

**NATIONAL UNIVERSITY OF ENGINEERING**  
**College of Petroleum Engineering Natural Gas**  
**and Petrochemicals**



**Technical and Economic Feasibility for the**  
**Installation of an Industrial Plant for Producing**  
**High-Octane Gasoline from Methanol**

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## INDEX

1. Executive Summary	1
2. Definitions	3
2.1 Name	3
2.1 Nature	3
2.3 Location	3
2.4 Problem Conception	4
2.5 Project Objectives	7
2.5.1 General objective	7
2.5.2 Specific objective	7
2.6 Strategies	5
3. Market studies	10
3.1 Natural Gas	10
3.2 Demand analysis	15
3.2.1 Methanol	15
3.2.2 High octane gasoline	20
3.3 Supply analysis	24
3.3.1 Methanol	24
3.3.2 High octane gasoline	27
4. Technical study	30
4.1 Processes for obtaining synthetic gasoline	30
4.2 Processes MTG	33
4.3 Catalyst Description	39
4.4 Results of the simulation considering the selected technology.	41
4.4.1 Description of the simulator used	41
4.4.2 Advantages and disadvantages of using the simulator	41
4.4.3 Bases for simulation	42
4.4.4 Thermodynamic aspects of DME	42
4.4.5 Reaction mechanism of gasoline production	43
4.4.6 Kinetic aspect of gasoline production	46
4.4.7 Catalyst	47
4.4.8 Description of Equipment, Operating Conditions and Thermodynamics of the simulated MTG process	48
5. Legal study	58
5.1.1 Law N° 26221	58
5.1.2 Law N° 271333	58
5.1.3 Law N° 29163	59
5.1.4 Supreme Decret N° 54-2007 EM	59
5.1.5 Ministerial Resolution N° 118-2010-MEM/DM	60
5.1.6 Law N° 28611	60
5.1.7 Law N° 28054	61
5.1.8 Law N° 28317	62
6. Environmental Study	64
6.1 Potential health effects	65
6.2 Effects on the environment	66
7. Equipment sizing and cost	70
7.1 Sizing	70
7.2 Cost of equipment	86

8. Economic evaluation	89
8.1 Calculation of battery limit and total inversion	89
8.2 Operating cost calculation	90
8.3 Fixed load calculation	92
8.4 Cash flow calculation	93
8.5 Calculation of TIR, VAN and return of investment	94
8.6 Sensitivity of the Project	96
9. Conclusions	99
10. Bibliography	100

# **ECONOMIC EVALUATION FOR THE OBTAINMENT OF HIGH OCTANEAN GASOLINE FROM METHANOL**

## **1. EXECUTIVE SUMMARY:**

Over the years, the laws governing the Organic Law of the Transport Sector have been implemented and modified by the General Directorate of the Environment, which is responsible for proposing the improvement and quality control of the environment. D.S. N ° 044-98-PCM approved the National Regulations for the Approval of Environmental Quality Standards and Maximum Permissible Limits, which establishes the procedure for formulation and approval of Maximum Permissible Limits.

This regulation limits emissions of carbon monoxide, carbon dioxide, the amount of aromatics and other compounds harmful to the environment and humans. Currently in Peru the control of emissions of harmful gases is governed by the EURO III Standard, placing limits on the content of sulfur and aromatics as the most outstanding points of this standard.

The main objective of this research project is to analyze the technical and economic viability of the implementation of a high octane gasoline production plant similar to that obtained in Fluidized Catalytic Cracking. This plant will reduce the imports of gasoline (Cracked Nafta and Reformed Nafta) made by the national refineries in order to formulate their own products to obtain marketable gasolines in Peru according to the laws in execution. The raw material used for the production of this gasoline will be Methanol, which will be obtained from Natural Gas.

The technology used for the production of Methanol is the Combined Reforming of the licensor Lurgi. This technology allows to consume less raw material, reduces the consumption of energy and reduces the cost of investment.

This licensor has more experience in the market and its technology presents greater advantages compared to that of other licenciantes. Using this technology, according to the existing Thesis of Degree that analyzes all this process

(GIANNINA IBARRA. Simulation of the process of obtaining methanol with the objective of Industrialize Natural Gas in Peru). This will be used as the basis for the development of this project, an approximate ratio of Natural Gas / Methanol of 0.0367 MMPC / TM.

On the other hand, the technology that is planned to be used for the production of Gasolines is ExxonMobil's "Methanol to Gasoline" (MTG Process). This technology has a high energy efficiency and allows the generation of gasolines free of sulfur and nitrogen. Using this technology an approximate methanol / gasoline ratio of 0.3182 TM / bbl can be obtained.

It should be noted that this project is a good option for countries that have large reserves of natural gas and have a high demand for liquid fuels, it is in this problem where the methanol to gasoline (MTG) process is a viable option for the use Of Natural Gas.

The technical and economic results of the research will determine if feasible the execution of the same to start the possible realization of a basic engineering study.

This report will try to give added value to Natural Gas and promote industrialization in Peru through the construction of these plants, which will give work and improve the quality of life of Peruvians.

## **2. DEFINITIONS:**

### **2.1. NAME:**

The name used for the project is:

*"Economic Evaluation for the Obtention of High octane Gasoline from Methanol"*.

### **2.2. NATURE**

This project aims to make a technical and economic evaluation of the possible installation of a high octane gasoline production plant from Methanol. To obtain methanol, it has been decided to carry out the implementation of a production plant from natural gas.

The project is focused on the viability of the Gasoline Production Plant, but not on the Methanol Plant. The analysis of this last one is already detailed in a Thesis of Degree that will be used as base for the realization of this investigation.

### **2.3. LOCATION:**

According to the provisions of Supreme Decree No. 042-2009-EM, the location for the installation of a Petrochemical Complex is the Marcona district (Figure 1), in the province of Nazca and in the department of Ica. For this reason, the plants proposed in the present study would have to be located in the Department of Ica, facilitating the transportation of gasoline produced to the main national refineries as well as the export of the production to the countries of the USA, Mexico and Central America.

From a competitive point of view, on this side of the Pacific, the largest petrochemical plants are located in Chile, but this country is experiencing serious problems of supplying natural gas, since Argentina has stopped supplying natural gas.

On the other hand, the proximity of this location to the Peruvian Southern Gas Pipeline facilitates the transport of the raw material needed for the project (Natural Gas).



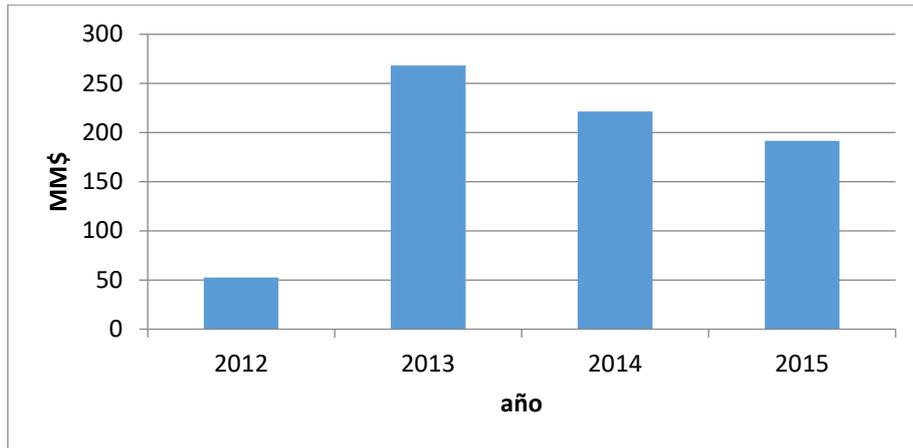
**FigurE 1: Possible Plant Location**

Source: Google Maps

#### **2.4. PROBLEM CONCEPTION:**

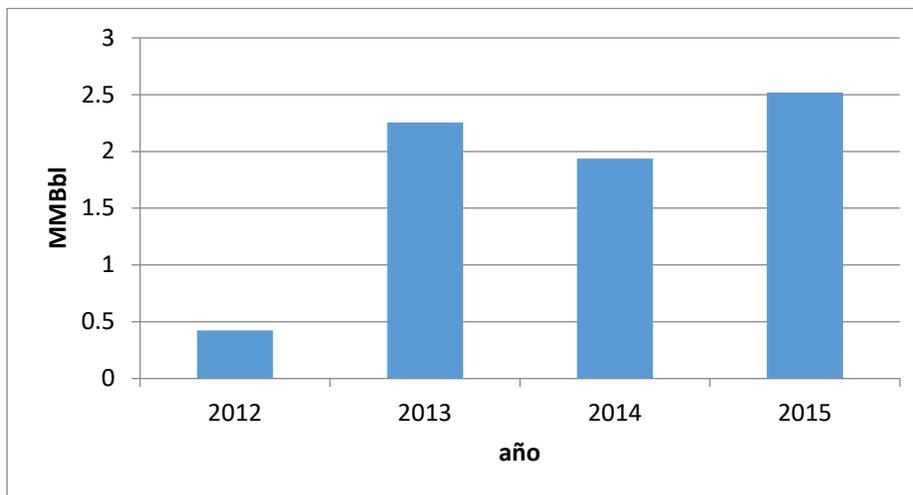
With the purpose of obtaining commercial gasolines that comply with Peruvian laws; the national refineries make Blending between the virgin naphtha they produce and high octane gasoline.

Due to the fact that there is currently no production of high octane gasoline sufficient to meet demand in Peru; Refineries choose to import them. These imports incur high costs, delay in the arrival of the product among other drawbacks.



**Figure 2: MM \$ in imports of Gasoline per year**

Source: Aduanet



**Figure 3: MMBbl imported from Petrol per year (Aduanet)**

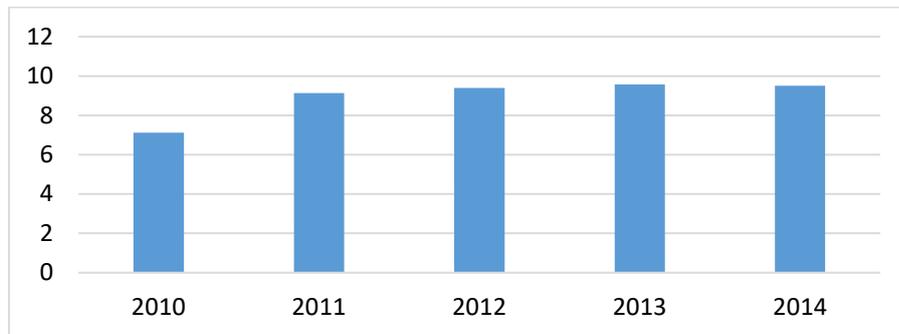
Source: Aduanet

According to data obtained from Aduanet (Figure 2 and 3), about 2.5 MMBbl (280 MBbl / month) of high octane gasoline has been imported so far in 2015, at a cost of approximately 190 MM \$. The current trend shows an increase in volume and a decrease in the cost of imports of high octane gasoline due largely to the decline in the price of oil in the world.

In view of this national problem, it is proposed the installation of a high octane gasoline production plant in order to reduce or eliminate these imports. With the installation of the plant would cover domestic demand for

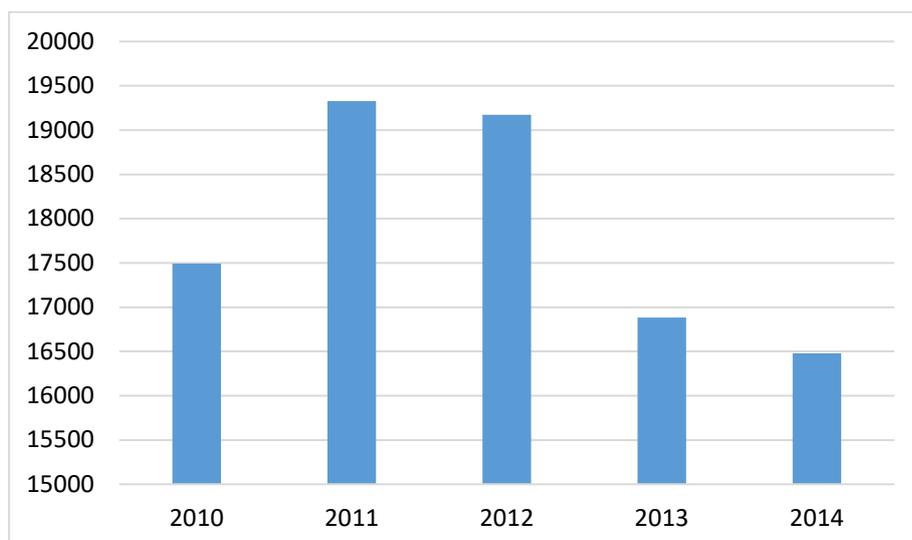
high octane gasoline and the surplus could be exported to other countries making Peru a competitive country in this area.

On the other hand, methanol imports from the country also incur high costs (Figure 4). In 2014, according to Aduanet data, the amount of industrial methanol (Figure 5) that was imported in the country amounted to 16.5 MTM (thousands of metric tons) incurring a cost of approximately 9.5 million dollars. With the implementation of the methanol production plant, it would not only supply the gasoline production plant but also the surplus of methanol could be used to cover part of the country's domestic demand.



**Figure 3: Imports of Methanol (MM \$) vs. years**

Source: Aduanet



**Figure 5: Imports of Methanol (TM) vs. years**

Source: Aduanet

## **2.5.PROJECT OBJECTIVES:**

### **2.5.1. General Objective:**

- Reduce imports of high octane Gasoline.
- Reduce imports of methanol.
- Use of Natural Gas as an alternative energy source.

### **2.5.2. Specific objective:**

- Analyze the technical and economic feasibility of the Project.
- Analyze the Gasoline market outside the country for future export.
- Analyze the market for methanol in the country to be able to cover domestic demand or part of it.
- Carry out projections on the behavior of the prices of gasoline and methanol.
- Suggest a construction site.
- Show the benefits of high octane gasoline.

## **2.6. STRATEGIES:**

The strategies used to carry out this research are the following:

- The pre-existence of a methanol plant will be assumed. Whose capacity will be 3,500 TMD of methanol, as a basis for the realization of the gasoline production plant with the Methanol to Gasoline (MTG) process.

- Carry out the corresponding market study, analyzing the supply and demand both internal and external methanol and high octane gasoline.
- Conduct the technical study of the MTG process and perform its respective simulation (HYSYS), which will allow us to obtain data with which we can carry out the feasibility study of the project. Information can be obtained from the technology licensor.
- Analyze the legal factors of the implementation of the plant and associated regulations.
- Analyze the environmental factors of the implementation of the plant and associated regulations.
- Analyze the cost of installation, equipment, investment and financing of the plant.
- Carry out the final economic and technical feasibility study of the project.

### **2.7. FORMULATION OF HYPOTHESES AND VARIABLES:**

The hypothesis formulated is that the operation of the plant to obtain Methanol from Natural Gas.

The variables used to carry out this research are the following:

- Price of the Barrel of High octane Gasoline and / or barrel of crude oil.
- Price of the cubic foot of Gas Natural in the local market and export.
- Price of Methanol.
- Environmental legislation.
- Production capacity.

## **3. MARKET STUDIES**

### 3.1. Natural gas

The raw material used for the Project is Natural Gas. The project will seek to use the national reserves of Gas Natural in order to give them added value and promote their industrial use. For the production of Natural Gas, the Peruvian State granted in concession the field activities (exploration and exploitation), transportation and distribution of Gas Natural to first level companies which are shown below:

Table 1:

#### Natural Gas Production by company

	Pluspetrol	Aguaytia	Petrobras	Savia	GMP	Sapet	Olympic	Repsol	Monterrico	Total
nov-13	1,173.56	11.43	6.38	6.46	6.75	1.58	6.51		1.62	1,214.29
dic-13	1,147.08	11.32	6.15	4.58	6.71	3.20	6.59		1.25	1,186.89
ene-14	1,136.78	14.41	7.35	7.46	6.31	2.56	6.54		1.59	1,182.99
feb-14	1,184.75	15.98	8.04	3.91	5.52	2.57	8.15		1.64	1,230.55
mar-14	1,231.08	16.13	8.15	5.26	6.53	2.38	9.94	17.31	1.62	1,298.40
abr-14	1,121.94	10.31	8.10	4.10	6.68	2.22	10.95	91.00	1.53	1,256.85
may-14	1,049.73	12.95	8.07	3.30	7.18	3.03	5.48	82.86	1.53	1,174.13
jun-14	1,012.03	17.60	8.33	2.74	7.82	3.05	5.70	54.40	1.54	1,113.21
jul-14	1,107.91	13.20	14.38	8.12	8.56	3.17	6.11	115.83	1.70	1,278.97
ago-14	1,154.82	15.28	14.83	8.08	9.96	3.60	6.37	37.54	1.96	1,252.42
sep-14	1,103.96	15.79	13.93	7.01	8.67	2.53	5.24	62.53	1.95	1,221.62
oct-14	1,194.17	13.54	14.63	6.41	9.85	2.62	6.77	93.74	1.95	1,343.68
nov-14	1,192.96	15.57	14.00	6.56	9.52	2.90	8.32	92.97	2.10	1,344.89
Var % Nov 14/Nov 13	1.7%	36.3%	119.4%	1.5%	41.0%	83.0%	27.7%	---	29.6%	10.8%

**Note.** Values in MMPCD (millions of cubic feet day). Source: Diario Gestión (November 2014)

As can be seen in Table 1, the company that owns the largest natural gas production in Peru (1192 MMPCD in 2014) is the PlusPetrol company, which holds the license to exploit the hydrocarbons of the Camisea Project.

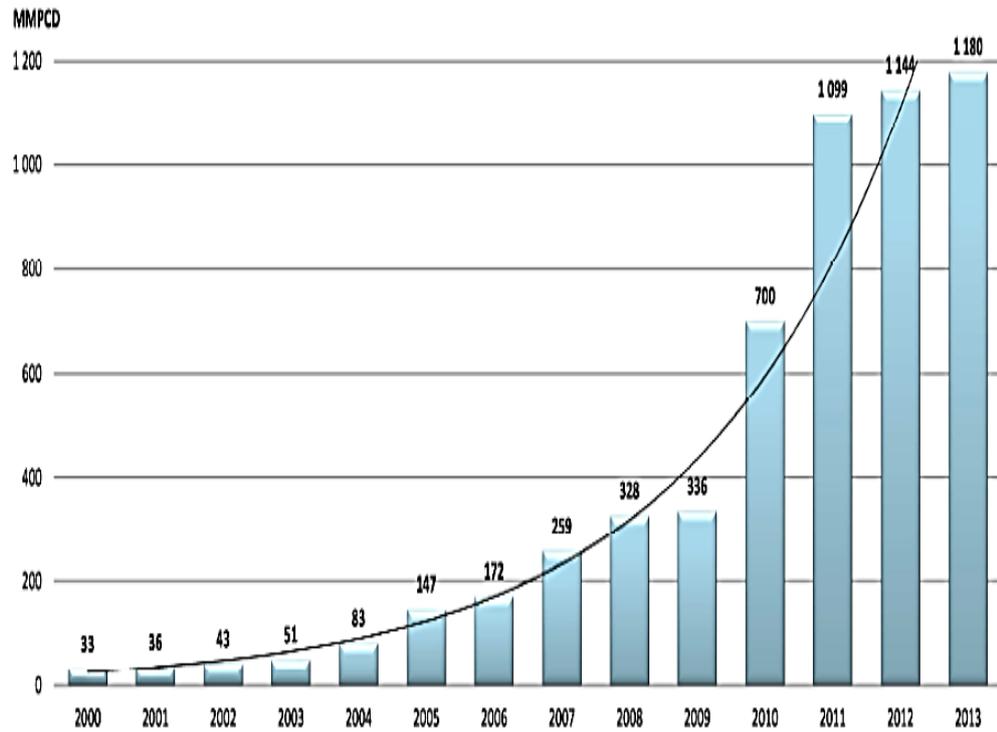
Natural gas production during the period 2000-2013, with the entrance of natural gas from Camisea, registered an exponential growth with an

Average Annual Variation of 31.6% (Figure 6). At the end of 2013 the National production of Natural Gas was 1180 MMPCD (million cubic feet per day). This production was destined as follows (Figure 7):

- Exports: 560 MMPCD
- Electricity generation: 314.1 MMPCD
- Industrial Sector: 120.2 MMPCD
- Sector Transportation: 62.59 MMPCD
- Residential sector: 3.76 MMPCD
- Future Projects (Petrochemical): 120 MMPCD

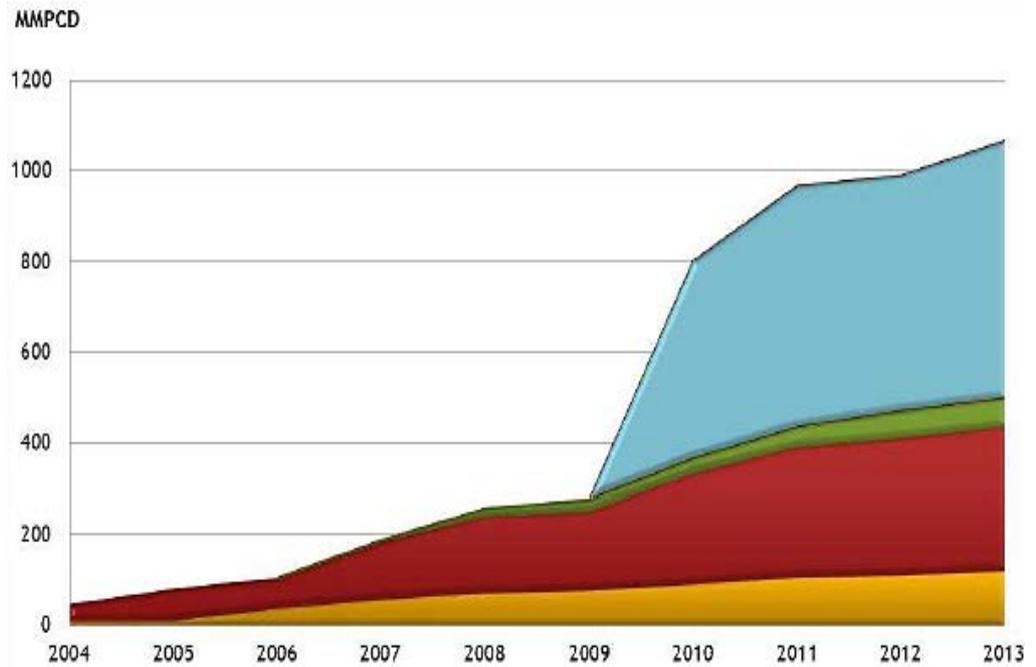
As can be noted, 120 MMPCD of natural gas has been allocated to future projects, including petrochemicals. It is this Natural Gas that is available as raw material for the development of the Methanol plant and subsequent plant for obtaining high octane gasoline.

In addition to the data shown, the projections shown in the national energy plan 2014-2025 predict that in 2025 the production of Natural Gas will reach a maximum level of 541 MBEPD (3137.8 MMPCD), In the PBI scenario 4.5% per year 2025 and 585 MBEPD (3393 MMPCD) in the PBI scenario 6.5% by 2025 (Figure 8 and 9). At the same time, the demand for it, which includes the final consumption plus that required for the generation of electricity and the development of petrochemicals, will increase from 1 900 MMPCD to 2 400 MMPCD by 2025 (Figure 10). Supply a national pipeline system.



**Figure 6: Evolution of Natural Gas Production 2000 - 2013 (MMPCD)**

Source: PERUPETRO, MINEM



**Figure 7: Evolution of demand for Natural Gas by Consumption sectors**

Source: MINEM, OSINERGMIN

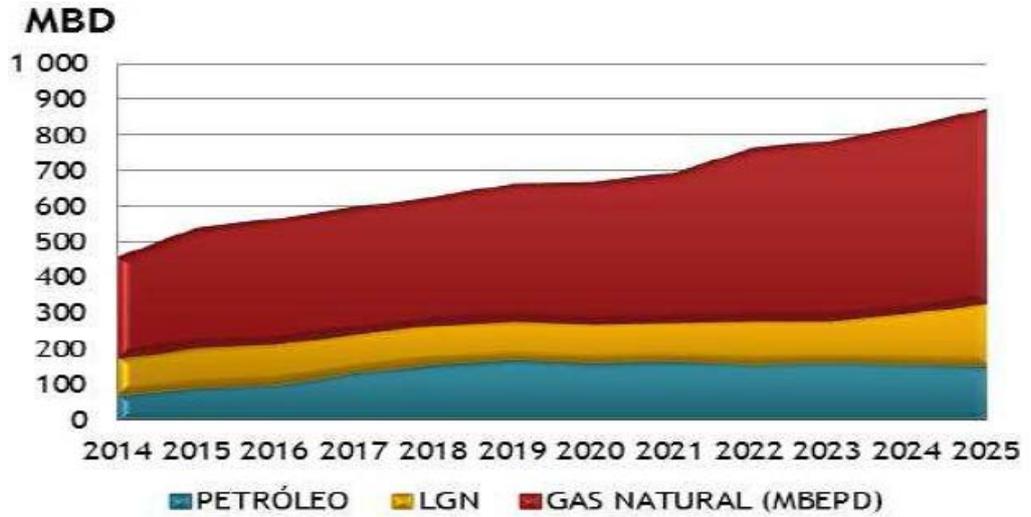


Figure 8: Hydrocarbon Production (MBD). Scenario 4.5%.

Source: DGEE

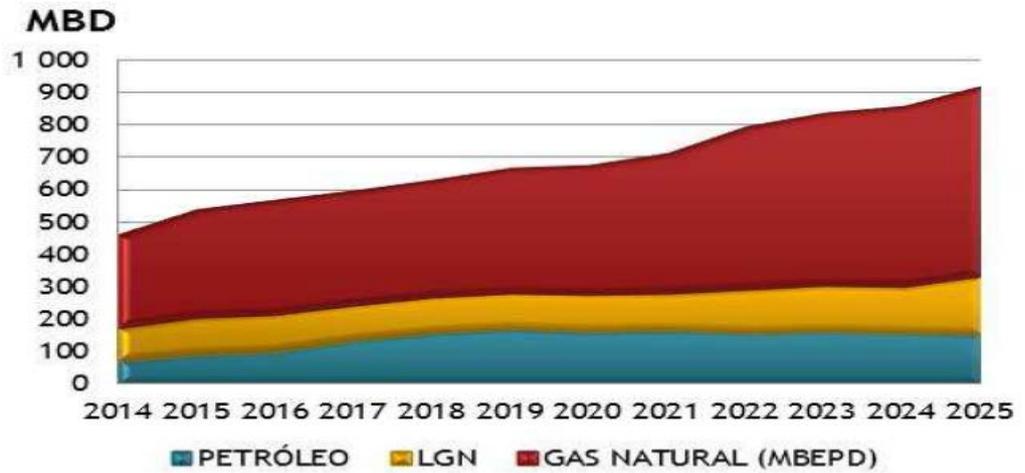


Figure 9: Hydrocarbon Production (MBD). Scenario 6.5%.

Source: DGEE

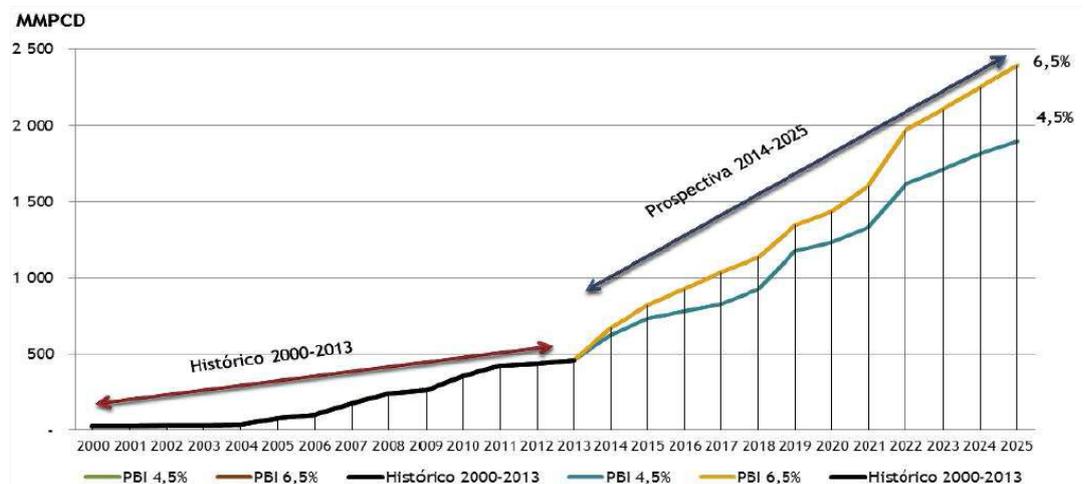


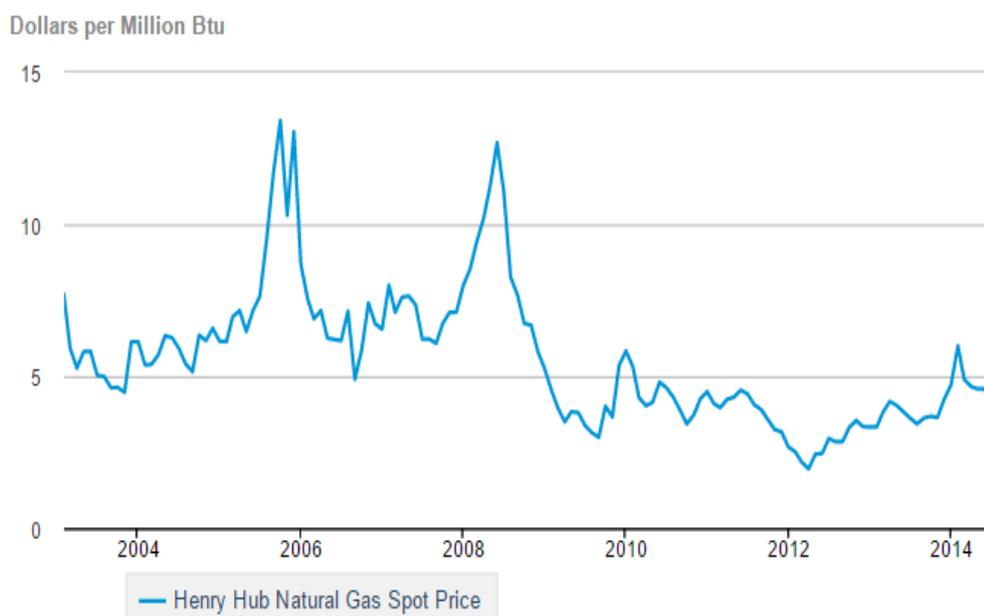
Figure 10: Growth of Natural Gas Demand

**Source: MINEM**

With these data and projections ensures the sufficiency of raw material for the realization of the project.

On the other hand until September 2015, the price of Natural Gas in the world according to Henry Hub, was around \$ 2.66 / MMBTU. Figure 11 shows the historical evolution of the price of Natural Gas over the last few years. High historical peaks can be observed in 2005 and 2008, which were influenced by Hurricane Katrina in the US in 2005 and the global economic crisis unleashed in 2008, but it is now appreciated that the price trend is declining (February 2014 : \$ 6 / MMBTU - September 2015: \$ 2.66 / MMBTU).

In the Peruvian case, the natural gas price at the well of Camisea Gas of Lot 88 since September 2013 is US \$ 1.83 / MMBTU for electricity generation and US \$ 3.18 / MMBTU for industrial-petrochemical use.



**Figure 11: Evolution of the price of Natural Gas in \$ / MMBTU (Henry Hub)**

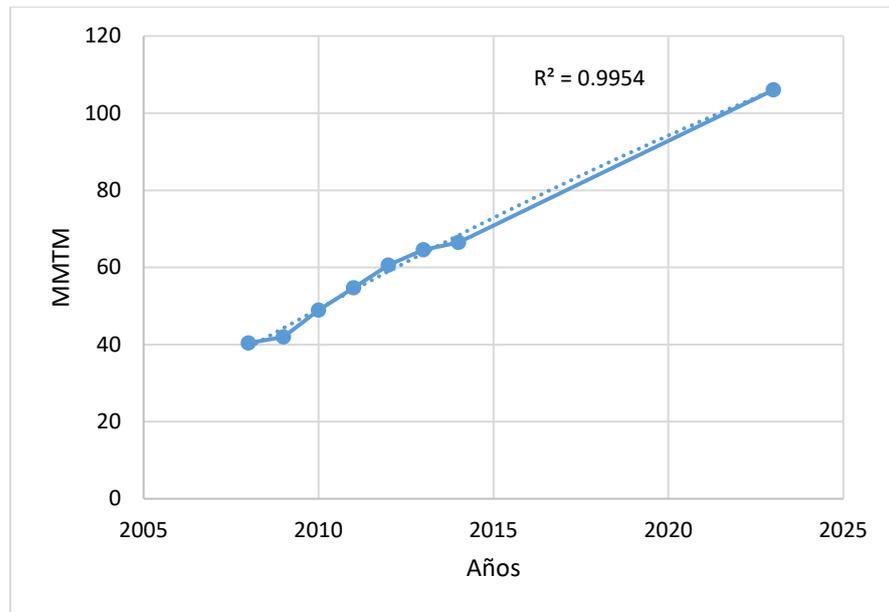
**Source: U.S Energy Information Administration (EIA)**

## **3.2.Demand Analysis**

### **3.2.1. Methanol**

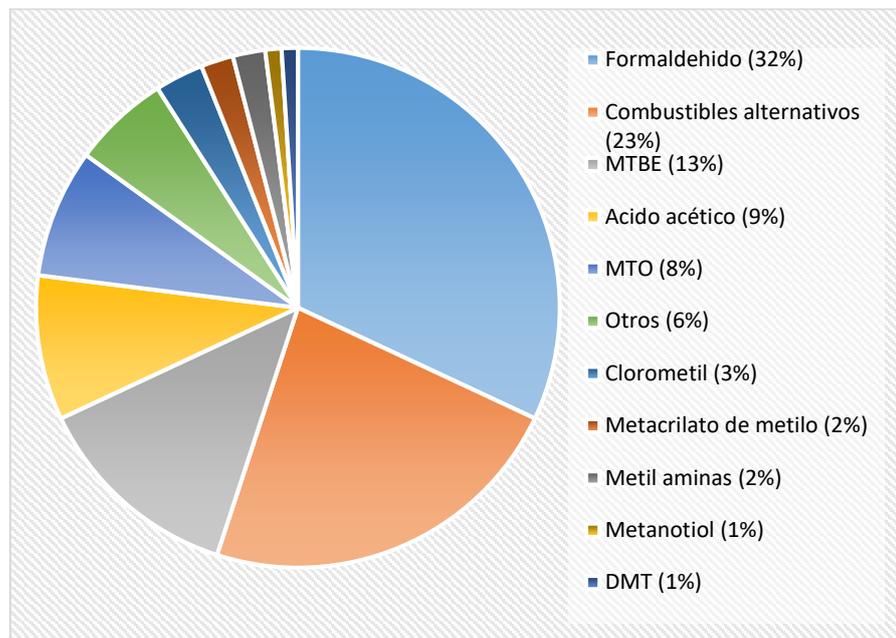
Methanol is a very important compound for the chemical industry due to its use as a raw material for a great variety of products such as Formaldehyde, alternative fuels, MTBE, acetic acid, Methanol to Olefines (MTO), etc. It is for this reason that its global demand has grown steadily in recent years (Figure 12 and 13) with a rate between 7% and 9% per year.

Approximately between 2008 and 2014 world demand for methanol rose from 40.4 MMTM to 66.5 MMTM respectively and the global trend shows that this demand will grow to approximately 106 MMTM in 2023 (IHS Global Methanol Report 2014).



**Figure 12: Evolution of global demand for methanol per year**

**Source: Own elaboration**

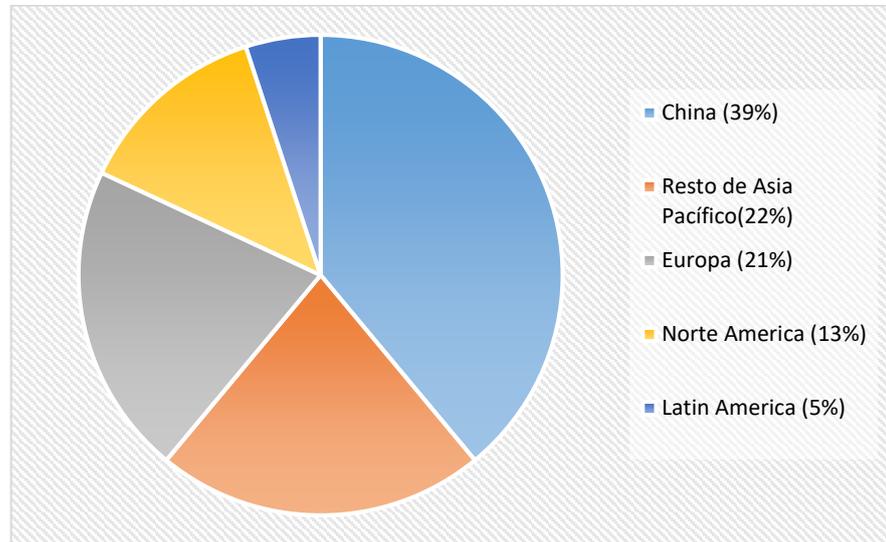


**Figure 13: World Demand for Methanol by Derivatives**

**Source: Own elaboration**

The world's largest consumer of methanol is China, accounting for more than 40% of global demand (Figure 14). The main applications that justify the massive consumption of methanol in this country are

applications related to energy, Manufacture of olefins and direct mixing of methanol with gasoline.



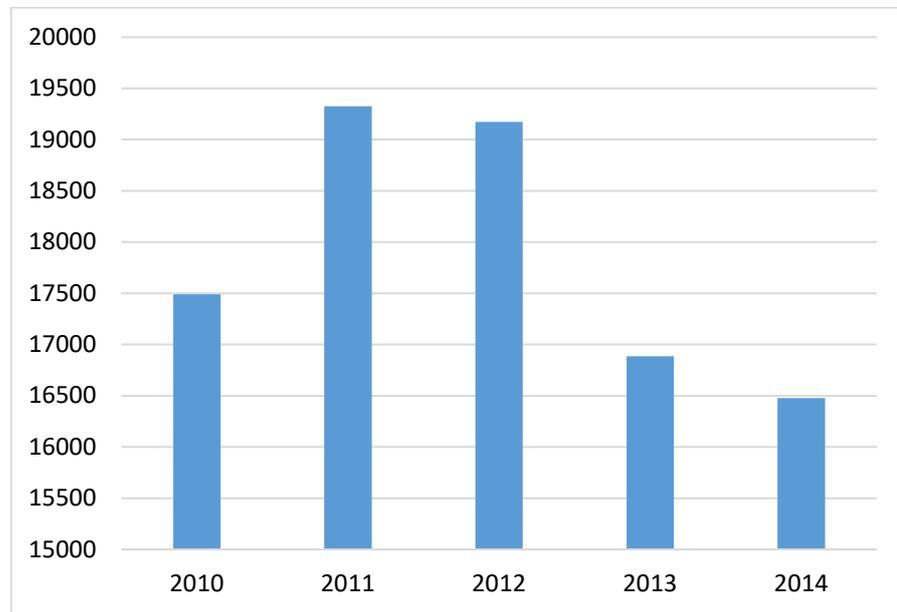
**Figure 14: Demand for Methanol by Region**

**Source: Own elaboration**

Latin America accounts for only 5% of world methanol demand. In Peru the demand for Methanol is manifested in imports of the same. According to Aduanet in 2014, approximately 16.5 MTM of industrial methanol (thousands of metric tons) were imported, which involved a cost of approximately 9.5 MM \$ (Figure 15 and 16).

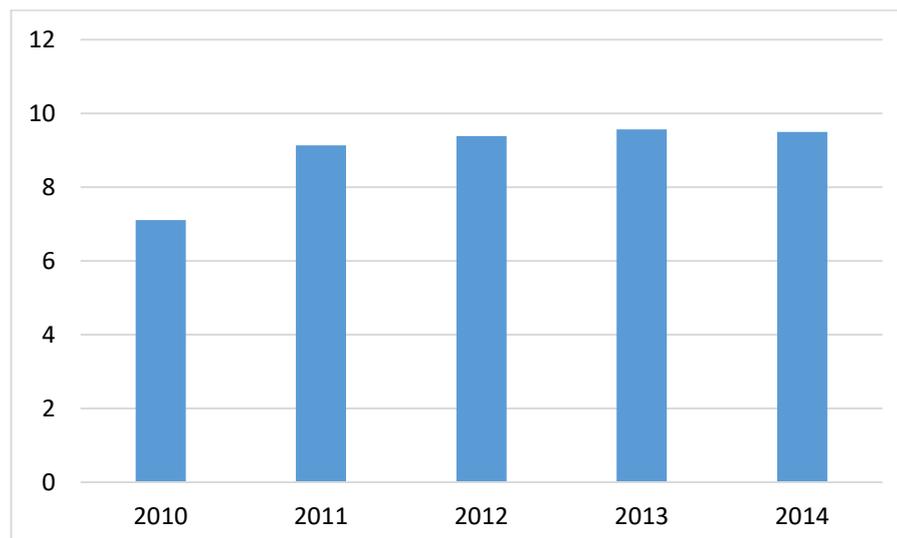
The main importing companies of Methanol in the country are Peruquimicos S.A.C and Transmerquim of Peru S.A (Figure 17), which in 2014 have reported imports of 13.1 MTM and 3.4 MTM of methanol respectively (Source: Aduanet). These imports come mainly from Trinidad and Tobago and the United States. In previous years, 2010 and 2011, a large amount of methanol was imported from Chile (Methanex), but the export capacity of this country was

affected when Argentina stopped supplying them with natural gas which was raw material for methanol production.



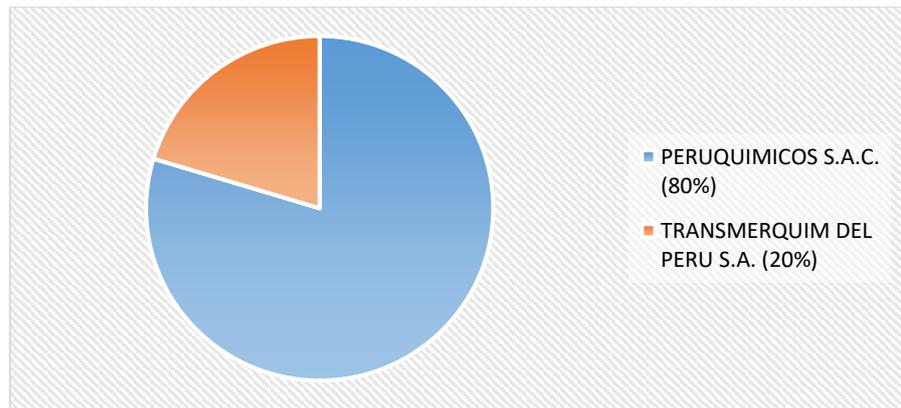
**Figure 15: Imports of Methanol (TM) vs Year**

**Source: Own elaboration (Aduanet)**



**Figure 16: Imports of Methanol (MM \$) vs Year**

**Source: Own elaboration (Aduanet)**



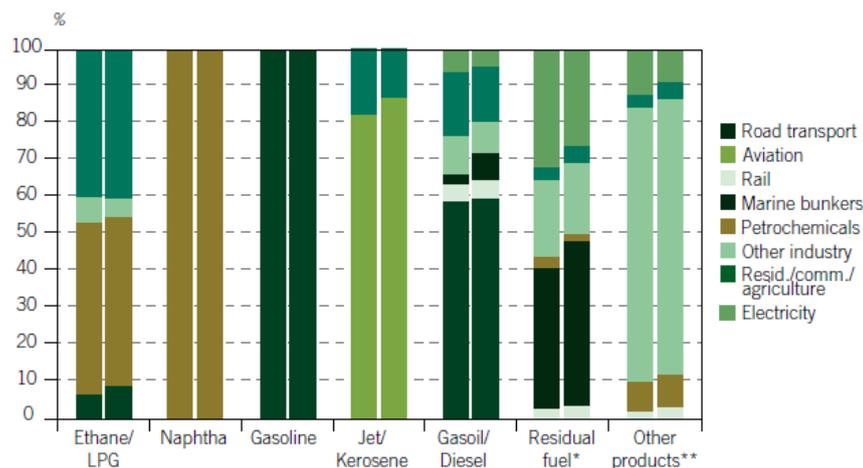
**Figure 17: Major Importers of Methanol in Peru in 2014**

**Source: Own elaboration (Aduanet)**

### 3.2.2. High Octane Gasoline

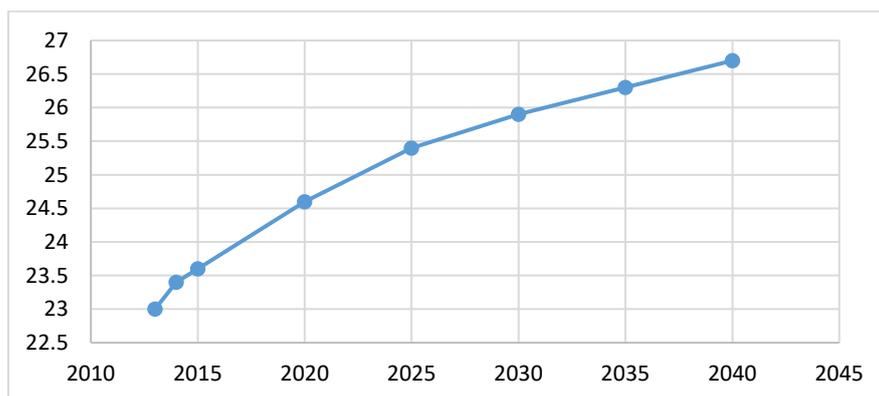
Gasolines generally have a high demand in countries that have energy deficit or that require Blending with their own production to comply with the technical specifications required by their national regulations for the sale and marketing of gasoline. The main use of gasoline in the world is in the energy sector as fuel for land transportation (Figure 18).

In 2014 the demand for gasoline in the world totaled 23.4 million barrels per day (DBP), with a growth rate of approximately 1% per year. This growth rate has been reduced compared to previous years due to the high efficiency of low-power vehicles and the appearance of large numbers of alternative vehicles. The projections shown by the 2014 World Oil Outlook (WOO 2014) allow us to see that demand for gasoline will increase in the year 2040, reaching an estimated 26.7 MMBblD (Figure 19).



**Figure 18: Participation of the different sectors in the demand for product**

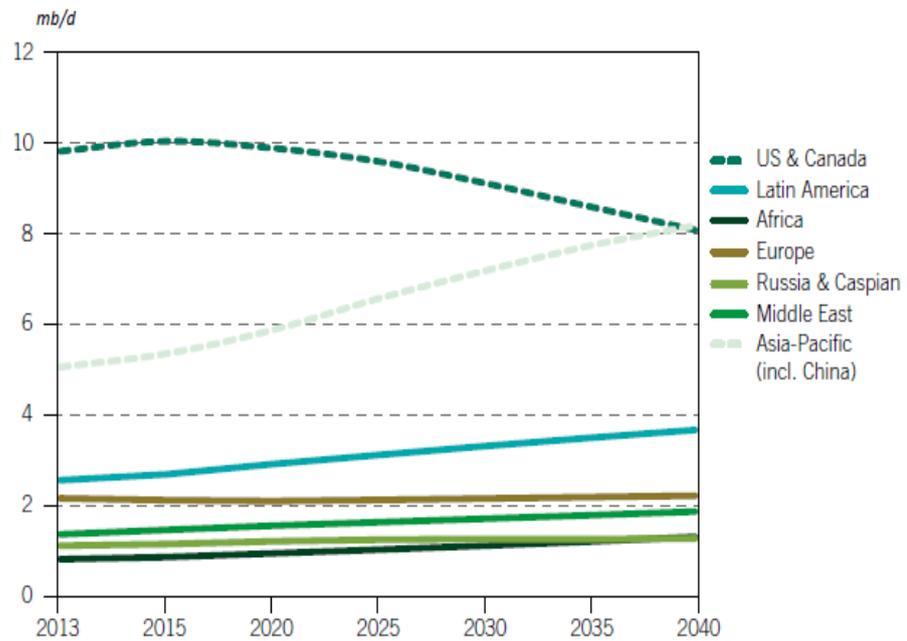
**Source: 2014 World Oil Outlook**



**Figure 19: Global Demand for Gasoline Projection (MMBbID) 2013 - 2040**

**Source: Own elaboration (2014 World Oil Outlook)**

The main consumer of Gasoline in the world is United States possessing more than 40% of the world demand (Figure 20). In 2014 this large energy consumer registers a demand of approximately 10 MMBbID of gasoline. On the other side, Latin America presented a local gasoline demand of approximately 2.6 MMBbID. The projections show that demand for Gasoline by 2040 will be reduced in the United States to approximately 8 MMBbID while in Latin America it will increase to 3.7 MMBbID of gasoline.



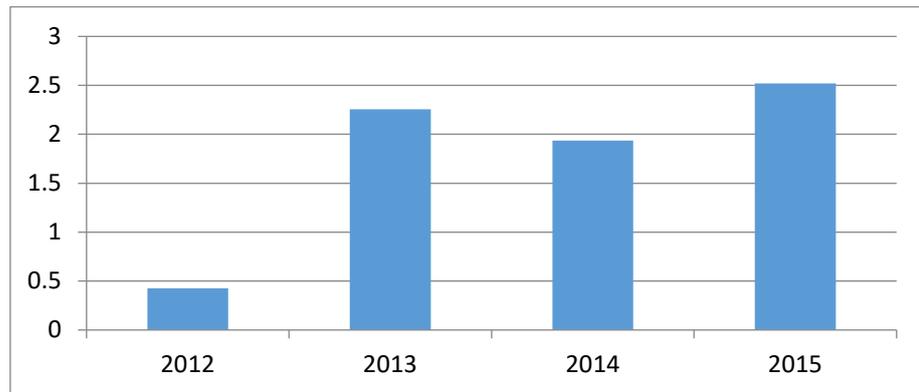
**Figure 20: Gasoline Demand by Region**

**Source: 2014 World Oil Outlook**

In Peru the demand for high octane gasoline is high due to the need for the national refineries to perform the Blending with Virgin Naphtha from their production units in order to produce gasolines that comply with the technical specifications that they command The Peruvian laws. This high demand is manifested by the imports of gasoline that are made in the country. According to Aduanet in 2014, 1.90 MMBbl (million barrels) of high octane gasoline were imported, which involved costs of approximately 220 MM \$ (Figure 21 and 22).

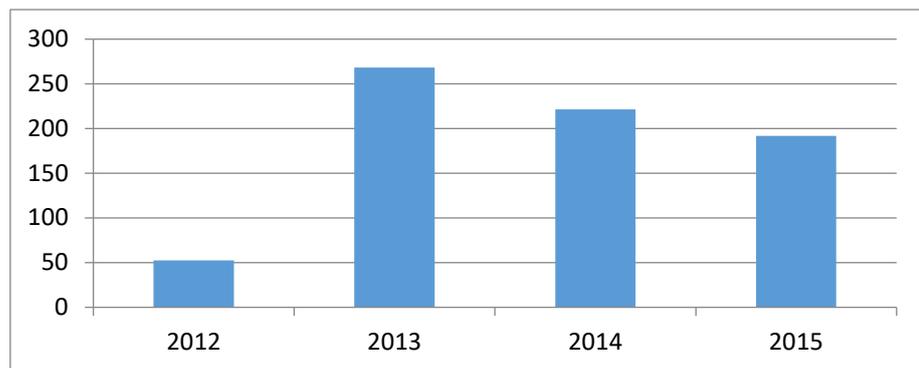
The main companies importing high octane gasoline in the country are mainly those that operate the national refineries: Repsol and Petroperú (Figure 23). These companies in 2014 have reported imports of 0.180 MMBbl and 1.9 MMBbl of high octane gasoline, specifically 92 octane gasoline, respectively (Source: Aduanet). These imports come from the United States almost entirely with the

participation of Brazil, Aruba, Chile and the Dominican Republic in a minimal proportion.



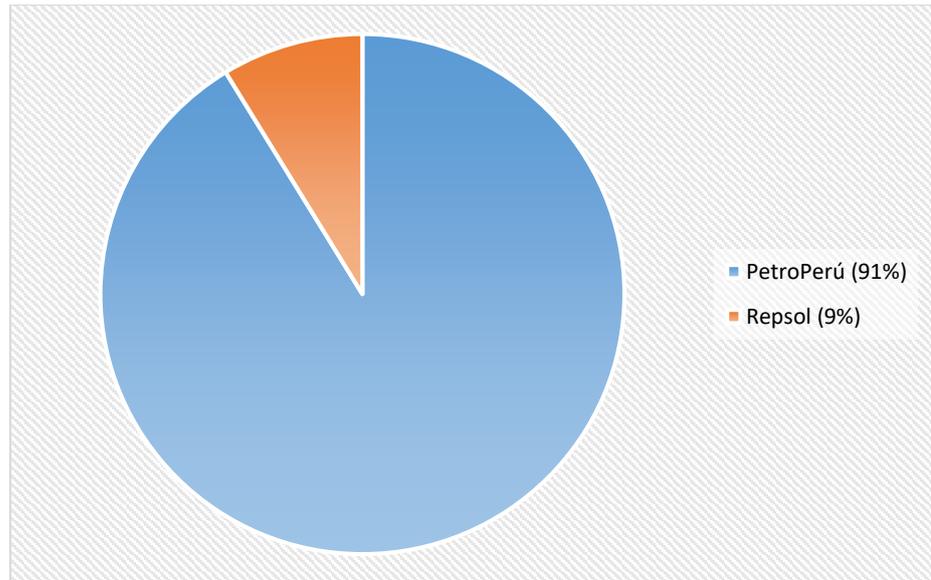
**Figure 21: Volume (MMBbl) of imports of Gasoline per year**

**Source: Own elaboration (Aduanet)**



**Figure 22: Cost (MM \$) of Imports of Gasoline per year**

**Source: Own elaboration (Aduanet)**



**Figure 23: Main Importers of Gasoline in Peru in 2014**

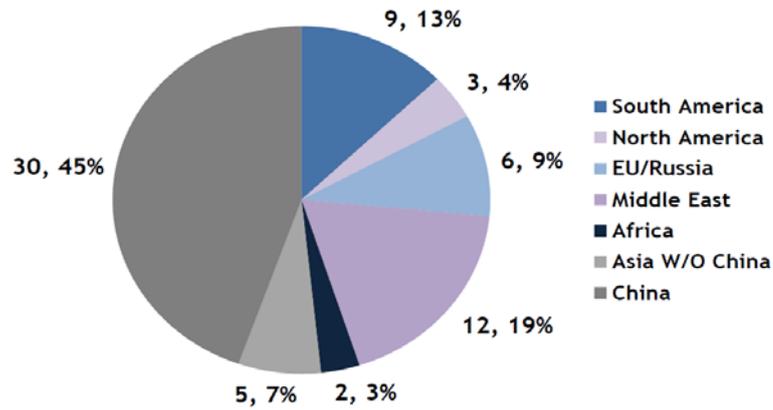
**Source: Own elaboration (Aduanet)**

### **3.3. Supply analysis:**

#### **3.3.1. Methanol**

The world's largest producer of methanol is China with more than a third of world methanol production (Figure 24). It has about 200 production plants, almost 80% using coal as raw material, the rest uses coke and natural gas.

The United States is also a major producer of methanol, the problem was that at the beginning of the 21st century, many American methanol plants closed due to high production costs. Just in 2012 with the Shale Gas boom is that the American methanol industry began to reactivate.



**Figure 24: Methanol Production by Region 2014**

**Source: ADI Analytics: Monetizing North American Shale with Methanol (April 2015)**

On the other hand, Methanex is the largest methanol producer in the world with 16% of the international market. It has a large number of methanol-producing plants around the world (Figure 25). Methanex marks methanol reference prices in most markets.



**Figure 25: Methanex Plants in the World**

**Source: 2014 Annual Report - Methanex Corporation**

In Latin America the main producers of Methanol are Metor 1 and 2 (Venezuela), Complejo Independencia (Mexico), YPF and Alto Paraná (Argentina); GPC and Braskem (Brazil), Caribbean Methanol Company Ltd. (Trinidad and Tobago) and Methanex (Chile). The

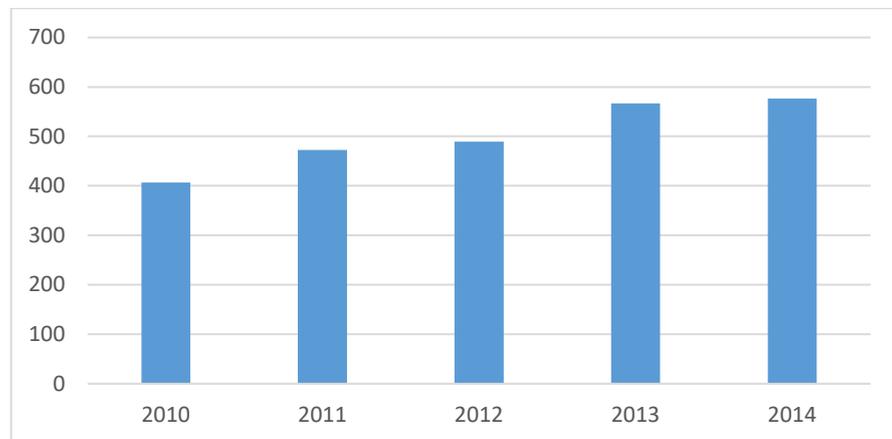
latter has already ceased its activities in Chile due to the lack of raw material (Natural Gas) (Illustration 26).



**Figure 26: Distribution of petrochemical plants in South America**

**Source: Ministry of Energy and Mines. Peru.**

In Peru methanol is imported mainly from the United States and Trinidad and Tobago reporting, according to Aduanet, in 2014 imports of approximately 16.5 MTM of industrial methanol at a price of approximately US \$ 577 / MT. According to the Aduanet data, this price has increased over the years (Figure 27).

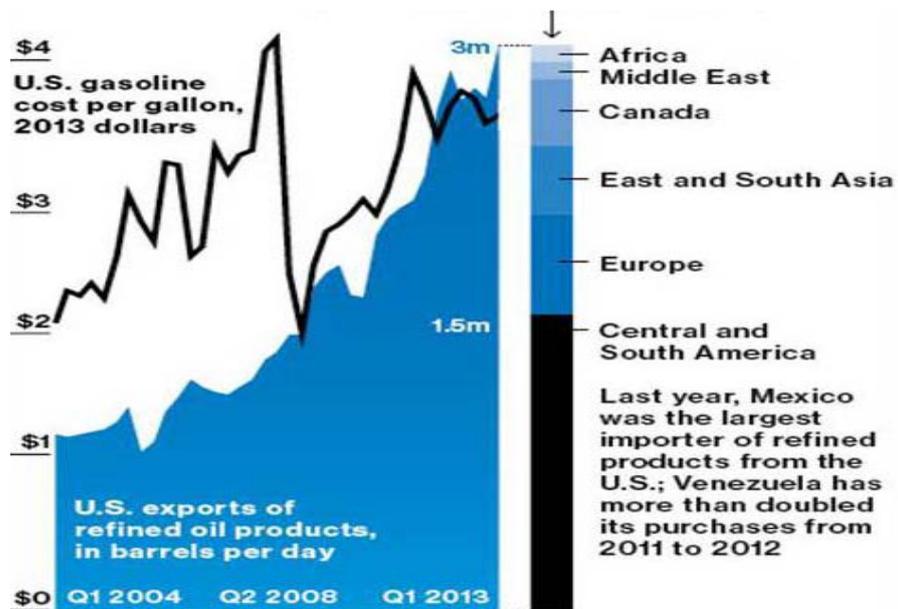


**Figure 27: Methanol TM price per year**

**Source: self made. (Aduanet)**

### 3.3.2. High Octane Gasoline

The United States is the main producer and exporter of gasoline in America, more than 50% of its gasoline exports (Figure 27) are destined for Latin American countries such as Mexico and Venezuela. These countries have ample resources to exploit hydrocarbons but the investments of State-owned enterprises are not reflected in the refining industry. In the case of Venezuela many of its heavy oils are refined in US refineries and they in turn ship the derivatives as gasoline to Venezuela.

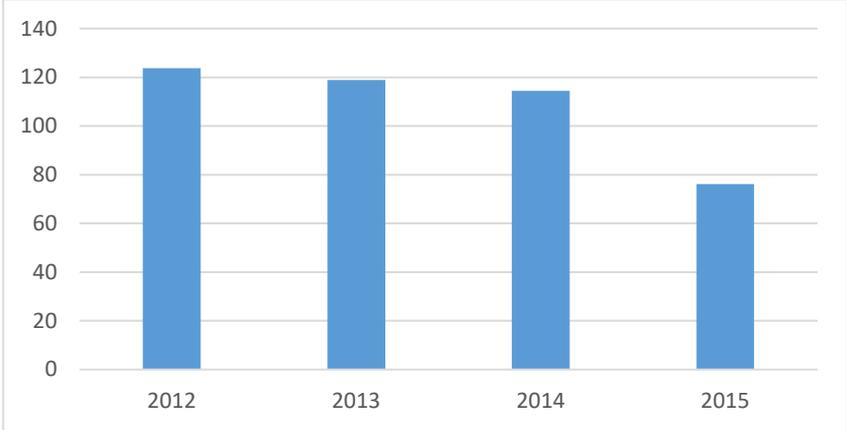


**Figure 28: US Gasoline Exports**

**Source: Bloomberg Businessweek. Energy information Administration**

United States is also the main supplier of high octane gasoline for Peru. As shown above according to Aduanet so far in 2015 has imported approximately 2.5 MMBbl of gasoline at a price of approximately 76 US \$ / Bbl. According to the Aduanet data, this

price is lower than in other years, this is mainly due to the decrease in the price of crude oil since the cost of gasoline is closely linked to it (Figure 28).



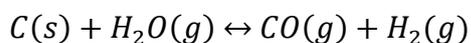
**Figure 29: High octane gas price per barrel**

**Source: self made. (Aduanet)**

## 4. TECHNICAL STUDY

### 4.1. Processes for obtaining synthetic gasoline

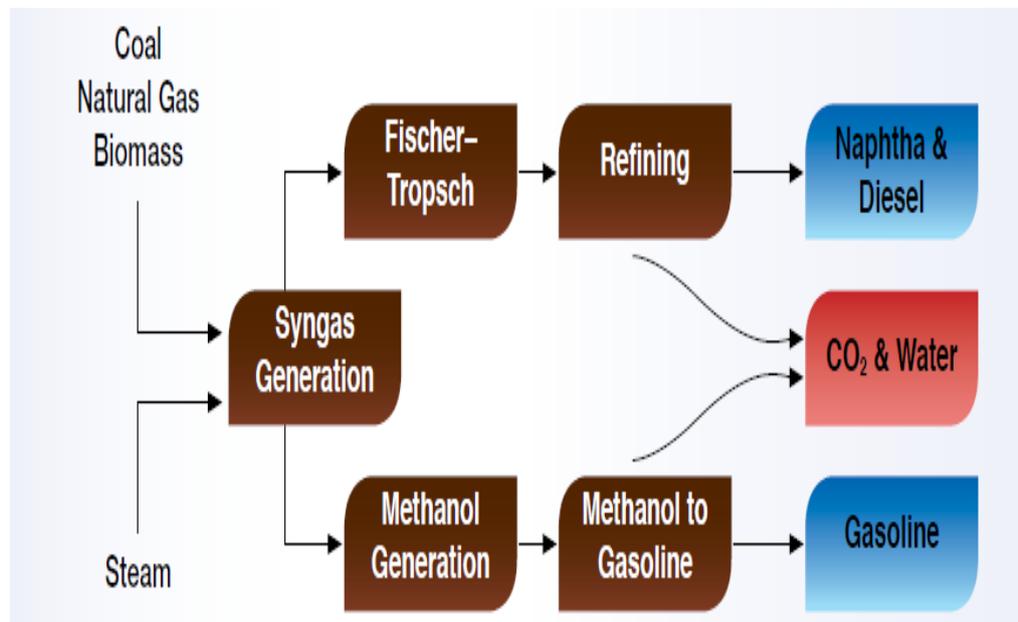
In the 1990s, South Africa produced synthetic gasoline via the Fischer-Tropsch process. Coal, used as raw material, was converted to synthesis gas (a mixture of carbon monoxide and hydrogen) by gasification of coal with steam:



The synthesis gas was then contacted with the metal iron surface, deposited on the silica (10% Fe) and promoted with potassium, at temperatures around 500 K and pressure 1 MPa, to produce a complex mixture of the hydrocarbons methane, Ethane, propane, butane, pentane and the corresponding alkenes; The aliphatic and aromatic C6-C9 hydrocarbons; The oxygenated products methanol, ethanol, and the higher alcohols; Heavy oil and waxes. The condensation of CO with H<sub>2</sub> was discovered by Fischer and Tropsch in 1925 and, since Germany lacks its own oil fields, this process was very important for the production of fuel from engines from coal, especially in the years of the Second World War. Since CO and H<sub>2</sub> were obtained from coal, the mixture of synthetic liquid hydrocarbons has been called Kogazin (from KohleGas-Benzin) and the fraction corresponding to gasoline - Sintin.

Synthetic gasoline is now produced from coal in South Africa at plants near Johannesburg, as this area of the country has the cheapest coal deposits in the world, while oil prices are high because of the shortage of Oil and the remoteness of this region of the sea.

In the 1970s, Mobil Corp. developed an innovative process for the production of synthetic gasoline from methanol (Figure 30). In the Mobil process, methane (or coal) is first converted into synthesis gas, which is then converted into methanol by a catalytic process, and finally the methanol is condensed in the presence of the HZSM-5 catalyst to aliphatic and aromatic hydrocarbons of the boiling range of gasoline. The HZSM-5 catalyst is a synthetic zeolite, where SM are the initials of Socony Mobil (part of the name of the Mobil Corporation at that time) that has developed the catalyst.



**Figure 30: Processes for Obtaining Synthetic Fuels**

**Source: Exxon Mobil Research and Engineering: MTG**

The process involves the reactions (Figure 31) which occur in the following sequence: methanol is converted to dimethyl ether and to low molecular weight olefins, the latter are oligomerized or alkylated with methanol and finally dehydrocyclinated to the aromatic hydrocarbons or Hydrogenate aliphatic hydrocarbons, of boiling range of gasoline, with high anti-knock-off quality:

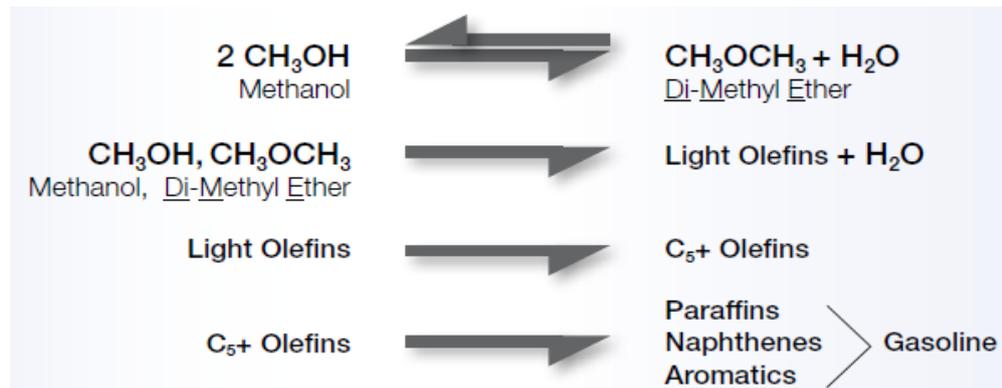


Figure 31: Chemical equations of the MTG process

Source: Exxonmobil Research and Engineering: MTG

The process is known under the name MTG (Methanol To Gasoline) process and the gasoline it produces is known as M-gasoline. The MTG process differs from those of Fischer-Tropsch mainly in that it produces only gasoline (Figure 32).

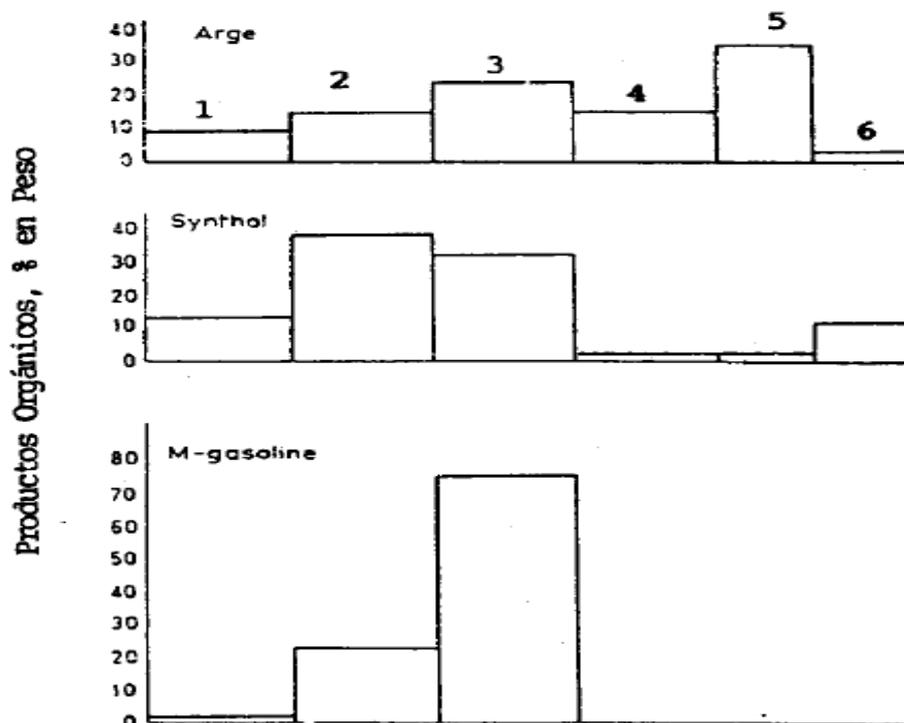
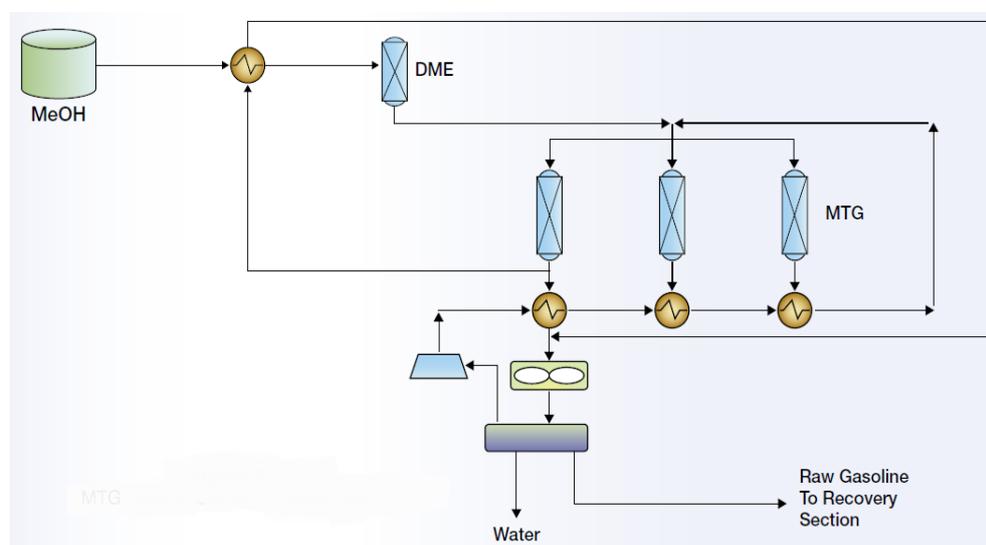


Figure 32: Typical general distribution of products originating from the Fischer-Tropsch (Arge and Synthol) plants, and the M-gasoline plant. 1.-Methane; 2.-C2-C4 products; 3.-Gasoline (C5-C11); 4.-Fuel Diesel; 5.-Heavy oils and waxes, and 6.-Oxygenated products

## 4.2. Processes MTG

The MTG process was discovered by accident when a gasoline additive made from methanol was being created. The process instead created olefins, paraffins, and aromatic compounds, which in combination is known as gasoline. The process uses a catalyst of a synthetic zeolite called the HZSM-5 catalyst. The process uses as methanol feed, which is produced by means of the combined reforming technology of licensor Lurgi. This technology allows to consume less raw material, reduces the consumption of energy and reduces the cost of investment. The natural gas is first desulfurized and saturated before entering reforming and then reacted with steam to produce the synthesis gas. Subsequently the synthesis gas is compressed for cooling, then reheated and sent to the methanol converter, where the produced methanol contains about 20% water. Feed gas desulphurisation facilities are included to protect the reformer and catalyst from the sulphide poison, ie the H<sub>2</sub>O is removed by ZnO pellets contained in a reactor. Subsequently the methanol is sent to the MTG process (Figure 33).



### **Figure 33: MTG Process Diagram**

**Source: Exxonmobil Research and Engineering: MTG**

The produced methanol is first heated, then vaporized and finally superheated between 300-320 ° C with a series of heat exchangers using the product obtained from the MTG process. The vapor is then sent to the reactor for the production of dimethyl ether where there will be a dehydration catalyst (alumina) which will dehydrate 75% of the methanol for a balance of dimethyl ether (DME), water and methanol. This reaction is fast. Reversible and exothermic, around 20% of the heat produced in the whole process is released in this step.

The mixture is then mixed with recycled gas (light hydrocarbons) where the function of the recycle gas is to absorb the heat of the reaction. Subsequently this mixture is sent to the conversion reactors where the DME is further dehydrated to give light alkenes which agglomerate for the formation of longer and cyclic chains to give the final product with the release of the remaining heat.

The reactor mixture is quenched by the recycle gases obtained from the three-phase separator. This mixture contains about 94% by weight hydrocarbon and 16% water. The conversion is practically 100%, 85-90% of the hydrocarbons produced can be used as gasoline, the rest as fuel gas. Small amounts of CO, CO<sub>2</sub> and coke are formed as a by-product. Coke is defined as the product of the reaction that is deposited on the surface and fills the pores of the catalyst. This process leads to the deactivation of the catalyst.

The hydrocarbon produced by the MTG process is brought to a section of 3 distillation columns (Figure 34), where in the first column is a deethanizing column where the uncondensable gases are separated and some water is

removed in this column, then the second Column (debutanizer) removes the light hydrocarbons, these hydrocarbons are cooled to form the LPG.

Finally the stabilized gasoline is divided into a separator, this separator divides into light gasoline and heavy gasoline, the heavy gasoline is sent to a treatment center.

The heavy gasoline produced in the MTG process contains a component known as durene (1, 2, 4, 5-tetramethylbenzene), which has a large melting point (79 ° C). Dureno has a high octane rating (around 100 R + O). However, due to its high freezing point (175 ° F), this can cause problems in the formation of ice in an engine. The concentration of dureno is reduced in the treatment of heavy gasoline by increasing temperature and decreasing the pressure.

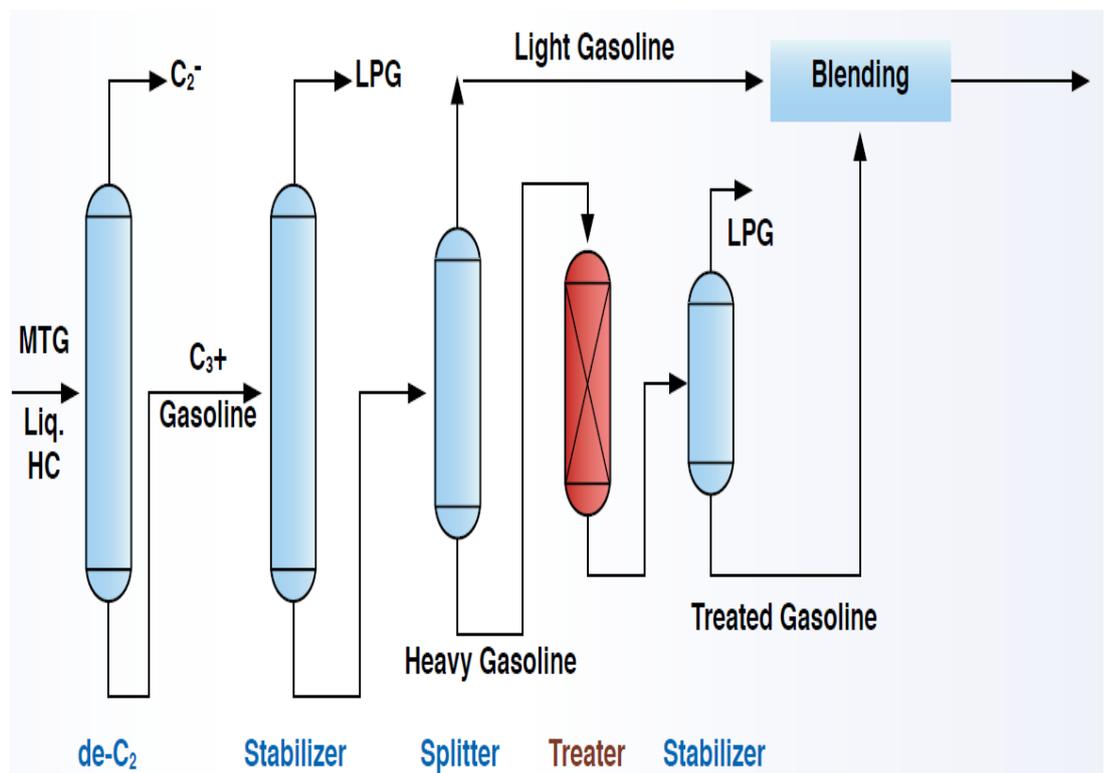


Figure 34: Gasoline treatment section

Source: Exxon Mobil Research and Engineering: MTG

The yields usually obtained by the MTG process are shown in Table 2:

Table 2:

**MTG process yields**

MTG Gasoline Performance		
	Feeding%	Hydrocarbon%
Gas	1	2
LPG	5	11
Gasoline	38	87
H2O	56	0

Note. Values in% in Volume. Source: Exxonmobil Research and Engineering: MTG

The gasoline properties obtained in the MTG process are shown in Table 3:

Table 3:

**Properties of gasoline obtained in the MTG process**

	Average	Range
Octane Number, RON	92.2	92.0-92.5
Octane Number, MON	82.6	82.2-83.0
Reid Vapor Pressure, kPa	85	82-90
Density, kg/m <sup>3</sup>	730	728-733
Induction Period, min.	325	260-370
Durene Content, wt%	2	1.74-2.29
<b>Distillation</b>		
% Evaporation at 70°C	31.5	29.5-34.5
% Evaporation at 70°C	53.2	51.5-55.5
% Evaporation at 70°C	94.9	94-96.5
End Point, °C	204.5	196-209

Note. Properties Source: Exxon Mobil Research and Engineering: MTG

The contact time between reactants and the catalyst is very important in the MTG process. If the contact time is very fast ( $10^{-3}$  hr), water and the DME are the main products obtained, when the contact time is increased the DME performance reaches a maximum but then begins to decrease, where the DME will have more Chance to dehydrate to give C2-C5 alkenes. With an additional increase of the contact time the alkanes, alkenes, C6 + and aromatics are obtained.

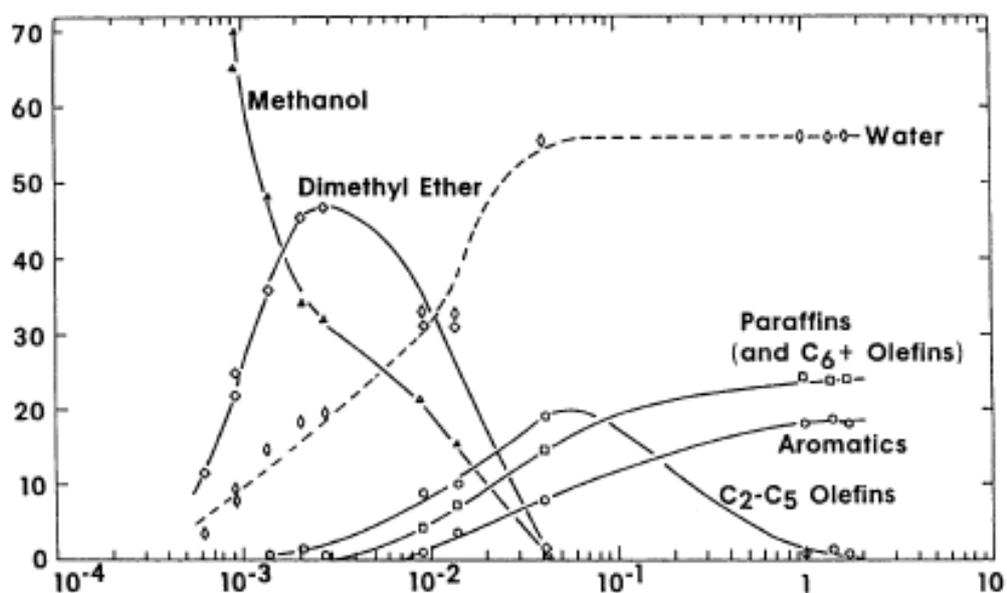


Figure 35: Product obtained in w / w% vs spatial time in hours.

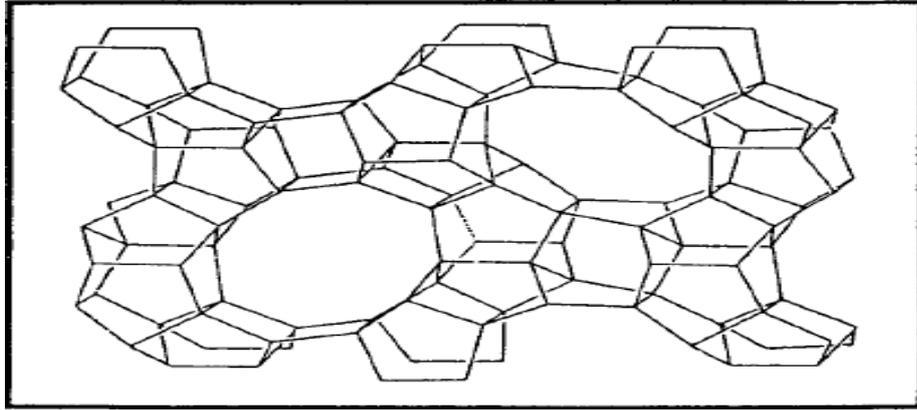
Source: THE PRODUCTION OF METHANOL AND GASOLINE, Rewritten by John Packer from the two articles of volume 2, compiled by P. Kooy (Petrolgas- Waitara Valley) and Dr CM Kirk (Taranaki Polytechnic - New Plymouth) with information supplied by Clare Wrinkes of Methanex New Zealand Ltd

#### 4.3. Catalyst Description

All this process inside the MTG reactor is carried out by the catalyst ZSM-5 (25% by weight zeolite, 30% bentonite and inert material ( $\alpha$ -alumina)), the

catalyst to contain zeolites will be porous, crystalline and with three structures Dimensional. Compared with other acidic zeolites used as catalysts, HZSM-5 leads to high yields in isoparaffins (C7) and aromatics (C6-C8) and shows high resistance to coke formation. Zeolite HZSM-5 has medium pores, which is essential for this process. Zeolites with small diameter pores do not produce aromatic hydrocarbons, and, in addition, require very drastic operating conditions, due to the slow diffusion. Zeolites with large pores produce heavy aromatic hydrocarbons (> C10) and are deactivated very quickly because these hydrocarbons are the coke precursors.

The ZSM-5 has a pore with a diameter around 6 Å and a single channel structure (Figure 36). There are 2 intersecting paths in the channels, which are elliptical, 10 channel channels and almost circular (sinusoidal). It is this unique combination of channels and sizes that make the ZSM-5 catalyst so efficient and special in MTG conversion, producing gasoline with a range of molecules (C4-C10) with practically no carbon above C10. It can be said that the ZSM-5 catalyst selectively produces the correct type of shape and sizes of suitable properties in the synthesis of gasoline, this selectivity gives ZSM-5 a reputation for high resistance against deactivation.



**Figure 36: Linear diagram of the ZSM-5 structure**

**Source:** THE PRODUCTION OF METHANOL AND GASOLINE, Rewritten by John Packer from the two articles of volume 2, compiled by P. Kooy (Petrolgas-Waitara Valley) and Dr CM Kirk (Taranaki Polytechnic - New Plymouth) with information supplied by Clare Wrinkes of Methanex New Zealand Ltd.

#### **4.4. Results of the simulation considering the selected technology**

##### **4.4.1. Description of the Simulator used**

In this chapter, the simulation of the process of obtaining methanol will be described, using the commercial simulator called HYSIS v.7., Steady-state modeling (selection of parameters and suitable hypotheses, thermodynamic properties package, Calculation, etc.).

The Hysys simulator is part of the Advanced System for Process Engineering (ASPEN) package.

##### **4.4.2. Advantages and disadvantages of using the Simulator**

The main advantages of using a Hysys simulator are described below:

- Ease of use.
- Extensive database.

- It uses experimental data for its correlations. Most of the data are experimental, although some are estimated (most simulators use predictive models such as UNIFAC).

The main disadvantages are:

- Few or no solids applications.
- Limited optimization software (the optimizer is not very powerful).

On the other hand, the Hysys simulator is a software used in the simulation of petrochemical and related plants. Includes tools to estimate:

- Physical properties.
- Liquid equilibrium - vapor.
- Balance of matter and energy.
- Simulation of many chemical engineering equipment.
- Simulation processes in steady and dynamic state.

#### **4.4.3. Bases for Simulation**

Gasoline production is an important part of the overall process. The methanol conversion is modeled using an equilibrium reactor and a conversion reactor.

To facilitate the production of gasoline, the methanol in dimethyl ether (DME) is first converted to the equilibrium reactor with the molar ratio of 1: 1.

This ratio represents the stoichiometric amounts required to produce DME, during the reaction water is formed.

#### 4.4.4. Thermodynamic Aspects of DME

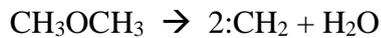
Reaction in equilibrium:



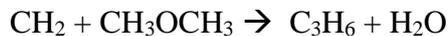
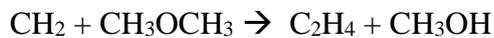
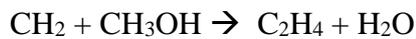
#### 4.4.5. Reaction mechanism of gasoline production

Scheme for the production of gasoline

➤ **Methanol / DME Reactions:**



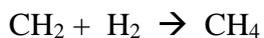
➤ **Formation of light olefins from carbenes and oxygenates:**



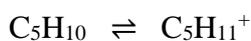
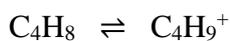
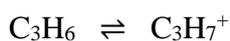
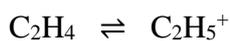
➤ **Formation of heavy olefins from carbenes and light olefins:**



➤ **Methane formation:**



➤ **Formation of carbanions from olefins:**



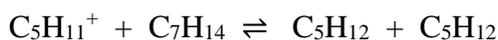
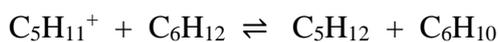
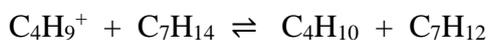
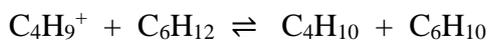
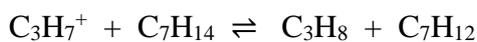
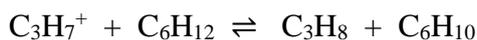
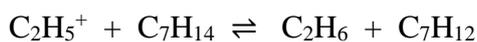
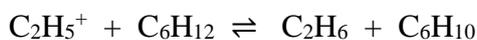
➤ **Carbanions attack light olefins forming heavy olefins**

**(oligomerization):**

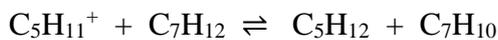
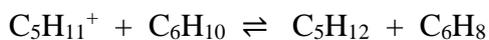
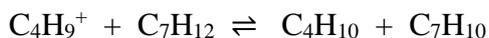
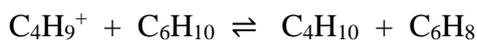
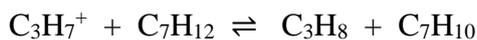
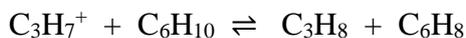


➤ **Carbanions attack heavy olefins forming paraffins and**

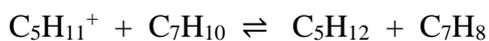
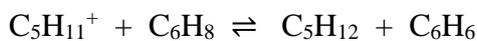
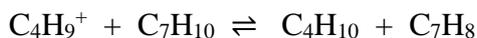
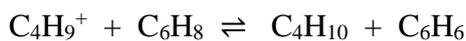
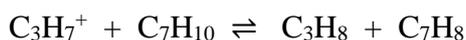
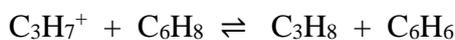
**dienes:**



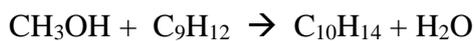
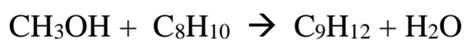
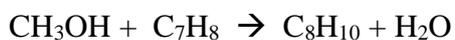
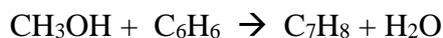
- **Carbanions attack the dienes forming paraffins and cyclodienes:**

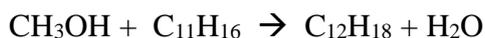
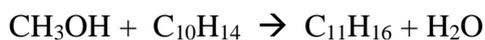


- **Carbanions attack cyclodienes forming paraffins and aromatics:**



- **Alkylation of aromatics:**





#### 4.4.6. Kinetic Aspect of Gasoline Production

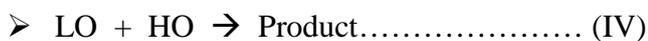
In order to jointly evaluate the conversion of methanol, and seeing the mechanism that occurs in the conversion reactor is decided to group the reactions according to their characteristic intermediates:



**MeOH: methanol; DME: dimethyl ether; LO: light olefins**



**HO: heavy olefins**



For the equilibrium reaction:

$$K_{eq} = e^{-26.64 + \frac{4019}{T} + 3,707 \ln(T) - 2,783e-03T + 3,8e-07T^2}$$

For the kinetic reactions, the values of the activation energies and frequency factors are shown in Table 4:

Table 4:

**Activation energies and frequency factors for reactions.**

Reaction	A	Ea (KJ/Kgmol)
I	0,733 E+13	139436
II	0,127 E+08	73705
III	0.204 E+12	117009
IV	0.634 E+06	66274

Note. A - Frequency Factor, Ea - Activation energy. Source: Chemical Engineering Science; MTG Fluidized bed reactor-regenerator unit with catalyst circulation: process simulation and operation of an experimental setup.

**4.4.7. Catalyst:**

Low temperatures cause reactions to occur more slowly, poor thermodynamic equilibria or conversions, for this the catalysts must be used to overcome these drawbacks. ZSM-5, (Zeolite Socony Mobil-5) is a mineral zeolite. Its chemical formula is  $\text{Na}_n\text{Al}_n\text{Si}_{96-n}\text{O}_{192} \cdot 16\text{H}_2\text{O}$  ( $0 < n < 27$ ).

Patented by Mobil Oil Company in 1975, it is widely used in the petroleum industry as a heterogeneous catalyst for hydrocarbon isomerization reactions, representing practically all DME production (approx. 75-85% conversion).

The ZSM-5 has a high proportion of aluminum silicon, copper or other metals are added to it to sharpen the diversity and specificity of the products.

#### **4.4.8. Description of Equipment, Operating Conditions and Thermodynamics of the simulated MTG process.**

In order to simplify the MTG Synthesis simulation process (Figure 37), a division was performed: water separation zone at the exit of the MeOH / DME balance reactor, gasoline production zone and separation zone of the gas.

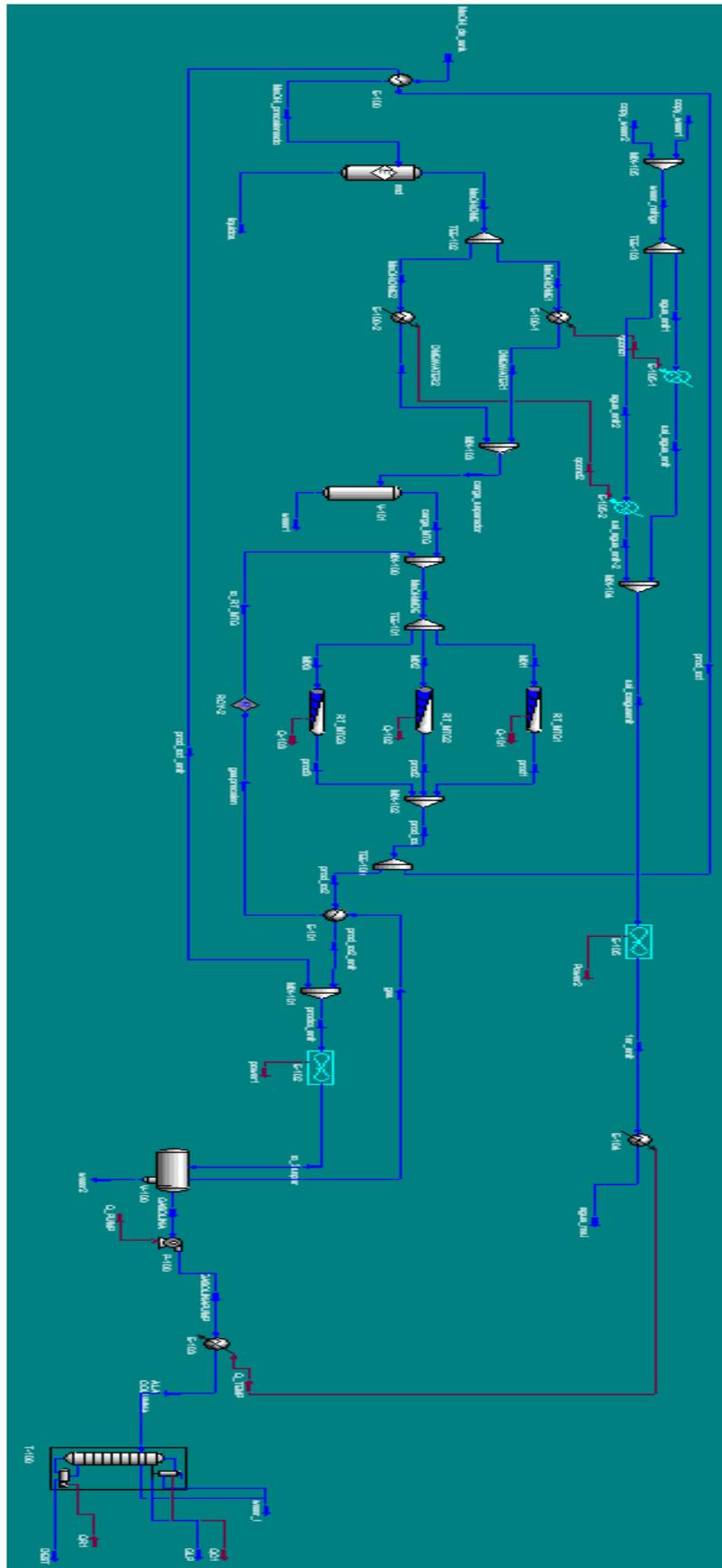
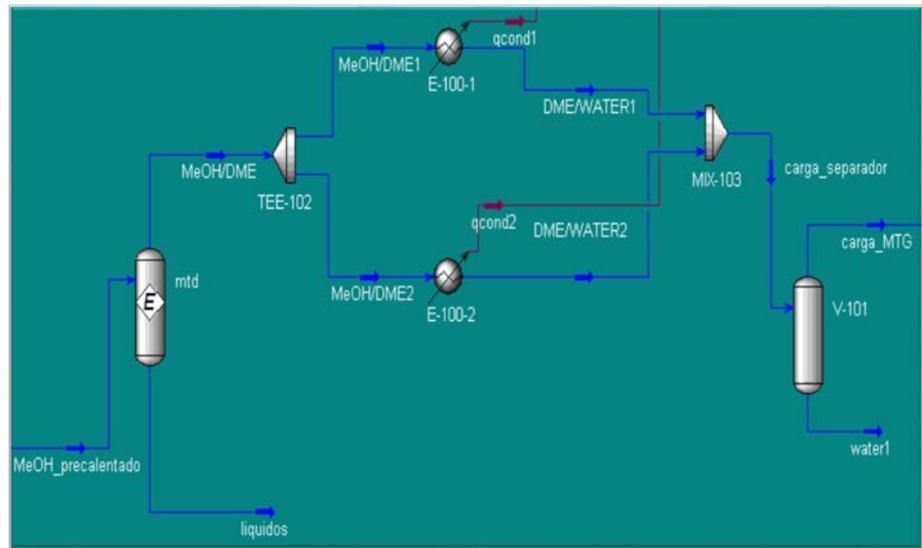


Figure 37: Diagram of the Simulation in HYSYS of the MTG process

Source: Own elaboration

### a) MeOH / DME equilibrium zone

In Figure 38, the formation of the DME



**Figure 38: Diagram of the MeOH / DME equilibrium zone**

**Source: Own elaboration**

#### ❖ MT BAT balance reactor:

It is one of the types of reactors that is included in the simulator, the characteristics of this type of reactor is that it is based on data of stoichiometry and equilibrium coefficient ( $K_{eq}$ ). The operating conditions are:

- Entry temperature: 300 - 320 ° C
- Pressure: 1 atm
- Molar flow: 3500 MT / day

At these conditions, the reaction was given in the gas phase to form water in the process and a conversion between 75-85% of methanol, and the conditions of the products at the exit are:

- Output temperature: 400 - 420 ° C

❖ **TEE-102 Separator:**

The load from the separator is divided into 2 currents to minimize the dimensioning of the exchanger, condition:

- Input temperature: 417 ° C
- Distribution of currents to the outlet: 0.5

❖ **Cooler E-100-1 Y E-100-2:**

The products at the exit of the reactor are cooled to be able to separate the largest amount of water from the products. The operating conditions of each cooler are:

- Input temperature: 417 ° C
- Output temperature: 68 ° C
- Duty: 8.49 e + 07 KJ / h

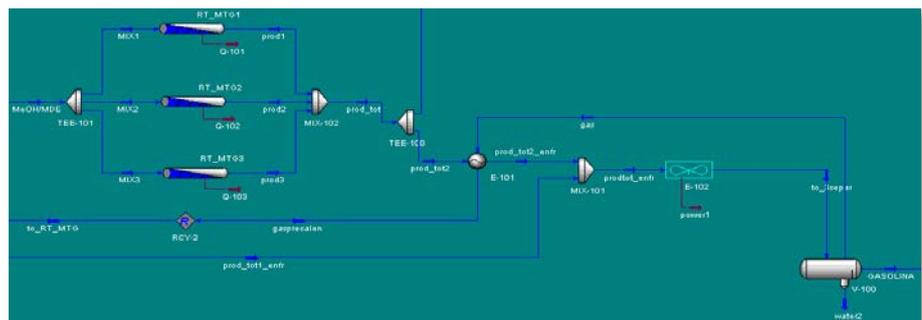
❖ **V-101 Separator:**

In this equipment we separated most of the water that was formed in the equilibrium reactor, being:

- Input temperature: 68 ° C
- Pressure: 1 atm
- Liquid recovery: 50%

**b) Gasoline production zone**

Figure 39 shows the production of gasoline, and then its separation.



**Figure 39: Diagram of the gasoline production zone**

Source: Own elaboration

### ❖ TEE-101 Separator:

The charge from the separator is divided into 3 streams to minimize reactor sizing, condition:

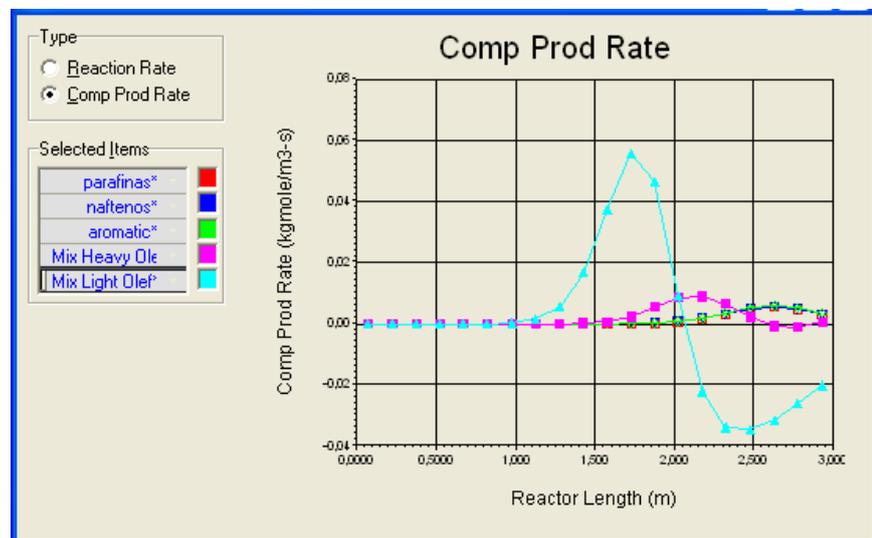
- Temperature of entry: 81.8 ° C
- Distribution of currents at the exit: 0.333

### ❖ Kinetic Reactors RT\_MTG 1. RT\_MTG2 and RT\_MTG3:

The conditions of the currents that enter each reactor are:

- Temperature of entry: 81.8 ° C
- Length of the reactor: 3 m
- Diameter of the reactor: 1 m

In Figure 40, we observe this condition as the formation of the products varies.



**Figure 40: Variation in the formation of MTG process products**

Source: Own elaboration

As we see our product will be in greater proportion at the end of the reactor, with the composition at the exit of the reactor:

- Output temperature: 600 ° C

- Gasoline production: 10540 bbl / day
- Duty:  $2.73 \times 10^6$  KJ / h

❖ **TEE-100 separator:**

Due to the high temperature of the reactor, it is decided to take advantage of this energy by separating the current in two streams, one to preheat the tank methanol for admission to the MTD reactor and the other to preheat the gases from the V-100 separator.

❖ **E-101 Exchanger:**

The product exchanges heat with the gases from the v-100 separator, the conditions being:

- Housing temperature:  $15 \text{ }^\circ\text{C}$
- Output temperature per cuff:  $170 \text{ }^\circ\text{C}$
- Inlet temperature per tube:  $600 \text{ }^\circ\text{C}$
- Output temperature per tube:  $362 \text{ }^\circ\text{C}$
- Transfer area:  $60,32 \text{ m}^2$
- Duty:  $4.1 \times 10^6$  KJ / h

❖ **Aero Cooler E-102:**

Our product has a lot of water in its composition, so we cool it to be able to separate it later, the operating conditions are:

- Temperature of entry:  $67.5 \text{ }^\circ\text{C}$
- Output temperature:  $15 \text{ }^\circ\text{C}$
- Duty:  $5.57 \times 10^7$  KJ / h

❖ **V-100 Separator:**

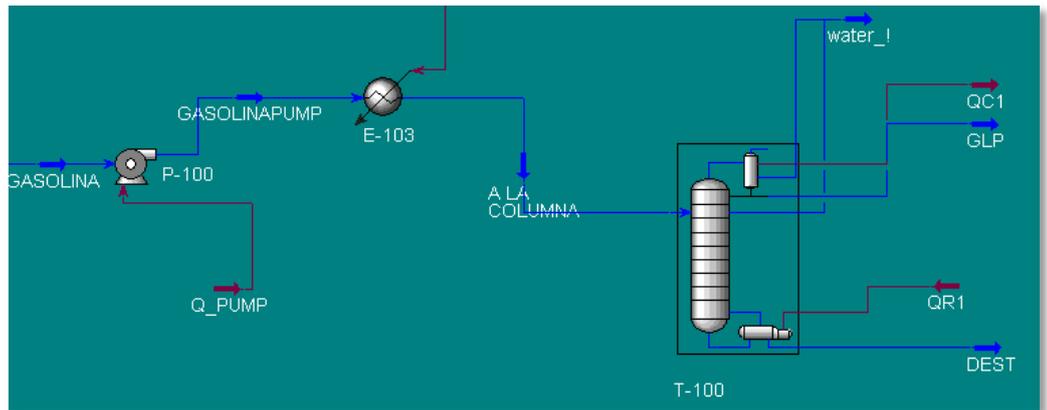
In this equipment we separated most of the water that was formed in the kinetic reactor, being:

- Input temperature:  $15 \text{ }^\circ\text{C}$

- Pressure: 1 atm
- Liquid recovery: 50%

**c) Gasoline distillation zone**

Figure 41 shows the last stage of our process and consists of distilling the product (high octane gasoline) and co-products.



**Figure 41: Diagram of the gasoline distillation zone**

**Source: Own elaboration**

❖ **P-100 pump:**

The "GASOLINA" stream from the V-100 separator containing gasoline crude has a composition which can be seen in Table 5:

Table 5:

Composition of the gas stream

	Mole Fractions
Methanol	0,0013
H2O	0,0003
diM-Ether	0,0000
Mix Light Olef*	0,0382
Mix Heavy Olef*	0,3010
parafinas*	0,2121
naftenos*	0,2165
aromatic*	0,2306

Source: Own elaboration (HYSYS)

It is pumped to the T-100 column, under pressure:

- Pump output pressure: 20 atm
- Duty:  $2.22e + 05$  KJ / h

❖ **E-103 Heater:**

Prior to entering the T-100 column, the feed is preheated in the Heater E-104, to obtain a liquid / steam feed:

- Fraction of vapor: 0.7056
- Duty:  $4.28e + 07$  KJ / h
- Output temperature: 229 ° C

❖ **Column T-100:**

For the gas distillation process, a plate distillation column (trays) was used in the HYSYS simulation, where the high-octane gasoline is obtained by the top of the LPG and by the bottom. The compositions of these streams are observed in Tables 6 and 7:

Table 6:

Composition of the LPG stream

	Mole Fractions
Methanol	0,0057
H2O	0,0012
diM-Ether	0,0000
Mix Light Olef*	0,1668
Mix Heavy Olef*	0,8232
parafinas*	0,0030
naftenos*	0,0001
aromatic*	0,0000

Source: Own elaboration (HYSYS)

Table 7:

Composition of the Gasoline Stream

	LiqVol Fractions
Methanol	0,0000
H2O	0,0000
diM-Ether	0,0000
Mix Light Olef*	0,0000
Mix Heavy Olef*	0,1450
parafinas*	0,3202
naftenos*	0,2826
aromatic*	0,2522

Source: Own elaboration (HYSYS)

Given the conditions in our column (Table 8):

Table 8:

**Operating conditions of the column**

Property	Column T-100
Number of theoretical steps	30
Food dish	22
Condenser Type	Total Reflux
Condenser pressure	270 psia
Pressure in the reboiler	290 psia
Inlet temperature (° C)	229

Outlet temperature (° C)	117
Bottom outlet temperature (° C)	241

Source: Own elaboration (HYSYS)

## 5. LEGAL STUDY

### 5.1.1 Law No. 26221: Organic Law that regulates the activities of Hydrocarbons in the national territory

The main law governing all activities to extract hydrocarbons, published on 08/20/93, in which Article 97 establishes compliance with the provisions on the Environment.

### 5.1.2 Law No. 271333: Law to promote the development of the natural gas industry

The purpose of this Law is to establish the specific conditions for the promotion of the development of the natural gas industry, fostering competition and encouraging the diversification of energy sources that increase the reliability of energy supply and the competitiveness of the country's productive apparatus .

Under Law No. 27133, by Supreme Decree No. 041-99-EM, the Regulations for the Transport of Hydrocarbons by Ducts were approved, which regulates the activity of the Transport of Hydrocarbons by Ducts, including provisions on the granting of Concessions , Setting tariffs, safety measures, environmental protection, regulatory authorities, as well as rules related to control.

This is complemented by Supreme Decree No. 018-2004-EM which mentions the regulatory framework in order to regulate the relationship between agents linked to the provision of the Natural Gas Transportation Service by Pipelines.

### **5.1.3 Law No. 29163: Promotion Law for the Development of the Petrochemical Industry**

This Law contains the rules for the development of the activities of the Petrochemical Industry, based on the components of Natural Gas and others, providing a decentralized development. Article 3 of the present Law mentions the Priority of Use of Natural Gas related to the supply of the domestic market, including the demand generated by the Basic and Intermediate Petrochemical Industry with the provisions of Article 4 of Law No. 27133 and mentioned.

In turn, Art 4 of Law No. 29163, refers to commercial relations regarding the use of Natural Gas and Condensates to generate added value.

### **5.1.4 D.S. N ° 0.54-2007-EM: Provisions to authorize the operation of Petrochemical plants**

Article 1 mentions the authorization for the installation and operation of a Petrochemical Plant, in which the interested party must attach in his Application a detailed description of the facilities and equipment with which the Plant will be available, which must be new and of technology tip.

Likewise, it must include the investment program and the schedule for its execution, which will specify the deadlines for the installation and start-up of the Petrochemical Plant.

In addition, the Petrochemical Plant must comply with the international standards of Safety and Environment declares Art 2 of this D.S.

**5.1.5 Ministerial Resolution No. 118-2010-MEM / DM: Specified area of determined geographical area for the installation of Petrochemical complex in San Juan de Marcona in the province of Nazca in the department of Ica.**

Article 1 of this Ministerial Resolution declares San Juan de Marcona in the district of Marcona, in the province of Nazca and in the department of Ica as a geographical area determined for the installation of the Petrochemical Complex of decentralized development, according to Law No. 29163.

To complement, it is also declared of sectorial interest the petrochemical projects that are installed in the determined geographical area referred to in Article 1 (Article 2).

**5.1.6. Law No. 28611: General Environmental Law**

The present Law is normative rule of the legal normative framework for the environmental management in Peru. It establishes the basic principles and norms to ensure the effective exercise of the right to a healthy, balanced and adequate environment for the full development of life, as well as the fulfillment of the duty to contribute to an effective environmental management and to protect the environment, as well as Its

components, with the aim of improving the quality of life of the population and achieving the sustainable development of the country.

Article 1, Rights and Principles (preliminary title), mentions that every person has the inalienable right to live in a healthy, balanced and adequate environment for the full development of life, and the duty to contribute to an effective management Environmental protection and to protect the environment and its components, particularly ensuring individual and collective health, conservation of biological diversity, sustainable use of natural resources and sustainable development of the country.

Article 9 of Law No. 28611, General Environmental Law, aims to improve the quality of life of people by ensuring the existence of healthy, viable and functional ecosystems in the long term; And the sustainable development of the country through the prevention, protection and recovery of the environment and its components, conservation and sustainable use of natural resources, in a manner that is responsible and consistent with respect for the fundamental rights of the individual.

#### **5.1.7 Law No. 28054: Promotion of the Biofuels Market**

This Law establishes the general framework to promote the development of the biofuel market based on free competition and free access to economic activity, with the objective of diversifying the fuel market, promoting agricultural and agro industrial development, generating Employment, reduce environmental pollution and offer an alternative market in the fight against drugs.

### **5.1.8 Law No. 28317: Law on control and inspection of the marketing of methyl alcohol**

The purpose of this law is to establish control and inspection measures for the commercialization of methyl alcohol, from its manufacture or entry to the country to its final destination; including the activities of deposit, transportation, marketing and use of methyl alcohol, without prejudice to the provisions of other regulations on the subject.

Article 3 mentions that manufacturers, importers, transporters and traders of methyl alcohol must carry a special register stating information related to the levels of production, importation and / or sales, and a description of the quantities of use, deposit And / or transportation.

#### **Related Legal Norms**

The list of Legal Norms relating to the Environment and production of fuels are presented below:

- Political Constitution of 1993, Article 2, paragraph 22.
- Code of the Environment and Natural Resources, Legislative Decree 613 (08-09-90).
- Organic Law of Hydrocarbons, Law No. 26221 (02-08-93).
- Regulation of Environmental Protection for Hydrocarbon Activities D.S. No. 046-93 MS (12-11-93) and its modification the D.S. No. 09-95-EM published 10-05-95.
- D.S. No. 015-2006-EM 03/03/2006. Regulation for Environmental Protection in Hydrocarbon Activities.
- Regulation for the Refining and Processing of Hydrocarbons D.S. No. 051-93-MS

- Law regulating the sulfur content in diesel fuel, Law No. 28694.
- Schedule of Progressive Reduction of Sulfur Content in Diesel Fuel No.1 and 2, D.S. No. 025-2005-MS.
- Modification of D.S. No. 025-2005-EM that approves the schedule of progressive reduction of the content of Sulfur in the fuel Diesel N ° 1 and 2, D.S. No. 041-2005-MS, dated 14.10.2005.

## 6. ENVIRONMENTAL STUDY

The impact on the environment, including the socio-economic effects of setting up a project in the community to be set up, is an issue that must be properly considered during the planning and development of the Project in all its phases:

- Construction Stage (Installations)
- Stage of Operation (Methanol Production).

For each phase of the Project, its purpose, objectives and characteristics will be established, detailing the specific activities to be carried out, the chemical substances and wastes that will be generated, as well as the methods provided for their final disposal. The Environmental Management Plan will be established, which will include a set of programs aimed at the conservation, protection and improvement of the ecosystem, including measures to control and minimize degrading processes.

As described above, the first step leads to an Environmental Impact Assessment, which evaluates the positive and negative impacts of the project proposal on the environment. This is a critical step in deciding where and how to build and operate a plant, so that the ecological and community impact is minimal. Within the Evaluation, an Environmental Impact Assessment (EIA) is prepared, which must comply with local regulations, and be submitted to regulatory authorities for review and approval before beginning the construction phase. The EIA process concludes with a Resolution confirming that the project:

- It satisfies the applicable ecological requirements;
- Complies with ecological regulations, including permits; and

- It includes satisfactory mitigating measures and compensation and repair measures.

It is necessary to know the normal contaminating factors of a methanol plant, within them:

- Atmospheric emissions from the reforming furnace chimneys, auxiliary boilers and methanol plant incinerator, including: carbon monoxide (CO), nitrogen dioxide (NO<sub>2</sub>) and fully suspended particles (PTS). No emissions of sulfur dioxide (SO<sub>2</sub>) will be obtained, since the Camisea gas does not contain sulfur components.
- Domestic and industrial liquid effluents (wastewater)
- Household solid waste (stage of construction and operation of the project, categorized as non-hazardous) and industrial (such as: inactive catalysts, chemical storage containers, and oil / water separator bottom sludge).

The effects of methanol on human health and the environment depend on the amount of methanol present and on the frequency and time of exposure. The effects also depend on the health of the person or the conditions of the environment when the exposure occurs.

#### **6.1. 6.1. Potential Health Effects**

- Epidermal: irritant (causes drying and redness of the involved area).
- Eye contact: Moderately irritating (causes redness and severe burning)
- Inhalation of vapors: in high concentrations produces cough, dizziness, nausea, headache, weakness and visual disturbances.

Note: The limit value for exposure to methanol (TLV) for a measured average time (TWA) is 200ppm (maximum exposure value of one person for a period of 8 hours). The short-term exposure limit for methanol is 250ppm (STEL) (exposure for 15min). The olfactory threshold of the methanol aroma is higher than TLV-TWA.

Oral ingestion: may pose a serious threat to human life. An amount of methanol between 30 and 120 ml can cause fatalities. Ingestion produces effects similar to that of inhalation of vapors, but with greater severity and speed in the appearance of symptoms.

## **6.2. Effects on the environment**

Methanol is a rapidly volatilizing substance in the air even at room temperature; Also evaporates rapidly from aqueous mixtures or soil contaminated or moistened with this substance. For this reason, most methanol leaks are directed into the atmosphere. Once in the air, it decomposes or is transformed into other substances by the action of solar radiation and by reaction with constituents of air present naturally or artificially. Microorganisms that live on water and soil can also degrade methanol.

Methanol is easily degraded in the environment by processes of photo oxidation and biodegradation. The half-life for methanol in the atmosphere has been reported to be between 7 and 18 days for atmospheric reaction with hydroxyl radicals. Emissions during industrial uses are so low that their impact can be ignored. This situation may vary if one considers the use of methanol as a large-scale substitute for current fuels.

The catalysts used in the production of methanol generally contain auxiliary and support agents as active components that present high potential for the generation of waste to the environment, including copper (synthesis), nickel (gas generation), cobalt and molybdenum (desulfurization) . In well-designed and operated process plants these metals are usually recovered and reused.

There are many microorganisms that are able to use methanol as growth substrate by completely degrading it to carbon dioxide and water. Methanol is readily degradable in both aerobic and anaerobic conditions in a wide variety of natural environments, including fresh and salt water, sediments and soils, groundwater, aquifer material and industrial wastewater; 70% of the methanol in the sewage system is usually degraded within 5 days.

Methanol is not very toxic to aquatic organisms and terrestrial organisms and is not likely to have effects due to its exposure to the environment, except in case of a spill.

➤ **Air**

Methanol reacts in the atmosphere with oxidizing species. It has been reported that the half-life of methanol because of these reactions is approximately 8.4 days.

The reaction of methanol with nitrogen dioxide may be the major source of methyl nitrite found in contaminated atmospheres. Methanol levels in the air range from less than 0.001 mg / m<sup>3</sup> (0.8 ppm) in rural air to about 0.04 mg / m<sup>3</sup> (30 ppm) in urban air.

➤ **Water**

The effluents containing the highest proportions of methanol come from chemical plants, wastewater treatment, paper and latex production.

Very broad values have been reported for the half-life of methanol in water by photo-oxidation reactions, some are as long as 5.1 years and others shorter than 46.6 days, these values have been based on information for the reaction of hydroxyl radicals in aqueous solutions.

➤ **Soil**

Methanol is biodegradable in soil and sediments, both under aerobic and anaerobic conditions. Methanol is a growth substrate for many microorganisms, which are able to completely mineralize it to carbon monoxide and water.

The rate of degradation of methanol varies considerably depending on the type of soil in which it is released, so the soils can be characterized in two classes basically; In which the rate of degradation is high and increases with the addition of nitrates or sulphate and the slow ones, in which the rate of biodegradation is low and decreases even further with the addition of nitrate or sulphate, and inhibition Of sulphate increases the rate of degradation. Biodegradation rates were used to estimate the methanol half-life, finding values between 58 and 263 days.

Table 9 shows the maximum permissible limits of some parameters that Methanex considers in its methanol plants.

Table 9:

Permissible maximum limits for methanol emissions

Parámetros	Kitimat ,CB	Punta Arenas, Chile	Motunui, NZ	Valle de Waitara, NZ
Amoniaco	10 mg/l	-	-	200 mg/l
Demanda Química de Oxígeno – DQO	100 mg/l	-	200 mg/l	-
Tasa de Flujo	3200 m <sup>3</sup> /día	-	12096 m <sup>3</sup> /día	5000 m <sup>3</sup> /día
Metanol	-	-	15 mg/l	15 mg/l
Aceite y grasa	-	350 mg/l	10 mg/l	10 mg/l
pH	6.5 a 8.5	5.5 a 9.0	6.0 a 9.0	6.0 a 11.0
Temperatura	30°C max	-	-	-
Cantidad de Sólidos Suspendidos - CSS	-	700 mg/l	70 mg/l	1000 mg/l
Residuo volátil no filtrable –RVNF	40 mg/l	-	-	-

Source: Global Environmental Report 2005 - Methanex Corporation

It should be clarified that in 2008 the Maximum Permissible Limits of Liquid Effluents were established for the sub-hydrocarbon sector "D.S. No. 037-2008-PCM ", as shown in Table 10.

Comparing the values shown in Table 9 and Table 10, the values shown in the first table are lower than those established in the Peruvian regulation.

Table 10:

Maximum Allowable Liquid Effluent Limits for Activities of the Hydrocarbon Subsector

Parámetro regulado	Límites Máximos Permisibles (mg/l)
Hidrocarburos Totales de Petróleo (TPH)	20
Cloruro	500 (a ríos, lagos y embalses) 2000 (estuarios)
Cromo Hexavalente	0.1
Cromo Total	0.5
Mercurio	0.02
Cadmio	0.1
Arsénico	0.2
Fenoles para efluentes de refinerías FCC	0.5
Sulfuros para efluentes de refinerías FCC	1.0
Demanda Bioquímica de Oxígeno (DBO)	50
Demanda Química de Oxígeno (DQO)	250
Cloro residual	0.2
Nitrógeno amoniacal	40
Coliformes totales (NMP/100mL)	< 1000
Coliformes Fecales (NMP/100mL)	< 400
Fósforo	2.0
Bario	5.0
pH	6.0 – 9.0
Aceites y grasas	20
Plomo	0.1
Incremento de Temperatura <sup>a</sup>	< 3°C

Note. \* Is the increase with respect to the ambient temperature of the receiving body measured at 100 m diameter of the pouring point Source: Global Environmental Report 2005 - Methanex Corporation

## 7. EQUIPMENT SIZING AND COST

### 7.1. Sizing

#### Design temperature and pressure for different equipment

$T_{design} = T_{operation} * \left(1 + \frac{A}{100}\right) + B$  (Except the compressor, where  $T_{design} = T_{op}$ )

$P_{design} = P_{operation} * \left(1 + \frac{A}{100}\right) + B$

Where A and B are parameters adjustable by the user.

Table 11:

Default parameters A and B for temperature

Temperature (°F)				
	Lower limit	Upper limit	A	B
Range 1	-459.67	32	0	-50
Range 2	32	70	-100	70
Range 3	70	200	-100	250
Range 4	200	600	0	50
Range 5	600		0	50

Table 12:

Default parameters A and B for pressure

Pressure (Psia)				
	Lower limit	Upper limit	A	B
Range 1	0	15	-100	15

Range 2	15	50	-100	50
Range 3	50	265	0	25
Range 4	265	1015	0	50
Range 5	1015		5	0

❖ **Pumps**

Minimum data to be specified, information on input and output currents.

Important data for the design Over-design factor.

Results:

Design temperature and pressure, hydraulic load, engine power, engine speed (rpm), efficiency and weight.

Sizing

The flow obtained from the simulator information is multiplied by the over-design factor of the pump located in "Design Criteria". This increases the power required by the pump.

$$V_{\text{design}} = V_{\text{operation}} \times \text{Overdesign factor}$$

The efficiency is taken from the simulator, but if it is not specified a default value of 70% is used. If the power is not given, Aspen IPE calculates the base based on the capacity, viscosity and head, and then multiply by the efficiency to obtain the power to the brake, which is compared with a table of available standard power motors to choose the final power.

In case there is more than one inlet current, the lowest pressure will be used as the operating pressure of the pump.

The hydraulic load is calculated with the following expression:

$$H = h_d - h_s$$

$$H = \frac{2.31 \cdot P}{Sg}$$

Where:

H = Total load in ft

Hs = load on suction ft

h = Load in ft

P = Pressure in psia

hd = load at discharge, ft

Sg = Fluid Specific Gravity

For the calculation, it is assumed that

there are no friction losses in either the inlet or the outlet, and that there are no static charges or charges per speed.

*Defaults:*

Efficiency = 70%

Overdesign factor = 1.1

#### ❖ Air Coolers

*Minimum data to be specified, information on input and output currents.*

*Results:*

Design temperature and pressure, number of fans, power of fans, number of tubes and weight.

#### Sizing

For the thermal design:

$$Q = U \cdot A \cdot \text{MTD}$$

$$\text{MTD} = F \cdot \text{LMTD}$$

For mechanical design:

$$A = \pi \cdot D_{\text{tube}} \cdot N_{\text{rows of tubes}} \cdot N_{\text{tubes per row}} \cdot \text{Length of tubes}$$

An iterative algorithm is used to size the equipment. First calculate the Q value that can be reached using the specified geometry (number of tubes, number of rows of tubes, length, etc.). If the user does not specify such geometry, Aspen IPE uses the default values. Next, the calculated Q is compared using the geometry of the tube set with the required Q according to the properties of the input and output currents. If the first is greater, the iteration ends; otherwise, the parameters are incremented and the process is repeated.

The heat transfer coefficients are calculated using ratios that take into account the geometry of the tube set. The pressure drop of the air through the tube bank and the heat transfer are obtained using the correlations of Young, Briggs and Robinson. This drop is used to estimate fan power. The number of fans is based on the aspect ratio (tube length / platform width). For any ratio less than 1.5 only a fan is chosen.

*Defaults:*

Pitch of pipes = 2.5 in

Thickness of pipe = 0.125 in

Platform width = 4 ft to 20 ft

Rows of tubes = 3 to 6

Maximum pipe length = 3 x Platform width

❖ **Tanks**

*Minimum data to be specified: information on the input and output currents*

*Design Requirements:*

A maximum of 3 output currents are allowed, of which 2 can be liquid.

*Important data for design:*

*Time of residence, height / diameter (L / D), method for calculating maximum steam velocity, liquid particle diameter, design factor for steam velocity.*

*Results:*

*Design temperature and pressure, diameter, height or length and weight*

**Horizontal tanks**

*Calculation of length*

The length is determined on the basis of the volume of liquid retained, which is obtained from the liquid flow and the residence time. The length is calculated with the following formulas:

$$l_{vol} = l_{vfr} * r_t$$

$$L = \frac{4(l_{vol})}{\pi D^2(1-r_{vc})}$$

Where:

L = Length of tank

Lvol = Volume of liquid retained

Lvfr = Volumetric flow of the liquid

Rt = Time of residence

R\_vc = Steam area / tank cross-sectional area

If not specified, the L / D value is calculated as follows:

If  $P \leq 250$  Psia,  $L / D = 3$

If  $250 < P \leq 500$  Psia,  $L / D = 4$

If  $P > 500$  Psia,  $L / D = 5$

### *Calculation of the diameter*

The diameter is calculated based on the maximum allowed vapor velocity within the separator to decrease the entrainment of liquid in the vapor.

To obtain the vapor velocity, two methods are used, which can be selected in "Design Criteria":

- Liquid entrainment method

$$W = \frac{l_{mfr}}{v_{mfr}} \sqrt{\frac{\rho_v}{\rho_l}}$$

$$X = \ln(SF)$$

$$Kv = e^{(A+BX+CX^2+DX^3+EX^4)}$$

$$K = kv * kv_m$$

$$v_m = K \sqrt{\frac{\rho_l - \rho_v}{\rho_l}}$$

Donde:

Lmfr = Liquid mass flow

Vmfr = Steam mass flow

P<sub>l</sub> = Liquid density

P<sub>v</sub> = Vapor density

K = System factor

SF = Separation factor

Kv = Polynomial function of the SF

$K_{vm} = \text{SF Multiplier}$

$V_m = \text{Steam design speed}$

$A = -1.877478097$

$B = -0.814580459$

$C = -0.1870744085$

$D = -0.0145228667$

$E = -0.0010148518$

- Method of separation of particle size

$$K = dp \left[ \frac{g \cdot \rho_v (\rho_l - \rho_v)}{\mu_v^2} \right]^{0.33}$$

For laminar flow ( $K < 3$ )

$$v = \frac{g(\rho_l - \rho_v)(dp^2)}{18 \cdot \mu_v}$$

For turbulent flow ( $K > 3$ )

$$v = 1.74 \left[ \frac{g \cdot dp (\rho_l - \rho_v)}{\rho_v} \right]^{0.5}$$

$$v_m = v \cdot f$$

Donde:

$v = \text{Speed of steam}$

$g = \text{Gravitational constant}$

$\rho_v = \text{Vapor density}$

$\mu_v = \text{Vapor viscosity}$

$v_m = \text{Steam design speed}$

$f = \text{Design factor for steam velocity}$

$d_p$  = Liquid particle diameter

$\rho_l$  = Liquid density

The cross-sectional area of the tank is obtained as follows:

$$v_{csa} = \frac{v_{vol}}{v_m}$$

$$t_{csa} = \frac{v_{csa}}{I_{vc}}$$

Where:

$V_{csa}$  = Steam area

$V_m$  = Steam design speed

$V_{vol}$  = Volumetric flow of steam

$R_{vc}$  = Steam area / tank cross-sectional area

$T_{csa}$  = Area of cross-section of tank

The diameter of the tank based on the vapor flow is calculated from the area obtained in the above procedure.

$$D = \sqrt{\frac{4 \cdot t_{csa}}{\pi}}$$

On the other hand, the diameter can be calculated on the basis of the volume of liquid retained (used to calculate L) and the value of L / D (specified by the user in "Design Criteria"). The larger diameter of the two is used in the final design.

After estimating the length and diameter of the tank (based on the steam flow), the corresponding L / D value is compared to that found in the "Design Criteria" form. If they do not match, the calculated diameter is compared using the vapor flow with the one obtained based on the volume of liquid retained and the L / D

ratio given by the user, and the largest one is chosen; The length is then adjusted to reach the specified L / D.

*Defaults*

Horizontal tanks

Method for calculating the maximum velocity of the vapor = Liquid entrainment method

Liquid particle diameter = 0.15 in

Design factor for steam speed = 0.5

Residence time = 5 min

Height / Diameter (L / D) = 3

Steam Area / Tank Cross-sectional Area = 0.2

Separation Factor Multiplier = 1.25

❖ **Separator**

The design of pressure vessels normally complies with ASME Code VIII Division I. Design, Construction and Inspection of Pressure Vessels.

Equation A1.1 indicated in the book "Gas Conditioning and processing" was applied to determine the internal diameter of the separator:

$$d = \frac{0.0188(\frac{m}{F_g K_s})^{0.5}}{[(\rho_L - \rho_g)(\rho_g)]^{0.25}} \dots \dots \dots A1.1$$

Donde:

	<b>SI</b>
d = D.I. Separator	m
m= Standard mass flow	Kg/h
Fg = Fraction of available gas area	-
Ks= Gas size parameter	m/s
pL = Density of liquid	Kg/m <sup>3</sup>
pg = Gas density (currnet)	Kg/m <sup>3</sup>

- Standard mass flow

Equation A1.2 indicated in the book "Gas Conditioning and processing" was applied to determine the mass flow under standard conditions:

$$m = (1762) \left( 10^6 \text{std} \frac{m^3}{d} \right) (MW_{gas}) \dots\dots\dots A1.2$$

Applying the equation A1.1 for separator V-101 gives:

Data:

$$10^6 \text{std} m^3/d = 5.12$$

$$MW_{gas} = 24.31$$

$$\text{Then: } m = 215,395 \text{ kg/h}$$

- Fg

The book "Gas Conditioning and processing" indicates that for the case of vertical separators the value corresponding to Fg is one.

- Ks

The book "Gas Conditioning and processing" indicates based on his experience that for vertical separators the value corresponding to Ks could vary in the range of 0.07-0.105 m / s. To determine the diameter of the present vertical separator the value of 0.105 m / s is being used.

Data:

$$p_L = 889.3 \text{ kg/m}^3$$

$$p_g = 1.495 \text{ kg/m}^3$$

Then:  $d = 1.54\text{m}$

Equation A1.3 indicated in the book "Gas Conditioning and processing" was applied to determine the volume of the separator:

$$V_L = \frac{(qL)(t)}{1440} \dots\dots\dots \text{A1.3}$$

Where:

	<b>SI</b>
$V_L =$ Liquid volume of separator	m <sup>3</sup>
$qL =$ Current net flow	m <sup>3</sup> /d
$t =$ Time of residence (Range of varia	Min
7 min)	

Data:

$$qL = 1638.72$$

$$t = 7.5$$

Then:  $V_L = 8,535 \text{ m}$

The volume height of the separator was determined by applying the following formula:

$$h = \frac{4V_L}{\pi d^2} \dots \dots \dots A1.4$$

$$h = 3.415\text{m}$$

In order to verify that the height and diameter determined are correct, the book indicates that the relation between them must vary between 2 and 4.

$$h/d = 2,218$$

❖ **Heat exchanger**

- Delta Pressure (housing-pipes) = 6454000 kg / m<sup>2</sup>
- Number of Steps per Carcass = 1
- Number of housings = 2
- LMTD = 75.65 °C
- Duty = 3,595e+008 KJ/h
- UA = 4,75e+006 kJ/C.h
- A = 60.32 m<sup>2</sup>
- Pitch = triangular
- THEME = OF
- Orientation = horizontal
- Number of Required Exchangers = 2

❖ ***Desbutanizing Column (T-100)***

- Type of internal = sieve (sieve = fill)
- Column diameter = 1,5 m
- Spacing between dishes = 0.55 m

- Number of theoretical dishes = 30
- Feeding plate = 19
- P design = 1.1 x P operation = 1.1 x 1965KPa = 2165.5KPa
- T design = 217°C
- Reflux Ratio = 4.07

#### ❖ **MTG Conversion Reactor**

Reacts DME with LO and HO to get gas. The reaction is exothermic, with the heat of reaction at 25 ° C equal to  $-1.089 \times 10^5$  kJ / kg mol.

Analysis:

- We assumed a residence time of 0.8min
- V reactor = 6.567 m<sup>3</sup>
- Orientation = Horizontal
- T design = 86,61°C
- P design = 1.1 x P operation = 1.1 x 101.3KPa = 111.43KPa

#### ❖ **DME Balance Reactor**

Reacts methanol in equilibrium to achieve DME. The reaction is exothermic, with the reaction heat at 25 ° C equal to  $-1.2 \times 10^4$  kJ / kg mol.

Analysis:

- A residence time of 1.0min was assumed
- V reactor = 5.0 m<sup>3</sup>
- Orientation = Vertical
- T design = 300°C

- $P_{\text{design}} = 1.1 \times P_{\text{operation}} = 1.1 \times 101.3\text{KPa} = 111.43\text{KPa}$

#### ❖ **Wind turbine**

In the whole process there are 3 airfronters assuming that they have the same specifications you get your design variables.

Analysis:

- A residence time of 3 min was assumed
- Orientation = Horizontal
- Duty = 2.122 Kcal / h
- Relationship  $h / d = 2.12$
- Diameter = 0.5 m
- $T_{\text{design}} = -47.58^{\circ}\text{C}$
- $P_{\text{design}} = 1.1 \times 101.3\text{KPa} = 111.43\text{KPa}$

#### ❖ **Three - phase separator**

Its function is to separate the final remaining water in the process for the final treatment in the fractionator and obtain the final product.

Analysis:

- A residence time of 5 min was assumed
- Ratio  $h / d = 3.06$
- Diameter = 1.75 m
- Orientation = Horizontal
- $T_{\text{design}} = 23.56^{\circ}\text{C}$
- Ratio of  $D / d_{\text{boot}} = 3.97$
- $P_{\text{design}} = 1.1 \times 101.3\text{KPa} = 111.43\text{KPa}$

## ❖ Pump

Once the water and gases are separated from gasoline condensate, it is pumped for preheating and entering the fractionator.

Analysis:

- Design factor = 1.1
- Efficiency = 70%
- Total load H = 272.1 m
- V design = 1.1 x V operation = 116.8 m<sup>3</sup>

## 7.2. Cost of equipment:

### ❖ Heat Exchangers, Condensers, Air Coolers & Retainers:

	Type	MOC	Área (m <sup>2</sup> )	Cost (\$)
E-101	Double Pipe	Titanium / Carbon Steel	60.3	344,000
E-102	Air Cooler	Titanium / Carbon Steel	17.06	97,338
E-103	Air Cooler	Titanium / Carbon Steel	17.06	97,338
E-104	Double Pipe	Titanium / Carbon Steel	60.3	344,000
E-105	Air Cooler	Aluminum	24.69	140,860
E-106	Kettle Reboiler	Titanium / Carbon Steel	10.29	58,677
E-107	Kettle Reboiler	Titanium / Carbon Steel	49.58	282,864
E-108	Air Cooler	Aluminum	52.03	296,818
E-109	Air Cooler	Aluminum	52.03	296,818

❖ **Reactors:**

	Type	Volume (m3)	MOC	Cost (\$)
R-101	Conversion	16	Stainless Steel	1,546,554
R-102	Conversion	16	Stainless Steel	1,546,554
R-103	Conversion	16	Stainless Steel	1,546,554
R-104	Balance	5	Stainless Steel	147,000

❖ **Towers:**

	N° of plates	Height	Diameter	MOC	Cost (\$)
T-101	30 Platos	20	2	Carbon Steel	2,880,000

❖ **Mixers:**

	Type	Flow (m3/h)	Cost (\$)
M-101	Impeller	195	83,772.0
M-102	Impeller	195	83,772.0
M-103	Impeller	203.4	87,380.6
M-104	Impeller	203.4	87,380.6
M-105	Impeller	180	77,328.0
M-106	Impeller	180	77,328.0
M-107	Impeller	1130	485,448.0

❖ **Pumps:**

	Type	Power (kwats)	MOC	PD	Cost (\$)
B-101	Centrifuge	63.4	Stainless Steel	20	79,793

❖ **Separators:**

	Orientation	Length (m)	Diameter (m)	MOC	Cost (\$)
V-101	Vertical	16	4	Carbon Steel	714,000
V-102	Horizontal	10	2.8	Titanium	747,000

❖ **Tanks**

	Type	Volume (m3)	Cost (\$)
Tk-101	Floating roof	2620	392,209
Tk-102	Floating roof	2620	392,209
Tk-103	Floating roof	2620	392,209
Tk-104	Floating roof	2620	392,209

Adding all equipment costs we get a total cost of 13.72 MM \$, which represents our value of Battery Limit II.

## 8. ECONOMIC EVALUATION

### 8.1. Calculation of Battery Limit and Total Investment:

Cost of equipment (HYSYS): I1: \$ 13.72 million

$$I_2 = 0.4 I_1 = 5.49 \text{ MM \$}$$

$$I_1 + I_2 = \$ 19.2 \text{ million}$$

Correction factor 2015: 2

$$(I_1 + I_2) \text{ corrected} = \$ 38.42 \text{ million}$$

Engineering Expenses: I3

$$0.2 * (I_1 + I_2) = 7.68 \text{ MM\$}$$

Expenses of Licensor: I5

$$0.1 * (I_1 + I_2) = 3.84 \text{ MM\$}$$

$$\text{Fixed Capital: } (I_1 + I_2 + I_3 + I_5) = 49.94 \text{ MM\$}$$

Expenditure on chemical inputs and catalyst: I6

$$I_6 = 11.89 \text{ MM\$}$$

Interim Interest: I7

$$I_7 = 0.09 * (\text{Fixed Capital}) = 0.09 * (49.94) = 4.5 \text{ MM\$}$$

Start-up costs: I8

3 months of operating expenses

$$I_8 = 79.25 \text{ MM\$}$$

$$\text{Amortizable Capital: } (I_1 + I_2 + I_3 + I_5 + I_6 + I_7 + I_8) = 145.56 \text{ MM\$}$$

Working Capital:  $2 \cdot I_8 = 2 \cdot (79.25) = 158.49$  MM\$

**Total inversion: CA + CT = 145.56 MM\$ + 158.49 MM\$ = 304.05 MM\$**

## 8.2. Operating Cost Calculation:

### Variable Loads:

- **Raw material:**

Relationship Raw Material / Product: 0.318 TM Methanol / Bbl Gasoline

Cost of raw material production: 204.9 \$ / MT Methanol

**Cost Raw Material:  $204.9 \cdot 0.318 = 65.2$  \$ / Bbl Gasoline**

- **Chemicals, Catalyst and Industrial Services:**

Cost catalyst and additives: 12 \$ / Bbl Gasoline

Cost of industrial services:

Electricity consumption: 4.8 Kwh / Bbl Gasoline

Electricity Price (South Light): 0.055 \$ / Kwh

Electricity cost:  $0.055 \cdot 4.8 = 0.26$  \$ / Bbl of Gasoline

Other: 2 \$ / Bbl Gasoline

Cost of industrial services: 2.3 \$ / Bbl Gasoline

**Cost of catalyst and industrial services: 14.3 \$ / Bbl Gasoline**

**Cost of Variable Loads:  $65.2 + 14.3 = 79.42$  \$ / Bbl Gasoline**

### Workforce:

Production of Gasoline: 3630000 Bbl / year

N° days / year = 330

- **Operators:**

Number of operators / shift = 6

Salary \$ / operator = 70

Number of shifts / day = 3

Annual Salary \$ / year =  $6 * 70 * 3 * 330 = 415,800$

**Operator costs =  $415,800 / 3,630,000 = \$ 0.115 / \text{Bbl of gasoline}$**

- **Supervisors:**

Number of operators / shift = 6

Salary \$ / operator = 140

Number of shifts / day = 3

Annual Salary \$ / year =  $6 * 140 * 3 * 330 = 831,600$

Cost Supervisors =  $831,600 / 3,630,000 = \$ 0.230 / \text{Bbl of gasoline}$

- **Auxiliary Personnel:**

Number of operators / shift = 12

Salary \$ / operator = 35

Number of shifts / day = 3

Annual Salary \$ / year =  $12 * 35 * 3 * 330 = 415,800$

Personal Aux. Cost =  $415,800 / 3,630,000 = \$ 0.115 / \text{Bbl of gasoline}$

- **Management:**

Number of operators / shift = 2

Salary \$ / operator = 700

Number of shifts / day = 1

Annual Salary \$ / year =  $2 * 700 * 1 * 330 = 462,000$

Cost Management =  $462,000 / 3,630,000 = \$ 0.127 / \text{Bbl of gasoline}$

Cost of Labor:  $0.127 + 0.115 + 0.115 + 0.230 = 0.58 \$ / \text{Bbl Gasoline}$

Operative Cost:  $0.58 + 79.42 = 80.0 \$ / \text{Bbl Gasoline}$

**Calculation of plant start-up expenses: 3 months of Operating Expenses**

$$x = \frac{(80.00)kUS\$}{1000 * Bbl Gasoline} * \frac{3630000Bbl Gasoline}{330 days} * 90 days$$

**I<sub>s</sub> = 79.25 MM\$**

**8.3. Fixed Load Calculation:**

- **Amortization and interest:**

**Payment Annuity (Amortization + Interest)**

$$R = \frac{P(1+i)^n i}{[(1+i)^n - 1]}$$

Where:  
P = Loan  
i = Interest-Peru (0.15)  
n = Years (10)  
R = Annuity

We will consider that of the total investment, the bank will finance 40% of the total required.

Company: 60% (\$ 304.05 million) = \$ 182.43 million

Bank: 40% (\$ 304.05 million) = \$ 121.62 million

Calculating R:

R = 24,232 MM \$ / year = 6.68 \$ / Bbl Gasoline

In 10 years:

R = \$ 242.33

**Annual interest = R - Bank = (242.33 - 121.62) / 10 = 12.07 MM \$ / year**

**Amortization: R = 6.68 \$ / Bbl Gasoline**

- **Rate and insurance**

T & S = 0.02 \* (I1 + I2) = 0.02 \* (38.42) = 0.768 MM \$

T & S = 0.21 \$ / Bbl Gasoline

- **General expenses:**

$$GG = 0.01 * (I1 + I2) = 0.01 * (38.42) = 0.384 \text{ MM } \$$$

$$GG = 0.11 \$ / \text{Bbl Gasoline}$$

- **Maintenance:**

$$M = 0.05 * (I1 + I2) = 0.05 * (38.42) = \$ 1.921$$

$$M = 0.53 \$ / \text{Bbl Petrol}$$

$$\text{Fixed Load} = 6.68 + 0.21 + 0.11 + 0.53 = 7.52 \$ / \text{Bbl Gasoline}$$

#### 8.4. Cash Flow Calculation

- **Income:**

**Product Cost: 116 \$ / Bbl Gasoline**

**Capacity: 3, 630,000 Bbl Gasoline / year**

**Income (I) = 421.08 MM \$ / year**

- **Expenses:**

**Cost of production: Operational C. + Fixed Load = 87.6 \$ / Bbl Gasoline**

**Production cost without depreciation: 87.6 - 6.68 = 80.9 \$ / Bbl Gasoline**

**Egress (E): 80.9 \* (3,630,000) = 293.64 MM \$ / year**

- **Depreciation:**

**Applies to the physical part of the Project**

**(I1 + I2) = \$ 38.42 million**

**Linear Depreciation (10 years) = 38.42 / 10 = 3.84 MM \$ / year**

- **Gross margin:**

**MB = I - (E + Depreciation)**

**MB = 421.08 - (293.64 + 3.84) = 123.6 MM \$ / year**

- **Tax:**

**Taxes (25% MB) = 0.25 \* (123.6) = 30.9 MM \$ / year**

**Cash Flow: FC = I - E - Impuestos = 421.08 - 293.64 - 30.9 = 96.54 MM \$**

## 8.5. Calculation of IRR, NPV and Return on Investment

- **IRR:**

It relates the amount of initial investment with the flow of profits that the project generates during the estimated time, in the present case 10 years. In order to consider feasible the NPV must be greater than zero.

$$VAN = INV + \frac{U_1}{(1+i)^1} + \frac{U_2}{(1+i)^2} + \dots + \dots + \frac{U_{20}}{(1+i)^{20}}$$

Where:

INV = Initial Investment

U1 = Flow of the 1st year

U20 = 20th year flow

i = Discount rate

For our project the discount rate is 15%, Table 13 shows the cash flows corresponding to the 10-year duration of the project:

Table 13

### Cash Flows for the 10-Year Project Duration

YEAR	INVESTMENT	I	E	Taxes	Interest	FC
2015	304,049					-304,049
2016		421,08	293,63	30,9	12,07	84,472
2017		421,08	293,63	30,9	12,07	84,472
2018		421,08	293,63	30,9	12,07	84,472
2019		421,08	293,63	30,9	12,07	84,472
2020		421,08	293,63	30,9	12,07	84,472
2021		421,08	293,63	30,9	12,07	84,472
2022		421,08	293,63	30,9	12,07	84,472
2023		421,08	293,63	30,9	12,07	84,472
2024		421,08	293,63	30,9	12,07	84,472
2025		421,08	293,63	30,9	12,07	84,472

Source: Own elaboration

With this data we can calculate the NPV:

**NVP = 104.26 MM\$**

- **IRR:**

It is the rate that allows the current value of future earnings flow to be zeroed with the initial investment, obtaining the profitability of the project investment. In order to consider the project feasible, the IRR should be greater than the discount rate considered for the country's standard investment projects or the item under consideration.

The IRR obtained by our project is:

TIR = 25%

- **Recovery of Investment (PAYOUT)**

This indicator indicates the time in which the investment will be recovered, expressed in terms of years.

YEAR	FC	Unrecovered investment
2015	-304,049	
2016	84,472	219,577
2017	84,472	135,104
2018	84,472	50,632
2019	84,472	-33.84
2020	84,472	-
2021	84,472	-
2022	84,472	-
2023	84,472	-
2024	84,472	-

2025	84,472	-
------	--------	---

Table 14 shows the unrecovered investment per year:

Table 14

Unrecovered investment

Source: Own elaboration

To calculate the recovery of the investment we divided the initial investment with the annual cash flow:

$$304.049 / 84.472 = 3.6 = 3 \text{ years, } 7 \text{ months and } 6 \text{ days}$$

## 8.6. Sensitivity of the project

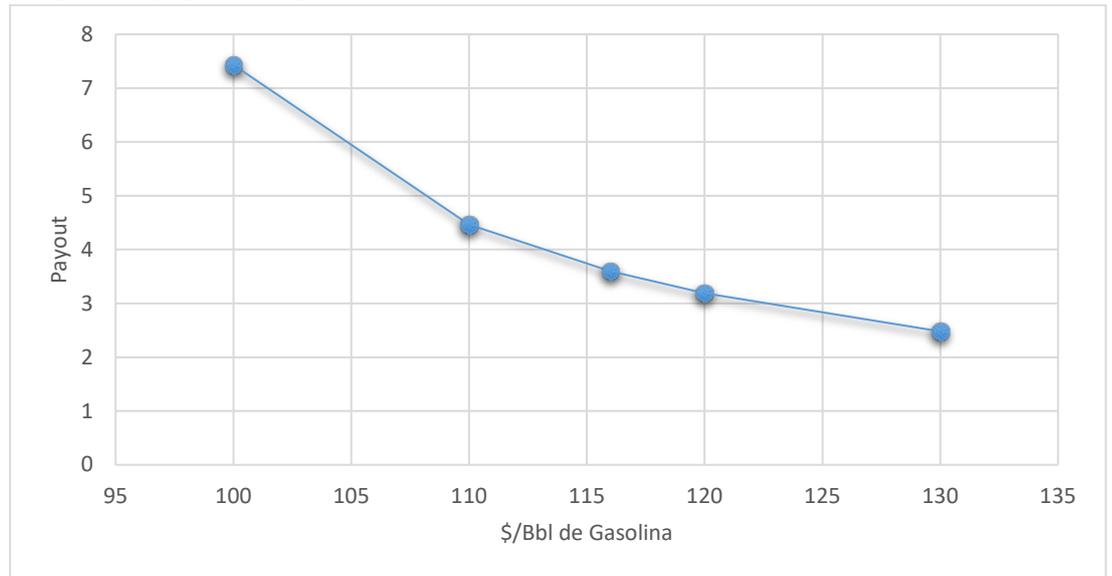
Sensitivity analyzes were carried out with the variation of the price of the gasoline barrel (Table 15, Figure 42) and by varying the bank's intervention in the investment (Table 16, Figure 43), obtaining the following results:

Table 15

\$/Bbl GasolinE	NPV	IRR	PAYOUT
130	\$270,598.14	39%	2.48026621
120	\$151,784.25	29%	3.18835871
116	\$104,258.69	25%	3.5993961
110	\$32,970.36	18%	4.46230429
100	-\$85,843.53	6%	7.43174323

**Sensitivity to the variation of the price of Gasoline**

Source: Own elaboration

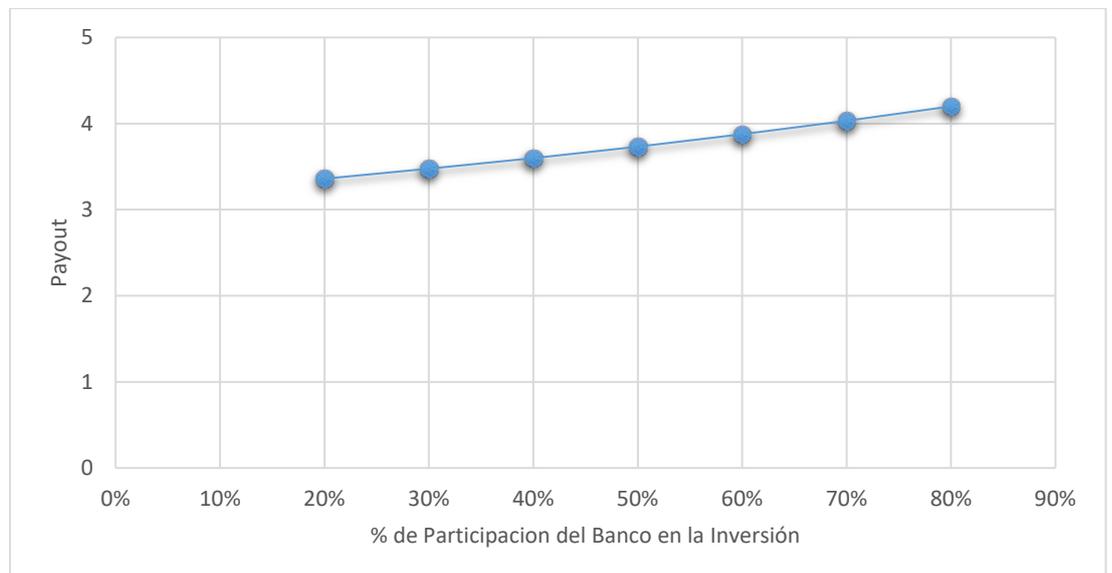


**Figure 42: Sensitivity to the variation of the price of Gasoline**

Source: Own elaboration

Table 16  
Sensitivity with the variation of the bank's share

Participación Banco	VAN	TIR	PAYOUT
20%	\$130,598.48	27%	3.35937075
30%	\$117,428.59	26%	3.47524388
40%	\$104,258.69	25%	3.5993961
50%	\$91,088.80	24%	3.73274757
60%	\$77,918.91	22%	3.87636008
70%	\$64,749.02	21%	4.03146536
80%	\$51,579.12	20%	4.1995005



**Figure 43: Sensitivity with the variation of the bank's share**

Source: Own elaboration

As you can see the viability of the project is given for gasoline sales prices above 100 \$, so far in 2015 the sale price of high octane gasoline is approximately 77 \$ / Bbl, to this Price the project would be non-viable, but this price is momentary due to the reduction of the price of crude, it is for this reason that was taken as the basis for this study the price of gasoline in 2014 amounting to 116 \$ / Bbl, At this price the project is very attractive to investors.

On the other hand, if we vary the participation of the bank in the total investment, we can realize that when the intervention of the bank is greater, the financial indicators of the project diminish and make the investment less attractive, for this reason an intermediate participation of the bank was taken Because if the participation is too low, taxes are also higher which is not convenient for the viability of the project.

## **9. CONCLUSIONS AND RECOMMENDATIONS**

- For the MTG project to be viable it is recommended to start from the raw material which must be natural gas, thereby avoiding methanol imports and the higher cost of raw material. The project will be viable due to the large amount of natural gas destined to the petrochemical industry, which will serve as raw material to obtain 92 octane gasoline.
- The exact location of our plant will be in Marcona by the laws already stated where we will choose a small pier in which the water will be quiet so as to avoid waves, which would affect the maritime transport of the product. The product was transported by means of buoys.
- All the heat released by our production reactors will be used to heat our food and thus avoid more energy expenditure and release the heat to the environment, which would be harmful.
- The gasoline obtained is immediately sent to the sales area because it is an environmental gasoline and does not have to be sent to the hydrotreatment section to reduce the concentration of sulfur.
- With the current price of crude oil our project will not be viable, therefore with the previous price of crude oil which was between 90 and 100 dollars per barrel, our project will be viable as our gasoline sale will be 116 dollars per barrel.
- The production of the plant will be 330 days per year so as to be able to maintain the equipment and avoid accidents in the plant, in these days of zero productions, the production stored in the tanks will be used.
- It was destined to distribute to all the refineries located in the maritime coast of Peru, to facilitate the transport and expedite the purchase of our product.

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# ANEXES

# CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

## Economic Indicators

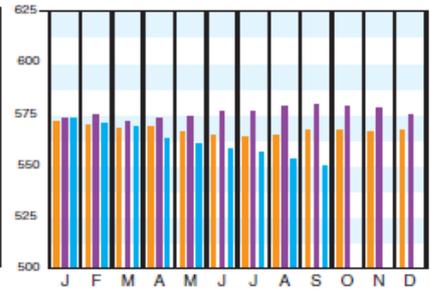
2013 2014 2015

Download the CEPCI two weeks sooner at [www.chemengonline.com/pci](http://www.chemengonline.com/pci)

### CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957-59 = 100)	Sept. '15 Prelim.	Aug. '15 Final	Sept.'14 Final
CE Index	550.4	553.9	580.1
Equipment	661.2	665.6	704.6
Heat exchangers & tanks	586.2	582.2	650.9
Process machinery	655.6	658.2	668.1
Pipe, valves & fittings	816.8	822.3	877.4
Process instruments	390.5	392.1	413.4
Pumps & compressors	956.4	956.5	939.0
Electrical equipment	510.0	511.8	515.7
Structural supports & misc	728.7	733.2	775.1
Construction labor	320.3	323.4	323.9
Buildings	540.3	542.0	546.3
Engineering & supervision	318.5	318.2	321.4

Annual Index:  
2007 = 525.4  
2008 = 575.4  
2009 = 521.9  
2010 = 550.8  
2011 = 585.7  
2012 = 584.6  
2013 = 567.3  
2014 = 576.1



Starting with the April 2007 Final numbers, several of the data series for labor and compressors have been converted to accommodate series IDs that were discontinued by the U.S. Bureau of Labor Statistics

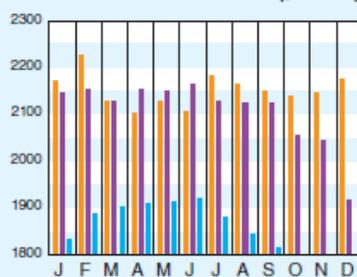
### CURRENT BUSINESS INDICATORS

	LATEST	PREVIOUS	YEAR AGO
CPI output Index (2012 = 100)	Oct. '15 = 106.0	Sept. '15 = 105.1	Aug. '15 = 105.1
CPI value of output, \$ billions	Oct. '15 = 1,815.5	Aug. '15 = 1,841.6	July '15 = 1,879.9
CPI operating rate, %	Oct. '15 = 76.5	Sept. '15 = 75.9	Aug. '15 = 75.9
Producer prices, industrial chemicals (1982 = 100)	Oct. '15 = 237.3	Sept. '15 = 238.1	Aug. '15 = 249.1
Industrial Production in Manufacturing (2012=100)*	Oct. '15 = 106.3	Sept. '15 = 105.9	Aug. '15 = 106.0
Hourly earnings index, chemical & allied products (1992 = 100)	Oct. '15 = 159.3	Sept. '15 = 160.6	Aug. '15 = 158.6
Productivity Index, chemicals & allied products (1992 = 100)†	Oct. '15 = 107.0	Sept. '15 = 107.2	Aug. '15 = 106.8

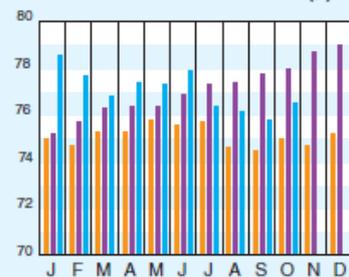
### CPI OUTPUT INDEX (2000 = 100)†



### CPI OUTPUT VALUE (\$ BILLIONS)



### CPI OPERATING RATE (%)



\*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing Index from the U.S. Federal Reserve Board.

†For the current month's CPI output Index values, the base year was changed from 2000 to 2012

#Correction: The values for the Productivity Index published in the September and October issues of *Chem. Eng.* were not correct due to the omission of an adjustment factor. The correct value for the July Productivity Index in the September issue should have been reported as 106.9, and the correct value for the August Productivity Index (October issue) should have been 107.3. We apologize for any confusion.

Current business indicators provided by Global Insight, Inc., Lexington, Mass.