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THEME

CONTRIBUTION TO SUSTAINABLE MANAGEMENT OF CO_2 EMISSIONS – ENERGY EFFICIENCY OF PETROCHEMICAL PROCESSES

(CASE OF ALGERIA)

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Dedications

FIRST OFF, I THANK ***ALLAH*** FOR GIVING ME HEALTH, PASSION & THE RIGHT MINDSET TO COMPLETE THIS WORK.

THEN, I HONORABLY DEDICATE THIS WORK TO MY DEAR MOM ***A.AICHA***, I AM TOO MUCH GRATEFUL FOR EVERYTHING. YOU HAVE BROUGHT ME TO LIFE, WELL RAISED ME, AND MAKE EVERY SINGLE POSSIBLE EFFORT TO KEEP ME UP ON THE RIGHT PATH. THANK YOU MOM FOR GIVING ME LOVE, KINDNESS & TENDERNESS AS WELL. I REALLY LOVE YOU, MOM.

MY DAD ***B.MOHAMED***, ONE DAY, I HOPE THAT I COULD FIND A WAY TO GIVE YOU BACK EVEN A LITTLE OF WHAT YOU GAVE ME, I'M TOO MUCH APPRECIATED DAD.

-TO ALL MY DEAR FAMILY, BROTHERS, AND SISTERS

-TO ALL MY FRIENDS, EACH IN HIS OWN NAME.

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– benzine mohamed sobhi

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AT FIRST, AL-HAMDOU'LI ALLAH WHO LEADS, SET & GAVE TO THOSE WHO WAIT. THEN I DEDICATE THIS HUMBLE WORK TO MY DEARS:

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Summary

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List of Abbreviations

AFCs : Alkaline fuel cells

ALGADISK : Biofilm reactor for algae biomass production

BP : British Petroleum Company

COVID-19: Coronavirus disease 2019

CIS : South industrial center

CFC: Chlorofluorocarbon

CT: Cold torch

DEA: Diethanolamine

DFA: Direct formic acid

DME: Dimethyl ether

DMFC: Direct methanol fuel cell

GT: Giga tonne

HP: High pressure

HRSG: Heat Recovery Steam Generator

HT: Hot torch

IGCC: Integrated Gasification Combined Cycle

IPCC: Intergovernmental Panel for Climate Change

LDHP: High pressure direct line

LPG: Liquefied petroleum gas

MCFCs: Molten carbonate fuel cells

MDEA: Methyl diethanolamine

MEA: Monoethanolamine

MOH: Methanol production

MTBE: Methyl tertbutyl ether

M4: Condensates

ORC: Organic Rankin Cycle

PEMFCs: Proton exchange membrane fuel cells

SCR: Selective Catalyst Reduction

SDGs: Sustainable Development Goals

SOFCs: Solid oxide fuel cells

Sm3: Standard Cubic Metre

TAME: Tert-Amyl methyl ether

TEA: Triethylamine

THF: Tetrahydrofuran

UAE: United Arab Emirates

VIIRS: Visible Infrared Imaging Radiometer Suite

VNF: Visible Night fire

WHB: Waste Heat Boiler

ZCINA: New Naili Abdelhalim Industrial Center

General introduction

General Introduction

It is recognized today that carbon dioxide predominantly plays a role in the greenhouse effect. Carbon dioxide emissions come schematically from two levels: diffuse sources of pollution (transportation, local heating, etc.) and concentrated sources of pollution (industries).

Carbon dioxide is a greenhouse gas and representatives of the energy transition are trying to limit its production and ban its emission into the atmosphere due to its high concentration in the air. Its massive presence is partly responsible for global warming. Approximately 87% of these emissions are assigned to humans and come from the combustion of fossil fuels [18].

The rate of carbon dioxide in the atmosphere has been a subject of variation long before the advent of humans and industrial society, but it is no longer questioned in recent decades, whose origin is no longer anthropogenic. The industrial sector is the major human source of carbon dioxide emissions.

In 2019, this sector generated 28% of emissions related to fossil fuels [8]. The rise in carbon dioxide emissions since the beginning of the Industrial Revolution has prompted many major industrialized countries to search for technologies to mitigate the impact of climate change. The most important of these factors is the capture, use and storage of carbon dioxide. Waste energy that rises with greenhouse gases is helping to raise atmospheric temperatures. Furnace, torch, and turbine combustion produce a lot of waste heat that is released into the atmosphere. As a result, industry has exposed the planet to over 1.5 °C in recent years [7].

Some international companies and scientific research centers have resorted to developing technologies for capturing, separating and storing carbon dioxide for use in a number of emerging fields and applications, such as the production of synthetic fuels and some types of chemicals, in addition to recent trends towards re-designing new building materials, such as cement and concrete, and materials Financial and insulation with a performance that exceeds that of traditional building materials, at a low cost, with the aim of increasing their efficiency and reducing their cost. in a way that contributes to its spread. However, there is a need to exert more effort in this vital and important area, through support policies, legislation, increasing tax exemptions, granting incentives and the necessary funding.

At the national level, ALGERIA is a country with significant CO_2 emissions, registering 155 million tons in 2020 [5]. This is due to various industrial activities such as fossil fuel extraction, coal mining, cement, and iron and steel industries. This is why industrial companies are looking for technologies to capture and store carbon dioxide, which contributes to its use in other industries and lowers environmental tax costs

The study aims to highlight the importance of applying techniques to capture and use carbon dioxide emitted by the exhaust gases of production units through the quantification and localization of emissions, and to study the possibility of recovering waste energy in the petrochemical production complexes in ALGERIA, in order to keep up with the global trend towards reducing carbon dioxide emissions, and to maximize the use of carbon dioxide through its use to increase the production of some petrochemical products and increase profitability.

This graduation thesis under the name Contribution to sustainable management of CO_2 Emissions- energy efficiency of petrochemical processes (Case of Algeria) contains five chapters:

The first chapter (Bibliographical Studies): contains a bibliographical study on carbon dioxide, its impacts and emissions in the world and in Africa, and the position of the Algerian state in the emissions of Arab countries, and in the end, it talks about the goals of sustainable development

Chapter Two (CO_2 Capture Technologies): This chapter contains most of the methods that can be used to capture carbon dioxide, some of which have been applied and some are still under study.

Chapter Three (CO_2 Valorization and Waste Energy Recovery): It contains a set of methods for valuing carbon dioxide in the field of petrochemicals and the possibilities of recovering wasted energy.

Chapter Four (Sources of CO_2 Emissions and Waste Energy in Algeria -LPG ZCINA-): This chapter contains the sources of carbon dioxide emissions in the industrial field, and it deals with the definition of the location of the burner tracking in the world, as well as a description of the place of the training internship

Chapter Five (Calculations and Results Discussion): This chapter contains a method for calculating and estimating the results of carbon dioxide emissions using equations, as well as using the site, and finally, suggestions for capturing and exploiting carbon dioxide, and a proposal for the recovery of wasted energy and simulation of these suggestions.

Bibliographic studies

1. DEFINITION OF CO_2

Carbon dioxide, commonly called carbonic acid gas or carbonic anhydride. It consists of one carbon atom and two oxygen atoms, although carbon dioxide is less abundant than nitrogen and oxygen in the Earth's atmosphere, at more than 400 ppm in the atmosphere. Before industrial activity, there were about 270 parts per million in the atmosphere, and so our atmospheric CO_2 levels have gone up about 40% since the beginning of the Industrial Revolution, which led to global warming and disrupted other aspects of the Earth's climate [1].

2. Physical and Chemical characteristics of CO_2

Carbon dioxide is a one-carbon compound with the formula CO_2 in which the carbon is attached to each oxygen atom by a double bond.

- A colorless, odorless gas under normal conditions.
- A density about 53% higher than that of dry air, incombustible.
- CO_2 is the second most important greenhouse gas in the atmosphere after water vapor.
- Carbon dioxide is dissolved in water and forms carbon acid (H_2CO_3).

The following figure shows some properties of this gas [2].

FIGURE I.1: Chemical and physical properties of carbon dioxide [2].

3-Available energy sources

An energy source is a source from which exploitable energy can be extracted or recovered, either directly or through a conversion or transformation process.

There are two types:

3.1-Primary energies:

The numerous existing energy sources can be classified in different ways. Primary sources can be used directly, as they appear in the natural environment: coal, oil, natural gas and wood, nuclear fuels (uranium), the sun, the wind, tides, mountain lakes, the rivers (from which hydroelectric energy can be obtained) and the Earth heat that supplies geothermal energy.

3.2-Secondary energies:

Secondary sources derive from the transformation of primary energy sources: for example, petrol, that derives from the treatment of crude oil and electric energy, obtained from the conversion of mechanical energy (hydroelectric plants, Aeolian plants), chemical plants (thermoelectric), or nuclear (nuclear plants). Electric energy is produced by electric plants, i.e. suitable installations that can transform primary energy (non-transformed) into electric energy [3].

Primary energies **Secondary energies**

FIGURE I.2: Available energy sources [3].

4-Carbone Dioxide Emissions

4.1- Global Emissions

One of the key features of 2021 global CO_2 emissions is the rebound from 2020 levels. In particular, global annual emissions increased from 33.3 GtCO_2 in 2020 to 34.9 GtCO_2 in 2021, representing a 4.8% increase (3.8–5.7% range). Despite rising case numbers and new variants, the impact of the COVID-19 pandemic on CO_2 emissions, therefore, appears to be less in 2021 compared to 2020 owing to a reduction in restrictive policies [4].

In general, developed countries have higher CO_2 emissions. In the United States, energy use has increased in the past five years, most likely due to increased heating and cooling requirements and lower oil prices, leading to an increase in passenger numbers. China has the highest level of CO_2 emissions, producing 10.67 billion tons of CO_2 in 2020, followed by the United States with 4.71 billion tons. The following graph is the total CO_2 emissions of each of the top five CO_2-producing countries for 2020 [5].

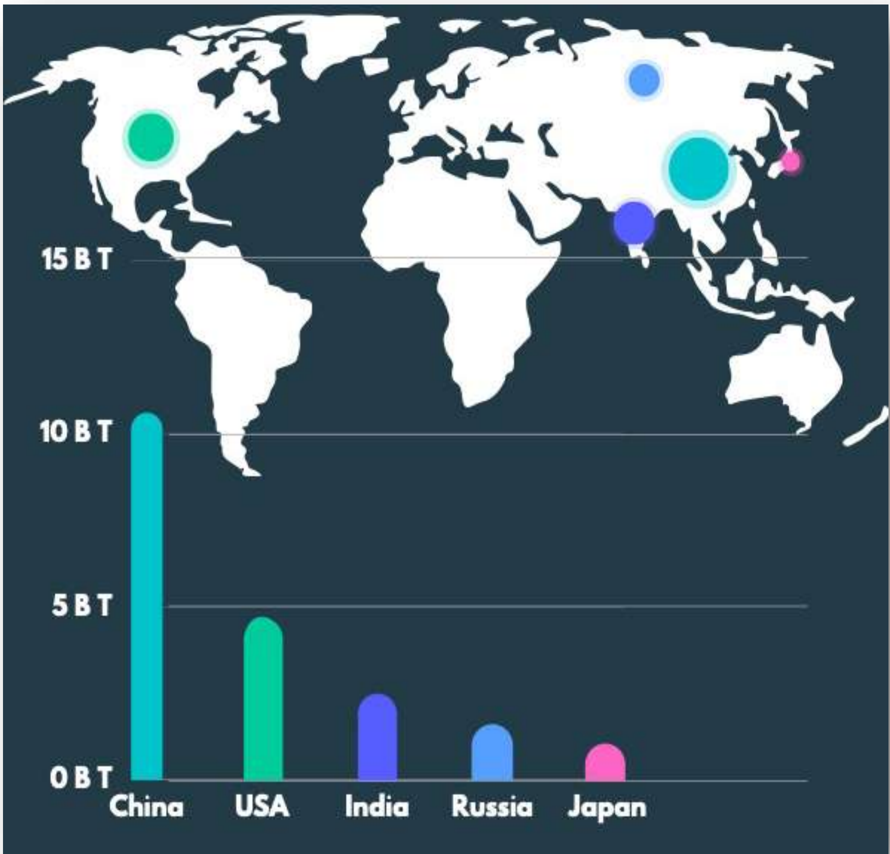


FIGURE I.3: Emissions of the top five CO_2-producing countries for 2020 [5].

4.2- Africa's Emissions

South Africa was the most polluting country in Africa in 2020. That year, it emitted nearly 452 million metric tons of carbon dioxide (CO_2). Egypt ranked second with around 213 million metric tons of CO_2 emissions. Other large producers of CO_2 emissions on the continent were Algeria, Nigeria, and Morocco. The following graph represents the African countries that produce the most carbon dioxide [4].

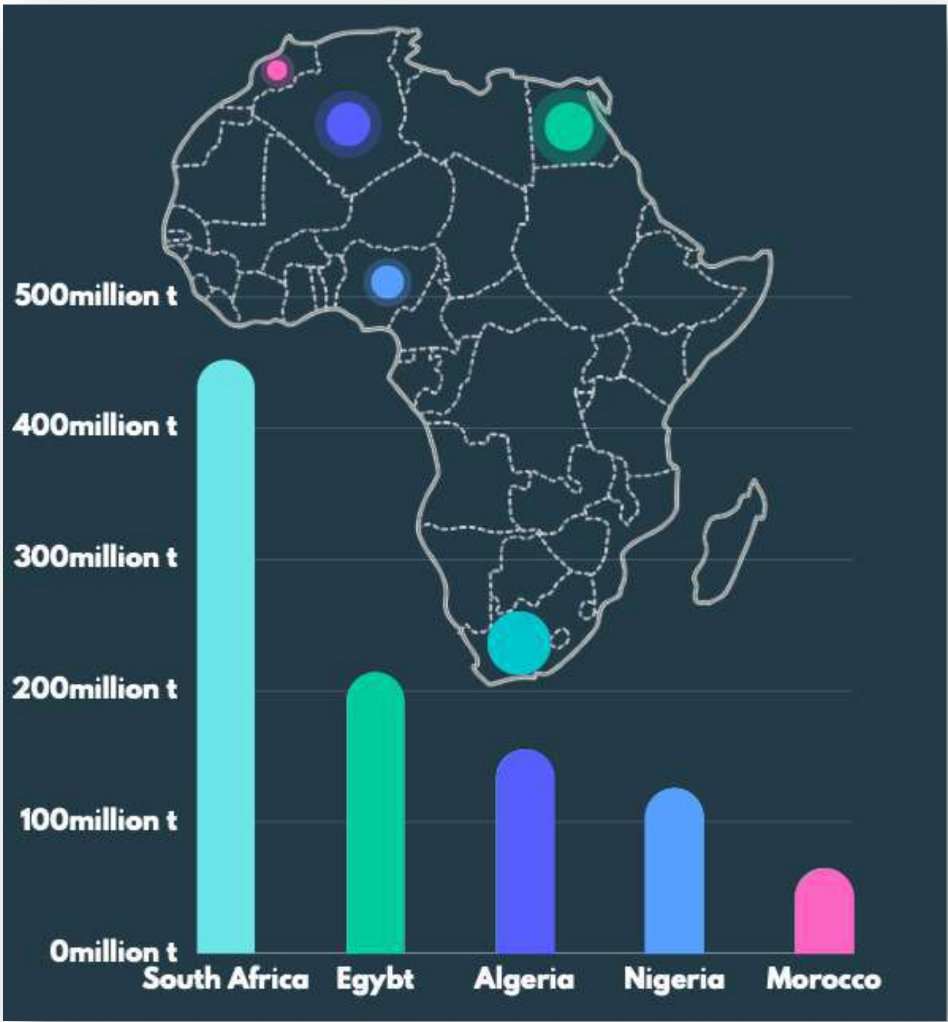


FIGURE I.4: Africa's countries that produce the most carbon dioxide [5].

4.3-Algeria's position on the emissions of Arab countries:

As the Arabic's 4th largest gas emitter (at 9.3 billion Cubic Meters per year, or 10% of gas production, according to a World Bank report), the practice must be eliminated. Flaring not only leads to a loss of revenue, but also, the damage to the environment (flaring generates 150 million CO_2-equivalent tons) and damages Algeria's international reputation (discouraging international investment). The table below shows the rank of Algeria among the Arab countries according to the emission of CO_2 [6].

TABLE I.1: Amount of CO_2 emissions by Arab countries [5].

	Country	Year	Value (Mt)
1	Saudi Arabia	2020	625,510
2	Egypt	2020	213,460
3	Iraq	2020	210,830
4	Algeria	2020	155,000
5	United Arab Emirates	2020	150,270
6	Qatar	2020	106,650
7	Kuwait	2020	88,940

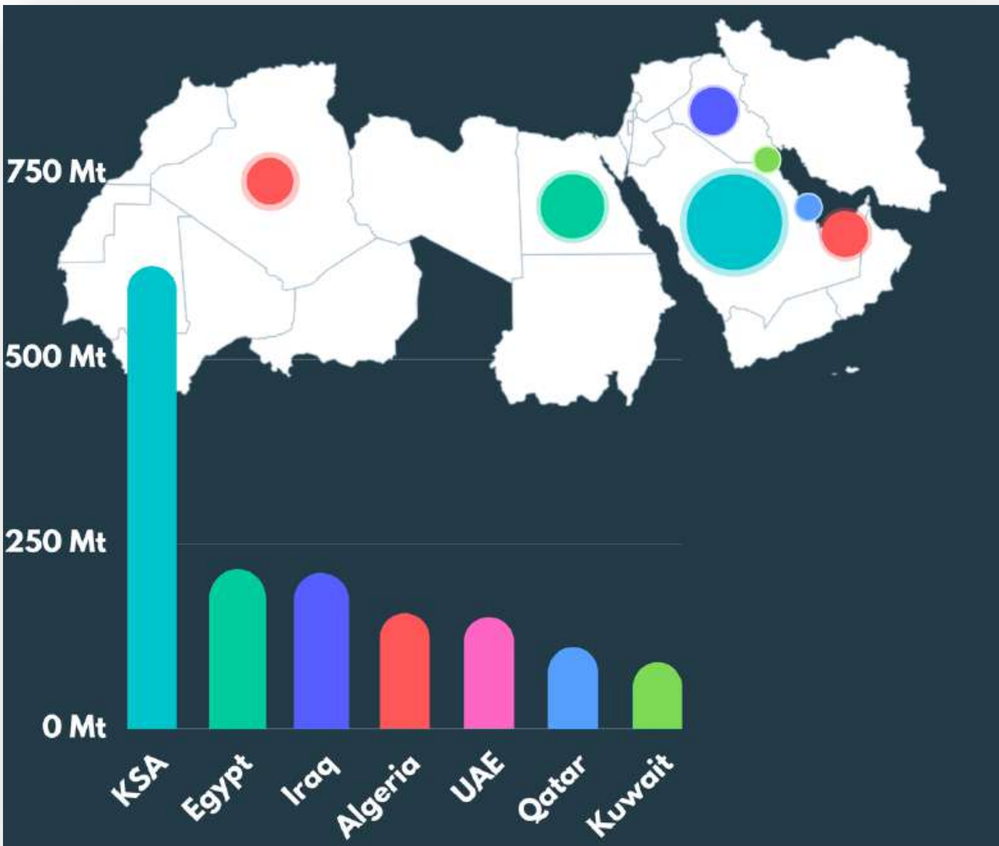


FIGURE I.5: Arab countries that produce the most carbon dioxide [5].

5-CO_2 capturing

Carbon dioxide is the main driver of human-induced climate change wherefore the Intergovernmental Panel for Climate Change (IPCC) recently released the special report Global Warming of 1.5 °C. It is recommended that all available tools should be implemented to reduce CO_2 emissions. Energy efficiency, fuel switching, renewables, and carbon capture represent the largest impact on CO_2 emission reduction in power and industrial sectors (coal, gas, or fuel-fired energy plants, steel or petrochemical plants, cement plants, oil refineries, etc) [7].

CO_2 capture (also called CO_2 sequestration or carbon capture) involves a group of technologies aiming to separate CO_2 from other compounds released during the production of energy or industrial products, obtaining a CO_2-rich gas that can be stored or used for the obtention of valuable products. The main classification of CO_2 capture technologies relies on where in the process the CO_2 separation occurs. For the power sector, it can be divided into pre-, oxy-, and post-combustion. For the industrial sector, the classification is similar, although their integration would be different [7].

- **Post-combustion technology** involves capturing the carbon dioxide from the flue gas before releasing it to the atmosphere, this technology uses amino solvents to capture, among the most developed solvents, monoethanolamine (MEA).
  As this setup is made to install at the tail end of the plant, any emergency shutdown of the carbon-capturing setup can still allow the concerned plant to operate uninterruptedly [8].

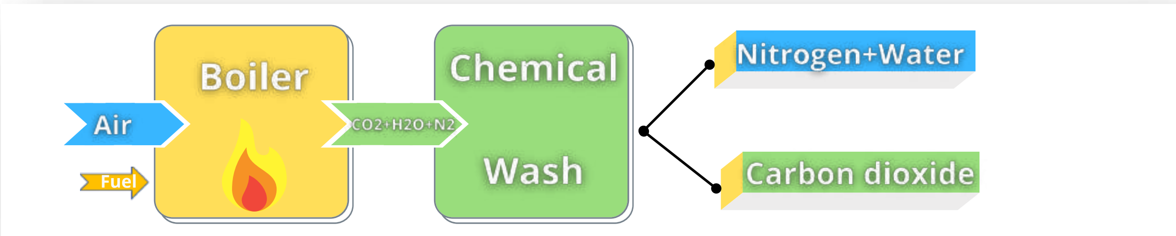


FIGURE I.6: Post-combustion technology.

- **Pre-combustion technology** is based on well-known technologies that are currently used in commercial operations such as: hydrogen, ammonia and syngas production. The technology comprises two main steps: reforming/conversion of fossil fuel to syngas (a mixture containing hydrogen, CO, and CO_2), and separation of CO_2 and hydrogen to produce a hydrogen-rich stream [8].

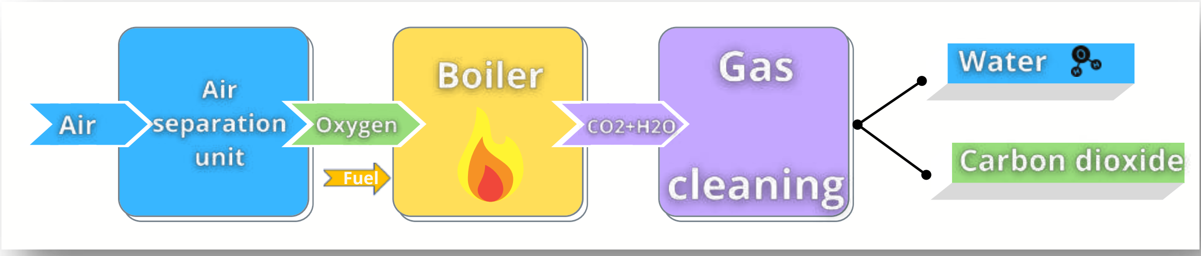


FIGURE I.7: Pre-combustion technology.

- **Oxyfuel combustion technology** requires the delivery of oxygen rather than air to the combustion chamber so that the gaseous combustion reaction product is near-pure CO_2 rather than a mixture from which CO_2 needs to be separated. Oxygen may be delivered either as a gas stream, produced by the separation of O_2 from the air (effectively an O_2 N_2 binary mixture) or as a solid oxide in a chemical looping process [8].

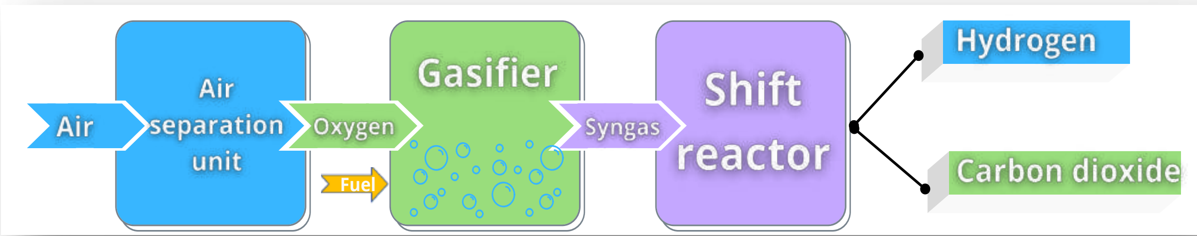
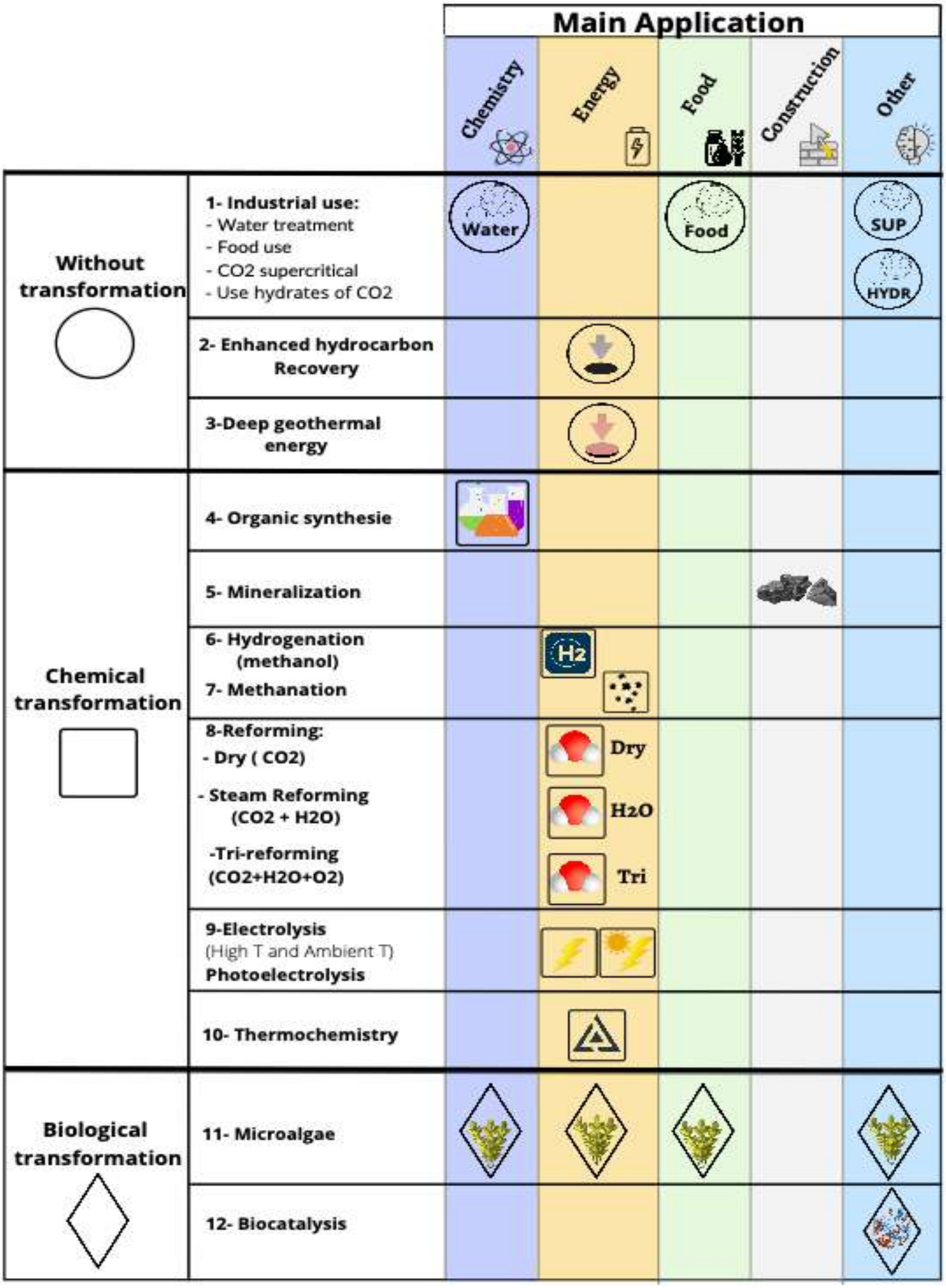


FIGURE I.8: Oxyfuel combustion technology.

6- Carbon dioxide uses

Carbone dioxide can be used in a variety of ways, and the processes involved can usually be divided into three different categories: direct use without transformation, chemical transformation or biological transformation.

The main areas of application concern the chemical (e.g. organic synthesis), the energy (e.g. improvement of the yield in thermal extraction processes or the synthesis of molecules with an energy value), food or construction industries [9]. The following table represents the main routes for CO_2 valorization.



		Main Application				
		Chemistry	Energy	Food	Construction	Other
Without transformation	1- Industrial use: - Water treatment - Food use - CO2 supercritical - Use hydrates of CO2	Water		Food		SUP HYDR
	2- Enhanced hydrocarbon Recovery					
	3-Deep geothermal energy					
Chemical transformation	4- Organic synthesie					
	5- Mineralization					
	6- Hydrogenation (methanol) 7- Methanation		H2			
	8-Reforming: - Dry (CO2) - Steam Reforming (CO2 + H2O) -Tri-reforming (CO2+H2O+O2)		Dry H2O Tri			
	9-Electrolysis (High T and Ambient T) Photoelectrolysis					
	10- Thermochemistry					
Biological transformation	11- Microalgae					
	12- Biocatalysis					

TABLE I.2: Main routes for CO_2valorization [9].

7-Possibility of energy recovery (waste energy)

The interest for low grade heat recovery has been growing for the last ten years, due to the Increasing concern over energy shortage and global warming.

An important number of new solutions have been proposed to generate electricity from low Temperature heat sources [10]. Among the proposed solutions, the Organic Rankine Cycle system is the most widely used, the typical Examples of Waste Heat Recovery:

- Waste Heat Boiler (WHB).
- Heat Recovery Steam Generator (HRSG).
- Organic Rankin Cycle (ORC).
- Heat Recovery with pre-heater.

8- Sustainable Development Goals

The Sustainable Development Goals (SDGs), also known as the Global Goals, were adopted by the United Nations in 2015 as a universal call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity [11].

The Seventeen Goals of the United Nations are a call for action by all countries – poor, rich, and middle-income – to promote prosperity while protecting the planet. They recognize that ending poverty must go hand-in-hand with strategies that build economic growth and address a range of social needs including education, health, social protection, and job opportunities while tackling climate change and environmental protection [11].

FIGURE I.9: Sustainable development goals cycle.

What is the relationship between our study and the Sustainable Development Goals?

Our study tries to contain some of the Sustainable Development Goals in industry and help the Algerian state to achieve these noble goals of reducing carbon taxes. This study solves three goals: 7, 9 and 13. These goals revolve around the production of clean energy, the raising of efficiency, the development of industry, and the pursuit of climate change, towards the production of zero emission plants.

these are the three goals touched and its targets:

- **Affordable and clean energy (Goal 7):** The goal is to double the global rate to improve energy efficiency and strengthen international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency, and advanced and cleaner fossil- fuel technology, by 2030 [11].

- **Industry, Innovation, and infrastructure (Goal 9):** This goal seeks to upgrade infrastructure and modified industries to make them sustainable, while increasing resource efficiency and increasing the adoption of clean and environmentally sound industrial techniques and processes, with all countries taking actions according to their respective capabilities, by 2030.

- **Climate Action (Goal 13):** This goal seeks to integrate climate change measures into national policies, strategies, and planning, as each country needs to initiate long-term systemic shifts that change the trajectory of atmospheric CO_2 levels, by 2030[11].

9. Economic and environmental impacts

9.1-On the environment

The emission of carbon dioxide is a serious environmental problem (air pollution, noise, odors, flashlight, greenhouse gas emissions, and local air pollution) and can cause long-term or short-term damage.

This practice is a sensitive environmental issue: it has produced nearly 350 million tons of CO_2 per year worldwide, equivalent to the annual emissions of around 75 million cars.

In addition, flaring causes light pollution that disorients insects and night birds. Noise from operations can also disrupt the surrounding ecosystem at oil extraction sites [12].

In 2015, the World Bank launched a "zero routing flaring by 2030" initiative with seve ral governments and oil groups, which aims to end regular gas flaring operations in oil fields by 2030 [13].

9.2- On the economy

Under a carbon tax, the government sets a price that emitters must pay for each ton of greenhouse gas emissions they emit. Businesses and consumers will take steps, such as switching fuels or adopting new technologies, to reduce their emissions to avoid paying the tax [3].

The carbon dioxide gas emitted by industries is considered a treasure that all countries that release it into the atmosphere lose and do not process, sell or benefit from it to raise production efficiency, in addition to the aforementioned reduction of the carbon tax.

Chapter: 2

CO2 CAPTURE TECHNOLOGIES

1- Introduction

There are four main techniques for capturing carbon dioxide, which are classified according to the stage at which it is captured. If gaseous carbon dioxide is captured from the mixture of exhaust gas "flues" resulting from the combustion of fossil fuels used in the production of energy, or used as raw materials for production, it is referred to as "post-combustion" carbon capture techniques. and no incineration was required, such as separation processes during natural gas processing or synthesis gas production, it was called "pre-combustion" carbon capture technology, and "Oxyfuel Combustion" technology is a technology that relies on combustion using gaseous oxygen instead. Atmospheric air, and finally, the capture of gaseous carbon dioxide has been determined by industrial processes, in which carbon dioxide is separated from a mixture of other gases by a number of industrial processes [14].

2- Pre-combustion

Carbon dioxide capture technology Pre-combustion is based on converting "solid, liquid or gaseous" fuels into syngas. Synthetic gas is produced by the "gasification" method of fuel [15].

This operation allows us to capture carbon dioxide or CO_2 and maximize power output by an air separation unit produces a stream of almost pure oxygen which flows into the gasifier and reacts with fuel to form syngas which is a mixture of hydrogen, carbon monoxide, CO_2 and water, steam is added to the syngas in shift reactor converting the carbon monoxide to hydrogen and carbon dioxide CO_2 is captured from the gas stream compression and dehydration is ready for Transfer & Storage, today the hydrogen is burnt to power turbines and make electricity tomorrow it could also be used as a fuel for transport the excess heat is recovered and used to power steam turbines optimizing energy output **(Figure II.1)**.

The main theoretical advantage of pre-combustion is the production of hydrogen, which will add value to the business model, and a lower energy penalty compared to using the traditional chemical absorption within a post-combustion configuration. However, large projects demonstrated that this difference is only 1–2%, as reported by National Energy Technology Laboratory (NETL).

The most notable pre-combustion project was the Kemper County IGCC plant in the United States, which stopped its operation in 2017 [7].

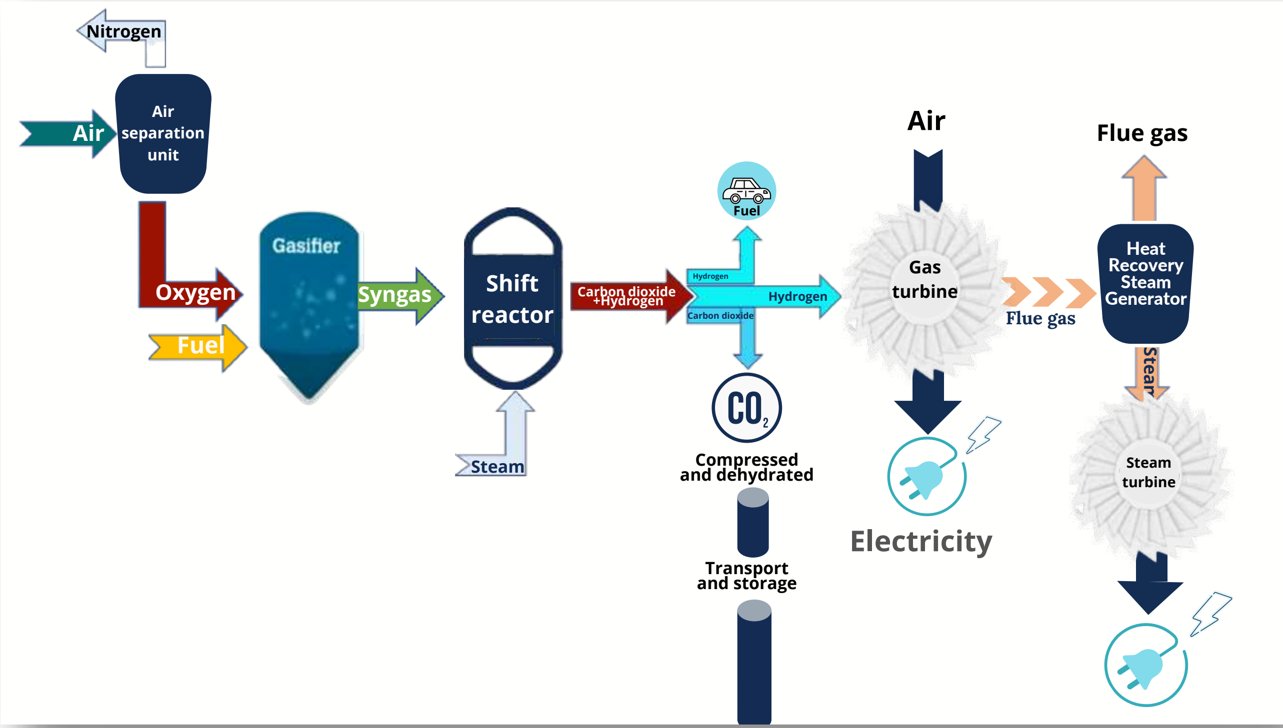


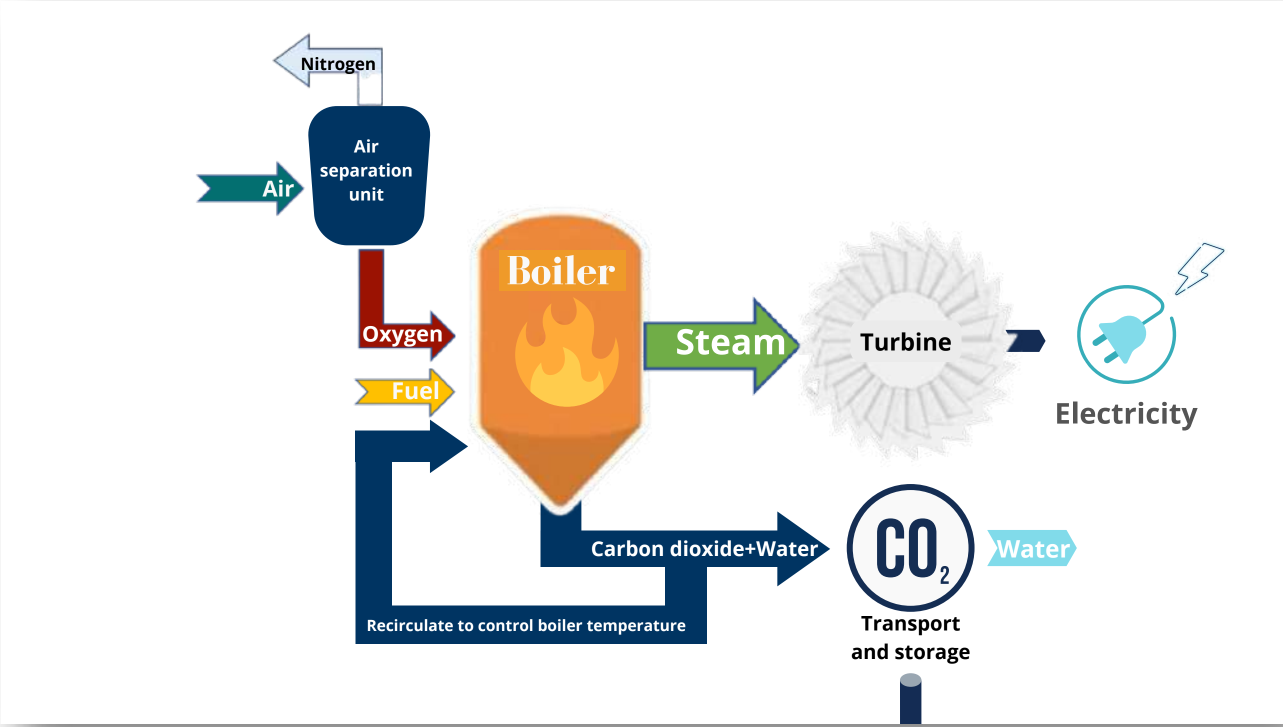
FIGURE II.1: Pre-combustion technology.

3- Oxyfuel Combustion

In the oxyfuel process, the air is split into nitrogen and oxygen, generally using an air separation unit, for the combustion of fuel with nearly pure oxygen [7].

oxyfuel combustion: burns fuel and pure oxygen instead of air, an air separation unit removes nitrogen from the air producing oxygen, which is injected with the fuel into a boiler where combustion takes place, steam is generated and used to power turbines and make electricity, the flow gas of carbon dioxide and water vapor is recirculated to manage the unstable flame and cool the boiler, leaving the capture CO_2 to be compressed and dehydrated ready for transport and Storage **(Figure II.2)**.

The technology is still on an experimental scale and under continuous development and the progress is focused on the reduction of air separation costs and the enhancement of process configuration to reduce capture costs [14].



FIGUREII.2: Oxyfuel Combustion technology.

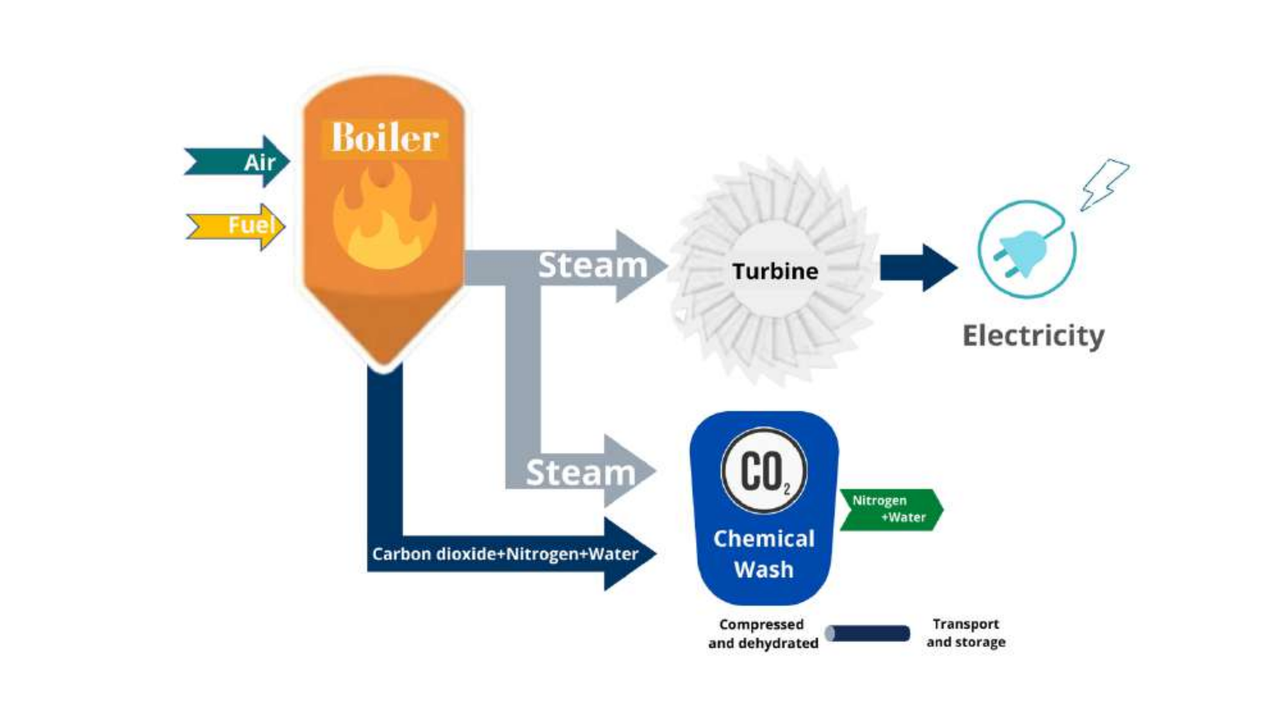
4- Post-combustion

This technology is used to capture CO_2 from the mixture of exhaust gases emitted from industrial facilities through the combustion of fossil fuels (coal, oil, natural gas), and this technology is considered one of the proven techniques at the commercial level.

The concentration of carbon dioxide emitted by combustion varies according to the industrial activity and the type of fuel, for example: the percentage of carbon dioxide when burning coal to produce electric power ranges (12%-20%), while when using natural gas, it ranges between (3%-4%) [16].

This technology is widely used to capture the carbon dioxide produced by electric power plants, and contributes to reducing carbon dioxide emissions from them by rates ranging between 80-90%, but provided that carbon capture systems operate at high rates ranging between 85-95 % [16].

Post-combustion technology can be retrofitted to existing power plants and used on new ones, fuel is injected into a boiler and combusted in air this produces steam to power turbines and the flue gas of carbon dioxide nitrogen and water, the gas passes through a chemical wash which separates the CO_2, the CO_2 is captured compressed and dehydrated ready for transport and storage.



FIGUREII.3: post-combustion technology.

5- Technologies able to separate CO_2Pre and/or Post-combustion

There are numerous procedures or strategies for isolating carbon dioxide, whether by pre-combustion or post-combustion detainment methods, some of which are attempted and demonstrated, for example, physical or chemical absorption techniques. or a number of other techniques that are as yet under modernization and advancement like adsorption, cryogenic distillation, or membrane separation. Every technique has various benefits.

5.1- Chemical absorption

The carbon dioxide present in low levels in the synthetic gas is separated from the gasification of coal (post-combustion), or from the products of the natural gas processing processes (pre-combustion).

Depends on the principle of neutralization (the material reacts with carbon dioxide) to form a weak intermediate compound that is easy to dismantle by increasing the temperature of its original components. This reaction requires the absence of NOx, SOx, as the latter two produce salts with solvents, and small parts produce foam.

Solvents are characterized by high efficiency and thermal stability, which facilitates their interaction with carbon dioxide, as they are available and at a low cost (eg: NaOH NH_3 H_2O MEA DEA TEA) [17].

$$C_2H_4OH\ NH_2 + H_2O + CO_2 \leftrightarrow C_2H_4OHNH_3 + HCO_3^-$$

One of the disadvantages of this technology is that it is used to separate low percentages of carbon dioxide, which leads to the need for large and many equipment and greater energy consumption, and the use of some amino solvents may lead to problems with equipment corrosion, deterioration of the solvent or its loss by evaporation, which contributes to high Operating costs, which led to the closure of some projects based on this technology [17].

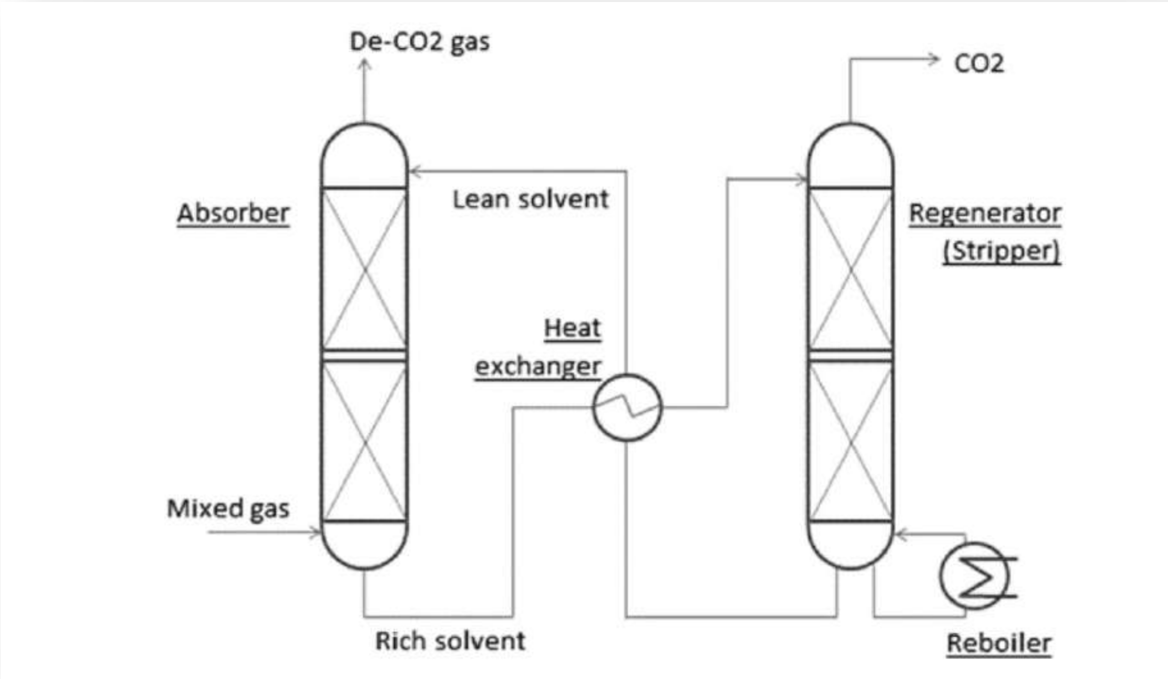


FIGURE II.4: Simplified process flow diagram of chemical absorption process for post combustion CO_2 capture [18].

5.2- Physical absorption

Suitable for separating high concentrations of carbon dioxide held by (pre-combustion) processes, commercially used to absorb carbon dioxide from syngas of coal gasification and carbon sequestration from natural gas treatment at an altitude of more than 4%.

This technique is based on Henry's law (the Quantity of gas dissolved in liquid is increased by increasing pressure and decreasing temperature).

Where carbon dioxide molecules are dispersed between solvent molecules such as (glycol carbonate, propylene carbonate, N-methyl-2-pyrrolidone), there are also two additional methods in the commercial range:

- **Selexol Process:** It uses dimethyl ether solvent polyethylene glycol.
- **Rectisol method:** it uses cold methanol.

The disadvantage of this technology is the large size of separation equipment, which is difficult to install in facilities with limited space, and this makes it very expensive too [19].

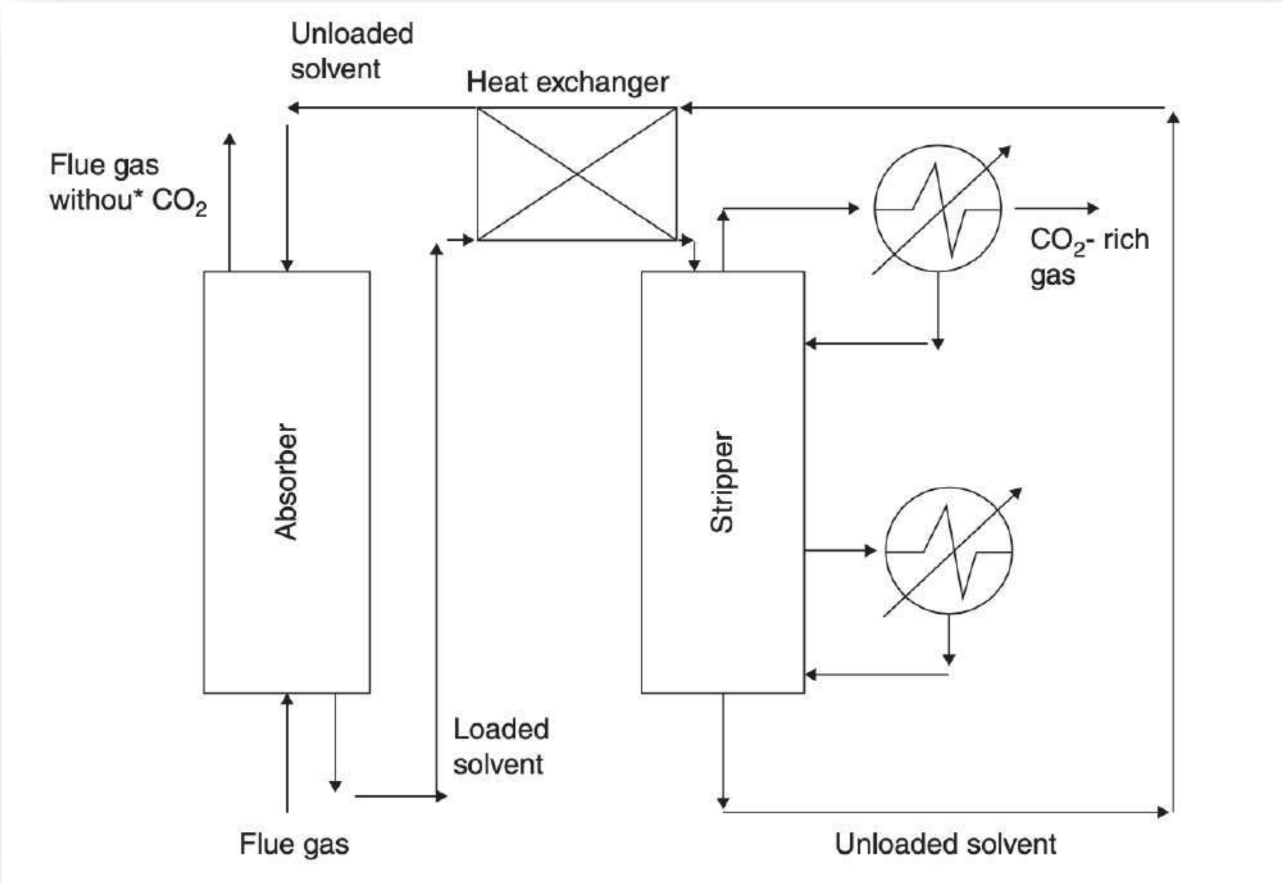


FIGURE II.5: General chemical absorption configuration [7].

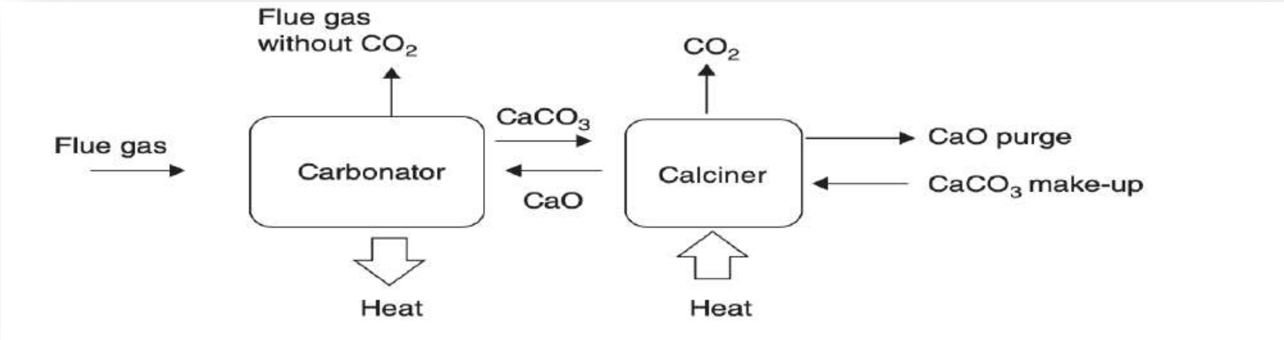
5.3-Chemical looping

Chemical looping is a form of oxyfueling in which oxygen is introduced to the combustion reactor via a metal oxide carrier, which is either fully or partially reduced in the combustion reaction, it can be applied to capture CO_2, either in a post-combustion application or in gasification systems, where it can be used in combination with a chemical loop to provide oxygen to the gasifier [20]

$$CH4_{(g)} + 4Me_xO_{y\,(s)} \rightarrow 4Me_xO_{y-1(s)} + CO_{2\,(g)} + 2H_2O_{(g)}$$

The most common types of high-temperature solids looping technologies are calcium and chemical looping combustion. Calcium looping uses CaO as a sorbent, which produces

$CaCO_3$ at approximately 650 °C, Chemical looping is a two-step conversion process where the fuel reacts with almost pure O_2 as in the Oxyfuel process, while a metal oxide acts as an oxygen carrier and reacts with the fuel, obtaining CO_2 and water. In both cases, the metal oxide or CaO is regenerated [7].



FIGUREII.6: Calcium looping system as post-combustion configuration [7].

5.4- Gas Separation (Membranes)

Membrane's separation technology has been widely used to separate carbon dioxide from hydrogen H_2 / CO_2 in pre-combustion capture techniques, and it was also used to separate it from nitrogen CO_2 / N_2 in post-combustion capture techniques, while it was used in oxygen combustion technologies to separate oxygen from nitrogen N_2 / O_2 [21].

Membranes are permeable materials that can be utilized to specifically separate CO_2 from different segments of a gas stream. It utilizes porous or semiporous materials that take into account the particular separation and transport of CO_2 from flue gas.

Membrane technology provides the prospect of changing energy-inefficient division approaches that are limited thermodynamically a membrane should possess different properties in order to be used for CO_2 capture.

This includes resistance to heat and chemicals resistance to ageing, cheap, selectivity to high CO_2 and N_2, permeable to CO_2, resistance to plasticization and the capability to be constructed into distinctive membrane modules.

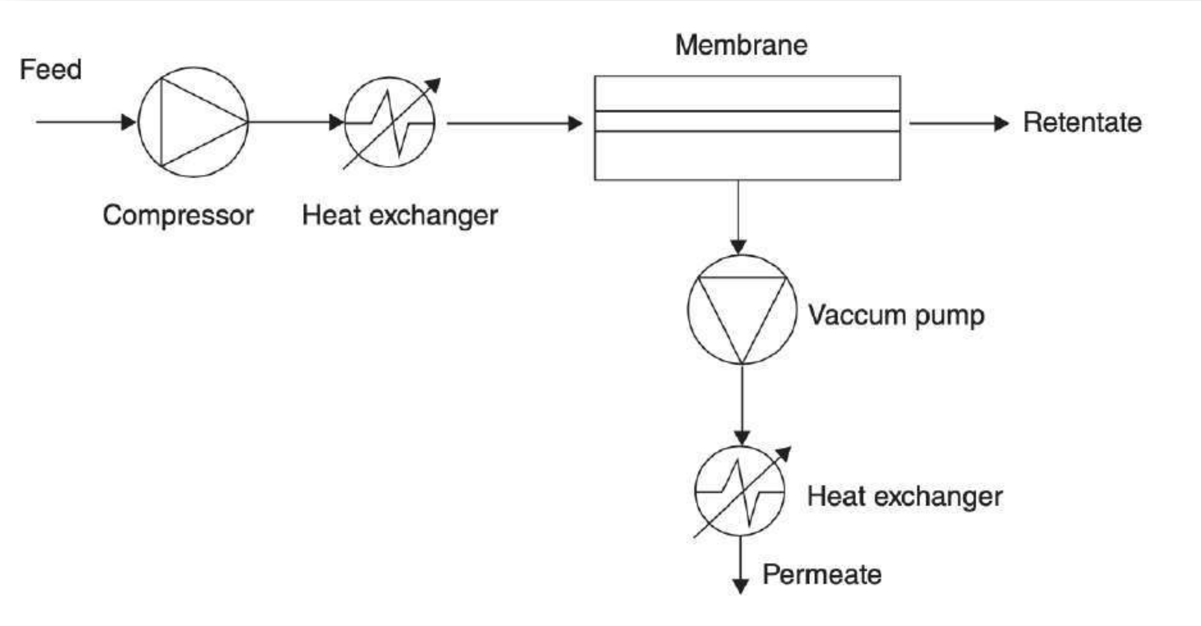


FIGURE II.7: Scheme of a single-stage membrane system [7].

Along with it, permeability and pore size of the membrane are also to be considered because higher membrane permeability gives higher-quality production Membrane based technology uses different materials for the separation process. Polyimides, a class of polymer, is considered to have exquisite thermal and chemical durability along with extensive range of CO_2 porosity.

5.5-Adsorption

Adsorption is also a different method for CO_2 separation and capture, A high pressure is applied in the system where CO_2 particularly gets adsorbed on the surface of a solid adsorbent, and then the pressure is gradually shifted to low pressure, i.e. atmospheric pressure to desorb the adsorbent and thus CO_2 is discharged for the next step of the process, i.e. transport.

Adsorption can be classified into two types: (1) physical adsorption and (2) chemical adsorption. In physical adsorption, the molecules are physisorbed because of physical forces (dipole–dipole, electro- static, apolar, hydrophobic associations, or van der Waals) and the bond energy is 8–41 kcal mol^{-1}, while in chemical adsorption, the molecules are chemisorbed (chemical bond; covalent, ionic, or metallic) and the bond energy is about 60–418 kcal mol^{-1} [7].

A theoretical advantage of adsorption against other processes is that the regeneration energy should be lower compared to absorption because the heat capacity of a solid sorbent is lower than that of aqueous solvents.

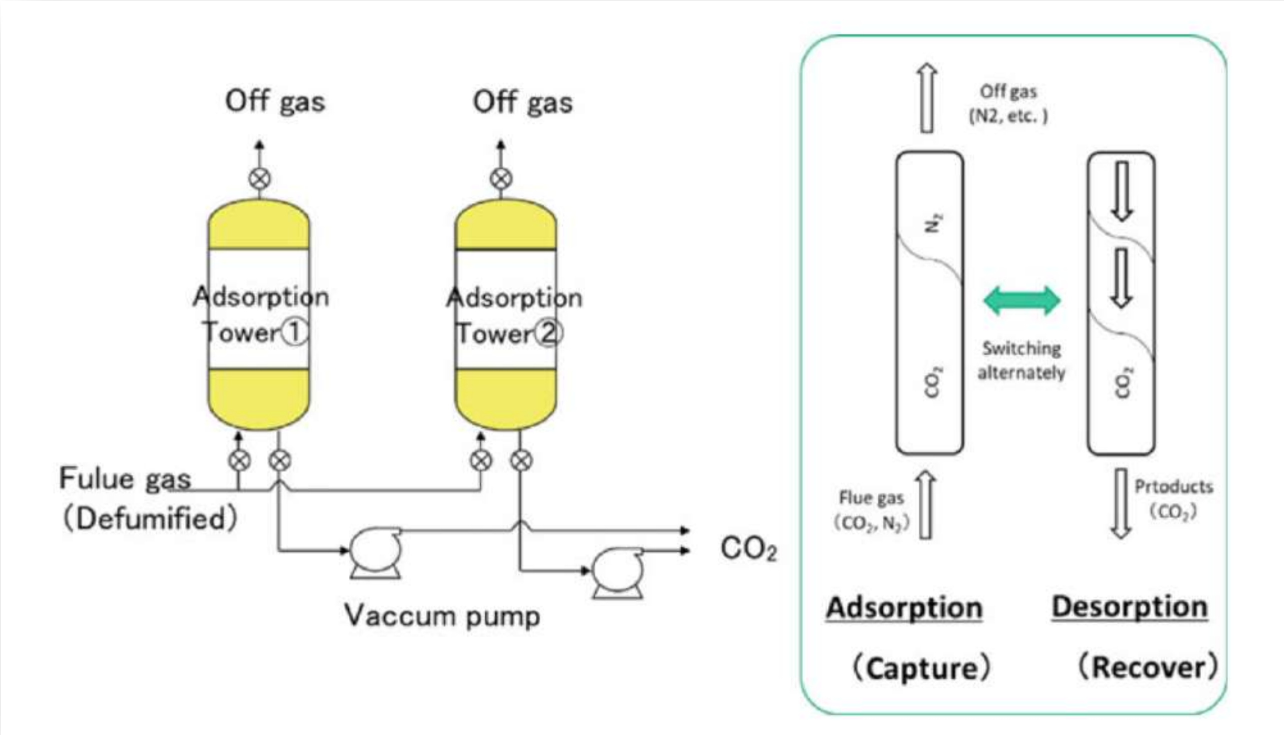


FIGURE II.8: Principle of adsorption separation method [18].

5.6- Cryogenic Distillation

This technology is used to separate carbon dioxide gas, which amounts to about 90% of the flue-exhaust gas mixture. This process depends on the condensation of carbon dioxide gas, and its transformation into a liquid at very low temperatures, to facilitate its separation from the rest of the components of the mixture that are in the gaseous state [22].

The cryogenic CO_2 capture process dries and cools flue gas from existing systems, modestly compresses it, cools it to a temperature slightly above the point where CO_2 forms a solid, expands the gas to further cool it, precipitating an amount of CO_2 as a solid that depends on the final temperature, pressurizes the CO_2, and reheats the CO_2 and the remaining flue gas by cooling the incoming gases. The final result is the CO_2 in a liquid phase and a gaseous nitrogen stream. CO_2 capture efficiency depends primarily on the pressure and temperature at the end of the expansion process. At 1 atm, the process captures 99% of the CO_2 at -135 °C and 90% at -120 °C. These are relatively mild conditions as compared to competing processes. Most alternative processes are not reasonably capable of achieving 99% CO_2 capture. Furthermore, the captured CO_2 has virtually no impurity in it [22].

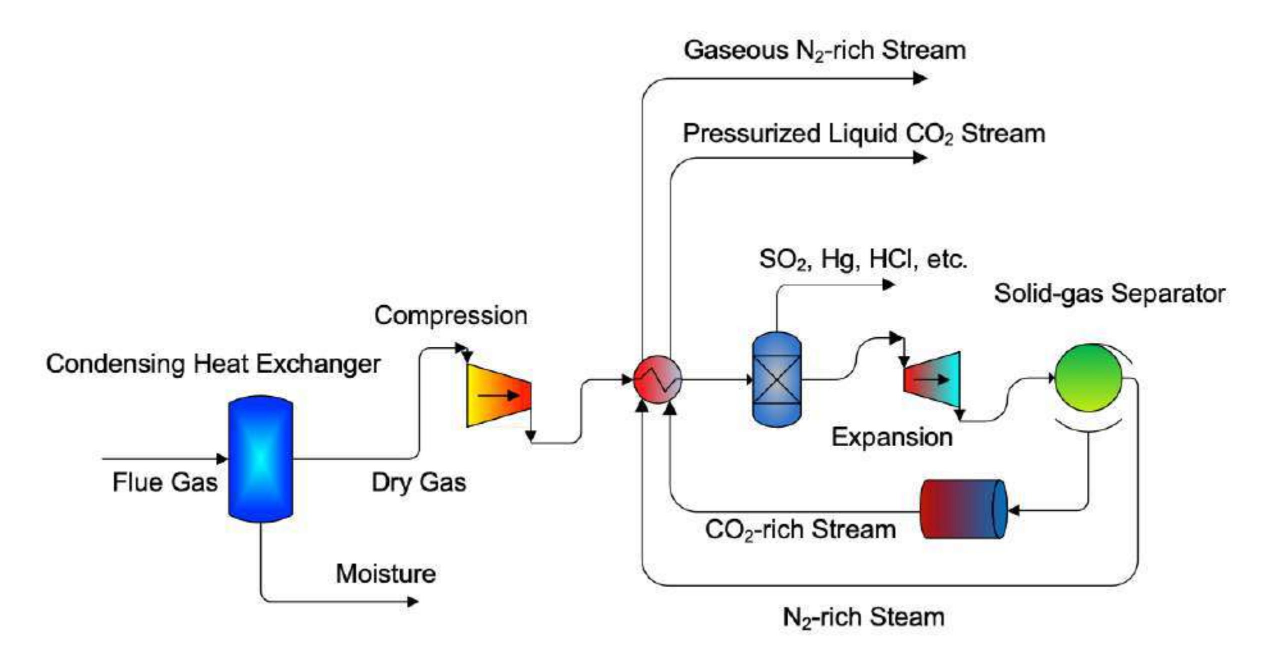


FIGURE II.9: Simple schematic diagram of the cryogenic carbon capture process [22].

5.7- Fuel Cells

Fuel cells convert chemical energy of a gaseous fuel directly into electricity and heat. The fuel is oxidized electrochemically, which leads to lower exergy losses compared to direct combustion.

In general, fuel cells are classified by the electrolyte material and their operating temperature. Low-temperature fuel cells include alkaline fuel cells (AFCs), phosphoric acid fuel cells (PAFCs), and proton exchange membrane fuel cells (PEMFCs), while high-temperature fuel cells refer to Molten carbonate fuel cells (MCFCs) and solid oxide fuel cells (SOFCs), When MCFCs/SOFCs are fueled with natural gas or syngas, CO_2 capture can be implemented at different points, for example, after the fuel cell.

Alternatively, H_2 can be produced by reforming/partial oxidation of natural gas or coal gasification upstream the fuel cell and CO_2 can be removed after syngas is shifted by means of physical solvents, membranes, or adsorbents – «pre-anode CO_2 capture,» similar to pre-combustion, Fuel cells generally operate with an approach that is similar to the «oxyfuel» concept, oxidizing fuel with oxygen extracted from air while generating power and releasing concentrated effluents at the anode outlet **(FIGURE II.9)**.

In this configuration, the fuel cell operates with a post-combustion approach, although also oxidizing a minor portion of additional fuel with the same «oxyfuel» features discussed above. The parameters affecting the selection of operating conditions of the SOFC/MCFC are stack size, heat transfer rate, voltage output and cell life, load requirement, and cost. The main operating conditions are pressure, fuel utilization factor at the anode and O_2/CO_2 utilization factor at the cathode, voltage, current density, and temperature [7].

5.7.1-Solide Oxide

SOFC for CO_2 separated into first- and second-generation systems as a function of the operating pressure of it.

Low-pressure, first-generation SOFC systems are the most promising option for SOFC commercialization at large scale in the short term. Second-generation SOFC systems are high-pressure SOFCs with separate streams for the anode and cathode exhausts. This arrangement promotes the use of an SOFC system that captures and compresses CO_2 at significantly reduced costs and minimum complexity via «pre-anode» and/or «post-anode» capture. In the pre-anode CO_2 capture process, syngas is generated at high pressure through high pressure coal gasification or by reforming the natural gas available from a natural gas pipeline at high pressure.

The post-anode CO_2 capture has been extensively studied in SOFC IGCC and natural gas cycles. «Post-anode» CO_2 capture can be applied via CO_2 separation from H_2O via H_2O condensation (or via cooling, knockout, and additional drying) and can effectively result in a 100% CO_2 removal. A separation system that uses condensation followed by a cascade of flash drums can be used to produce CO_2 at high enough purity for pipeline transport at the SOFC anode exhaust pressure [7].

II.5.7.2-Molten Carbonate

MCFC is used to separate carbon dioxide through functional reactions that occur inside the cell, where the flue gas is entered to the cathode and the carbon dioxide is separated from the flue gas automatically and concentrated at the anode, in a mixture of water and small amounts of unreacted hydrogen and methane, then The "cleaner flue gas" is released to the atmosphere with a lower content of 70% of CO_2, which is transferred to the MCFC anode exhaust stream where it can be separated much more effectively, producing high purity carbon dioxide.

The main advantage in this process is that extra power is generated because the MCFC will be fueled and operated normally to carry out the separation, and it increases the overall efficiency of the power plant and compactness of the post-combustion unit, while reduces the energy penalty [7].

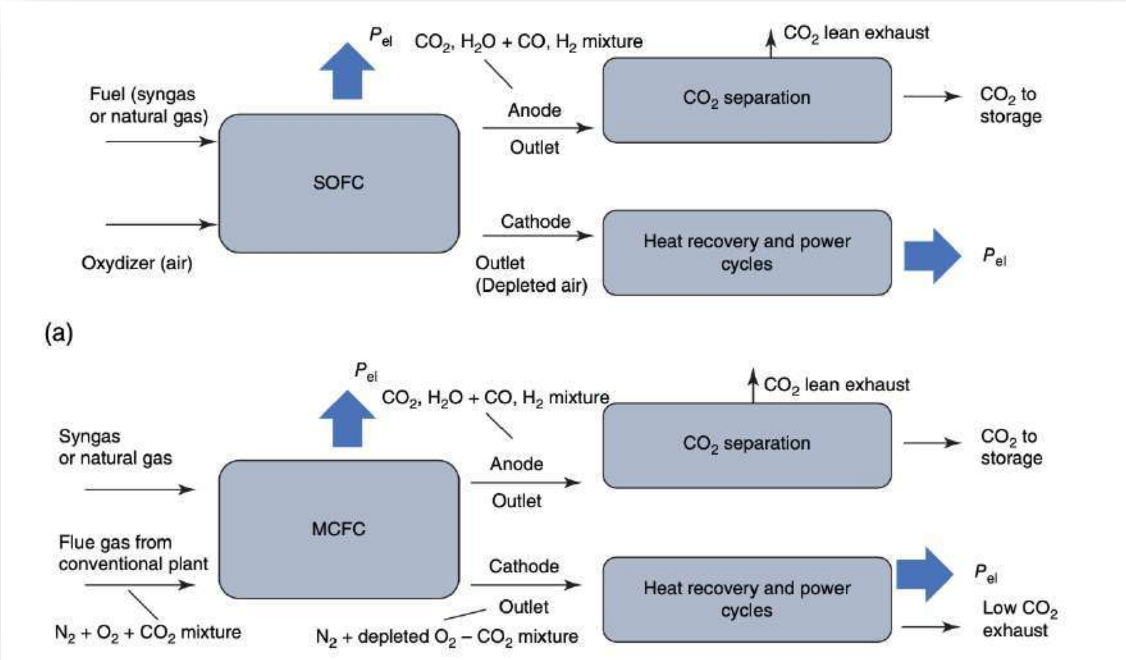


FIGURE II.10: Two main options for CO_2 capture using fuel cells [7].

Chapter: 3

Carbon dioxide valorization and waste energy recovery

1- CO_2Valorization in petrochemical processes

The production of some chemicals dominates the use of carbon dioxide as raw material, especially for the production of ammonia and urea, which are well-known and commercially applied methods and have been successfully marketed. In addition to the production of ethylene of various degrees, ethylene oxide, nitric acid, Adipic Acid, salicylic acid, annualized carbonate, polycarbonate, and caprolactam are used in the production of plastics, fertilizers, and synthetic fibers [25].

Carbon dioxide can be hydrogenated to produce various products of C_1 and longer hydrocarbon chains depending on the interaction conditions applied. Hydro is among the methods used for the production of synthetic fuels, synthetic gas, and methanol production (MOH) [26].

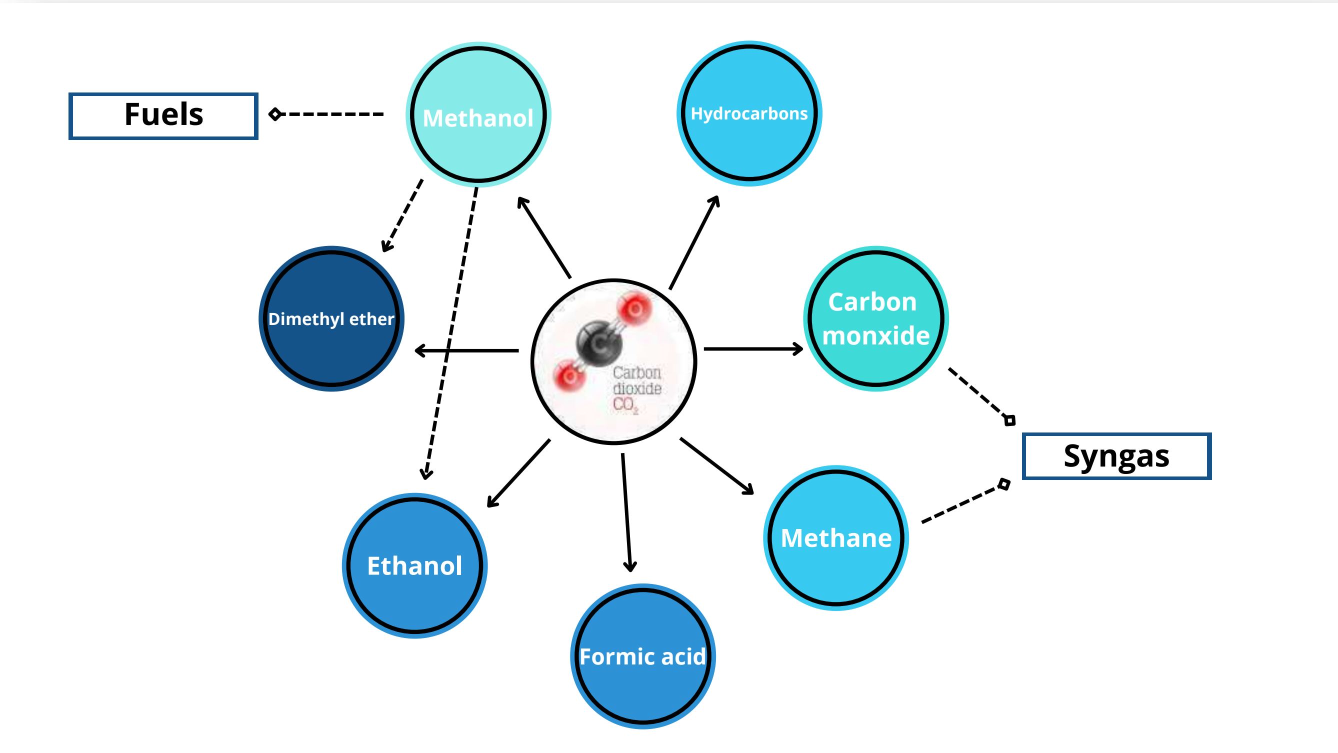


FIGURE III.1: Uses of CO_2 in the production of certain fuels and fuel additives [26].

Recently, researchers at the University of California at Los Angeles discovered a new way to use genetically engineered microorganisms to convert carbon dioxide into "isobutanol, 3 methyl 1-butanol" [26] fuels. Some companies have been able to develop biological catalysts to convert carbon dioxide into hydrocarbons such as methane, ethane, and propane gas.

1.1- Urea production:

The urea production technology is a well established and applicable technique, one of the largest commercial uses of carbon dioxide in the petrochemical industry, in some countries that capture and use carbon to produce urea: Malaysia, India, Bahrain, and UAE [27].

TABLE III.1: Commercialized carbon capture and utilization plant for urea production [27].

Operation Year	Country	Source of Flue Gas	Capacity (TCO_2/D)
1999	Malaysia	Natural gas	210
2006	India	Natural gas	450
2006	India	Natural gas	450
2009	India	Natural gas	450
2009	Bahrain	Natural gas	450
2010	UAE	Natural gas	400
2010	Vietnam	Natural gas	240
2011	Pakistan	Natural gas	340
2012	India	Natural gas	450
2013	Iran	Natural gas	132

Urea is produced using carbon dioxide by a two-stage chemical reaction: Condensation reaction is the first stage, between ammonia and carbon dioxide for the formation of ammonium carbamate, this reaction is exothermic according to the following formula:

$$\mathbf{2NH_3 + CO_2 \rightarrow NH_2COONH_4}$$

And then in the second stage, the Dehydration Reaction, in which the carbamate molecule lose a water molecule turns it into a urea, this reaction is endothermic according to the following equation:

$$\mathbf{NH_2COONH_4 \rightarrow NH_2CONH_{2\ (Urea)} + H_2O}$$

Urea production is produced in detail this way in five different production steps [28], as shown in **(FIGURE III.2).**

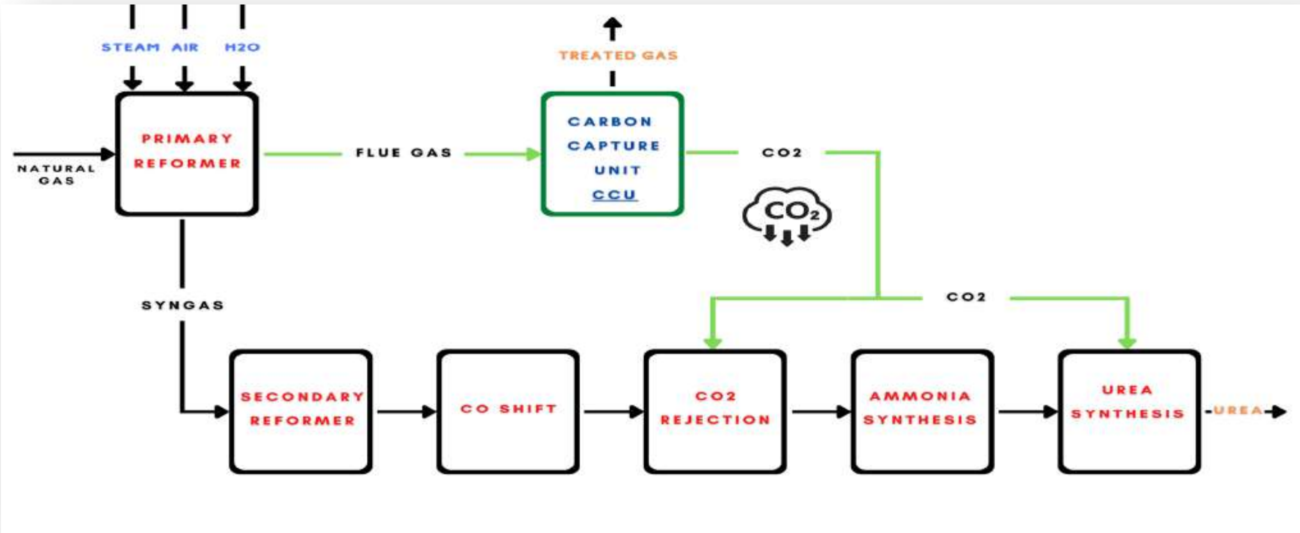


FIGURE III.2: Enhance urea production using carbon dioxide gas [27].

1.2- Melamine production

Melamine production can be enhanced by integrating ammonia and urea (CO_2 produced) production units, which are primary raw materials for its production, especially as the exhaust fumes from melamine production units contain amounts of ammonia, CO_2, and water. These can be recovered back to be used in urea and melamine production through a closed loop, as shown in **(FigureIII.3).**

melamine is combined with formaldehyde and other agents to produce melamine resins. Such resins are characteristically durable thermosetting plastic used in high-pressure decorative laminates such as Formica, melamine dinnerware, laminate flooring, and dry erase boards.

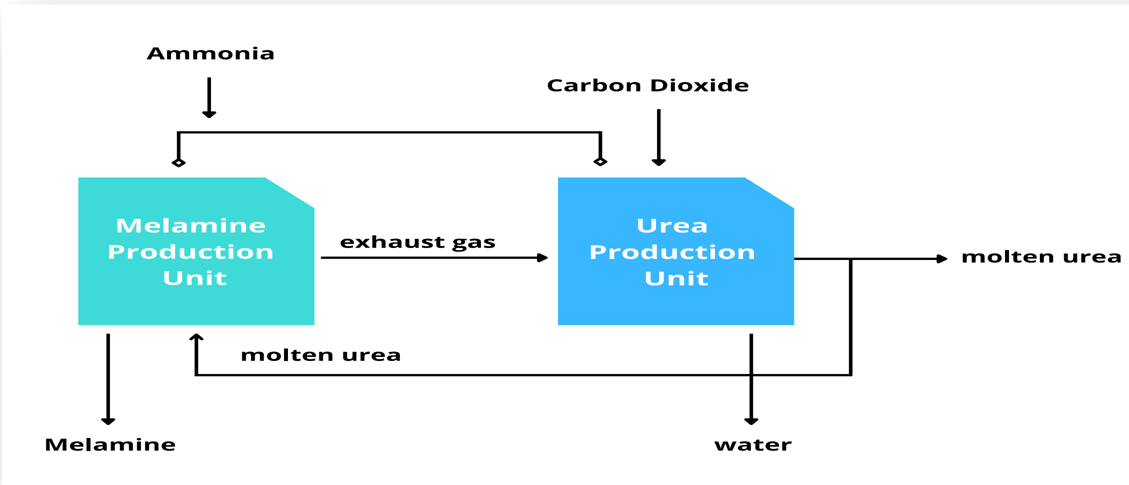


FIGURE III.3: Urea and Melamine Industry Integration.

1.3- Converting carbon dioxide to methanol and its derivatives

Renewably produced methanol has been actively promoted as an alternative fuel and chemical to the traditional energy and petrochemicals markets based on oil and natural gas. The methanol market is well-established with a global consumption of 58 million tons in 2008 and 83 % of the product going to chemicals production.

Catalytic hydrogenation of mixture of CO_2 and CO is at the basis of syngas processes. These syngas processes make it possible to produce a variety of chemical products, including methanol. Chemical reactions involved for methanol production are :

$$\mathbf{CO + 2H_2 \longrightarrow CH_3OH}$$

$$\mathbf{CO_2 + 3H_2 \longrightarrow CH_3OH + H_2O}$$

Methanol production can hence be enhanced by injecting CO_2. Both reactions are exothermic and favored by high pressures. The standard operating conditions are 50–80 bar pressure and 210–290 C temperature (reactor inlet/outlet).

There is a large group of catalysts with a mineral basis that can be used in the CO_2 catalytic gradient for methanol production, copper metal-based catalysts are the most efficient, especially copper and zinc oxide catalysts (CU / ZnO).

Methanol production has trended toward very large plants with daily capacity at 3000–5000 t. This trend has been largely due to the economies of scale and the lower production costs. The Middle East, Latin America, and Asia produce 80 %.

Methanol can be used in various sectors, and if CO_2 comes from the atmosphere in the beginning, the methanol is then considered CO_2 neutral when burned in an internal combustion engine or when used in a direct methanol fuel cell (DMFC), for instance. This is the basis for the so-called “methanol” economy where methanol replaces fossil fuels and is used as an energy carrier.

Production of higher hydrocarbons from methanol is a well established technology as well. For example, methanol to olefins and methanol to gasoline technology is well known.

Methanol is also used to produce some fuel additives, which are used to improve the properties and raise the octane number of gasoline such as : MTBE and TAME. another possibility is the formation of DME from methanol, this reaction is also exothermic:

$$\mathbf{2CH_3OH \longrightarrow CH_3OCH_3 + H_2O \qquad \Delta H = -21.25\ kJ/mol}$$

DME has many advantages: its fuel characteristics are similar to LPG, it is relatively environmentally friendly, and it is nontoxic and noncarcinogenic [28].

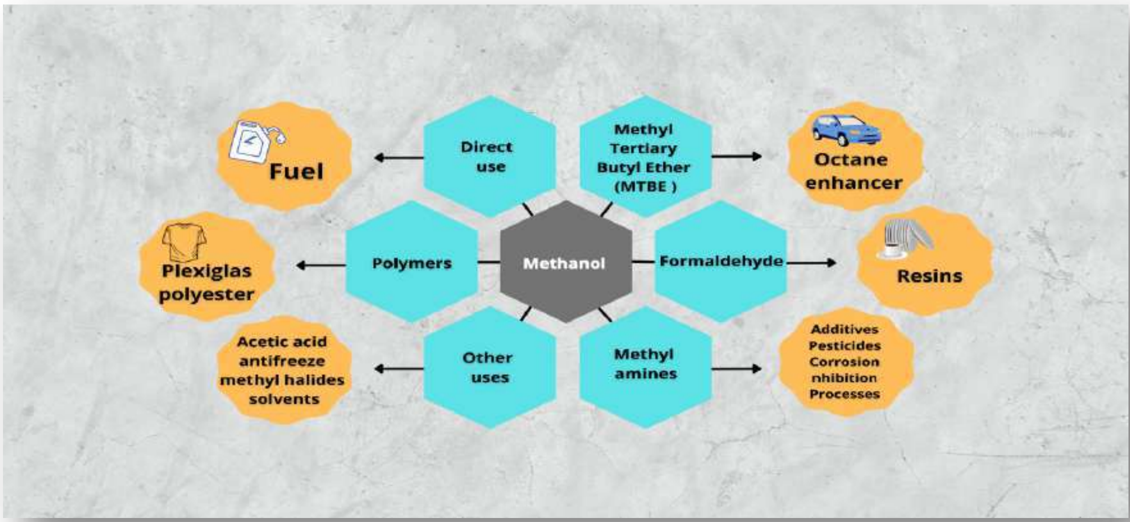


FIGURE III.4: Methanol uses [36].

The methanol production plant in Arzew is one of the best places where CO_2 can be captured and priced in Algeria, due to the existence of combustion and the need to produce methanol to CO_2. The CO_2 gas can be captured from the chimney of the reconfiguration furnace used to produce hydrogen, CO_2 and injected directly into the reactor, where it enhances methanol yields and enhances the self-sufficiency of raw materials (CO_2).

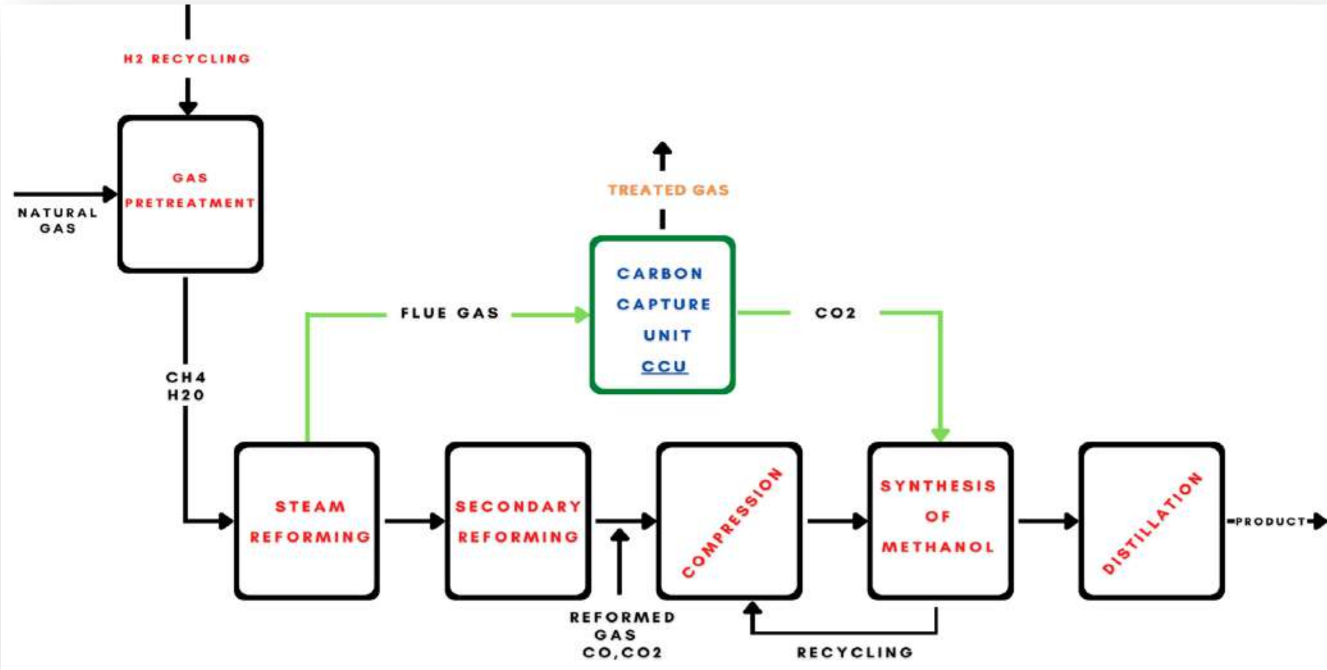


FIGURE III.5: Enhance methanol production using carbon dioxide gas in Arzew unit.

1.4- Production of HCOOH

Formic acid appears as an energy storage medium being considered as a fuel for direct formic acid (DFA) fuel cells and as a source of H_2 for hydrogen fuel cells. Formic acid is manufactured by recycling carbon dioxide gas through unfavorable thermodynamic hydrogenation because the reaction is exothermic as shown in the following chemical equation:

$$CO_2 + H_2 \rightarrow HCOOH$$

High selectivity of formic acid from electrochemical reduction of CO_2 is found on metals with high hydrogen overpotential such as indium (In), lead (Pb), mercury (Hg), and tin (Sn), depending on the metals, CO_2 pressure, and electrolytes. Tin may be the most practical candidate for production of formic acid as it has been studied extensively in the literature, as well as its availability, cost, and low toxicity to humans [28].

1.5- Methane production CH_4

The methanation of carbon dioxide, also known as the Sabatier reaction, allows producing methane from carbon dioxide and hydrogen and is a strongly exothermic reaction:

$$CO_2 + 4H_2 \rightleftharpoons CH_4 + 2H_2O,\ \Delta H_{298} = -165\ kJ\ mol^{-1}$$

The methane produced can then be used for many purposes, and again if the CO_2 comes from the atmosphere and if the hydrogen is produced from renewable sources, the methane is also considered CO_2 neutral.

The methanation reaction is also referred to as “power to gas” in some instances. This is attractive in some geographies which do not have natural gas readily available. Domestically produced renewable gas successively permits the displacement of fossil gas, thus reducing dependence on gas imports. While this synthetic natural gas is equivalent to natural gas and can be fed into the gas grid without limitations, the produced gas will be limited by the amount of unreacted hydrogen remaining.

As a CO_2 mitigation strategy, this should be pursued only when the CO_2 storage capacity is completely utilized. Natural gas itself can store CO_2; however, it is typically consumed via combustion for heat and power purposes [28].

1.6- Production of bioplastics from carbon dioxide gas

Researchers in ‘the Center of Activating CO_2 Reactions’ at the Technical University of Munich are studying the possibility of producing biopolypropylene from CO_2 gas, the researchers discovered the catalyst to accelerate chemical reactions, through which CO_2 particles can be controlled, the properties of the new polypropylene can be changed according to the required specifications to be transparent, dark, flexible, or solid. In the next few years, scientists hope to be able to use carbon dioxide (CO_2) at more then 50% as a feedstock to boost the production of polypropylene (PCO) and its use in all traditional PPROPYLENE applications. In 2021, Novomer successfully produced in the United States about 14 kilograms of "Composite" bioplastic compounds, called "Rinnivo" based on the capture of carbon dioxide, and converted to carbon monoxide to react with ethylene oxide using a special catalytic technology with a high selectivity capacity to produce "non-biotic compounds", such as "Rinnivo" for the production of carbon monoxide and its use in the production of primitive chemicals butanediol and THF, as shown in **(FIGURE III.5)** [29].

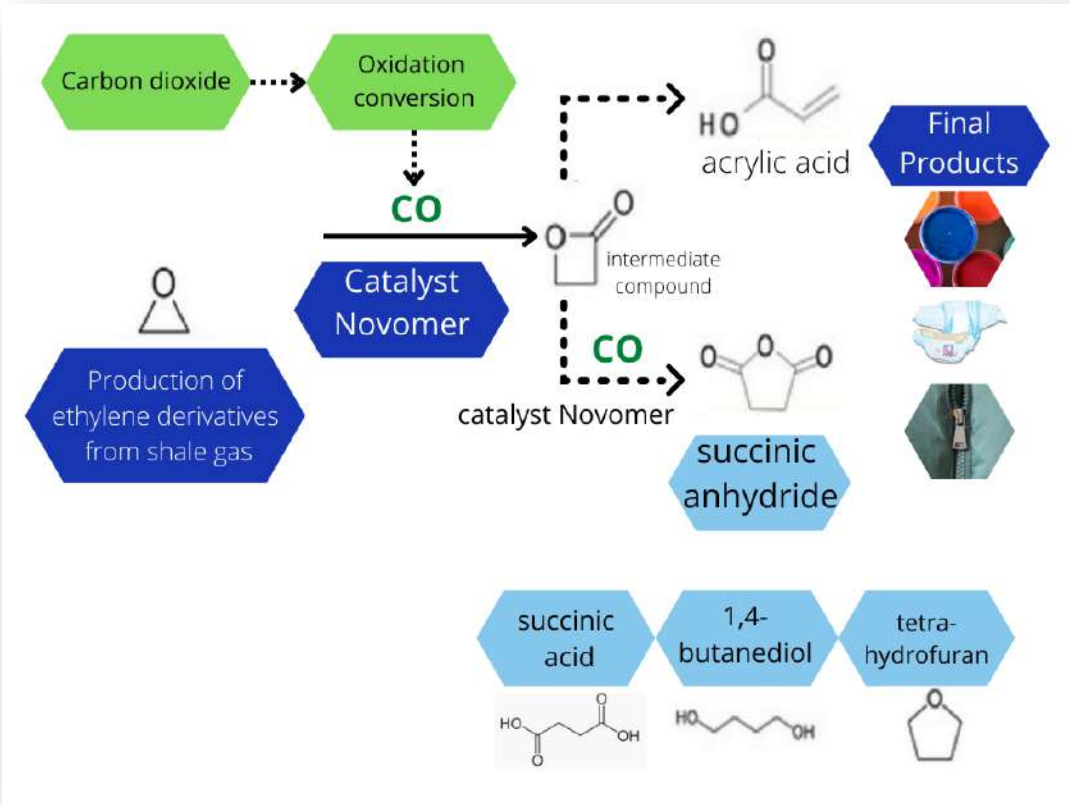


FIGURE III.6: Carbon dioxide biodegradable plastic production scheme [15].

1.7- Converting carbon dioxide to biofuel from algae:

Algae are one-celled or multicellular organisms that contain chlorophyll. They grow through a process called photosynthesis. During photosynthesis, chlorophyll absorbs the light energy of all colors but green. The green light is reflected back off of the algae which result in its green color. The photosynthesis process is the means in which algae make food and oxygen for survival. It is an endothermic chemical process that uses sunlight to turn carbon dioxide into sugars. In order for photosynthesis to occur, a combination of carbon dioxide, water, and light energy must be present. When these elements are present, algae grow[30].

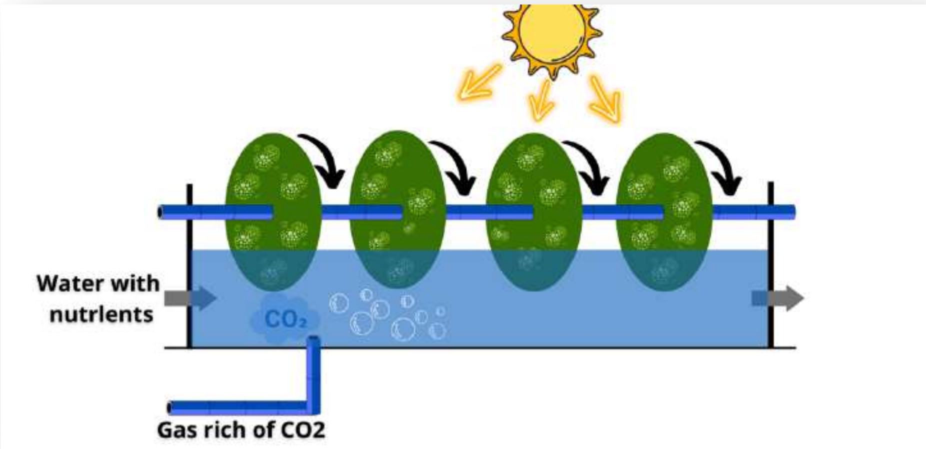


FIGURE III.7: Schematic view of the second type ALGADISK reactor [20].

The synthesis of biodiesel by trans – esterification:

Trans-esterification is the reaction of conversion of oils (triglycerides) into biodiesel in the presence of an alcohol as reagent and catalysts (acids, bases or heterogeneous: acid and base), glycerol and the co-product of this reaction. The transesterification reaction as follows [20] :

CH2OOC-R | **CHOOC-R+ NaOH + 3CH3OH ⟶ CHOH + 3 R-COOCH3** (CH2OH above and below)

CH2OOC-R			**CH2OH**	
|			|	
CHOOC-R+	**NaOH**	**+ 3CH3OH ⟶**	**CHOH**	**+ 3 R-COOCH3**
|			|	
CH2OOC-R			**CH2OH**	
Lipid		***Methanol***	***Glycerol***	***Biodiesel***

1.8- IN-SALAH geological injection

"In Salah" project to produce natural gas from the Kreishba field in the middle of the Algerian desert is one of the important projects in the North African region, and it is a joint project of the local company, Sonatrach, BP, and Statoil. The field consists of 8 natural gas production wells, and the gas produced from it contains high proportions of carbon dioxide, ranging from 4 to 9%. In order to meet the requirements of the European consumers, it is necessary to reduce this percentage to about 0.3%, and the project relied on methods of chemical absorption using a solvent."Ethanol -Amino Solution" [23].

The storage mechanism relies on pumping carbon dioxide through ground pipelines to 3 wells to produce natural gas, there are layers of saltwater below it. The results of geological studies showed that carbon dioxide would remain trapped in the saltwater layer below natural gas throughout the life of the project, and would replace the natural gas layer after the field had been fully depleted [24].

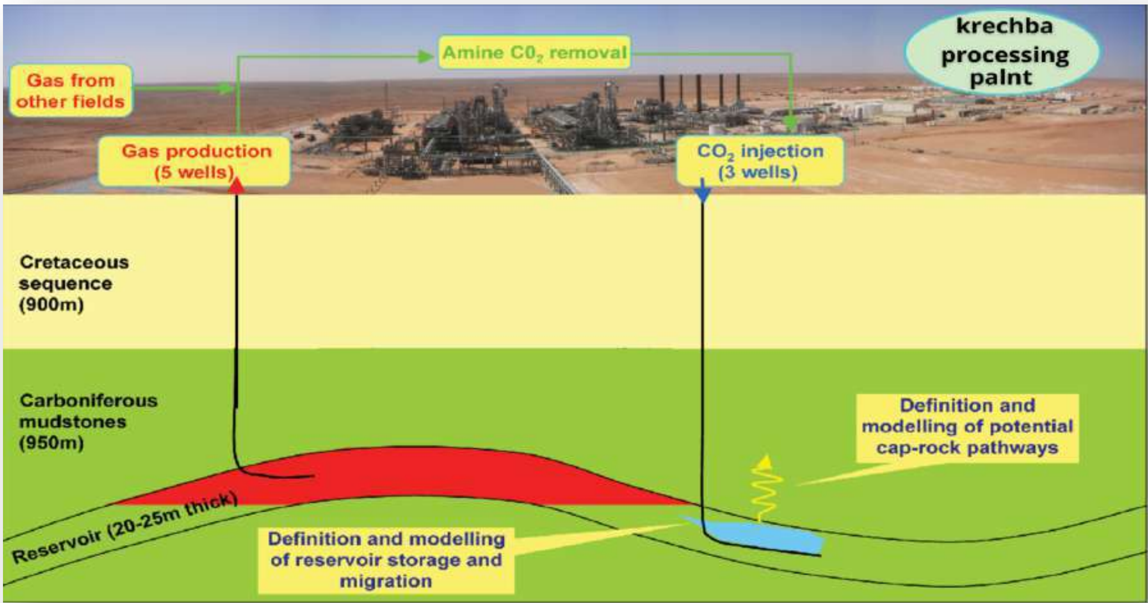


FIGURE III.8: Summary of the In Salah CO_2 injection and storage site at Krechba [23].

The project is one of the largest model research projects in the world on a commercial scale, and the project does not aim to reap any commercial benefits, but was implemented as a basis for evaluating the geological storage technology for carbon dioxide used, verifying the effectiveness of safe storage operations for it, and emphasizing that the expansion in Carbon dioxide storage projects on an industrial scale, is one of the important options to increase productivity and profitability, and help countries reduce their emissions of gases polluting the environment.

This project cost 100 million dollar to store 1 million tons of carbon dioxide per year, or 17 million tons for the life of the project, and also reduces CO_2 emissions to 60%, equivalent to emissions of 250,000 cars or 200 cubic kilometres from forests [24].

2- Waste Energy Recovery

2.1- Possibility of energy recovery (waste energy):

Industrial waste heat recovery systems come in a variety of styles and designs, but they all serve the same basic purpose. They capture the energy from hot exhaust and gases exiting industrial equipment like turbines and incinerators, then repurpose that energy to heat other materials and mediums, like oil and asphalt.

Essentially, they capture heat that would otherwise be wasted and enable a facility to use that heat and energy for other purposes and processes. They are ideal for use in a wide variety of applications and industries, and can positively impact your plant from an efficiency standpoint [37].

2.2- Some wasted energy recovery process

2.2.1- Heat Recovery Steam Generator (HRSG)

A heat recovery steam generator (HRSG) is one of the major pieces of equipment in a gas turbine combined cycle power plant that boasts a high thermal efficiency and produces minimal CO_2 emissions. An HRSG is a kind of heat exchanger that recovers heat from the exhaust gases of a gas turbine to an extreme degree. The heat is recovered in the form of steam which is served as the power source of a power-generating steam turbine.

For the heat-transfer tubes of an HRSG, finned tubes with excellent heat-transfer performance are employed. By adopting a compact design, the installation footprint of the equipment is reduced.

In addition, Selective Catalyst Reduction (SCR) equipment is installed inside the HRSG, reducing the content of nitrogen oxides in the exhaust gases released into the atmosphere [38].

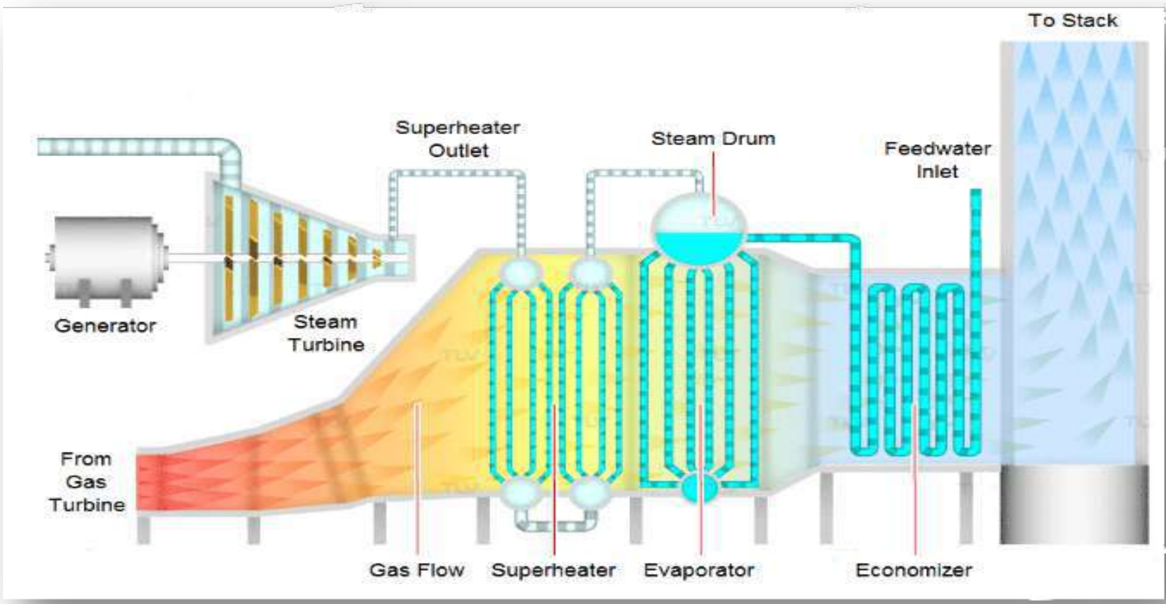


FIGURE III.9: Heat recovery steam generator [39].

2.2.2- Waste Heat Boiler (WHB)

Using a principle similar to economizers, waste heat boilers recover heat generated in furnaces or exothermic chemical reactions at industrial plants. These locations may contain significant energy that should not be wasted up a stack. Instead, this energy can be captured to generate low-to-medium pressure steam in a waste heat boiler (WHB).

A WHB can also be used to remove the heat from a process fluid that needs to be cooled for either transport or storage, and generate steam from that heat. The steam generated in WHB may be used for heating applications, or to drive turbines that generate electricity, compress vapors, or pump liquids.

WHB steam may contain significant wetness, so it is recommended that a high efficiency separator and steam trap combination is installed to ensure that the WHB delivers optimal quality steam to the recipient process [39].

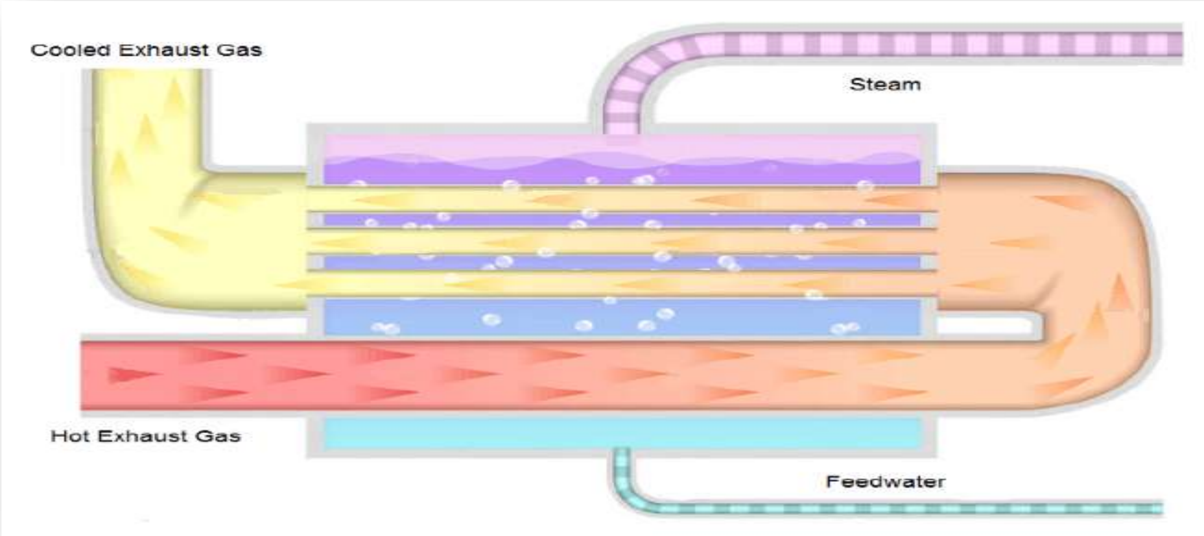


FIGURE III.10: Waste heat boilers [39].

2.2.3-Organic Rankin cycle

The organic Rankin cycle operates on the principle of the Clauseus-Rankin cycle; however, the system uses organic materials with low boiling points and high vapor pressure as a working liquid to generate energy instead of water or steam. The use of organic fluid as a working liquid has been shown to make the system suitable for the use of low-waste heat and for power generation using energy sources such as geothermal, biomass, and solar energy applications.

An organic ORC system usually consists of a heat exchanger which is connected to an evaporator and a preheater in a cycle, and a recuperator that is linked to a condenser. In this way, when the waste heat moves from the source and passes over the heat exchanger, the heat exchanger heats the mean liquid that then rotates through the evaporator and preheated. The organic liquid is heated by an intermediate liquid and evaporates into superheated steam.

The vaporized organic liquid passes a high amount of heat content through the turbine and the steam expands causing the turbine to spin and generate electricity. The steam then comes out of the turbine and passes over the recovery machine to reduce the temperature and heat the organic liquid at a later stage.

In a capacitor, air or water from a cooling tower or the environment condenses organic vapor back into a liquid. Once the fluid has reached the pump, the system is compressed to the required level and the fluid will then pass back to the recovery unit where it is reheated, and the cycle repeats [37].

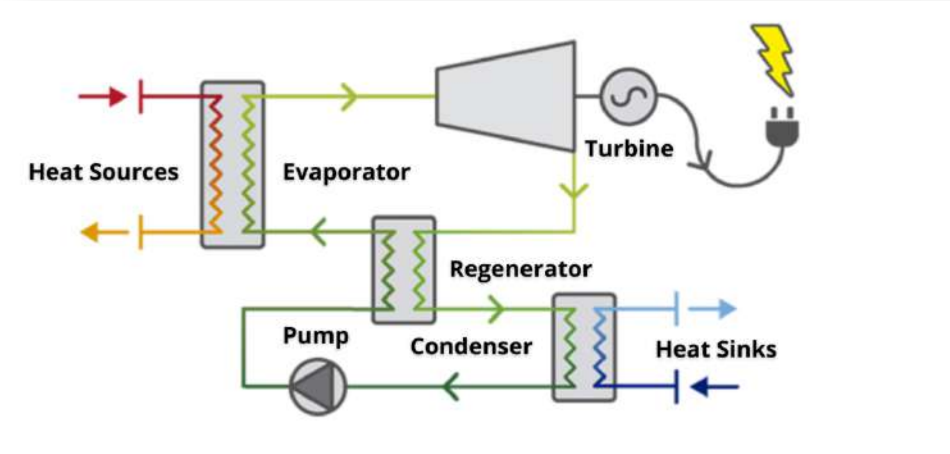


Figure III.11: Schematic of a Typical Organic Rankin Cycle [40].

2.2.4-Heat Recovery with pre-heater

Preheaters are used to recover heat from the flue gases (in some cases two preheaters can be used) and this heat is used to increase the temperature of the oil before it enters the furnace. Pipes are placed near to chimney and the oil passes through them for preheating, the heat is extracted from the flue gases and the oil is transferred to the furnace at a high temperature. The portion of the heat that would have been wasted is used to raise the efficiency of the furnace, reduce fuel consumption and reduce greenhouse gas emissions.

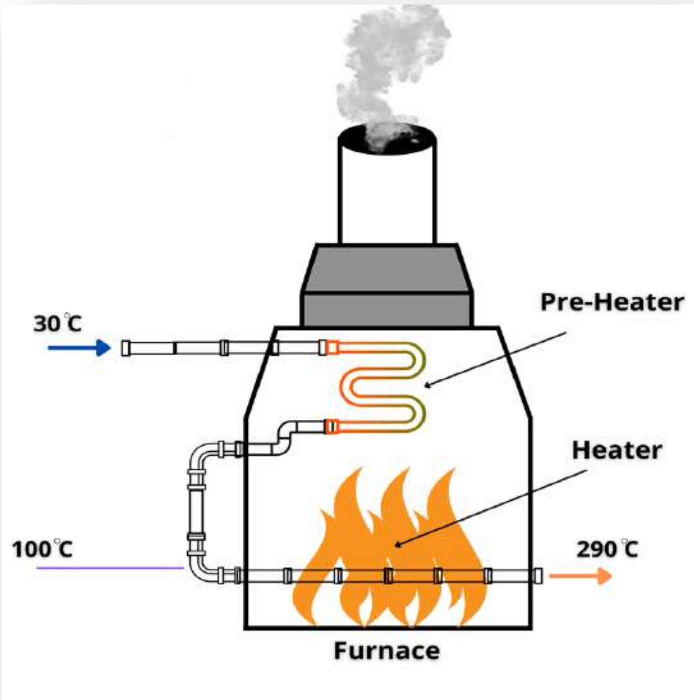


FIGURE III.12: Preheater position on furnace.

SOURCES OF CARBON DIOXIDE EMISSIONS AND WASTE ENERGY IN ALGERIA (LPG-ZCINA)

Chapter:4

1- Sources of CO_2 emissions in the industrial field

The main sources of CO_2 emissions are essentially represented by combustion sources using fossil fuels. In the industrial field, there are equipment that are considered the main emitters of carbon dioxide, including:

- Furnaces.
- Turbines.
- Torches.

1.1- Furnaces

1.1.1- Definition of a furnace

Furnaces are devices in which fluids are heated by the fumes produced by the combustion of a liquid or gaseous fuel. it is directly heated because the heat from the fumes is transferred directly to the cold fluid which circulates in a tubular coil.

These furnaces are distinct from indirect heating furnaces, in which the fluid to be heated circulates in a tubular bundle bathed in a hot fluid, and then heated directly by the fuel fumes [31].

1.1.2- Construction of a furnace

- **Radiant section:** Consists essentially of a combustion chamber, in which tubes are arranged and connected to each other by bends. The fluid to be heated circulates inside this bundle of tubes. Heat transmission is mainly by radiation and a little fraction of the exchange is also done by convection between the fumes and the tubes [31].
- **Convection section:** In order to recover the sensible heat of the fumes, the fluid circulates at high speed through a bundle of tubes, where the exchange is carried out by convection. These tubes can be lined with needles to increase the exchange surface on the fume side. The efficiency depends on the temperature of the heated fluid, but also on the size of the exchange surface that has been installed [31].
- **chimney section (stack):** The flue gas stack is a cylindrical structure at the top of all the heat transfer chambers. The breeching directly below it collects the flue gas (whose temperature is often above 300°C) and brings it up high into the atmosphere where it will not endanger personnel [31].

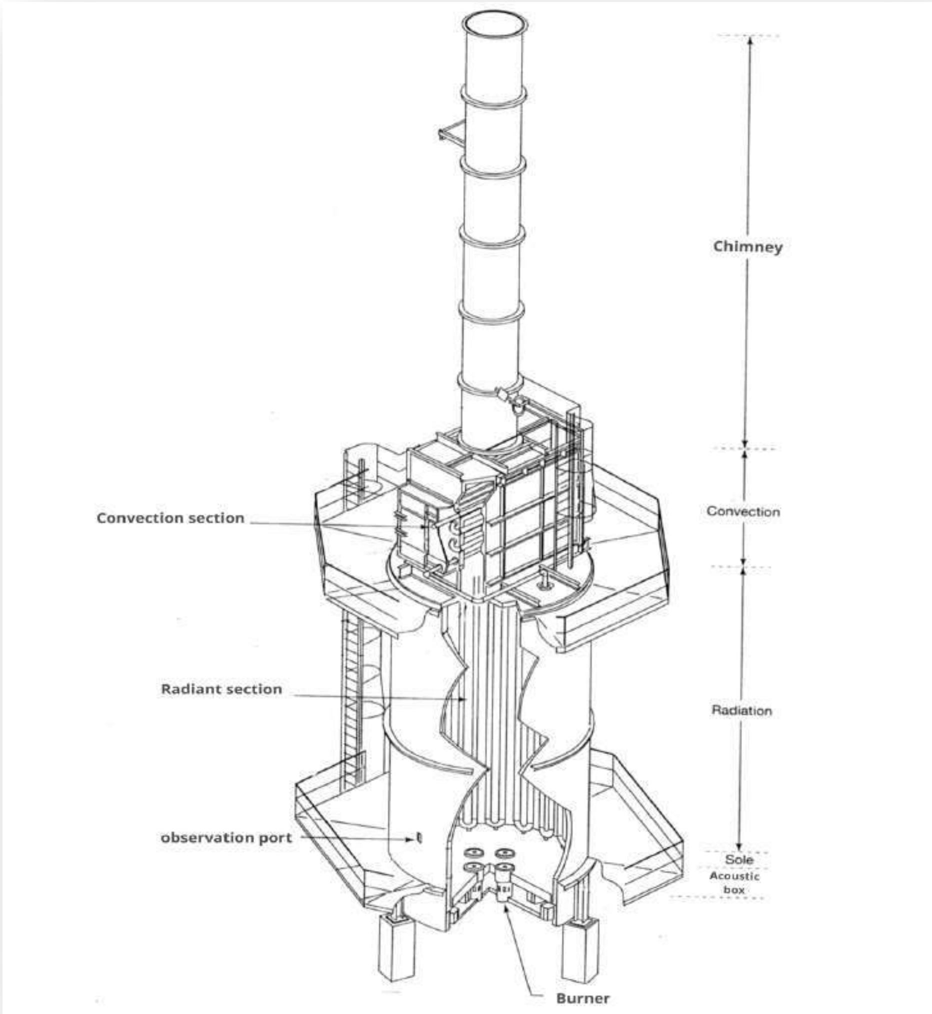


FIGURE IV.1: Schematic diagram of an industrial process furnace [31].

1.2- Turbines

1.2.1- Gas Turbine Definition

The gas turbine working principle mainly depends on the Brayton cycle or Joule cycle [32].

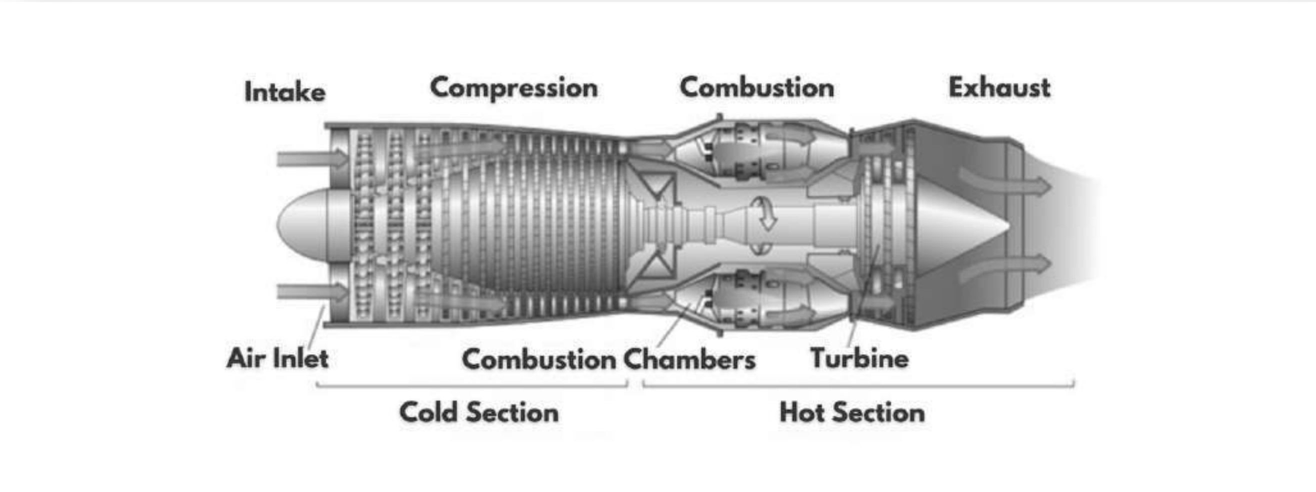
The Brayton cycle states that it is a thermodynamic cycle that explains a particular heat engine operation that has gas or air as its working fluid. Sometimes, it is also called the Joule cycle. Throughout this Brayton cycle, the mixture of air-fuel is burned, pressurized & supplied through a turbine & discharged.

A combustion engine within LPG units used to change the natural gas or fuels of liquid to mechanical energy is known as a gas turbine. This energy is used to spin the rotor within the compressor to charge gas pressure once the air enters into the inlet of the turbine, the compressor in the turbine increases the pressure of air before it goes into the combustion chamber.

After that, this compressed air is mixed with fuel & ignited to create an expanding gas. At last, this hot gas drives the turbine & spins a compressor to compress the gas [32].

1.2.2- Gas Turbine Construction

- **Suction:** In the suction process, the turbine sucks the air from the atmosphere to the compression chamber then the air is transmitted to the compressor [32].
- **Compression:** In the compression process, once the air comes into the compressor, then it reduces the air & changes the energy from kinetic to pressure. After this, the energy changes the air into high-pressure air [32].
- **Combustion:** After the process of compression, the compressed air moves into the combustion chamber. This chamber includes an injector that injects fuel into the combustion chamber and mixes the fuel with the air. Once the mixing is done, the chamber ignites the mixture of air & fuel. This mixture changes into high-temperature & high-pressure gases because of the ignition process [32].
- **Turbine:** As the combusted gas enters into the turbine section, some energy of this gas transforms into mechanical energy, and some energy is exhausted. As the combustion gas expands through the turbine, it rotates the turbine blades. The rotating blades have a dual function: they run the compressor to draw in more air for operation and also drive a gas generator connected with the turbine [32].



FIGUREIV.2: Construction of a Gas Turbine [32].

1.3-Torches

1.3.1- Definition of flared gas

The torch (or flare) is a safety device for refineries and industries, particularly in the oil, chemical and petrochemical sectors. Its installation and use are regulated. Very visible when the flame is bright and even more when it produces a plume of smoke.

The flare networks collect depressurization gases, exhaust gases from the plant's pressure relief valves and control valves. Three types of flaring network have been defined according to the backpressure and the temperature generated by the flow of fluids in the network (HP, HT, CT) [33].

1.3.2- Description of the torch system

The flaring system is a priority system over an oil treatment plant because it ensures the protection of equipment against overpressures that could cause untimely explosions. The role of this system is to:

- Safely collect all process gas discharges to keep equipment within operating pressure in the event of depressurization or valve opening.
- Separate gas and condensates in scrubbers.
- Send the gas to the torch to be burned [34].

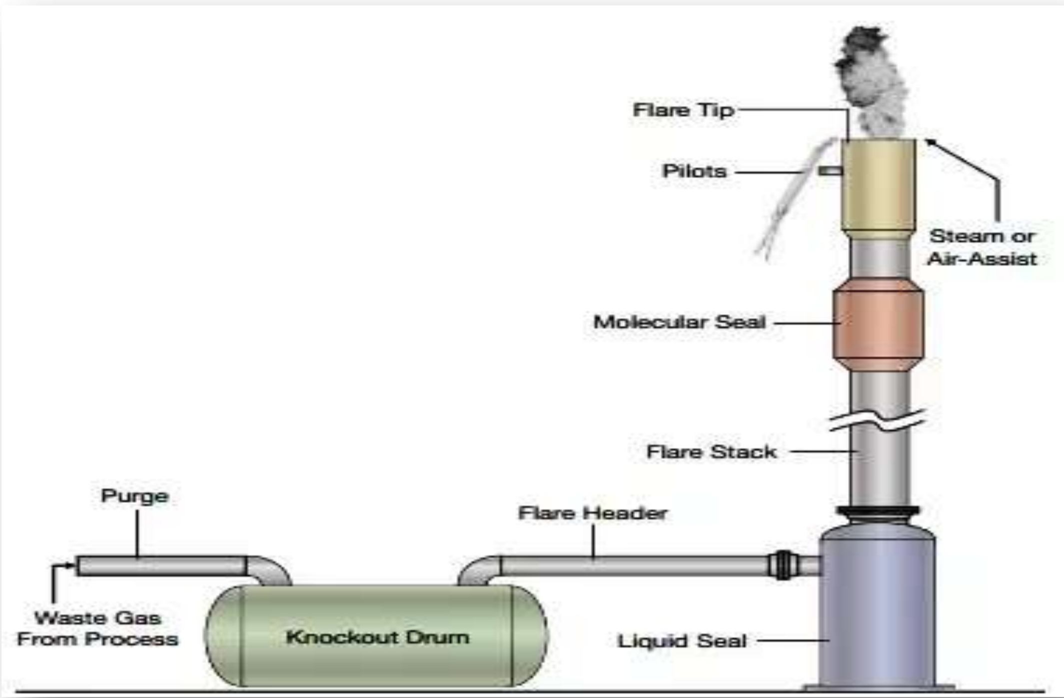


FIGURE IV.3: Flaring system.

The torch system consists of several sections [34]:

- A collection network consisting of a set of lines connecting the protective devices to the flaring drum.
- A set of depressurization devices.
- A primary collection network and secondary collectors.
- A torch barrel, at the top of which is placed a torch nose.
- A sealing device to prevent air from entering the system.

2- DESCRIPTION OF THE STUDY AREA

2.1- GENERAL DESCRIPTION OF THE ZCINA LPG PLANT [35]

2.1.1- Purpose of the ZCINA LPG Plant

SONATRACH has decided to build a new extraction unit for the associated gas liquids on the Hassi Messaoud North field, called LPG ZCINA (new Naili Abdelhalim Industrial Center Zone).

LPG ZCINA is an associated gas liquid extraction unit for receiving recoverable associated gases from the CINA crude processing unit on the Hassi Messaoud North field, and for returning depleted gas to CINA and for shipping the LPG extracted from the charge gas to a new pumping station 17 km away (station not supplied). This new unit will be located about 5 km north of CINA.

Part of the LPG plant's charging gas can also come from the LDHP oil separation unit also located in ZCINA [35].

2.1.2- Presentation of the ZCINA LPG plant

2.1.2.1- General description of the installation

This plant includes:

- Connections to CINA's existing 40” line of associated gases, to supply the feed gas and export the residual gas.
- A charging gas receiving section.
- A charging gas compression unit.
- Three gas treatment trains including a gas dehydration section, a liquid recovery section, an LPG and condensate separation section and a hot oil system.
- LPG storage and shipping pump.
- Storage and a condensate shipping pump.

- Utility Systems.
- Flaring systems.
- Product shipping lines (LPG, condensates).
- Infrastructure and buildings.

The facilities are designed to recover liquids from associated gases from the CINA crude processing plant and the LDHP oil separation unit.

The treatment of the gas consists, after receiving the gas from the existing line going to the gas re-injection sections located at the CIS, in compressing the gas at high pressure, then dehydrating it, and then dilution it in a turbo-expander.

The gas obtained is rectified in an absorber and the liquid obtained is stripped in a deethanizer to extract the liquids contained in the charge gas. A heat exchange train allows all these operations to be integrated.

The necessary heat supplement is provided by a hot oil system. The depleted residual gas is re-compressed in the existing gas line to the gas re-injection sections at the CIS via the directly coupled recompressor with the turbo-expander. The extracted liquids are finally separated in a debutanizer to obtain the LPG and condensates to the desired specifications.

2.1.2.2- Block diagram of the ZCINA LPG plant

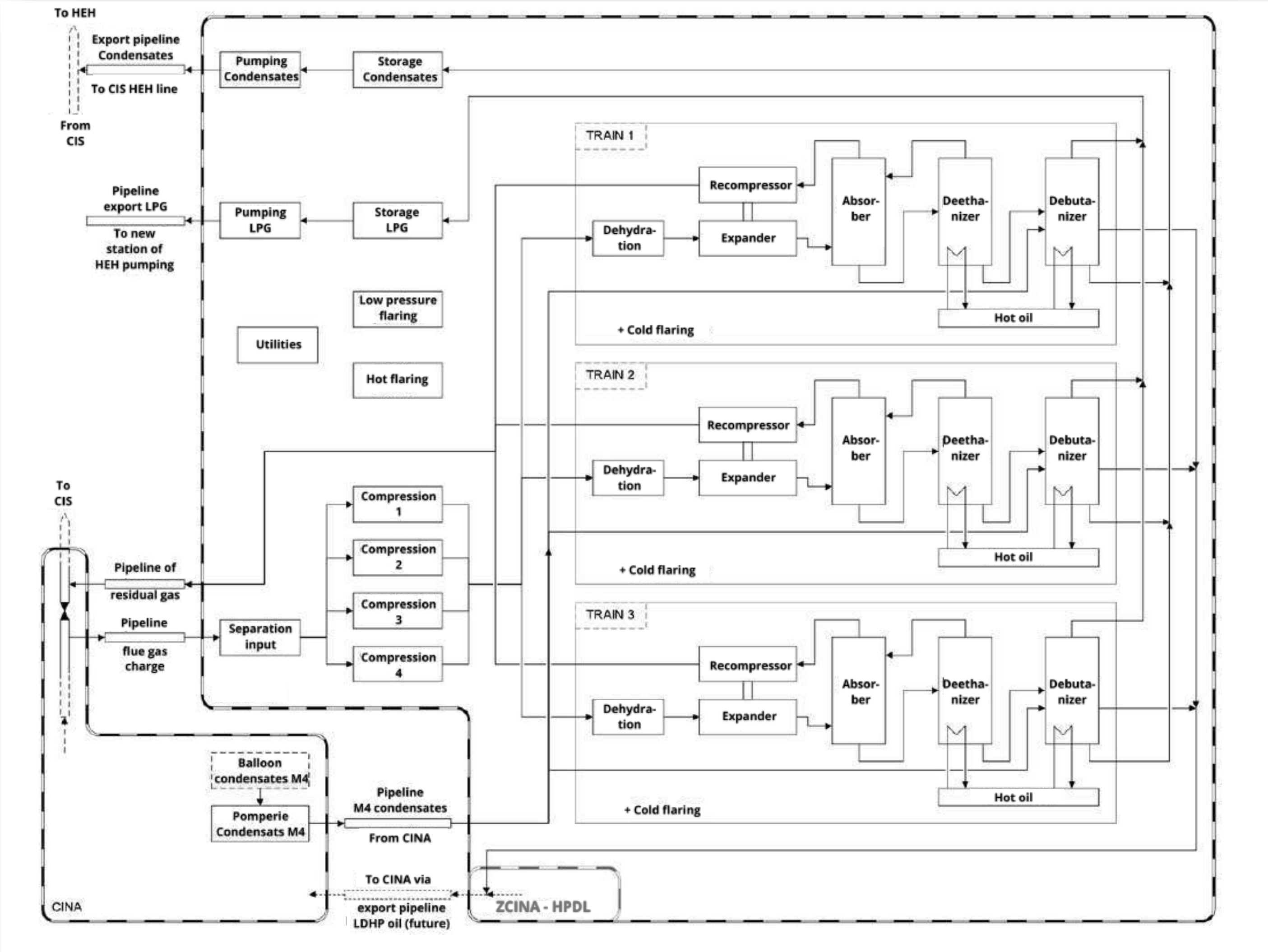


FIGURE IV.4: Block diagram of the ZCINA LPG plant [35].

2.2- Description of ZCINA LPG plant units [35]

The purpose of this section is to recall the objectives of each of the facilities of the ZCINA LPG plant in order to extract the liquids from the associated gases coming from the CINA crude processing facilities.

The Manuel includes:

- **<u>Process units:</u>**

❑ Gas supply systems:

- Charge gas line from CINA (Unit 27)
- Entrance separation (Unit 20)

❑ Compression of charge gas (Unit 23)

- ❑ Dehydration of the charge gas (Unit 24)
- ❑ Liquid supply systems:

-Import & distribution of M4 condensates from CINA (Unit 37)

- ❑ Liquid treatment trains (Unit 32):

- Cooling Section & Deethanization Section
- Debutanization section

- ❑ Storage and shipping of liquid products:

- Storage, export and recycling of LPG (Unit 33)
- LPG export pipeline (Unit 36)
- Storage, export and recycling of condensates (Unit 35)
- Condensate export pipeline (Unit 37)

- ❑ Shipping system for gaseous products:

- Residual gas export pipeline (Unit 34)

-<u>Utility units:</u>

- ❑ Fuel gas system (Unit 45).
- ❑ Hot oil system (Unit 41).
- ❑ Torch Systems (Unit 43).
- ❑ Chemical injection system (Unit 42).
- ❑ Air instrument / Air service (Unit 63).
- ❑ Nitrogen (Unit 64).
- ❑ Closed drains (Unit 57).
- ❑ Open drains (Unit 56).
- ❑ Treatment of oily water (Unit 44).
- ❑ Diesel (Unit 62).
- ❑ Raw water and drinking water (Units 50 & 53).

3- Enumerate sources of carbon dioxide emissions in the LPGZ CINA unit

This unit contains three trains for the production of LPG, in each train there are two furnaces, one for regeneration and the other for hot oil.

At the torch level, each train has its own cold torch, and there is a dedicated high-pressure torch and hot torch, two torches that include all three trains. Finally, turbines This unit contains four gas turbines.

TABLE IV.1: Number of carbon dioxide sources [35].

Furnaces	Turbines	Torches
3 Regeneration furnaces	**4 Gas turbines**	**3 Cold torches**
3 Hot-oil furnaces		**1 Hot torch**
		1 High pressure torch

4- Waste energy from CO_2 emission source

This information was taken from the control room of the ZCINA LPG unit, where we can see in the photos below, the waste heat from the Hot oil furnace (four de huile chaude) **(FIGURE IV.5)**, and the Generation furnace (four de génération) **(Figure IV.6)**, the exhaust temperature is about 300 ºC, and for the turbine it's 504.3 ºC **(FIGURE IV.7).**

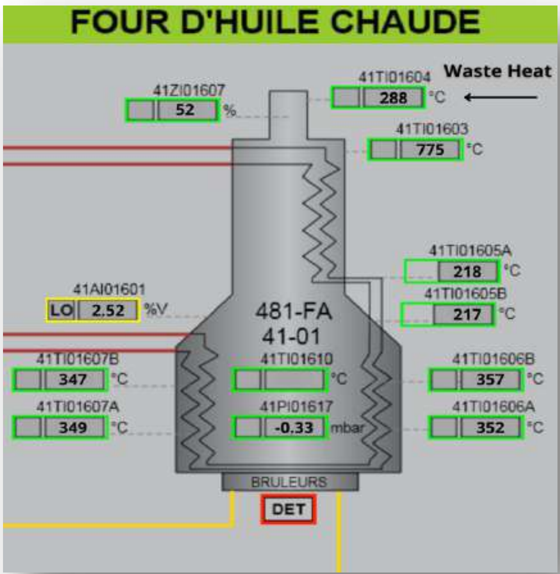


FIGURE IV.5: Hot oil furnace.

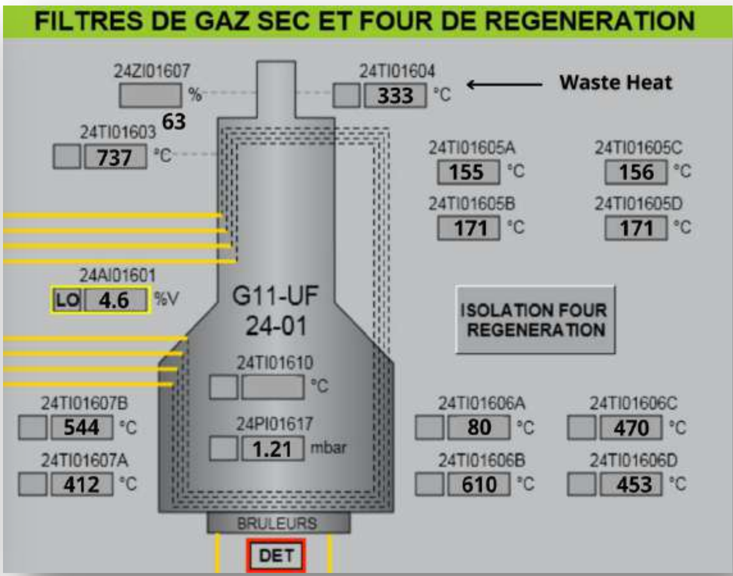


FIGURE IV.6: Generation furnace.

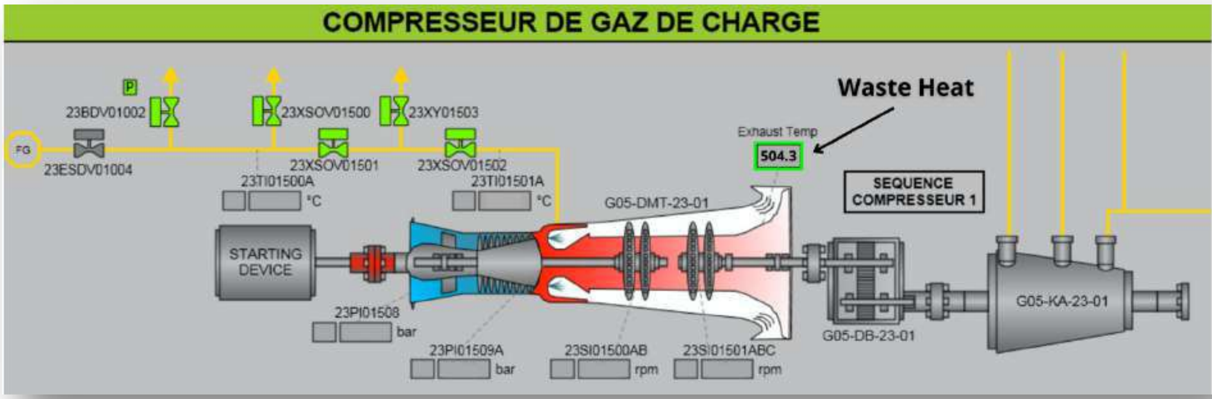


FIGURE IV.7: Gas turbine.

5- Enumeration of LPG units in Algeria

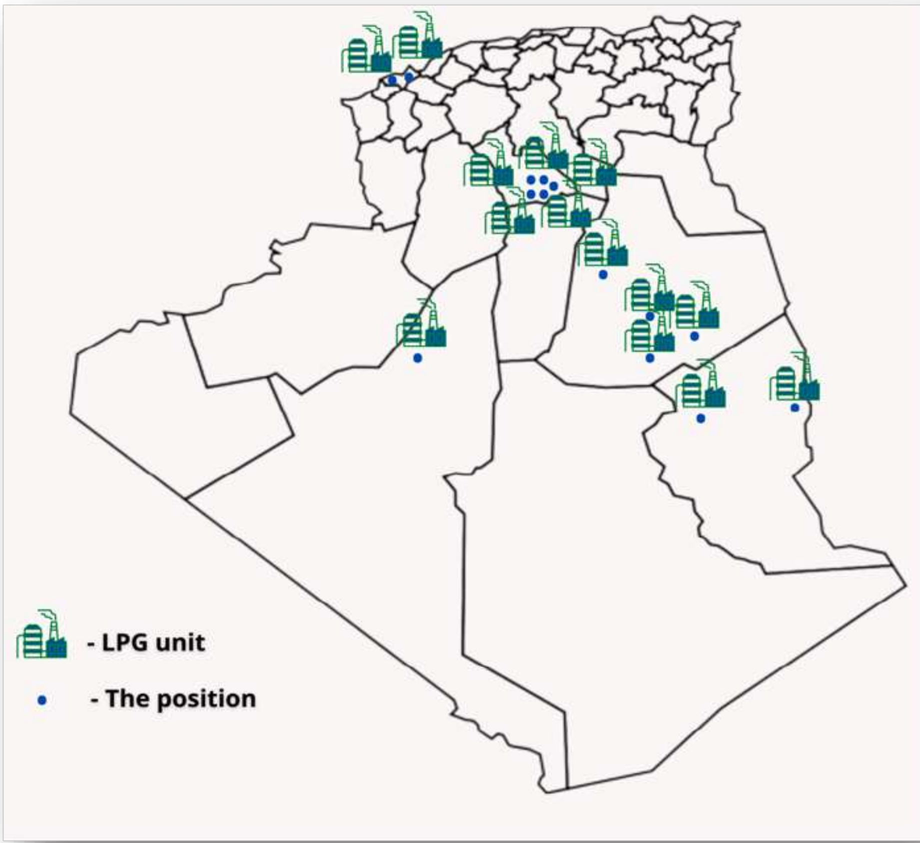


FIGURE IV.8: The location of LPG units on the national territory.

TABLE IV.2: LPG units in ALGERIA.

Stat	LPG Units	Furnaces	Turbine	Torch
Hassi Messaoud	ZCINA	06	04	05
	GPL 1	01	-	-
	GPL 2	03	-	-
Geulalla	01	02	-	-
Hassi R'Mel	05	10	-	-
Rhourd-Nouss	01	04	-	-
Sbaa Adrar	01	01	-	-
Ohanet	02	02	-	-
Arzew	01	11	-	-

6- Description of the Flareintel estimation Tool

Capterio-Flareintel- website uses independent, credible and verified third-party satellite data and incorporates Visible Infrared Imaging Radiometer Suite (VIIRS) Night fire (VNF) nightly data produced by the Earth Observation Group – part of the Payne Institute for Public Policy at the Colorado School of Mines – and other data., it shows flare sites, and calculates CO_2 emitted with million tons per year unit, and also lets know the company or the factory responsible for the torch, the exact location (place name, coordinates),This process takes place in two steps:

- **Step 1:** Flares have a combustion efficiency, say of 90, 95 or 98%. Then they calculate the CO_2 from the combustion of this amount of gas that is burned.
- **Step 2:** Calculate the methane slip - the remaining 2-10% - assuming methane is 30-83x more potent.

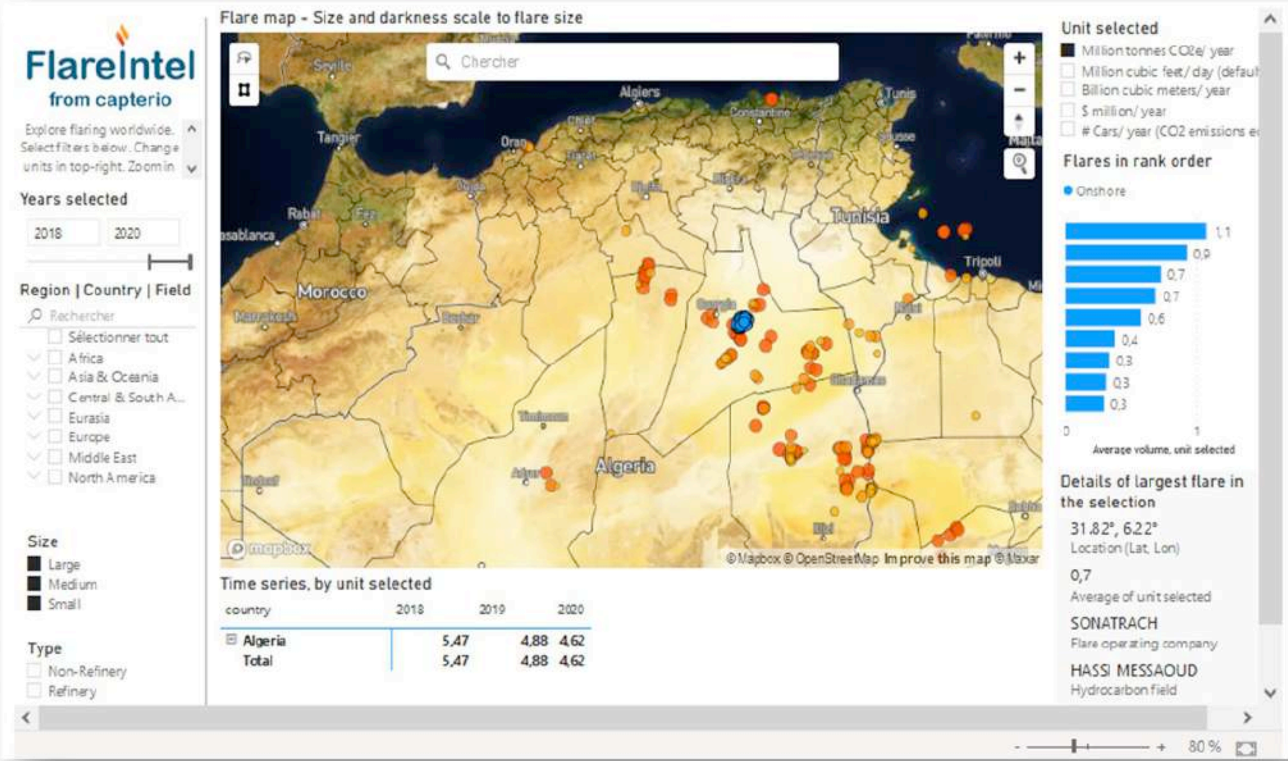


FIGURE IV.9: A screenshot from Flareintel website [6].

7- GENERAL SIMULATIONS

Nowadays, due to the great development of computer software, simulation has become a basic working tool for the chemical engineer. the latter are models of knowledge based on solving mass and energy balance sheets and equilibrium equations. Chemical process simulations traditionally used in a thermodynamic industry are capable of providing the basic process design information and are used primarily for designing new processes for optimization and evaluating changes to operating conditions.

There is a very large number of chemical process simulation software on the market. The most well-known and globally used industrial simulators are:

- Aspen Plus (Aspen Technologies).
- Design II (deWinSim).
- HYSYS, Prosim, (Hyprotech).
- PRO/II (Simulation Sciences).

The simulator is based essentially on the choice of a thermodynamic model representing the best system to be studied.

7.1- Simulation Definition

Simulation is the use of a suitable mathematical model or set of models to study the behavior of a physical system. It gives us a good overview of the system to be studied and its most important characteristics without interfering with the actual process.

7.2- Definition of the mathematical model

A mathematical model is a set of equations that describe the behavior of a system to be studied such as unit operation, phase separation, extraction, heat transfer...etc. These equations are often relationships of mass conservation, energy, momentum, and thermodynamic equilibrium. Using this mathematical aspect of reasoning, simulation offers a major and important advantage, as it provides a good approach to the behavior of the real system.

7.3- Choice of Simulation Program

To study a system and its parameters by simulation, the choice of the program is an important step that is based on the characteristics of functioning and achievements that the software must contain:

The operation of a process shall perform:

- The resolution of material and energy balances.
- Sizing of equipment.
- The economic evaluation of the process.
- The optimization of the process.

And for the realization of this one, a simulator must contain:

- A model library for calculating the physical and thermodynamic properties of pure bodies and mixtures, coupled with a database of pure bodies.
- A library of standard modules for simulating the unit operations most commonly presented in a manufacturing process.
- A library of algebraic numerical method modules.
- A library of diagnostic generation modules.

For the rest, we used HYSYS program for our study.

8- Description of the HYSYS Simulator

The HYSYS is a chemical engineering process simulation software developed by the Canadian company HYPROTECH. It was designed to address a wide range of problems from separation to distillation and chemical processing.

Engineers engaged in the design field use HYSYS software to make quick calculations using efficient models and optimal techniques.

Simulation by HYSYS reduces engineering costs by:

- Quick calculations of different designs to ensure that process equipment is correctly specified to deliver the desired product characteristics at the desired production yields.
- Creation of models that can be applied during the operation of the unit from concept design to details.

8.1- Choosing the equation of state

Simulation can be done in static or dynamic mode, based on the equation of state used for liquid-vapor mixtures and recommended for Peng Robinson hydrocarbons of the form:

$$P = [R \times T / (V - b)] - (a \times \alpha / [V (V + b) + b (V - b)]) \ [Kg. Cm-2]$$

With:

P: Pressure expressed in (Kg. Cm^{-2}).

A: Perfect gas constant that has value 8,314 Kj. $Kmol^{-1}$. K^{-1}.

T: Temperature expressed (K).

V: Volume expressed (m^3).

The simulation can take place in two modes: static and dynamic.

8.2- Static Simulation:

In static simulation, the pipe segment is used which provides a rigorous estimate of charge losses and heat transfers.

8.3- Dynamic Simulation:

To have a profile that is based on the progress of the depressurization of the buffer balloon while reducing the vapors of the propane, a dynamic simulation is required.

Estimate

Chapter: 5

Calculations

&

Results Discussion

1- Introduction

In this chapter, we evaluated the amount of carbon dioxide gas emitted by the torches at the national territory level using the Flareintel website.

Second: We calculated the amount of carbon dioxide gas emitted from the furnace, turbine, and torches in the LPG ZCINA unit, using the complete combustion reactions.

Third: We made a proposal to capture carbon dioxide and simulated it on the HYSYS program and presented the simulation results.

fourth: We presented a proposal to recover the wasted energy from the furnace with a proposal to re-design the torches to benefit from it. We simulated the technology of recovering wasted energy carbon on the HYSYS program and presented the simulation results.

fifth: We evaluated the price of the capture technology and the waste energy recovery technology and studied the profitability of both technologies.

2- Carbon dioxide estimation with Flareintel

We relied on estimating the emissions of carbon dioxide from torches on Flareintel website, which determines the locations of torches via satellite and gives the quantity of carbon dioxide emissions, in addition to key information (torch coordinates, responsible company distance of the torch from the nearest gas pipe), where we identified every flame on the national territory, or rather all the flares that were captured by the satellite, with this we arrived at the total carbon dioxide emitted by the torch in Algeria and ranked the states from most to least, where the state of Ouargla topped the ranking with 15,65 million tons per year (**TABLE V.1**), followed by Ilizi with 10,58 **(TABLE V.2**), then the remaining five states (Laghouat (**TABLE V.3**), Oran (**TABLE V.4**), Ghardaia (**TABLE V.5**), Skikda (**TABLE V.6**), Adrar (**TABLE V.7**), and Algiers (**TABLE V.8**)).

TABLE V.1: Enumeration of torches in OUARGLA region.

Region	Quantity Million tons CO_2e/year	Location (Lat-Lon)	Flare operating Company	Distance From gas pipe (km)
OUARGLA	0.08	30.39-7.91	PT PERTAMINA	5.5
	0.18	30.61-8.26	SONATRACH	52.0
	0.24	30.66-8.1	COMBANIA ESPANOLA	42.3
	0.04	30.83-8.03	SONATRACH	54.3
	0.41	31.01-8.17	SONATRACH	79.4
	0.40	31.01-8.17	SONATRACH	79.3
	0.09	31-8.02	SONATRACH	72.5

	0.31	31.06-8.03	SONATRACH	78.8
	0.28	31.06-8.02	SONATRACH	78.9
	0.06	31.18-8.11	ENI	94.1
	0.18	31.23-8.56	ENI S.P. A	89.6
	0.08	30.41-6.54	SONATRACH	10.7
	0.09	30.48-6.47	SONATRACH	7
	0.07	31.19-6.79	SONATRACH	65.8
	0.27	31.4-6.94	SONATRACH	88.6
	0.17	30.76-5.45	SONATRACH	88.5
	0.16	30.78-5.51	SONATRACH	75.8
	0.08	30.88-5.64	SONATRACH	58.5
	0.10	30.89-5.63	SONATRACH	59.1
	0.07	30.9-5.59	SONATRACH	63.7
	0.14	30.97-5.76	SONATRACH	43.4
	0.16	30.98-5.76	SONATRACH	42.6
	0.16	31.33-6.04	SONATRACH	1.6
	0.20	31.33-6.06	SONATRACH	0.7
	0.23	31.46-5.94	SONATRACH	8
	0.24	31.5-5.85	SONATRACH	17.3
	0.10	31.75-5.23	SONATRACH	0.7
	0.29	31.85-5.05	SONATRACH	2.8
	0.10	31.96-5.22	SONATRACH	1.6
	0.03	32.17-4.74	SONATRACH	14.6
	0.60	32.51-6.76	PETROVIETNAM	97.3
	0.24	32.16-6.6	SONATRACH	76.7
	0.42	32.13-6.67	SONATRACH	63
	0.03	32.16-6.44	SONATRACH	62.1
	0.04	32.19-6.39	SONATRACH	60
	0.86	31.59-5.96	SONATRACH	2.9
	0.74	31.7-5.81	SONATRACH	3.1
	0.23	31.63-5.98	SONATRACH	0.4
	0.29	31.65-5.99	SONATRACH	0.5
	0.77	31.64-6.06	SONATRACH	2.1
	0.03	31.62-6.09	SONATRACH	4.8
	0.35	31.7-5.96	SONATRACH	0
	0.69	31.7-5.96	SONATRACH	0.1
	0.03	31.77-5.95	SONATRACH	0.9
	0.95	31.66-6.06	SONATRACH	2
	1.8	31.66-6.06	SONATRACH	2.7

	0.16	31.68-6.05	SONATRACH	1.5
	0.06	31.63-6.13	SONATRACH	9.6
	0.04	31.69-6.05	SONATRACH	1.9
	0.22	31.69-6.19	SONATRACH	16.9
	0.06	31.75-6.14	SONATRACH	13.6
	0.27	31.79-6.07	SONATRACH	5.9
	0.12	31.8-6.06	SONATRACH	5.5
	0.25	31.85-6.06	SONATRACH	6.7
	0.04	31.88-5.97	SONATRACH	9.6
	0.31	31.81-6.16	SONATRACH	17.1
	0.89	31.82-6.22	SONATRACH	23.8
	0.15	31.86-6.17	SONATRACH	19.0
TOTAL	15.65			

TABLE V.2: Enumeration of torches in ILIZI region.

Region	Quantity Million tons CO_2e/year	Location	Flare operating Company	Distance From gas pipe
ILIZI	0,05	27.15-8.81	SONATRACH	72.7
	0,03	27.41-8.84	SONATRACH	47.8
	0,10	27.53-9.62	SONATRACH	53.8
	0,06	27.62-9.87	REPSOL SA	60.5
	0,06	27.64-9.87	REPSOL SA	58.3
	0,06	27.67-9.88	REPSOL SA	57
	0,05	27.69-9.89	REPSOL SA	55.5
	0,06	27.71-9.88	REPSOL SA	54
	0,06	27.72-9.92	REPSOL SA	56.3
	0,09	27.72-9.88	REPSOL SA	52.7
	0,11	27.74-9.92	REPSOL SA	54.9
	0,12	27.7-9.17	SONATRACH	2.7
	0,14	27.74-9.18	SONATRACH	4.2
	0,04	27.73-9.16	SONATRACH	1.9
	0,27	27.75-9.15	SONATRACH	0.7
	0,31	27.76-9.19	SONATRACH	4.3

	0,25	27.92-9.25	SONATRACH	1.0
	0,14	27.93-9.11	EQUINOR ASA	11.5
	0,35	28.08-9.79	SINOPEC GR	30.2
	0,18	28.19-9.8	SONATRACH	35.2
	0,25	28.14-9.49	SONATRACH	0.5
	0,08	28.15-8.97	SONATRACH	37.4
	0,16	28.45-9.13	SONATRACH	1.4
	0,15	28.47-9.06	SONATRACH	6.4
	0,19	28.53-9.12	SONATRACH	3.4
	0,09	28.62-9.79	SONATRACH	1.4
	0,30	28.63-9.79	SONATRACH	1.5
	1,11	28.74-9.79	SONATRACH	11.7
	0,12	28.92-9.75	SONATRACH	30.9
	0,12	28.73-9.15	SONATRACH	5.7
	0,22	28.71-9.04	SONATRACH	2.0
	0,10	28.71-8.95	SONATRACH	2.5
	0,20	28.7-8.74	SONATRACH	1.3
	0,06	28.66-7.91	SONATRACH	24.9
	0,35	28.6-7.71	SONATRACH	20.7
	0,15	28.65-7.68	SONATRACH	24.4
	0,16	28.58-7.65	SONATRACH	16.2
	0,20	28.64-7.62	SONATRACH	23.0
	0,37	28.64-7.54	SONATRACH	22.9
	0,09	28.61-7.5	SONATRACH	20.4
	0,23	28.56-7.52	SONATRACH	14.4
	0,54	28.56-7.46	SONATRACH	14.2
	0,06	28.72-7.52	SONATRACH	32.5
	0,07	28.47-7.51	SONATRACH	4.5
	0,03	28.46-7.52	SONATRACH	3.1

	0,09	28.43-7.51	SONATRACH	0.3
	0,05	28.41-7.54	SONATRACH	0.8
	0,98	28.68-7.19	SONATRACH	13.1
	0,14	29.03-7.52	SONATRACH	64.3
	0,19	29.27-6.49	SONATRACH	12.7
	0,06	29.67-6.72	SONATRACH	6.3
	0,47	29.69-6.7	SONATRACH	7.2
	0,40	29.7-6.71	SONATRACH	8.4
	0,06	30.18-7.69	ENI S.P.A	3.2
	0,21	30.25-8.08	SONATRACH	17.3
TOTAL	10,58			

TABLE V.3: Enumeration of torches in LAGHOUAT region.

	Quantity Million tons CO_2e/year	**Location (Lat-Lon)**	**Flare operating Company**	**Distance From gas pipe (km)**
LAGHOUAT	0.42	32.95-3.23	SONATRACH	4.9
	0.30	32.93-3.24	SONATRACH	3.8
	0.28	33.13-3.32	SONATRACH	2.1
	0.24	33.07-3.33	SONATRACH	3.0
	0.08	33.87-2.66	SONATRACH	0.9
	0.05	32.91-3.37	SONATRACH	0.6
	0.04	33.02-3.22	SONATRACH	1.3
	0.03	33.02-3.21	SONATRACH	1.6
TOTAL	1.44			

TABLE V.4: Enumeration of torches in ORAN region.

Region	Quantity Million tons CO_2e/year	Location (lat-lon)	Flare operating Company	Distance From gas pipe (km)
ORAN	0.47	37.18_-0.25	SONATRACH	0.1
	0.42	35.81_-0.27	SONATRACH	0.7
	0.22	35.81_-0.24	SONATRACH	1.4
	0.11	35.8_-0.22	SONATRACH	3.0
	0.07	35.8_-0.18	SONATRACH	5.1
	0.06	35.83_-0.3	SONATRACH	2.6
	0.04	35.82_-0.32	SONATRACH	2.1
TOTAL	1.39			

TABLE V.5: Enumeration of torches in GHARDAIA region.

Region	Quantity Million tons CO_2e/year	Location (lat-lon)	Flare operating Company	Distance From gas pipe (km)
GHARDAIA	0.25	32.4-4.1	SONATRACH	5.2
	0.25	32.74-3.18	SONATRACH	6.1
	0.23	32.28-3.99	SONATRACH	1.4
	0.17	32.84-3.24	SONATRACH	1.6
	0.16	32.55-3.17	SONATRACH	4.3
	0.05	29.09-2.21	SONATRACH	2.8
TOTAL	1.11			

TABLE V.6: Enumeration of torches in SKIKDA region.

	Quantity Million tons CO_2e/year	Location (lat-lon)	Flare operating Company	Distance From gas pipe (km)
SKIKDA	0.30	36.88-6.95	SONATRACH	0.3
	0.26	36.87-6.98	SONATRACH	2.1
TOTAL	0.56			

TABLE V.7: Enumeration of torches in ADRAR region.

Region	Quantity Million tons CO_2e/year	Location (Lat-Lon)	Flare operating Company	Distance From gas pipe (km)
ADRAR	0.23	28.12-0.3	NEPTUNE ENERGY GR	2.4
	0.15	27.8-0.46	SONATRACH	20.9
	0.05	27.78-0.63	SONATRACH	12.0
	0.04	28.21-0.16	NEPTUNE ENERGY GR	7.7
	0.03	28.15-0.13	NEPTUNE ENERGY GR	0.8
TOTAL	0.5			

TABLE V.8: Enumeration of torches in ALGIERS region.

Region	Quantity Million tons CO_2e/year	Location (Lat-Lon)	Flare operating Company	Distance From gas pipe (km)
ALGIERS	0.10	36.68-3.12	SONATRACH	1.5
TOTAL	0.10			

TABLE V.9: Total emissions of CO_2 in Algeria from torches.

	Wilaya (state)	CO_2 emission (Mt /year)
1	Ouargla	15.65
2	Ilizi	10.58
3	Laghouat	1.44
4	Oran	1.39
5	Ghardaia	1.11
6	Skikda	0.56
7	Adrar	0.5
8	Algiers	0.10

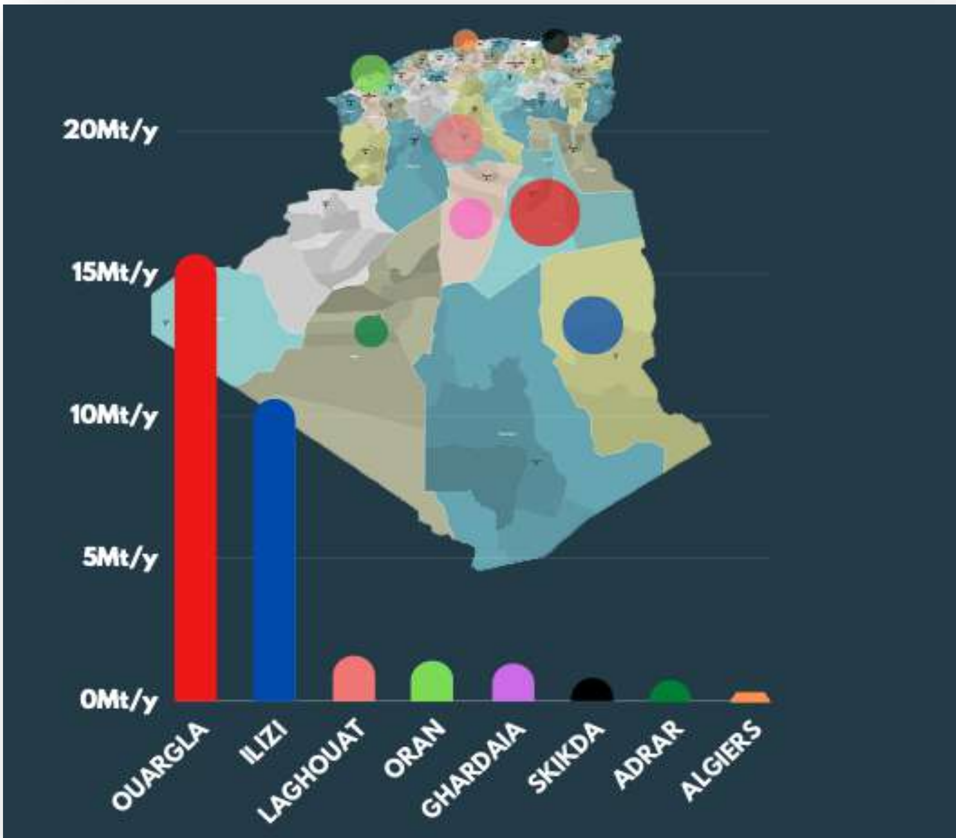


FIGURE V.1: Bar graphs of CO_2 emitted by the states of Algeria from torches presented on map.

3- CARBON DIOXIDE ESTIMATION

3.1- Carbon balance

In the first stage, we calculate the carbon balance of the LPG ZCINA unit. **(FIGURE V.2)** shows a schematic diagram of the amount of gas at the entrance to the unit and the results of the gas treatment. It also shows the fuel sources for the furnaces, turbines, and gas directed to the torches.

These applicable data were taken from the daily production report, on 25/05/2022, which can be found in **(Appendix 1)**.

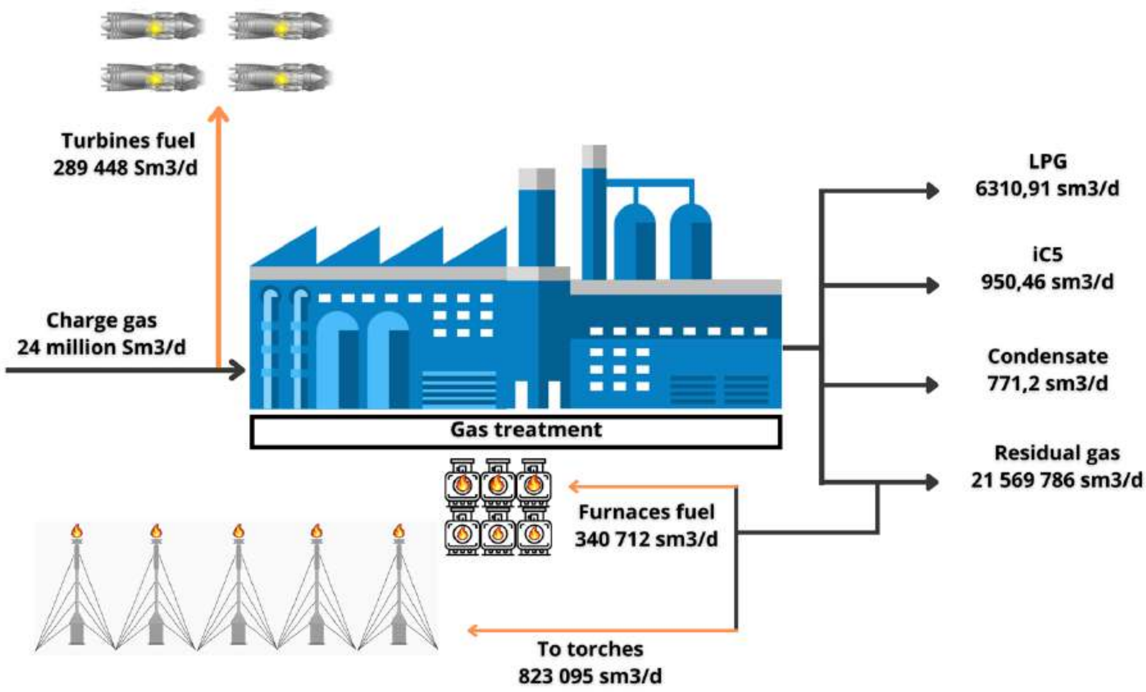


FIGURE V.2: Balance of the LPG ZCINA.

3.2- Estimate of CO_2 emitted by the furnaces

The steps to calculate CO_2 emitted by the furnaces are:

1- We consider all combustion processes to be a complete reaction.

$$C_XH_{Y\,(g)} + (4X+Y)/4O_{2\,(g)} \longrightarrow XCO_{2(g)} + Y/2\; H_2O_{(g)}$$

$$1 \text{ mol of } C_XH_{Y\,(g)} = n \text{ mol of } CO_{2\,(g)}$$

2- Identification of Quantities and fractions of combustion:

The fuel for the furnace is residual gas, its flow (Q_f) is 340712 sm3/d as shown in **(FIGURE V.1)** and its components are shown in **(TABLE V.10)**.

3- Using the HYSYS simulator and all information in step 2, to calculate the Molar Flow Rate and molar fraction of residual combustion gas as shown in table V.10.

TABLE V.10: Combustible gas composition (residual gas).

Compounds	Residual gas ZCINA (% mole)
N_2	3,03
CO_2 (from Inlet Gas)	2,31
CH_4	72,66
C_2H_6	21,81
C_3H_8	0,19

Volumetric Flow Rate	340 712 Sm3/d
Molar Flow Rate	14462 kmol/d

<u>Calculation of quantity of CO_2:</u>

Methane combustion reaction:

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

1 mol	2 mol		1 mol	2 mol
16,04 g/mol	2×31,998 g/mol		44,01 g/mol	2×18,015 g/mol
10508,08 kmol/d	X_1		X_2	X_3

Q_{CH4}= Qf× Y $_{CH4}$= 14462×0,7266 = 10508,8 kmol/d

$$X_2 = \frac{10508 \times 44}{16} = 28897{,}24 \text{ kmol/d}$$

Q_{CO2} = 28897,24 kmol/d

TABLE V.11: The rest of component Flows.

Compounds	*Charge gas ZCINA (% mole)*
N_2	2,52
CO_2	1,78
CH_4	66,41
C_2H_6	17,49
C_3H_8	7,87
I C_4H_{10}	0,71
N C_4H_{10}	2,06
I C_5H_{12}	0,38
N C_5H_{12}	0,50
C_6H_{14}	0,28

Volumetric Flow Rate	*289448 Sm3/d*
Molar Flow Rate	*12285.6 kmol/d*

– Knowing that M_{CO2} is 44.01 kg/kmol.

SO The total flow of CO_2 is: Q_{CO2} **= 70704.228 kg/h**

3.3- Estimate of CO_2 emitted by the turbines

The fuel for the turbines is charge gas, its volumetric Flow Rate (Qt) is 289 448 sm3/d as shown in **(FIGURE V.2)** and its components are shown in **(TABLE V.12)**.

TABLE V.12: combustible gas composition (Charge gas).

Compounds	*Flow (kmol/d)*
CO_2 (from Inlet Gas)	334,07
CH_4	28897,24
C_2H_6	9252,20
C_3H_8	82,433
Total	38565.943

Calculation of quantity of CO_2:

Methane combustion reaction:

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

1 mol	2 mol		1 mol	2 mol
16,04 g/mol	2×31,998 g/mol		44,01 g/mol	2×18,015 g/mol
8158,86 kmol/d	X_1		X_2	X_3

$Q_{CH4} = Qt \times Y_{CH4} = 12285.6 \times 0{,}6641 = 8158{,}86$ kmol/d

$$X_2 = 8158{,}86 \times 4416 = 22436{,}8841 \text{ kmol/d}$$

$Q_{CO2} = 22436{,}8841$kmol/d

TABLE V.13: The rest of component Flows.

Compounds	*CO2 from reaction Molar Flow Rate (kmol/d)*
CO_2 (from Inlet Gas)	***218,683***
CH4	***22436,8841***
C2H6	***6303***
C3H8	***2900,63***
I C4H10	***264,69***
N C4H10	***767,977***
I C5H12	***142,649***
N C5H12	***187,69***
C6H14	***105,599***
Total	***33327,80***

– Knowing that M_{CO2} is 44,01 kg/kmol.

SO the total flow of CO_2 is: **Q_{CO2} = 61100.966 kg/h**

3.4- Estimate of CO_2 emitted by the torches

The gas that lights the torch is residual gas, its volumetric Flow Rate (Qto) is 823 095 sm3/d as shown in **(Figure V.2)** and its components are shown in **(Table V.14)**.

TABLE V.14: Combustible gas composition (residual gas).

Compounds	*Residual gas ZCINA (% mole)*
N_2	*3,03*
CO_2 *(from Inlet Gas)*	*2,31*
CH_4	*72,66*
C_2H_6	*21,81*
C_3H_8	*0,19*
Volumetric Flow Rate	*823 095 Sm3/d*
Molar Flow Rate	*34 944 kmol/d*

Calculation of quantity of CO_2:

Methane combustion reaction:

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

1 mol	2 mol		1 mol	2 mol
16,04 g/mol	2× 31,998g/mol		44,01 g/mol	36,03 g/mol
25390,31 kmol/d	X_1		X_2	X_3

$Q_{CH4} = Q_{to} \times Y_{CH4} = 34944 \times 0,7266 = 25390,31$ kmol/d

$$X_2 = \frac{25390,31 \times 44}{16} = 69823,3536 \text{ kmol/d}$$

$Q_{CO2} = 69823,3536$ kmol/d

TABLE V.15: The rest of component Flows.

Compounds	*CO2 from reaction Molar Flow Rate (kmol/d)*
CO_2 *(from Inlet Gas)*	*807,206*
CH_4	*69823,3536*
C_2H_6	*22355,77*
C_3H_8	*199,180*
Total	*93185,50*

– Knowing that M_{CO2} is 44,01 Kg/Kmol,
SO the total flow of CO_2 is: **Q_{CO2} = 170840,083 kg/h**

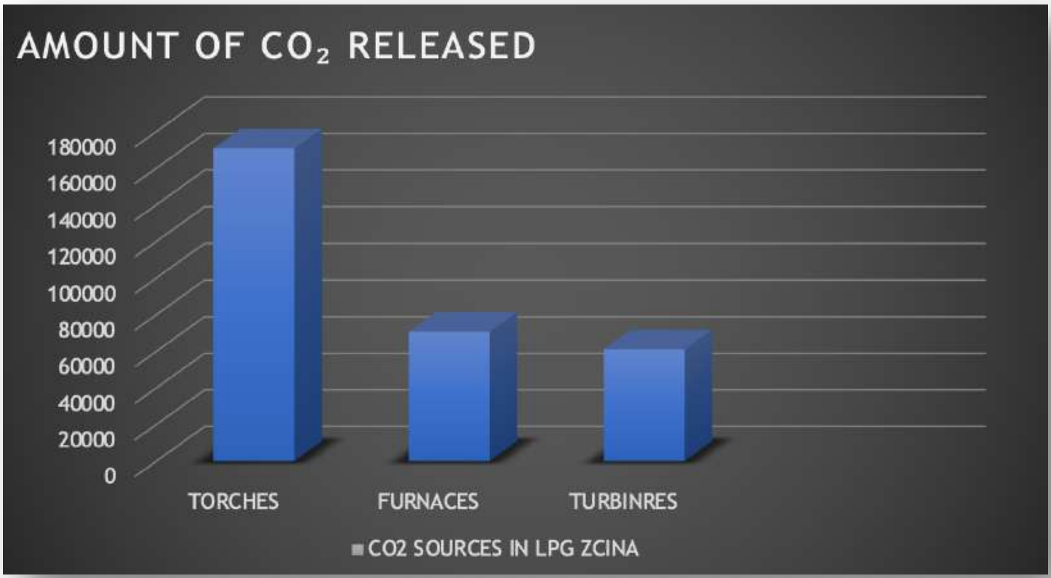


FIGURE V.3 Amounts of carbon dioxide emissions from the combustion places in LPG ZCINA.

4- Technical proposal of capturing carbon dioxide from furnaces and turbines in LPG ZCINA unit

As for the emitted carbon dioxide capture processes, there are several techniques as they are listed in the second chapter. In this context, we suggest for (LPG/ZCINA) to use chemical absorption technology due to its simple principle where the absorbing chemical (solvent) reacts with carbon dioxide gas, forming a weak intermediate compound, which is easy to dismantle by heating to its original components. In the flue gas mixture, in this case, the proportion of sulfur oxide (SOx) and Nitrogen oxide (NOx) is required to be low in order not to cause the formation of salts with the used solvents and thus deteriorate the properties of the used solvent.

The chemical absorption solvents used are characterized by high efficiency, as Monoethanolamines has a balanced loading capacity of approximately 1 mole of carbon dioxide per mole of amine, in addition to its abundance and low cost, (the cost of the solvent used in our experiment 6,78-euro MEA per 1 Litre).

The chemical absorption technique to capture pre-combustion carbon dioxide in Algeria was applied in the Ain Salah project, one of the two largest CCS projects in the world, after the Sleipner gas field project in Norway.

4.1- Equipment used

Absorber

In these simulations, the absorber is used to remove carbon dioxide from the exhaust gas by bonding the MEA with weakly bonded carbon dioxide molecules.

Rich amine Pump

Rich amine solution from the bottom of the absorber is pumped to an elevated pressure to avoid acid gas breakout in the rich / lean exchanger and to overcome the operating pressure and height requirements in the stripper

Stripper

The main function of the amine regenerator is to remove CO_2 from the rich solution by steam stripping. The absorption reactions are reversed with heat supplied stripping generated in the reboiler.

Heater

The heat exchanger is used in this case in order to raise the temperature of the amine solution to about 105 °C so as to allow the stripper to separate carbon dioxide at a high temperature.

4.2-Technique Simulation

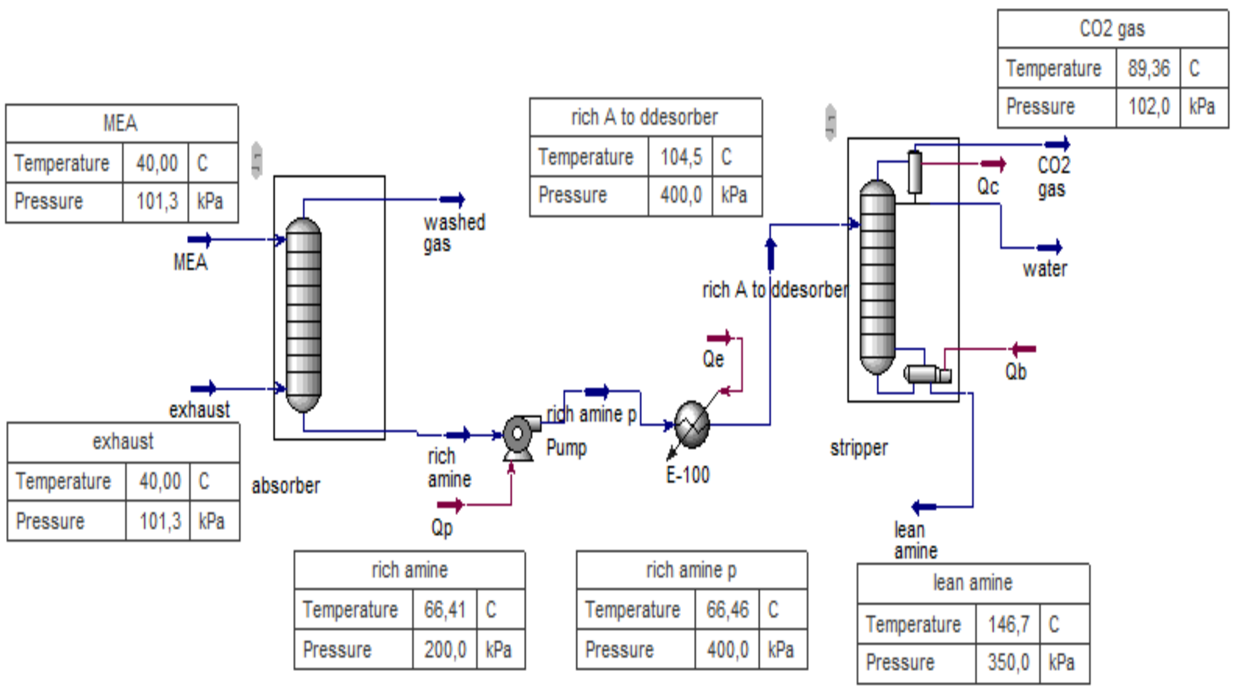


Figure V.4: Simulation of CO_2 absorber.

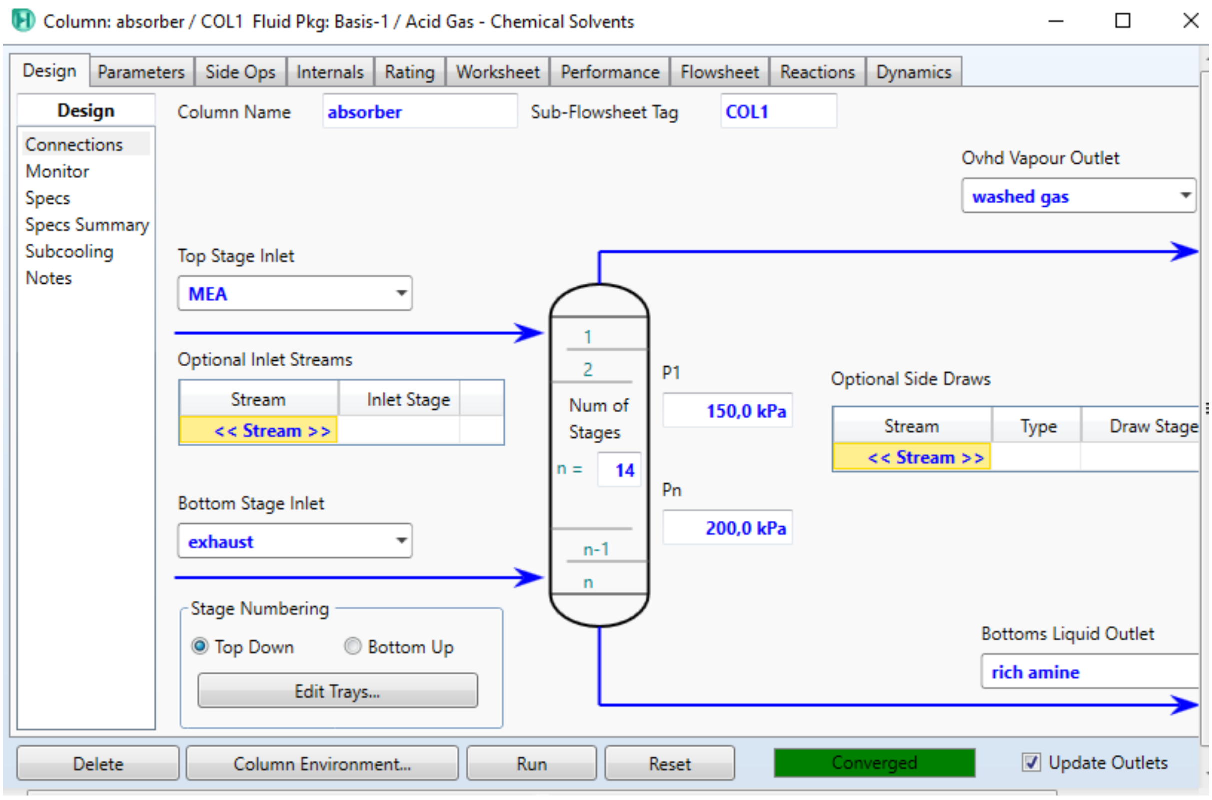


FIGURE V.5: Absorption column design.

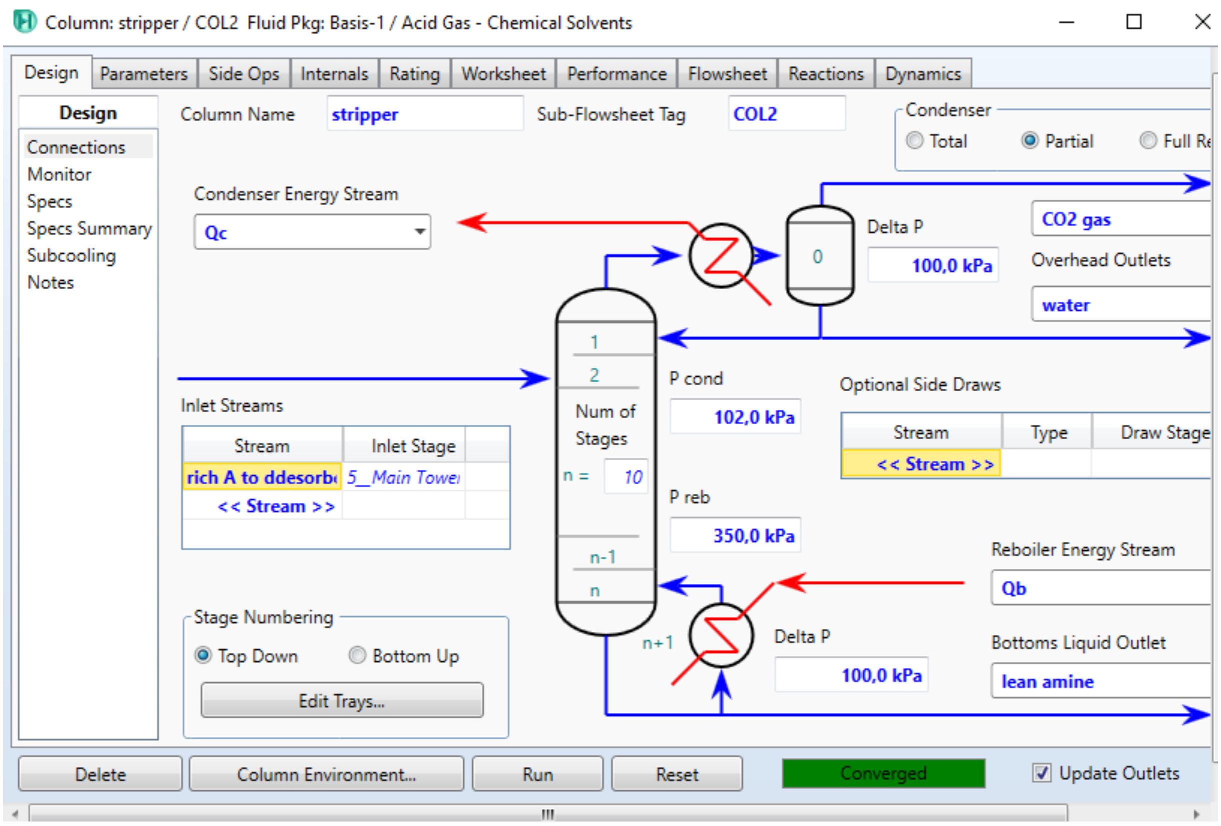


FIGURE V.6: Stripper column design.

Absorption simulation steps:

- **first step:** the exhaust gases enter the absorption tower with a flow rate of 31060 kg/h and a temperature of 40 °C. and (H_2O/MEA) solution with a flow rate of 160000 kg/h and a temperature of 40 °C.

- **second step:** The reaction takes place inside the absorption tower, where the solvent (MEA) captures the carbon dioxide and leaves the remaining gases released at the top of the tower.

- **third step:** The solvent with carbon dioxide comes out from the bottom of the tower directly to a pump.
  The pump boost the pressure from 200 kPa to 400 kPa at a temperature of 66° C.

- **Fourth step:** The compound (MEA/CO_2/H_2O) will pass through a heat exchanger to raise the temperature from 66 °C to 104 °C.

- **Fifth step:** The compound (MEA/CO_2/H_2O) is introduced into an absorption tower, where all the compounds are separated under the effect of heating, thus producing a net quantity of carbon dioxide estimated at 3595.74 kg/hr.

5- A proposal to recover the wasted energy from carbon dioxide emitting sources in the LPG ZCINA unit

There are a lot of wasted energy recovery technologies out there like we mentioned in Chapter 3, which are now new exploitation technologies.

the temperature in furnaces chimneys and turbines is great energy, so the temperature in the furnace and turbine chimneys is 333,500°C respectively, and in that sense, we suggest to the LPG unit to use the organic Rankin cycle technology.

Rankin's function is to convert heat into kinetic energy, using a low-boiling organic liquid (below water boiling temperature 100 °C), where this organic fluid in a tube passes toward a pressure-raising pump from 4.5 to 40 bars. The pipe then passes through the chimney in the pre-heater and then exits and re-enters under the main heater where the organic liquid is turned into 100% vapor, and then exits the chimney through a turbine connected to an electric generator to produce electricity.

Therein lies the goal of this cycle, which is to convert the thermal energy into electricity that can be utilized within the unit or sold. After the turbine, the steam passes to condensation, where it returns to its liquid state, returns to primary heating, and cycles again, this cycle can be applied to oven chimneys, turbines, and flares after they're restructured.

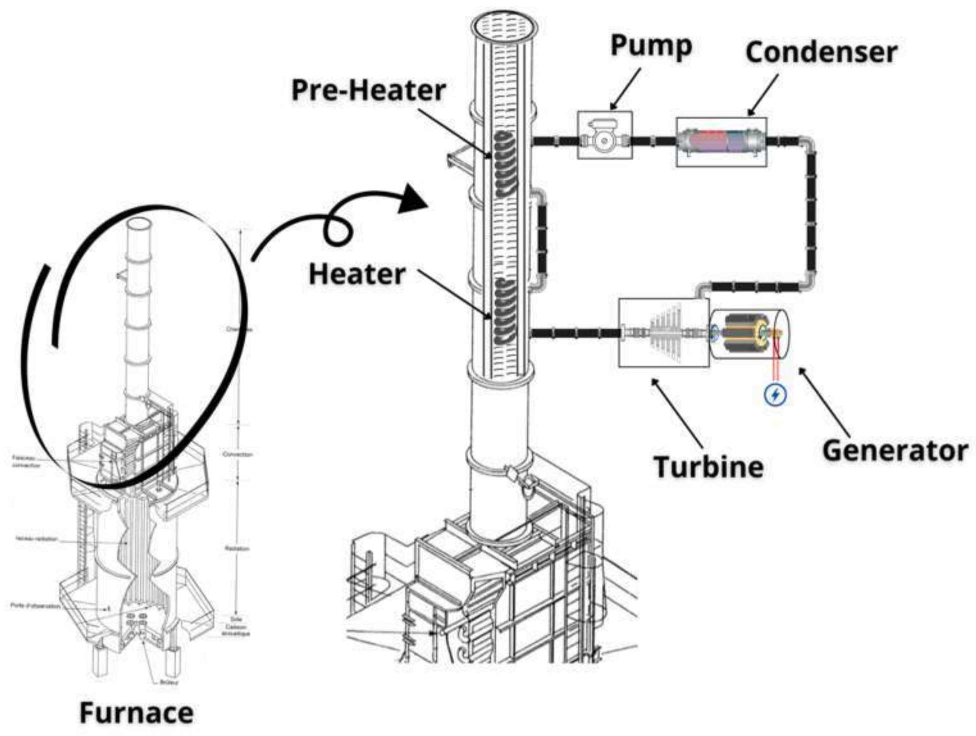


FIGURE V.7: Method of setting ORC cycle in LPG ZCINA unit furnace.

5.1- A proposal to restructure the torch

The flame system in the LPG unit states that the flame must be in a constant state of activity under the natural conditions of the plant for security reasons, therefore it receives a flow of 10 cubic meters per day of residual gas. We propose to this unit and all the units that contain the torch by adding an override to a second torch south of the original, containing a combustion chamber below and chimney where the furnace is similar in design terms. the original flame remains in an emergency situation where the flow is high and the combustion chamber in the proposed flame cannot support it.

the bypass valve is installed before the combustion chamber for use in the event of a factory problem requiring a large amount of gas to be ignited (the valve is normally opened and closed during an emergency). This is the best intermediate solution between CO_2 capture and recovery of energy lost from the flame.

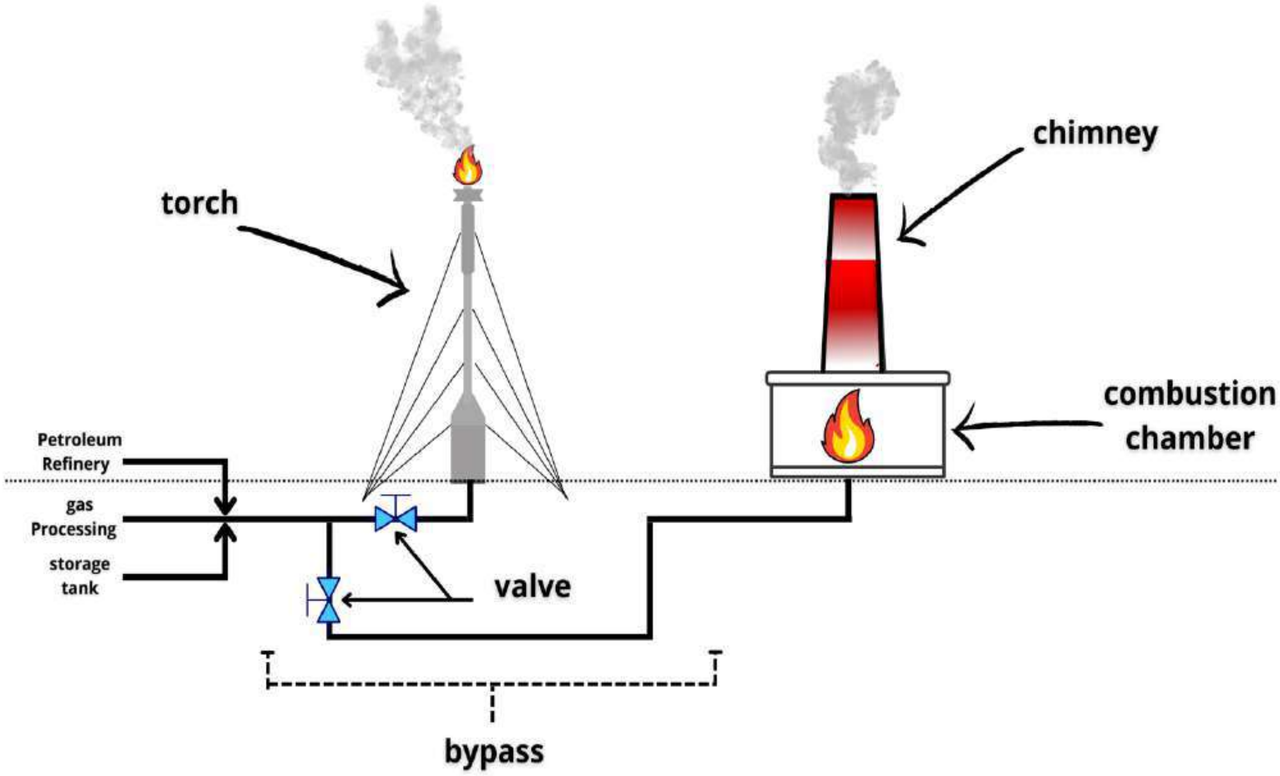


FIGURE V.8: Proposed restructuring of the torch and bypass valve.

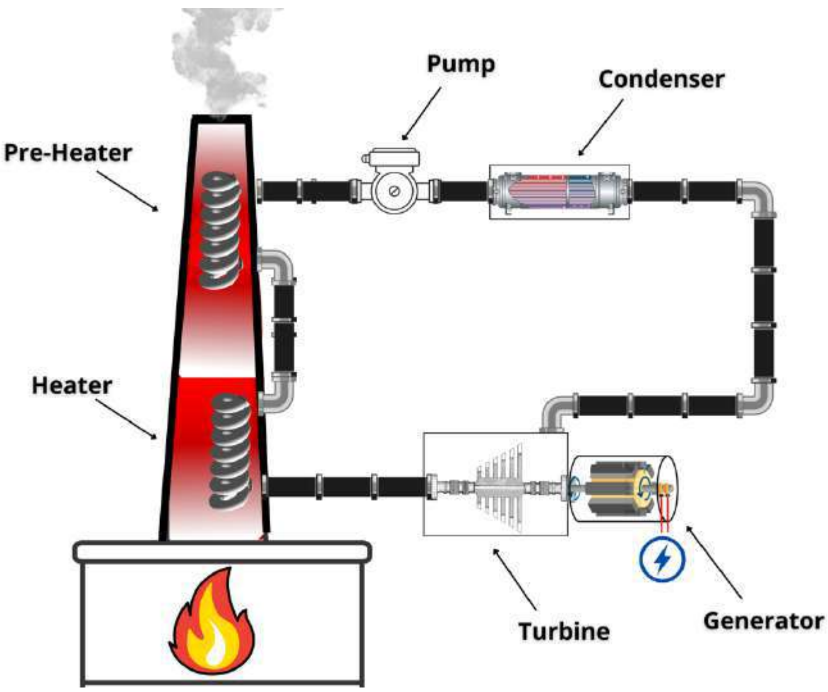


FIGURE V.9: Method of setting ORC cycle in LPG ZCINA unit second torch.

5.2- Simulation of Organic Rankin Cycle in a furnace

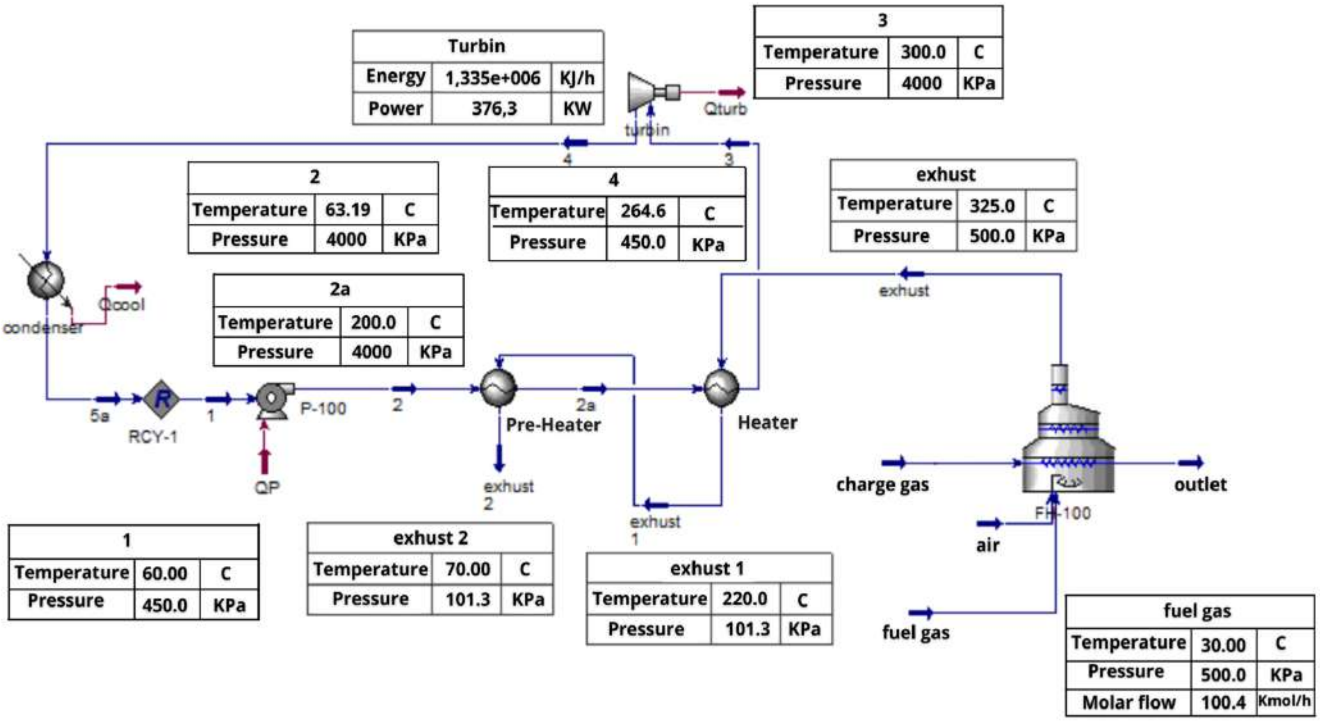


FIGURE V.10: Organic Rankine cycle simulation in LPG ZCINA unit furnace.

5.3- Used Equipment

Refrigerant R-13

Also known as Freon-13, CFC-13, is a haloalkane of the chlorofluorocarbon (CFC) family. It is a non-flammable, non-corrosive, colorless and odorless gas, its molar mass is 104.46 g/mol, and it turns into a gaseous state at a temperature of 20 °C, used as a refrigerant in the simulation [44].

Condenser

It is a technical heat exchanger used to remove heat from the refrigerant vapor and transfer it to the water running inside the tube, the system operates through networks of water coils that are used to transfer heat from the condenser coils

Pump

A pump is a device that moves fluids by mechanical action, typically converted from electrical energy into hydraulic energy.

Turbine

A rotary mechanical device, driven by a moving liquid or gas, such as a refrigerant gas, the turbine changes the kinetic energy of the refrigerant gas into a special type of kinetic energy, which is the rotational energy that is used in this case to produce electricity.

5.4- Explanation of the organic Rankine cycle simulation

The first step: It starts after burning the fuel in the regeneration furnace, where it produces exhaust gas with a temperature of up to 333 °C and Flow up to 31,060 kg/hr.

The second step: The organic solution is entered at a temperature of 60 °C to a pump to raise its pressure from 450 kPa to 4000 kPa.

The third step: is to enter the organic solution into the chimney at a temperature of 63.19 and a pressure of 4000 L. In the chimney, the solution undergoes pre-heating to reach its temperature of 200 °C., and here the solution is in its gaseous state at 100%.

The fourth step: The organic gas comes out from pre-heating and enters the main heating, so its temperature rises from 200 °C to 300 °C.

The fifth step: The steam passes with a flow of 40,000 kg/hr through a turbine where the steam expands causing the turbine to rotate and generate electricity from a generator connected to a turbine. In this simulation, we produced 376 kWh per cycle and this is a very large number.

The Sixth step: After the turbine, the steam passes at a temperature of 264.6 °C to a condenser, to return the steam to a liquid as in its first state, to start the cycle again.

6- The furnace used for ORC and absorption in the simulation

The regeneration furnace is taken as a source of exhaust gas that serves as Feed for both simulating and absorbing ORC, in the following figures, the furnace settings have been adjusted according to the information taken from the LPG ZCINA unit.

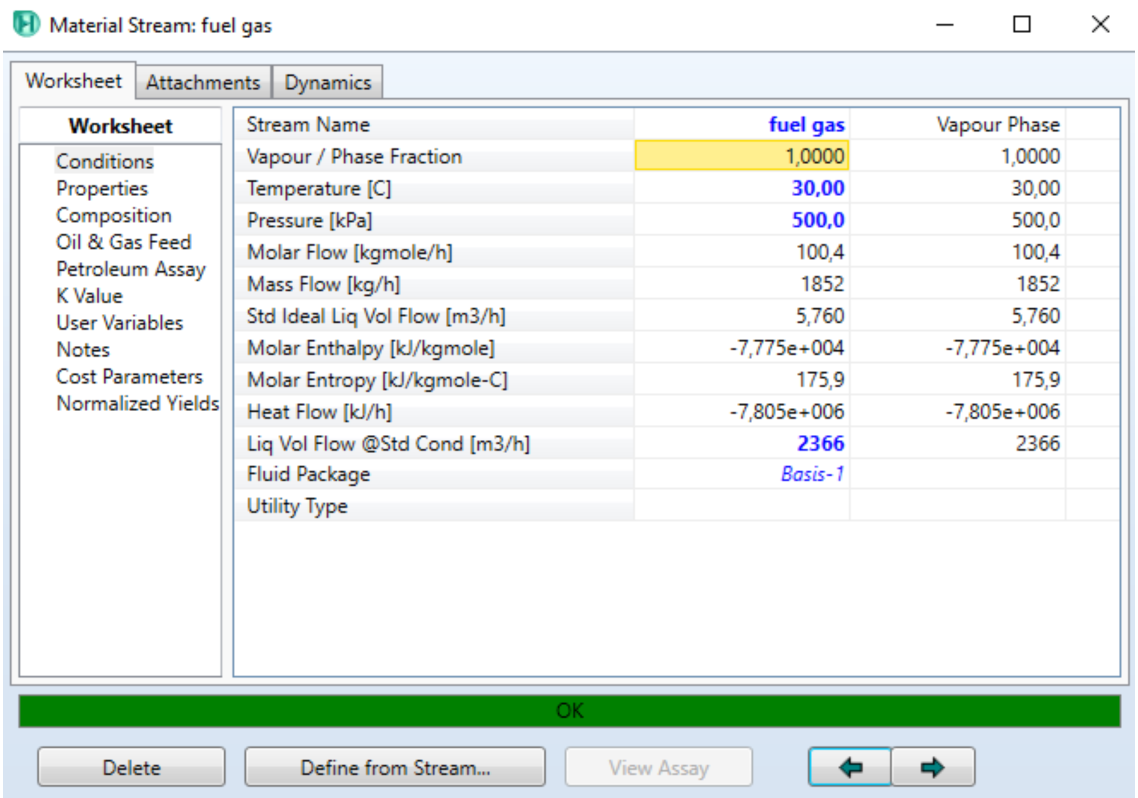


FIGURE V.11: Fuel gas settings.

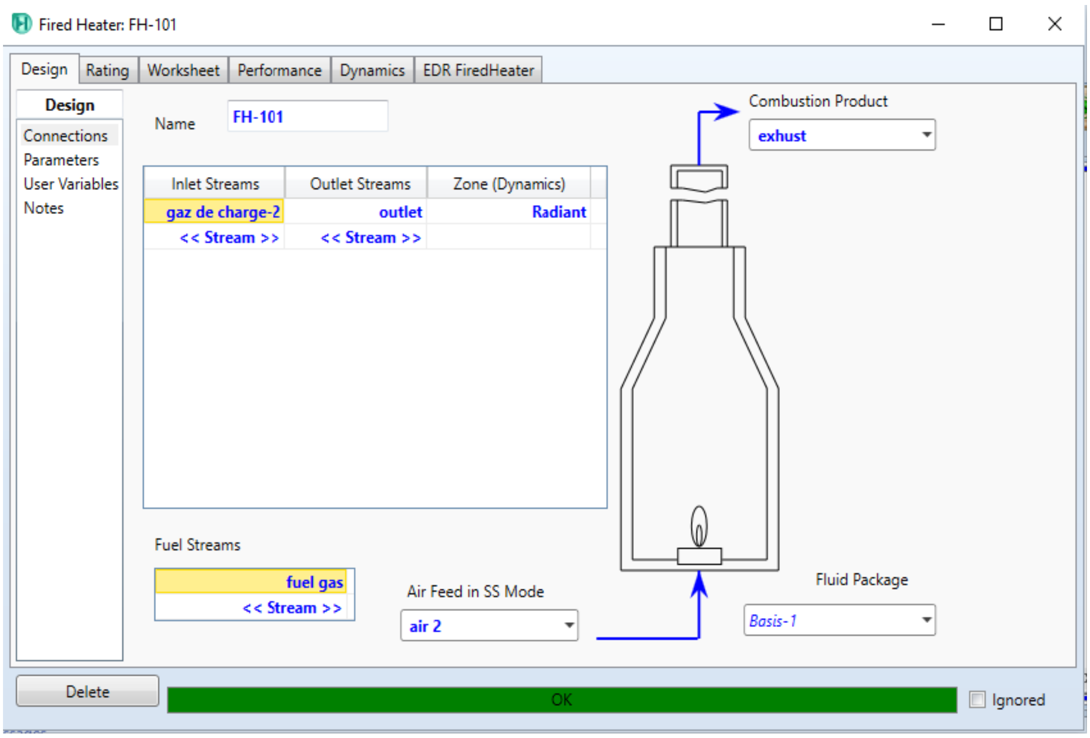


FIGURE V.12: Furnace settings.

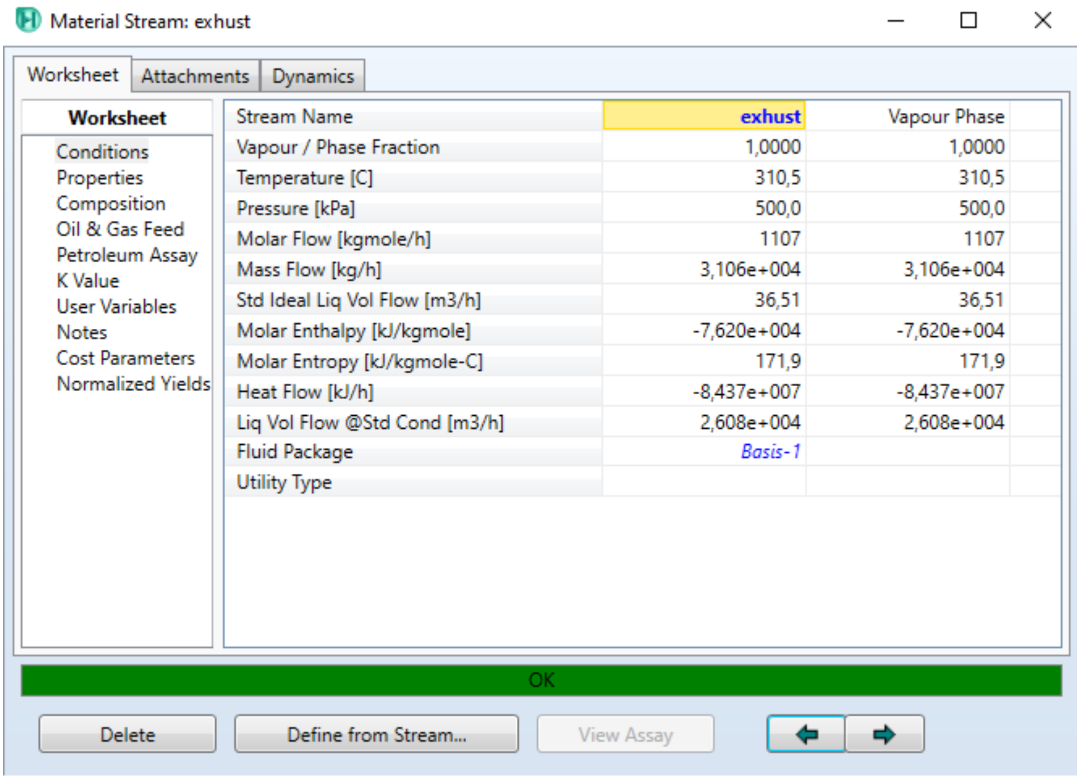


FIGURE V.13: Exhaust settings.

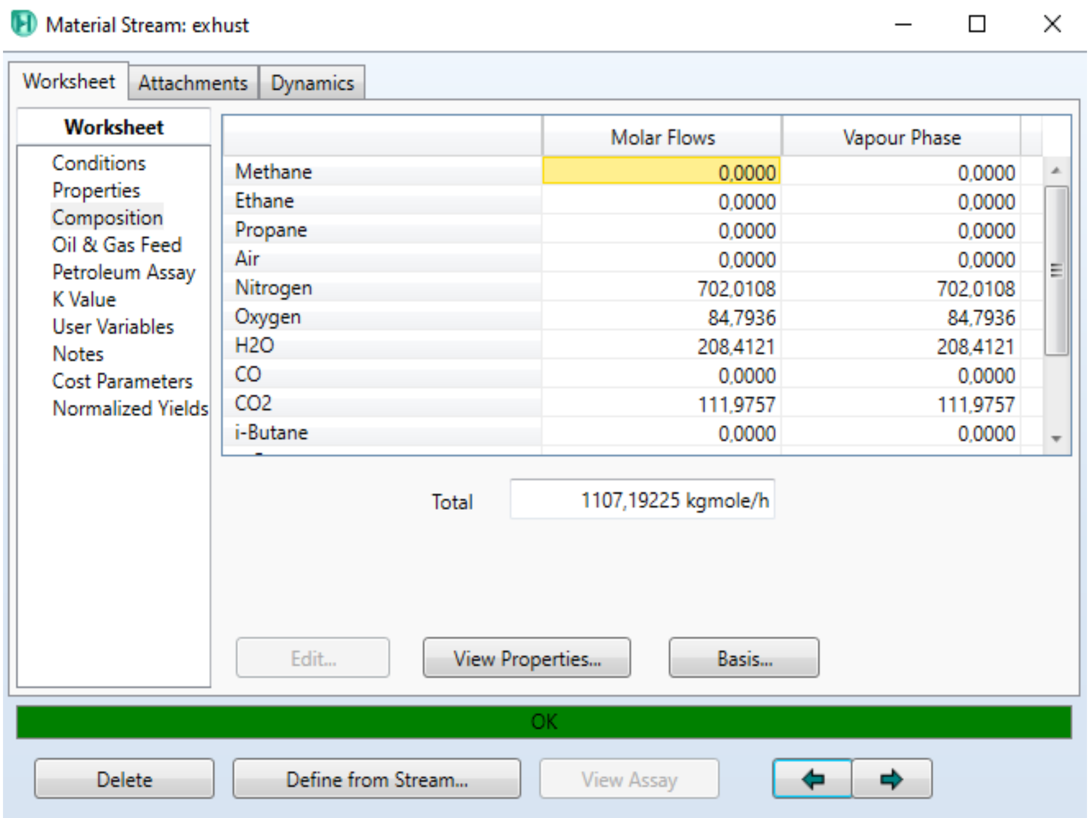


FIGURE V.14: Exhaust composition.

7- STUDY OF ABSORPTION AND ORC RETURNS

The technical and economic study will allow us to evaluate the profitability of the project, the financial estimates for its realization, which are fixed according to several comparisons, and contacts with economic specialists.

7.1-Absorption

The amount of Carbon dioxide produced from the chemical absorption project is 3595,74 kg/h.

7.1.1- The estimated cost of absorption project

In order to determine the approximate financing budget for this project, we included in our calculations the main equipment of your choice, which was mentioned below. The results of these calculations are listed in the following table:

TABLE V.16: Financial estimates for the completion of the absorption project.

Component	Cost DZD	%
Pump	8 971 797	4,65
Condenser-stripper	33 051 693	17,13
Reboiler-Stripper	41 165 571	21,33
Stripper	44 495 460	23,06
Absorber	50 399 106	26,12
Exchanger	14 846 361	7,69
Total	192 929 988	100

7.1.2- Absorption Revenues calculation

The price of carbon dioxide is: 1 ton of Carbon dioxide ⟶ 21,44 $

SO 3595,74 kg/h. $\frac{3595{,}74 \times 24 \times 365}{1000}$ = 31 498,77 tons /year

⟶ 31 498,77 × 21,44 $ = 675 333,62 $ /year.

⟶ 97 923 374,9 DZD/year.

The analysis of the results of the calculations indicated above allows us to conclude the profit rate of the project. with this profit rate, after two years the money spent on this project will be fully returned and the net profit starts permanently.

A 2017 study estimates a tax of $49 per metric ton of carbon dioxide could raise about $2.2 trillion in net revenues over 10 years from 2019 to 2028 [43].

If the oil companies in Algeria are forced to pay these taxes, the revenue from capture is doubled as they can save money from past taxes while benefiting from the CO_2 product.

31.498,77 tons/year × 49 $ = 154 343 973 $/year

(This is the amount of taxes that the LPG unit will provide).

7.2- Organic Rankin Cycle:

The amount of electricity produced from the ORC project is 376 kWh.

7.2.1- The estimated cost of ORC project

In order to determine the approximate financing budget for this project, we included in our calculations the main equipment of your choice, which was mentioned below. The results of these calculations are listed in the following table:

TABLE V.17: Financial estimates for the completion of the ORC project.

Component	Cost DZD	%
Pump	54 281 509,18	24,4
Expander	15 264 160,5	6,85
Condenser	85 041 363,97	38,27
Working fluid	18 159 513,3	8.20
Generator	49 469 964,54	22,28
Total	222 216 511,49	100

7.2.2- ORC Revenues calculation

Algeria, September 2021: The price of electricity is 0.037 U.S. Dollar per kWh for households and 0.031 U.S. Dollar for businesses which includes all components of the electricity bill such as the cost of power, distribution and taxes [41].

1 kWh ⟶ 0.037$ ***SO*** $376 \times 0.037 = 13{,}9\$/hr$

13,9 $/h ⟶ 121 764 $/year ⟶ 17 705 703,24 DZD/year

The analysis of the results of the calculations indicated above allows us to conclude the profit rate of the project. with this profit rate, after twelve years the money spent on this project will be fully returned and the net profit starts permanently.

General conclusion

General Conclusion

This work aims at studying carbon dioxide emissions and methods of capture, wasted energy, and methods of recovery in a liquefied petroleum gas (LPG) unit in ALGERIA, ZCINA unit. and applying the result to all LPG units in ALGERIA.

The work done during our training period allowed us to estimate carbon dioxide and energy emissions from various sources at the ZCINA level and to study the possibility of reducing these emissions as much as possible and recovering this energy.

So, the study that we did allowed us:

- Definition of the number and locations of LPG units in Algeria (as unit models for study) and enumerate the carbon dioxide sources within these units.

- From the calculation and simulation viewpoint, we were able to derive two things:
  - We were able to prepare a unit for capturing carbon dioxide and valorization it within petrochemical units, and a unit for recovering wasted energy within the sources of this gas.

- From the technical and economic viewpoint, we made an economic report and found that the return is quick and positive in the capturing compared to the recovery of wasted energy, and this is due to the low price of electricity in Algeria compared to France, which is 0.199 $.

This study is involved in environmental protection, the reduction of emissions, and the improvement of energy where the world needs more energy Demand is rapidly increasing in developing countries, with rising incomes, and expanding industry, but we need to change fast as CO_2 emissions are not decreasing we must produce cleaner and lower-carbon energy with less environmental impact that is more sustainable to face this dual challenge there is no single or simple solution but new technologies (Energy Efficiency), will be keen to help preserve our planet for us and future generations, This requires installing wasted energy recovery units in as many combustion sources as possible at the national level.

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Abstract: Total carbon dioxide emissions in Algeria are estimated at 155 million tons per year, according to the latest World Bank data for 2020, it is useful to identify the sources of carbon dioxide in Algeria and recover the wasted energy in these sources, which is positively reflected in the development of capturing and using CO_2 projects, which plays an important role in diversifying the economies of the oil and gas-producing countries, if it is well regulated, and these countries succeeded in developing appropriate and encouraging policies.
So we did a study to contribute to this subject ،where we found:
- General exposure to carbon dioxide gas.
- Global emissions of carbon dioxide and the location of Algeria from this.
-Methods of capturing and using carbon dioxide.
- Taking a study sample (LPG ZCINA) to assess the carbon dioxide emissions of this unit and study the wasted energy in the combustion places in the unit.
- Suggest solutions for capturing carbon dioxide and recovering wasted energy and calculating the cost of these projects.

Keywords: Carbon dioxide ,Waste energy, Energy sustainability, Zero flaring.

ملخص : يقدر إجمالي انبعاثات غاز ثاني أكسيد الكربون في الجزائر بنحو 155 مليون طن في العام ، طبقا لأحدث بيانات البنك الدولي لعام 2020 فمن المفيد تحديد مصادر غاز ثاني أكسيد الكربون في الجزائر وإستعادة الطاقة المهدرة في هذه المصادر، وهو ما ينعكس إيجاباً في تنمية وتطوير مشروعات احتجاز واستخدام غاز ثاني الكربون ، التي تلعب دوراً هاماً في تنويع اقتصادات الدولة المنتجة للنفط والغاز، إذا ما تم تنظيمها بشكل جيد ، ونجحت هذه الدول في وضع السياسات المناسبة والمشجعة لذلك قمنا بعمل دراسة مساهمة في هذا الموضوع وإلتمسنا هذه النقاط
- نضرة عامة على غاز ثاني اكسيد الكربون.
- الانبعاثات العالمية لغاز ثاني أكسيد الكربون وموقع الجزائر من هذا.
- طرق إلتقاط وإستخدام غاز ثاني اكسيد الكربون.
- أخذ عينة دراسة (LPG ZCINA) لتقييم إنبعاثات هذه الوحدة لغاز ثاني اكسيد الكربون ودراسة الطاقة المهدرة في أماكن الاحتراق في الوحدة .
- إقتراح حلول لإلتقاط غاز ثاني اكسيد الكربون وإستعادة الطاقة المهدرة وحساب تكلفة هاته المشاريع.

الكلمات المفتاحية: ثاني أكسيد الكربون، الطاقة الضائعة، استدامة الطاقة، صفر اشعال.

Résumé: Les émissions totales de dioxyde de carbone en Algérie sont estimées à 155 millions de tonnes par an, selon les dernières données de la Banque mondiale pour l'année 2020. Et le développement de projets de captage et d'utilisation du dioxyde de carbone, qui joue un rôle important dans diversifiant les économies du pays producteur de pétrole et de gaz, si elles sont bien régulées, et ces pays ont réussi à développer des politiques appropriées et encourageantes. Nous avons donc mené une étude contributive sur ce sujet et recherché ces points:
- Exposition générale au gaz carbonique
- Les émissions mondiales de dioxyde de carbone et la localisation de l'Algérie à partir de ce.
-Méthodes de captage et d'utilisation du dioxyde de carbone .
- Prélèvement d'un échantillon d'étude (GPL ZCINA) pour évaluer les émissions de dioxyde de carbone de cette unité et étudier l'énergie gaspillée dans les points de combustion de l'unité.
- Proposer des solutions pour capter le dioxyde de carbone et récupérer l'énergie gaspillée et calculer le coût de ces projets.

Mots clés : Dioxyde de carbone, L'énergie des déchets, Durabilité énergétique, Zéro torchage.

Appendix

APPENDIX 1

سوناطراك
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EXTRACTION DES LIQUIDES DES GAZ ASSOCIES HASSI MESSAOUD ET SEPARATION D'HUILE
LDHP ZCINA

Date: 25-mai-2022 Heure : 00:02:04

DETAILS GPL

		Volume (Sm³)	Masse (Tonnes)
TRAIN 1	Gaz entrée section froide	7 746 844	-
	Production GPL	2 038.05	1 088.115
	Production Isopentane	296.10	188.199
	Production condensats	254.16	170.718
	Gaz résiduel	8 035 135	-
TRAIN 2	Gaz entrée section froide	7 601 237	-
	Production GPL	2 119.82	1 131.771
	Production Isopentane	314.97	200.193
	Production condensats	262.42	176.268
	Gaz résiduel	6 930 795	-
TRAIN 3	Gaz entrée section froide	7 711 576	-
	Production GPL	2 153.04	1 149.507
	Production Isopentane	339.39	215.718
	Production condensats	254.62	171.028
	Gaz résiduel	6 603 856	-
TORCHAGE	Torche chaude	7 098	7.401
	Torche basse pression	27 951	58.975
	Torche froide Train 1	146 560	298.866
	Torche froide Train 2	328 320	668.837
	Torche froide Train 3	313 166	637.965

DETAILS LDHP

		Volume (m³ liq. / Sm³ gaz)	Masse (Tonnes)
SEP. A	Huile	1 952.46	1 549.665
	Gaz	7 228 762	-
	Eau	41.41	-
SEP. B	Huile	4.08	3.241
	Gaz	0	-
	Eau	0.08	-
SEP. C	Huile	1 938.71	1 538.756
	Gaz	5 504 033	-
	Eau	5.61	-
TOTAL	Huile	3 895.25	3 091.661
	Gaz	12 732 795	-
	Eau	47.11	-
TORCHAGE	Torche LDHP	0	0.000

سوناطراك
sonatrach

EXTRACTION DES LIQUIDES DES GAZ ASSOCIES HASSI MESSAOUD ET SEPARATION D'HUILE
LDHP ZCINA

Date: 25-mai-2022 Heure : 00:02:04

Rapport de Production Journalier

Gaz de charge	Gaz de charge depuis CINA			**27-FQY-00001**	**15 183 086 Sm³**
	Gaz de charge depuis LDHP			**20-FQY-90001**	**6 299 026 Sm³**
GPL	Cumul Production GPL	On Spec		36-FQY-00002A	2 886.44 Sm³
		Off Spec	Brut	36-FQY-00002B	9.17 Sm³
			Net	36-FQY-00002C	5.87 Sm³
		Global		**36-FQY-00002**	**2 892.31 Sm³**
	Cumul Expédition GPL			**33-FYQ-00520C**	**2 924.08 Sm³**
	Pressurisation des Sphères GPL (eq. liquide)			36-FQY-00004	- 3 418.60 Sm³
Condensats	Cumul Production Condensat	On Spec		35-QY-00102	1 238.85 Sm³
		Off Spec	Brut	35-QY-00103	120.60 Sm³
			Net	35-QY-00104	120.29 Sm³
		Global		**35-FQY-01002**	**1 359.15 Sm³**
	Cumul Expédition Condensat			**35-FQY-00003**	**1 137.35 Sm³**
Isopentane	Cumul Expédition IC5 via LDHP			32-FQY-90001	950.46 Sm³
Huile	Cumul Huile vers CINA			**29-FQY-90001**	**3 895.25 m³**
Eau	Cumul Eau vers CINA			44-FQY-90002	263.02 m³
Gaz résiduel	Gaz résiduel depuis LPG			34-FQY-00001	20 673 594 Sm³
	Gaz résiduel depuis LDHP			32-FQY-90002	6 868 201 Sm³
	Cumul Gaz résiduel vers CIS			**32-FQY-00110**	**27 541 795 Sm³**
Torchage	Gaz torché LPG			43-FQY-00001	823 095 Sm³
	Gaz torché LDHP			43-FQY-90001	0 Sm³
	Cumul Torchage LPG + LDHP			**43-FQY-00100**	**823 095 Sm³**
Gaz combustible consommé	Basse pression			45-FQY-00004	340 712.0 Sm³
	Haute pression			45-FQY-00003	289 448.0 Sm³
	Total			**45-FQY-00001**	**630 160.3 Sm³**
Cumul Eau consommée				50-FQY-00002	33.81 m³
Cumul Azote consommé				64-FQY-00503	10 633.58 Nm³
Cumul Eau vers bassin d'évaporation				44-FQY-00501	0.00 m³
Cumul d'huile récupérée dans le package des eaux huileuses				44-FQY-00502	0.42 m³

Etat des stockages

		Stock initial		Stock final	
		Volume (Sm³)	Masse (Tonnes)	Volume (Sm³)	Masse (Tonnes)
GPL	Sphère A	209.370	111.699	146.890	78.425
	Sphère B	55.394	29.553	67.954	36.281
	Sphère C	54.850	29.262	67.127	35.839
	Sphère Off-Spec	68.600	36.598	74.468	39.758
	Total	**388.214**	**207.112**	**356.439**	**190.303**
Condensats	Bac A	100.264	67.738	99.676	66.952
	Bac B	354.231	239.319	456.326	306.514
	Bac Off-Spec	241.448	163.122	361.740	242.980
	Total	**695.943**	**470.179**	**917.742**	**616.447**