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Optimal chosen for use gas flaring

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My heartfelt affection for everyone who reads my words ...

NOMENCLATURE

Symbol	Description
API	American Petroleum Institute
BarG	Gauge pressure
bbl	Barrel
BCM	Billion Cubic Meters
C2H6	Ethane
CAPEX	Capital Expenditure
CH4	methane
m^3	Cubic meter
CNG	Compressed Natural Gas
CCGT	Combined Cycle Gas Turbine
CO	Carbon Oxide
CO2	Carbon dioxide
C^0	Degree Celsius
DME	Dimethyl ether
FGRS	Flare Gas Recovery System
FLNG	Floating Liquefied natural Gas
GTP	Gas to Pipeline
GTF	Gas-To-Fuel
GTL	Gas-To-Liquid
GTM	Gas To Market
GTPP	Gas Turbine Power Plant
GTC	Gas Turbine Cycle
GTW	Gas To Wire
H2S	Hydrogen Sulphide
HC	Hydrocarbon
HRSG	Heat recovery steam generators
ICEC	Internal Combustion Engine Cycle
IEA	International Energy Agency

INPEX	International Petroleum Exploration Corporation
IRR	Internal Rate of Return
LNG	Liquefied natural Gas
LPG	Liquefied Petroleum Gas
M	Million
MRC	Midland Refineries Company
NGL	Natural Gas Liquid
NOAA	National Oceanic and Atmospheric Administration
NO_X	Nitrogen oxides
OPEX	Operational Expenditure
SOFC	Solid Oxide Fuel Cell
SOx	Sulfur oxides
SEI	Sustainable Energy Initiative
SNG	Synthetic Natural Gas
USD	United States Dollar
VOCs	Volatile organic compound sediment

ABSTRACT

The aim of this work is to consider and identify the best way for gas flaring recovery to achieve the highest flaring system efficiency. This case can be accompanied by an overview and study of the gas flaring and flaring system in the petroleum industry. The significance of this study in various petroleum positions as a general and, in particular, in established projects such as refining corporations, given the high income of gas as proven by World Bank.

The World Bank reports from July-2020 that between 150 and 170 billion m3 of gasses are flared or sold annually. Therefore, there is an urgent need to measure flared gas by its known composition, distribution, and volume, as well as by applying an appropriate flaring gas recovery or disposal system.

The four largest gas flaring countries (Russia, Iraq, the United States, and Iran) have continued to account for about fifty percentage (45%) of all global gas flaring for three years (2017-2019), suggesting that there may be structural and structural hurdles to the reduction of gas flaring activities in these places.

The study will explain the gas flaring in refinery through turning to the process and the implications of the practice in terms of negative impacts on the environment, energy loss and consequent economic losses.

Based on the case study, which was carried out on the midland refineries company - Aldura refinery to explain the way of choosing the optimal decision. According to that, the simulation could be done in other cases with other conditions (quantity, analysis, location, etc.).

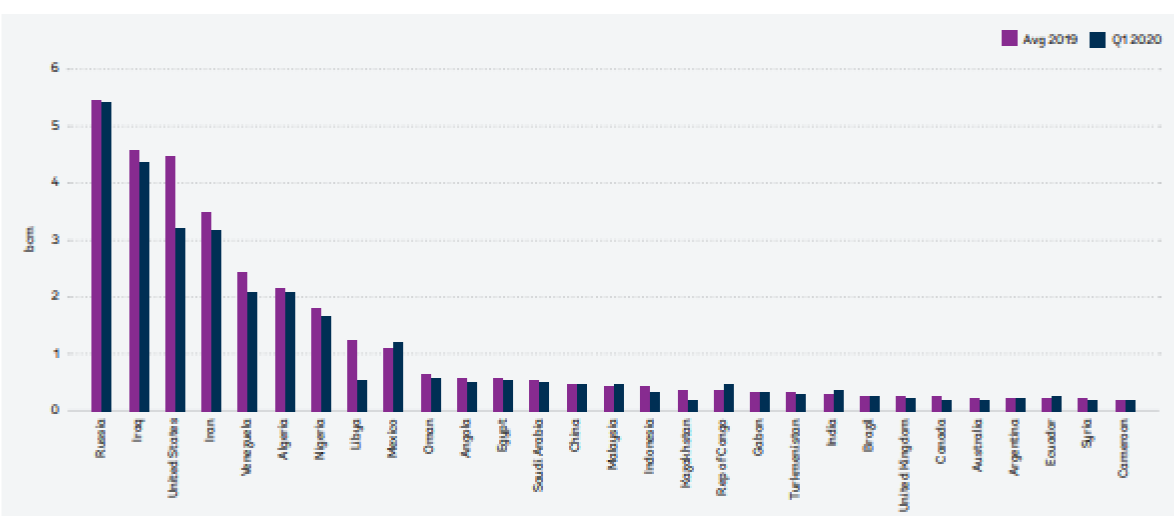


Figure 1 Top 30 flaring countries: Average 2019 quarterly and Q1 2020 flare volume estimates[84].

Introduction

Often the different process and operations of production the oil, gas and other source of fuel also during the petrochemical industrial the Gas is associated with these processes either intentionally or byproduct .

When study the gas flaring we should know the meaning of this gas through petroleum industrial which can classify as: associated gas (oil reservoir), gas reservoir and refineries gases and these types can also classify to number of types according to the analysis .

When explain the gas flaring is may be one of these gases but changed the name as indication of sent that gas to flaring system and since that we should take idea about flaring system and gases .

Gas from refineries and other process operations will produce a different combination of hydrocarbons and hydrogen . The change in gases compositions would affect the heating thermal energy of the gas and the efficiency .

The composition of flared gas is critical for determining its economic value and for fitting it with an acceptable method or disposal. For example, the H2S volume of the gas is a key factor for transport in the upstream piping system [1] .

The compositions of gas flaring in table(1) below [37] :

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

Table 1 typical gas flaring component

1-1 Objective of the study

More of the importance to reduce gas flaring and waste gas. The gas is represent a valuable source of power, electricity and sustainability energy source to future .The gross gas flaring amount approximately 140 Bm^3 with price about 30.6$billion, equivalent to one-quarter of US gas consumption .The recovery of gas flaring decrease the negatives influence on atmosphere [2] .

design of recovery process :

In topic of gas flaring should take in account two side .

Firstly ,as know there are more of way can use to treatment and method to recovery the gas flaring . Any type of recovery have advantage and limitations to use method or other one .

Secondly ,the positions and locations of flaring is different in characterization and description according to the capacity , location , gas components and amounts .

This work presents recent developments in gas flaring and venting reduction throughout the world. The best way of gas flaring reduction is using associated gas as a source of energy or re-injecting it into the reservoir in order to increase oil production .

Finally will make a general model to connection between the different recovery methods and different location to create chart diagram called – General model use to choose the most better way to benefits which include the following :

*sustainability energy * Economical * Environmental

The study will highlight the advantage and limiting factors of any recovery method which detected and should take in account before to take decide to choose the perfect way .In some case will try to make combined between two way to reach engineering solutions and target of that increase the benefit and performance of process at the lowest economic cost and environmental impact .

In the last research and according to new model which applied in case study of Midland Refineries Company /Al-daura refinery.

When applied the general model to case study we find the exact methods to recovery the gas flaring in refinery which located inside the capital of IRAQ –BAGHDAD . Finally ,since the severe scarcity and a shortage of electrical energy[69] in Iraq .The gas become a source of fuel inside the refinery and a source for generating electrical energy inside and outside the refinery .New suggested that to provide the two purposes, either fuel or energy.

1-2The flaring in petroleum industrial

The gas flaring : is define as waste ,or excess gasses emitted which produce during process and operation of different petroleum actions ,or when gas not represent the target of plant or process .Or it is the gas was sent to flare from any source for any reason .

1-3The Flare system

Define as a burning system used to combusted the gas flaring , during many industrial processes, such as oil-gas refining and chemical plants. The Flare device is a big cause of negative impacts and greenhouse gas pollution. It also gives rise to noise, heat and given wide areas are uninhabitable[1].

Gas flaring systems are built in production areas on offshore or onshore vessels ,in transport ships and in port stations, in storage farms and along delivery pipelines .The complete flare system consists of the flare stack or boom and the pipes which capture the gasses to be flared, as shown in the figure(2) [5].

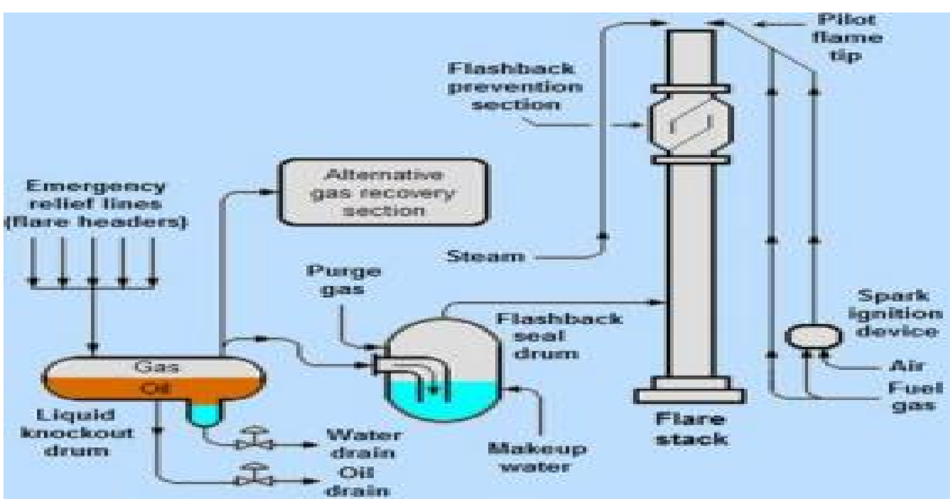


Figure 2 Overall flare stack system in a petroleum refinery [5]

The tip of flare at the end of stack to helping the air flow into the flare to improve the burn efficiency .The seals to prevent the back fire, and the vessel at the base of the stack removes and preserves any liquid to blowdown system (tank of liquid waste),and the gas that passes through the flare [5]. Based on the manufacturer, one flare or more may be needed at the same place of the process .Through flaring, excess gasses are mixed with steam and/or air and burned in the flaring system to produce vapor and carbon dioxide [1].

1-4 Sources of gas flaring

The gasses that obtained from different systems and sent to flare in high stacks is mainly due to safety or process operating concerns. Even non-associated gas containing flammable and hazardous materials from pressure relief pipes, process devices.

Flaring processes can be divided according the purpose [3] :

Emergency flaring : it is the important process to any type of petroleum plant to be safety as depressors point and prevent the explosion inside the units was caused by the high pressure confined to the various parts of the units as valves and regulator failure or other.

The situation which show the important of flare system as safety[20] :

1- Emergency shutdown in different unit or side of production processes .
2- Process, equipment, and safety control systems .
3- Electrical failures: failure of power generators, power distribution networks, motors, heaters, or other electrical equipment .
4- Flow assurance problems (slugs etc.) .
5- Any type of failure in a gas-injector well .
6- Human factors: any human action resulting in involuntary flaring (lack of preparation and procedures, non-compliance with an existing procedure, etc.) .

Process and production flaring : can find this type of processes in the new petroleum field during the appraisal and evaluation of well's output capability, the well testing ,the process of startup and shutdown of production unit inside refineries [4],and for insufficiency of facilities and equipment for different reasons .

In other ward when the purpose of flaring for emergency that called unplanned actives or process . And while in other situation the flaring called planned process and this type may became under control and recovery . the planned type of flaring can be categorized in the and will classify as:

1- Flaring gas in oil reservoir .
2- Flaring gas in Refineries and petrochemical plant gases .

These gases can classify to number of types according to the analysis in groups for different purposes, type of location, conditions and flow rate amount and continuation [6].

1-Flaring gas in oil reservoirs :

this type of associated with oil production or during the operations of extraction and due to the following :

a- Unavailability of receiving facilities (impossible to export gas)
b- Reservoir monitoring (well testing) .
c- Operations or safety testing
d- Well clean-up after drilling, workovers .
e- Difficulty restarting well production.

When the gas is continuous flow rate of gas flaring will called continuous production ,if uneconomic to recovery or impossibility this type can discussion to be economical for investment since the gas mostly can consider as natural gas and have constant composition . While when the cause of gas production is an accidental factor, it is called non-continuous production flaring .

2-Flaring gas in Refineries and petrochemical plant :

this type can produced during the different distillation process . Mostly the main reason for flaring is the lack of possibility to deal with it or the absence of economic vision during the early periods of the life of the old projects during their establishment . The gas flaring in refineries come from different unit in which more variable in properties and conditions – pressure, temperature . some of these gases can use it as fuel directly since have high pressure and other part more time need to change specially the pressure to be comfortable with fuel gas system ,or need treatment and purification to use in operation process or to injected in piping network .

The sources of the last type of gas :

1- product of distillation and cracking process of the large chains of hydrocarbon .
2- product as side result of catalyzing process in which treatment the final product .
3- during startup of unit since the properties of products not exact and need to correlation .
4- the maintenance and regulation (compressors, pumps , valves , measurement meter, etc. .
5- equipment Replacement .
6- rapidly changes in HC composition, flow, etc.

Finally ,there are several reasons for gas flaring and venting in oil production ,because these importance should have flare system .but not necessary to have gas flaring when recovery the gas of flare .

1-4 Effects and important of gas recovery

Gas flaring is one of the most energy and environmental issues facing the world today. Environmental effects associated with gas flaring have a major effect on local communities, frequently contributing to serious health problems [7] .

Technology to solve the issue of gas flaring exists today and the requisite policy regulations are commonly understood. Environmental impacts from gas flaring stand for 50 % of the annual Certified Carbon Emissions (624 Mt CO2) currently released under the Kyoto Clean Growth Frameworks [8].

The goal is to mitigate gas flaring, transform flares into useful energy and reduce pollution . There are also social, geographical and economic issues associated with gas that can contribute to a flare-up; these human factors link the needs in which equipment has been built and allow oil producers to enhance market sustainability [26] .The impacts of gas flaring can classify to :

1-4-1Economic and Energy effects

As economically the flare gasses contain useful hydrocarbons with high thermal efficiency, flaring contributes not only to major economic losses but also to substantial emissions of air contaminants. In order to avoid economic losses and minimize the environmental effects of gas flaring, consideration of flaring gas recovery processes is very necessary, particularly in countries with a large amount of flaring gas, such as Iraq[22] .

bcm	2015	2016	2017	2018	2019	Change 2019-2018
Russia	19.62	22.37	19.92	21.28	23.21	1.93
Iraq	16.21	17.73	17.84	17.82	17.91	0.09
United States	11.85	8.86	9.48	14.07	17.29	3.22
Iran	12.10	16.41	17.67	17.28	13.78	-3.50
Venezuela	9.33	9.35	7.00	8.22	9.54	1.32
Algeria	9.13	9.10	8.80	9.01	9.34	0.33
Nigeria	7.66	7.31	7.65	7.44	7.83	0.39
Libya	2.61	2.35	3.91	4.67	5.12	0.45
Mexico	5.00	4.78	3.79	3.89	4.48	0.59
Oman	2.43	2.82	2.60	2.54	2.63	0.10
Malaysia	3.72	3.16	2.83	2.25	2.37	0.12
Egypt	2.83	2.83	2.34	2.26	2.34	0.09
Angola	4.18	4.49	3.80	2.79	2.33	-0.46
Saudi Arabia	2.15	2.38	2.32	2.29	2.10	-0.19
China	2.08	1.96	1.56	1.82	2.02	0.20
Indonesia	2.90	2.77	2.33	2.06	2.00	-0.06
Rep of the Congo	1.18	1.14	1.14	1.58	1.67	0.09
Kazakhstan	3.69	2.67	2.42	2.05	1.57	-0.48
Gabon	1.56	1.56	1.50	1.38	1.46	0.08
Australia	1.14	0.73	0.66	0.86	1.39	0.53
Qatar	1.11	1.08	1.03	1.00	1.34	0.35
Turkmenistan	1.84	1.84	1.67	1.50	1.34	-0.17
India	2.20	2.06	1.50	1.34	1.31	-0.03
Brazil	1.33	1.44	1.10	1.00	1.14	0.13
United Kingdom	1.32	1.34	1.35	1.21	1.11	-0.10
Canada	1.81	1.30	1.34	1.33	1.05	-0.27
Cameroon	1.08	1.10	1.04	1.06	1.04	-0.02
Argentina	0.65	0.56	0.51	0.70	0.94	0.24
Syria	0.52	0.55	1.19	0.69	0.93	0.24
Ecuador	1.06	1.15	1.07	0.90	0.92	0.02
Rest of the world	11.3	10.45	9.22	8.72	8.49	-0.2
Total	**146**	**148**	**141**	**145**	**150**	**5.0**

Table 2 Gas flaring volumes 2015-19 (billion cubic meters)[84].

Constituents of Natural Gas

Name	Formula	Vol.%
Methane	CH_4	>85
Ethane	C_2H_6	3–8
Propane	C_3H_8	1–5
Butane	C_4H_{10}	1–2
Pentane[a]	C_5H_{12}	1–5
Carbon dioxide	CO_2	1–2
Hydrogen sulfide	H_2S	1–2
Nitrogen	N_2	1–5
Helium	HE	<0.5

Table 3 typical contents of natural gas.

In comparison, flared gas with natural gas it is more similar in methane percentage and generally the fuel gas more safer source of energy than other industrial fossil fuels [24] .the table(2) below show the contents of natural gas [72].

To find the energy of combustion the gas in simple calculation and assume that, all contain is CH4 since the methane have the maximum percentage of gas flaring also have the minimum potential energy according to molecular weight the result as equation bellow :

$$CH_4 (g) \quad + \quad 2\ O_2 (g) \quad ==> \quad CO_2 (g) \quad + \quad 2\ H_2O (g)$$

$$-74,6 \qquad\qquad 0 \qquad\qquad -394 \qquad\qquad -241,8$$

From thermodynamic tables, of CH4 reaction ΔHf [kJ/mol] → ((2*-394.4)+(-241.8)) – (-74) = -803,4[kJ/mol]

Due to the rising price of gas since 2005 and the increasing concern about the lack of oil and gas supplies, the interest in flare gas has grown and the amount of gas lost has been considered. The volume of gas flared could theoretically supply 50% of Africa's energy needs [8] .

1-4-2Environmental effects of CO2

Flaring creates a large amount of carbon dioxide. Carbon emissions from flaring have a high potential for global warming and contribute to climate change[18]. The gasses of flares are believed to have risen the average global temperature by around 0.5 degrees centigrade over the past 100 years [17].The increasing environmental stress on oil and gas production areas to reduce CO2 emissions has a direct impact on the practice of flaring [13] .

1-4-3Environmental effects of SOx, NOx and VOC

Pollutants released from flares also include sulfur oxides (SO_x), nitrogen oxides (NOx) and VOCs .The So_x compounds are combined with oxygen and water to produce "acid rain". The impact of acid rain can be harmful to the human body, reason for polluting water sources [18],and high pH levels in around zones which lead to loss plants cover . Gas flaring emissions include the health effects associated with exposure to these pollutants and the potential for ozone (and therefore indirect health impacts) associated with hydrocarbon and NOx emissions [15]. Daily emissions varied from 2.5 to 55 tons per day of overall organic materials, and from 6 to 55 tons per day of Sox [16] .

1-4-4Local impacts

Agriculture impact : thermal emission from gas flares is resulting in a reduction process of decomposition of organic matter by microbial communities. That lead to uneconomically the production within 2 km of the flare location[20] .

Smoke : This will arise where there is a rapid release of additional gas to the device and a pause in reaction until adequate steam can be provided to the combustion process [21].

Noise: Flaring can create a rumbling noise. It can sound like thunder. Noise is close to what you hear while the fan a campfire, and the oxygen is combined with the flames[21].

Heat radiation impact : Some of the components of full combustion from flares, add significantly to the heat radiation experienced surrounding flares.

Chapter 2 Recovery methods

There are different ways and methods to recovery the gas flaring .these method can summarized as the followings [29,30,11,31,32] :

2-1. Gas flaring collection and compression

a. FGRS (Flare Gas Recovery System) . b. Injection/reinjection

c . Marketing : in different ways (CNG), (LNG),and(LPG) (change physical properties) .

2-2. Gas to products . (change chemical properties) .

a-Gas-to-liquid (GTL) . b- petrochemical products .

2-3 Generating energy - (generation and co-generation of steam and electricity).

2-4 Conditional flaring .

Selecting the best method for recovery and reduction of flared gas, operators must have a clear understanding of how flares are made, dispersed and best consumed in the production plant[1] .

2-1 Gas flaring collection and compression

That mean all methods or process which contain compression part to transport the gas from point to other point . May the gas use as fuel as in flare gas recovery system (FGRS) or use it to injection inside the reservoir to increase the enhance energy or use the gas to marketing .The range of operation pressure according to process requirement .

2-1-a (Flare Gas Recovery System) FGRS

Flare gas recovery system define as system in which can increase the pressure of gas flaring to became appropriate for use as fuel gas to various fuel sinks inside the gas produce location ,such as furnaces, boilers, and power generators[29].

The compression equipment should be designed to accommodate about 2 to 3 times the typical daily flare charge. Many plants, such as chemical plants, may have lower natural fluctuations in flares rates [29]. For this purpose, installations can be planned for a lower discharge range.

General design of Flare Gas Recovery System (FGRS) :

After collecting the flare gas from the flare header, a liquid seal vessel is redirected to the FGRS downstream of the knock-out drum and moves through to the compressor. The compressed gas is then discharged into a mixed phase separator. The fuel is transferred into a heat exchanger and returned to the duty liquid inlet on the compressor. The compressed gas is removed from the liquid and piped to the fuel gas plant header or other suitable site. The general view of the FGRS [34] is seen in Figure(3) bellow :

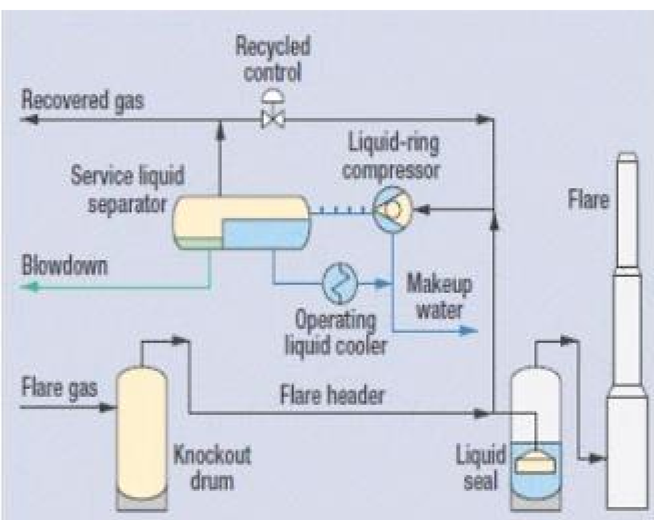


Figure 3 The general view of the FGRS[34].

Flare Gas Recovery System (FGRS) challenges[37] :

1- The difference in the gases composition stays with a mixture of highly variable ,low thermal energy and low pressure [38,39] .

2-The compressor cost which represent the main component of Flare Gas Recovery System FGRS.

2-1-b Re-injection

Re-injection is a process widely used to minimize gas flaring. In certain situations, The gas flaring of any source after stripping usable liquids may be re-injected into a production reservoir to maximize production or, alternatively, into a geological layers for temporary or permanent storage [43] .The technology requires a gas compressor in construction of injection system to increase the pressure of gas flaring (7- 15)bar, to be comfortable with the pressure gas formation and that lead to improving oil extraction .

Re-injection or recycling is also used in sea platforms to decreasing the needing for gas transport facilities [18].In Norway, for example, injection of flaring gas into the reservoir to sustain the pressure and flow rate of the oil produced in the field of Oseberg [8] .Both the producing reservoirs and depleted reservoir could be useful for gas storage [43].

The advantages process are :

1. Increase the productivity of the method of oil extraction [20] .

2. Low requirement to gas treatment (can injection any gas with impurities) .

3. Preserving energy to future consumption.

4. In certain situations, a way to get rid of gases.

5. Lowering the need for water injection in case of water shortage or lack of water [44] .

6. Used for small volumes of gas[18] .

A typical gas re-injection process is shown in Figure (4) bellow [18] :

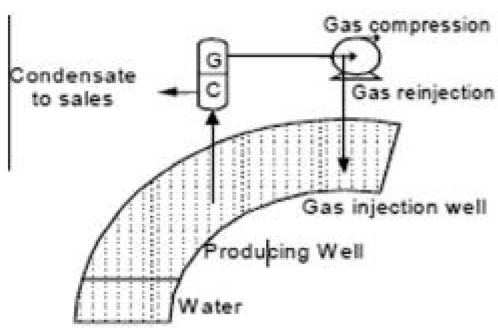


Figure 4 Typical gas reinjection process

Limited of reinjection :

1. Gas flaring has flared instead of re-injected into the output of reservoirs where there are minimal economic advantages involved with re-injection for increased oil recovery in a given region [43] .

2. Onshore, well building costs vary considerably based on a variety of variables, including depth, well structure and type of rock structures[43] .

3.Some reservoirs are not deemed ideal for re-injection due to pressure gas break-through issues that may have an effect on oil production due to lack of information about maximizing the production of reservoirs[43] .

4. For reservoirs with large gas supplies, re-injection is also perceived to be uneconomic[76] .

Economic benefits for re-injection for storage are restricted to the importance of retaining the resource for possible use in the future (e.g. for use in power generation) and any cost savings or decreased risks associated with flaring reduction. Although the opportunities for creating lucrative gas markets beyond the investment horizon of private companies may be low in many areas, investments in re-injection for storage would usually only make sense in the face of high fines for flaring or other equally stringent regulations [43] .

2-1-1 marketing in different cases

The task associated with having a gas flaring is to reduce the damage and increase the benefit, and since the equipment and capabilities sometimes do not allow for use on site, the guidance is the best way to reach a solution and allow the gas to be sold in areas or markets equipped for the purposes of use or reconfiguration and increase the benefit.

The process of transporting gases to areas of use and filtration units in different ways according to the site of production and consumption, the type of separation terrain, as well as the availability of technology and equipment. Among these methods is the process of marketing gas to the consumer through pipelines and has the ability to perform the purpose in terms of technical equipment and design specifications. But if the distances are very large and it is not feasible for the pipeline marketing process in terms of the cost of extending and correcting the pipelines, then the other option is the transportation by tugs and this needs to a change in the specifications of the gas to facilitate its transportation.

The conditions (pressure and temperature) are changed to obtain the lowest possible volume to facilitate the marketing process using special trucks or by ships equipped for this purpose. The common factor in the different marketing methods is that the change takes place in the gas is a physical change.

Pipeline natural gas (PNG)

The extraction and compression of flared gas(80 -100)bar for shipment in pipelines or other forms of refining that have good properties for sale .The pipeline is simple solution to minimizing flaring and ventilation [1] especially when available of pipe line net .

PNG is the primary and most convenient way of moving coal, either from offshore to onshore for refining or to interface with current distribution grids. It can be used for the transport of gas for export [18] .

In the case of high output volumes and short distances to the market, pipeline building is the best method for transferring the associated gas generated [2] .

The diameter of the pipeline is determined, the amounts of gases can be supplied is set by the pressures, but an increase in the overall quantity can be obtained by inserting compressors to the route, by adding additional piping in the form of loops or by raising the average pressure of the pipeline[20] .The pressures of the pipeline depend on the material of construction and the age of the pipe.

Limited of pipeline :

1. The economy of the gas pipeline is a result of length [76] .

2. Depending on the landscape (such as onshore, mountain or underwater, seabed flatness and depth) [77] .

3. Construction of pipeline costs is currently approximately 1–5 million USD per mile and addition compressor stations [20] .

Compressed natural gas (CNG)

CNG is the compression of gases to a much smaller volume (1/1200 of the initial volume) at a pressure of between 83 and 300 bar . CNG is contained and shipped in a cylinder [82]. CNG is used as a less costly alternative to LNG for lower capacity and medium distance transport [47] .

This technique offers great ability to become the alternative way of using associated gas on offshore platforms where pipeline installation or LNG projects are not economical and realistic [76] . Since CNG is easy to transport and thus readily re-deployable, it could be used in fields of relatively limited output horizons .

Liquefied natural gas (LNG)

Liquefied natural gas occupies about 1/600th the amount of natural gas in the gaseous form. Reducing the volume of LNG relative to natural gas makes it much more cost-effective to be shipped over large length where the transportation of natural gas by pipelines is not feasible or economical. Liquefied natural gas or LNG is the most economical method of processing oil/gas extracted with a high amount of related gas supply and a long path to the consumer.

In a standard LNG phase, the gas is shipped to a treatment plant for the purification and removal of gasses such as H_2S and CO_2 as well as other contaminants such as water, tar, mud and occasionally mercury. The purified gas is then compressed and cooled down in different stages until it is liquefied and then fit for transport [2] .

A recent concept of LNG technology that is yet to be developed and business analysts is called floating LNG (FLNG). This method is a mix of traditional LNG and processing technologies. The joint FLNG vessels can carry liquefaction facilities on board and can be transported quickly to remote and small oil fields without the need to construct massive, at each site [20] .

The comparatively low amount of gas associated with oil production which also fall below the FLNG commercial threshold, which needs an input of approximately 10 MMcmd [78] .

LNG plants are large-scale, long contract (approximately 20 years or more) that require large gas reserves of >85 BSCM and 1 billion USD investment in the production of trains of about 14 MMSCMD[77].

In the case of Qatar gas organization has created considerable gains from its LNG trains in line with the increased national attention on flare minimization and the company's desire to reduce its pollution and carbon footprint [46] .

Figure 5 floating liquefied natural gas technology [85] .

CNG compared to LNG [20] :

(1) There is no need for liquefaction or regasification.

(2) the gas must not be purified to the same degree as is required for the pre-processing of LNG;

(3) Gas container may be made of fine grain normalized steel, such as API 5L pipe grade steel, and not of much more costly high nickel, aluminum or stainless steel, which is required to hold cryogenic LNG[83] .

Liquefied petroleum gas (LPG)

This technology is mean the extraction of liquefied petroleum gases from mixing of gas which contain propane and butane .The gas must first be treated to remove the impurities, which including water vapor, CO_2, mercury vapor and H_2S [82] .

The LPG generated as a result of gas fractionation in a gas processing plant .The processed can applied on site and transported by truck, rail or ship [43] .The higher flow of flare removal can be accomplished by combining the recovery of LPG with other techniques. [48] . The most important characteristic of this process is the scarcity of this material and the large its use in cooking , so attention is paid to the process extraction from gaseous mix.

2-2 Gas to products (change chemical properties)

In this branch will clarify the chemical changing in gas molecular and interior structural of gas phase to be liquid or solid phase according to the chemical reaction which applied to produce the target of project .

2-2-1 Gas-to-liquid technology (GTL)

Gas-to-liquid (GTL): It is define as chemical process in which conversion of natural gas to a liquid fuel . Among the best approaches to minimize gas flaring in the implementation of environmentally sustainable technologies[81]. Gas-to-liquid technologies are rapidly becoming an attractive choice for gas in remote small and medium-sized fields [43] to transform natural gas to on-site chemicals [48] or a selection of finished products.

The first stage, oxygen (O2), which is removed from the air, is fed into the reactor for the reform of gas. The result is syngas, a combination of synthetic gas , hydrogen and carbon monoxide. Steam reforming or partial oxidation is commonly used for natural gas reforming :

$$\text{Steam Reforming :} \qquad CH_4 + H_2O \Rightarrow CO + 3H_2$$

Required syngas properties : H2/CO ratio is around 2.0 . [50]

The next step is the entrance of syngas into the Fischer–Tropsch reactor, where the gasses are recombined into long chain hydrocarbon molecules [2].

$$\text{Fischer} - \text{Tropsch Sythesis :} \qquad n(CO) + 2n(H_2) \Rightarrow (CH_2)_n + n(H_2O)$$

Various of reactors , including multi-tubular fixed bed reactors; bubble column slurry reactors , bubbling fluidized bed reactors , three-phase fluidized bed reactors, and circulating fluidized bed reactors, have been considered throughout the history of F-T technology development [51] .

The process have many economic points such as superheat vapor are generated as a by-product in the Fischer-Tropsch reactor. This steam will be used in a steam engine to generate electrical electricity. The power generated can be used by the plant and the remainder can be transmitted to the local market [2] .

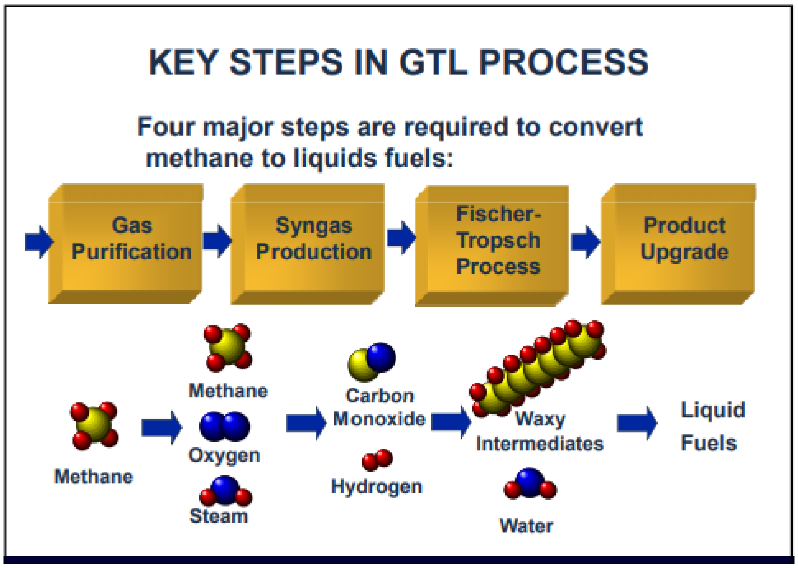


Figure 6 Gas To Liquid steps [50] .

The most important challenge of GTL :

The scale and cost of the installation of GTL plants are the boundaries. The GTL plants are very big systems that take up a large area. Any businesses are exploring the development of more lightweight systems [2] . The footprint of a 100 bpd plant is about 4 meters long x 3 meters wide x 5 meters high [48] .

Another difficulty is that raw materials for conversion to goods (silicon sand, limestone) can prove difficult to import to the site [54] .

GTL would be the best choice for large reservoirs and distant markets. However, the NG usage approach for any sector would rely on both technological and economic factors [20] .

2-2-2 petrochemical products

Methane in gas and related gas can also be transferred to other petrochemicals, such as methanol. Methanol is also used to manufacture dimethyl ether (DME) and olefins such as ethylene and propylene in basic reactor systems, traditional operating conditions and industrial catalysts[76]. Methane in associated gas can also be converted to ammonia via the Haber process to produce nitrogen fertilizers .

Synthesis gas (Syngas) is a combination of carbon monoxide and hydrogen and is used to produce petrochemicals such as ammonia and methanol. Ammonia is used in the production of fertilizers and weapons, where methanol is used as a medium for other chemicals. There are wide range of Primary petrochemicals are not finished products, but building blocks for a wide range of materials [47].

Some cases we cannot applied this technical because the special reasons such as according to Iraq's weather cannot use (DME) since it very high vaper pressure .

2-3 Power Generation

Combustion gas for electricity generation is widely recognized as a profitable application of flare gas. The process can happen in engine or turbine to recover energy as mechanical or electrical fuel burned [26] . The electricity power can also be marketed if not needed [56] .Consider from the best methods to recovery the gas flaring is use as cheap fuel to combustion for power generation [22].

For oil fields far from the integrated grid on-site power generation, It also provides adequate fuel that eliminates the transportation of fuel to remote extraction areas[43] .The choice of power generation it can simplify the process of transporting gas from areas that are difficult to lay the pipes or have climatic conditions that generate problems for gas phase flow .The application of the power obtained environmental and economic profits.

There are different type of power generation as [22] :

1 – Cycle of gas turbine (GTC)

2 – Combined Cycle Gas Turbines (CCGT) turbine.

3-The internal combustion engine cycle.

4 – Solid Oxide Fuel Cell (SOFC)

Disadvantage :

1-Difficult management of such revenues which could be constrained by on-site demand[57] .

2-If the volumes are decreasing over time.

3-The cost of exporting gas is smaller than that of electricity [43] .

2-3-1 Gas Turbine Cycle (GTC)

The Gas Turbine Cycle is define as system use the fuel gas to generate the different phases of energy .

The foundation of the gas turbine cycle ,that a continuous mixing flow of air and gas through a pump, radiator, turbine and cooler in Closed-Cycle [59].Figure(7) bellow show (GTC)[22] .

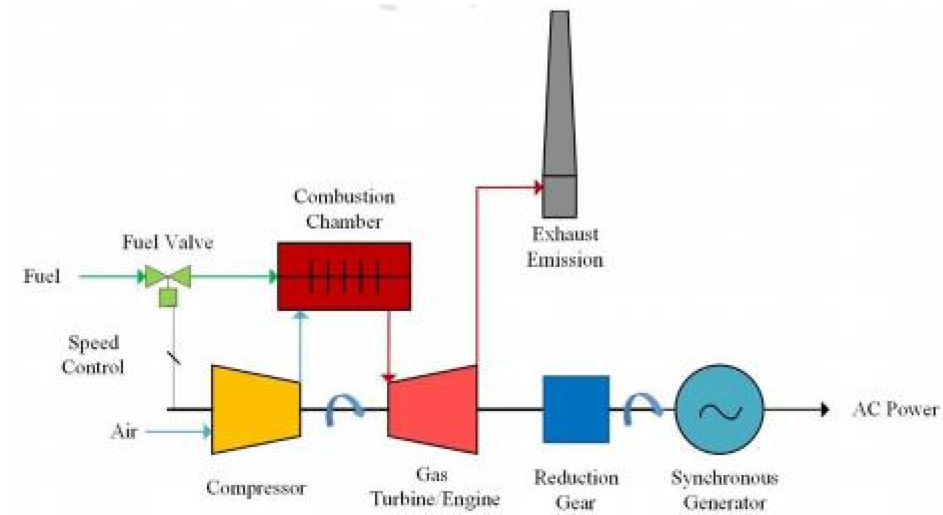


Figure 7 The Gas Turbine Cycle[22].

When choose this cycle the flared or natural gas burns with compressed air with a compression ratio of 12:1 in the gas turbine combustor Because most flare and associated gasses produce large quantities of H2S .

There are two options for steam injection into the combustion chamber of the gas turbine: the first is the use of steam from service utilities, and the second is the development of steam using heat recovery steam generators (HRSG)[22] .

2-3-2Combined Cycle Gas Turbine (CCGT)

Combined Cycle Gas Turbine : the residual quantities of heat content of the hot exhaust gas from the gas turbine is recovered to create steam to generate additional electricity. In the combined cycle the designer connect a steam cycle after the gas turbine cycle to increase the enhance and performance of power generation process .

The heat recovery steam generators (HRSG) have been used to generate steam from the hot exhaust of the gas turbine, and the resultant steam is extended to the steam turbine and generates additional electricity.Figure(8) bellow show (CCGT)[22] .

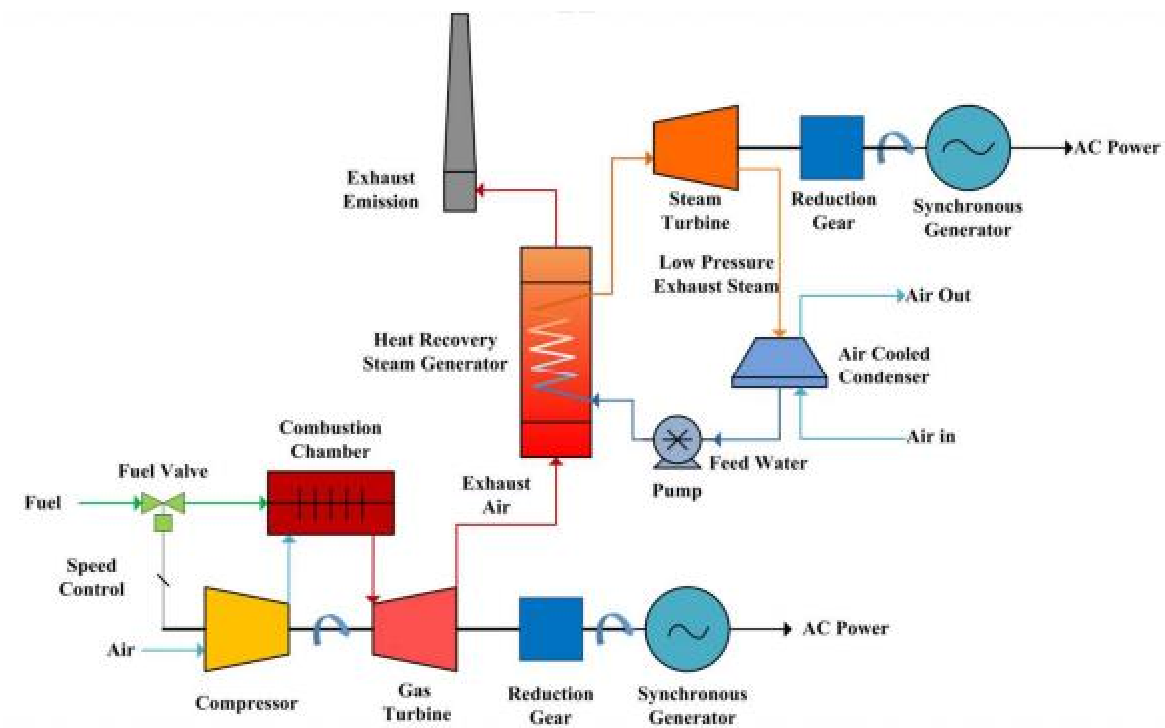


Figure 8 The Combined Cycle Gas Turbine [22].

The two types were compared from a technological and economic point of view.The findings suggest that, in the second case, the power production situation is stronger, but the first scenario is more economically justified based on the payback time [1] .

2-3-3 Internal Combustion Engine Cycle

Internal Combustion Engine Cycle(ICEC), is similar to the Gas Turbine Cycle, except that instead of the gas turbine ,in which the different is the size of system but have the same mechanical principle . The gas engine is used for power generation.

It contain turbocharger and cooler for hot exhaust gases moving a compressor that increases the pressure. The turbocharger is an axial engine with centrifugal compressor on the same line . The heating generated by compressing the inlet air removes by water. Turbocharging increases the engine output due to the denser air/fuel mixture

Internal Combustion Engine has several advantages over the Gas Turbine, including :

1. higher single-cycle efficiency .
2. Quickly startup .
3. use in different location and simple to transport .
4. Engine requires lower pressure compared to turbine [60].

The fuel point :

Now will explain the effect of using gas with an impure and heterogeneous composition . All previous system have similar style ,that can use gas flaring without treatment of purification.

Despite the increase in the design cost of these projects as a result of using untreated gas, there is a profitable element for the case, which is the amount of energy extracted and eliminating the environmental negative impact.

Corrosion-resistant enable gas engines working with sour gas ,but the determining of material should be consider in account for cost of the equipment and recognized in this situation[61] .

Or, the Amin dependent sweetening process and the Sulphur Recovery Unit (SRU) are mentioned before the cycle, and the capital and running costs of the sweetening process are viewed as part of the cycle expenditure[62] .

Each generator package uses SCR and oxidation catalysts installed in the exhaust system to monitor the emission of NOx and CO from the facility [63].The costs of NOx and CO pollution shall be included in the economic assessments carried out for the loops [22] . The example of use waste gas in chain for power production consists of 50 per cent of CH_4 and 50 per cent of other gasses such as CO_2[73] .

2-3-4Solid Oxide Fuel Cell (SOFC)

Gas Turbine Cycle Using a Solid Oxide Fuel Cell (SOFC) another method of producing electricity from hydrocarbon fuels which can be used for recovery purposes. SOFCs are capable of processing a wide variety of hydrocarbon fuels. Having a high working temperature of about $1000C^0$, SOFC produces a substantial amount of surplus heat which can be extracted by generating hot water, steam or additional energy via a bottoming cycle in order to increase the performance of the system [64] . The Solid Oxide Fuel Cell (SOFC) is composed of two porous electrodes with an electrolyte in the center. If the feed contains sulfur, it should be separated before joining the SOFC system because sulfur poisons the fuel reforming catalysts. This major reason which increase the difficulty to choose this type in case of gas flaring with high h2s contain, on the contrary, in comparison [22] .But the Solid Oxide Fuel Cell (SOFC) is consider as more efficient [65] .Figure(9) bellow show (SOFC)[22] .

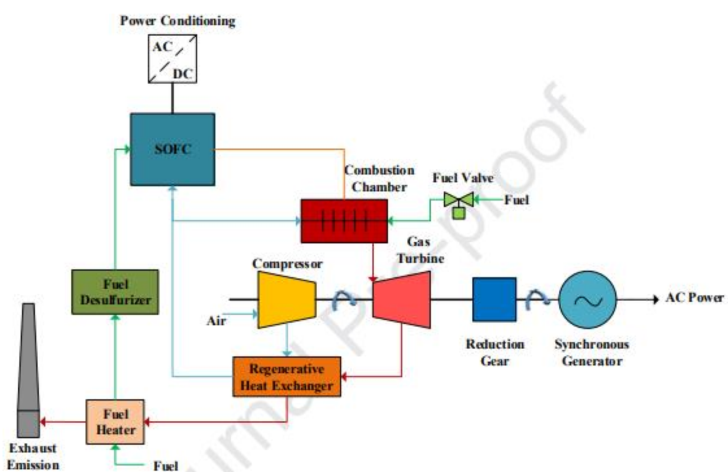


Figure 9 The Solid Oxide Fuel Cell (SOFC) [22].

2-4Conditional flaring

when cannot to use any methods to recovery the gas flaring, that lead to be carefully to flaring the gas but in high efficiency to ensure complete combustion and reduction the pollutant and emissions . Combustion efficiency calculated as a percentage is simply the volume of hydrocarbon transformed to CO_2. The quantity of emissions produced by flaring is important to the performance of combustion [12]. Conditional combustion is more environmentally sustainable because the complete combustion and produce 25 times fewer carbon dioxide than greenhouse gasses than methane [48].

Conditional flaring steps:

1. Steam or air volume is used as an assistance in flares that produce a turbulent mixing and stronger interaction with carbon and oxygen [66].
2. Proper management and maintenance of flare systems
3. Modifying the start-up and shut-off processes.

Cases that must go to conditional burning :

• The limited amount of gas flaring (non-continue flow rate).

• Distant geographic location .

• Change of temperature or pressure of gas over time, which complicates the technical nature of the project with considerable uncertainty .

• Composition of the gas which makes purification uneconomic .

• Purification, transport and injection costs .

• Lack of experience and engineering technology in the usage of sour gas for small-scale generators (gas-to-electricity) .

• Lack of knowledge and technology for turning gas to liquid (GTL) [20] .

2-5 Recap of recovery methods :

FGRS

Advantage :

a - economical and simple way to reduce emission and capital cost
b - may be applied without pretreatment
c - increase the safety inside industrial units
d – decrease the side effect of flaring such as noise and light specially near cities

Limits :

Need very good chosen and exact to the main part which is compressor

Reinjection

Advantage :

a - enhance production
b - storage and recovery method to get rid gas flaring
C - good option to recovery for offshore and remote fields
d - use for all scales
E – not need to treatment and processing the gas

Limits :

Present of reservoir and compatible with reservoir characteristic and management
The economic incentive for reinjection

Pipeline

Advantage :

a – Change location to interface processing or exporting
b – use for all range scale
c – not necessary to do gas treatment
d – can change the ability of system by increase the pressure without change diameter

Limits :

Distance of transport
Terrain of line

LNG

Advantage :

Strategic project to deal with large scale
Applied in offshore field

Limits :

Huge cost and require of especial equipment
You must be preceded by efficient purification

CNG

Advantage :

A - no need for liquefaction or re-gasification .
B - the gas does not need to be cleaned to the same extent as it is necessary for LNG
C - the CNG container may be made of fine grain normalized steel

Limits :

In the remote side and high distance be uneconomical

LPG

Advantage :

A . Relatively easy storage inside location and transport
B . Scarcity of source (small percentage but very useful)
C . decrease the plant size of recovery after LPG extraction

GTL

Advantage :

A . Converting to liquid phase mean simply by transporting and storage
B . economic benefits with large scale
C . applied to small scale but uneconomically

Limits :

large size of unit with high cost
Difficult processing with pretreatment
Requirement of catalyst material

Power generating

Advantage:

1 . applied in different scale and without depend on raw material composition (without purification)
2 . All industrial complexes and units, in addition to human gatherings, need such projects
3 . Speed up the installation process
4 . ability to use same equipment in multiple site
5 . economical choose since (reduce and use gas flaring – reduction of environment impacts instead of use fuel oil - power price)

Limits :

The necessity of providing a consumer compatible with the volume of production onsite or near
Losses of energy during transporting, as opposed to transporting gas

CHAPTER 3 METHODS SELECTION

In this chapter attention will be focused on the substantive topic of research which includes the individual analysis of the methods that were mentioned in the previous chapter. Where the detection and scrutiny of each method will be done separately to reveal all the weaknesses and forces that enable the business owner to be able to choose the best according to these characteristics and limitations. The following analysis will be made on the influences that have a direct and indirect impact on the matters mentioned in the introduction to the research, which are: environment, energy and economy.

3-1The most influencing factors to choose

The economics of flaring vs capture and sales of related gas is not inherently a straightforward estimate.

In reference to the estimated quantities of gas to be recovered and the expense of the collection lines and the processing equipment required, a range of other considerations need to be addressed. These may contain the following factors:

Capital spending, technology risks, the domestic market and its facilities, and the political environment, strategic planning of companies , compete for decision-making. These considerations which make it feasible for a technology to be commissioned elsewhere although implementing the same technology may not be appropriate somewhere else.

Also, if the long-term amounts, pressures and the flow of gas demand continue to be sustainable at levels that can economically justify the construction of new gas recovery facilities or the extension of existing infrastructure, these investments will be accepted and the flaring can end. If the economy cannot justify an investment, the related gas flaring can occur as long as it is not forbidden by state or federal regulations.

While it is impossible to make a general assessment of all options, a case-by-case review is commended for the widest selection of behavior [48] .

3-2 How to Selection the method

In order to answer this information, we will make several comparisons between the different methods and from several sources, in order to obtain a comprehensive understanding so that we can make a decision in all circumstances.

Technology commercialization relies on a variety of variables, such as technology access, promotion, alternatives and economic factors[7] .The commercial use of the related gas depends on the level of supply and the distance to the markets [2] .

The study indicates that for conventional schemes, per-unit prices are beginning to increase exponentially as the scale of the gas stream declines. Higher gas flow is equivalent to higher prices [20] .

The decision to flare or process gas depends on the price of gas. Gas flaring would be manufactured and sold if costs were high enough for a long period of time and all the required facilities could be developed for gas refining and transport [8] .

In the case of output of low gas, pipeline construction, GTL and LNG units are not economical. In this case, the best choice is to use the gas for on-site power generation and transmission of electricity which generated [2] .

Both alternatives for volumes smaller than 5 mm3/day and distances greater than 2500 km to the market are actually uneconomic [68]. For high output flows and remote locations to the market, GTL or LNG is the better choice, whereas for high production quantities and small periods to the market, pipeline construction is more economical.

If the volume of output involved and the path to the market are in the intermediate range of power generation and the delivery of the energy generated tends to be more economical than the transport of the gas[2] .

There is no net negative impact from flaring versus sales in terms of environmental impact, assuming the flared gas, if captured, would be sold and then burned elsewhere under the same conditions. change is Improving quality and moving from oil to natural gas help reduce the environmental effects of power production [69].

The gas quality standards for the use of gas flaring as fuel in boilers are less strict than those for the supply of gas transmission and distribution systems [43] .

There is no net negative effect from flaring versus sales in terms of environmental impact, assuming that flared coal, if collected, will be sold and then burnt elsewhere under the same circumstances. It's easier to change from burned better from burned [48] .

The use of flared gas to produce electricity for on-site use is a known option, but this solution is not always economic and may be constrained by on-site demand for electricity [57] .

In the case of comparatively short distances to markets and low gas volumes, the production of power or the delivery of gas by pipeline may be economical alternatives to flaring .The GTCC loss of control in the GTW sector is smaller than that of the Pipeline project due to transport losses [45] .

Gas flaring re-injection has been efficiently used at some locations to dispose of excess "acid-gas" (primarily hydrogen sulphide, H_2S, and CO_2 with traces of hydrocarbons) from gas sweetening projects.

Where the cost of re-injection is smaller than the cost of removal of Sulphur [70] .

No legal studies on the gas framework. However, the shortage of utilities and gas processing facilities has hindered the growth of the domestic gas industry[7].

Variation in demand for a related commodity, such as natural gas, also results in major distortions in end-use markets[7] .While each system has its own benefit due to the avoidance of gas flaring and the consequent difficulties, a distinction is made in order to consider the superior method economically. A summary of the overall capital expenditure for the three strategies is shown in Figure(10) bellow [35].

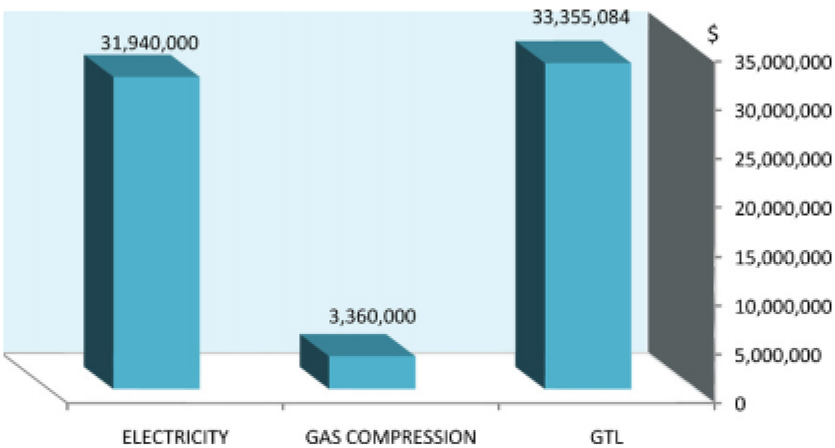


Figure 10 A comparison between total capital investments[35].

Gas compression has the lowest cost in money . Figure(11) bellow indicates that the annual benefit for electric energy is higher than that for GTL and that the profit per year for GTL is higher than gas compression[35].

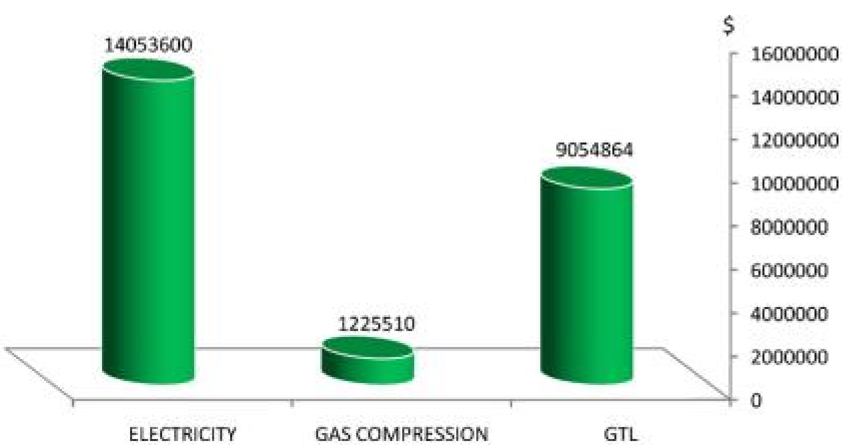


Figure 11 A comparison between annual profits [35].

Energy production is the lowest payback time due to higher ROR relative to GTL and gas compression alternatives as show Figure (12) bellow [35].

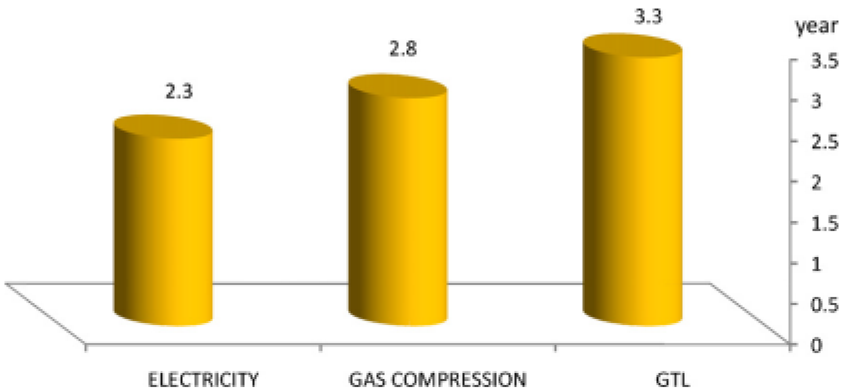


Figure 12 A comparison between payback period[35].

3-2-1Remote and offshore fields

The crucial factor for the development of offshore fields is the development of high voltage solid cables with high insulation so the power is quickly discharged into the sea and the long cable requires high voltage for the transmission of electricity [45] .

The power of sub - sea gas pipelines is connected with the transport to the market of vast quantities of gas at relatively short distances. For amounts less than 5.7 MMscmd, this option is increasingly losing ground to other alternatives such as CNG and energy conversion[80] .

The key explanation for the flaring of all of this associated gas in the Permian Basin was the shortage of gas pipeline ability to carry gas to markets [48] .

3-2-2Distance versus marketing methods

The research shows that PNG is the best choice for short distances (up to 2700 km). In this range, CNG has a lower cost of production than LNG and NGH, but the cost of production of CNG vs. distance increases dramatically and LNG becomes more desirable for distances greater than 2700 km. For the medium distance range (from 2700 to 7600 km), PNG also has the lowest cost of production. LNG is the best choice for distances greater than 7600 km [79] .As a solution of a marginal gas field or associated gas that is too small to be produced by Pipeline or LNG, Gas to Wire (GTW) would be relevant as shown below Figure if the gas field or associated gas is located within a specified area certain distance from a power market[45] .As figure (13) bellow.

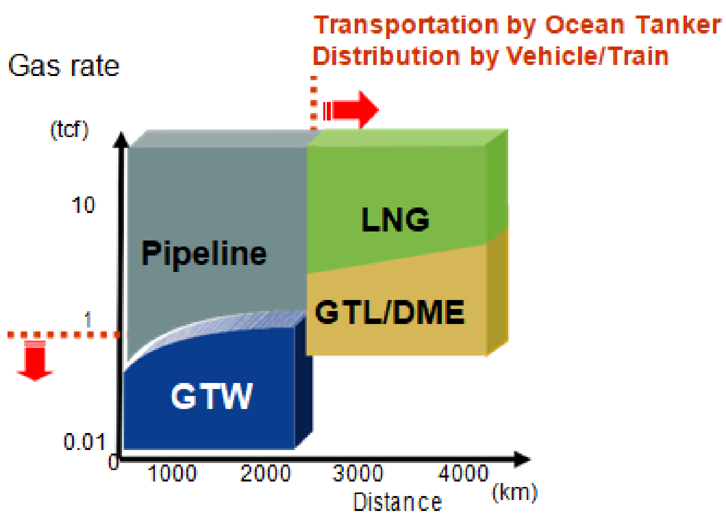


Figure 13 Solutions for Gas Transmission [45]

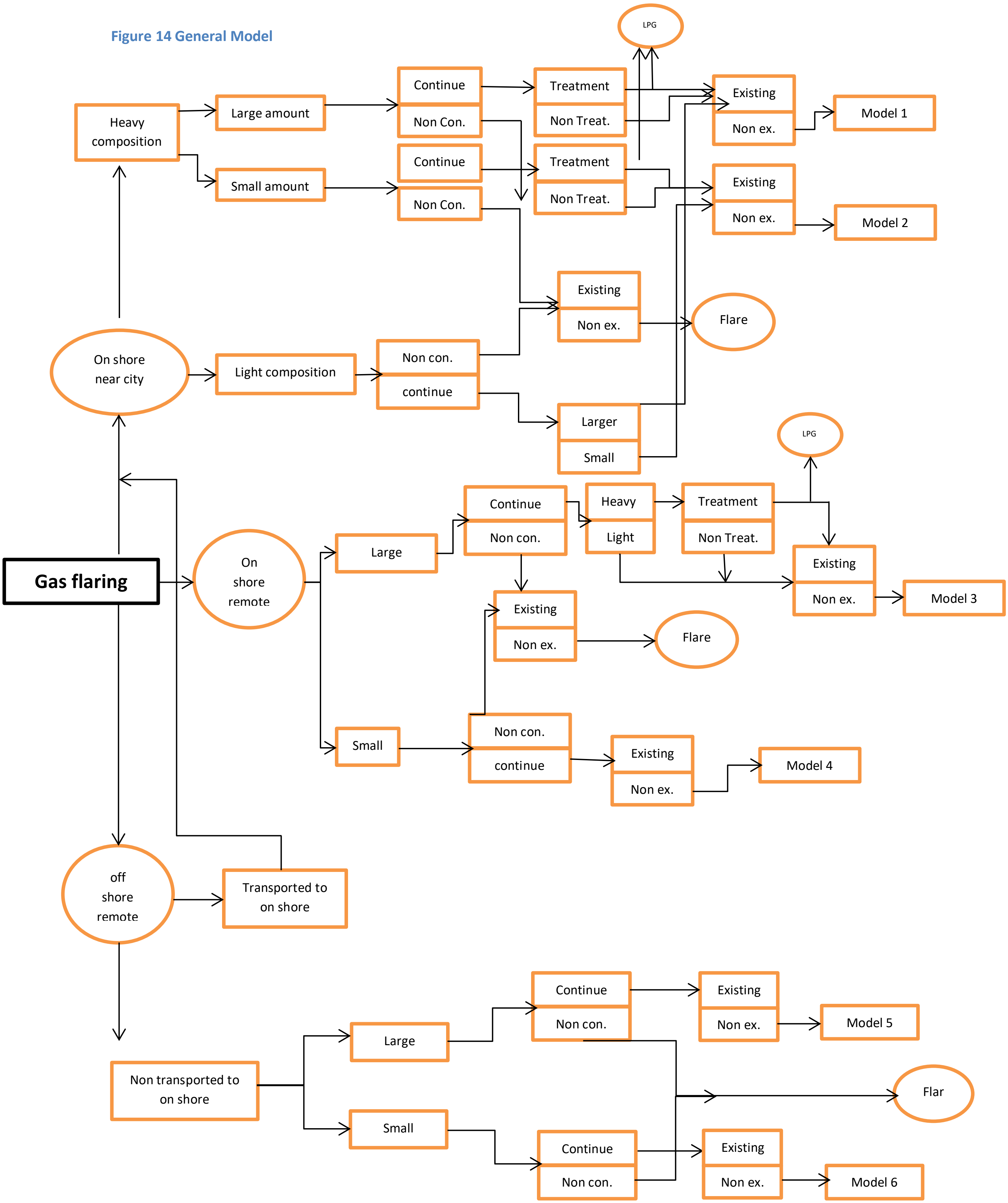
When recapitulating the methods, the influencing factors can be enumerated within a systematic division as follows :

1- flaring location	
onshore	. near to infrastructure . within petroleum unit . pipe line . reservoir . petrochemical plant . ship port
Offshore - Can trans. - cant .trans	

2-gas properties	
a. composition	
b. amount of gas	Small scale
	High scale
c. purity	sweet
	sour
d. condition	pressure
	temperature
e. production period	Continue
	Non continue

3	Required need	.FGRS	.GTL	.GTW	.GTM

Figure 14 General Model



3-3The models

Due to the many constraining and motivating factors, the different site conditions, the imbalance of the economic dimension and the urgent need that accompanies every petroleum project, the choice of the appropriate model will change accordingly. ”Therefore, the division of cases will allow for high flexibility and auxiliary to the correct orientation for each case.

The process of dividing the models included, and considerations, a number of constants and assumptions as follow :

1 – All models are continue production .

2 – The methods of recovery have the same environment impacts .

3 – The choice of Creation new project according to the cost from the minimum to maximum, if don’t have an emergency factor or a specific trend imposed by a ruling party .

Model – (1)

Model characteristic :

. Near to cities or demands

. large amounts of gas flaring

best suggestion

1. FGRS : There is a shortage of energy inside the operational units or the use of expensive fuel or waste liquid .
2. GTW - (steam , electricity) : to units – cities – large demand .
3. GTL : if there requirement , or LNG if close to sea .

Model – (2)

Model characteristic :

. Near to cities or demands

. small amount of gas flaring .

best suggestion

1. FGRS : There is a shortage of energy inside the operational units or the use of expensive fuel or waste liquid .
2. GTP - (steam , electricity) : to units – cities – large demand .(can applied to small scale)

Model – (3)

Model characteristic :

. Remote to cities or demands .

. large amounts of gas flaring .

best suggestion

1 . FGRS , or any type of power requirement inside the petroleum facility .

2 . GTL ,if there are demand for very large period - LNG if flare site is near to transport way (rail train, sea).

3 . pipeline if there are very large marketing for continue period .

4 . GTW , if there are electrical scarcity in the around zone and can connection .

5 . Injection , since more less cost if there is geology structure .

Model – (4)

Model characteristic :

. Remote to cities or demands .

. small amounts of gas flaring .

best suggestion

1 . FGRS , or any type of power requirement inside the petroleum facility .

2 . any marketing system depending on cost and profits .

3 . Injection if have permit of technical and reservoir conditions .

4 . Conditional flaring .

Model – (5)

Model characteristic :

. Inside the offshore .

. Large amounts of gas flaring .

best suggestion

1 . FGRS , or any type of power requirement inside the petroleum facility .

2 . LNG project depending marketing plan for very long period .

3 . GTL project depending marketing plan for very long period .

Model – (6)

Model characteristic :

. Inside the offshore .

. Small amounts of gas flaring .

best suggestion

1 . FGRS , or any type of power requirement inside the petroleum facility .

2 . Injection if have permit of technical and reservoir conditions .

3 . Conditional flaring .

3-4 Existing infrastructure :

As it was mentioned in the introduction to the research that the greatest interest will be focused in particular on the previously established projects, so the presence of existing infrastructure is certain.

Therefore, he will explain how to take advantage of the available systems .The conditions for selecting new project models are clarified through the use of the appropriate model .

As for the process of coordination and utilization of the established systems, it shall be as follows :

In the event that there are multi choice system , it is possible to accommodate the gaseous product, the choice will be according to the critical demand or better from the point of the body responsible for planning and managing resources.

This means that the more profitable side of the environment, the economic resource, or the energy harvest. It must also be taken into account that solutions are farfetched and flexible in terms of industrial treatment.

In the following figure(16), a simplified description of the systems that may be available on the site is presented and the profit return that can be derived from using that available system.

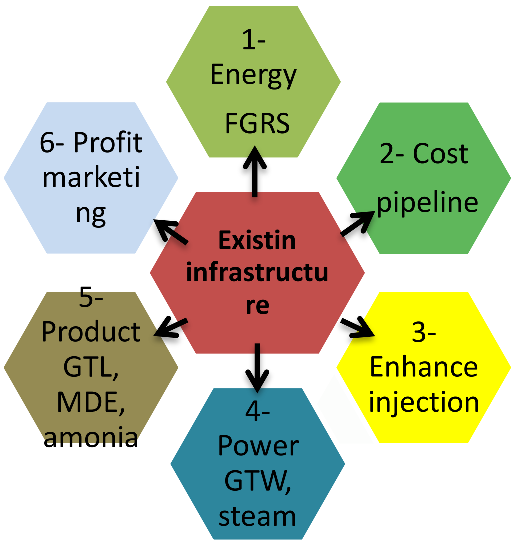


Figure 15 Existing infrastructure

CHAPTER 4 Case study

MIDLAND REFINERIES COMPANY (MRC)- AL-DAURA REFINERY was established in 1955 located in the capital Baghdad, Iraq along the Tigris River. The Refinery has been operated and has undergone in many expansions, reaching capacity of 140000 BPSD [71].

4-1Characteristic of Al DAURA Refinery

1 . Location : in capital of IRAQ – Baghdad which is considered one of most populated cities .

2 . The startup of refinery was according to Techniques of the 1950s

3 . Current source capacity based on the two aerial refining units with a capacity of 70,000 barrels per day per unit is 140,000 barrels per day.

4 . It receives crude oil from several local sources, all but from different fields in terms of location and specifications, mainly from Basra fields in southern Iraq, which is the main economic center in the Iraqi oil industry in terms of production and the only export ports through the sea port .

5 . Continuous development processes to keep pace with the global technical modernity as well as to provide the required products .

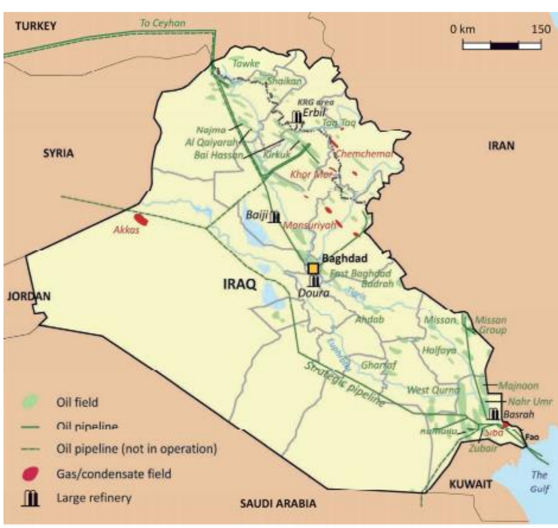


Figure 16 Map of IRAQ with petroleum industrial location

4-2The structural of refinery :

MRC planned for new A number of future projects will be constructed, such as the Isomerization Unit and the hydrogen purification unit, which will soon be in operation. Continuous Catalytic Regeneration (CCR) Unit, Catalytic Cracking Unit (FCC), etc.

As shown in figure (17)the plans of the refinery units .

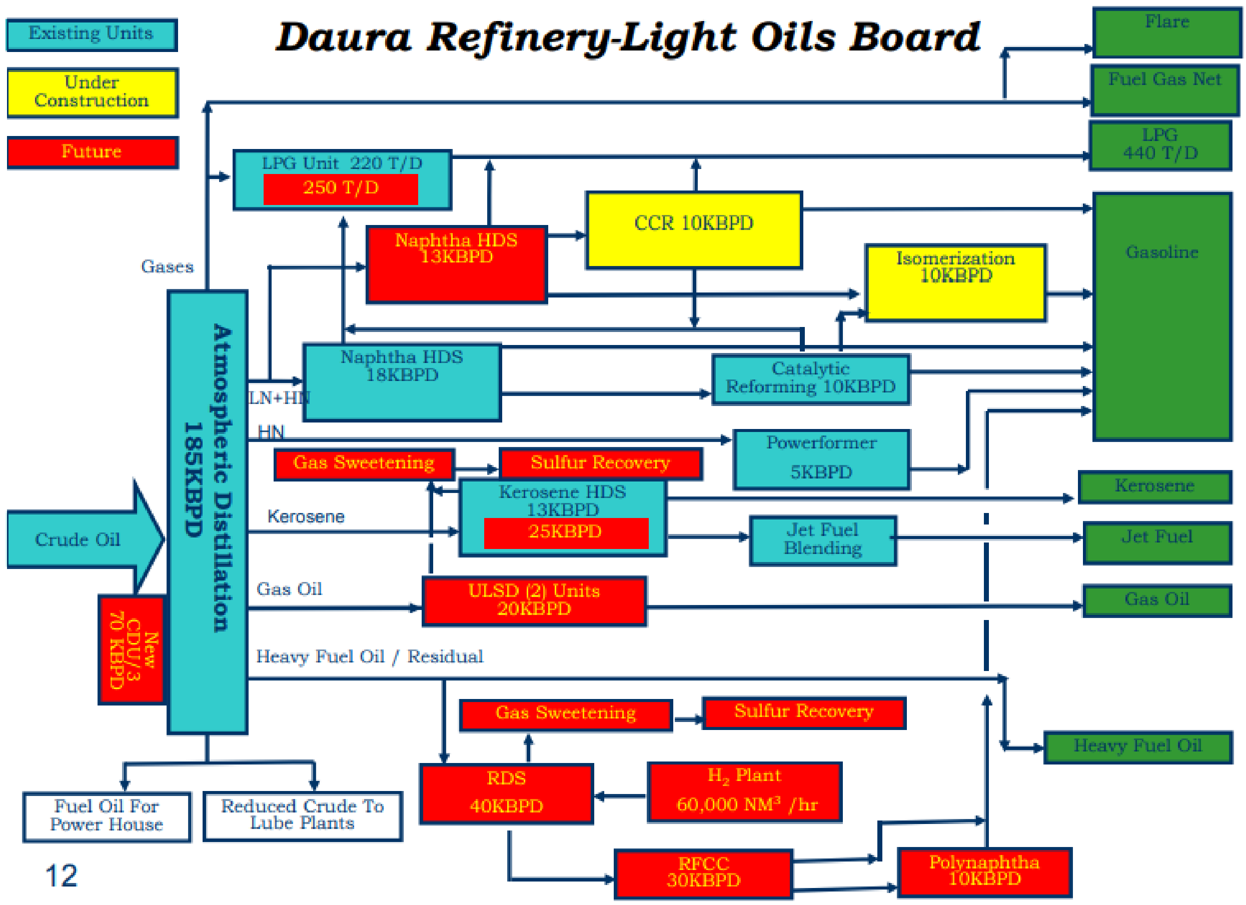


Figure 17 diagram of AL-DURA REFINERY [71].

There are more of unit type as process and operation and that lead to different in composition and amount of gas flaring so that the distillation units have a lower gas pressure than the pressure coming from the reformer units because the refining process, as it is known, takes place within the atmospheric pressure, while the conditions for the units of product improvement and hydrogenation units are that the operating pressure is high .

4-3Flare system of Al-daura

Daura Refinery has current flare stacks. The flare was installed in 1980 The ability of currently flare 205 ton/h with a smoke-free capacity of 9 ton/hr. The type of this flare is the wire support (GW) type[71].

The flare system connected with all unit of refinery as emergency case ,and during normal processes of distillations and reformer unit as show in figure below .

Stream	Operating bar	Operating T, ºC
Gas to Flare	0.2 -1	40-118

Table 4 gas flaring condition of AL-DURA REFINERY

Quantity to Flare (emergency capacity)	205 ton/hr
Quantity to flare (normal capacity)	3 ton/hr
Smoke less steam	9 ton/hr

Table 5 capacity of AL-DURA REFINERY flare

4-4 Applied the modeling on case study :

To determine which models are consistent with the studied case, the following questions must be answered and diagnosed :

1- flaring distance

The site is refinery inside a city - it is about 550 km from the nearest marine area . The city of Baghdad is also characterized by a large population momentum that has a proven relationship in terms of the difficulty of laying pipe structures or transporting to nearby oil fields (east Baghdad reservoir) .

2-gas properties

From the chemical analysis attached above, the gaseous components are inconsistent, so we find different ratios between the components of natural gas and liquefied gas, as well as non-hydrocarbon gases, especially hydrogen sulfide.

On the other hand, the difference in the type of units of the refinery in terms of number, type and operating conditions creates a kind of continuous change in the gas composition during normal operation or during scheduled and emergency stops.

Gas type	Vol. %	Mass kg	LHV MJ/M^3	LHV* Vol. % MJ
N2	0.04	0.04		
H2	0.20	0.01	7.8	1.56
H2S	0.02	0.04	23.3	0.46
CH4	0.16	0.09	35.8	5.7
C2H6	0.08	0.09	64.3	5.1
C3H8	0.12	0.19	93.2	11.1
C4H10	0.20	0.40	123.8	24.7
C5H12	0.14	0.46	156.5	21.9
Total	1	1.32		70.5

Table 6 gas flaring composition of AL-DURA REFINERY For 1 scm

3-project limit

1- Catalysts :The procedures to get the catalyst from outside Iraq facing several difficulties, The fact that the country, in general, does not have a supporting factor industry, but an importing country, and this thing creates a kind of industrial dependence on external sources. It is not easy to continue to supply for commercial, technical and political reasons.

2- Environmental Pollutions : Due to high and rapid development in the oil industry at the last century, many different problems had occurred, one of them is the environmental pollution in all elements of the environment, such as water, soil and air, which began to raise serious questions that need a rapid solutions, a good example of this is (Health, Safety, and Environment) should be considered [71] .

3- Required need

Electricity demand in Iraq was about 57 terawatt-hours (TWh) in 2010, but the installed electricity generation capacity was able to reach just 58 % that amount, some 33 TWh. Final energy usage is five which imported gas from Iran to operate its power plants, while Iraq ranks fourth in the world in the burning gas; in 2016, Iraq produced 29.32 mcm of gas, while in 2035 it burned 170 TWh [69].

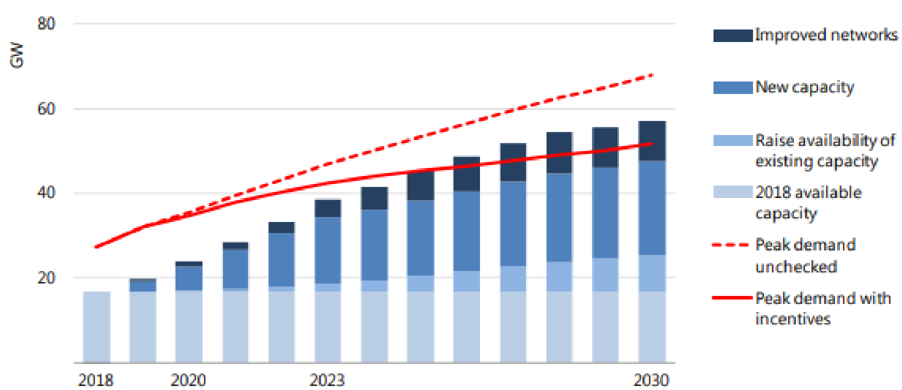


Figure 18 diagram of Iraq electricity amounts

Through the application of the general model and taking into account that the location on land and gas is a mixture of a wide range, a high percentage of heavy and quantitative gases is continuous and in a state of increase due to the continuous development of the refinery units .

we find that the choice is either the first or second model depending on the future increase of gas over time

4-5How can applied the optimal model

After choosing the special model from the general model, it is necessary to verify the similarity between the first and second models and to indicate that the similarity is identical between the two selected models in terms of development projects that can be established if we take into account that the site is far from offshore platforms, as well as the challenges facing the industrial environment. The only difference between the first and second models is the carrying capacity, that is, the increase in gas quantities, and this came from the characteristic that accompanies the work of oil refineries, which is the continuous development and creation of new units. Therefore, the project established for the use of gas must meet the desire and need of the refinery and the adjacent marketing medium to ensure the continuation of the solution in all circumstance

According to modes 1 and 2 that will lead to consider the (FGRS) inside the refinery as first choice as source of fuel to furnace and boilers to generate the steam .

The second choice of the both models is new project to power generation . The last choice is the pipeline to marketing the flare gas to near market and this choice cannot applied because :

1- The difficulty of piping inside Baghdad city .
2- The continuous different of gas flaring component which increase the difficulty of signing an investment contract with a specific entity bound by specific specifications .

Through what has been mentioned above, the choice is limited to internal equipping of the refinery units established as furnaces and boilers in order to reduce the environmental impact to the environment, because the environmental damage due to gaseous fuels is less harmful than liquid fuels. And before leaving this point, we must not forget that the main factor in making a board (FGRS) is the presence of an efficient pressure unit .

Or the second choice is power generation unit which depending completely the gas flaring as fuel and this have more advantages such as :

1- The power generation unit is : The establishment of a new gas-fired energy production unit without relying on multiple burning sites avoids the recovery process from being stopped during regular maintenance operations and various emergency situations.
2- It is often noticed in the practical side that the percentage of thrust towards the torch increases proportionally in the case of stoppages, and this increases the utilization of the installed power generation units.
3- The implementation of such a project that facilitates the process of converting gas into various forms that can be easily transported, such as electricity. Especially in the shadow of great scarcity and a high need for electricity in Iraqi cities, according to the latest energy reports .

4-6 THE NEW IDEA

When discussing the two options (FGRS)and (power generation unit), we find that (FGRS) is easy and quick to implement and install, but it is specific to consumers 'needs and their stops.

While choosing the power generation unit, it is characterized by the carrying capacity and flexibility with changing capacity as well as the possibility of external marketing, but it is characterized by a relatively high cost .

THE IDEA OF AL-DAURA :

Since the essential part of (FGRS) is the pressure unit, it is also considered one of the structural parts of the power generation units. This point is the key to the new idea that can be applied by mixing the two options, and this will be clarified later .

The products from the Flare Gas Recovery System shall meet the conditions in the table(7) below at the battery limits of the project.

Stream	Operating Pressure, bar	Operating Temperature, ºC	Design Pressure, bar	Design Temperature, ºC
Gas to fuel gas system	2	40 – 50	5	85

Table 7 typical condition of Flare Gas Recovery System

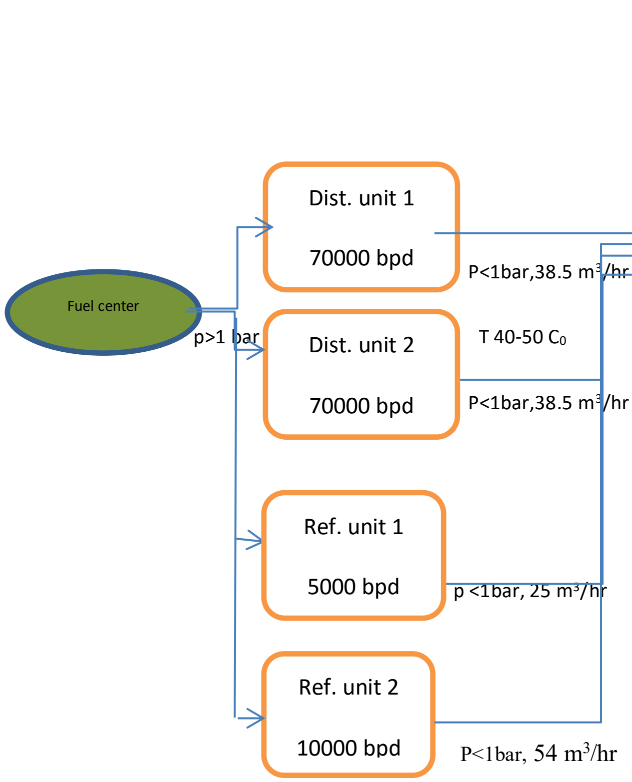


Figure 19 actual design of gas flaring network

Calculation

HEAT RELEASED BY COMBUSTION OF GAS

Total (LHV)gas = Σ yi (LHV)i

Where yi :volume fraction, (LHV)i :Lower

Heating Value, i the component (according to table 4 data)

Thermal energy of 1 m3 of gas phase

=(H2 vol.*LHV H2)+(H2S vol.*LHV H2S)+(CH4 vol.*LHV CH4)+(C2H6 vol.*LHV C2H6)+(C3H8 vol.*LHV C3H8)+(C4H10 vol.*LHV C4H10)=48.6 MJ/hr.

Total thermal energy=Total flow rate*Thermal energy of 1 m3 gas phase=7484 MJ/hr.

In power generation, the efficiency of process (30-50)%

The electricity power 1 MJ=0.277 Kwh

The total electric power =(Thermal energy*0.277)*efficiency = 1 GW

Mixing between (FGRS) & power generation unit to recovery 154 m3/hr to be fuel or electricity

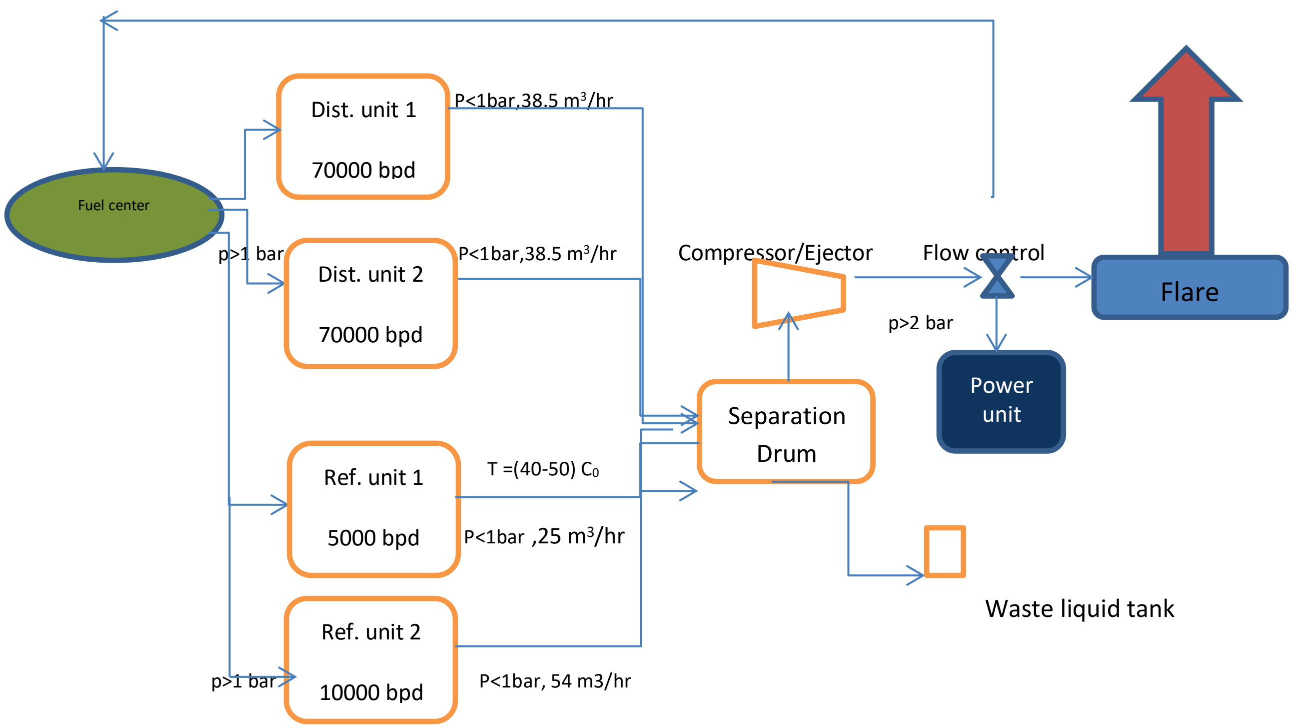


Figure 20 future design of Flare Gas

Design stage :

The final stage that follows a selection process is the stage of designing the processing unit, and according to the options that have been selected, both options Flare Gas Recovery System (FGRS) and (Power generation unit) are linked to the following figure and in the following purpose:

After receiving the gas from the throwing units, it is delivered to the pressure unit, dual-purpose, to raise the gas pressure to the specified operational value for use either: - the furnaces and boilers of the plates in the refinery, which may be the same as the units equipped with gas but with a low pressure.

Or: - To equip a new power generation unit. The primary compressor/ejector shall be multi-purpose, so limit the cost. As for the principle of integration and flexibility in the options, it is important when stops some units , as well as to ensure the existence of continuous gas consumption.

4-7 Chosen of power generation unit

The cost of operational ,maintenance , and fuel costs of new generation plants allows the total costs per unit to be compared . Using international oil and gas prices and considering the main generation technologies and fuels available in Iraq, gas-fired CCGTs emerge as the lowest cost base-load technology. Based on international prices in the Central Scenario, they have a liveliest cost of $77 per megawatt-hour (MWh) in 2020 (Figure). For plants operating only at peak periods, gas-fired GTs are the most economic at international fuel prices, due to their lower capital costs [69] .

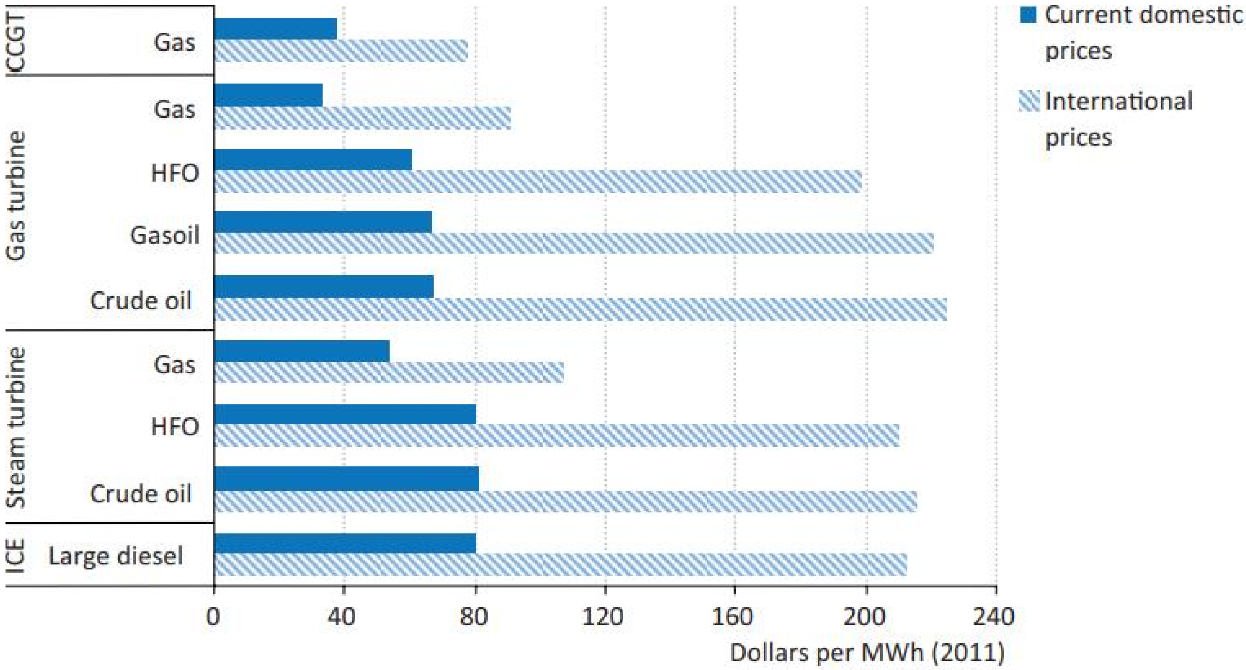


Figure 21 Liveliest cost of base-load plants with international fuel prices in 2020 (Central Scenario) and current domestic fuel prices in Iraq[69]

The power production units as mentioned above are many, but the best choice is GTCC system. GTCC system is applied widely in the world and mainly used for huge power plant due to high thermal efficiency and less environmental impact.

And its reliability and availability have already been proven by long-term operation. However in order to apply GTCC for marginal gas field or associated gas adjacent to oil fields producing an inconstant volume of gas with uneven properties, it is necessary to design countermeasures for fuel back-up such as oil[45] .

5-Conclusion

- Due to numerous considerations (economic, environmental), flare gas must be recovery .
- There are several approved technological methods to deal with gas flaring recovery, any method of recovery can be adopted under specific advantage and limitations
- Analysis condition of gas depend on several points included, position, gas properties, the economic and marketing consideration
- Made flowchart as general model based on gas, location composition and amount.
- Selecting the special model provides the best option for the investor, so that the benefit is in all respects and more cost-effective as sustainably with the life of the project .
- Applied the research in case study to determine the best solution in Midland Refineries Company – Aldaura Refinery in Baghdad city and improve the solution by mixing more than recovery choice in on to became more comfortable with the city requirement – environmentally, sustainability power supplier and increase the profits of the project .

6-Reference

1. GAS flaring in industry: An overview . 1
2. Technical Possibilities and Environmental Approaches for the Future . 18
3. SENES Consultants Limited. Retrieved Oct. 13, 2012, 25 from The Science and Community Environmental Knowledge (SCEK), (May 2007). Available at: http://scek.ca/documents/scek/Final_Reports/RA%202006-08%20Sour%20Gas% 20Final%20Report-May%2017_%202007.pdf (1-11)
4. United States Enviromental Protection Agency, Industrial Flares, Retrieved Oct. 13, 2012, from United States Enviromental Protection Agency. (Sep. 1991). Available at: http://www.epa.gov/ttn/chief/ap42/ch13/final/c13s05.pdf (1-12)
5. Wikipedia, The Free Encyclopedia, Gas flare, Oct. 25, 2012. Available at: http://en.wikipedia.org/wiki/Gas_flare (1-8)
6. https://www.ipieca.org/resources/energy-efficiency-solutions/flaring-and-venting/flaring-classification/
7. Harnessing upstream gas resources for power generation in Nigeria: Issues, strategies & economics (20)
8. Andersen, R.D.; Assembayev, D.V.; Bilalov, R.; Duissenov, D.; Shutemov, D.: TPG 4140 – Natural Gas, Trondheim, Nov. 2012.(1-2)
9. Johnson, M.R.; Coderre, A.R.: Canada, International Journal of Greenhouse Gas Control. 2012, 8, 121–131.(1-13)
10. Ezersky, A.; Guy, B.: Proposed regulation 12, Rule 11: Flare monitoring at petroleum refineries. 2003.
11. Global Gas Flaring Reduction Partnership (GGFR) and the World Bank, Guidelines on flare and vent measurement, 700, 900-6 Avenue S.W. Calgary, Alberta, T2P 3K2 Canada,(Sep. 2008).
12. Gzar, H.A.; Kseer, K.M.: Journal of Al-Nahrain University, 2009, 12(4), 38-57.
13. Manshaa, M.; Saleemia, A.R.; Javeda, S.H.; Ghaurib, B.M.: J. Nat. Gas Chem., 2010, 19(5), 539–547.
14. Ezersky, A.; Lips, H.: Characterisation of refinery flare emissions: assumptions, assertions and AP-42, Bay Area Air Quality Management District (BAAQMD), 2003.
15. E. Cairncross, Report and technical protocol for the monitoring and regulation of flaring from oil refineries in South Africa, UEM flaring project final report, 2007.

16. A. Ezersky, H. Lips, Characterisation of Refinery Flare Emissions: Assumptions, Assertions and AP-42, Bay Area Air Quality Management District (BAAQMD), 2003.
17. R.D. Bowden, K.M. Newkirk, G.M. Rullo, Carbon dioxide and methane fluxes by a forest soil under laboratory-controlled moisture and temperature conditions, Soil Biol. Biochem. 30 (12) (1998) 1591–1597.
18. Economics of gas to wire technology applied in gas flare management .
19. [19] D.N. Hewitt, W.T. Sturges, A. Noa, Global Atmospheric Chemical Changes, Chapman and Hall, New York, 1995.
20. A review of global gas flaring and venting and impact on the environment: Case study of Iran .
21. https://www.exxonmobil.com.sg/en-sg/Company/Overview/Who-we-are/Understanding-flares .
22. Power generation as a useful option for flare gas recovery: Enviro-economic evaluation of different scenarios
23. Energy storage for natural gas fueled electric drilling rigs
24. K. Akachidike, Remote Stranded Gas-Challenges and Opportunities for Development: Proceedings of the 38th Annual Conference of NSChE, Effurun, Delta State, Nigeria, 2008.
25. Deo, V.; Gupta, A.K.; Asija, N.; Kumar, A.; Rai, R.: 31 Oct.-3 Nov., New Delhi, India, Paper ID : 20100584, Petrotech-2010.
26. SPE-198533-MS Flare Gas Monetization Understanding Rich Gas - The Importance of Gas Treatment
27. Orimoogunje, O.O.I. and A. Ayanlade, and T.A. Akinkuolie and A.U. Odiong, Perception on Effect of Gas Flaring on the Environment, Research Journal of Environmental and Earth Sciences, 2(4): 188-193, 2010.
28. World Bank Staff, Global Gas Flaring Reduction, A Public-Private Partnership, Report #5, May 2004.
29. Sangsaraki, M.E.; Anajafi, E.: International Conference on Chemical, Food and Environment Engineering (ICCFEE'15), Dubai (UAE), Jan. 11-12, 2015.
30. Rahimpour, M.R.; Jokar, S.M.: Journal of Hazardous Materials, 2012, 204-217.
31. Rahimpour, M.R.; Jamshidnejad, Z.; Jokar, S.M.; Karimi, G.; Ghorbani, A.; Mohammadi, A.H.: J. of Natural Gas Science and Engineering, 2012, 4, 17-28.
32. Mourad, D.; Ghazi, O.; Noureddine, B.: Korean J. Chem. Eng., 2009, 26(6), 1706-1716.
33. Duck, B.: Hydrocarbon World, 2011, 6(1), 42-45.

34. Fisher, P.; Brennan, D.: Hydrocarbon Processing, 2002, 83-85.
35. Feasibility of flare gas reformation to practical energy in Farashband gas refinery: No gas flaring
36. Evolution of dual fuel pressure pumping for fracturing: Methods, economics, field trial results and improvements in availability of fuel
37. Peterson, J.; Cooper, H.; Baukal, C.: Hydrocarbon processing, 2007, 111-115.
38. Ghadyanlou, F.; Vatani, A.: Chemical Engineering, Essentials for the CPI Professional. 2015, chemengonline.com.
39. Abdulrahman, A.O.; Huisingh, D.; Hafkamp, W.: Journal of Cleaner Production 2015, 98, 116-122.
40. Saadwai, H.: SPE-166133-MS, 2013.
41. Blanton, R.E.: Presented at the National Petroleum Refiners Association Environmental Conference , San Antonio, Sep. 21, 2010. Available at: http://www.johnzink.com/wpcontent/uploads/NPRA-2010-Environmental-Conference-Paper.pdf
42. Blackwell, B.; Leagas, T.; Seefeldt, G.: Hydrocarbon Engineering, Jan. 2015.
43. Associated Petroleum Gas Flaring Study for Russia , Kazakhstan , Turkmenistan and Azerbaijan
44. Statoil awarded IOR prize. Retrieved Nov. 3, 2012, from Statoil. available at: http://www.statoil.com/en/NewsAndMedia/News/2012/Pages/28aug_ior.aspx.
45. Gas to Wire (GTW) system for developing "small gas field" and exploiting "associated gas"
46. Bawazir, I.; Raja, M.; Abdemohsen, I.: 2014, IPTC-17273-MS.
47. Oil and Gas Production Handbook - An introduction to oil and gas production, transport, refining and petrochemical industry
48. Natural Gas Flaring and Venting : State and Federal Regulatory Overview , Trends , and Impacts
49. Iandoli, L.; Kjelstrup, S.: Energy Fuels, 2007, 21, 2317-2324.
50. Overview of New Advanced Fuel Technologies
51. Shahhosseini, Sh.; Alinia, S.; Irani, M.: World Academy of Science, Engineering and Technology, 2009, 3, 12-24.
52. Tolulope, A.O.: Environ. Inform. Arch., 2004, 2, 387-393.
53. Pederstad, A.; Gallardo, M.; Saunier, S.: Improving utilization of associated gas in US tight oil fields, Carbon Limits, April 2015, Registration/VAT no.: NO 988 457 930.

54. S. Thomas, R.A. Dawe, Review of ways to transport natural gas energy from countries which do not need the gas for domestic use, Energy 28 (2003) 1461– 1477.
55. Takayuki, T.; Kenji, Y.: Energy Policy, 2008, 36, 2773-2784.
56. Bott, R.D.: Flaring answers + questions, Retrieved Oct. 20, 2012, from Stuff Connections - World Bank Intranet, 2007. Available at: http://siteresources.worldbank.org/EXTGGFR/Resources/578068-1258067586081/FlaringQA.pdf.
57. California Oil Producers Electric Cooperative, Offgases project oil-field flare gas electricity systems, California Energy Commission Public Interest Energy Research Program, 2008. Available at: http://www.energy.ca.gov/2008publications/CEC-500- 2008-084/CEC-500-2008-084.PDF.
58. Jafarian H, Sattari S, Lajevardi H. Technical and Economical Investigation of Electricity Generation from Associated Gas. Iran Electr Ind J Qual Product 2015;4:33–47.
59. Paoli N. Simulation Models for Analysis and Optimization of Gas Turbine Cycles. Università di Pisa, 2009.
60. https://www.power-eng.com/2016/11/17/turbines-vs-reciprocating-engines/#gref n.d.
61. Earl D. Oliver. SO2 Removal from Flue Gases, Supplement C, Process Economics Program, IHS Markit (SRI International), Report No. 63C. n.d.
62. Agrawa A. Natural Gas Acid Gas Removal and Sulfur Recovery, Process Economics Program, IHS Markit Report 216A. n.d.
63. United States Energy Information Administration. Capital Cost Estimates for Utility Scale Electricity Generating Plants. United States Dep Energy 2016:1–201. https://doi.org/10.2172/784669.
64. Zhang W. Simulation of Solid Oxide Fuel Cell-Based Power Generation Processes with CO 2 Capture. University of Waterloo, 2006.
65. Petruzzi, L.; Cocchi, S.; Fineschi, F.: J. Power Sources, 2003, 118, 96-107.
66. U.S, EPA, Emission standards division, Control Technologies, Vol. 1B, November 1992.
67. McMahon, M.: Estimating the atmospheric emission from elevated flares. BP Amoco Suhubury Report, 1994.
68. International Energy Agency Staff, Optimizing Russian Natural Gas, OECD/IEA, 2006
69. Iraq Energy Outlook

70. Bachu, S.; Gunter, W.D.: In: Proceedings of the 7th International Conference on Greenhouse Gas Control Technologies, 2005, 443–448.
71. Technical Possibilities and Environmental Approaches for the Future
72. The_Chemistry_and_Technology_of_Petroleum,_Fifth_E_2722684_z_lib.pdf
73. Energy efficient cities initiative, Good practices in city energy efficiency: Tianjin, China - landfill gas capture for electricity generation, 2009. Available at: https://www.esmap.org/sites/esmap.org/files/Tianjin_Case_Study_033011_coverpa ge.pdf
74. Integrated science assessment for ozone and related photochemical oxidants. US Environmental Protection Agency.
75. A review on bioremedation of petroleum hydrocarbon contaminants in soil. Kathmandu Univ. J. Sci. Eng. Technol. 8 (1), 164–170.
76. Natural gas utilisation in Nigeria: challenges and opportunities. J. Nat. Gas Sci. Eng. 2, 310–316.
77. Review of ways to transport natural gas energy from countries which do not need the gas for domestic use. Energy 28, 1461–1477.
78. Flare gas reduction – Recent global and policy considerations. GE Energy, Global Strategy and Planning.
79. Economic evaluation of natural gas transportation from Iran's South-Pars gas field to market. Appl. Therm. Eng. 29, 2009–2015.
80. Evaluating the viability of offshore LNG production and storage. GASTECH, Qatar.
81. Associated gas monetization via miniGTL conversion of flared gas into liquid fuels & chemicals. Global Gas Flare Reduction Partnership.
82. Gas flaring and venting: extent, impacts and remedies. James A. Baker III Institute for Public Policy of Rice University.
83. 5. ABS development of a guide for compressed natural gas carriers. In: International Society of Offshore and Polar Engineers (ISOPE), Seoul.
84. NOAA, Colorado School of Mines, GGFR
85. https://search.tb.ask.com/search/AJimage.jhtml?&enc=0&n=78689cc8&p2=%5EBZD%5Exdm272%5ES39155%5Eus&pg=AJimage&pn=1&ptb=379EA442-E4D6-4209-82E7-7ED54240A1D8&qs=&searchfor=Floating+liquefied+natural+gas&si=26211831986&ss=sub&st=sb&tpr=sbt&imgs=1p&filter=on&imgDetail=true