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Techno-Economical Feasibility Studies on Establishing Petro Refineries and Their Advantages in Iran

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Abstract

Nowadays, establishing a petro refinery instead of conventional oil refineries has been the focus of attention in petroleum and petrochemical industries in advanced countries. In this research, three different scenarios of petro refinery establishment with addition of naphtha cracking, kerosene cracking and aromatics production units to an oil refinery have been investigated and feasibility studies have been carried out to construct an oil refinery individually and three scenarios of establishing a petro refinery with the capacity of 250,000 bbl/d. The results indicated that establishing a petro refinery with kerosene cracking and naphtha cracking units will have the best return of capital investment. The cost of construction of such petro refineries have been estimated to be 6.361 and 5.949 billion dollars respectively and the internal rate of return on investment are predicted to be 30 and 31% respectively whilst the internal rate of return of investment of an oil refinery is 13% at its best case. Also the studies reveal that process pattern for production of aromatics in petro refinery will increase the rate of return of investment to 13.23%. Moreover, the ratio of converting propylene to ethylene in naphtha or kerosene cracking units is about ten times more than gas cracking units while in the past years and because of developing South Pars gas fields, most petrochemical plants are programmed or established based on gaseous feed. By developing petro refineries, more propylene can be produced as a petrochemical substance with huge market demand.

Keywords: *Petro Refinery; Olefin; Aggregation; Refinery; Economics; Return of Investment.*

1. Introduction

The refining industry started and further developed earlier than petrochemical industry in Iran and the surplus products were exported since 1989, by taking advantage of available feedstock (huge gas reserves and cheap available naphtha) started to develop in Iran but with increasing oil prices and consequently with increasing prices of naphtha, the profits from petrochemical industry with dependency on liquid feed was reduced and the argument regarding aggregation of an oil refinery with a petrochemical plant to produce variety of feeds for petrochemical units was investigated. The first findings in economical scope showed that internal rate of return on investment was reduced in petrochemical units due to an increase in crude oil price and by integration of two plants, expenses can be lowered which subsequently will be resulted with more profits. The aggregation of an oil refinery and a petrochemical plant has been the objective of producing diverse products, reducing the fixed prices of products, optimizing energy efficiency, making more profits and optimizing energy consumption.

There are different examples for aggregation of an oil refinery with a petrochemical plant or a petro refinery. One of the most suitable types is to convert naphtha and kerosene to olefins or aromatics. Aggregation of an oil refinery and a petrochemical plant offers many advantages such as producing higher quality feed; value added by-products and achieving better productivity [1-3]. The integration of petroleum refining and petrochemical production has gained significant attention because the implementation of such coordination can lead to obvious benefits improvement [4]. In one scenario, excess naphtha, LPG and ethane can be transferred to a petrochemical plant to produce ethylene and butens raffinate due to extraction of butadiene, pyrolysis gasoline, diesel and hydrogen may be sent either to the oil refinery or directly to gasoline mixing pool. The quality and type of crude oil e.g. light and heavy will change the type of by-products transferred from oil refining to petrochemical section. Light oil sends more liquid feed to petrochemical section while for heavy oils; more gaseous feed is transferred to petrochemical section [5]. With respect to plans and locations of factories and type of available crude oil, internal rate of return on investment is higher in the case of aggregation in comparison to an individual oil refinery case. Hydrogen production as a by-product in petrochemical section is vastly consumed in refinery section, which can even fulfill total requirements of a refinery unit and eliminates the need for establishing a hydrogen production unit in a refinery. Another petrochemical section by-product is octane number improver which can be separated and be added to gasoline mixture pool to enhance the octane number. Exit gas recovery from a FCC unit in a refinery can be used to produce ethylene in a petrochemical section. With respect to large production of propylene in new refinery processes, polypropylene production units with higher capacity can be established at petrochemical complexes. With regards to environmental restrictions for refineries where sulfur content in oil products must be less than 10 to 50 ppm and benzene content should be lowered to permissible limits, additional costs have been imposed on refineries.

Therefore, a percentage of produced VGO in a refinery may be sent to petrochemical units prior to sending it to highly costing hydrocracking and hydrotreating units. Also aromatic compounds can be separated from produced gasoline in a refinery and send them to aromatic separation units in petrochemical section [6]. Taking advantage of new processes, an aggregated plant will offer longer service life of units, optimization of energy consumption, common use of utilities, torch system, wastewater system, skilled manpower and administration and training systems will considerably reduce the capital expenses. In aggregated systems, heavy compounds such as C_9, C_{10} and heavy aromatics can be used in furnaces. Low octane number LSRG can be converted to gasoline in isomerization units as well as being used as feed in ethylene production units. With aggregation of an oil refinery with a petrochemical plant guarantees feed security for petrochemical units and with regards to diversity of products, there will be more flexibility in consumer market. Due to environmental restrictions and price rise in petroleum products production of alternative fuels (such as bio ethanol, bio diesel and hydrogen) have had an enhanced growth and utilization hybrid machineries have extended. This issue can reduce oil refineries' profitability in future [7]. Pyrolysis gasoline from ethylene production unit can be used to extract value added aromatic products at petrochemical plants. LPG can be used as feed in an ethylene unit. For this particular condition, to make more profit, domestic petrochemical complexes operating based on liquid feed, must aggregate with the relevant refinery. Table 1 shows existing typical streams that are used at petrochemical units.

When these typical streams are used in refinery units, they may be used only as stream providers of fuel for combustion purposes inside a refinery while in aggregation cases producing of quality products are manufactured by them.

The catalytic cracking and hydrocracking units produce suitable feeds for production of olefins and aromatics like benzene, toluene and xylene at petrochemical units [8]. Moreover, pyrolysed gasoline produced by olefin production steam cracking unit, can be used as suitable as feed for catalytic cracking unit at refinery section of a petro refinery plant. The pyrolysed gasoline used as feed, contains a large amount of diolefins that should be saturated under hydrogenation reaction before being used [9]. The investigation of reputable European oil companies show that these companies have turned to design and construction of petro refinery units (BP 24%, Shell 39%, Total 74%, Exxon Mobil 90%) [10]. In fact, by commissioning petro refinery units in Iran, it will be possible to produce a value added petrochemical product such as propylene in oil refineries and at the same time, production of heavy fuel oil decreases in oil refining basket.

Table 1: Typical refinery streams which may be used at petrochemical units [8]

Refinery stream	Petrochemical stream	Alternative refinery use
FCC off gas	Ethylene	Fuel gas
Refinery propylene (FCC)	Propylene	Alkylation / Poly gasoline
Reformate	Benzene, toluene, xylenes	Gasoline blending
Naphtha and LPG	Ethylene	Gasoline blending
Dilute ethylene(FCC and delayed coker off gas)	Ethylbenzene	Fuel gas
Refinery propylene (FCC product)	Polypropylene, Cumene, Isopropanol, Oligomers	Alkylation
Butylenes (FCC and delayed Coker)	MEK (methyl ethyl ketone)	Alkylation, MTBE
Butylenes (FCC and delayed Coker)	MTBE, ETBE	Alkylation, MTBE
Refinery benzene and hydrogen	Cyclohexane	Gasoline blending
Reformer	O-xylene	Gasoline blending
Reformer	P-xylene	Gasoline blending
Kerosene	N-paraffins	Refinery product
FCC light cycle oil	Naphthalene	Diesel blending

2. Different scenarios for petro refinery units

2.1. Aromatics production

One of the main scenarios of aggregating an oil refinery with a petrochemical plant is to add an aromatics production unit to an oil refinery to produce aromatic products such as benzene, toluene and xylene. Aromatics production unit is designed to produce cyclohydrocarbons that includes hydrodesulfurization of feed, catalytic cracking, solvent extraction, hydrodealkylation sections. Following hydrodesulfurization refining, naphtha enters catalytic cracking section where it is converted to aromatics. In separation section, cyclo-compounds are extracted by solvent and then separated to finished products. In hydrodealkylation, toluene and heavy aromatics are converted to benzene. The schematic diagram of this unit is shown in figure 1. Aromatic products like chemical substances group include a wide spectrum of products such as benzene, toluene, ortho-xylene, para-xylene, heavy aromatics.

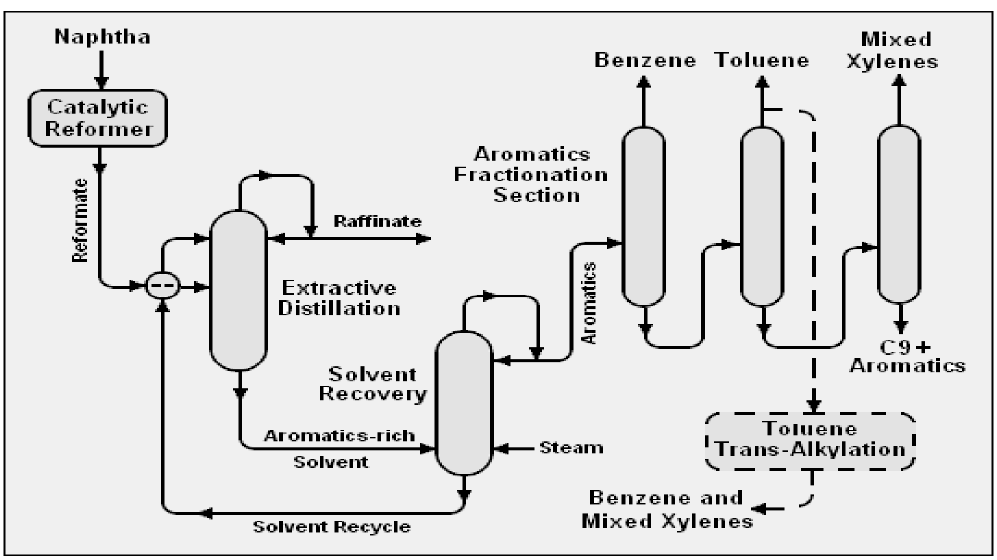

Fig. 1. Schematic figure of an aromatics production unit

Despite diversity of products of aromatics group and their importance in production process, the rate of consumption of them is negligible compared to other groups. Aromatic products do not create much added value and for this reason, their production is economically justified in large scales in most countries. Since, a considerable amount of profit is obtained from aromatics exports; most producers are giant companies which produce them in large scales. With this view, establishing a petro refinery by addition of an aromatics production unit is not attractive business wise. Moreover, three Iranian petrochemical plants like Boo Ali Sina, Noori and Isfahan are actively involved in aromatics production.

2.2. Naphtha steam cracking or kerosene production

One of the scenarios to establish a petro refinery is to add a steam cracking unit to produce ethylene, propylene and butadiene products. Schematic diagram of a steam cracking fired heater for a pyrolysis unit is shown in Fig 2.

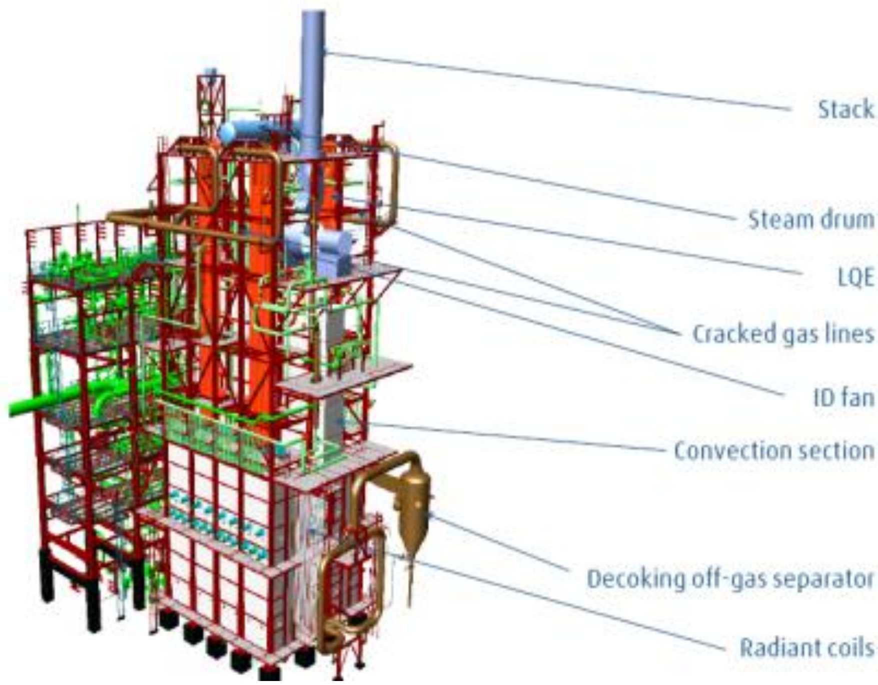

Fig. 2- Schematic figure of a steam cracking furnace of a pyrolysis unit

As it can be seen, this equipment consists of the following sections:

1- Conduction heat transfer section
2- Radiation heat transfer section
3- Product transfer lines through cracking process section
4- Quick cooling heat exchanger section

To add a steam cracking unit to a petro refinery, several combinational cases are considered by changing the type of feed to this unit. Two types of suitable feeds for this unit are:

1. Naphtha as input feed to olefin production unit (steam cracking)
2. Kerosene as input feed to olefin production unit (steam cracking)

3. Economic feasibility studies

Four different scenarios were considered assuming the input feed to be 250,000 barrels per day:

1. A typical oil refinery
2. First scenario petro refinery: addition of a steam cracking unit to an oil refinery with naphtha feed

3. Second scenario petro refinery: addition of a steam cracking unit to an oil refinery with kerosene feed
4. Third scenario petro refinery with feed specification given in Table 2

Table 2. Feed specification

Boiling point, °C	%vol. recovered	Boiling point, °C	%vol. recovered
15	2.8	300	48.7
65	8.97	425	67.97
150	21.5	500	78.5
250	39.33	565	84.75
Specific gravity		0,8545 (API=34)	

The economical calculations are carried out by COMFAR III with the following assumptions:

- The share of investor is assumed to be 15 % and the remaining investment is provided by loan
- Discount Rate: 10%
- Production period: 20 years.

3.1. A typical oil refinery

In the following a schematic Figure 3. a petro refinery is shown and in continuation economic calculations such as capital investment, feed and product prices and the rate of return of investment are summarized in Table 3.

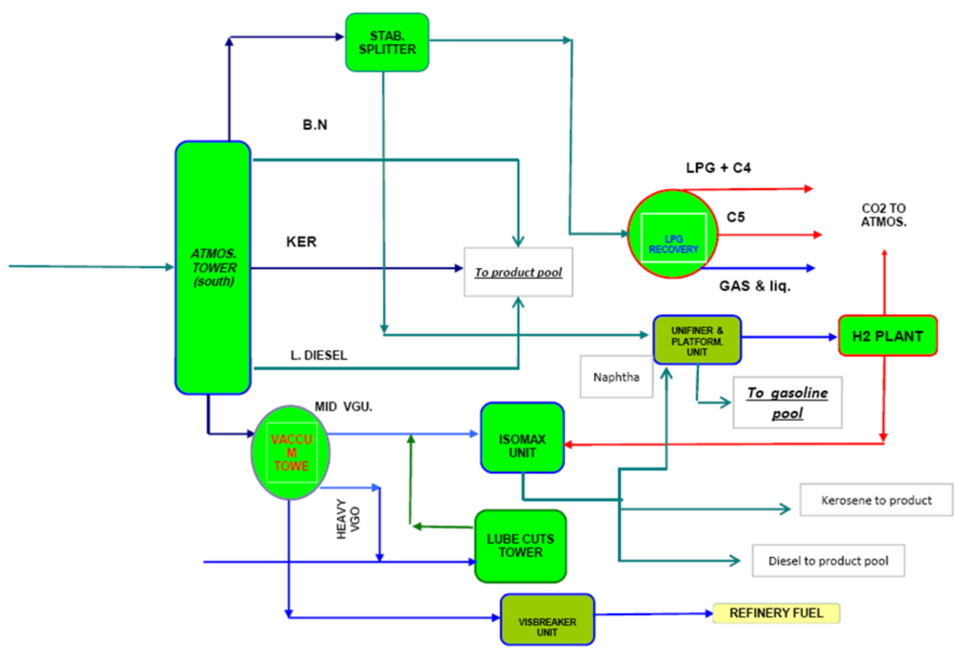

Fig. 3. Schematic figure of a typical petro refinery

Table 3. Economical parameters in an oil refinery

	ton/day	$/day	$/BBL
Feed flow rate	34155	20,322,225	81
Total sales	28,935	21,971,575	
Utility purchases	18,789		
Total profit		1,630,561	
Capital cost (MM $)		4,191	16,764
Net Profit Value of total capital investment (MM $)		690	
Internal rate of return on investment		12.48%	

3.2. A petro refinery by addition of a steam cracking unit to a refinery with naphtha feed

In the following figure a schematic figure of a petro refinery is shown and in continuation economical calculations such as capital investment, feed and product prices and the rate of return of investment are summarized in Table 4.

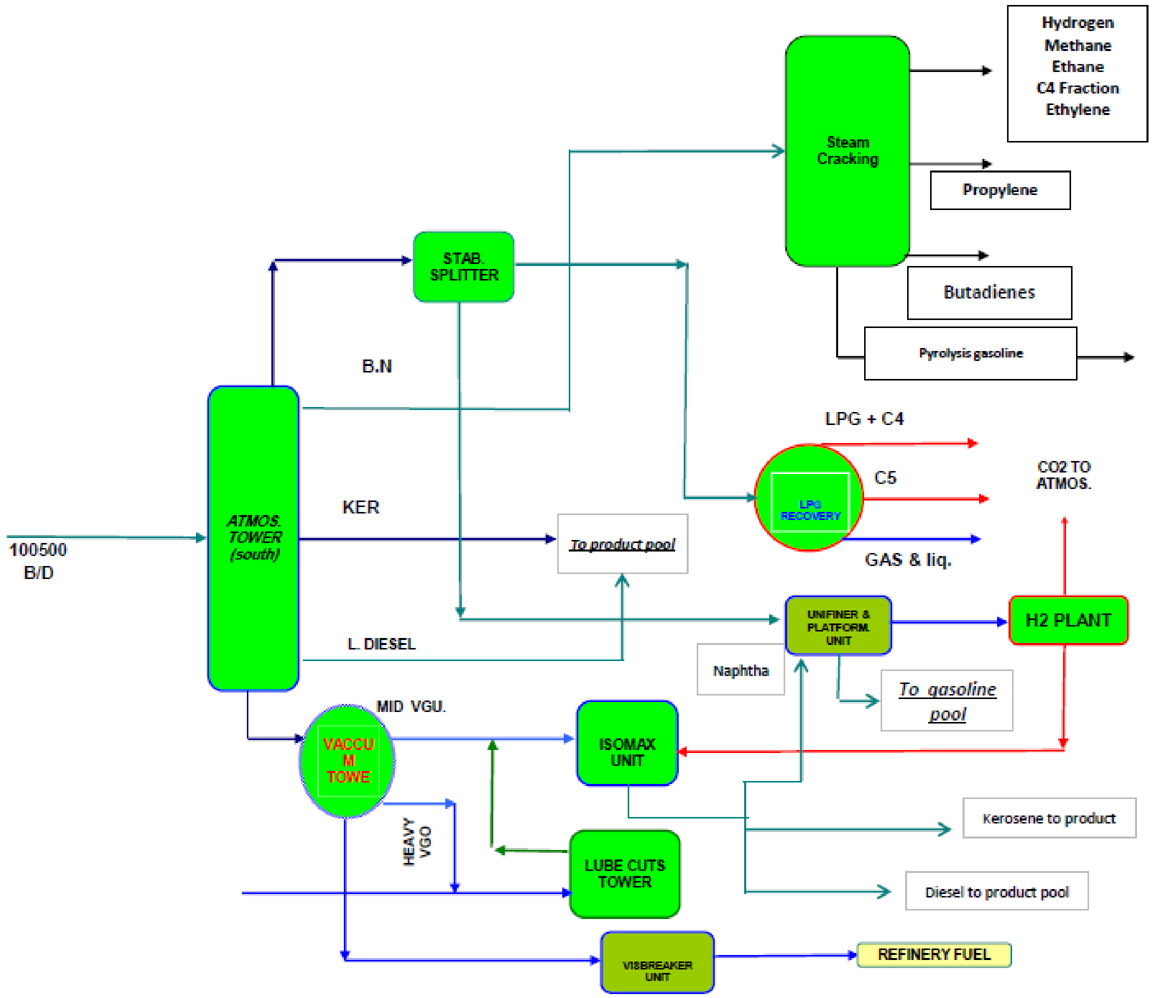

Fig. 4. First scenario: A petro refinery by addition of naphtha steam cracking unit

Table 4. Economical parameters of establishing a petro refinery with naphtha steam cracking unit

	ton/day	$/day	$/BBL
Feed flow rate	34,155	20,322,225	81
Total sales	31,820	26,762,911	
Utility purchases	26,734		
Total profit		6,413,952	
Capital cost MM $		5,949	23,796
Net Profit Value of Total Capital Investment (MM $)		10,717	
Internal Rate of Return on Investment (%)		30.73 %	

3.3. A petro refinery by addition of a steam cracking unit to a refinery with kerosene feed

In the following figure a schematic figure of a petro refinery is shown and in continuation economical calculations such as capital investment, feed and product prices and the rate of return on investment are summarized in Table 5.

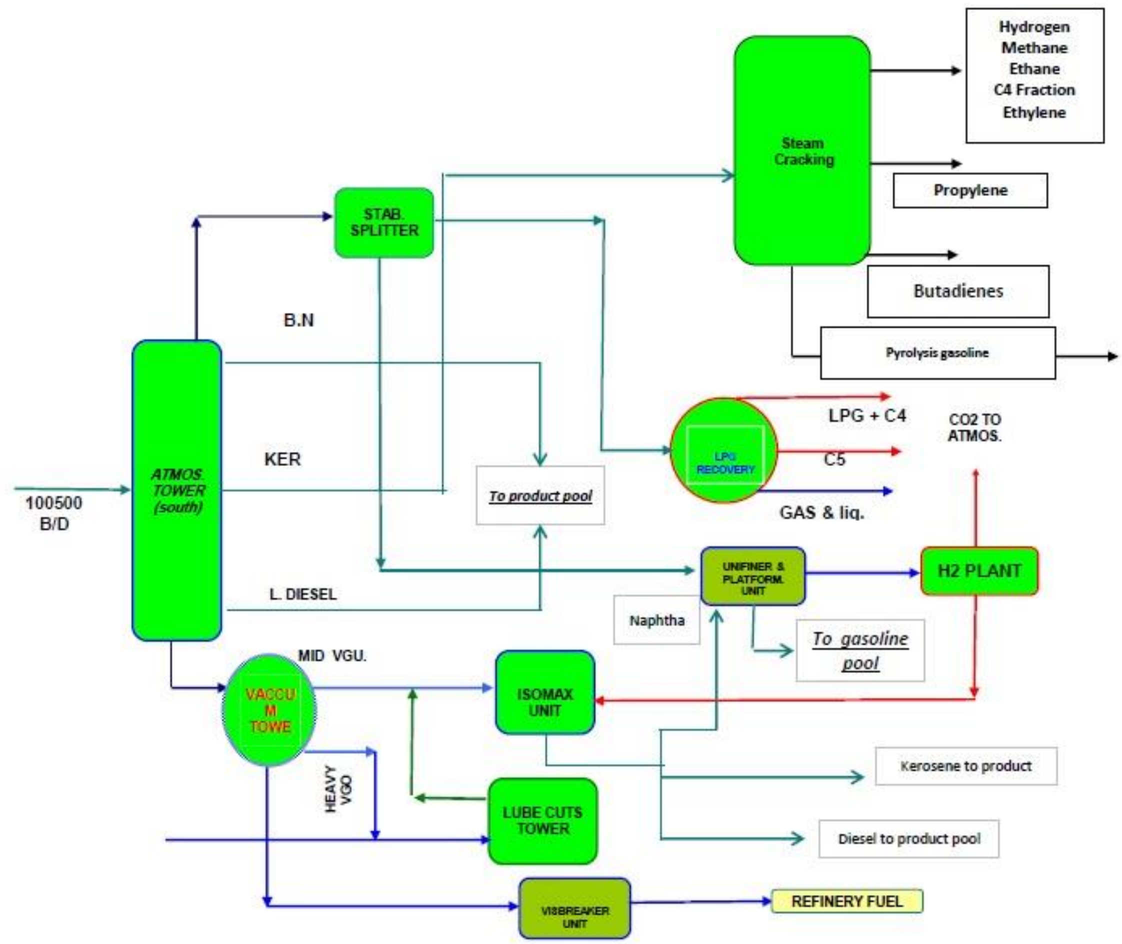

Fig. 5. Second scenario: A petro refinery by addition of kerosene steam cracking unit

Table 5- Economical parameters of establishing a petro refinery with kerosene steam cracking unit

	ton/day	$/day	$/BBL
Feed flow rate	34,155	20,322,225	81
Total sales	32,848	26,876,902	
Utility purchases	24,036		
Total profit		6,530,641	
Capital cost MM $		6,361	25,444
Net Profit Value of Total Capital Investment MM $		10,640	
Internal Rate of Return on Investment		29.62 %	

3.4. A petro refinery by addition of an aromatics production unit to a refinery

In the following figure a schematic figure of a petro refinery is shown and in continuation economical calculations such as capital cost, feed and product prices and internal rate of return of investment are summarized in Table 6.

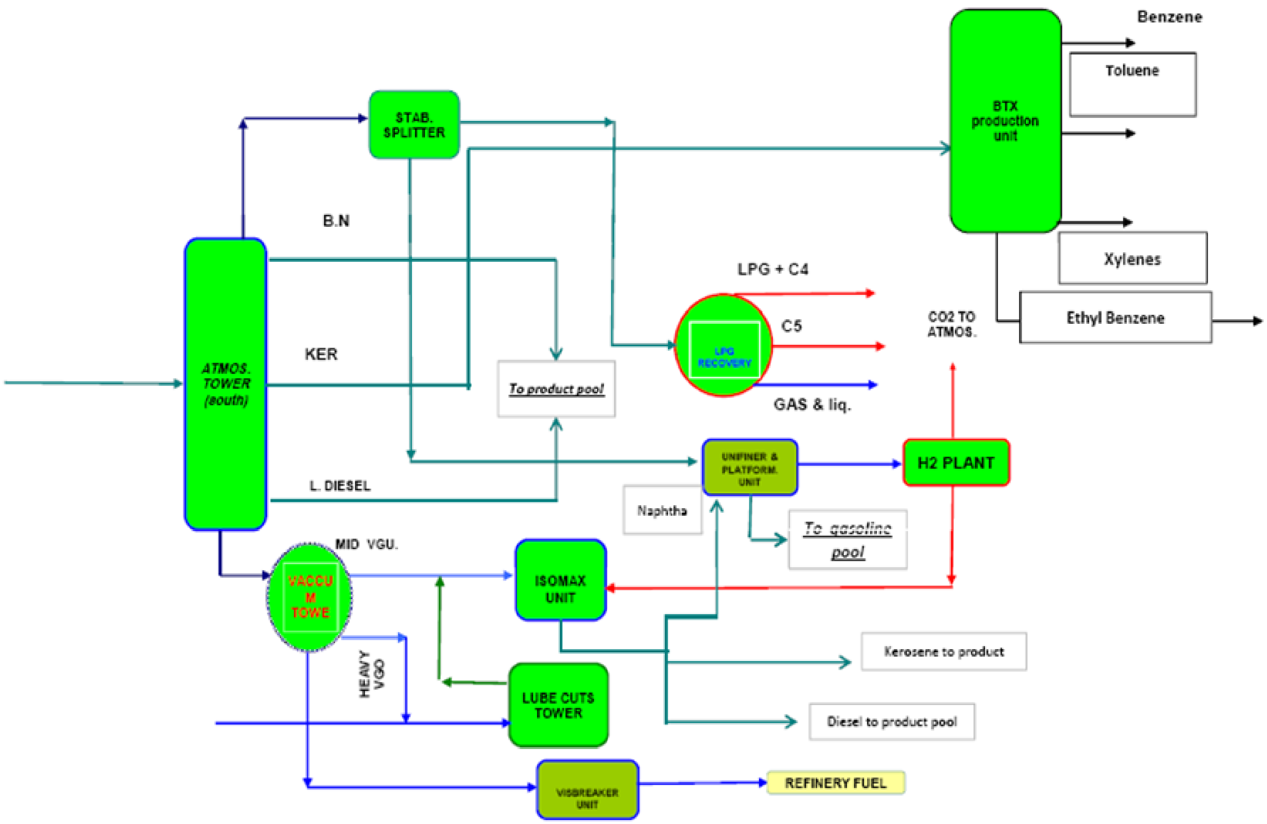

Fig. 6. Third scenario: A petro refinery by addition of an aromatics production unit

Table 6. Economical parameters of establishing a petro refinery with aromatics production unit

	ton/day	$/day	$/BBL
Feed flow rate	34,155	20,322,225	81
Total sales	27,707	22,551,561	
Utility purchases	20,898		
Total profit		2,208,438	
Capital cost MM $		5,481	21,924
Net Profit Value of Total Capital Investment MM $		1,198	
Internal Rate of Return on Investment		13.33%	

4. Conclusions

The summary of economical calculations to establish an individual refinery and three scenarios of petro refineries with process pattern of using naphtha cracker, kerosene cracker and aromatics production units are presented in Table 7. Based on cost estimations, the rate of return of investment to establish an individual oil refinery is predicted to be 12.48 %. The rate of return of investment to establish a petro refinery with naphtha steam cracking unit is increased to 18%. In the scenario of a petro refinery with kerosene steam cracking unit, the rate of return of investment is about 17% while for the third scenario, the rate of return of investment for a petro refinery with aromatics production unit shows only 1% more than of that for an individual oil refinery.

Table 7. Techno-economical evaluation of an oil refinery and three scenarios of a typical petro refinery

	Oil Refinery	Naphtha Petro Refinery	Kerosene petro Refinery	Aromatics Petro Refinery
Feed Flow Rate (ton/day)	34,155	34,155	34,155	34,155
Feed Price ($/day)	20,322,225	20,322,225	20,322,225	20,322,225
Total Sales ($/day)	21,971,575	26,762,911	26,876,902	22,551,561
Utility Purchases ($/day)	18,789	26,734	24,036	20,898
Total Profit ($/day)	1,637,561	6,413,952	6,530,641	1,612,445
Capital Cost (MM $)	4191	5949	6361	5481
Net Profit Value of Total Capital Investment (MM $)	690	10717	10640	1198
Internal Rate of Return on Investment (%)	12.48	30.73	29.62	13.33

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