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Cost- Benefit Analysis of Gas to Liquids Project for the South-Pars Gas Field of Iran

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Abstract

This paper presents an economic evaluation of gas to liquids (GTL) project using "South-Pars" gas field of Iran based on the latest actual performing GTL projects. Iran has the world's largest reserves of natural gas and can satisfy the projected long-term market demand of GTL products which have lower pollution and higher quality than refinery products. The results of cost-benefit analysis show that GTL project in Iran is fully economical. Sensitivity analyses are conducted and the results show that the capital expenditure is the most sensitive factor in this project, followed by the price of crude oil and the price of feed gas respectively.

Keywords: Cost-benefit analysis; Gas to Liquids technology; Sensitivity analysis.
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1. Introduction

Currently crude oil provides 34% of the worldwide primary energy while natural gas and natural gas liquids (NGLs) supply nearly 26%. The share of natural gas in total energy consumption continues to rise and it is predicted that it will provide nearly 30% of the global primary energy demand, surpassing crude oil in 2035 (BP Energy Outlook 2035, 2014).

At the end of 2013, with 18.2% of global proven natural gas reserves, Iran had 33.8 trillion cubic meters (tcm) and ranks as the largest holder of gas reserves in the world higher than Russia and Qatar. Iran is the third largest producer and consumer of natural gas (BP, 2014) and follows Nigeria and Russia in flared gas (World Bank, 2012) which is equivalent to around 8% of the enriched gas and 40% of the associated gas (Iran Energy Balance Sheet, 2011).

There are several plans for Iran to increase its use of natural gas such as domestic consumption, gas injection into the oil fields to prevent pressure drop, and export through pipelines. Other options for Iran to transport gas to potential markets include conversion to Liquefied natural gas (LNG), Compressed Natural Gas (CNG), Natural gas hydrates (NGH), Methanol and dimethyl Ether, Oxidative coupling of methane (OCM) and also Gas to liquids (GTL) (Kessel, 2006; Iran Polymer and Petrochemical Institute, 2008).

In this paper we focus on gas to liquids technology and after reviewing literature and investigating the specifications and market of GTL products, the application of this technology in Iran will be assessed economically.

Gas to liquids (GTL) technology refers to the process which converts natural gas to valuable products include methanol, dimethyl ether, middle distillates and other products such as LPG, gasoline and naphtha. Compared to the refined petroleum products, liquid products obtained from GTL process, have higher quality and lower pollution. The process consists of several steps:

- gas separation and purification
- Reforming of the natural gas to produce syngas
- Fischer-Tropsch process
- Upgrading to produce finished products

The major products of GTL process include the middle distillates products such as gas oil, kerosene and jet fuel, the petrochemical products such as naphtha, liquefied petroleum gas (LPG), and specific products such as solvents, waxes and lubricants which have lower sulfur than refined petroleum products. The products of this process are basically differentiated from the refined products. Although the application of GTL technology is not globally pervasive, considerable investment of international oil & gas companies in GTL industry is an indicator of its development and profitability in near future. Provided that GTL projects are economical to perform in Iran, the application of this technology will be useful to monetize natural gas reserves; in addition, it will pave the way for the enhancement of technology and will cause the growth of the value added compared to the export of crude oil or natural gas.

2. Literature Review

Basic GTL technology was invented in 1923, when two German scientists, Franz Fischer and Hans Tropsch, discovered the catalytic conversion of carbon monoxide and hydrogen (syngas) into synthetic hydrocarbons. For over 70 years, development in commercial gas to liquids (GTL) technology was limited to only a few companies and countries. Technical advances in GTL technology and its applications have taken place in the last two decades. Since the late 1990s, major oil and gas companies with commercial GTL experiences such as Sasol, Shell, ExxonMobil, ConocoPhillips, have planned to build GTL plants. These companies have expanded the technology of Fischer-Tropsch on the basis of their own diverse reactors and specific catalysts. (Fleisch, Sills & Briscoe, 2002; Keshav & Basu, 2007).

Except three commercial units which convert coal to liquid (CTL) with Fischer–Tropsch process in South Africa, there are four GTL units which currently produce commercially:

1) Shell project in Bintulu, Malaysia
2) PetroSA project in Mossel Bay, South Africa
3) Oryx project in Ras Laffan, Qatar
4) Pearl project in Ras Laffan – Qatar

Other planned GTL projects in Qatar, Nigeria and Algeria are in different stages of completing. (Rahmim, 2008 & Shell, 2012)

In addition, some GTL projects were proposed by the international companies in different regions of the world especially in the countries which have major gas reserves and even the countries with small or remote gas reserves or associated gas.

Since using new technologies necessitates economic justification, investing in GTL technology with high capital expenditures requires feasibility study. As this issue has been considered in many countries and by their economic experts; the following section mentions some of them:

In 1999 “Raytheon Engineers and Constructions” has done a feasibility study for Venezuelan state-owned oil and natural gas company (PDVSA) assessing the possibility of GTL technology application in this country. (Raytheon Engineers and Constructions, 1999)

In 2001, Chevron Australia and Sasol Chevron undertook a feasibility study for a GTL project to be based in northwest of Australia. As this country has enormous reserves of gas, two companies assessed construction of a three-train GTL plant for Western Australia's Pilbara region by considering oil and gas prices, transportation cost and potential markets.

Purwanto et al. (2005) reviewed the emerging gas technologies and their economic considerations in Indonesia. Analyses on technical and economical aspects of integrated GTL application on Indonesia’s gas reserves were presented with the case study of “Matindok” gas fields.

Al-Shalchi (2006) focused on the progress of the GTL technology, starting from its first origin in the twenties of the previous century, and ending with today's giant GTL projects which are being built in some countries like Qatar. He also analyzed the economic value of this technology according to the current oil and natural gas prices. The impacts of this technology on other petroleum industries like the oil refining, LNG production industry, and the utilization of other clean fuels, are also considered. In addition, the possibility of using the GTL technology in Iraq discussed in details throughout this research. (Al-Shalchi, 2006)

Chedid et al. (2007) presented a comprehensive methodology for evaluating the economic attractiveness of GTL technology in Qatar. The Qatari gas volume needed to fully satisfy the projected long-term market demand of GTL products in the Asia-Pacific region is evaluated. In this research the economic attractiveness of GTL investment is assessed based on the internal rate of return, and the impact of adopting large-scale GTL projects on Qatar oil refining industry. Sensitivity analyses are conducted using several scenarios to account for variations in GTL premium, capital cost, and cost of gas feedstock (Chedid, Kobrosly, & Ghajar, 2007).

Also in 2007 "National Petroleum Council (NPC)" in US carried out a study about the reasons of growing interest in developing GTL on a larger scale, and assessed GTL capacity projections to 2030 based on several plants which were under construction (Slaughter, 2007).

Alaska Gasline Development Corporation (AGDC) has commissioned Hatch Associates Consultants in 2011 to conduct an economic feasibility study of a Gas to Liquids plant in Alaska. This study investigated whether or not this GTL facility would economically be justified based on some effective factors such as natural gas price, crude oil price and capital expenditures. Additionally, Sensitivity analysis determined the most important drivers of the GTL plant's economy (Hatch Associates Consultants, 2011).

The "Oxford Institute for Energy Studies" in 2013 investigated the viability of substituting GTL products with clean-burning and high-quality characteristics for oil-derived products in the global market. Based on the results of this research, the confluence of narrowing gas and oil differentials and modular GTL units could affect large-scale GTL industry. (Brown, 2013)

Iran as the world top holder of natural gas reserves is a newcomer in using GTL technology. Most of the researches have focused on technical aspects such as catalysts developments. Although Iran Polymer and Petrochemical Institute, Petroleum University of Technology and also Iran Development and Renovation Organization (IDRO) have inaugurated small units, laboratory and pilot plant, it is too soon to access the commercial units of GTL.

In addition, we should perceive some important point using GTL technology in Iran and the necessity of economic evaluation of the project:

- Opportunity cost of delay in exploitation of planned phases of South-Pars gas field as the largest independent gas field in the world which is shared between Iran and Qatar
- Environmental considerations of GTL fuels and the increase in value added by producing GTL products compared to the export of crude natural gas
- Since imposed sanctions on Iran limit access to the financial resources, it is necessary to allocate resources to the most profitable projects based on economic considerations.

So, after reviewing the specifications of GTL products and investigating predicted global demand in the next section, economic appraisal of GTL technology application using the South-Pars gas field of Iran has been conducted.

3. GTL Products: Characteristics and Potential Markets

The growth in liquefied products demand and environmental considerations are the most important reasons for using GTL technology to monetize gas reserves of the world.

In Table 1, Ultra Low-Sulfur Diesel produced from oil refining and the diesel from GTL process, have been compared based on European standards.

Table 1: Typical diesel specifications (Wood Mackenzie, 2010)

	ULSD Conventional	Diesel GTL
Sulfur (ppm)	10	<5
Cetane number	minimum 48	~75
Specific gravity	0.82-0.86	~0.78
Poly aromatics	<11	<5

GTL process produces diesel fuel with an energy density comparable to conventional diesel, but with a higher cetane number, lower sulfur and lower poly aromatics compositions. Higher quality increases the price of the product.

GTL diesel has two natural markets: It can be blended with conventional diesel to meet lower sulfur specifications or be used as a cost effective alternative to more costly refining processes. It can also be sold as a specialty product for transportation section and fuel market to alleviate air pollution problems.

Table 2: Global demand by products, volumes and shares (World Oil Outlook, 2012)

	demand mb/d				share in demand%	
Year / Products	2011	2016	2020	2035	2011	2035
Ethane/ LPG	9.2	9.8	10.2	11	10.5	10.3
Naphtha	6	6.5	7.1	8.8	6.8	8.2
Gasoline	21.5	22.5	23.4	26.1	24.5	24.3
Jet/kerosene	6.5	6.8	7.1	8.0	7.4	7.5
Gasoil/diesel	26	28.9	31.3	36	29.6	33.6
Residual fuel [a]	8.8	8.2	7.5	6.3	10.1	5.8
Other [b]	9.8	10.2	10.2	11	11.1	10.3
Total	84.5	91	96.2	105.5	100.0	100.0

a. Includes refinery fuel oil.
b. Include bitumen, lubricants, waxes, coke, sulfur, direct use of crude oil, etc.

As it is seen in Table 2, the main products of GTL process are petroleum products such as naphtha and gasoil/diesel that will have considerable share in comparison with total demand of petroleum products in the next years.

Studying the long-term demand for refined products reveals that naphtha demand out of total refined products has increased from 6.8% in 2009 to 8.2% in 2035; this growth is the highest after the demand for gas oil in the same period. However, gasoline, kerosene, ethane and residual fuels have encountered a decrease in demand (World Oil Outlook, 2012). Additionally, the predictions of international institutions such as EIA and

IEA confirm the long-term growth of demand for these products (International Energy Outlook, 2012; World Energy Outlook, 2012).

The global demand for diesel and gas oil rose to 1.1 billion tons in 2007 and its global demand will increase to 1.5 billion tons in 2015 and in 2020 it will exceed 2 billion tons. Global naphtha demand is increasing due to growing demand for petrochemicals.

Three of the major demand regions for diesel are Europe, North America and Asia-Pacific. Europe is the most likely destination for GTL diesel produced in Qatar, Nigeria and Algeria (Jamieson and McManus, 2007, p. 52).

The key region for naphtha demand is Asia-Pacific, which already has a growing deficit. Based on the forecasts, greater variations in the destination for GTL naphtha than diesel are expected. The potential 3 million tpy of products from Qatar and Australia will likely to be exported to Asia, making a small dent in the huge deficit here. The US will be the target market for Nigerian, and Algerian GTL naphtha will likely flow to Mediterranean Europe (Jamieson and McManus, 2007, p. 53).

Regarding the potential and actual market for the refinery and GTL products, the current projects will not be an entry barrier for Iran to the GTL global market. The considerable supply deficit in markets of refined products such as diesel and naphtha indicates that Iran will confront a wide market for its products specially GTL products due to the superior features; the domestic market with high volume of consumption must also be considered.

4. Economic Evaluation

In our economic appraisal, we have used Discounted Cash Flow (DCF) method with some criteria:

4.1. Net Present Value (NPV)

In this method, future benefits and costs are converted into the beginning time of the project, with an appropriate discount rate, and the required initial capital of project is deducted from it. In comparisons, this value is considered as NPV. Equation (1) is provided for this purpose.

$$NPV = -C_0 + \sum_{i=1}^{N} \frac{C_i}{(1+r)^i} \tag{1}$$

Where NPV is net present value, C_0, initial investment cost, C_i, expected cash flow in the i-th period, r, discount rate and i, the number of project plant life period. The expected cash flow consists of all incomes and expenditures of the project during plant life.

In this method of evaluation, if the NPV of a project is positive, the project is considered acceptable and economical, and if the NPV is negative, it will be evaluated as unacceptable and non-profitable.

4.2. Internal Rate of Return (IRR)

IRR is the rate of return which equals the present value of project income to the present value of its costs and with that rate, the NPV of the project equals to zero. Therefore, calculating IRR will be as fallow:

$$-C_0 + \sum_{i=1}^{N} \frac{C_i}{(1+IRR)^i} = 0 \tag{2}$$

We must find IRR from above equation as an unknown variable.

Based on this method, if the project rate of return is more than the interest rate of investment, then the project is considered economical and profitable, and if it is less, then the plan will be evaluated non-profitable.

In GTL project appraisal, the main factors which we have considered are:

Capital expenditures, operational expenditures, feed gas price, depreciation costs, inflation rates, the price of crude oil, the price of GTL products, GTL products premium, tax rate, the security for gas supply, plant life period, the quality of feed gas and also construction period.

Given the information and the latest data of the currently performing GTL projects, a base case scenario has been designed; subsequently alternative scenarios have been presented to study the effect of changes in capital expenditures, crude oil price and feed gas price. Table 3 shows the assumptions for the base case scenario.

Table 3: Base case scenario assumptions of economic evaluation of GTL project in Iran

Item description	Value
Capital Expenditures	$100000/(bbl/d)
Operating Costs	3% CE
Feed gas price	$2/MMBTU
Depreciation	4%
Debt	50%
Inflation	2%
Crude oil price	$100/bbl
Price difference between GTL products and refined products	$+9.95/bbl
GTL products premium	$4/bbl
Tax rate	25%

1) Capital expenditures: 100 thousand dollars for construction of each capacity unit (b/d) [1].

2) Operational expenditures: currently, for each GTL production unit, the operational expenditures including labor costs, operation and maintenance costs, marketing and administrative costs are considered 3% of capital expenditures.

3) Feed gas price: 2 dollar per million Btu ($2/MMBTU). The cost of gas production in majority of Iranian gas fields is less than 50 cents per MMBTU; the price of the delivered gas to the domestic petrochemical units in 2011 is 2$ per MMBTU[2]. In similar GTL projects, for example in Qatar, the price of feed gas is considered 75 cent per MMBTU (Chedid et al., 2007). The price of feed gas in GTL plants in the base case scenario is considered $2/MMBTU. This will minimize the risk of increase in feed gas price in the economy of the project.

4) Depreciation cost for each GTL unit is linearly 4% in plant life with the scrap value of zero at the end of operational period.

5) The project finance will include 50% of the capital costs by the shareholders and the remaining with 6% interest rate by a loan which takes four years to repay; after a break of 6 month in the first year of production, the repayments will start and continue 4 years.

6) The inflation rate has been considered 2% which is equivalent to

global inflation rate, because the majority of equipments and technologies used in this project are provided from abroad and our computations are in terms of dollar. This inflation will affect the costs of the projects including the capital and operational costs during plant life.

7) The price of crude oil is the major factor affecting the economy of GTL projects. This factor influences the price of petroleum products and the incomes of the projects. Due to the fluctuations of the crude oil price in recent years and the prediction of international institutions, the price of each barrel of crude oil has been considered $100; this will minimize the risk of decrease in the crude oil price in the economy of the project.

8) Since there are several products in one GTL barrel, the value of each barrel of products was estimated based on the weighted average of each product. These GTL products will be priced on the basis of refined products. The price of oil influences the price of these products; the price difference of these GTL products and refined products will lead to estimation of weighted average. Each barrel of GTL products may include nearly 60% of gas oil, 25% of naphtha, and 15% of other products. The price of gas oil was estimated based on three important markets of Rotterdam, Singapore, and US Gulf Coast price during 2004-2011. The difference between gas oil and crude oil price has been $14 based on the average price of crude oil and refined products markets during 2004-2011. In that period, the average of price differences between naphtha and Brent crude oil was $5.09/b. Thus, in the estimation of cost-benefit, surplus of price of gas oil and naphtha compared to that of the crude oil will be $14 and $5.09 respectively and this price difference for the other products (including LPG, wax, and lubricants) is $2 (BP, 2013; IIES, 2011; Petroleum Argus, 2011; Platts Crude Oil Market, 2011). Considering the average portion of gas oil, naphtha, and other GTL products in different production processes, $+9.95/b will be considered in estimation of cost-benefit due to the weighted average that represents the excess of the price of GTL products over crude oil price.

9) The premium will be considered for GTL products which have higher quality and lower pollution compared to the refined products (Vatani, Nazeri, Alizadeh & Rahmani, 2006). This premium is

considered $3-5 per barrel which then will be added to the weighted average of these products price compared to crude oil price.

10) There is a ten-year tax holiday of the performed projects of "Assaluyeh" port since it belongs to the deprived regions. This law is based on the article no.132 of reformation in "direct taxes law". However, in the 11th year of exploitation and after that, the annual sales tax will be 25%[3]. The discount rate will be 11%[4].

11) Other specifications of the project are given in Table 4.

Table 4: GTL plant characteristics

Item	Value
Plant capacity	75000 b/d
Plant products:	
Diesel	45000 b/d
Naphtha	18750 b/d
LPG & other products	11250 b/d
Daily required feed gas	700000 MMBTU
Plant life period	25 years (350 day per year)
Construction period	4 years
Total Investment	$7.72 billion
On stream factor	95%

4.3. The Result of Cost-Benefit Analysis:

As Fig. 1 illustrates, based on the presumptions of the base case scenario, the Internal Rate of Return (IRR) is 25.9%; considering incomes and costs, the net present value (NPV) of the project during 25 years is $7 billion and NPV/I is 1.18. The payback period will be the fifth year. Consequently, this project, under the presumptions of the base case scenario, will be economical.

The feed gas price of $7.7/MMBTU is the boundary price, that causes NPV become zero. This means it is the maximum price for feed gas that the project can afford. With the same logic, the oil price of $50.82/bbl, is the minimum price that the project can survive. Finally the maximum capital cost for the project is 207.3 thousand dollars for each barrel a day that the project will be justified economically.

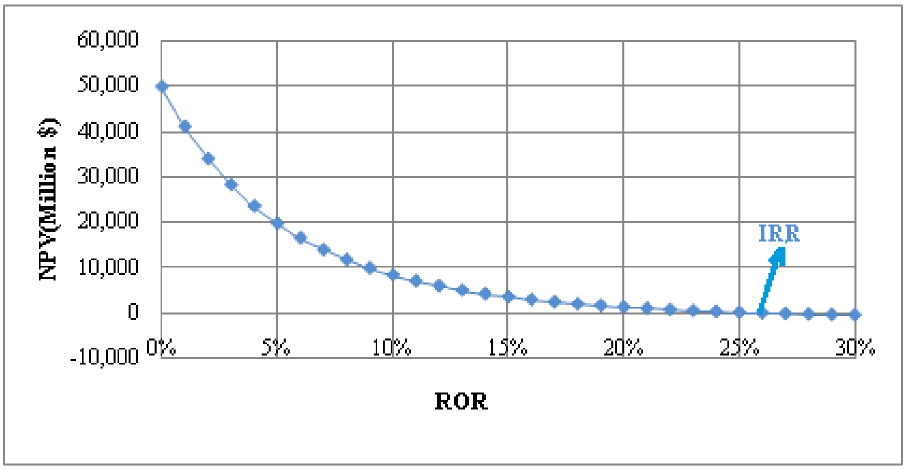

Figure 1. Relationship between NPV and different Rates of Return (Source: Author's computations)

4.4. Other Scenarios For the Economic Evaluation of GTL Technology in Iran:

Changing the most important factors of the GTL project include capital expenditures, feed gas price and the price of crude oil, it will be possible to define other scenarios and determine the effects of changing these major parameters on the model results. Then, with the capital expenditures of 70, 100, and 120 thousand dollars for each capacity unit [5] (b/d), the optimistic and pessimistic prices of crude oil based on the predictions of energy institutions like International Energy Agency and international oil& gas companies such as British Petroleum (50, 100, 150 dollars per barrel), and also the price of feed gas: \$1, \$2, and \$3/MMBTU, other scenarios have been considered and the relevant changes on the model results (NPV and IRR) are shown. The considered prices for the natural gas in these scenarios are relevant to the new policy of actualizing the prices of energy sources (Subsidy reform plan) in Iran. Table 5 shows different scenarios by changing the main factors which affect on the economy of GTL project.

In the most optimistic conditions, if the feed gas price is 1 dollar per MMBTU, the price of crude oil, \$150/bbl and the capital expenditures for each barrel of GTL products per day is \$70, then IRR will be 52.35% and the payback period is the second year of operation.

Table 5: Different scenarios with related IRR and NPV (Source: research findings)

Capital expenditures (\$/(bbl/d))	Feed gas price (\$/MMBTU)	Crude oil price (\$/bbl)	IRR (%)	NPV billion \$
70000	1	50	20.88	3.08
		100	38.79	10.26
		150	52.35	17.43
	2	50	17.05	1.86
		100	35.87	9.03
		150	50.04	16.20
	3	50	13.08	0.628
		100	32.81	7.800
		150	47.63	14.97
100000	1	50	13.68	1.11
		100	28.30	8.28
		150	39.95	15.45
	2	50	10.71	-0.117
		100	25.90	7.06
		150	37.96	14.23
	3	50	7.64	-1.34
		100	23.43	5.83
		150	35.91	13
120000	1	50	10.57	-0.204
		100	23.65	6.97
		150	34.28	14.140
	2	50	7.96	-1.43
		100	21.52	5.740
		150	32.46	12.91
	3	50	5.21	-2.66
		100	19.34	4.51
		150	30.59	11.68

In the most pessimistic conditions, if the price of feed gas is \$3/MMBTU, crude oil price is \$50/bbl and the capital expenditures for each daily barrel of GTL products is \$120, then the IRR will be 5.21% and the payback period is the 15th year of operation.

5. Sensitivity Analysis

An increase in capital expenditures and the price of feed gas directly decreases the IRR and NPV/I. An increase in crude oil price will increase the IRR and the NPV. This parameter also affects the payback period.

Figure 2 illustrates the compared effects of increase or decrease of the feed gas price, crude oil price and capital costs which influence the IRR. The most sensitive parameter is capital expenditures. Any change in this parameter will have the greatest impact on the achieved results; after that, crude oil price and then, price of feed gas have a great effect on the economy of the project.

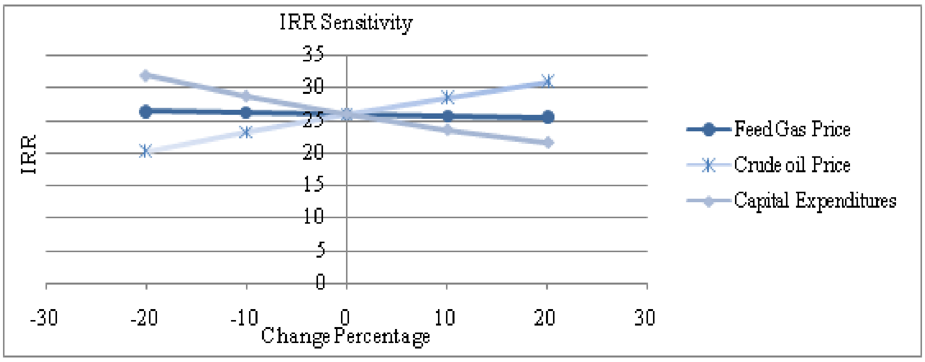

Figure 2. The project's IRR sensitivity to capital expenditures, crude oil and feed gas price fluctuations (Source: Author's findings)

6.Conclusions

Inspecting the potential and actual markets for GTL products shows the considerable supply deficit of products such as diesel and naphtha.

The total proven natural gas reserves in Iran, at the end of 2013, were 33.8 tcm, the highest in the world. However, with respect to the production of GTL, Iran is far behind the pioneers such as Qatar, South

Africa and Malaysia.

In this paper, we have conducted a cost-benefit analysis for gas to liquids (GTL) project from "South-Pars" gas field in Iran. The results show that investment in GTL technology is very profitable. According to the base case scenario, NPV of the project during the plant life is $7 billion and IRR is 25.9% with the payback period of five years.

The sensitivity analysis shows that the capital expenditure is the most sensitive factor in this project, followed by the price of crude oil and the price of feed gas respectively.

Even though our study shows a high rate of return for the production of GTL, we should consider other gas exporting options due to strategic situation of Iran: Gas exports through pipelines to Europe via Turkey or Iraq, to east through Pakistan and India, and to other potential markets.

Having old oil fields, gas injection into these fields to prevent pressure drop, should be considered in comparison with different options for Iran's gas consumption.

Endnotes

1- Considering the current GTL projects and given information from the experts of National Iranian Gas Export Company (NIGEC).
2- Sales Accounting of Financial Management of National Iranian Gas Company (NIEC).
3- Based on the article number 105 of Direct Taxes Law .
4- President Deputy Strategic Planning and Control, The guide to provide the report for technical, financial, economical and social justifications of plan, Journal no. 3122.
5- Considering the current GTL projects and the predictions of the experts of Gas Industry.

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