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The impacts of a GTL plant on Brazil's oil products supply and refinery expansion

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Abstract

This paper assesses the impacts of a GTL plant on the expansion of Brazil's oil refining segment. The GTL plant (50,000 bpd) was sized to start up operations in 2015, producing diesel and naphtha through the indirect route (FT-synthesis). This plant will consume the non-associated natural gas production from the recent discoveries at the Santos Basin (around 419 Bm^3), and the associated gas production from the Campos Basin. Both basins are located in the Southeast of Brazil, the most populated, rich and industrialized region of the country. Two different criteria for refinery expansion were simulated in order to meet oil product demand scenarios. Findings show that depending on the refinery expansion criteria considered GTL will play a fundamental hole to meet the oil product demand forecast to Brazil in the next 10 years.

Keywords: GTL; Oil refining in Brazil; Oil products market; Oil supplies

1. Introduction

Brazil is a continent-sized country with the world's fifth-largest population (177 million inhabitants in 2002) clustered in urban centers where road transportation predominates.

The country's gasoline and diesel consumption has risen by 5.5 and 4.1% p.a., respectively, since 1990, while fuel oil used by industry has remained virtually unchanged [1]. Actually, during the 1990s, Brazil's oil demand growth (4.9% p.a.) was only smaller than China and India (respectively, 7.2 and 4.9% p.a.), while considerably higher than the world average (1.2% p.a.) [1]. In addition, the country's oil market growth affects the Atlantic Basin.

For the oil products and fuel market, Brazil has also important specificities, related to its preeminence in the bio-fuel use (particularly ethanol). This affects the country's gasoline market, but also it is an example for countries intending to expand the use of bio-fuels.

However, as domestic output has not been sufficient to meet oil product demands in Brazil, particularly for diesel, LPG and petrochemical naphtha, imports of these products have been required to supplement this output. Particularly noteworthy is the increase in diesel imports (11% p.a.) over the past 10 years, outstripping the average growth rates for all imports [1]. Consequently, if Brazil maintains its economic growth, in parallel to the steady increase in its crude output, it will become a net low-grade crude exporter and a net importer of white oil products (diesel, naphtha and LPG).

In this sense, Brazil is reaching a bottleneck on its capacity for supplying the oil products market, owing to the consumption growth rate of key-fuels like diesel, which presented high level of dependence in the last 2 decades [1].

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Simultaneously, Brazil has been increasing its oil production, but the country's existing refinery park is not adapted to process crude inputs increasingly heavier and acid [2].[1]

In sum, Brazil is a net importer of diesel. Although the country's existing refineries are been converted to face the quality reduction of the average processed crude and the oil product market change towards medium cuts, these refineries might not be able to respond to the diesel market growth. Moreover, the increasing specification of the diesel supplied to the domestic market poses new challenges to the Brazilian oil industry. In this case, refinery expansion or investment in a GTL plant might be needed.

Therefore, this paper assesses the impacts of a GTL plant on the expansion of Brazil's oil refining segment. It derives from two recent studies undertaken, respectively, to the Ministry of Mines and Energy of Brazil [1], and to the Brazilian Institute of Petroleum [3].

The GTL plant will consume the non-associated natural gas production from the recent discoveries at the Santos Basin (around 419 Bm^3) [4], and the associated gas production from the Campos Basin. Both basins are located in the Southeast of Brazil, the most populated, rich and industrialized region of the country. To forecast Brazil's natural gas production, we followed two different paths:

- For the associated gas production, we adjusted a Hubbert curve for the oil production and kept the country's typical associated gas-to-oil ratio from the last decade. For the Hubbert curve, this study considered a cumulative probability of 75%, in order to estimate the ultimate recoverable oil reserves (EUR). This lead to a EUR of 41 Gb.
- For the non-associated gas, we built a typical field curve for the Santos Basin development and production estimates. In this case, we used only 18.6% of the estimated Santos Basin natural gas possible reserves. This proportion represents the last proven figures for this basin [4].

As can be seen (Table 1), Brazil's natural gas available production is expected to increase in the next 2 decades.

However, to use all this increased gas production huge investments are needed in pipelines and appliances. In addition, Brazil electric power generation is based on large hydropower plants, which reduce the market-share for natural gas. As mentioned before, Brazil is a net importer of diesel and Brazilian refineries are reaching their bottlenecks. In this case, the expansion of diesel and petrochemical naphtha supplies through a GTL should be assessed. To compare GTL and new refinery investments, this paper will sketch a GTL plant and three refining schemes to supply the oil products market expansion in Brazil.

[1] Brazil's refinery park includes 13 refineries totaling 2008 (1000) barrels per calendar-day in 2003.

Table 1
Natural gas production (Mm^3/day)

	2002	2010	2015	2020
Associated gas	33.1	53.3	67.7	73.6
Non-associated gas				
Santos Basin	0.0	40.3	58.2	47.0
Other basins	9.4	21.0	14.0	7.0
Total	42.5	114.6	139.9	127.6
Losses and injection (applied to associated gas)				
Injection	9.3	13.3	16.9	18.4
Losses/burn-offs	5.8	5.3	2.7	2.2
Available production (Mm^3/day)	27.4	95.9	120.3	107.0

Source: ANP [12], for 2002; Schaeffer et al. [3], for other years (projections).

2. Scenarios of oil products demand

Two different scenarios for the Brazilian oil products demand were elaborated: a ''Business-as-Usual Scenario'' (BAU Scenario, hereafter) and an ''Alternative Scenario''. As a matter of fact, those scenarios derive from a former study performed by some authors of this paper to the Ministry of Mines and Energy of Brazil [1].

Basically, the conceptual difference between these two scenarios lies in the assumptions considered for sectoral growth, intra-sectoral product mix, interfuel substitutions and energy efficiency gains. In the BAU Scenario, as a matter of fact an update of MME [5] and MPOG [6], sectoral growth, intra-sectoral product mix, interfuel substitutions and energy efficiency gains (basically through replacing consumption equipment) follow business-as-usual trends. The Alternative Scenario, although based on the same macroeconomic scenario, assumes a shift toward higher value added economic activities, intra-sectoral product mix upgrade (also higher value added), equipment substitution programs as part of energy efficiency policies, intermode substitution in the transportation sector and higher penetration of more environment-friendly energy sources. The rationality of such scenario is to make good use of Brazil's current and potential competitive advantages, which was elaborated mainly according to special studies performed for the Brazilian Government, such as Bonelli and Gonçalves [7], EMBRAPA [8], Giambiagi [9] and Coutinho et al. [10]. Finally, the Alternative Scenario includes an uptick in Brazil's social inequality indicators (more specifically, the Gini Index) which leads to a relative drop in the consumption of traditional energy sources by low-income rural households, compared to the BAU Scenario.

Obviously, for the horizon of the single decade, the differences between these scenarios are incremental, although important. Both scenarios are based on the same GDP growth rate for 2003–2015, which is derived from a study performed for the Ministry of Planning, Budget and Management of Brazil [11]: 4.26% per year from 2005–2010 and 4.11% per year from 2010–2015. The

Table 2
Demand growth rate by oil product (percent per year)

	2002–2005	2005–2010	2010–2015	2002–2015
Business-as-Usual Scenario				
LPG	0.44	1.84	2.11	1.62
Gasoline	0.73	0.28	1.80	0.97
Kerosene	5.35	3.75	4.92	4.57
Gasoil	1.51	2.97	2.27	2.36
Residual fuels	1.16	3.65	3.72	2.22
Fuel oil	−6.09	1.54	1.15	−0.42
Coke	8.52	5.14	5.23	5.94
Naphtha	2.08	2.75	2.89	2.65
Alternative Scenario				
LPG	0.26	1.68	1.94	1.45
Gasoline	0.48	−1.86	−0.65	−0.86
Kerosene	5.99	6.25	6.27	6.20
Gasoil	1.96	2.54	1.50	2.00
Residual fuels	0.55	2.38	1.98	1.59
Fuel oil	−6.48	0.77	−0.49	−1.43
Coke	7.72	3.56	3.52	4.49
Naphtha	2.10	2.06	1.91	2.01

Note: Residual fuels include fuel oil, coke and other oil products.

Table 3
Estimated production profiles for Brazil's current refining segment, as shown in the modeling (%)

	2001	2010	2015
LPG	8.1	8.9	9.1
Gasoline	19.5	21.9	23.8
Naphtha	10.5	11.3	9.6
Kerosene	2.6	5.4	5.9
Gasoil	36.4	40.7	41.6
Fuel oil and coke	22.9	11.9	10.1

Source: Schaeffer et al. [2].

Table 4
Production profiles for new refining schemes as shown in the modeling (%)

Capacity (39,746 m^3/day)	
LPG	9.5
Gasoline	34.1
Naphtha	5.3
Kerosene	0.0
Gasoil	44.6
Fuel oil and coke	11.6

macroeconomic development of the Alternative Scenario for the market and its energy policies do not cause any drastic changes to the current and trend profiles for Brazil's economic development.

According to those scenarios [1], total oil products demand increases from 286,602 m^3/day in 2002 to 380,338 m^3/day in 2015 in the BAU Scenario and to 352,077 m^3/day in 2015 in the Alternative Scenario. In order to provide a better sense of such findings, Petrobras [4], the major oil company in the Brazilian market (it still holds 98% of refining industry in Brazil), forecast a total oil products demand growth rate of 2.3% per year in the period 2003–2010. Taking the same period for comparison, this study's oil product demand projections are very close to Petrobras demand forecast: 2.7% per year for the BAU Scenario and 2.2% per year for the Alternative Scenario. Table 1 summarizes demand growth rate by oil product for both scenarios.

As shown in Table 2, the differences between the fuels market findings for the two simulated scenarios indicate possible strategies that would allow Brazil to meet its fuels demands. Particularly through energy policies encouraging fuel conservation and wider use of alternative sources, such as ethanol and biodiesel and CNG/VNG for heavy vehicles in 2015, the Alternative Scenario indicates a total oil products market some 7.4% smaller than the base scenario—market. For gasoil produced from petroleum, this difference reaches 4.4%,[2] 21.3% for gasoline; 1.5% for LPG.

3. Technical options for expanding the oil product supply in Brazil

To evaluate the expansion of oil product supply in Brazil, in order to meet the market growth presented in the last section, three technical options were assessed in parallel:

- Firstly, we estimated the impacts of the short-term planned investments in the existing refineries, in terms of their average yield.[3] These investments will change the conversion capacity of the existing park. Table 3 presents the evolution of the average yield of the existing refineries, according to our estimates.
- Secondly, one basic refining scheme was drawn up focused on gasoil whose optimum yields are presented in Table 4. We also considered that fine-tuning of the proposed refining scheme may vary, according to market demands and the variations in the oil processed.
- Finally, as an alternative source of supply, a GTL plant was proposed, absorbing part of the increased natural gas output from the Santos Basin.[4] This plant was modeled on the basis of the indirect production route. It costs round 1.5 billion dollar with an installed capacity of 50,000 bpd of output. It consumes 8500 ft^3 of natural gas per barrel of

[2] The total gasoil market includes gasoil made from crude or natural gas (GTL plant) and biodiesel. Looking at this total gasoil market, the difference between the two scenarios alters to 6.3%, due to blending 5% biodiesel with oil-based diesel.

[3] A model for the "average" Brazilian refining park was used. This model rebalances mass flows, integrating all Brazilian refineries in compliance with five different oil crudes and a basic scheme. In this case, it is assumed that the overall optimum level for this segment is compatible with the optimum level of each refinery, which tends to occur in segments that are controlled largely by a single enterprise [13]. This is exactly the case of Brazil, whose refinery sector is largely controlled by a single company.

[4] The non-associated gas production of this basin is expected to start by 2007.

output. The natural gas derives from the domestic production, and is priced at US$ 1.0–1.5/MMBTU during the period under analysis. The GTL plant is focused on diesel (the key oil product impacting the country's energy trade), yielding 70%. In addition, the diesel produced by this plant has excellent specifications, especially for sulphur contents (null), aromatics contents (less than 1%, w/w) and ketane number (more than 70). It also presents higher hydrogen content than the conventional diesel, allowing lower combustion temperatures and, consequently, lower NO_x emissions.

4. Expansion criteria

Two criteria were adopted for expanding oil products supply in Brazil.

1. The initial criterion (energy vulnerability) refers to the logic of minimizing the energy vulnerability of the oil chain. In this case, two expansion scenarios are analyzed for each oil products market scenario: one for self-sufficiency in gasoil (no gasoil imports) and the other for a gasoil imports ceiling set at 20% of the total market for this oil product in 2010 and 2015.
2. The second criterion (minimum processing) is designed to boost the profitability of domestic oil production. This is worthwhile in the case of Brazil, bearing in mind that the Brazilian oil is largely non-conventional (acid/heavy). In this case, there are once again two expansion scenarios for each oil products market: one for total processing of an equivalent volume of oil produced in Brazil; the other for a processing/production ratio of 80%.

5. Impacts of a GTL plant on oil products supply

BAU Scenario indicates expansion of Brazil's refining segment by up to three refineries. However, given the criteria, the results vary from no additional refinery, other than the expansion planned for the current facilities (criterion of maximum gasoil imports for 20% of the total market, with the installation of a GTL plant in 2015), to three new refineries optimized for gasoil, two in 2010 and one in 2015 (processing all oil produced in Brazil).

Consequently, if the expansion criteria are focused mainly on energy security, expansion through gasoil refineries is not necessarily the most appropriate outcome, and the possibility of setting up a GTL plant should be assessed. Although this plant is less versatile than the gasoil refinery proposed here, with ample coking and HCC capacities, in addition to a lower refining margin than the gasoil refinery, the investments in the GTL plant are some 50% of the amounts required for the new refinery. In a scenario where capital for heavy investments is limited, or with high interest rates, the GTL solution may be the more robust. Consequently, these findings suggest that more detailed studies are required for the introduction of GTL technology into the gas and oil chain in Brazil.

On the other hand, if the criteria are designed to add value to Brazil's crude output through highly versatile refineries, the ''100% processing'' may be indicated. In this case, where expansion takes place through three refineries (total investments of around US$ 9 billion), it is worthwhile noting that:

- Expansion on this scale may be justified only through refineries with high conversion capacities and high versatility.
- There are prospects for gasoil shortages over the short term in Southeast Asia and Western Europe.
- There are also prospects for broadening price gaps between light and heavy acid oils over the short term, encouraging investments in complex, versatile refineries with high operating margins.

For the Alternative Scenario, the previous results remain almost unchanged. However, the more sluggish oil products market growth indicates that the energy security criteria (self-sufficiency in gasoil or import levels at 20% of this oil product) are more affected by the GTL plant coming on-stream, simply because the gasoil market is smaller in the Alternative Scenario. As there are uncertainties about the future oil products market in Brazil, particularly the gasoil market, these findings show the advantage of drawing up robust planning for the expansion of the refining segment in Brazil.

The GTL plant avoids investments in a new gasoil refinery, buffering a lower investment option (around one-half of the refinery investments) and a smaller scale, although with slimmer net margins than the proposed gasoil refinery.

It is also interesting to note that, for the self-sufficiency in the gasoil criterion, the expansion based on the GTL plant in 2015 and a gasoil refinery in 2010 almost offset the physical gasoil balances.

6. Conclusions

Two different scenarios for the Brazilian oil products demand were considered here. Both scenarios are based on the same GDP growth rate for 2003–2015, which is derived from a study performed for the Ministry of Planning, Budget and Management of Brazil [11]: 4.26% per year from 2005–2010 and 4.11% per year from 2010–2015. Those GDP real growth rates are in line with other scenarios considered for Brazil, such as IMF [14], IEA [15], EIA-US DOE [16] and Wilson and Purushothaman [17]. Those scenarios have sectoral growth and technical different assumptions,

resulting in different fuel demand scenarios. More details about are available in Schaeffer et al. [1,3] or, alternatively, in IAEA [18]. Two different criteria for refinery expansion were simulated in order to meet oil product demand scenarios.

On the one hand, the considered GTL plant of 50,000 bpd is a more robust solution, given its smaller total fixed cost. GTL's naphta has low aromatic content favoring olefins production; GTL's jet fuel has high ignition point, reducing blowout risks and low aromatic content, been also parafinic; the GTL's diesel has high cetane number and no sulphur and aromatic content. Its environmental advantages also are reflected in its hydrogen content, which reduces NO_x emissions. Therefore, GTL's diesel is placed in the market as a high-quality and priced product.

On the other hand, a diesel-driven refinery scheme is a best known technology (therefore, less risky), which also adds value to Brazil's oil production (mostly heavy acid oil with considerable discounts in the oil market). It has a smaller unitary cost (for example, dollars per barrel per day). Finally, the economic feasibility of the GTL plant is affected by the natural gas price, which is, in turn, related to oil prices in the international market.

A sounder and more prudent criterion for Brazil's energy policy would indicate that the strategy of investing in energy conservation endows the nation with greater flexibility over the long term and, depending on the expansion criteria adopted, leads to the expansion of no more than two refineries by 2015, one optimized for gasoil and the other optimized for gasoil or basic petrochemicals (propene, in this case study). However, the GTL plant may alter the situation, resulting in expansion not taking place through refineries, depending on the criteria adopted, or expansion through only one new refinery by 2015, optimized for gasoil or petrochemicals. However, the second option has the advantage of offering integration economies, producing high-value oil products, such as propene, being smaller, adding value and making good use of natural gas produced in Brazil.

Such findings have important implications since Brazil is an important emergent economy (comparison with China and India, in terms of oil and oil products market growth) and as a country with important singularities (the use of biofuels). Also, Brazil is a key player in Latin America, in such a way that a grass-root GTL plant in Brazil would have probably a significant impact on natural gas trade partners, such as Bolivia (the main NG exporter to Brazil), Argentina and, in the future, Peru (there is a new NG pipeline project which aims at increasing energy-economic integration among South America countries – Peru, Chile, Argentina and Brazil – as well as reducing NG supply vulnerability, which has became a key issue for Argentina and Brazil due to the current social tensions in Bolivia). Old LNG projects, such as Trinidad & Tobago—Brazil and Nigeria—Brazil, might also become true through GTL in Brazil. In this sense, a grass-root GTL plants in Brazil might open an entirely new regional market for GTL technologies.

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