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Emergence of the gas-to-liquids industry

A review of global GTL developments

Natural gas has significant advantages over many fuels in that it is both plentiful and environmentally clean. This article takes a look at the production methods used in the gas-to-liquids industry and describes why BP's vision of a future 'Gas Economy' may not be all that far away.

During the last few decades, BP, other oil and gas majors and many technology companies have invested time and resources in gas-to-liquids (GTL) technology development primarily using the Fischer–Tropsch conversion process. The investments have yielded process improvements that significantly reduce expected capital and operating costs. Falling costs and new market options for remote gas utilisation have increased the pace of commercial activity and promise to accelerate this trend over the next several years. Consequently, the GTL industry appears to be entering a significant growth period. Today's current 35 000 barrel/day (b/d) GTL capacity (representing about 0.1% of fuel and petrochemicals markets) could increase to 1–2 million b/d by 2015, exploiting 10 to 20 billion cubic feet of natural gas per day. This article reviews GTL technologies under development and current commercial activity.

Several factors are converging to drive the growth in the GTL industry, such as:

- the desire to exploit existing gas resources with no economical link to a market (also referred to as remote or stranded gas)
- market demand for cleaner fuels and new low-cost chemical feedstocks
- increasing economic viability due to capital cost reductions
- diversification interest from gas-rich host governments.

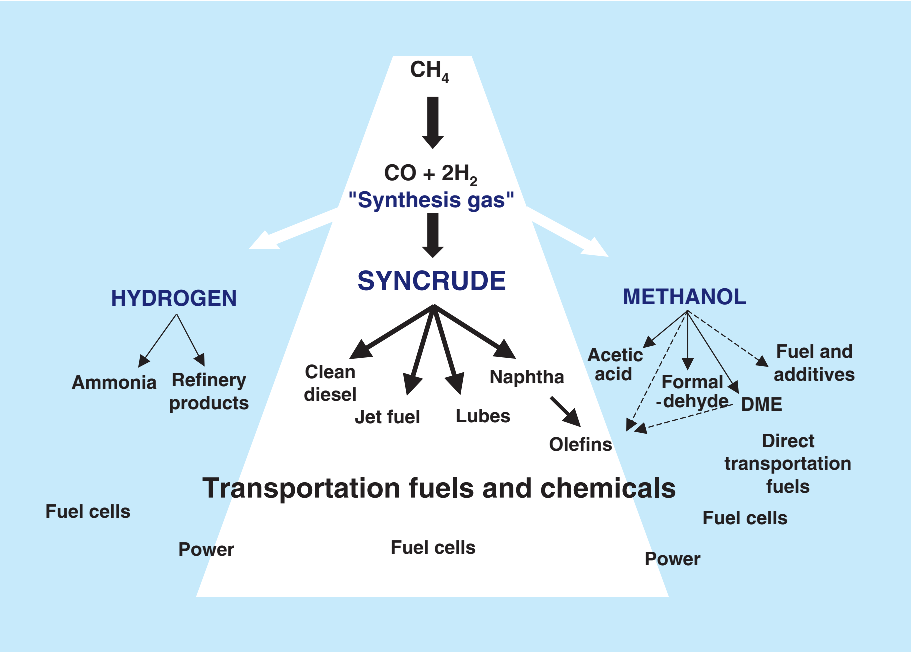

Figure 1 Gas-to-products (GTP) options

What is GTL?

GTL has become synonymous with the Fischer–Tropsch route for producing liquid fuels, petrochemical feedstocks and other products from natural gas. GTL is a member of the gas-to-products (GTP) family that also includes the production of oxygenates like methanol, as well as hydrogen for use in refineries and for the production of ammonia (Figure 1).

Production of synthesis gas (syngas) is the common link to the products and markets shown. Gas conversion is the basis of a sizeable industry today, consuming the equivalent of 4 trillion cubic feet of gas a year, about the same scale as the liquified natural gas (LNG) industry.

GTL process technology and products

GTL conversion processes consist of three principal reaction steps.

- **Production of syngas.** Natural gas (primarily methane) is reacted with steam and/or oxygen to produce syngas, which is a mixture of hydrogen and carbon monoxide. Three main reactions occur:

  Steam reforming:

  $$CH_4 + H_2O \longrightarrow CO + 3H_2$$

  Partial oxidation:

  $$CH_4 + \tfrac{3}{2}O_2 \longrightarrow CO + 2H_2O$$

  Water gas shift:

  $$CO + H_2O \longrightarrow CO_2 + H_2$$

  Syngas production is carried out at high temperature (typically above 1800°F or 1000°C). Both catalytic and non-catalytic processes are used. Syngas production is a common process in the petrochemical and petroleum industries to make hydrogen, ammonia and methanol.

- **Conversion of syngas to syncrude.** Syngas is reacted via Fischer–Tropsch technology to produce a mixture of synthetic hydrocarbons, commonly referred to as synthetic crude oil or syncrude, a mixture of primarily straight-chain paraffins. The basic chemistry can be represented as:

  $$nCO + 2nH_2 \longrightarrow C_nH_{2n+2} + nH_2O$$

  where n typically varies between 1 and greater than 30, with an average of about 12. The reaction continues via chain propagation, with $–CH_2–$ groups adding to the chain to give long linear chain, primarily paraffinic, hydrocarbons. The reaction produces water and low temperature heat (230°C or 450°F) as by-products, and is carried out in either tubular fixed-bed or slurry phase catalytic reactors. The conversion of some H_2 into H_2O is a significant cause of GTL's apparent low energy efficiency of about 60% today. The carbon efficiency is close to 80%, and is expected to reach refinery levels by 2015.

- **Syncrude upgrading.** In the third step, the raw syncrude is upgraded to marketable products such as diesel fuel, naphtha and other liquid petroleum or specialty products. Using mild hydrocracking conditions, hydrogen is added (a) to break the long-chained waxy hydrocarbons into diesel and naphtha, and (b) for product stabilisation to remove some olefins and oxygenates in the lighter products. Similar hydroprocessing units are operating in many oil refineries.

Gas conversion is the basis of a sizeable industry today, consuming the equivalent of 4 trillion cubic feet of gas a year

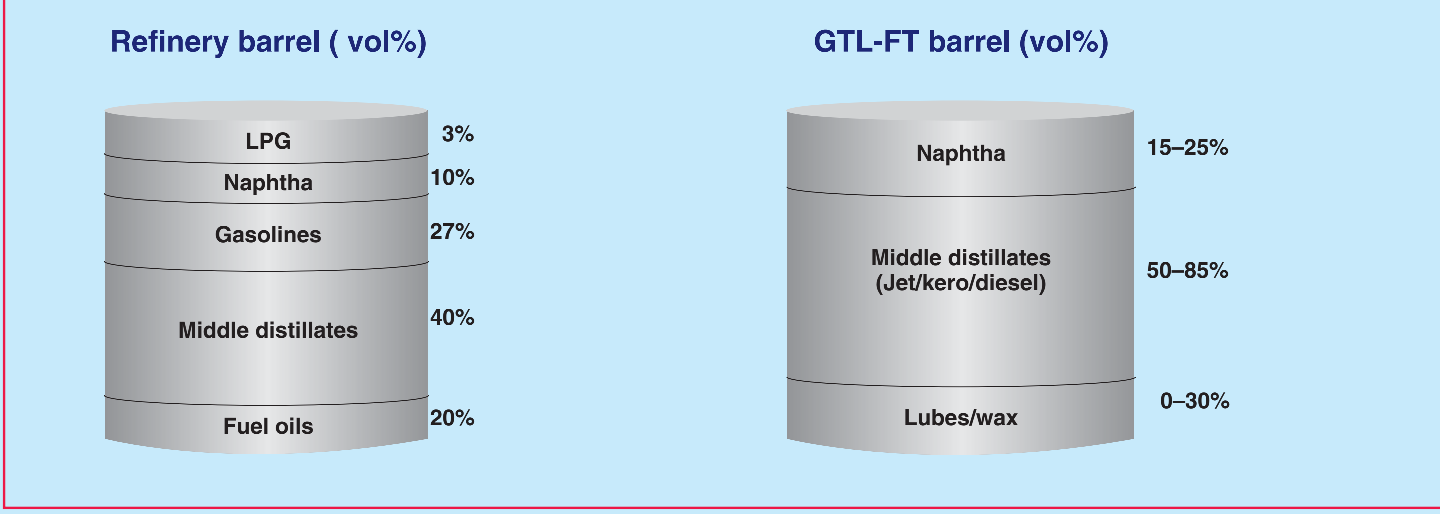

Figure 2 Comparison of GTL-FT barrel vs conventional barrel

GTL plants produce a range of high-quality, sulfur-free fuel and chemical feedstock products that are quite different from those produced from a typical crude oil refinery. They include lube basestocks, premium fuels, petrochemical naphtha and waxes (Figure 2). These products meet or exceed virtually all product requirements and are fully fungible with conventional petroleum-derived products. The value of a GTL barrel is estimated to be about $30 per barrel, compared with about $25 per barrel for a refinery barrel, based on $20 per barrel crude oil price.

Global GTL commercialisation activity

A review of global commercialisation activity (Table 1) indicates that today's operating and announced GTL projects represent about 1 million b/d of new capacity, of which 35 000 b/d is operating. The locations with the most projects are Qatar, with 330 000 b/d to 500 000 b/d, and Australia, with about 120 000 b/d. The significant number of demonstration facilities (70–1000 b/d) scheduled to start up within the next year indicates the intensity of current effort. These demonstrations represent the culmination of lengthy research efforts on laboratory/pilot plant scale equipment.

Construction and operation of pilot, demonstration and commercial scale plants has enhanced the level of GTL experience. Several companies have large-scale plant operating experience.

- Sasol has successfully produced liquid fuels from coal-derived syngas since 1955 in South Africa and today produces about 135 000 b/d of synthetic fuels in this way. Future GTL plants using Sasol Fischer–Tropsch technology would use autothermal reforming technology supplied by Haldor Topsoe to produce syngas from natural gas.
- Mossgas, the South Africa-owned GTL producer, uses a Fischer–Tropsch process licensed from Sasol to produce 22 500 b/d of high-quality, sulfur-free finished products.
- Shell's experience derives from its GTL plant in Bintulu, Malaysia, that converts about 100 million standard cubic feet per day of natural gas into 12 500 b/d of middle distillates (gasoil, kerosene, naphtha) and specialty products (lubricant, detergent and solvent feedstocks; various grades of waxes, and drilling base fluids).

Starting construction of several new GTL plants in the next one to two years is critical to the development of a

Stage of development	Total capacity (b/d)	Comments
Large-scale		
Commercial	35 000	In operation
Front-end engineering design	68 000	Production from Sasol/Qatar Petroleum 34 000 b/d plant expected by late 2005
Study	1 100 000	
Demonstration plants	1 770	Expected start-up within 1 year
Total	1 204 770	

Table 1 GTL commercialisation activities

significant GTL industry, if output of more than one million barrels per day of premium liquids is to be achieved by 2015. Projects at an advanced stage are:

- Sasol and Qatar Petroleum are building a GTL plant, at Ras Laffan Industrial City, Qatar, that will produce 24 000 b/d fuel, 9000 b/d naphtha and 1000 b/d of liquified petroleum gas (LPG). In January 2003, a US$675 million engineering, procurement and construction (EPC) contract was awarded to Technip-Coflexip of Italy. Production is expected by late 2005.
- Sasol ChevronTexaco is progressing plans to build a 34 000 b/d GTL plant on a site adjacent to the Escravos River in Nigeria. The plant is designed to produce 22 300 b/d of ultra-clean diesel, 10 800 b/d of naphtha and 1000 b/d of LPG.

In addition to operating experience associated with commercial facilities, technology developments are being driven by the operation of relatively large demonstration facilities.

- BP is starting up a 300 b/d plant in Nikiski, Alaska.
- ExxonMobil has experience operating its 200 b/d demonstration plant, located in Baton Rouge, Louisiana.
- Other companies, including Statoil, ConocoPhillips, Syntroleum and Rentech, have or are in the process of acquiring operating experience with demonstration plants in the 70–1000 b/d scale.

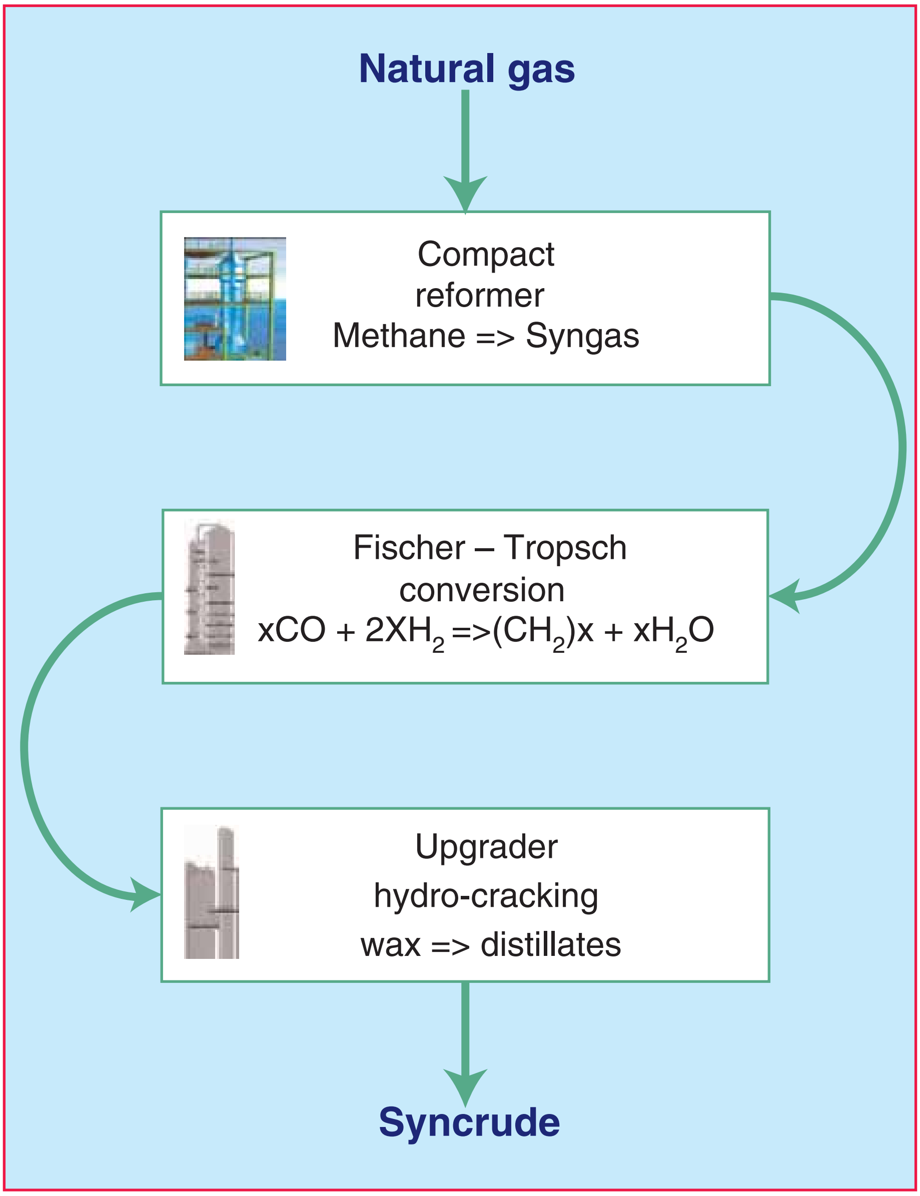

Figure 3 The three major processes inlolved in converting natural gas into syncrude

A technology demonstration activity example – Alaska GTL test facility

BP has been working to advance GTL technology since the early 1980s. BP established a partnership in 1996 with Davy Process Technology (DPT) to strengthen this effort. The result is a flexible syngas process, with multiple applications beyond Fischer–Tropsch conversion, and a simple process that utilises a proprietary Fischer–Tropsch catalyst. The technology is currently being demonstrated at the Nikiski Test Facility in Alaska.

The focus of the facility is to provide a cost-effective, non-oxygen-based route to syngas production by using the BP-DPT compact reformer (CR) technology in combination with a simple fixed-bed Fischer–Tropsch syngas conversion process. The test facility will convert about three million standard cubic feet of natural gas into roughly 300 barrels of syncrude a day, in three major processes (Figure 3). The processes are:

1. reforming of natural gas and steam to syngas
2. Fischer–Tropsch conversion of the syngas to a mixture of primarily straight-chain paraffins
3. mild hydrocracking, using commercially available technology, to make pumpable syncrude.

The syncrude is stored in a storage tank and then exported via road transport for further processing.

The compact reformer is a modular reactor, which allows close integration of combustion with catalytic steam reforming.

The compact reformer design is the first significant advance in steam reforming in more than two decades. The test facility will demonstrate a number of the key characteristics of this technology component:

- a compact design giving a reduced footprint and weight of both the reformer box and the waste heat recovery section that is about one-third of that for a conventional steam reformer
- increased thermal efficiency, compared with a conventional reformer, because of the large internal heat recycle
- design standardisation, resulting in reduced site construction man-hours and schedule
- a design that is compact enough to allow commercial-scale units to be transported to offshore platforms or remote sites for stranded natural gas conversion
- no need for an oxygen plant
- a flexible and scaleable technology that is economically viable through a wide range of scales and relevant to a wide range of applications.

BP and DPT will make the compact reformer and Fischer–Tropsch conversion technologies available to third parties through license with DPT.

> Technology innovations in the process, as well as catalyst developments, are making chemical conversion of the very stable methane molecule a commercially viable option

Conclusion – the gas economy

In BP's vision of a Gas Economy – an economy fuelled by natural gas: 'The world's plentiful gas supply sources, ongoing technological innovation, a desire for less carbon-intensive fuels, and the need for cleaner air in urban areas, will continue to increase the importance of natural gas to the development of world, regional and country economies. The gas economy would be supplied from a truly global market consisting of gas reservoirs geographically dispersed but linked to consumers by such options as gas pipelines and LNG, and also by the emerging options of gas by wire and by tankers carrying liquid or solid products manufactured via gas conversion' (Figure 4). In this world, the role of GTL/GTP is not only to provide another option to exploit gas for existing markets, but also to create new markets.

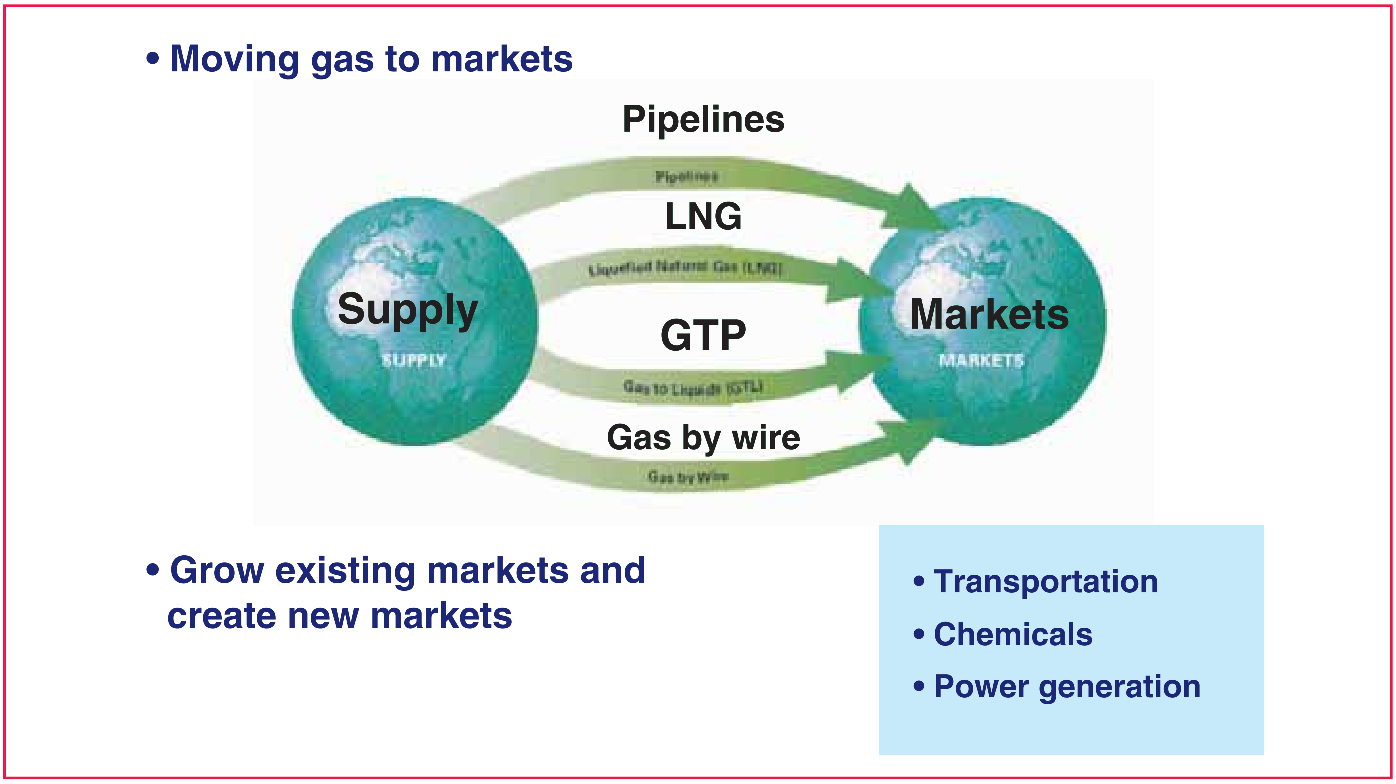

Figure 4 The role of GTP in the gas economy

Figure 5 The Alaska GTL test facility

Most of the world's gas production is brought to the market via pipelines, but the high cost of gas pipelines limits the connection of resource and consumer to less than about 5000 km. The second commercially viable transport means today is LNG, which is shipped to market in heavily insulated tankers and regasified for use in conventional applications.

An emerging method of transport is gas by wire. Electricity is generated at the point of the gas resource. The alternating current supply is converted into direct current, transported by power lines, and then converted back to alternating current for transmission to consumers. Gas by wire has so far been limited to application distances less than about 5000 km.

GTL/GTP will provide another method of bringing remote gas resources to distant markets. Liquid hydrocarbons, paraffinic distillates or oxygenates can be readily shipped over long distances using standard logistics practices. The natural gas-derived fuels must compete with conventional fuels in a marketplace that pays little, if any, premium for the cleaner GTL fuels. However, technology innovations have made GTL/GTP a commercially viable option today. As seen in the LNG industry, further cost reductions will be derived from economy of scale, value engineering and competition. In the near future, there will be exciting opportunities for gas refineries with synergies from the co-location of GTL/GTP, LNG and power plants. ■

Further reading and useful websites

About BP's vision for the gas economy: www.bpgaseconomy.com

About BP's GTL Nikiski Test Facility: *BP Frontiers* magazine, December 2002: www.bp.com/frontiers

About the compact reformer: 'Process technology for gas to liquids breakthrough', *Hydrocarbon Processing*, February 2003.

The Fischer–Tropsch Synthesis, by Robert Bernard Anderson, Academic Press, 1984

Archive of publications, patents, etc. on Fischer–Tropsch technology: www.Fischer-Tropsch.org

Dr Theo Fleisch is a Distinguished Advisor for BP's leadership in the emerging Gas Economy, the Director of the Berkeley/ Caltech University Methane Conversion Consortium and an academic committee member of BP's Clean Energy programme with the Chinese Academy of Sciences. He has been working for 15 years on the development of technologies, strategies and projects to bring remote gas to the market place.

Dr Ronald Sills is the Gas Conversion Network Leader for the E&P Technology Group, BP. He facilitates the knowledge management and communications among cross-sector gas conversion teams. He has authored numerous articles on gas-to-products (GTP) topics, and is active in external GTP organisations. He has been working for 20 years on the development, evaluation and commercialisation of synfuels technologies.

Michael Briscoe is GTP Senior Engineer for the E&P Technology Group, BP. He provides technical and economic support for BP's global GTP development and commercial-isation activities and has over 26 years of technical experience in upstream, refining and synfuels research, including the design, construction and operating of a major GTL-Fischer–Tropsch pilot plant.

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