Gas-to-Liquid:

A Viable Alternative to Oil-Derived Transport Fuels?

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WPM 50

May 2013

ISBN 978-1-907555-74-9

Abstract

A number of high-profile projects and a wave of recent investments have focused attention on the global gas-to-liquid (GTL) industry, suggesting a latent potential for gas-to-liquid fuels to usher in a new conceptualization of oil product markets. The clean-burning, high-quality characteristics of GTL diesel fuels lend support to this outlook, seemingly offering a viable substitute to oil-derived diesel in the global transport sector. However, doubts over the long-term viability of large-capacity GTL projects in the absence of heavily subsidized gas feedstock prices leads to an alternative narrative, suggesting that GTL products will have only a limited impact in the global transport sector by virtue of the industry's unsustainable growth potential. Evidence of this is seen in Europe, where despite the favourable market conditions for diesel imports, GTL diesel remains a niche product with relatively narrow commercial applications. As such, the recent wave of GTL investments may not be totally justified by market context, and the potential for GTL fuels to impact oil product markets may be overstated.

Keywords: GTL, diesel, blend stock, transport fuel, natural gas substitution, downstream, refining, Fischer–Tropsch

Acknowledgments

I would like to thank my advisor Bassam Fattouh at the OIES for his support, guidance, and suggestions that were instrumental in researching and shaping this analysis. I would also like to thank Kate Teasdale at the OIES, as well as my editor Catherine Riches for her comprehensive corrections and comments. I must also acknowledge the contributions and insight from my talented colleagues at PFC Energy, whose expertise was vital to this analysis. Most importantly, I would like to thank my family, for their unwavering support and encouragement.

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Introduction

Industrialization of non-oil-derived fuels

The technology to synthesize liquid fuels from hydrocarbons other than crude oil has existed since the 1920s; however, it has only been industrialized on a limited scale over the past 90 years. In 1923, the German scientists Franz Fischer and Hans Tropsch developed a process of forming long-chain hydrocarbons by reacting carbon monoxide and hydrogen gas molecules through a catalyst as a means of producing synthetic liquid fuels. Development of the Fischer–Tropsch process was encouraged by Germany's post-World War I effort to become energy independent, and it was shortly thereafter industrialized as part of Hitler's 1936 Four Year Plan. The German government sought to fuel military vehicles by transforming the country's abundant coal resources into motor gasoline and jet fuel, thereby assuaging the war effort's vulnerability to allied blockades on foreign oil supply (Stranges, 2003).

Due to high production costs and the existence of cheaper alternative crude distillation methods, however, the nascent industry's development hinged on various forms of government support and incentives (Stranges, 2003). As such, the earliest developments of Fischer–Tropsch (F–T) technology and the subsequent industrialization of synthetic fuels were deemed inseparable from the Nazi war effort. Following World War II, international conventions mandated that Germany's synthetic fuel industry be dismantled,[1] and by 1949 the remnants of the industry had been relocated to Siberia or broken down for scrap iron (Stranges, 2003). The only other significant industrialization of synthetic fuels occurred during the apartheid era of isolation in South Africa from the 1950's, when international embargos severed crude supplies and the country's National Party bolstered its synthetic fuels industry in order to derive transport fuels from the country's indigenous coal reserves.

The synthetic fuels industry has been hindered by its legacy of being foremost a politically driven, rather than a commercially motivated, endeavour (Greene, 1999). Given this heritage, it is unsurprising that the industry (and the related outlook for commercialization of gas-to-liquid (GTL) synthetic fuels) has suffered from its characterization as a technologically feasible, but not economically viable, means of converting hydrocarbons such as gas into liquid fuels (Greene, 1999). Between 1950 and 2010, global volumes of GTL product output

[1] Certain coal to liquid (CTL) plants were relocated to Britain, and those in eastern Germany were dismantled and relocated to eastern Russia. The ban on synthetic fuels production in Germany was lifted by 1950; however, the domestic industry failed to stage a recovery.

capacity had materialized at less than 100,000 b/d – roughly equivalent to the output of just one average-sized east European refinery.

However, the recent confluence of several factors has altered the commercial viability of the GTL industry, suggesting that wide margins and robust revenues can be earned by converting natural gas into clean-burning liquid fuels and other high value oil-linked commodities. Broadly speaking, these factors are: (1) improvements in the lifespan of the catalysts used to derive hydrocarbon chains from natural gas (methane) and efficiency gains in the Fischer–Tropsch process; (2) the detachment of natural gas markets from oil prices and the subsequent wide differential between the two prices, courtesy of the unconventional gas boom; and (3) long-term global demand trends favouring low-emissions fuels in the transport sector.

Despite these auspicious circumstances, however, this paper argues that GTL fuels will have only a limited reach into oil product markets and the transport sector going forward. While downward pressure on natural gas prices and increasing demand for clean-burning motor fuels have ushered in 'visions of a new future of transport fuels [that] will soon go global' (Mackenzie, 2013), the transient conditions that had supported a favourable outlook for the proliferation of GTL liquid fuels over the period of 2009–12 have, more recently, shown signs of deterioration. Moreover, alternative and less capital-intensive pathways to natural gas monetization are emerging via small-scale 'modular' GTL plants, whose development has been encouraged by the rapidly increasing supply of unconventional and associated gas which has necessitated more practical and localized gas monetization solutions. The confluence of these factors has the momentum to derail the trajectory of the GTL industry from large-scale capacity builds towards modular sites. This suggests that overall GTL volumes will be smaller and more dispersed than currently anticipated, dampening the expected impact of GTL fuels in global oil product markets.

Part I of this paper discusses GTL as a pathway to natural gas monetization, focusing on the trade-off between gas transportation versus chemical transformation of gas and the respective commodity market implications. This is followed by an analysis of the inherent product yields of the F–T GTL process, the existing global capacity of GTL liquid fuels output, and product pricing movements in the corresponding commodity markets. Building on this analysis, Part II identifies the ideal market conditions supporting GTL's main product yield (diesel), and identifies Europe's low-sulphur and structurally short gasoil/diesel markets as an ideal destination for GTL diesel – both in terms of product quality alignment and attractive spot market conditions. This section also covers the current methods of commercializing existing GTL diesel supply in Europe, highlighting the gas-derived fuel's proclivity to remain as a niche product even within markets that are significantly short of marketable gasoil and diesel volumes. This is followed, in Part III, by an analysis of the economic conditions required to sustain large-scale global GTL capacity, the viability of significant capacity materialization in the medium- and long-term, and the growing split between emerging modular and large-scale GTL alternatives. To conclude, this analysis posits that the limited impact and narrow commercial applications of GTL diesel as evidenced in European diesel markets suggests that GTL lacks the potential to usher in a significant reconceptualization of oil product markets in the transport sector – even as the global energy context shifts increasingly in favour of gas-derived energy sources.

Part I: GTL conversion as a gas monetization pathway

Gas transportation vs. transformation

The boom in unconventional gas and the resulting downward influence on natural gas prices has motivated major oil and energy companies to seriously reconsider the options for monetizing natural gas. Methods currently employed to deliver and monetize natural gas are primarily limited to fixed destination pipelines and, increasingly, to liquefied natural gas (LNG). While the former method is the less flexible of these options (generally reliant on long-term and increasingly out of favour oil-indexed contracts between supplier and a limited number of buyers in a specific market) the latter option allows for significant flexibility in delivering gas to markets and, moreover, facilitates lucrative arbitrage between regional gas markets with diverging price dynamics.

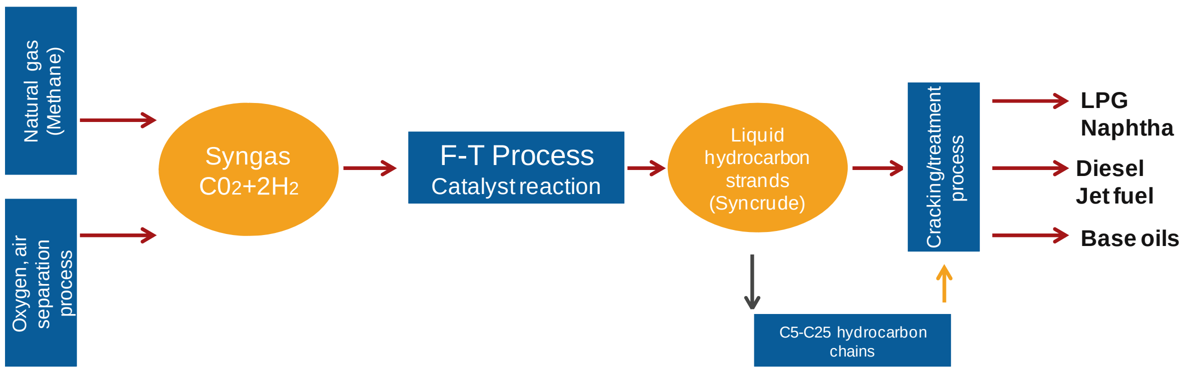
Nevertheless, gas monetization via LNG is restricted by the chemical composition and relatively more limited commercial applications of hydrocarbons in a gaseous state, when compared to hydrocarbon liquids derived from crude oil.[2] LNG induces only a physical change in the natural gas input; it is condensed into a liquid state for ease of transport and then re-gasified at its destination, for commodity markets that remain predominately restricted to power generation and other stationary sectors (Foster Wheeler, 2005). Developments to support infrastructure which would enable natural gas fuelling across the dominant global passenger (and to a lesser extent commercial) vehicle fleet have thus far lagged expectations, hindering the potential of natural gas vehicles (NGV). This logistical constraint subdues the medium-term outlook for natural gas substitution in the global transport sector. While gas vehicles will indeed continue to make strong inroads over time as the infrastructure needed to accommodate fuelling is put in place, the magnitude of the infrastructure investments required to significantly offset the hegemony of oil-derived liquid fuels in global transport is only achievable in an aggressive long-run scenario.

The Fischer–Tropsch gas-to-liquid conversion process alters the molecular configuration and physical state of natural gas via a combination of the Fischer–Tropsch process and subsequent molecular cracking/conversion and treatment processes (Figure I.1), thereby opening the hydrocarbon to broader commercial applications and commodity markets (Figure I.2). In the

[2] Crude oil can be distilled into 19 different products depending on the properties of the crude run and refinery configuration. In the absence of molecular conversion, natural gas commercialization is relatively limited

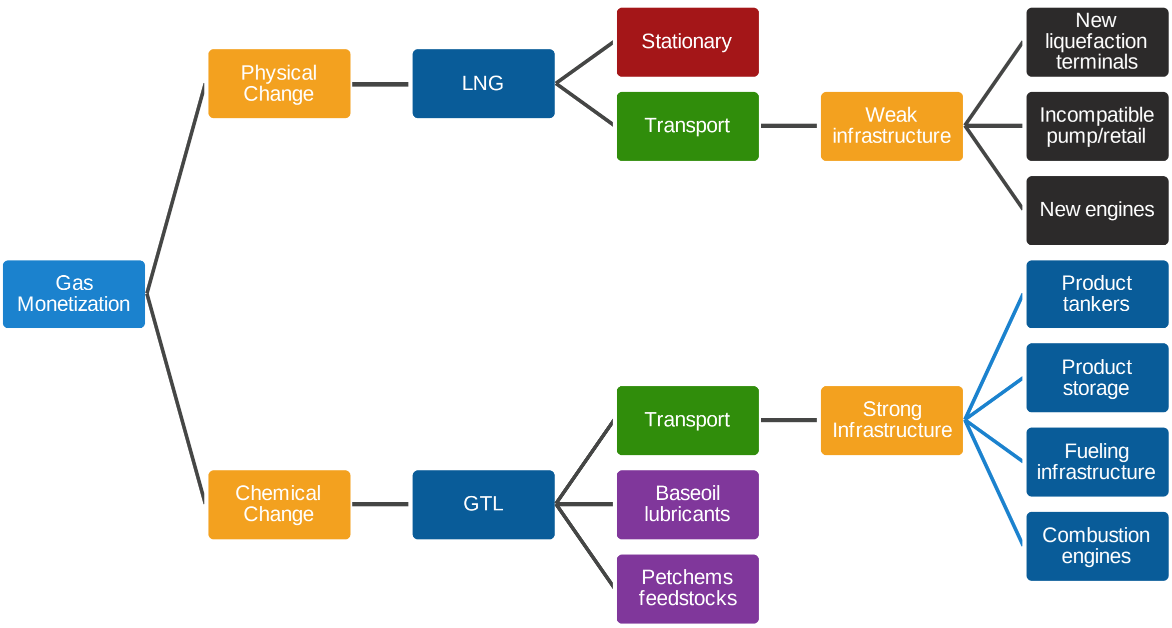
transport sector, the F–T process renders gas-to-liquid fuels that are readily able to employ the full array of existing downstream oil product infrastructure due to the identical physical characteristics of GTL-derived and crude-derived diesel. Applying F–T technology to expose natural gas feedstock to oil-linked commodity markets has become an increasingly attractive proposition in the persistent high oil price/low gas price environment. As such, the monetization of natural gas has evolved into a question of whether to transport or transform the hydrocarbon, in order to achieve optimal gas monetization (Foster Wheeler, 2005).

Figure I.1: The Fischer–Tropsch Synthetic Fuel Conversion Process



Adapted from Foster Wheeler (2005) andStanford.edu

Figure I.2: Chemical versus physical changes and gas monetization

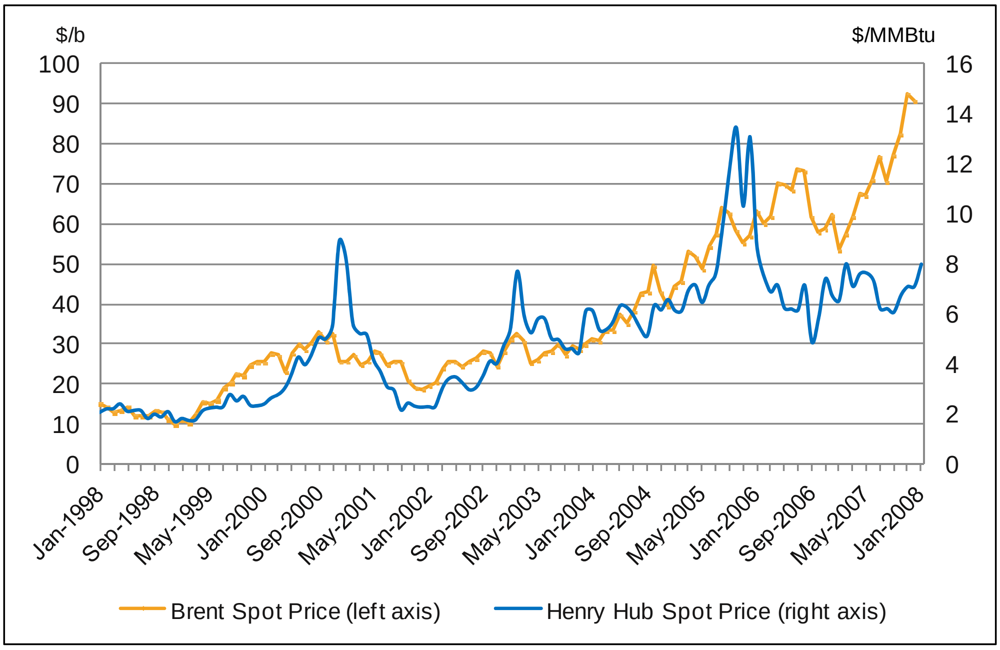


Source: Author representation

Liquid fuels output capacity

Despite the wider market applications associated with chemically transformed GTL products, the materialization of global operational capacity pales into insignificance when compared to that of LNG capacity. While the global super-majors have been conducting research on developing and commercializing gas-to-liquid fuels since at least the 1960's, the tight correlation between oil and gas markets (see Figure I.3), together with the low oil price environment, eroded the economic and commercial rationale to develop GTL capacity to any significant extent until well into the first decade of the twenty-first century. Not only would the capital-intensive gas-to-liquid conversion process be uncompetitive with crude distillation in a low oil price environment, but the product would yield narrow (if any) margins relative to gas feedstock costs on oil-linked commodity markets.

Figure I.3: Brent Crude Spot Price vs Henry Hub Spot Price (1998–2008)



Source: EIA monthly averages

As a result, the super-major international oil companies (IOCs) abstained from deriving liquid fuels from hydrocarbons other than crude oil on a mass-commercialization scale throughout the twentieth century.[3] Although Fischer-Tropsch pilot plants were established sporadically to test the conversion technology, and to commercialize certain products on a limited scale, the majors' initial F-T GTL and Coal-to-Liquid (CTL) sites proved to be either uneconomical or

[3] This excludes biofuels

too technically challenged to deliver the technology on a global basis, and GTL remained only a marginal industry. In 1985 ExxonMobil explored synthetic fuels production by opening a 14.5 kb/d test plant in New Zealand that converted methanol into gasoline (MTG), but the site was eventually shut down in 1997 amidst an environment of persistently low fuel prices (PennEnergy, 2013a). Shell followed in 1993 with a GTL plant in Bintulu, Malaysia (see Table I.1), whose aim was to export speciality waxy hydrocarbon products to regional markets – this would become a prototype for later large-scale developments.[4] The only other existing operational GTL plant by the turn of the century was the Mossel Bay GTL plant of PetroSA, South Africa's national oil company (NOC). While the site was the largest GTL facility in the world by the turn of the century (with a capacity of 45 kb/d in liquid product output), Mossel Bay was minor in comparison to any standard crude distillation refinery (NatGas.info, 2013).

The difficult economic conditions faced in sustaining GTL projects on an economic and commercial level were compounded by the complex technical conversion processes and massive capital costs, dissuading global majors from aggressively pursuing projects. Nevertheless GTL, as an alternative gas monetization option, became increasingly aligned with the needs of emerging regional gas producers and their respective national development strategies which sought to maximize and diversify the value of abundant national gas reserves, and the process started to gain attention moving into the twenty-first century (PennEnergy, 2013b). Gas-producing NOCs in the Middle East, Russia, and the Caspian Sea region welcomed partnership opportunities with major IOCs that promised to maximize the value of gas resources for the host government and NOC, while offering the prospect of healthy revenues for the latter (Crooks, 2007). Gas-rich Qatar stood out in facilitating major GTL development partnerships. With supportive leadership welcoming foreign partnerships, a stable operating environment, and abundant natural gas reserves in the massive North Field, 'the journey of GTL from a concept through commercial viability became uniquely a Qatari success story' (PennEnergy, 2013b). This was underpinned by the country's focus on economic development via natural resources and a responsible diversification of gas monetization options that favoured opportunities to develop GTL capacity (PennEnergy, 2013b; EIA Qatar, 2013).

[4] The plant is actually a Joint Venture: Shell (72%) Mitsubishi (14%), Petronas (7%), and Sarawak State (7%).

Early in the twenty-first century, ExxonMobil, Shell, and South Africa's synthetic fuels pioneer Sasol had each engaged in separate GTL development partnerships with Qatar Petroleum (QP). Generally speaking, in exchange for supplying subsidized natural gas feedstock from the North Field (a critical project enabler) QP would maintain an ownership stake and/or profit sharing arrangements in the projects (EIA Qatar, 2013). While a number of collaborations failed to materialize as planned investments costs soared beyond targets, ORYX GTL, a joint venture between Sasol (49 per cent) and Qatar Petroleum (51 per cent), became the first partnership site to stream in the twenty-first century. Officially commissioned in June 2006, the modestly sized 32.4 kb/d plant in Ras Laffan, Qatar paved the way for a generation of future large-scale plants, enabled by unique economic circumstances and subsidized or equity gas feedstock.

Table I.1: Existing GTL Capacity – 2012

Plant name	Country	Operator	Year Operational	Nameplate Capacity* (bpd)
Mossel Bay GTL	South Africa	PetroSA	1992	30,000
Bintulu GTL	Malaysia	Shell	1993	14,700
Mossel Bay GTL Expansion	South Africa	PetroSA	2005	15,000
ORYX GTL Phase 1	Qatar	Sasol/Qatar Petrol	2006	32,400
Pearl GTL Phase 1	Qatar	Shell**	2011	70,000
Pearl GTL Phase 2	Qatar	Shell**	2011	70,000
Total Existing Capacity				**232,100**

Note: Capacity refers to large scale GTL plants (>10,000 b/d), excludes pilot and demo plants

**Refers to liquid fuels output capacity*

***Production sharing agreement with Qatar Petroleum*

Source: Company websites, various

Four years later, in 2011, the ORYX site was eclipsed both in capacity and project magnitude by Shell's 140 k/bd 'megaplant' Pearl GTL, similarly situated in Ras Laffan, Qatar.[5] The approximately $19bn project (reportedly the largest single investment in Shell's history) focused attention on the GTL industry. The facility's enormous upside revenue potential and product slate flexibility, courtesy of deeply discounted, high quality gas feedstock, acted as a lightning rod for investments in the GTL industry. The project ushered in an unprecedented wave of media attention, encouraged by demonstrations showcasing GTL diesel powering Formula 1 racing cars and GTL jet fuel powering flights from Doha International Airport to

[5] Total nameplate capacity is 260 kb/d with 120 kb/d of capacity dedicated to condensates; 140 kb/d is dedicated to liquid fuels output such as diesel, jet fuel, and LPG

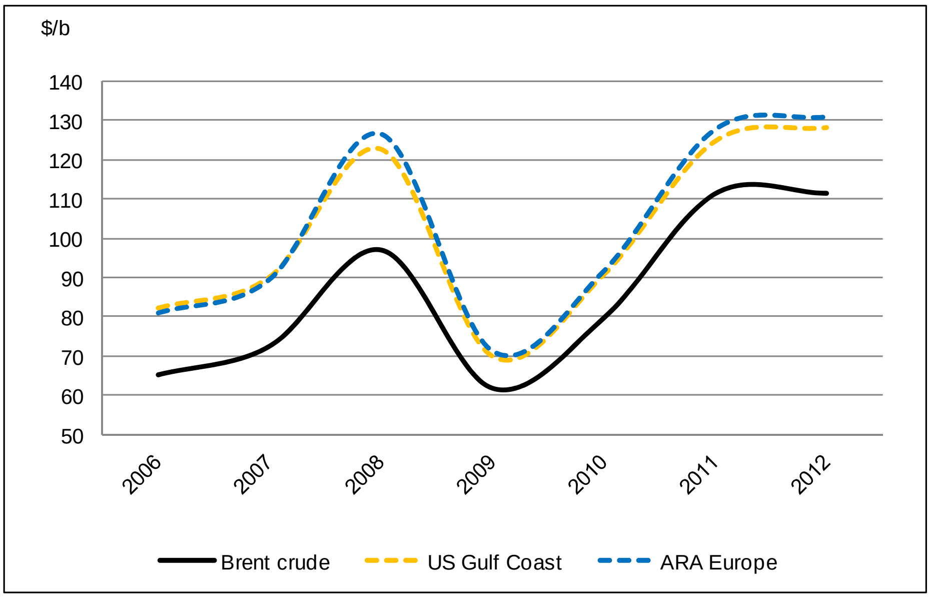
London. Supported by the broader context of retreating gas prices and rising oil and oil commodity prices, the demonstrations seemingly legitimized the industry's commercial viability, suggesting GTL's potential to develop as a viable substitute to oil-derived fuels in increasingly gas-oriented energy markets.

Product slate characteristics

The extraction of long-chain carbon compounds from synthetic gas during the Fischer–Tropsch GTL process (Figure I.1) inherently yields hydrocarbon chains whose molecular configuration corresponds to the physical properties of middle distillates such as diesel and jet fuel – consumed ubiquitously in the global transportation sector. Accordingly, the high portion of diesel in the product slate (up to 75 per cent) dictates that the revenue potential of typical GTL plants is driven foremost by the commercialization of GTL diesel in global commodity markets.

Commodity prices for transport fuels such as diesel are closely correlated to crude price movements (see Figure I.4) and, moreover, trade at a premium to crude benchmarks depending on regional dynamics such as product balances and cyclical demand conditions. GTL products sharing identical physical characteristics with crude-refined diesel have the potential to exploit not only the market price differential between gas feedstock and oil prices but, in addition, the spread between oil benchmark prices and oil product markets. The confluence of these dynamics leads to significantly wider margin potential than that experienced by crude-refined alternatives in oil product markets, at least in a context defined by high oil and low gas prices. Accordingly, the upside revenue potential of large-capacity GTL builds is dictated by the relatively straightforward principle that the more capacity dedicated to products trading at a premium to crude a plant has, the higher the plant's revenues will be.

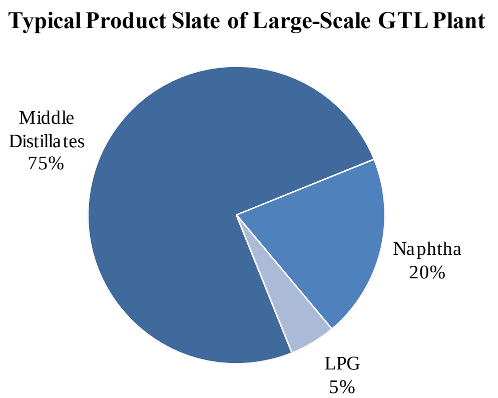
Figure I.4: Correlation between ultra-low sulphur diesel spot prices and Brent crude

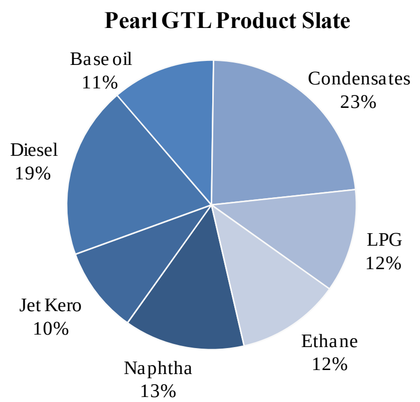


Source: EIA, Bloomberg. f.o.b. spot prices for ARA ULSD and USGC Diesel 2.

As with crude-derived liquid fuels, the quality of the feedstock plays a vital role in influencing the value of the product yield, and not all GTL plants have the same revenue potential by virtue of their feedstock and resulting product slate. “Depending on the gas wetness, the type of petroleum product sold from the GTL could vary widely. [Shell’s] Pearl GTL has developed substantial condensates capacity [120,000b/d] to accommodate the liquid streams associated with the North Field gas. (PFC Energy, 2011). This provides the Pearl site with an even more robust product slate (see Figure I.v.b) than other existing, under construction, or proposed large-scale GTL builds (see Figure I.v.a), and by extension a more robust revenue potential on commodity markets.

Figure I.V: Product Slates





Source: Sasol and Shell project presentations and websites

Despite this versatile product slate, however, ‘the middle distillate and base oil products of Pearl GTL represent some 40% of the project’s volume [and] some 50% of the sales value’ (Gainsborough, 2009). Given the large emphasis on diesel fuel and the necessary logistical and market considerations in commercializing GTL diesel, GTL plants have been characterized as valuable downstream assets in the portfolios of major oil and petrochemical companies. According to Shell:

> Pearl will leverage global supply chains and leading [downstream] marketing positions in fuels … to maximize the value derived from those products … the value of [Pearl GTL’s] product slate is comparable to the most complex refineries, but with no feedstock purchase costs. (Gainsborough, 2009)

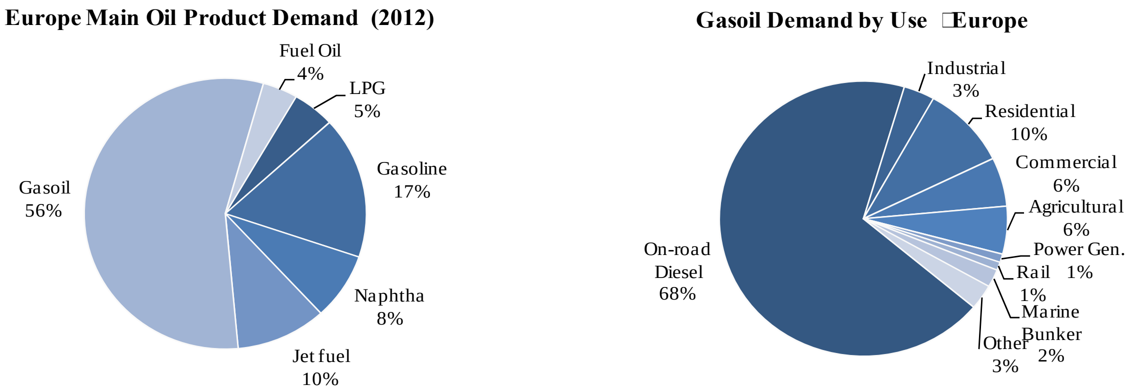
Part II: Commercialization of GTL Diesel

Europe: an ideal market context

Europe offers an ideal destination for GTL-derived diesel. A combination of stringent fuel quality specifications and declining domestic supply supports a healthy environment for gasoil and diesel imports. Moreover, the oil product market is predominately driven by gasoil/diesel consumption, which accounted for well over half (56 per cent, see Figure II.1.a) of main product demand in 2012.[6] As such, the current application and commercialization of GTL diesel in Europe reflects the potential of GTL diesel to impact global gasoil markets.

Gasoil, the middle distillate fraction of crude distillation, has a broad range of applications which span from road and off-road sectors to power generation and marine fuels (see Figure II.1.b). Diesel is often referred to, interchangeably, as gasoil, as it is a high cetane gasoil that readily ignites under compression in combustion engines. For this reason, diesel is consumed primarily in Europe's road transport sector in both passenger and commercial vehicles and accordingly constitutes the bulk of gasoil demand, at roughly 68 per cent in 2012.[7] As described below, the uptake of diesel over gasoline has been strongly encouraged and incentivized by national and supranational policies implemented across Europe over the past several decades in order to promote fuel economy and reduce greenhouse gas emissions. By 2012, diesel accounted for a dominant 70 per cent of Europe's motor fuel demand.[8]

Figure II.1: Europe's Oil Product and Gasoil Demand



Source: IEA, national sources, and PFC Energy

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[6] Source: IEA, national sources, and PFC Energy. Main products classified as gasoil, gasoline, jet fuel, naphtha, and heavy fuel oils

[7] Author estimate for 2012 based on IEA gasoil by use data. Other gasoil uses include home heating, marine fuels, industrial, and commercial sectors

[8] Excludes LPG and CNG consumption, which remains relatively minor on a Europe-wide basis despite strong uptake in specific European markets. Source, IEA and PFC Energy

Regulatory environment and tight fuel quality specifications

The transition to gasoil and diesel consumption in Europe has been hastened by EU legislation promoting the superior fuel economy offered by diesel combustion engines in its passenger and commercial vehicle fleets. In order to meet supranational carbon emissions targets, progressively tighter EU-wide Fuel Quality Directives have mandated a sharp reduction of sulphur content in gasoil/diesel marketed within the European Union. The specifications for sulphur content in motor fuels (gasoline and diesel) in the road sector were reduced from 350 parts per million (ppm) in 2000 to just 10 ppm in 2009. The legislation was amended in 2011 to encompass gasoil and diesel consumed in off-road sectors such as railways and inland navigation, and, by 2012, 10 ppm gasoil accounted for an estimated 80 per cent of Europe-wide gasoil demand.[9]

Structural diesel deficit and gasoil premiums

Meeting the increasingly tighter and broader-reaching sulphur specifications has put greater strain on Europe's refiners, exacerbating gasoil deficits and at the same time supporting higher spot market prices for gasoil and diesel imports. The gasoil produced by refineries in Europe has varying physical characteristics in terms of sulphur content (affecting particulate emissions), cetane index (influencing ignition quality in combustion engines), and viscosity (affecting energy content and fuel efficiency), each influencing market value. The inherent physical properties of crude-distilled middle distillates are rarely within the acceptable range of EU product specification guidelines, meaning that the fuels must undergo extensive processing and treatment before becoming marketable (domestic) fuels.

Compounding the problem, Europe's refinery configuration remains overly skewed towards fluid catalytic conversion (FCC) units designed to optimize the production of gasoline at the expense of on-spec middle distillates (notably diesel). The refining complex was constructed in the wake of World War II and expanded during Europe's economic boom years of the 1960's through 1980's when domestic product markets were dominated by gasoline. By the 1980's, however, supranational carbon legislation and Europe-wide policies began to promote the uptake of the superior fuel economy diesel combustion engines over gasoline, detaching domestic supply from demand trends and rendering product markets chronically 'short' on diesel and 'long' on gasoline. Domestic refiners mitigated the expanding product gap by

[9] Author estimates. Based on IEA demand by use data and fuel quality directives.

exporting gasoline surplus to markets in the Atlantic Basin, particularly to the structurally short north-eastern USA, while relying on imports to meet diesel and gasoil demand, offsetting the immediacy for investing in the expensive diesel-yielding hydrocracking conversion units. As a result, Europe's refining industry continues to be structurally mismatched for domestic consumption trends, mandating increasing gasoil and diesel imports.

The ongoing dieselization of passenger and commercial vehicle fleets in Europe combined with the increasingly tight sulphur specifications has sustained upward pressure on spot prices, particularly following rationalization of around 1.2 million b/d of refinery capacity across Europe since 2009. Spot market prices for imported ultra-low sulphur diesel (ULSD) and gasoil have seen continuous upward movement since 2009, creating a favourable context for imported GTL diesel as either a substitute, or as a blending component, for slightly off-spec refinery diesel.

From 2009 through 2012, the average annual spot price of 10 ppm diesel imported into north-west Europe's Rotterdam (ARA) hub increased from an annual average of $71.25/bbl in 2009 to $130.69/bbl in 2012. While this evolution is closely correlated to the trend of oil price rises over the same period, the gasoil/diesel market is also elevated by the deepening structural supply deficit of low-sulphur diesel. Accordingly, the premium of 10 ppm diesel against Brent crude markets has continued to widen, improving from an average of $9.51/bbl in 2009 to $19.06/bbl in 2012.[10]

GTL diesel as a neat[11] product or refinery blend stock

Given the premium enjoyed by ultra-low sulphur gasoil and diesel in Europe's product market, the inherently sulphur-free GTL diesel would appear to have robust commercialization opportunities within European markets. Nevertheless, the practical applications of the product remain relatively narrow. While GTL diesel has been showcased as running 'neat' in combustion engines, it is below the density/energy content requirement to be marketed completely as a pure motor fuel in Europe, meaning it must be blended with denser crude-refined gasoil or diesel. Accordingly, GTL diesel is commercialized primarily as a blend stock in Europe, allowing domestic refineries to enhance the qualities of their gasoil

[10] IEA, Bloomberg f.o.b spot prices for ARA 10 ppm diesel
[11] The term 'neat' refers to the fuel running without being blended with an oil-based fuel, a prerequisite typical of other alternative fuels such as biodiesel and ethanol.

and diesel pools in order to meet market specifications. Alternatively, foreign fuel distributors lacking domestic refining capacity can opt to blend GTL diesel into slightly off-spec product imported from foreign refineries to render a diesel/gasoil product marketable within Europe.

For European refiners, blending GTL diesel into existing refinery gasoil or diesel pools permits operators with inadequate conversion and desulphurization capacity to modify and add potentially significant value to their existing (but slightly off-spec) gasoil and diesel yields (see Table II.1). If a domestic refinery, for example, produces a diesel pool that has slightly higher than 10 ppm sulphur content (either due to insufficient conversion or desulphurization or to the physical characteristics of the crude run itself), the refiner may opt to blend the nearly sulphur-free GTL diesel into the existing diesel pool in order to lower the overall sulphur content of the refinery diesel pool. Alternatively, if the refinery's diesel pool is too viscous, or if its cetane number is too low to meet the European Union's mandated Fuel Quality Directives, refiners can blend GTL diesel to conform the overall diesel pool to mandated EU market specifications and boost diesel performance under certain conditions.

Table II.1: Physical Properties Comparison – Diesel

	F-T GTL Diesel	Refinery Diesel	EU Specification
Sulphur content	<5 ppm	~10ppm	10 ppm max
Cetane number (kg/m3)	>70	45–55	48–51
Density, 15°C	0.77	0.84	0.82–0.84

Source: Center for Global Energy Studies (2005), EU Directive 2009/30/EC

Because the diesel pool of a refinery is a blend of the various 'streams' of gasoil from the different distillation, conversion, and treatment units in the refinery, the physical characteristics of the gasoil or diesel from each of these streams can vary greatly (see Table II.2). This offers different opportunities in the refining process, based on the specific characteristics of the gasoil or diesel stream, to blend GTL diesel.

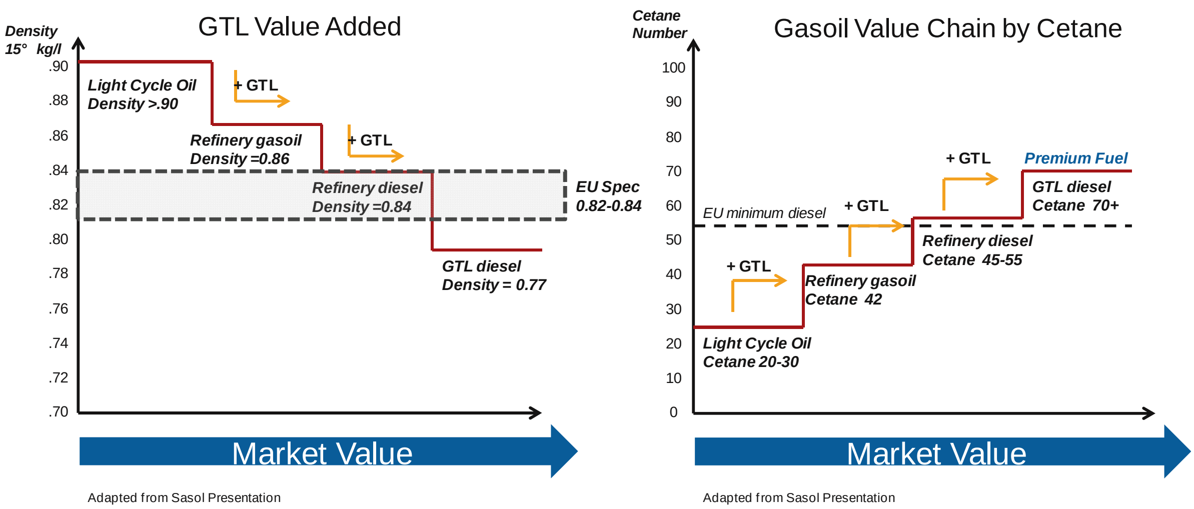
Table II.2: Physical Properties and Blend stock Opportunities

	Typical Light Cycle Oil (LCO) from FCC	FT GTL Diesel	Refinery Gasoil	Refinery Diesel	EU Specification (Euro V)
Sulphur content	10,000	<5 ppm	50-2,000	>10ppm	10 ppm
Cetane number (kg/m3)	20–30	>70	<42	45–55	48–51
Density, 15°C	0.90–0.96	0.77	0.86	0.84	0.82–0.84

Source: Center for Global Energy Studies (2005), PFC Energy, EU Directive 2009/30/EC

Typically, the low quality light cycle oil (LCO) from the FCC is rerouted toward heavier grade gasoil production, such as heating oil and marine gasoil, or alternatively blended with heavier fuel oils, rather than undergoing further processing. Each of these 'heavier' products has less stringent sulphur and cetane requirements, which translates into a lower market value (Chevron, 2007). On the other hand, the 'straight run' refinery gasoil or diesel derived directly from crude distillation may need only minor treatment for use as an on-road (Euro-V) diesel fuel, depending on the quality and physical characteristics of the crude slate (Chevron, 2007). In order to make the slightly off-spec straight run diesel compatible with regulatory specifications and combustion engine performance guidelines in the road sector, volumes of GTL diesel can be blended into the pool of straight-run diesel (see Figure II.3). In addition, diesel that is cracked from distillate conversion units may need only minor upgrading – in terms of reducing sulphur content or boosting cetane content – to attain the road sector minimum specification of 51 (see Figure II.2), providing another opportunity for GTL diesel as a blend stock to add value to the refinery yield.

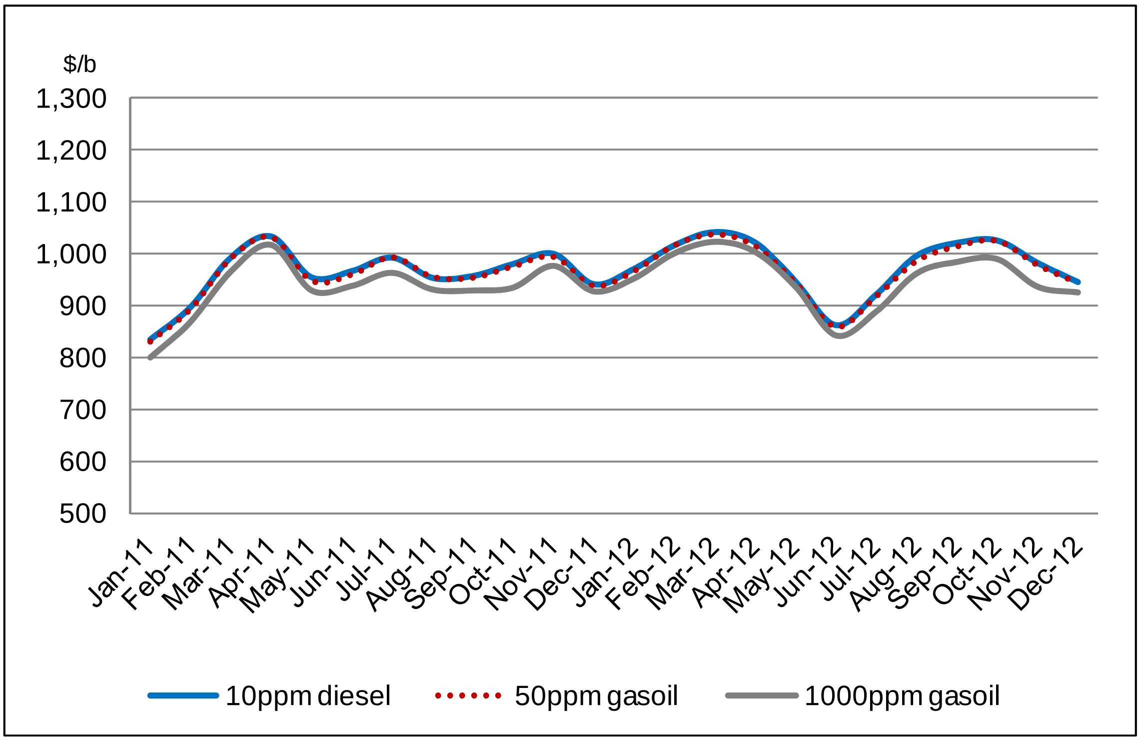
Figure II.2: Adding value to distillation products



Optimal commercialization: sulphur vs cetane premium

The different physical characteristics of gasoil yields translate into disparate market values, which are dictated foremost by the cetane and sulphur content of the gasoil/diesel yield and its corresponding marketability. The physical properties of the yield influence the optimal point in the refining process (more specifically in which gasoil pool) where GTL can be blended in order to achieve the greatest market value for the given yield of gasoil or diesel. In general, sulphur-free high cetane diesel marketed at retail pumps as *premium* diesel (cetane content above 51) earns the highest market value due to its price premium advantage (consequently earning higher margins at the pump relative to typical on-spec road diesel). Higher sulphur, low cetane gasoil used in heating oil and marine bunkers, on the other hand, earns a relatively low market value (Figure II.3).

Figure II.3: Gasoil Spot Price by Sulphur Content (Europe ARA f.o.b.)



Source: Bloomberg f.o.b. spot prices Europe ARA.

The progressively tighter sulphur content limits for diesel fuels have focused attention on differentials in market values between the mandated 10 ppm sulphur diesel and higher sulphur gasoil and diesel markets. As discussed above, the structural conditions within Europe's product markets have resulted in climbing premiums for low-sulphur 10 ppm gasoil and diesel as refiners struggle to render the product, due primarily to insufficient conversion. At the same time, however, the premium for higher sulphur gasoil used in other sectors has mirrored the spot market movements of 10 ppm diesel (Figure II.4). This tight correlation suggests that premiums on European gasoil/diesel markets are driven primarily by the tightness in overall gasoil supply, rather than by the specific quality of the gasoil’s sulphur content. Accordingly, the highest market value from GTL commercialization is likely to come from blending it with existing refinery diesel pools in order to render a high cetane premium diesel offering that commands a steep relative pricing premium in the market.

Part III: Global Capacity Development

The relatively limited commercial applications of GTL diesel, combined with the industry's negligible product output capacity relative to global transport demand, suggests that GTL has only a limited potential to impact global transport markets. In order to support significant GTL capacity expansion that is independent of heavily subsidized gas pricing, and facilitate GTL inroads into the global transport sector, a wide differential between oil and gas spot market prices must be sustained in the long term.

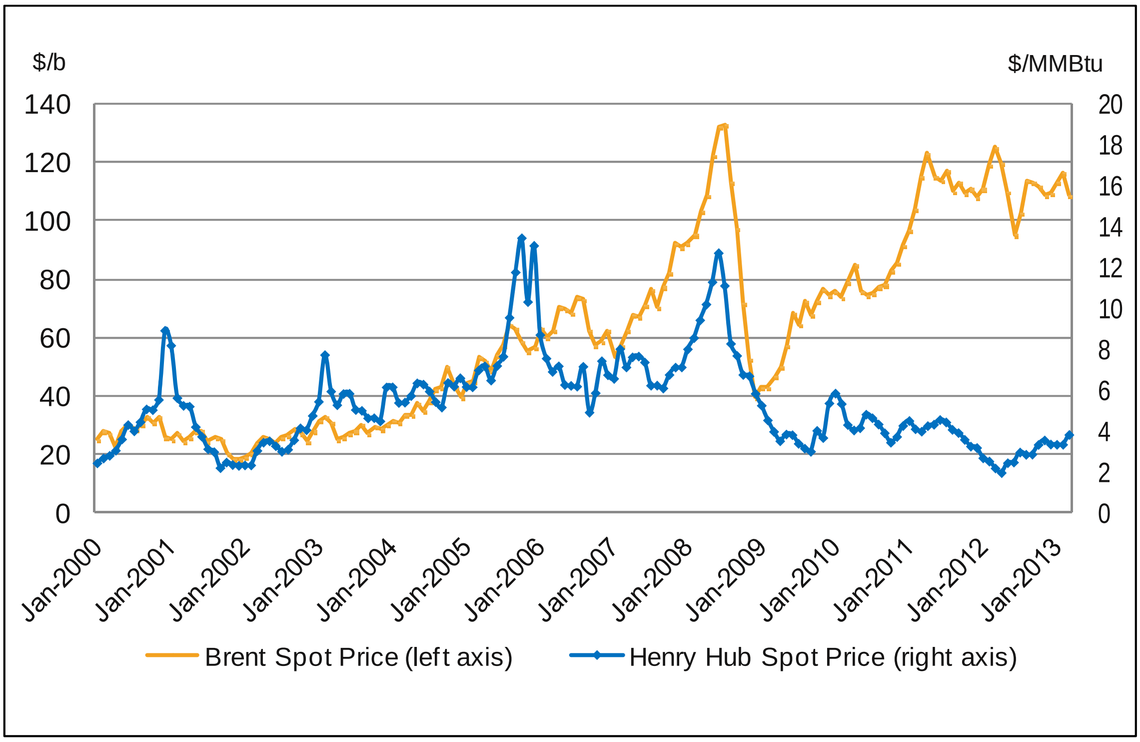
Prerequisite economic conditions for the support of large-scale GTL capacity

The challenging economic constraint of balancing pricing movements in two increasingly detached commodity markets (see Figure III.1) poses a serious threat to the proliferation of GTL liquid fuels moving forward. Industry analysts along with the Energy Information Agency (EIA) suggests that project economics for the type of large-scale plants championed by Shell, Sasol, and Chevron become uneconomic when oil benchmarks fall below $110/b and gas feedstock costs exceed $4 per million British thermal units (MMBtu). In other words, for a large-scale greenfield GTL project of average relative capital investments costs and product capacity output, oil spot prices must maintain a multiple of over 25 times the spot price of 1 standard unit (1 MMBtu) of natural gas procured as feedstock in order for the plant to render the project economically viable.[12]

Due to volatility in both oil and gas markets, however, this is a risky proposition. Over the past five years, pressure from the global economic recession, geopolitical turmoil in north Africa and the Middle East, the advent of hydraulic fracturing, and a boom in unconventional gas and oil supply have each ushered in significant unpredictability and volatility in oil and gas markets. Over the period 2008–12, the multiple of Brent crude benchmark prices to North America's Henry Hub (HH) gas spot market (see Figure III.2) varied from a factor of just 7 when oil prices bottomed out in December 2008 (at a time when the HH prices were relatively buoyant at around $6/MMBtu) to a multiple of 61 when oil reached $120/b in early 2012 and HH prices fell to under $2/MMBtu).

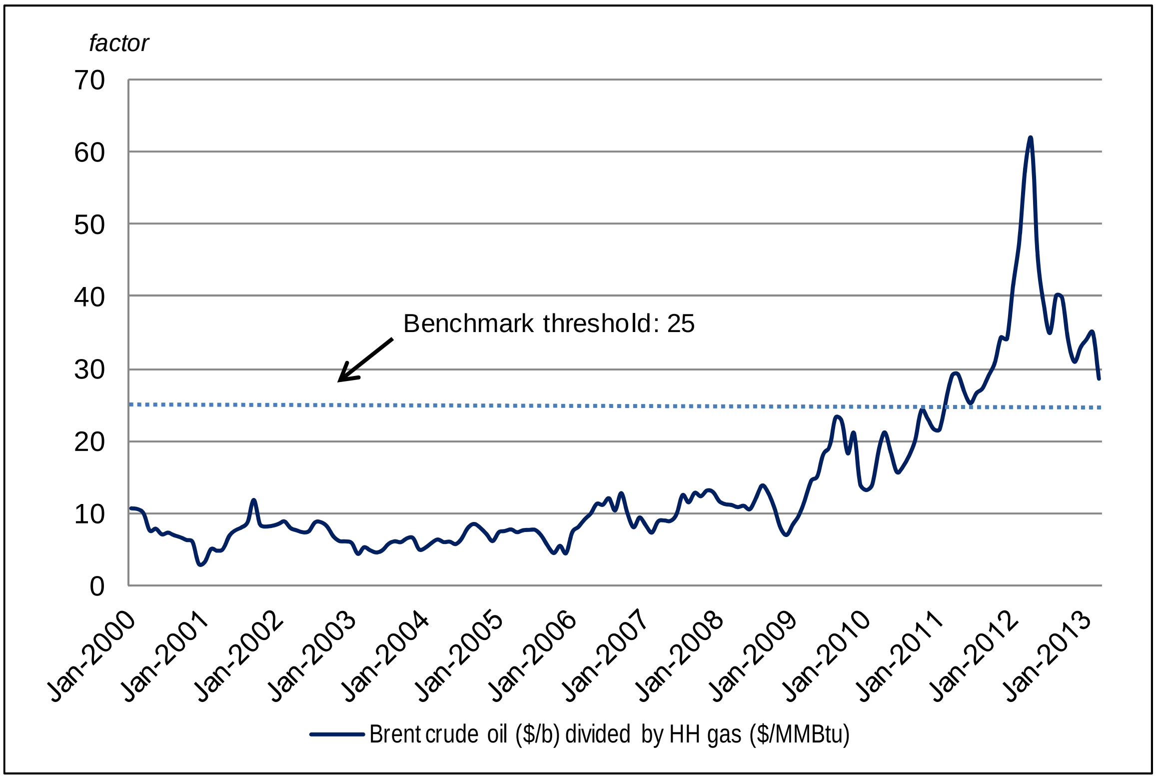
[12] 'Gas-To-Liquid (GTL) Technology Assessment in support of AEO2013', presentation by the Energy Information Agency, 2012. www.eia.gov/oiaf/emdworkshop/pdf/AEO2013_GTL_Assessment.pdf

Figure III.1: Brent crude spot price vs. Henry Hub spot price (2000–13)



Source: EIA Monthly averages.

Figure III.2: Crude oil (Brent) to natural gas spot ratio (2000–13)



Source: EIA Monthly averages.

Financing large-scale capacity builds is a compelling proposition when market prices for gas linger at \$2–3/MMBtu and oil benchmarks hover comfortably above \$100/b, as was the prevailing scenario over much of 2009–12 (Figure III.1). This position was lent further support by the increasing detachment of oil and gas prices via the de-indexing of gas contracts to oil prices over the same time period. However, the rationale for GTL conversion erodes as the oil/gas pricing differential narrows, due to cyclical and/or structural factors in either gas or oil markets, which compounds the element of volatility facing GTL economics. Accordingly, the growth potential and actual materialization of global GTL capacity moving forward will be determined foremost by the duration and sustainability of gas and oil prices on global spot markets and the ability of prospective GTL operators to secure 'cheap' natural gas in the absence of subsidized feedstock procurement arrangements.

Global Capacity Outlook

In a sustainable market scenario that supports a sufficiently wide spread between natural gas and oil benchmarks, the bulk of future GTL capacity additions by volume are anticipated to come from the development of three proposed large-scale GTL plants. In the short term (2013–15), global capacity is expected to expand by 30 per cent (or 72 kb/d) following the slated completion of projects underway in Nigeria (2013) and Uzbekistan (2016/17) as Table III.1 shows. Through 2020, an optimistic materialization of large-scale plants which are currently proposed and past the feasibility study stage could see global GTL product output capacity expand by 75 per cent on 2012 levels, reaching approximately 400 kb/d.

Table III.1: Firm proposed large-scale GTL capacity outlook

Plant name	Country	Operator	Proposed completion	Nameplate Capacity (bpd)
Escravos	Nigeria	Chevron/NNPC	2013	34,000
Oltin Yo'l GTL	Uzbekistan	Sasol/UNG/Petron	2017	38,000
Sasol Louisiana	USA	Sasol	2018–19	96,000
Firm Proposed GTL Capacity*				**168,000**
Existing capcity at end-2012				**232,100**
Potential global capacity 2020				**400,100**

**Projects past the feasibility study and in FEED process*

Note: Capacity outlook excludes modular GTL developments, pilot and demo units

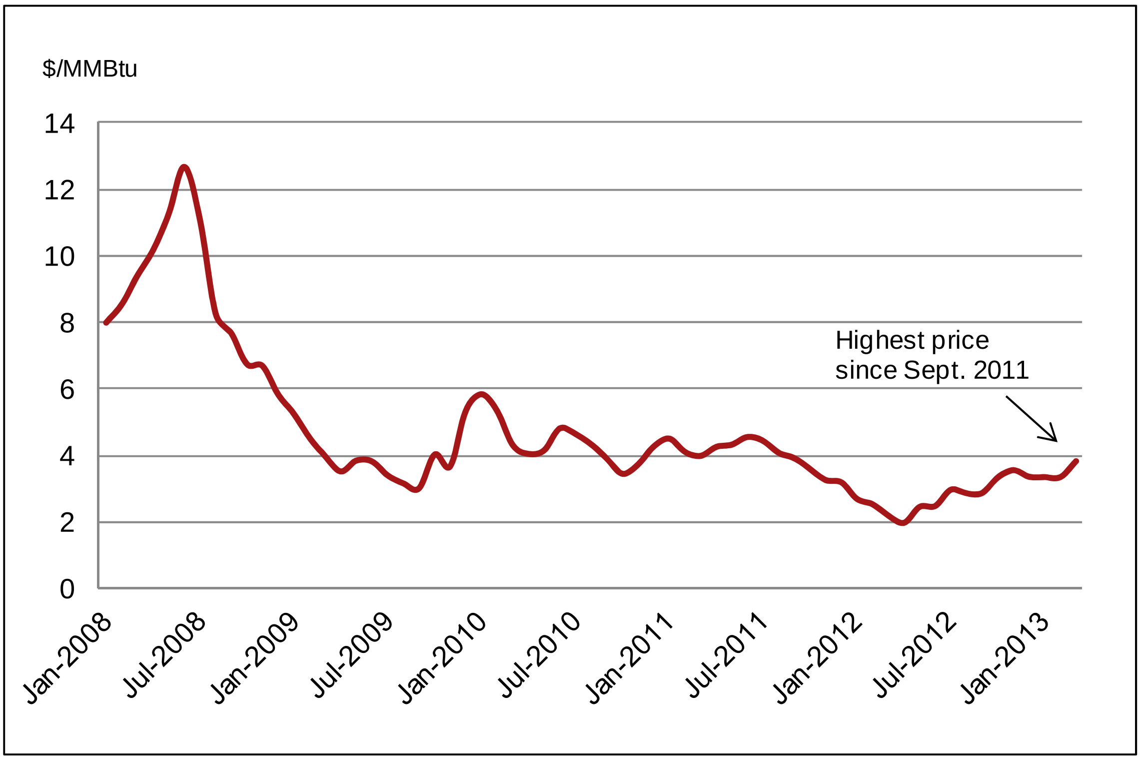
Source: Project websites

As indicated in Table III.1, the bulk of capacity additions (134 kb/d) through 2020 are anticipated to come from Sasol. Unlike Shell and Chevron, the pure-play synthetic fuels company has aggressively targeted large-scale GTL opportunities in North America, as opposed to locations in gas-rich basins in Nigeria, the Middle East, and Caspian Sea region where GTL sites are more likely to benefit from heavily subsidized gas prices and large gas reserves.[13] Sasol has announced plans to construct and operate a 96 kb/d GTL plant at Lake Charles, Louisiana by 2018/19 primarily to produce transport fuels, in addition to high-value petrochemical products. If materialized, the site will represent the second largest GTL facility in the world behind Pearl, and more importantly it would be the first large-scale site intended to leverage predominantly structural market developments within North America’s gas market to support project feasibility.

Underlying this project, Sasol executives contend that opportunities for US GTL are advantaged by a favourable long-term oil/gas pricing ratio in North America, citing the Energy Information Agency (EIA) in forecasting that crude oil multiples (Brent) to natural gas prices (Henry Hub) will remain above a factor of 20 throughout 2040, presumably supporting the project’s economics (Sasol, 2013). Nevertheless, the recent deterioration of the gas and oil price differential casts legitimate doubt on the prospects of North American large-scale GTL builds in a longer-term scenario. By March 2013, Henry Hub gas prices in North America had increased to \$3.80/MMBtu, the highest price level seen in 18 months (see Table III.3). Brent crude benchmarks continued to converge downward towards the \$100/barrel market (see Table III.4), with deep inland crude discounts on North America WTI poised to put even further downward pressure on crude commodity and futures markets. Year-on-year, the crude oil to natural gas price ratio has eroded from a healthy 57 in March 2012 to a troubling 28 in March 2013 (see Table III.2). In the medium term, the advent of US LNG exports is also poised to apply upward pressure on North American hub prices, further threatening large-scale project economics in North America.

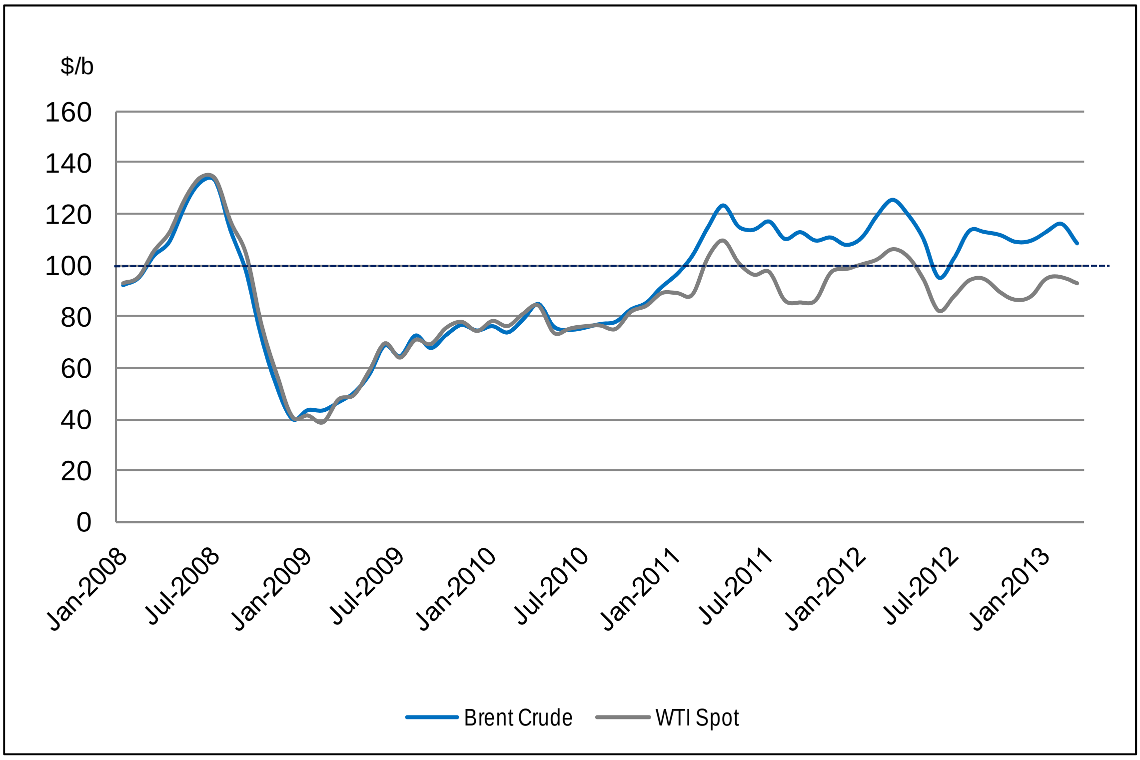
[13] Oltin Yo'l is the exception, but the company’s plans for two plants in North America (Louisiana and Alberta, Canada) with a combined capacity of 192 kb/d, would far eclipse Oltin Yo'l.

Figure III.3: North America Henry Hub Gas Price Evolution



Source: EIA.

Figure III.4: Crude Market Evolution



Source: EIA.

Large Scale vs Modular GTL

Despite dual forces exerting opposing pricing pressure on oil and gas markets, GTL capacity is relatively certain to increase from 232 kb/d at the end of 2012, to just over 300 kb/d by 2015. Nevertheless, post-2015 developments appear increasingly unlikely, as structural fundamentals apply unfavourable downward pressure on oil markets and upward pressure on gas spot markets. Moreover, the disparate proliferation of new natural gas reserves, courtesy of a boom in unconventional gas, favours a shift towards more localized solutions (particularly in North America) rather than large-scale developments which require, and seek to exploit, massive gas reserves.

As exploration and production activities shift in favour of unconventional gas and oil resource plays, GTL commercial developments have already started to capitalize on this trend via smaller-scale ‘modular’ plants. Unlike their large-scale counterparts, modular GTL plants have product sendout capacities of just 1–3 kb/d and are typically associated with monetizing small or stranded gas fields and otherwise flared gas lacking viable alternative monetization options (Baxter, 2012).

An emerging type of F–T based GTL solution monetizes associated natural gas by converting it into high-quality synthetic crude oil at the wellhead. The F–T derived synthetic crude oil is subsequently mixed with the naturally produced crude and delivered to market in the oil barrel. This solution is employed primarily to unlock oil field value rather than to convert natural gas reserves into liquid fuels for use in transport and petrochemical sectors, which marks a significant paradigm shift in gas monetization through the F–T GTL process.

Alternatively, a second and emerging type of modular GTL plant links up with downstream producers who have limited amounts of cracking and conversion capacity already installed, in order to yield limited amounts of liquid fuels and speciality products on a local basis. This option is of increasing appeal to smaller North American speciality products producers in close physical and logistical proximity to shale plays, allowing the producers to capitalize on low-cost gas feedstock runs as an alternative to crude oil.[14]

[14] ‘Calumet turns crude oil into waxes and white oils, and then into personal care and pharmaceutical products. Velocys is planning to provide Calumet with technology to use gas instead of expensive crude oil. That same process can turn gas into liquid fuels, such as gasoline.’ (Puko, 2013)

The future employment of the F–T GTL process will ultimately be influenced by a multitude of factors; these include the plant's proposed location, the quality of gas sourced, the capital investment capabilities, and perceived market conditions both in oil and gas markets. The emergence of modular GTL – given the broader economic constraints affecting large-scale GTL developments – has significant implications for the impact of F–T GTL liquid fuels in transport markets going forward, suggesting a more dispersed and limited proliferation of GTL liquid fuels by volume.

Conclusion

Potential of GTL to impact oil product markets

While Fischer–Tropsch based GTL is a technologically feasible option for diversifying natural gas monetization opportunities, its implementation on a scale large enough to impact the hegemony of oil-derived liquid fuels in global transport markets is undermined by significant economic, and to a lesser extent commercial, constraints. The favourable context between 2009 and 2012 that was driven by plummeting natural gas prices and stubbornly high oil prices temporarily supported potential for the GTL industry to offer a seemingly viable substitute for crude-derived liquid fuels. However, this context has more recently shown signs of deterioration, due to structural factors in both oil and gas markets, rapidly undermining the rationale for large-scale GTL projects.

As the GTL industry itself adapts to developments in natural gas supply, it will rationally seek smaller and more dispersed GTL options that carry a limited capacity to deliver liquid fuels to transport markets. This paper posits that the confluence of narrowing gas and oil price differentials and the advent of modular GTL units is sufficient to derail momentum in the large-scale GTL industry, whose existing supplies will remain niche, but high value, components primarily in diesel import markets. As such, the current optimism surrounding the GTL industry as a viable alternative to crude-derived liquid fuels in the global transport sector is overstated, and the further development of large-scale GTL capacity will fail to usher in a significant transformation of oil product markets for transport fuels, on either a European or global basis.

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