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An Alternative to Flare Gas Processing: A Feasibility Study of Natural Gas to Liquid Processes

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Abstract: The quantities of gas released into the environment during the extraction and processing of crude oil, by flaring, constitute a vast source of mineral wealth which can be used to produce other useful products. The processes studied in this paper, as alternatives to the above problem, are the ones used in Shell Pearl Qatar project and Oryx GTL project. Both projects produce liquid fuels, mainly naphtha and diesel, in addition to more special fuel such as kerosene. This paper is a feasibility study of a project that makes use of the flare gas from the State of Texas, U.S.A., as a feedstock to a process similar to either Shell Pearl Qatar project, or Oryx GTL project. The objective of this study is to determine the price range for crude oil over which an investment to similar projects can be profitable. An MS Excel Model was developed in order to perform calculations having as a variable the crude oil price and taking into account all the process and project's financial data. The results of this model showed that a project similar to Shell Pearl Qatar remains profitable in crude oil price above $57.76/barrel, while a project similar to Oryx GTL remains viable for crude oil price over $31.4/bbl. In the price range $55-$60/barrel, the payout of the corresponding to Shell Pearl Qatar project will be in about 15.2 years and 3.3 years for a project similar to Oryx GTL. Finally, using the financial principles of this study we can apply them to any process in order to determine under what conditions will remain viable.

Key words: Natural gas conversion, liquid fuel production, membrane reactor technology, economical assessments, Shell Pearl Qatar process, petroleum engineering.

1. Introduction

One of the greatest energy related challenges the world faces today is how to satisfy the global increase in energy demand, with minimal negative impact on the environment whilst, at the same time, promoting economic growth [1]. A solution of this challenge is the use of natural gas. In recent years there has been great interest in the use of natural gas, on a global scale, both as a source of energy and to produce useful chemicals. This interest becomes larger when one considers environmental benefits compared with the use of crude oil.

The interest increased in the last 20 years when the proven gas reserves worldwide have increased by 55%, as presented in Table 1 [2]. By proven hydrocarbon reserves we mean the estimated quantities of hydrocarbons, which, on analysis of geological and engineering data, can be recovered under existing economic and operating conditions. Estimates of reserves change annually as new exploration discoveries come to light, existing exploration areas are fully valued, existing deposits are mined, and the technological and operational costs are constantly changing.

Natural gas reserves can be categorized according to the location of the deposit and its use:

(1) Most commonly, natural gas is pumped from the deposit to the final customers by pipelines. The main commercial use of natural gas is burning, either for electricity or heat production, from residential or industrial consumers or for moving vehicles. Before its consumption the gas should be transferred from the pumping space. It has been found that the transport of gas by pipeline remains economically feasible when the total distance of the pipeline does not exceed 4,000 km [3]. According to the U.S. Energy Information

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Table 1 Proven world gas reserves for the years 1993, 2003 and 2013 [2].

Year	Natural gas (in oil equivalent)	Crude oil
1993	106.6 bn. ton	146.9 bn. ton
2003	140.1 bn. ton	189.6 bn. ton
2013	167.1 bn. ton	238.2 bn. ton

Table 2 The products of two GTL plants.

	Shell Pearl Qatar	Oryx GTL
Natural gas processed daily (ft^3/d)	1.6 billion	328 million
Ethane (bbl/d)	30,000	-
LPG (bbl/d)	30,000	1,000
Condensate (bbl/d)	60,000	-
Naphtha (bbl/d)	35,000	9,000
Kerosene (bbl/d)	25,000	-
Diesel (bbl/d)	50,000	24,000
Base oil (bbl/d)	30,000	-
Total (bbl/d)	260,000	34,000

Administration [4] there are more than 210 natural gas pipeline systems in the U.S.A., which result in total of 305,000 miles of interstate transmission pipelines.

(2) When the total distance of the pipeline exceeds 4,000 km then it is more economically feasible to further process the natural gas in order to produce other chemical products, with higher intrinsic value. Gas-to-Liquids, or GTL, is ideally placed to deal with this challenge as it converts natural gas to low emissions, high performance liquid fuels, such as diesel, naphtha, jet fuel as well as other premium products.

Two examples of GTL plants are Shell Pearl Qatar and Oryx GTL, both located in Qatar. Table 2 presents the products of each process together with the quantity of natural gas processed daily.

(3) Finally, there is the associated gas, which is a form of natural gas found with deposits of petroleum, either dissolved in the oil or as a free "gas cap" above the oil in the reservoir [5]. This gas is not further processed but is simply burnt off in gas flares. It has been found that 5% of global gas supply is rejected through flaring, because it can not be further processed or sold as such [6]. The amount of gas that in 2014 rejected to the environment was about 5 trillion ft^3. The World Bank has estimated that the rejection of this quantity of gas through flaring corresponds to the release of 300 million tones CO_2 into the environment. Should this quantity be used to generate electricity it would cover the annual needs of the entire Africa [6]. According to the U.S. Energy Information Administration [7] the amount of natural gas flared in 2013 was 260,394 million ft^3.

In this paper we proposed a solution to the problem of natural gas flaring by applying the processes utilized in Shell Pearl Qatar and Oryx GTL projects, in order to produce liquid fuels. We applied these processes to a project in U.S.A., specifically in the State of Texas, where the flared gas according to the U.S. Energy Information Administration [7] is equal to 76,113 million ft^3. An example of flare gas composition is listed in Table 3. This amount of flared gas can produce up to 24,000 barrels/day of liquid fuels. We assumed that a pipeline system for the transportation of the flared gas to the GTL plant exists. We also assume that separation of the components of the flare gas is taking place prior to this project, utilizing separation techniques, such as the use of distillation columns.

The objective of our study is to carry out a feasibility study in this new proposed project, in order to determine the conditions under which the project will remain viable.

2. Scientific Background

Both Shell Pearl Qatar and Oryx GTL projects utilize a process that follows the general steps that are presented in Fig. 1. Initially, the crude natural gas is "cleaned" and entered the process with pure oxygen in order to produce synthesis gas. Then, the mixture of carbon monoxide and hydrogen enters the Fischer-Tropsch, F-T reactor and, depending on the catalyst and the reaction conditions, produces an intermediate product, which is, finally, upgraded. The final products consist of naphtha, diesel, liquified petroleum gas (LPG) and others.

Table 3 Typical flare gas composition [8].

Gas flaring constituent	Gas composition, %	Gas flaring, %		
		Min.	Max.	Average
Methane	CH_4	7.17	82.0	43.6
Ethane	C_2H_6	0.55	13.1	3.66
Propane	C_3H_8	2.04	64.2	20.3
N-Butane	C_4H_{10}	0.199	28.3	2.78
Isobutane	C_4H_{10}	1.33	57.6	14.3
N-Pentane	C_5H_{12}	0.008	3.39	0.266
Isopentane	C_5H_{12}	0.096	4.71	0.530
neo-Pentane	C_5H_{12}	0.000	0.342	0.017
n-Hexane	C_6H_{14}	0.026	3.53	0.635
Ethylene	C_2H_4	0.081	3.20	1.05
Propylene	C_3H_6	0.000	42.5	2.73
1-Butene	C_4H_8	0.000	14.7	0.696
Carbon monoxide	CO	0.000	0.932	0.186
Carbon dioxide	CO_2	0.023	2.85	0.713
Hydrogen sulfide	H_2S	0.000	3.80	0.256
Hydrogen	H_2	0.000	37.6	5.54
Oxygen	O_2	0.019	5.43	0.357
Nitrogen	N_2	0.073	32.2	1.30
Water	H_2O	0.000	14.7	1.14

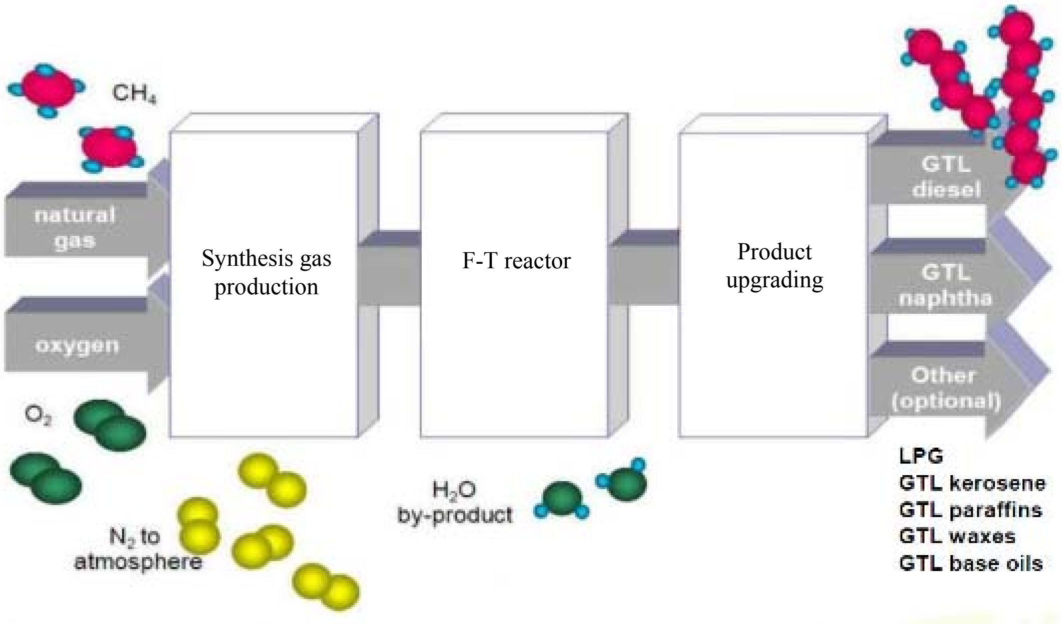

Fig. 1 Block flow diagram of GTL projects [1].

Royal Dutch Shell plc. invested $19 billion for the construction of the project Shell Pearl in Qatar, which makes use of the Shell Middle Distillate Synthesis (SMDS) process for the production of liquid fuels. In more details, the project includes the following four steps [9] as shown in Fig. 2 below.

(1) The extraction of natural gas from 22 wells from the marine space of Qatar through two unmanned platforms. Natural gas is transported to land 60 km away, where it is "cleaned". The daily volume of gas processed is 1.6 billion ft^3, which is equivalent to 275,840 barrels of oil.

(2) Production of synthesis gas by the non-catalytic partial oxidation of methane with pure oxygen in gasifiers (Shell Gasification Process, SGP). The reactions taking place within the gasifiers are:

$$CH_4 + \frac{1}{2}O_2 \leftrightarrow CO + 2H_2 \ (\Delta H^o = -36 \text{ kJ/mol}) \quad (1)$$

$$CH_4 + (3/2)O_2 \leftrightarrow CO + 2H_2O \ (\Delta H^o = -519 \text{ kJ/mol}) \quad (2)$$

$$CH_4 + 2O_2 \leftrightarrow CO_2 + 2H_2O \ (\Delta H^o = -802 \text{ kJ/mol}) \quad (3)$$

$$CH_4 \leftrightarrow C + 2H_2 \ (\Delta H^o = 74.6 \text{ kJ/mol}) \quad (4)$$

$$CO + H_2 \leftrightarrow C + H_2O \ (\Delta H^o = -131 \text{ kJ/mol}) \quad (5)$$

$$2CO \leftrightarrow C + CO_2 \ (\Delta H^o = -172 \text{ kJ/mol}) \quad (6)$$

The desired chemical reaction (1) of partial oxidation of methane with pure oxygen is slightly exothermic and from the reaction stoichiometry, the ratio of oxygen to methane should be 0.5:1. In real conditions the ratio of oxygen to methane is 0.7:1, so that some of the methane is consumed in reactions (2) and (3), which are very exothermic and generate large amounts of heat. The amount of energy produced is consumed in the remaining part of the process and makes the entire process self-sufficient. This requires very good temperature and pressure control of the reactor and the reaction conditions are: temperature of 1,300-1,400 °C, pressure of 1-65 bar and yield of 35-40% [10]. Due to the very high temperatures of the reactor the side reactions (4)-(6) may occur, which lead to carbon formation. Finally, the oxygen is produced in air separation units (Air Separation Units, ASU), which are the most energy consuming unit operations.

(3) Heavy Paraffin Synthesis (HPS), through the Fischer-Tropsch reactions. The reactor used is a tubular fixed bed reactor and the catalyst carrier is alumina or silica or a mixture of both. The active centers of the catalyst consist of cobalt molecules and smaller quantities of zirconium, titanium and chromium. The typical Shell composition of the catalyst system is 3-60 parts by weight cobalt with 0.1 to 100 parts by weight zirconium, titanium and/or chromium, per 100 parts by weight alumina/silica carrier. The catalyst is prepared by conventional impregnation methods, or kneading. Finally, the presence of the catalyst in the reactor is in the form of fixed bed, the catalyst bed has an external surface 5-70 cm^2/mL and an internal surface of 100-400 m^2/mL. The catalyst activation requires contact with hydrogen or a gaseous stream containing hydrogen at a temperature of 200-350 °C [11]. Finally, the reactor operating conditions are: temperature of 175-275 °C and pressure of 10-75 bar.

The reactions that take place in this reactor are:

Methane:

$$3H_2 + CO \rightarrow CH_4 + H_2O \quad (7)$$

$$2H_2 + 2CO \rightarrow CH_4 + CO_2 \quad (8)$$

$$4H_2 + CO_2 \rightarrow CH_4 + 2H_2O \quad (9)$$

Paraffin:

$$(2n + 1)H_2 + nCO \rightarrow C_nH_{2n+2} + nH_2O \quad (10)$$

$$(n + 1)H_2 + 2nCO \rightarrow C_nH_{2n+2} + nCO_2 \quad (11)$$

$$(3n + 1)H_2 + nCO_2 \rightarrow C_nH_{2n+2} + 2nH_2O \quad (12)$$

Olefin:

$$2nH_2 + nCO \rightarrow C_nH_{2n} + nH_2O \quad (13)$$

$$nH_2 + 2nCO \rightarrow C_nH_{2n} + nCO_2 \quad (14)$$

$$3nH_2 + nCO_2 \rightarrow C_nH_{2n} + 2nH_2O \quad (15)$$

Alcohols:

$$2nH_2 + nCO \rightarrow C_nH_{2n+1}OH + (n - 1)H_2O \quad (16)$$

$$3nH_2 + nCO_2 \rightarrow C_nH_{2n+1}OH + (2n - 1)H_2O \quad (17)$$

The reactions that are thermodynamically favored are reaction (11) for the production of paraffin and reaction (14) for the reaction of olefin [12].

The industry of Shell in Qatar includes 12 heavy paraffin reactors, each of them comprising 200 tones catalyst and each weighing a total of 1,200 tones.

(4) Heavy Paraffin Conversion (HPC), to finished products in a diffusion reactor (trickle bed reactor) in the presence of a catalyst. The catalyst comprises one or more noble metals of group VIII of the periodic table of elements. Specifically, the catalyst system used in the SMDS process consists of 0.2 to 1% by weight platinum or palladium on alumina-silica carrier. The reactor operating conditions are: temperature of 250-350 °C and 10-75 bar pressure. The product of this reactor is subjected to fractionation in a traditional distillation column. The lightweight products of distillation are recycled to the HPC reactor.

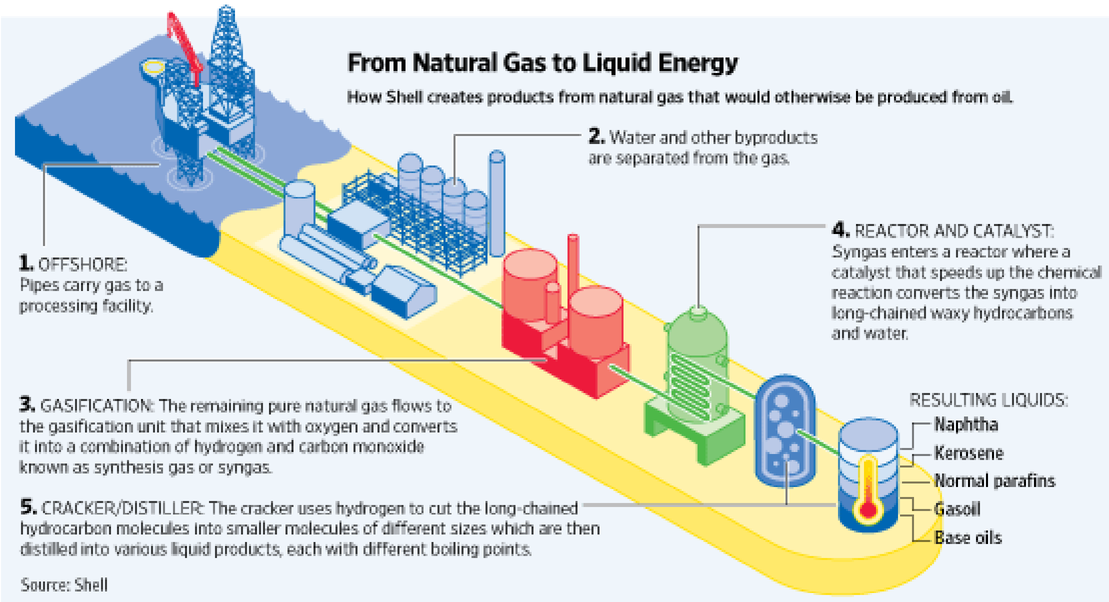

Fig. 2 Simplified process flow diagram of SMDS [13].

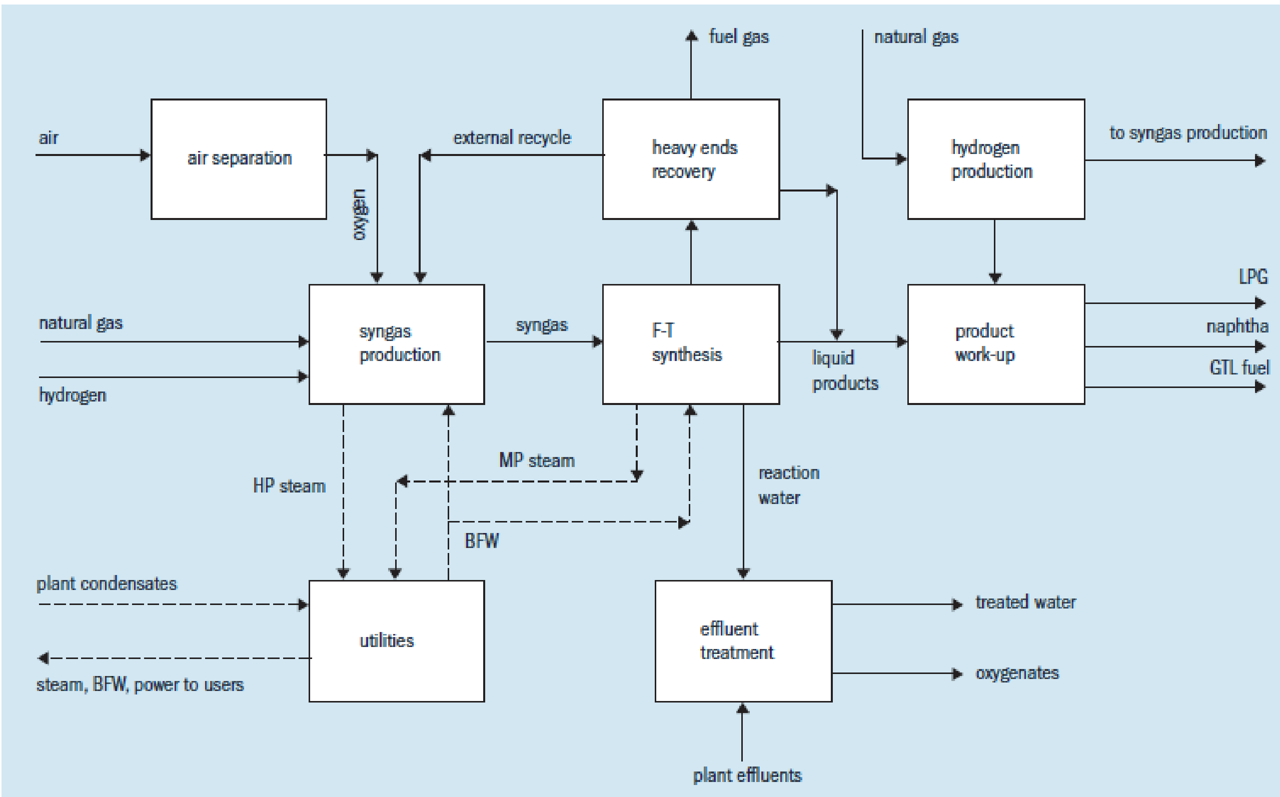

Fig. 3 A detailed block diagram of Oryx GTL [14].

On the other hand, Qatar Petroleum and Sasol Ltd. joint to construct the project Oryx GTL also located in Qatar. The process applied in this project includes the following steps [14], as shown in Fig. 3:

(1) Natural gas is drawn from Qatar's North Gas Field and routed to LNG facilities located in Ras-Laffan industrial city in the north of Qatar. After removing unwanted components from the natural gas

it is sent to Oryx GTL as its main feed stream, of which around 96% is used to produce synthesis gas while the rest is used for fuel.

(2) Natural gas conversion to synthesis gas starts in the synthesis gas production unit. The gas is first desulphurised, then preheated and adiabatically pre-reformed with steam before entering the autothermal reformer (ATR). In the ATR the feed is mixed with oxygen and steam in open flame burner, where partial combustion takes place before further steam-methane reforming in the catalyst bed to produce high temperature synthesis gas (~1,000 °C). The high temperature gas is cooled to produce high pressure steam, which is used in other unit operations of the process. The main reactions in the reforming process gas are:

$$CH_4 + \tfrac{1}{2}O_2 \leftrightarrow CO + 2H_2 \quad (18a)$$

$$CH_4 + H_2O \leftrightarrow CO + 3H_2 \quad (18b)$$

$$CO + H_2O \leftrightarrow CO_2 + H_2 \quad (19)$$

(3) The cooled synthesis gas feeds the Low Temperature Fischer-Tropsch reactor, entering at the bottom of the slurry bed of liquid hydrocarbons and F-T catalyst. It is converted into long chain paraffinic hydrocarbons via the exothermic synthesis reaction:

$$CO + 2H_2 \rightarrow -(CH_2)- + H_2O \quad (20)$$

The exothermic reaction inside the Low Temperature Fischer-Tropsch reactor is cooled by water and the steam generated is primarily used to drive the steam turbine generators to power the plant.

(4) The heavier fractions are removed from the slurry and fed into the product work-up unit. Proprietary hydrocracking and fractionation techniques are used to break down these long chain hydrocarbons into the required product slate of GTL diesel and naphtha.

3. Feasibility Study

A feasibility study incorporates financial terms that need to be explained as follows [15].

Capital: the commodity expressed in monetary units, which has the capacity to produce other goods.

Capital Cost: in industry, the cost of all fixed assets (land, machinery, and other services) of an investment. Often it referred to as the compensation required by investors or lenders to convince to provide funding to an investment since investment must return at least the cost of capital, and ideally an amount greater than the cost.

Annual Operating Costs: the cost of operation covers the whole production process in relation to the nature of the product, and general selling expenses, administration, etc.

Annual Revenue: income generally equals to the product of the sale price of the product multiplied by the annual production.

Payout: the accounting statement of the damage caused to the asset value of the use or over time. The practice of payout consists of removing a specific amount from the gross profits annually until the sum of annual payout is equal to the market value of assets. Usually, the rate of payout is 20%.

Interest: performance (increase) of capital for a certain period of time.

Interest Rate: the interest on capital for a monetary unit at a specific time period.

Inflation: expresses the reduction in the purchasing power of money, i.e. the fact that over time the same amount can buy increasingly fewer goods.

Discount Rate: is used to calculate the future value of a current amount or the present value of a future amount. In the case of reducing an amount in future value, the discount rate is often called as compound interest rate, whereas in the case of calculating the present value of an amount, the discount rate is referred to as the discount rate.

Future Value (FV): suppose an amount K, which invested today (time 0) with discount rate e. The value of this amount K after a year is $K \times e$ and the amount will increase to $K + K \times e$ or $K \times (1 + e)$. Following the practice of capitalization of interest, the future value of the initial amount K after t years at an annual interest rate e will be:

$$FV_K = K \times (1 + e)^t \quad (21)$$

Present Value (PV): if you are going to pay X amount after t years, then the value of the amount currently (at time 0), called Present Value will be:

$$PV_x = X \times (1 + e)^{-t} \quad (22)$$

Cash Flow (CF): the cash flow of the project is defined as the algebraic sum of all the years of life investment. However, since financial flows take place at different times, it is necessary before realized the sum of cash flows to calculate the present value of each cash flow.

Net Present Value (NPV): defined as the difference between the present value of annual income less the present value of annual expenses, including initial and subsequent investment in the project. The NPV is given by:

$$NPV = \sum_{\tau=1}^{v} \frac{CF_\tau}{(1+e)^\tau} - E_0 \quad (23)$$

where, NPV = net present value;

CF_τ = cash flow for year t;

E_0 = initial investment in year 0;

v = the lifetime of the project, and

e = the discount rate.

Internal Rate of Return (IRR) on capital: when the discount rate for a particular cash flow increases, the NPV value of cash flows is reduced. The IRR of the capital can be defined as the discount rate that resets the cash flow, i.e. the rate that equates the initial investment value of all future cash flows. The formula that gives the IRR is:

$$NPV = 0 = \sum_{\tau=1}^{v} \frac{CF_\tau}{(1+IRR)^\tau} - E_0 \quad (24)$$

where IRR = the internal rate of return for $NPV = 0$.

When considering a project, regardless of the options, then the terms of acceptance or rejection in relation to the NPV or IRR are as follows:

(a) For NPV

NPV > 0, the investment is considered advantageous;

NPV = 0, the financial result of the investment is marginal;

NPV < 0, the investment is rejected.

(b) For IRR

IRR > the minimum acceptable discount rate, the investment is considered advantageous;

IRR = the minimum acceptable discount rate, the investment is considered marginal, applicable when there is no better alternative;

IRR < the minimum acceptable discount rate, then the investment is rejected.

The financial analysis aims at calculating the cash flows arising from the implementation of the future project. Cash flow is defined by the difference of two ratios: the cash inflow and cash outflow. This difference may be positive or negative. Cash flow refers to a specific period of operation, usually annually. Therefore, for an investment project a list of annual cash flows should be made for the economic lifetime of the investment [15]. The list of cash flows of an investment project is in Table 4.

4. Results

This paper aims to carry out a feasibility study of the new proposed project that makes use of all the flare gas of the State of Texas, in order to produce liquid fuels. This study aims to determine the price range for crude oil over which an investment similar to Shell Pearl Qatar project or Oryx GTL project can be profitable.

Table 4 A typical table of cash flows of an investment project [15].

	0	1	2	…v
(1) Capital cost				
(2) Annual revenue				
(3) Annual operating cost				
(4) Gross profit = (2) – (3)				
(5) Payout (20%)				
(6) Interests				
(7) Taxable income = (4) – (5) – (6)				
(8) Taxes = (7) * tax rate				
(9) Net profit after tax = (7) – (8)				
(10) Installment credit				
(11) Internal rate of return = (9) + (5) – (10) – (1)				

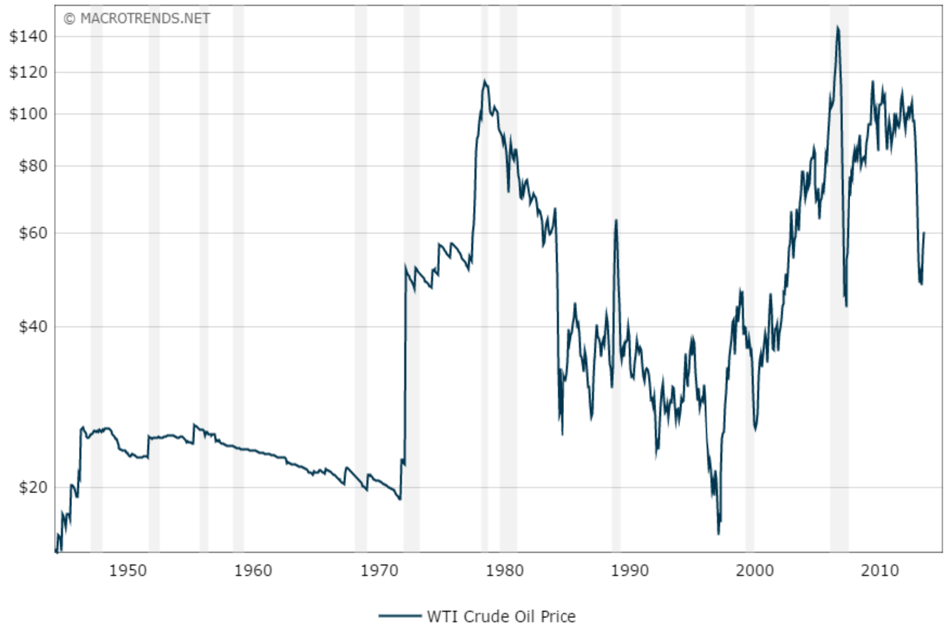

Fig. 4 Oil prices (boe), historically from 1950 to date [16].

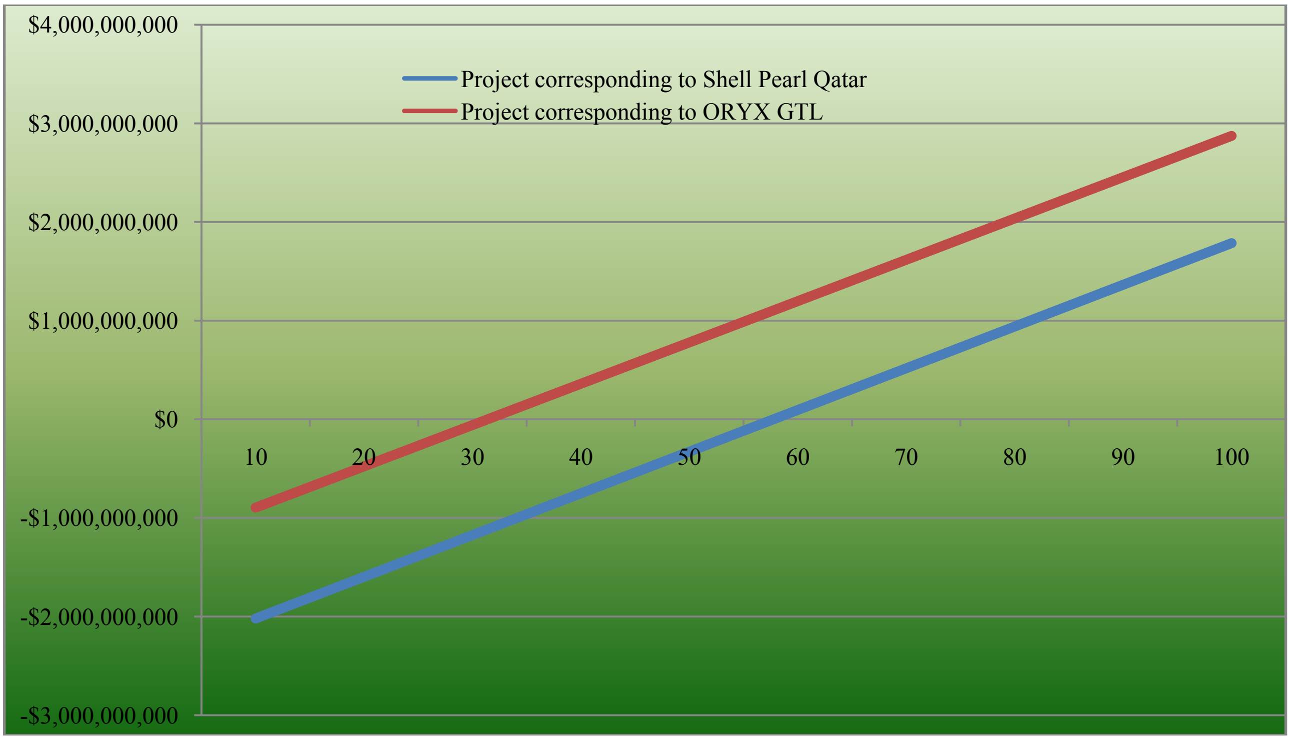

Fig. 5 The net present value of the projects with respect to the price of west texas intermediate (WTI) crude oil in $.

The crude oil prices variation from 1950 to date is presented in Fig. 4, where it seems that in the last 15 years the price has not fallen below the $30/boe.

In Table 5 the products of the Shell Pearl Qatar project are presented, as well as the capital and operating costs, versus the products and the capital and operating costs of the proposed project in the State of Texas.

In order to draw our conclusions regarding the viability of each project, we need to draw, utilizing the terms of Table 3, three graphs of the Net Present Values of each project against the price of crude oil, the lifetime of the project in years and the Internal Rate of Return, respectively. These graphs are presented in Figs. 5-7.

Fig. 5 presents the graph of the Net Present Value of each project versus the crude oil price. The project corresponding to Shell Pearl Qatar remains profitable as long as the crude oil price is higher than \$57.76/bbl, while for the Oryx GTL corresponding project the price needs to be higher than \$31.4/bbl.

In Fig. 6 the Net Present Value of each project versus the lifetime of the project in years was drawn. It is clear that the project will payout, for oil prices \$55-\$60, in about 15.2 years for the project corresponding to Shell Pearl Qatar, while the payout of the other project is 3.3 years.

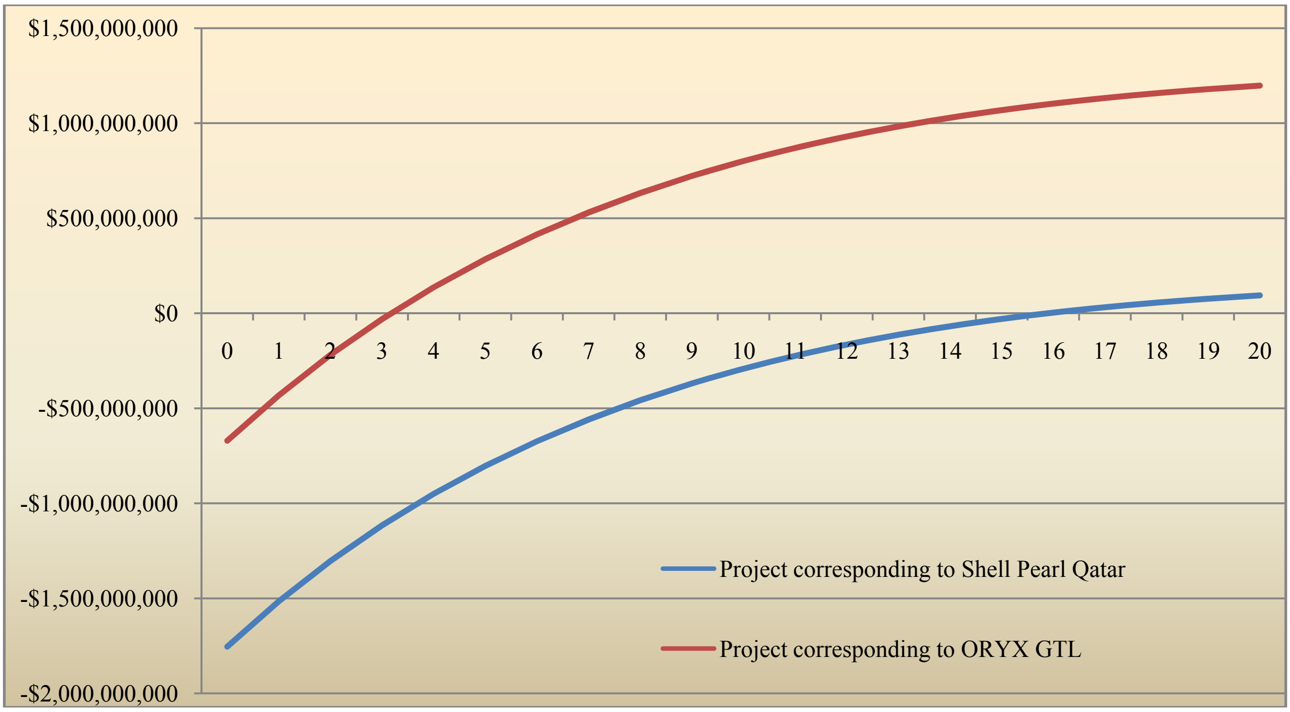

Fig. 6 The net present value of the projects over the years of operation.

Table 5 The products and costs of Shell Pearl Qatar project and the corresponding project in the State of Texas.

	Shell Pearl Qatar project	New proposed project in the State of Texas
Natural gas processes daily (ft^3/d)	1.6 billion ft^3	231.7 million ft^3
Products		
Ethane (bbl/d)	30,000	2,770
LPG (bbl/d)	30,000	2,770
Condensate (bbl/d)	60,000	5,538
Naphtha (bbl/d)	35,000	3,228
Kerosene (bbl/d)	25,000	2,309
Diesel (bbl/d)	50,000	4,615
Base oil (bbl/d)	30,000	2,770
Total (bbl/d)	260,000	24,000
Costs		
Capital (\$)	19,000,000,000	1,753,846,154
Operating (\$/year)	821,000,000	75,765,240

Table 6 The products and costs of Oryx GTL project and the corresponding project in the State of Texas.

	Oryx GTL project	New proposed project in the State of Texas
Natural gas processes daily (ft^3/d)	328 million ft^3	231.7 million ft^3
Products		
Ethane (bbl/d)	-	-
LPG (bbl/d)	1,000	696
Condensate (bbl/d)	-	-
Naphtha (bbl/d)	9,000	6,360
Kerosene (bbl/d)	-	-
Diesel (bbl/d)	24,000	16,944
Base oil (bbl/d)	-	-
Total (bbl/d)	34,000	24,000
Costs		
Capital ($)	950,000,000	670,588,235
Operating ($/year)	100,521,000	70,956,000

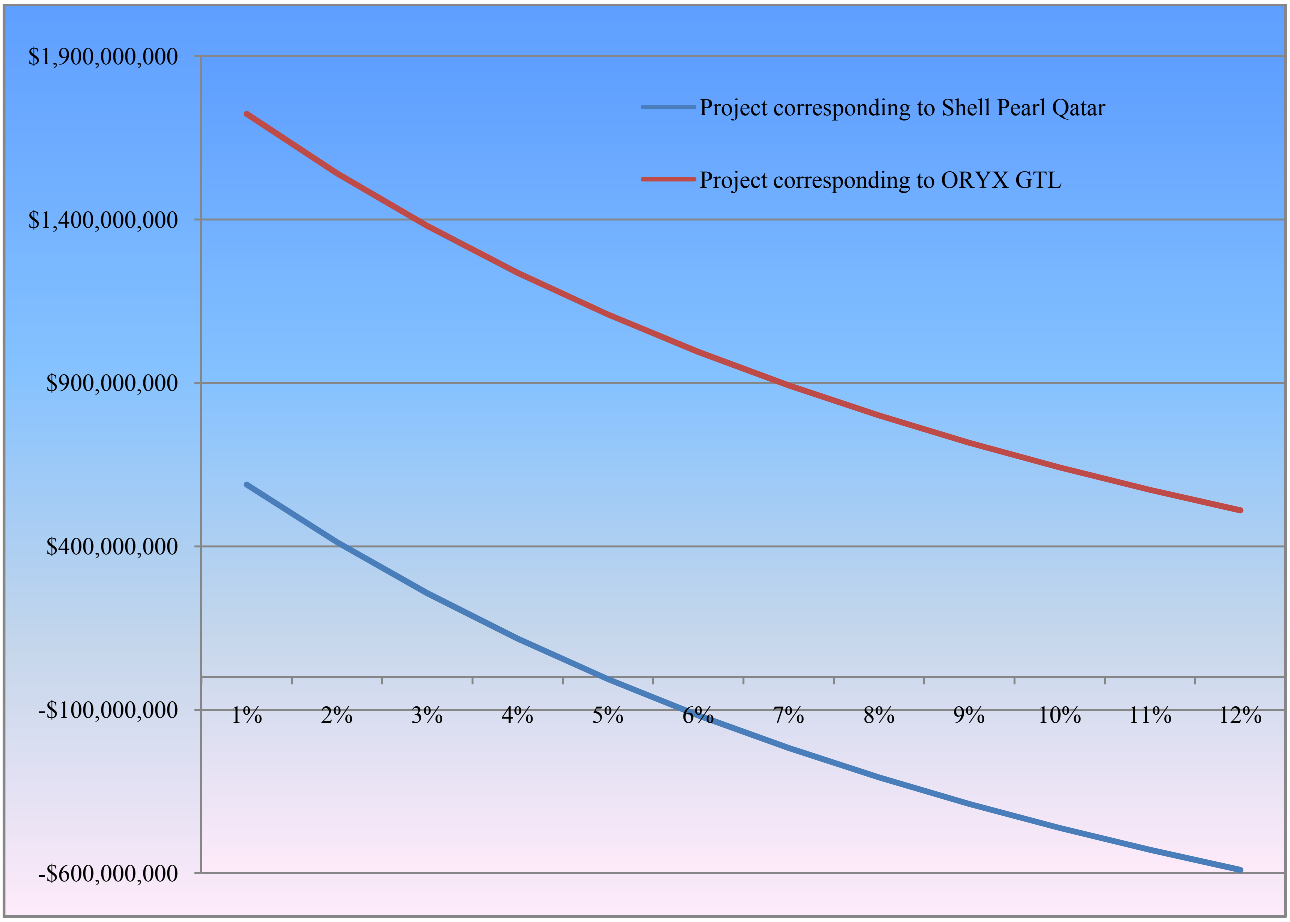

Fig. 7 NPV versus IRR, when the oil price is $50.51/barrel.

The final analysis to be made has to do with the IRR of the projects. For this analysis the oil price of $50.51/barrel was used, which is the 2015 average WTI oil price. According to the theory presented above, the IRR is the discount rate that makes the Net Present Value NPV = 0. Fig. 7 shows the graph of the NPV versus IRR for each project. We can see that, for the project corresponding to Shell Pearl Qatar, IRR = 5.8% < the minimum acceptable discount rate = 8%. Therefore, the investment is not considered advantageous. On the other hand, the Oryx GTL corresponding project IRR = 26% > 8%, which makes this investment advantageous.

5. Discussion

The first observation of this study takes into consideration the processes that were utilized in Shell Pearl Qatar and Oryx GTL projects. In Shell Pearl Qatar project, synthesis gas is produced by non-catalytic partial oxidation of natural gas with pure oxygen. On the contrary, in Oryx GTL project, synthesis gas is produced by catalytic partial oxidation with pure oxygen and steam reforming of natural gas. The first project requires higher reaction temperature and large amounts of pure oxygen to manufacture synthesis gas, while the second needs lower temperature and does not need high amounts of pure oxygen. The economic terms of capital and operating costs in Tables 5 and 6 show these observations. The capital cost of the corresponding to Shell Pearl Qatar project is almost 3 times higher than the capital cost of the corresponding to Oryx GTL project. Furthermore, the annual operating cost of the first is higher in the amount of $5 million than the second project.

To study the financial viability of the projects we created an MS Excel model. The model was constructed so that there is only one variable, the price of crude oil. The purpose of this approach is to determine under what conditions, specifically the crude oil price, is economically feasible to build similar projects to Shell Pearl Qatar and Oryx GTL. It is easily understood that for very low oil prices, investment in the exploitation of flared natural gas will not be viable.

The results of the model showed that the project corresponding to Shell Pearl Qatar will remain profitable as long as the oil price will be above $57.76/bbl. According to historical oil price data of Fig. 4 and because of the great geopolitical tensions in major oil producing countries it is almost certain that oil prices will not fall below $50/barrel for long periods of time. On the other hand, one has to take into consideration the very low crude oil prices over the second half year of 2015, before thinking about investing to a similar project. But, investing to a project similar to Oryx GTL will be profitable as long as the crude oil price remains higher than $31.4/bbl.

Furthermore, investing to a project similar to Oryx GTL will give the opportunity for a payout in a period of time of 3.3 years, as long as the crude oil price remains in the range of $55-$60/bbl. If the crude oil price remains as low as $35/bbl, then the payout will be in about 8.8 years. On the contrary, an investment in a project similar to Shell Pearl Qatar will not be advantageous, because there will not be a payout for low crude oil prices. Fig. 7 confirms the previous statement, as it shows the NPV of the project versus the IRR. From all the above is clear that an investment in a project similar to Oryx GTL is preferred than an investment to a project corresponding to Shell Pearl Qatar. In order to make the process utilized in Shell Pearl Qatar more attractive to investors we propose new technologies that will increase the production of synthesis gas and will increase the total efficiency of the process. Technologies that can contribute to such a process could be either a membrane reactor technology or a pressure swing adsorption technology. We may propose the use of a membrane reactor, which will be applied after appropriate modifications to the conventional process [17-23]. The process that we propose includes methane steam reforming to produce synthesis gas and carbon dioxide [17-23]. The selection of the membrane materials is based upon the selectivity of the appropriate products in order to achieve the desired conversion of the process. By using this membrane technology the Oryx-GTL process can be improved as well. Membrane reactor technology is a very interesting new sector, which can help us achieve higher better conversions considering specific conditions. Operating conditions and specifications are going to be selected and investigated in order to collect the optimized results

[17-23]. The materials sector for the appropriate membrane selection and utilization is going to contribute the most, so that improved results can be achieved. The better the separation factor of the membrane materials, the better the outcome of the proposed updated processes. One of the main advantages of the membrane reactor technology is operation at lower temperatures, beneficial for both reactor and catalyst. Finally, it needs to be stated that the Shell Pearl Qatar project's capital cost is so high, because the project itself is the first and biggest of its kind and therefore, every process unit is the largest ever built. Construction cost errors during the design of the project have increased the capital cost so much. Work in this area is of high interest worldwide [24-40]. The last three steps of the SMDS process can be found in Fig. A1 in the Appendix.

6. Conclusions

The quantities of gas released into the environment during the extraction of crude oil, by flaring, constitute a vast source of mineral wealth which can be used to produce other useful products. In this paper we carried out a feasibility study of a project that will be constructed in the State of Texas in order to process the state's flare gas into liquid fuels. This project utilizes a process similar to the ones used to Shell Pearl Qatar project and Oryx GTL project. Both of these processes include, after the "cleaning" of crude natural gas, the production of synthesis gas and, then, using a Fischer-Tropsch reactor to produce liquid fuels, which include mainly naphtha and diesel. Financial study of these projects was implemented in order to establish under what crude oil prices they remain viable.

We concluded that a project similar to Oryx GTL project will be more viable and more profitable than a project corresponding to Shell Pearl Qatar. In order to make the second project more attractive to investors we proposed the use of membrane reactor technology or another modern reactor technology (with higher yields) to increase the production of synthesis gas and the overall efficiency of the process. Our study on the use of membrane reaction and separation technology and related modern processes will continue.

Finally, we can carry out feasibility studies for similar reaction processes in order to determine whether or not they can be utilized in other areas of the world rich in mineral (oil and gas) resources.

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Appendix

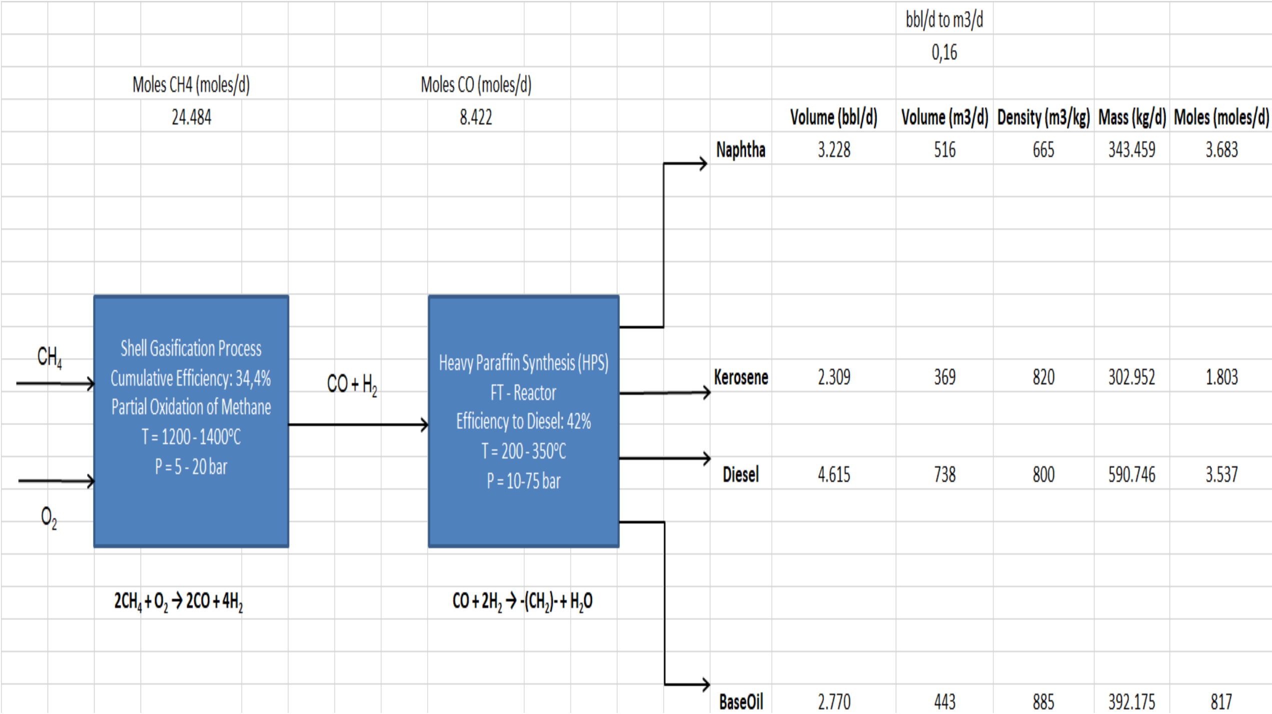

Fig. A1 The Shell Pearl Qatar process.