per day of natural gas into 400 B/D [64 m^3/d] of sulfur-free diesel and naphtha.[13]

BP has produced its first synthetic oil from an $86 million GTL test plant in Nikiski, near Kenai, Alaska, USA (right).[14] The BP plant, designed to produce 250 B/D [40 m^3/d], is testing a more compact gas-reformer design than the designs Sasol and Shell are currently operating in South Africa and Malaysia. The new reformer is about one-fortieth the size of reformers in use at other GTL plants. If the compact GTL technologies being tested in Alaska are successful, BP will consider using them to develop stranded natural gas reserves worldwide.

ExxonMobil Corp. has invested $400 million in GTL research since 1981 and has a commercial test plant at the ExxonMobil refinery in Baton Rouge, Louisiana, USA.[15] The company is carrying out a technical feasibility study for a large-scale plant in Qatar that could convert the reserves of the North field at a rate of 75,000 B/D. The North field is the largest natural-gas field in the world, and ExxonMobil is one of several companies interested in developing GTL plants to help exploit it. Qatar could soon become home to several plants capable of generating more than 200,000 B/D [31,800 m^3/d] of synthetic fuels (above left).

Japan, lacking domestic petroleum resources, has long had an interest in synthetic fuels. Japanese research on synthetic fuels began in the 1920s, only a few years after Fischer and Tropsch invented their successful technique. The Japanese conducted laboratory research on the Fischer-Tropsch conversion processes, but in their haste to construct large synthetic-fuel

11. Cottrill A: "GTL Seeking Its Big Break into Stardom," *Upstream* (March 8, 2002): 24.
    Snieckus D: "Shell Considers Gas-to-Liquid Plant in Egypt," *Middle East Times*, http://www.metimes.com/2K/issue2000-41/bus/shell_considers_gas.htm
12. "NNPC and Chevron Sign Agreements on Escravos Gas Project-3 and Escravos Gas-to-Liquids Project," http://www.chevrontexaco.com/news/archive/chevron_press/2001/2001-08-22.asp (August 22, 2001).
13. "Conoco Gas Solutions Offers New GTL Technology for Economic Development of Stranded Gas Reserves," http://www.conoco.com/pa/special/gtl.asp (2002).
14. Bradner T: "BP's GTL Test Plant Begins Production," *Alaska Oil and Gas Reporter* (August 12, 2003).
    Font Freide J, Gamlin T and Ashley M: "The Ultimate Clean Fuel—Gas-to-Liquid Products," *Hydrocarbon Processing* (February 2003): 52–58.
15. "Qatar Petroleum and ExxonMobil Sign Letter of Intent for GTL Project," June 15, 2001, http://www.exxonmobil.com/Corporate/Newsroom/Newsreleases/corp_xom_nr_150601.asp
    Cottrill, reference 11: 24.
    Bradner, reference 14.

^ Flaring during well testing of a discovery well in the Gulf of Mexico (*inset*). Worldwide, the industry flares or vents 2 Tcf [57 billion m^3] of gas per year. GTL technology may offer ways to bring to market gas that is currently flared or vented. (Photographs courtesy of Energy Data Solutions, LLC, www.ocsbbs.com)

plants, they bypassed the pilot-plant stage, and were unable to advance to large-scale production in those early years.[16]

Early failure has been replaced by recent success. The Japan National Oil Corporation (JNOC) announced late in 2002 that its venture with five private Japanese companies successfully produced the country's first manufactured GTL products at their pilot plant in Yufutsu, Tomakomai-City, Hokkaido, Japan.[17] The construction of the pilot plant began in July 2001 and finished in March 2002; the first GTL products were produced in November 2002. Pilot-plant operation, with a maximum liquid-fuel production capacity of 1.1 m^3/d [6.9 B/D] will continue through 2003, allowing engineers to evaluate the basic design for commercialization. JNOC and Pertamina, an Indonesia state oil and gas enterprise, have been conducting a joint feasibility study on the applicability of the Japanese GTL technology to development of gas fields in Indonesia.

The Russian Federation has discovered natural-gas reserves of around 48.5 trillion m^3 [1690 Tcf].[18] However, production from their major gas fields is declining, and the remaining 90% of reserves lie in East and West Siberia, the Arctic shelf and the Russian Far East. These regions are too remote to access existing Russian gas-transmission networks.

After searching over the last decade for gas-transportation alternatives to pipelines, Russia's Gazprom, the world's largest gas company, announced in March 2003 that it would begin preliminary analysis into building a GTL industry in Russia.[19] An agreement between the Gazprom research and development affiliate, VNIIGAZ, and Syntroleum Corporation, based in Tulsa, Oklahoma, outlines a study of 12 locations throughout the Russian Federation as potential GTL sites. The GTL plants would use Syntroleum technology to produce low-viscosity arctic-grade diesel, petrochemical feedstock and specialty lubricants. Plant capacities designed by Syntroleum could handle gas input rates from 1 billion m^3 [34.9 Bcf] per year to 10 billion m^3 [349 Bcf] per year.

Another project involving Syntroleum Corporation's GTL technology was recently announced by the United States Department of Energy (DOE) to tap stranded gas reserves on the North Slope of Alaska, USA.[20] Converted gas from Alaska's North Slope could be transported through the underutilized Trans-Alaska Pipeline System. The pipeline currently carries crude oil from the giant Prudhoe Bay field on the North Slope to Valdez, Alaska, for tanker shipment. Production from Prudhoe Bay field is declining at a rate of about 10 to 12% per year. Even with additional oil from new fields, pipeline flow will eventually fall below the minimum volume needed for economic operation.

The focus of the DOE project is to demonstrate the feasibility of using a compact GTL plant to convert natural gas into ultraclean diesel fuel for use in vehicles. The project team will include experts from Syntroleum Corporation, Marathon, the University of Alaska, Daimler-Chrysler Corporation, West Virginia University, Massachusetts Institute of Technology, Sloan Automotive Laboratory and A.D. Little. After building and operating a GTL plant of sufficient size to prove the technology on a commercial scale, the team will then evaluate the produced fuel in existing and next-generation diesel engines, and in laboratory research engines focused on future engine and emission-control technologies.

16. Stranges AN: "Synthetic Fuel Production in Prewar and World War II Japan: A Case Study in Technological Failure," presented at the American Institute of Chemical Engineers Spring National Meeting, New Orleans, Louisiana, USA, April 2, 2003.
17. "Japan National Oil Corporation Succeeded in Producing First GTL Products in Japan," Press release November 29, 2002, http://www.jnoc.go.jp/english/news/pdf/2002/021129.pdf
18. US Energy Information Administration, International Energy Outlook (May 1, 2003), http://www.eia.doe.gov/oiaf/ieo/nat_gas.html
19. "Syntroleum to Support Effort to Build GTL Industry in Russia," Press release March 27, 2003, www.syntroleum.com
20. "ICRC Leads Gas-to-Liquid Ultra-Clean Fuels Project Team," June 1, 2001, http://www.icrc-hq.com/prnetl.htm
21. Freerks R: "Early Efforts to Upgrade Fischer-Tropsch Reaction Products into Fuels, Lubricants, and Useful Materials," presented at the American Institute of Chemical Engineers Spring National Meeting, New Orleans, Louisiana, USA, April 2, 2003.
22. For more on the greenhouse effect: Cannell M, Filas J, Harries J, Jenkins G, Parry M, Rutter P, Sonneland L and Walker J: "Global Warming and the E&P Industry," *Oilfield Review* 13, no. 3 (Autumn 2001): 44–59.
23. US Environmental Protection Agency press release (February 28, 2001), http://www.epa.gov/otaq/regs/hd2007/frm/final-pr.pdf
24. Browne J: "The Strategic Role of Gas," speech delivered at the World Gas Conference Tokyo, Japan, June 2, 2003, http://www.bp.com
25. "Global Gas Flaring Reduction," http://www.worldbank.org/ogmc/global_gas.htm
26. Thackeray F: "GTL in 2007," *Petroleum Review* (January 2003): 18–19.
27. Thackeray, reference 26: 18–19.
28. Bradner T: "BP to Produce Its First Barrels of GTL by April," *Alaska Oil & Gas Reporter* (March 6, 2002), http://www.oilandgasreporter.com/stories/030602/nat_gtl_april.shtml

GTL Benefits the Environment

Converting natural gas to liquid fuel benefits the environment in two ways. First, the resulting liquid hydrocarbons are pure and burn cleanly. They are colorless, odorless and low in toxicity. Second, converting gas to liquid allows producers to transport and market associated gas that would otherwise be flared into the atmosphere.

The clean-burning properties of diesel derived from converted natural gas were recognized as soon as Fischer and Tropsch tested their synthesized liquid fuel. Their synthetic diesel burned with negligible emissions and was preferred over petroleum-based diesels for powering underground motors.[21] Liquid fuels distilled from crude petroleum typically contain sulfur, nitrogen, aromatic compounds and other impurities. When burned, these crude-based fuels emit carbon monoxide, sulfur- and nitrogen-oxides and particulates, all of which contribute to air pollution and the greenhouse effect.[22]

Concerns over the environmental effects of fossil-fuel combustion have led global organizations to encourage efforts to reduce industry- and transportation-related emissions. Several countries now have legislated goals to improve the quality of fuel used for transportation. For example, the US Environmental Protection Agency has implemented rules that require refineries to reduce sulfur content in diesel fuel by 97% [from 500 parts per million (ppm) to 15 ppm].[23] These regulations will be phased in starting in 2006 and will be fully required by 2009. Japan, Australia and the European Union are also introducing stricter standards to take effect in 2006.

The high purity and low sulfur content of GTL synthetic fuels surpass the stringent requirements set for sulfur standards of the future. Products of GTL conversion can be blended with crude distillates of higher sulfur content to yield fuels that comply with current and future environmental specifications.

Further environmental benefits of GTL conversion come from facilitating production and transportation of associated gas that is normally flared (previous page). Worldwide, the industry flares or vents 2 Tcf [57 billion m^3] of gas per year.[24] When allowed, operators flare produced gas if their field's surface facilities are designed solely for oil production or if the gas cannot be reinjected. However, flaring wastes natural resources and contributes to air pollution.

Reducing the amount of gas flared requires curbing gas production, which is linked to oil production. For many fields with associated gas, strict limits on gas production translate into limits on oil production that can eventually make oil production uneconomic.

The World Bank has formed the Global Gas Flaring Reduction (GGFR) Partnership to encourage flaring-reduction initiatives.[25] The partnership, made up of the Bank, oil companies and governments, includes Shell, BP, ChevronTexaco, Total, Sonatrach of Algeria, and the governments of Angola, Cameroon, Ecuador, Nigeria, Norway and the USA. Several other organizations are considering becoming members. The GGFR works with countries and company stakeholders to identify activities that could overcome the barriers that currently inhibit flaring-reduction investments.

To reduce flaring of associated gas without jeopardizing oil production requires solutions for transporting gas from remote, and usually, offshore, locations. This is where GTL conversion promises to make a big difference, once the industry can build conversion plants that are small enough to install on floating platforms or vessels.

Challenges in Size and Cost

Before GTL conversion can become more widespread, certain technological challenges must be overcome, such as the size, cost and efficiency of GTL plants. The few gas-to-liquid plants in operation today are colossal facilities that cover large areas and require input gas reserves of about 1.3 Tcf [37.2 billion m^3] at a low cost over the course of 20 years of operation to remain economically attractive. The reforming units that are the basis of plant operations are massive and need to be constructed on site.

Companies are testing concepts of smaller plants in the hopes of developing compact facilities that can be installed in remote locations or placed on floating structures to exploit stranded and associated gas reserves offshore. One company, Rentech, is concentrating on developing technology aimed at small-scale projects from 5000 to 16,000 B/D [800 to 2500 m^3/d]. The company has announced studies for two such projects, one in Bolivia for 10,000 B/D [1580 m^3/d] and one with Pertamina in Indonesia for 16,000 B/D.[26] Rentech has also announced interest in applying its GTL technology to floating production systems, but no such systems have yet been built. Some companies are investigating even more compact systems that generate as little as 25 B/D [4 m^3/d] of liquids.

Physical size is not the only factor limiting the construction of new GTL plants. Capital investment for installation of new plants comparable to that of the large operations in South Africa is prohibitively high, ranging from $27,000 to $50,000 per B/D of liquid fuel produced. Smaller scale plants are less expensive to build. The 34,000-B/D Sasol plant planned for Qatar is estimated to cost between $20,000 and $25,000 per B/D.[27] BP hopes the compact reformer being tested in Alaska will reduce costs to about $20,000 per barrel of daily production, and then with further improvements, to $17,000—low enough to compete with new LNG projects.[28] At around $11,000 per B/D, GTL projects could compete with new crude-oil refineries.

Compact reformers may be one way to cut GTL costs, but other efforts also are underway to make the conversion process more efficient. The first step in the current process requires oxygen to combine with natural gas. Separating oxygen from air is one of the more costly steps in the GTL process. Scientists are exploring new avenues in air-oxygen separation, including new ceramic membranes. Preliminary research shows that some ceramic membranes selectively allow oxygen ions to pass while excluding other air components. Costs of GTL conversion could be reduced by as much as 25% with ceramic-membrane technology, depending upon conversion plant configuration.

Improving upon the Fischer-Tropsch process itself is one more focus of current GTL research. The multistep Fischer-Tropsch process first converts methane to synthetic gas, then converts the synthetic gas into liquid hydrocarbons. Scientists at Petroleum Energy and Environmental Research (PEER) and at the Molecular Process and Simulation Center (MSC), both at the California Institute of Technology (CalTech), Pasadena, California, are trying to find a single-step process that will convert natural gas directly into liquid hydrocarbons. They propose to combine theory, modeling and experiments to devise a direct conversion process. A single-step process could solve many of the problems that currently keep GTL from being economically viable. –LS