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Theme

Assessment of biomass-based power production from biofuel in Algeria:

Resource-environment-economic analysis

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شكر وعرفان

الحمد لله الذي وفقنا وهدانا وأعاننا ويسر لنا طريق العلم و المعرفة لإتمامهذا العمل المتواضع

اللهم لك الحمد كما ينبغي لجلال وجهك و عظيم سلطانك

نتقدم بالشكر الجزيل إلى الأستاذة المشرفة "الدكتورة. "رسيوي بختة"

التي لم تبخل علينا بنصائحها القيمة و إسهاماتها المفيدة و بصماتها الواضحة وتعاملها ذو الميزة العالية والذي نعتبرها من أفضل الأساتذة على مستوى جامعتناو وطنيا.

الشكر الخاص للأستاذ " مسعودي جيلالي" الذي كان لنا مساندا في هذه الدراسة المتميز بتواضعه والمحبوب من طرف الطلبة

الشكر العام إلى جميع زملائنا وأحبتنا الذين كانوا لنا سندا و عونا في مشوارنا الدراسي

كمانتقدم بالشكر الجزيل إلى أعضاء لجنة المناقشة على قبولهم مناقشة مذكرتنا، كما نتقدم بالشكر الجزيل إلى أساتذة قسم الهندسة الميكانيكية و بالأخص أساتذة الطاقوية

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Abbreviations List

AD:	Anaerobic Digestion
AHP:	Analytical Hierarch Process
AND:	National Waste Agency
ARS:	Absorption Refrigeration System
CA:	Conversion Coefficient Animal
CHP:	Combined Heat and Power
CCHP:	Combined Cooling, Heat and Power
CI:	Consistency Index
CM:	Conversion Coefficient Municipal
CP:	Conversion Coefficient Palm
CR:	Consistency Ratios
DM:	Decision Makers
EFMT:	Externally Fired Micro Turbine
ET10:	Microturbine Prototype from Compower
EU:	European Union
GIS:	Geographic Information System
HTHE:	High Temperature Heat Exchanger
HWHE:	Hot Water Heat Exchanger
IRR:	Internal Rate of Return
IEA:	International Energy Agency
kg:	kilogram
km^2:	Square kilometers
kt:	kiloton
LSI:	Land Suitability Index
LHV:	Lower Heating Value
m:	Meter
m^3:	Cubic Meters
MCDA:	Multi-Criteria Decision Aid
n:	Matrix Size
NA:	Number of Animals
NP:	Number of Palms
Npop:	Number of Populations
NREP:	National Renewable Energies Program
NPV:	Net Present Value
OM:	Organic Matter
ONS:	National Organization of Statistics
Pc:	Price of Cooling
PC19:	Pink Chiller

Ph:	Price of Heating
PR_P:	Residue to Product Ratio Per Palm
QW:	Quantity of Waste
QW_A:	Quantity of Animal Waste
QW_M:	Quantity of Municipal Waste
QOW_M:	Quantity of Organic Municipal Waste
QW_P:	Quantity of Palm Waste
RHE:	Regenerative Heat Exchanger
RP_A:	Rate of Production PerAnimal
Rc:	Cooling Revenues
Re:	Electricity Revenues
Rh:	Heating Revenues
RP_M:	Percentage of waste Produce per capita
TIT:	Turbine Inlet Temperature
VB_A:	Biogas Volume of Animal waste
VB_M:	Biogas Volume of Municipal waste
VB_P:	Biogas Volume of Palm waste
Wi:	Weight Value for Each Criterion
WHE:	Water Heat Exchanger
λ:	Maximal Eigen valuer

ملخص:في السنوات الأخيرة ، ازداد الاهتمام العالمي بالوقود الحيوي ازدادت كمصدر بديل للطاقة بعد أن كان يحسب لها البشر عقود على الوقود الأحفوري الذي تسبب في تغير المناخ جادة على هذا الكوكب تسعى دراستنا في تحويل الغاز الحيوي الناتج من الكتلة الحيوية الى كهرباء وتدفئة وتبريد و الاستفادة منه بأقصى قدر ممكن و تطريقنا الى معرفة اهم اماكن التي تكمن فيها الكتلة الحيوية و توزيعها و تم تركيز على ولايات (ورقلة و غرداية و المنيعة) لتمكننا من تحصيل المعلومات المتطلبة لتحديد اهم مصادرالممكنة. حيث حددنا اهم المصادر الممكنة للكتلة الحيوية من بينها المخلفات الزراعية ،و نفايات البلديات ، و بقايا الحيوانية و احصائيات التي مكنتنا من اعطائنا نتائج محددة للبيوغاز.ويتركز التحليل البيئي على تقييم التأثير المحتمل لإنتاج الطاقة المعتمد على الكتلة الحيوية على جودة الهواء، واستخدام الأراضي ، وانبعاثات غازات الاحتباس الحراري. بالإضافة إلى ذلك ، فإن التحليل الاقتصادي سيقيم فعالية التكلفة لتنفيذ محطات توليد الطاقة القائمة على الكتلة الحيوية ، بما في ذلك عوامل مثل تكاليف الاستثمار ، والنفقات التشغيلية ، وتدفقات الإيرادات المحتملة.

الكلمات المفتاحية: الكتلة الحيوية ، الوقود الحيوي ، ورقلة ، غرداية ، المنيا ، كهرباء ، تبريد ، تدفئة

Abstract: In recent years, global interest in biofuel has increased as an alternative source of energy after humans have relied on fossil fuels for decades, which has caused serious climate change on this planet. our study aims to convert biogas derived from biomass into electricity, heating, cooling, and make the most of it. Our approach involves identifying the key locations where biomass is found and distributed, with a focus on the states of Ouargla, Ghardaia, and El-Menea, in order to gather the necessary information to determine the most significant potential sources. We have identified the most possible sources of biomass, including agricultural waste, municipal waste, and animal residues. Statistics have provided us with specific results regarding biogas.The environmental analysis will focus on assessing the potential impact of biomass-based energy production on air quality, land use, and greenhouse gas emissions. Additionally, the economic analysis will evaluate the cost-effectiveness of implementing biomass-based power plants, including factors such as investment costs, operational expenses, and potential revenue streams.

Key words: Biomass, Biofuel, Ouargla, Ghardaia, El-Menea, Electricity, Cooling, Heating

General Introduction

General Introduction

In recent years, the global energy landscape has witnessed an increasing interest in renewable and sustainable sources of energy production. Among these sources, biomass-based power generation has emerged as a promising solution, using organic materials to generate electricity while reducing environmental impact. This assessment aims to explore the potential for biomass-based energy production from biofuels in Algeria, focusing on a comprehensive resource-environment-economic analysis.

Algeria, and in particular the three states studied –**(Ouargla-Ghardaïa-El-Menea)** in this research, with its abundant resources of biomass and its strong commitment to renewable energy development, provides a fertile ground for exploring the feasibility of power generation using biofuels. By harnessing the energy potential of organic waste and agricultural residues, Algeria can diversify its energy mix, reduce dependence on fossil fuels, and mitigate greenhouse gas emissions. However, before implementing large-scale biomass energy projects, it is critical to assess resource availability, economic feasibility, and environmental impacts.This assessment will delve into the three main aspects: resources, environment, and economics.

In the first chapter, it will an overview of biomass was dealt with regarding its sources and conversions, such as converting into biofuels by Thermochemical and Biochemical as we mentioned, the types of biofuels and the characteristics of biomass

Then, in the second chapter, we touched on the potential of biomass (municipal waste, animal waste and palm waste) and the estimated amount of biofuel produced from this waste for the states of **(Ouargla, Ghardaïa and El Menea)** in 2021, and maps of the potential, Created using GIS.

Finally, a biogas Combined Cooling, Heat, and Power (CCHP) system offers a sustainable solution for generating electricity, heat, and cold simultaneously. This innovative technology utilizes biogas, produced from organic waste through anaerobic digestion, as a fuel source. The biogas is efficiently converted into electricity through a generator, supplying power for various needs. Waste heat generated during electricity production is captured and utilized for heating purposes, providing a cost-effective and environmentally friendly heating solution. Additionally, The CCHP system incorporates absorption chillers, which employ the waste heat to generate cold water for cooling applications. By harnessing the potential of biogas, this integrated system optimizes energy utilization, minimizes waste, and contributes to a greener energy landscape.

By conducting a comprehensive resource-economic-environment analysis, this assessment aims to provide valuable insights into the prospects and challenges of biomass-based energy production from biofuels in Algeria. The results of this study can inform policy makers, investors and stakeholders about the feasibility, sustainability and potential benefits of integrating bioenergy into the national energy mix. Ultimately, the goal is to contribute to the energy transition of Algeria in general and the three wilayas in particular towards a greener and more sustainable future.

CHAPTER I:

General on Biomass And Biofuels

1.1. Introduction

Biomass energy has persisted as a significant renewable energy source on a global scale. It is an important part of national energy mix both for developed and developing countries towards achieving sustainable energy for heating applications, reducing environmental impact, creating bio-economies, reducing over dependence on fossil fuel, improving quality of rural and urban life, and for the production of various biofuels [1].

Biomass energy has shared the largest contribution up to 9 % of total primary energy supply in the world and ranks as the fourth available source of energy in the world[2]. Both biological and thermochemical techniques can be used to turn biomass into commercial goods. The entire biomass is transformed into gases during thermochemical conversion, which are either consumed directly or used to make chemicals. The primary goal of the gasification process should be the production of thermal energy and should take the form of combustion, pyrolysis, gasification, and liquefaction.The objective of chapter is an overview of the concepts of biomass and its resources and biofuels and its types and benefits and disadvantages.

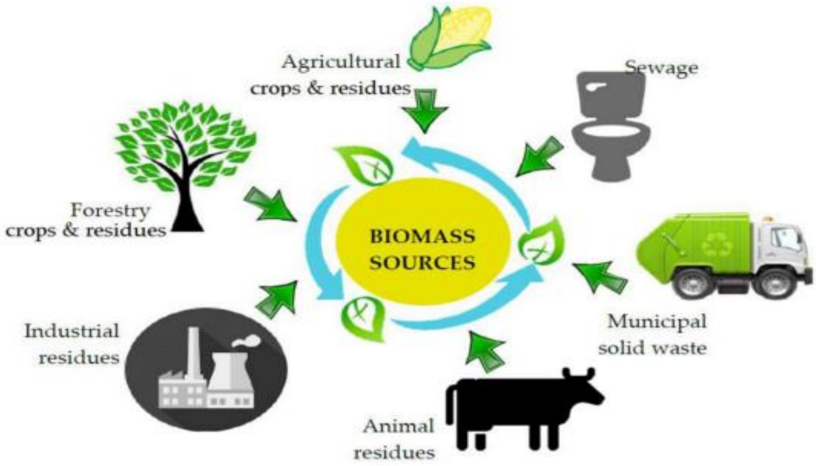
1.2. Biomass energy

1.2.1. Definition

Biomass renewable energy can be released through burning garbage, crops, and wood. When these biomass fuel products are burned, a chemical energy is released as heat, which can be used to make electricity. Burning is not the only way to get biomass renewable energy gases, like methane, which is released when garbage and waste starts to decompose. Even though it is stinky or more appropriately, “smelly,” the results are methane gas. Animal byproducts, such as manure from farming animals, can also be changed into methane. Crops or plants like sugar cane, soybeans, vegetable oils, corn, and animal fats, can be fermented to create ethanol, which is a form of fuel used in transportation.[3]

1.2.2. Resources of biomass

Biomasses resources that are available on a renewable basis and are used either directly as a fuel or converted to another form or energy product are commonly referred to as “feedstocks”.[4].



A)Agricultural Crops Residues:

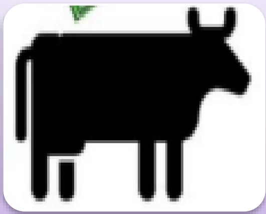
- Are the non-edible stalk type materials that remain after the harvest of the edible portions of the crops, such as corn, wheat, grain and sugar cane. Agricultural residues also include plant leaves, husks, some roots and stems.

B)Food Processing Waste:

- Is an effluent waste from a wide variety of industrial processes ranging from breakfast and cereal bar manufacturers to fresh and frozen vegetable manufacturers to alcohol breweries. Fermentation of liquid wastes and oils from food processing can produce Ethanol.

C)Municipal Solid Waste:

- This is the items that are thrown away in the garbage and is collected by the dustbin men or sent to the recycling centre. However, not all municipal waste is suitable as a biomass resource, especially metallic and plastic waste.



D)Animal Waste:

From farms, ranches, slaughterhouses, fisheries and dairies or any concentration of animals animal wastes, ,The treatment of animal waste produces combustible methane and biogas which can then be used for heating and transportation.

Figure 1.1: The different biomass resources

Biomassfeedstocks include dedicated energy crops, agricultural crop residues, food processing waste, municipal solid waste, municipal waste, animal Waste.

1.3. Conversions of biomass

1.3.1. Thermochemical conversion route of biomass

Thermochemical processes are most commonly employed for converting biomass into higher heating value fuels.

Pyrolysis	Direct Combustion	Gasification
• **A)** Thermal, anaerobic decomposition of biomass at temperatures of 377- 527°C is called pyrolysis. A temperature of at least 400°C in pyrolysis process.[5]	• **B)** Combustion is an exothermic chemical reaction of a fuel with oxygen. Common products of combustion are carbon dioxide and water with the release of heat. Direct combustion systems oxidize biomass to generate hot flue gas which can be used for heat or fed into a boiler to generate steam. The steam can then be used in a steam turbine to generate electricity.[6]	• **C)** Processes provide a competitive route for converting various, highly distributed and low-value lignocellulosic biomass to synthetic gas for generation of a broad sort of outputs: electricity, heat and power,and hus any lignocellulosic biomass can be considered appropriate.[5]

Major thermal conversion route is include direct combustion to provide heat, liquid fuel and other elements to generate process heat for thermal and electricity generation. [7]

1.3.2. Biochemical conversions of biomass

Biochemical conversion is a major and an efficient pathway for the production of biomass derived fuels chemicals and materials. It mainly involves hydrolysisoflignocelluloses polysaccharides into simple sugars and their further conversion into.fuel ethanol by fermentationorganisms [8]. It boils down to two different processes:

Anaerobic Digestion:

- **A)** Anaerobic digestion is a biological process that turns organic material into a gas mostly made of methane and carbon dioxide when there is a lack of oxygen. The process of anaerobic digestion occurs in three steps: hydrolysis, acid formation, and methane production. During hydrolysis, bacterial enzymes break down the organic material into simple sugars. The sugars are then converted to acetic acid, carbon dioxide, and hydrogen. Subsequently, the bacteria convert the acetic acid to methane and carbon dioxide and combine carbon dioxide and hydrogen to produce methane and water.[9][10]

Fermentation :

- **B)** A biomass to energy process called fermentation converts cellulose into glucose by hydrolysis. The glucose is then fed to a fermenter where it is converted into ethanol by microorganisms. A “pretreatment” is often employed as a means to expose the cellulose by separating it from hemicelluloses and lignin.[11]

1.4. Biofuels

1.4.1. Sources and Process of biofuels

Unlike other renewable energy sources, biomass can be converted directly into liquid fuels, called "biofuels," to help meet transportation fuel needs. The two most common types of biofuels in use today are ethanol and biodiesel, both of which represent the first generation of biofuel technology. biofuel demand in 2021 reached 4 EJ (159 200 million liters).[12]

Table 1.1: Types of biofuels

Types of biofuels	Sources	Process
A) Biogas	Biogas are gaseous products obtained from biomass by different processes, they are produced by fermentation (microbial digestion in the absence of oxygen) of organic matter.[13]	In practice, this biogas is obtained by putting organic materials in an enclosure which is sheltered fromthe air and by ``letting the bacteria do their job`` which will decompose them. The gases resulting from this fermentation are composed of 65% methane, 34% CO, and 1% other gases including hydrogen sulphide and dinitrogen[13]
B) Biodiesel	Biodiesel is a biofuel intended for use in diesel engines and comes from the conversion of lipids (vegetable oils and animal fats) into fuel. • including soybean, rapeseed, palm and other vegetable oils • Animal fats (relatively little used). it is a promising fuel that pollutes less. .[14]	Bacteria that consume organic matter (biomass) without oxygen produce biogas. Anaerobic digestion is the term for this procedure. It can be artificially replicated in specially designed containers known as digesters. It can occur naturally anywhere, including the interior of the digestive system and the bottom of effluent ponds.[14]
C) Ethanol	Bioethanol is the only liquid fuel for gasoline engines that is renewable and immediately available since it is produced from vegetable raw material, also called biomass. It is used in gasoline engines.[15]	Bioethanol is produced by fermenting the sugars and starches found in cereals, sugar beets, and their processing waste; it does not include palm oil. The most popular biofuel worldwide is bioethanol

1.4.2. Production of biofuels:

The biofuel industry has witnessed significant developments during the past century, as its production sources have evolved, and four generations can be identified for this fuel, namely:

A / thefirstgeneration Biofuels

First-generation biofuel production is characterized by developed commercial markets and well-understood technology, as shown in the production of sugarcane ethanol in Brazil, maize ethanol in the US, oilseed rape biodiesel in Germany, and palm oil biodiesel in Malaysia. Between 2000 and 2007, the demand for liquid biofuels on a worldwide scale more than quadrupled. Future goals and investment strategies indicate that robust growth will persist in the foreseeable future.[16][17]

B /Second generation Biofuels

Depends on vegetable waste to produce cellulose, ethanol, crucial methanol, and biological hydrogen, such as wheat, corn, sawdust, and straw. Although utilizing agricultural waste to make fuel is important, it is bad since it deprives livestock of feed and agricultural land of plant waste, which is an organic fertilizer. [5]

C / Third generationBiofuels

Many types of algae could be used: some cultivated specifically for biofuel production and some that are wastes collected from polluted waters. Production of biofuels from algae usually relies on the lipid content of the microorganisms. Species such as Chlorella are therefore targeted because of their high lipid content (around 60 to 70 %) and their high productivity. [18]

1.5. Advantages and disadvantages of biomass and biofuels

1.5.1. Advantages

Major advantages of biomass and biomass fuels:[16][17]

- Renewable energy source for natural biomass.
- Biomass is a reliable source of electricity
- Biomass helps reduce waste.
- Use of no edible biomass
- Reduction of biomass residues and wastes.
- Restoration of degraded and contaminated lands.
- Diversification of fuel supply and energy security.

1.5.1. Disadvantages

Major disadvantages of biomass and biomass fuels:

- Space requirements
- Adverse environmental impacts
- Expensive.
- Omission of sustainable criteria for production of biomass resources for biofuels andchemicals.
- Insufficient knowledge and variability of composition, properties and quality for assessment and validation.
- High investment cost.
- Insecurity of biomass feedstock supply.

1.6. Conclusion:

Biomass refers to any organic matter, such as wood, crops, agricultural waste, and even garbage that can be used to produce energy. Biomass is considered a renewable source of energy because it is derived from living or recently living organisms that can be regrown or replenished.

Reducing dependency on fossil fuels, reducing greenhouse gas emissions, and improving waste management are just a few benefits of using biomass as an energy source. It does, however, have certain drawbacks, including the possibility for land-use disputes, rivalry with food crops, and the requirement for huge biomass to provide significant energy.

Overall, using biomass as an energy source has great promise for lowering our reliance on non-renewable energy sources and combating climate change. To maintain its sustainability and reduce any negative effects, however, care should be taken in the source and handling of biomass.

CHAPTER II:

Potential of biomass and biofuel production:a case study of Ouargla, Ghardaia, El-Menea

2.1. Introduction

In current years, scientists, researchers, and manufacturers have been looking for the renewable and clean feedstock for fuel production processes aiming to satisfy the strict requirements of the sustainable development progress and strategy of the modern society in the future [19].They discovered that biomass is a renewable resource. Any biological material, including living species or their remains, can be utilized as a source of biomass. This includes wood, other organic materials, forest debris from trees, plant pruning materials, and wood splinters.

This chapter discuss the potential of biomass (municipal, animal and palm wastes) and biogas productionbased on the available potentials, as the biogas produced in this process consists of two components, methane and carbon dioxide with a small amount of other gases. Biogas usually contains about 55-65% methane, 30-35% carbon dioxide, and some hydrogen, nitrogen and otherimpurities. [20]

2.2. Describe the following fields of studies the following states (Ghardaia-Ouargla-El menia)

2.2.1.Province ofGhardaia

Thewilaya of Ghardaia is located in the north of the Algerian Sahara. It is bordered to the north by the wilaya of Djelfa and the wilaya of Laghouat, to the south by the wilaya of El-Meniaand to the east by the wilaya of Ouargla and to the west in the wilaya of ElBayadh (the new administrative division (see Figure 2.1)[21].

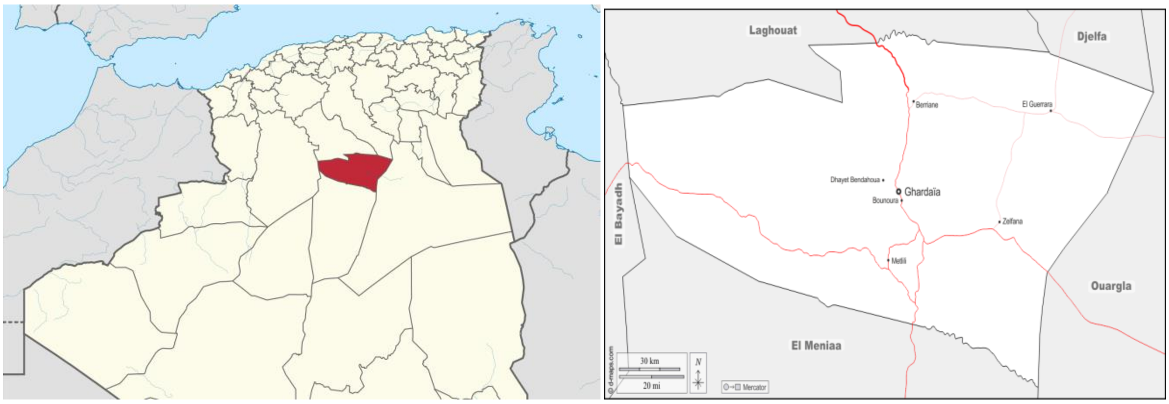


Figure 2.1: Borders and municipalities of the state of Ghardaia

Since the state is located in desert areas, the climate of the region is dry desert. The temperature range is wide between day and night, and between winter and summer. The temperature ranges from 1 to 25 °Cin winter, and between 18 to 48 °C in summer. [21]

According to the 2021 census, the population of the province of Ghardaïa was 457,513 with an estimated density of 7.44 persons/km².[22]

2.2.2.Province of Ouargla

The city of Ouargla is located in the southeast of Algeria. It is bordered on the north byOued-Souf and BiskraandDjelfa, on the east by Tunisia, on the south by the states of Illiziand Tamanrasset, and on the west by the state of Ghardaia. Its area is 163,230 km²(oldadministrative division). It is a desert city characterized by its wide geographical area, and itis one of the largest cities in Algeria, see Figure 2.2.

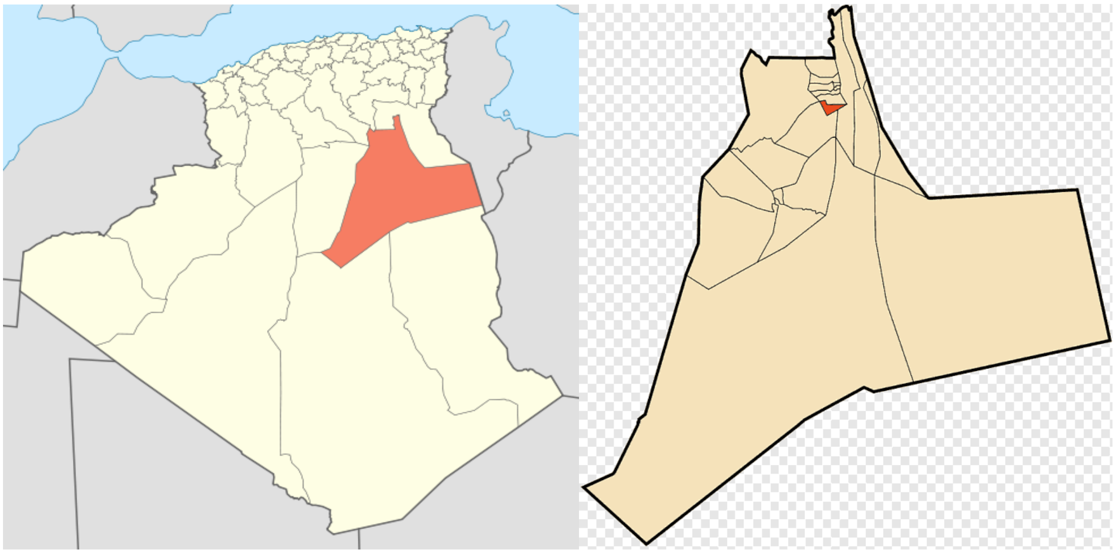


Figure 2.2: Borders and municipalities of the state of Ouargla

The population of the province is estimated to be about 708,463 in 2019 [23] , with apopulation density of 4.34 persons living within every square kilometer. The provinceconstitutes an economic pole in gas and oil reserves, contained on the territory of Hassi-Messaoud. Ouargla has a desert climate typical of the Sahara Desert. The averagetemperatures are the highest. The temperature of July (the hottest month) is around 43 °C. [24]

2.2.3. Province of El-Menea

The wilaya of El Menea is in the Algerian Sahara, its area 131,220 km².
It is delimited by:

- to the north by the Ghardaia Province
- to the east by the Ouargla Province
- to the west by the El Bayadh Province and Timimoun Province
- and to the south by the In Salah Province.

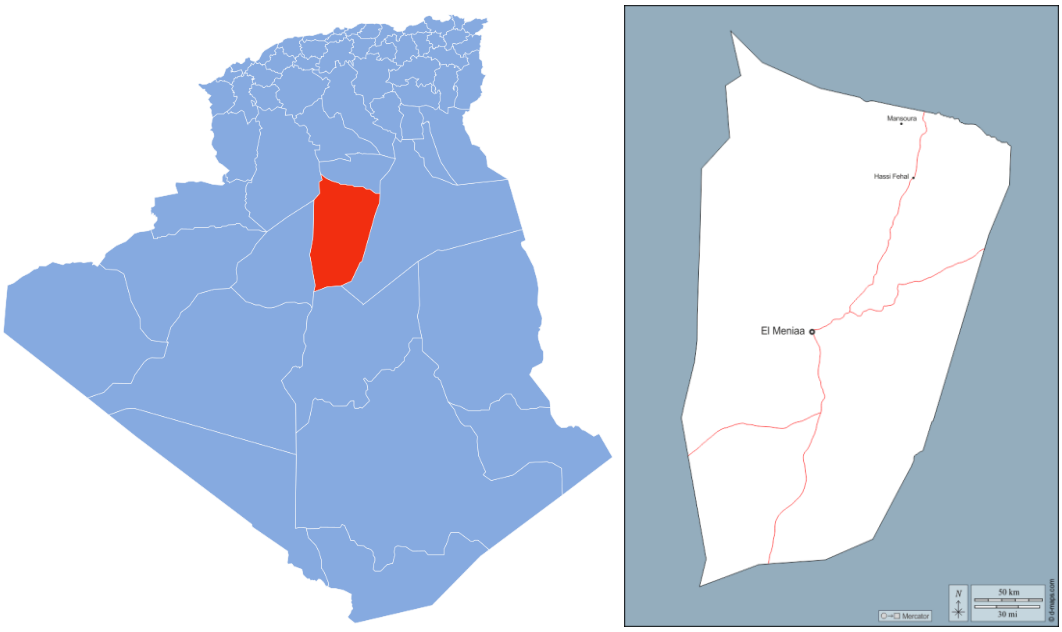


Figure 2.3: Borders and municipalities of the state ofEl-Menea

El-Menea has a hot desert climate , with long, extremely hot summers and short, warm winters. There is very little rain throughout the year, and summers are especially dry. Summer daytime temperatures are known to consistently approach 45 °C (113.0 °F). The sky is clear throughout the year and sunny, bright days are guaranteed. On July 7, 2021, the record high temperature of 49.1 °C (120.4 °F) was registered. [25]

Total Area is 62,215km². According to the 2021 census, the population of the province of El-Menea was 71574 with an estimated density of 1.16 persons/km². [22]

2.3. Biomass potential in Algeria

A) Potential of the forest

A 37 Mtoe potential is thought to be the current estimate. The potential for recovery is in the range of 3.7 Mtoe. At the moment, the recovery rate is around 10%. Biomass has a rather limited potential. There are around 250 million hectares of trees in the area.

Roughly 10% of the country's overall land, with the Sahara taking up nearly 90% of the continent. Whereas alfa tier zones only make up around 2.5 million hectares, or just more over 1% of the whole land, forests make up roughly 4.2 million hectares, or 1.8% of the total area. Contrarily, more than 188 million hectares, or 79% of the total area, are deemed to be unproductive lands.[26]

B)Household and similar waste

Around 37 Mtoe is thought to be the present potential. The potential for recovery is in the range of 3.7 Mtoe. The recuperation rate at the moment is about 10%. Urban and agricultural garbage totaling 5 million tons is not recycled. This potential corresponds to a deposit of around 1.33 Mtoe each year. [27]

2.4. Biomass potential and biofuel production in three provinces (Ouargla , Ghardaia , El-Menea):

In this study, the possibility for producing biogas from city garbage and agricultural waste from date palms and livestock manure is evaluated (sheep, cows, camels and goats). The technology used to produce biogas is the anaerobic digestion.

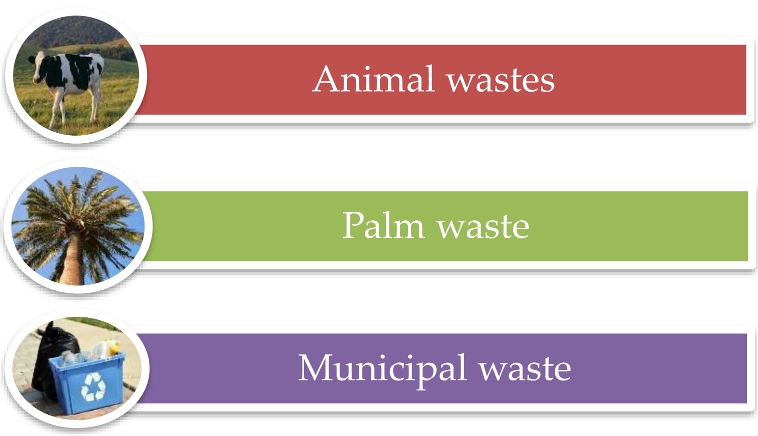


Figure 2.4: The classification of biomass used in this study.

The combined use of statistical and spatially explicit approaches forms the foundation of the developed method. The created method consists of the following key steps:

- Assessment of the biomass potential;
- Energy valorization of the biomass potential (biogas);
- GIS mapping.

2.4.1. Biomass potential

A) Animal wastes production:

The most significant sources of biomass for the creation of biogas is animal waste. Animals in great numbers and a large amount of trash are produced in Ouargla, Ghardaia, and El-Menea. The following table shows the animal statistics for Ouargla in (2019) and Ghardaia and El-Meneain (2021):

Table 2.1: Census of cattle camel's sheep and goats in the wilayas (ouargla ,ghardaia, El-Menea)

The states	The cows	The camels	The sheep	The goats	Rf:
Ouargla	999	41503	1458778	213690	[23],[24],[28]
Ghardaia	4363	11532	327220	153588	[29]
El-Menea	512	6468	79780	46412	[29]

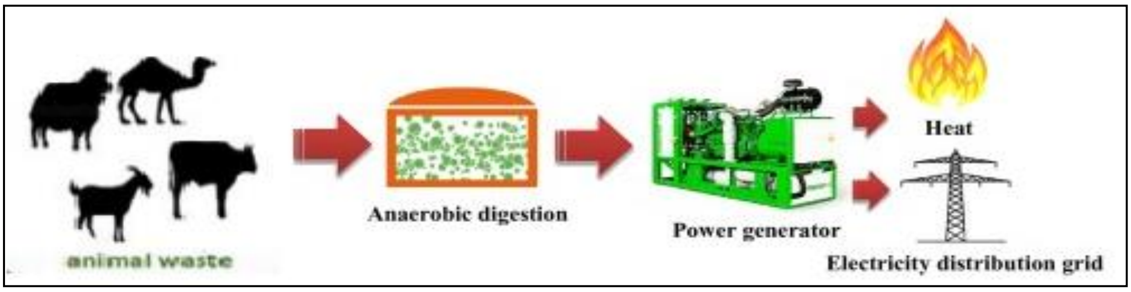


Figure 2.5: Biogas production from animal waste [30].

On the basis of these figures, it can be concluded that three states have a large potential for producing biogas by using the waste from cattle husbandries. Based on the animal feed, body weight, and particles in the waste, biogas can be produced from livestock wastes.

Total animal waste production (QW_A) is estimated at the city level under study during the reference year by multiplying the number of livestock heads (N_A) and the rate of production per head (RP_A). These steps are summarized in the following equation:

$$\mathbf{QW_A = N_A.RP_A .365} \quad (2.1)$$

For large livestock (cows and camels), the daily amount of manure is calculated as 9% of the livestock weight, and for small livestock as 4%.(goats and sheep). [31]

B) Palm waste production

As the examined states have a huge potential for palm trees, estimated at 2,628,814 for Ouargla, 995,455 for Ghardaia and 322,565 for El-Menea, palm waste is one of the most significant sources of biomass for the generation of biofuels.[32][29]

The annual production of residues produced during agricultural production is referred to as the theoretical potential of residues from plant production. Leaf stalks, empty fruit clusters, and leaves make up the garbage that has been collected. Each palm tree typically produces 6 to 10 empty fruit clusters, 12 to 15 stalks, and 120 to 240 leaves per stalk. This sums to roughly 15–35 kilograms of garbage per tree per year.[33]

By multiplying the total number of palms (N_P) and the residue to product ratio per palm, the total production of palm waste (QW_P) at the provincial level under study during the reference year is calculated (PR_P). Equation (2.5) estimates total production as follows:

$$\mathbf{QW_P = N_P.PR_P .365} \quad (2.2)$$

Each palm produces 15 to 35 kg of residue on average (including fruit clusters, stems, stalks, leaves, etc.). An average of 25 kg was collected, according to scientific reports and published reference articles. [33] [34].

C) Municipal waste production

In accordance with Law No. 01-19 of December 12, 2001, "household and similar" and "municipal waste" refers to all waste generated by households (consumer waste), as well as waste generated similarly by industrial operations, commercial enterprises, artisanal activities, and other things that are similar to household waste in nature and composition.[35]

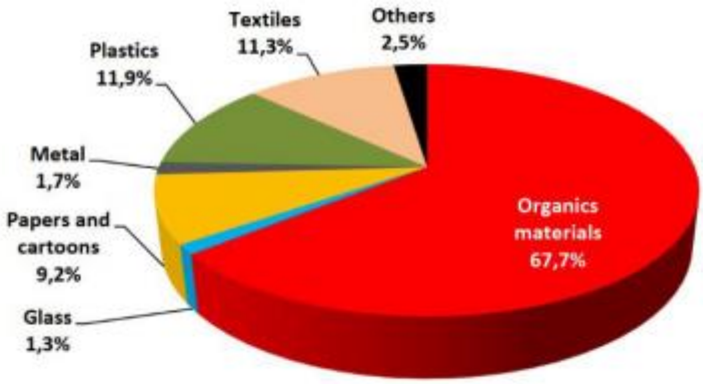


Figure 2.6: Composition of waste in Algeria (2011). [35]

After examining and counting the three different states in terms of municipal waste productionwe found for the state of Ouargla (215,50kt) And the state of the impenetrable (20,89kt)And finally, the state of Ghardaïa (133,59kt)[28]

The specific production ratio per resident and per day estimated for the area in question (RPM), multiplied by 365 (days), and multiplied by the population of that city (N_{pop}), based on estimates made for the base year, is used to estimate the production of waste at the level of a wilaya (QW) during the reference year 2019. [35]

$$QW_M = N_{pop} . RP_M . 365 \quad (2.3)$$

The production of city waste (QW_M) and the proportion of average organicmatter(OM) in this trash are multiplied to estimate the total production oforganic waste of urban origin (QWO_M) at the level of the city under investigation during the reference year. The following equation condenses these actions:

$$QWO_M = QW_M . OM \quad (2.4)$$

The national garbage agency [36] estimates that 67.7% of trash is organic matter (OM). We assume that the waste's composition is uniform throughout Algeria. This mixture is calculated for the year 2011. [35].

2.4.2. Biogas potential

A) Biogas production from Animal wastes

Depending on the type of diet and the living circumstances of the cattle, different types and amounts of manure are produced. The quantities of biogas generated from animal manure might vary. The amount of animal waste QW_A (kt/year) and the conversion factor C_A (m^3/tons) are used to calculate the volume of biogas VB_A (m^3).

$$\mathbf{VB_A = QW_A . C_A} \quad (2.5)$$

Therefore, in this study, according to published scientific reports and reference papers, different methods are used to calculate the biogas production factor from biomass (see Table2.1).[31].[36][34]

Table 2.2: Conversion coefficient to biomass and biogas

Resource	Biomass conversion coefficient (kg/head)	Biogas conversion coefficient (m^3/kg)
Cow and calf	22.5	75
Camels		
Sheep	1.6	13
Goats		

The conversion coefficient varies from animal to animal. according to published scientific reports and reference papers,the conversion coefficient for each animal has been determined in the Table 2.1.

B) Biogas production from palm waste

Based on the great potential of palm waste in the city of Ouargla, which is estimated at 2628814 palm trees et El-Menea322565.00palm trees et Ghardaia995445.00palm trees which can produce large quantities of biogas, according to published scientific reports and reference papers, the determination of the volume of biogas VB_P (m^3) estimated from the quantity of palm waste QW_P (kt/year) and conversion coefficient C_P (m^3 / tons) is as follows.[34][37][38]

C) Biogas production from municipal waste

According to the amount of organic refuse QOW_M (kt/year) and conversion coefficient CM (m^3/tons), the volume of biogas VBM (m^3) is calculated as follows:

$$VB_M = QOW_M . C_M \quad (2.6)$$

The conversion factor ranges (C_M) from 100 to 300 m^3 per ton of waste. In our study, we took an average of 200 m^3 / ton. This approach was used to assess biogas recovery frommunicipalwaste. the conversion factor (cm) ranges from 100 to 300 cubic meters per ton of waste. In our study, we took an average of 200 m^3/ton. This approach was used to evaluate biogas recovery from the following municipal waste, where the average population of Ouargla is 738,029 and Ghardaïa is 457,513and the impenetrable 71574. [35]

2.4.3. Total potential:

Organic waste can be recycled into biogas, which can be utilized as a fuel for the cogeneration of heat and power. Due to the comparatively low cost of cattle and agricultural resources in Ouargla, Ghardaia, and El-Menea, they have a significant potential to produce biofuels. This study seeks to provide an accurate and realistic estimate of resource availability by evaluating Ouargla's capacity to produce biofuels from both agricultural and animal resources. Table 2.3 reveals determine the annual production of biogas from biomass waste.

Table 2.3: The amount of biogas produced from biomass for the year of (Ghardaia)

	Biomass (kt/year)	Biogas(1000m^3)
animal waste	411.32	13440.62
municipal waste	90.44	18088.6
Palm waste	24.88	4.607168
Total potential	526.64	31532.61

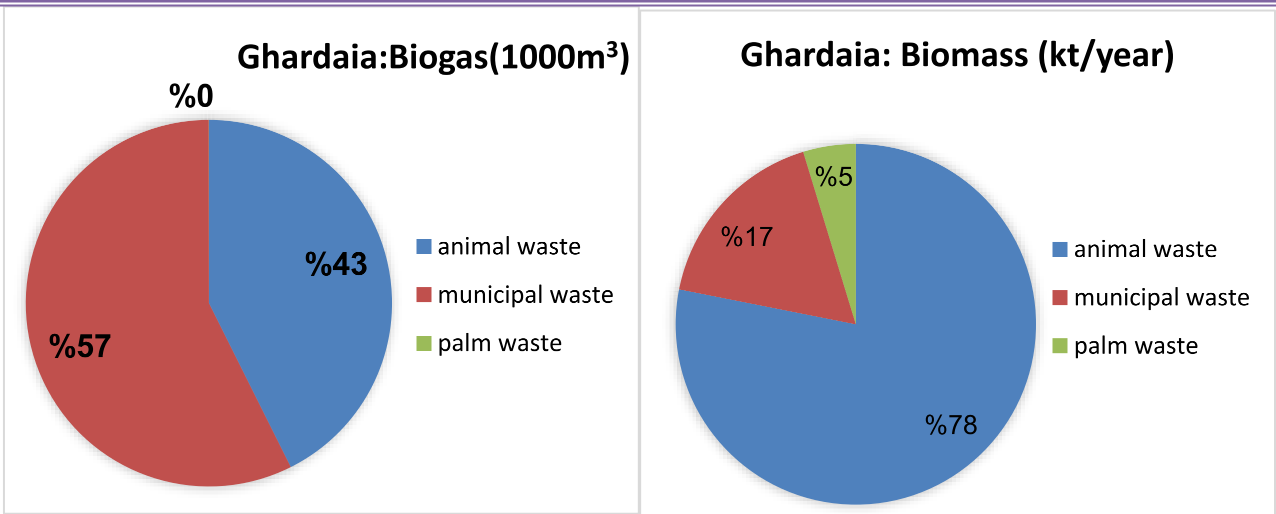


Figure 2.7: The total potential of biomass waste and biogas in Ghardaia

Table 2.4: The amount of biogas produced from biomass for the year of (El-Menea)

	Biomass (kt/year)	Biogas(1000m³)
animal waste	131.02	5257.29
municipal waste	14.14	2829.8
Palm waste	8.06	1.49291
Total potential	153.22	8088.58

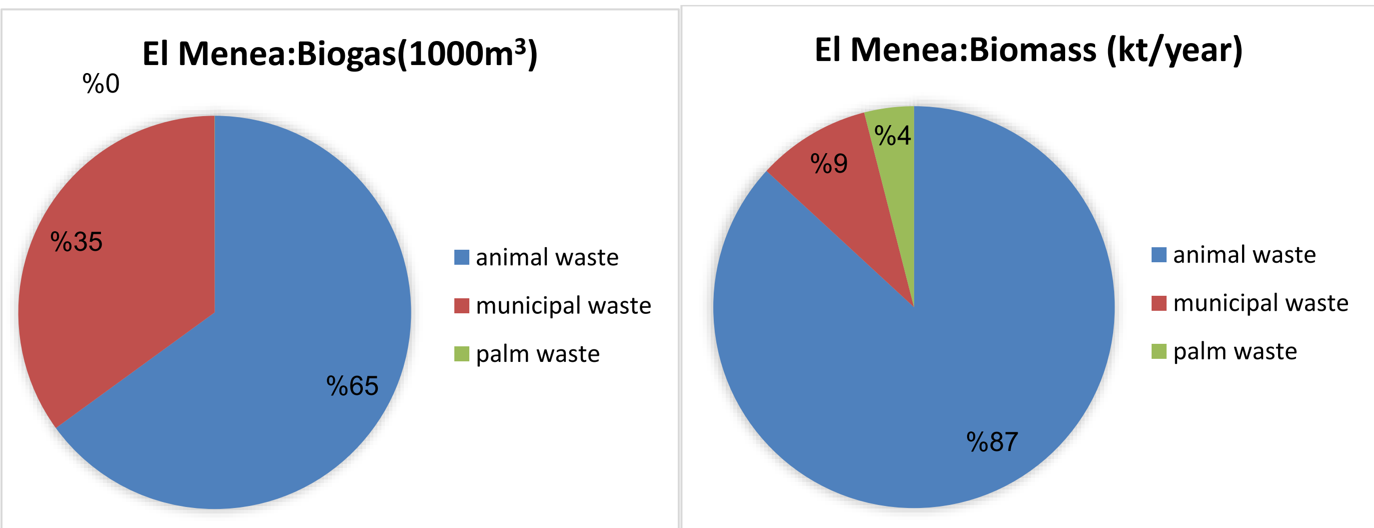


Figure 2.8: The total potential of biomass waste and biogas in El-Menea

Table 2.5: The amount of biogas produced from biomass for the year of (Ouargla)

	Biomass (kt/year)	Biogas(1000m³)
animal waste	559.03	28.90840
municipal waste	145.89	29.17930
Palm waste	65.72	12.16680
Total potential	773.61	70.2545

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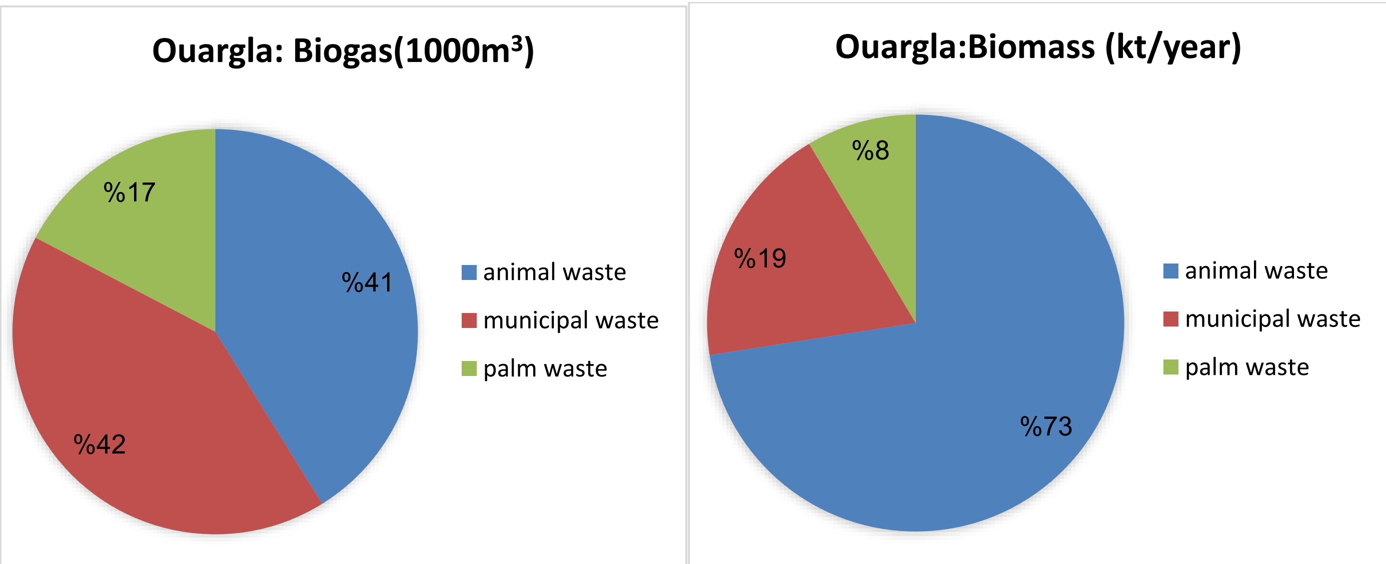

Figure2.9: The total potential of biomass waste and biogas in Ouargla

The total palm waste of three states in total is estimated at 98.66 kilotons/year, which can be considered as a potential raw material for the production of 18266, 88 m^3 of biogas. In addition, the potential of biogas from 1101,38 kt/year of livestock waste is estimated at 47606,32m^3/year, and municipal waste is estimated at 250488,55kt / year, which produces 50097,71m^3 / year, and the results showed that there is a great potential for this biofuel generation.

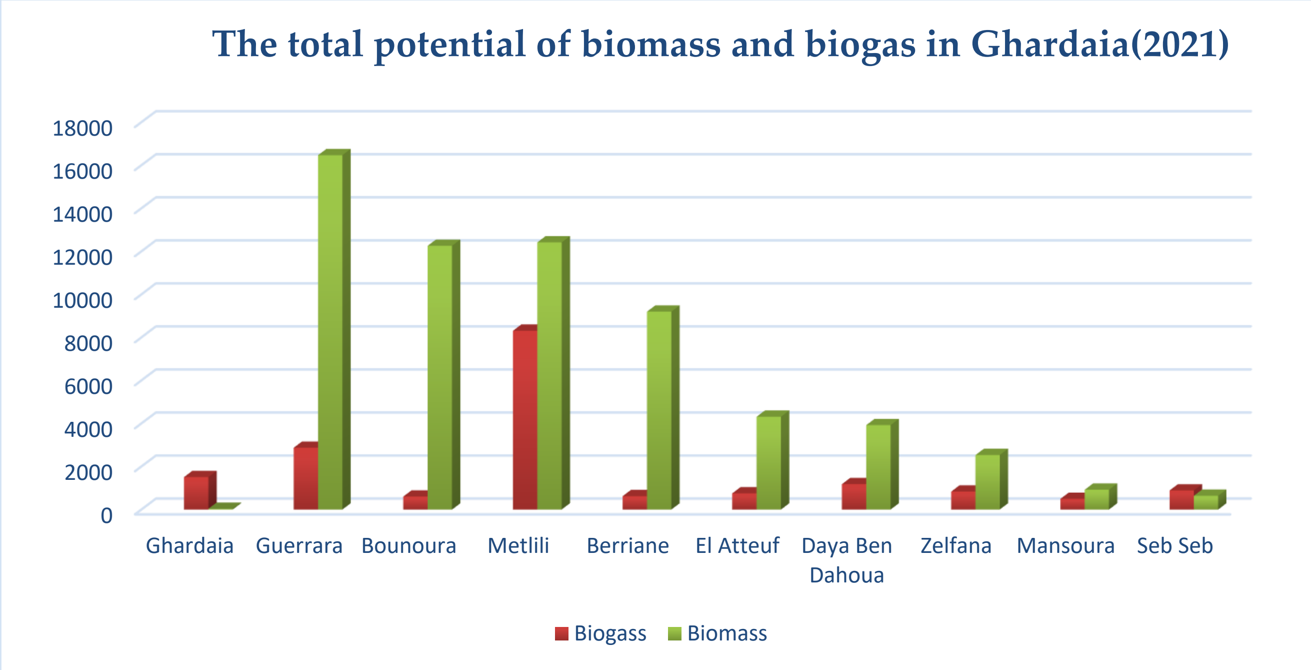

Figure 2.10: The total potential of biomass and biogas in Ghardaia(2021)

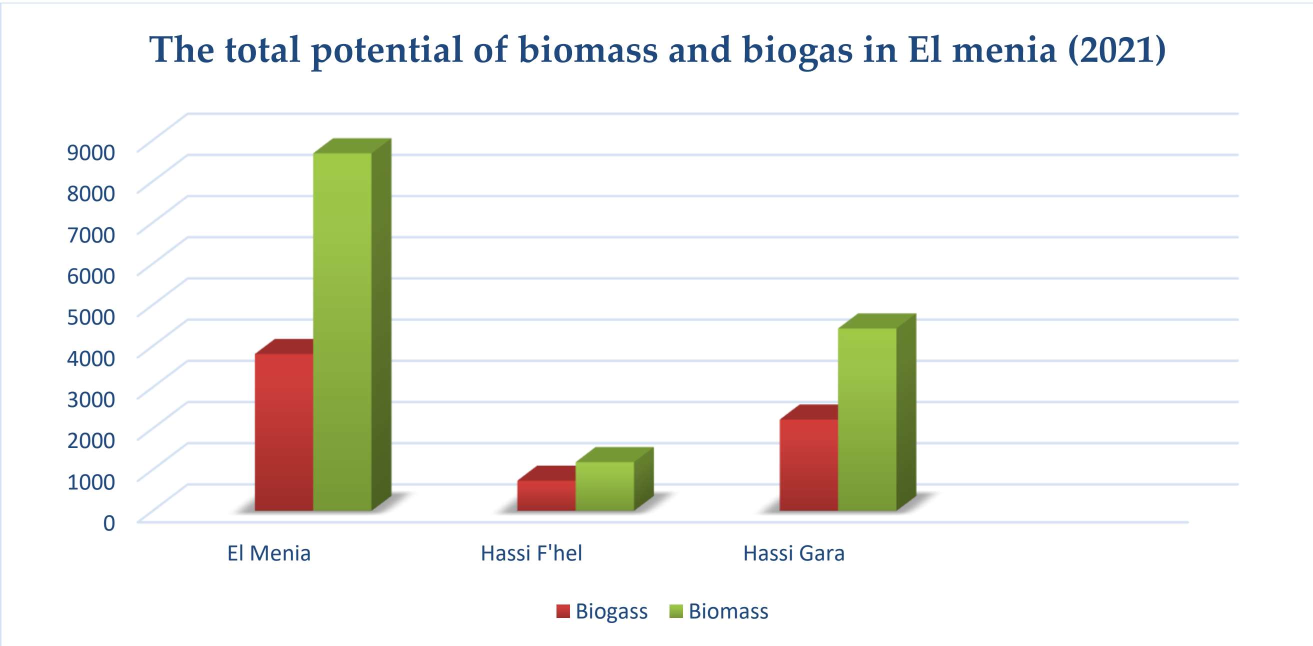

Figure 2.11: The total potential of biomass and biogas in El-menia (2021)

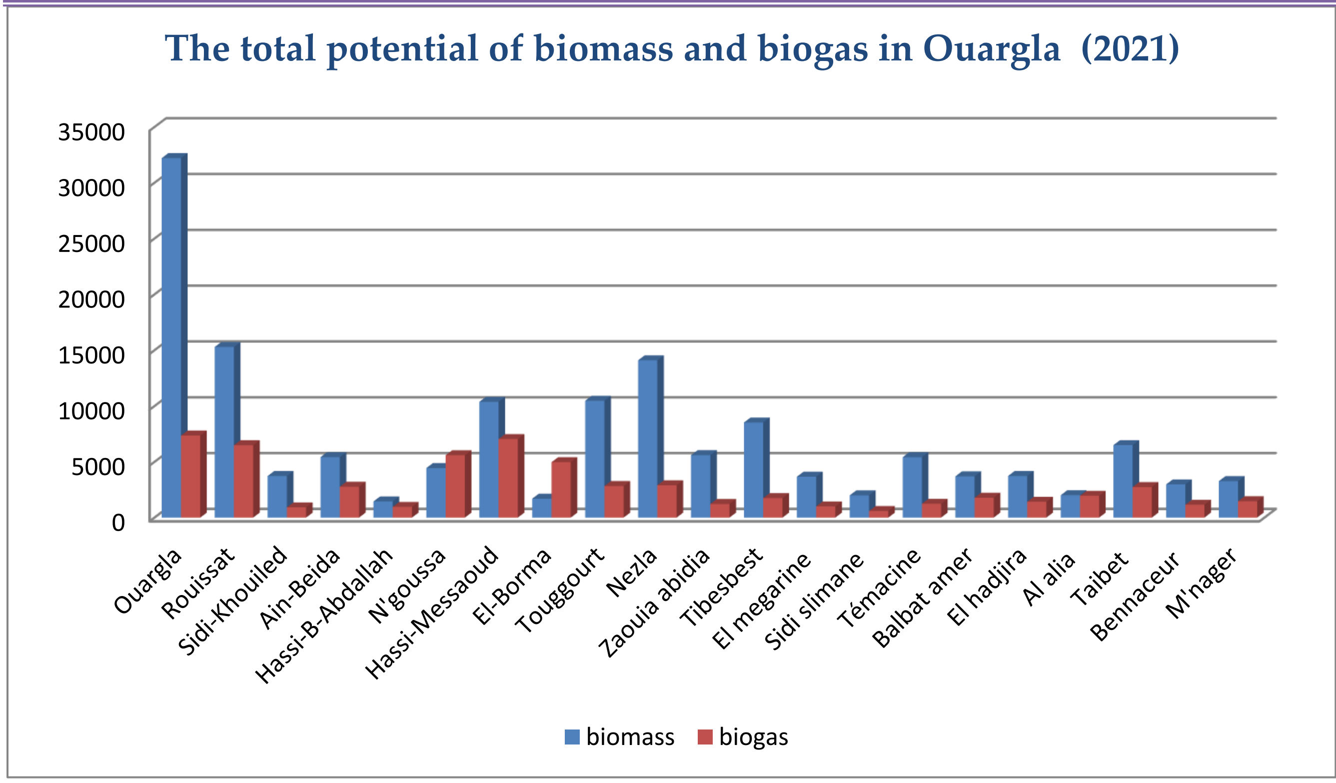

Figure 2.12: The total potential of biomass and biogas in Ouargla

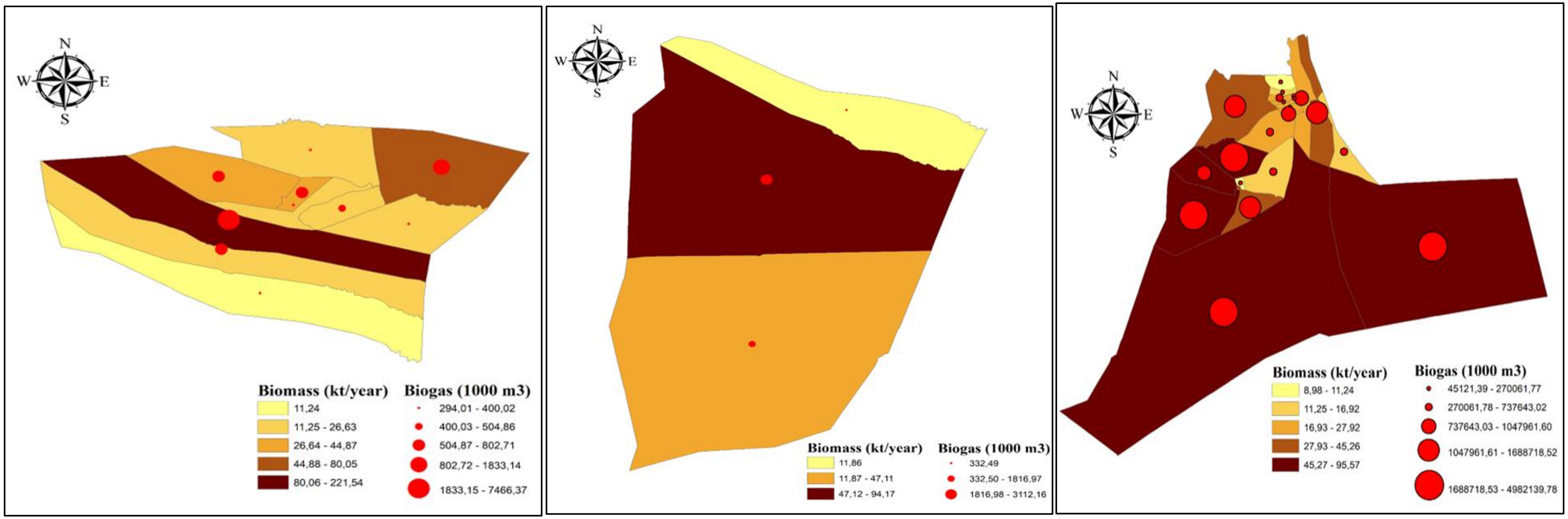

Figure 2.15: Geographical distribution of the biogas and biomass waste potential in Ghardaia, El-Menea et Ouargla

2.5. Conclusion

Biomass refers to any organic matter, such as wood, crops, agricultural waste, and even garbage that can be used to produce energy. Biomass is considered a renewable source of energy because it is derived from living or recently living organisms that can be regrown or replenished.

Overall, based on the case study conducted in Ouargla, Ghardaia, and El-Menea, it can be concluded that the regions have significant potential for biomass and biofuel production. The availability of biomass resources, favorable climate conditions, socioeconomic and environmental benefits, and advancements in technology all contribute to this conclusion.

This chapter presents a study on the potential of biomass and biogas production in the wilayas of Ouargla, Ghardaïa and El-Menea.Where the biomass potential (municipal, animal and palm waste) and the total amount of biogas are estimated. for each of the following states:

Ghardaia biogas(1346331.7m^3 / year) and biomass (526,6586844kt/year)

El-Menea biogas (5261616.132m^3 / year) and biomass (153.2325376kt /year)

Ouargla biogas (28949754.4m^3 / year) and biomass (770.6516778kt /year)

CHAPTER III:

Techno-economic analysis and environmental impact

3.1. Introduction

Biogas is a renewable energy source that is relatively cheap and available throughout the year. As a result, using biogas for CHP can reduce the overall energy costs of a facility or business. The waste heat produced by the generator can be captured and used for heating purposes in nearby buildings, further reducing energy costs. In addition, the waste heat can also be used to produce cold through absorption refrigeration, which can further reduce energy costs and increase efficiency.Biogas can be converted into electricity, heat, and cold through a process called combined heat and power (CHP) or cogeneration. The economic return on this process depends on several factors, including the cost of the biogas production system, the price of electricity and other energy commodities, and the incentives and subsidies available for renewable energy projects. [39]

Trigeneration or combined cooling, heat and power (CCHP) systems fueled by raw biogas can be an interesting alternative for supplying electricity and thermal services where biogas can be produced without requiring sophisticated equipment. In this sense, this study considers a performance analysis of a novel small-scale CCHP system where a biogas-fired, externally fired micro turbine (EFMT), an absorption refrigeration system (ARS) and heat exchangers are integrated for supplying electricity, refrigeration and hot water. The EFMT considered in this study is the ET10 microturbine prototype from Compower AB [40], while the ARS is the Pink Chiller PC19 [41]. which is commercially available.

3.2. Producing electricity and heat and cold from biogas:

First, the process begins with anaerobic digestion. It is a biological process in which microorganisms break down organic matter in the absence of oxygen, producing biogas as a by-product. This process can be used to treat organic waste such as agricultural residues, food waste, and wastewater sludge, while also producing renewable energy in the form of biogas. [42]

Biogas from anaerobic digestion typically consists of methane (50-75%), carbon dioxide (25-50%) and small amounts of other gases such as hydrogen and nitrogen. This biogas can be used for various purposes, including generating electricity and heat. After the anaerobic digestion process, the biogas produced is transferred to an generator system for extract electricity and heat. [43]

Producing electricity, heat, and cold from biogas can be achieved through the use of micro turbines, absorption chillers, and cogeneration systems.

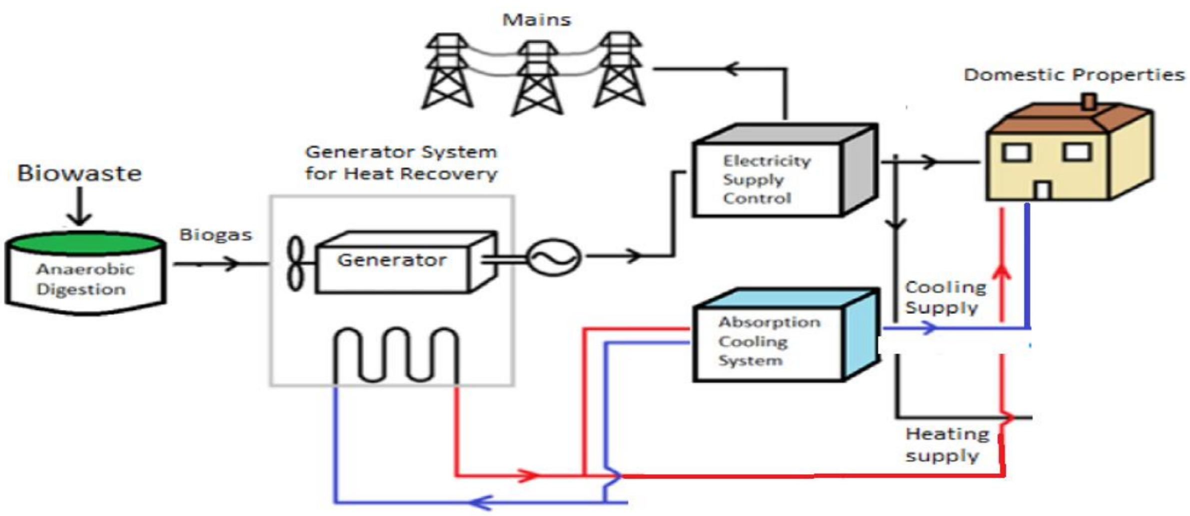

Figure 3.1: Trigeneration schematic detailing electricity, heat and cooling flows.

Micro turbines are small combustion turbines that can generate electricity by burning biogas. They can also be used in cogeneration systems, where the waste heat from the micro turbine is captured and used to generate hot water or steam for heating or other applications.[44]

Absorption chillers, on the other hand, can be used to produce cooling by using waste heat from the biogas plant. These chillers use a heat source to drive a refrigeration cycle, which can be powered by the waste heat produced by the biogas plant. [45]

Cogeneration systems can also be used to produce both electricity and heat from biogas. In this system, the biogas is burned in a generator to produce electricity, and the waste heat is captured and used for heating or other applications.[46]

3.3. The Benefits of Using Biogas in an Externally Fired Microturbine

When biogas is subjected to a cleaning process and has its methane content increased, it can be compared to natural gas [47]. There are internal-fired microturbines [48] and internal combustion engines [49] as well as other engines and turbines that have been developed to use biogas as a fuel that are available on the market [50,51]. However, because biogas is produced at low pressure, a gas compressor is typically needed to raise it to the high pressure needed in a gas turbine's combustion chamber. Additionally, due to contaminants, raw biogas generated in small plants without a rigorous cleaning procedure cannot be used forowing to contaminants and particles in the combustion gas [52] that harm the internal components of these devices, internally fired engines and turbines cannot be operated for an extended period of time.

It is not necessary for biogas to be ultra-clean and highly compressed when using it in externally fired gas turbines (EFMT), which is one of its benefits. Fuels with low purity and a reduced lower heating value are compatible with the EFMT. In EFMTs, the combustion process takes place outside of the turbine cycle at atmospheric pressure, and the flue gas then travels to a

High temperature heat exchanger (HTHE), which is less susceptible to impurities . Since the flue gas (produced by the combustion of biogas) does not come into direct contact with the turbine, it is therefore safe for the mechanical rotating parts of the turbine [53].

3.4 Definition of CCHP Plant:

A Combined Cooling, Heating, and Power (CCHP) plant is a type of distributed energy system that simultaneously generates electricity, heating, and cooling from a single energy source, such as natural gas, biomass, or waste heat.

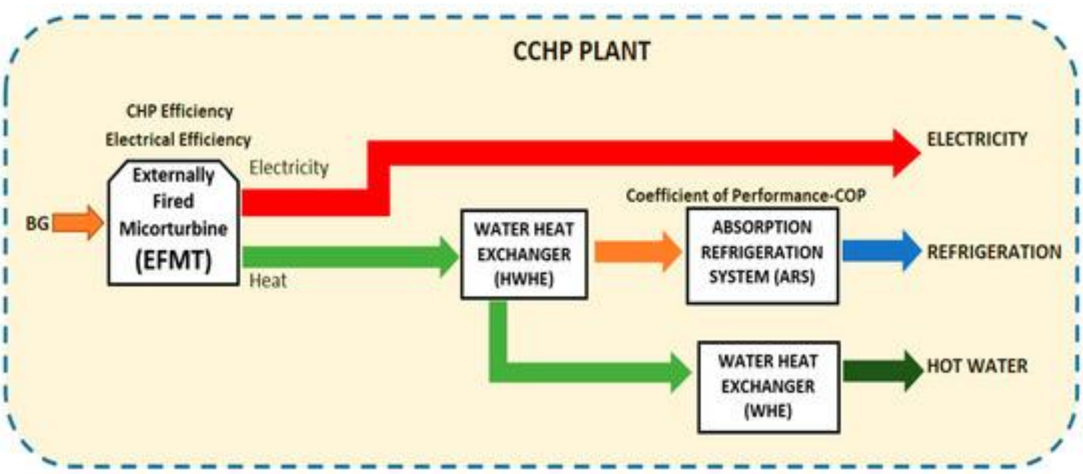

Figure 3.2: Simplified diagram of the combined cooling, heat and power (CCHP) plant.

CCHP plants can provide a highly efficient and sustainable energy solution for buildings and communities by utilizing waste heat that would otherwise be lost in traditional power generation.

3.4.1. CCHP Plant (Absorption Refrigeration System Integrated to the EFMT) Description

The proposed plant's processes are depicted in Figure 3. The biodigester's combustor receives the biogas produced there. The EFMT uses the combustion energy to produce electricity and thermal energy that is still present in the flue gas.

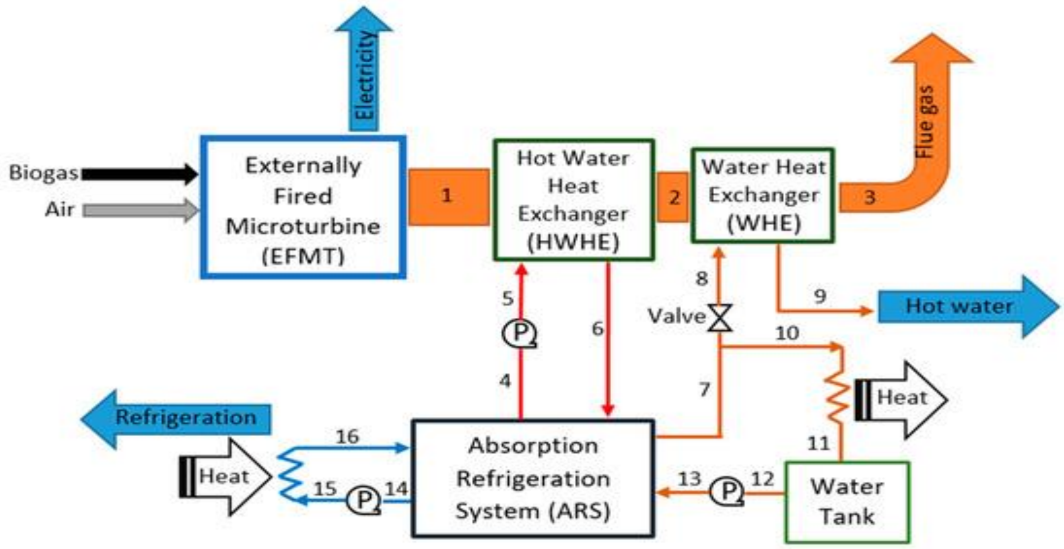

Figure 3.3: Block diagram of the proposed CCHP system.

Using a hot water heat exchanger (HWHE), where the water flow reaches 95 °C, this thermal energy is recovered. The thermal energy source for cooling production in the absorption refrigeration system (ARS) is this hot water flow.

Table 3.1: Presents the circuits and temperatures at the different streams of the CCHP plant.

Circuit	Stream	Temperatures(C°)
Flue Gas	1	269
	2	160
	3	76
Hot water circuit	4	88
	5	88
	6	95
Heat rejection circuit	7,8,10	24
	9	55
	11	18
	12,13	18

ColdWater circuit	14,15 16	-3 0

After the HWHE, the heat from the flue gas is transferred to a second water heat exchanger (WHE), which provides water at a temperature of 55 °C. the flue's final temperature.The flue gas that has been released into the atmosphere is expected to have a final temperature that is higher than its dew point temperature.

Condensate is thus prevented in the exhaust components. The final services of this CCHP system are biogas (which can also be used in other applications), hot water, cooling (for refrigeration), and electricity.

3.4.2. Description of the Primary CCHP Plant Components externally fired microturbine (EFMT)

The primary component (prime mover) of the suggested system is the ET10 microturbine from Compower AB (Sweden) [45]. The EFMT diagram in Figure 4 depicts the parts of the externally fired microturbine. They are a natural gas combustor with the option to operate biogas (COM), a compressor (C), a turbine (T), a high temperature heat exchanger (HTHE), and a turbine (T). The compressor, turbine, and electric generator (G) are all attached to the same shaft.

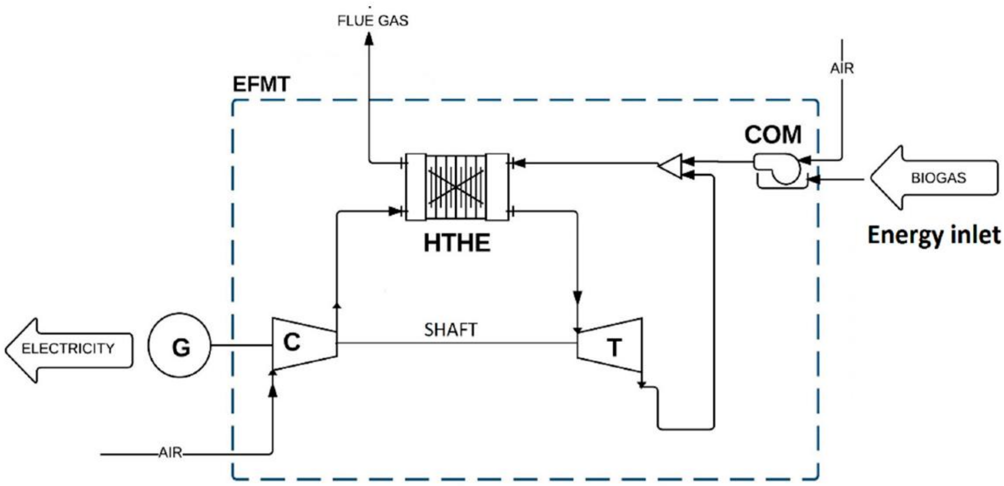

Figure 3.4: Externally fired microturbine (EFMT) diagram (G: Electric generator, C: Compressor, T: Turbine, HTHE: High temperature heat exchanger and COM: Combustor).

The compressor, which compresses air from the atmosphere, is where the thermal cycle begins. The heat exchanger's hot side transfers energy to the compressed air on the (cold) air side of the heat exchanger.

Table 3.2: EFMT, ET10 data current (experimental) state.

Fuel-Energy Inlet Rate	Unit	Current State
Mass flow of fuel	kg/s	0.0014
Mass flow of fuel gas	kg/s	0.1032
Mass heat capacity of flue gas	kj/kg.k	1.055
LHV	kj/kg	20,200
Total Energy Inlet Rate	kw	28.24
CHP efficiency	%	78.28
Electricity	kw_{el}	9.31
Turbine Work	kw	11.97
Compressor Work	kw	10.14
Electrical Efficiency	%	33
Heat availability	kw_{th}	20.62

After leaving the HTHE, compressed hot air enters the turbine where it is expanded, creating a torque that turns the shaft. Even though the pressure in the turbine's outlet air stream has been reduced to almost atmospheric levels, the air is still warm. The high temperature flue gas from the combustor is combined with the outlet air.

The combustion that occurs at atmospheric pressure results in this gas. To heat the compressed air, the mixture enters the (hot) gas side of the HTHE. the flue gas can then be directed to other heat-requiring devices or to a water heat exchanger. The turbine shaft's rotational speed can range from 110,000 to 160,000 rpm [55,56]. Given that the HTHE material can withstand that temperature, increasing the turbine inlet temperature (TIT), which increases cycle efficiency and increases electricity production, is possible if the heat transfer capability of the HTHE (regarded as a key component) is high. A crosshead, counter flow heat exchanger with corrugated plates that is designed for minimal pressure drop is called the HTHE [53].

3.4.3. System for absorption refrigeration (ARS)

The PC19 Pink Chiller is the chosen absorption refrigeration system (ARS) [41]. A typical diagram and the elements of a single effect ARS are shown in Figure 5. The hot water circuit must provide a flow of hot water at about 95 °C for the thermal generator (GT) of the absorption

cycle, which heats a working fluid (a mixture of absorbent and refrigerant). It causes the highly concentrated refrigerant fluid to evaporate, leaving a weak solution, primarily made up of absorbent, inside the generator. Similar to a traditional vapor-compressor.

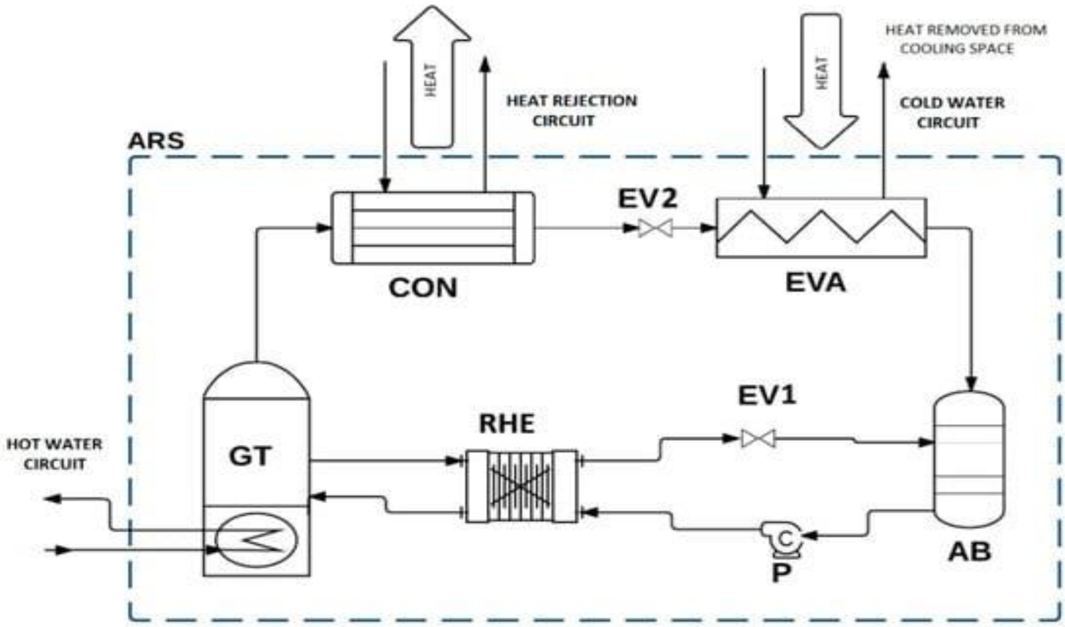

Figure 3.5: Absorption refrigeration system (ARS) plan.

Similar to a traditional vapor-compressor refrigeration system, the hot evaporated refrigerant goes through a condenser (CON), an expansion valve (EV2), and an evaporator (EVA). The expanded refrigerant is mixed with the weak solution in the absorber (AB), which allows the refrigerant to be absorbed (by the absorbent) in the working fluid. The working fluid is carried by the stream that exits the absorber to the small pump (P), where the fluid pressure is raised. The fluid is then heated in the regenerative heat exchanger (RHE) before being deposited in the generator by the hot "weak solution" stream. The weak solution that exits the RHE is then mixed in the absorber for the following cycle by passing through the expansion valve (EV1), which lowers its pressure [57, 58].

Table 3.3: Data of the ARS Pink Chiller PC19

Circuit Description	Paramater	Unit	Value
Cold water circuit	Power(Cooling capacity)[1]	kw	12.3/17
	Temperature in/out	C°	0/-3
	Flow rate	m^3/h	3.5
Hot water circuit	Power(generator)	kw_{th}	26
	Temperature in/out	C°	95/88
	Flow rate	m^3/h	3.2
Heat rejection circuit	Power (heat rejection)	kw	38
	Temperature in/out	C°	24/30 -18/24
	Flow rate	m^3/h	5.5

A cooling circuit with a flow of water or another fluid is required because the PC19 absorption system also requires a cold-water circuit to supply cooling and a heat rejection circuit (water at 24 °C or less) for heat dissipation in the condenser (CON). The system can produce cooling at various temperatures, and according to the data sheet, it has a COP of roughly 0.65 [41].

3.4.4. Energetic and exergetic Performance Indicators for the CCHP Solution

A) Equations for energetic performance calculation

The primary energy rate (*PER*) was found as an appropriate criterion for evaluating the energetic performance of a combined cooling, heat and power plant, a CCHP–trigeneration system. The *PER* is the ratio of the supplied energy products (electricity-P_{el}, cooling-Q_{eva} and heating-Q_{hw}) to the energy power contained in the primary fuel, E_{nin} (Equation (3.1)). If separate systems are used to provide these energy services, then the sum of the energy rate content in the fuels should be considered. The higher the *PER*, the better the system [57–59]

$$PER_{CCHP} = (Q_{eva} + Q_{hw} + P_{el})/E_{nin} \quad (3.1)$$

Q*eva*, is the cooling supplied by the absorption refrigeration system (ARS).

Q*eva*, ***Q****gen*(the heat required to drive the ARS) and *Pp* (the power of the pump used to recirculate the working fluid shown in Figure (5) are used to determine the *COP* in Equation (3.2)

$$COP=Q_{eva}/(Q_{gen} + P_p) \quad (3.2)$$

The power of the pump (P), P_p, is not explicitly described in the datasheet of the ARS. Instead, a total power demand is given; this includes the power required by the pump and the control system, which is 450 W. Assuming that *Pp* does not exceed 150 W, then its influence in the *COP* calculation is negligible, when Q_{eva} and Q_{gen} are 17 kw_{th} and 26 kw_{th}, respectively.

Equation (3.3) is used to determine the thermal power, Q_{gen}, available for driving the absorption refrigeration system (ARS); it considers the mass flow (m_{fg}), heat capacity (C_{fg}) and the inlet–outlet temperatures (T_{g_in} and T_{g_out} in the HWHE) of the flue gas. Q_{gen} is the heat recuperated by the HWHE.

$$Q_{gen}= m_{fg} C_{fg}(T_{g\_in}- T_{g\_out}) \quad (3.3)$$

In equation (3.4): Q_{hw} is the heat given by the combustion gas to the water flow in the WHE where the inlet–outlet temperatures of the flue gas are T_{w_in} and T_{w_out}, respectively.

$$Q_{hw}= m_{fg} C_{fg} (T_{win}- T_{wout}) \quad (3.4)$$

The electricity produced (P_{el}) in the system can be determined by Equation (3.5). The work of the turbine (P_{tur}) and compressor (P_{com}) are known results of the simulation, while mechanical (η_{mec}) and electrical generator efficiencies (η_{eg}) are given by a previous study on the ET10 EFMT [52]. The electric efficiency of the CCHP system expressed in percentage is calculated by using Equation (3.6), where m_f and LHV_f are the mass flow and the lower heating value of the fuel, respectively.

$$P_{el}= (P_{tur}*\eta_{mec}- P_{com})*\eta_{eg} \quad (3.5)$$

$$\eta_{el} = (P_{el} \times 100)/(m_f LHV_f) \quad (3.6)$$

Equation (3.7) was used to determine the power input (energy rate) to the system using the mass flow and the *LHV f* [60] of the fuel. If more than one fuel flow enters into the system, then the total power input will be the sum of their individual energy rates.

$$E_{nin} = m_f \, . LHV_f \quad (3.7)$$

B) Equations for exergetic performance calculation

In the same way as for the *PER* calculation, the primary exergy rate (PER_x) indicator of the combined system is determined by using Equation (8) where the exergy rate entering the system (E_{xin}, contained in the fuel) and the exergy rate generated in the services supplied (electricity (E_{xcel}), cooling (E_{xeva}) and hot water (E_{xhw})) are required. This indicator allows to know to what extent the use of the energy source is being utilized effectively [60,61]. The chemical exergies of the fuels are used to determine the exergy rate entering the system. The temperatures when delivering the thermal services (evaporator (T_{eva}) and WHE (T_{whe})) and a reference temperature (T_0) are also required to determine the overall exergy performance. The reference temperature for the calculations is set at25 ◦C (298.15 K [60,61]).

$$PER_{xCCHP} = (E_{xeva} + E_{xhw} + Ex_{el}) \, / \, Ex_{in} \quad (3.8)$$

The exergy rates generated when supplying the different services, cooling, heating (hot water) and electricity, follow the next equations [61,62]:

$$E_{xeva} = Q_{eva} \left(1 - \frac{T0}{Teva}\right) \quad (3.9)$$

$$E_{xeva} = Q_{hw} \left(1 - \frac{T0}{Teva}\right) \quad (3.10)$$

$$E_{xel} = P_{el} \quad (3.11)$$

Exergy generated in thermal services are affected by the temperature where the service is delivered, while electricity exergy rate is the same as its energetic value (Equation (3.11)). The exergy rate input to the system is determined using Equation (3.12), where the mass flow (*m. f*), chemical exergy (*ef*; obtained from the tables in [60], and the molar mass (*Mf*) of the fuel are required. If more than one fuel powers the system, then the sum of the individual exergy rates will be the total exergy rate entering the system.

$$Exin = m_f \,[(m_{.f})/M_f] \qquad (3.12)$$

For the exergy rate calculations, the temperatures assumed were T_{eva} = 2 C° (275.15 K, cooling in the evaporator for all the cases), T_{whe}= 80 ◦C (353 K, for hot water production in WHE) and 157 ◦C (430 K, for hot water production when using a stove or a water heater in reference systems) [63].

C) Energetic and Exergetic Performance of the CCHP Plant

Table 3.4 shows the total energy inlet rate required by the CCHP system in the electricity and thermal services supplied

Table 3.4: Electricity, thermal services and performance of the CCHP system

Energy Service And efficiencies	Parameter	Unit	CCHP Current State
	Total En_{in}	**KW**	**28.24**
EFMT Electricity	$En_{in\text{-}efmt}$	kw	28.24
	P_{el}	kw_{el}	9.31
	η_{el}	%	33
ARS Refrigeration	Q_{eva}	kw_{th}	7.61
	Q_{gen}	kw_{th}	11.70
	COP	-	0.65
WHE Hot water	Q_{hw}	kw_{th}	8.92
	Flow rate	L/min	4.0
	$T_{in\text{-}w}$	C°	24.00
	$T_{out\text{-}in}$	C°	55.00
CHP efficiency	η_{chp}	%	78.28

CCHP efficiency	PER	-	0.638
	PERx	-	0.118

3.5. Electricity, heat and cold potentials in the studied areas

According to a study by Moses Jeremiah Barasa et al., the electricity production from biogas by microturbine depends on several factors, such as the quality and quantity of biogas, the size and efficiency of the microturbine, and the heat recovery system [64].

A possible way to estimate the electricity production from biogas by the ET10 micro turbine is to use the following formula:

$$\text{Electricity production (kWh)} = \text{Biogas volume } (m^3) \times \text{Biogas energy content } (kWh/m^3) \times \text{Micro turbine efficiency (\%)} \qquad (3.13)$$

Energy content for methane is from 8500 to 9500 kcal. And the percentage of methane in the biogas is 60% so Energy content for bio gas is 5400kcal and equal 6kWh/m^3 [65].and the micro turbine has an efficiency of 33%, then the electricity production from 1 m3 of biogas by the ET10 micro turbine would be:

$$\text{Electricity production (kWh)} = 1\ m^3 \times 6\ kWh/m^3 \times 0.33 = 1.98\ kWh$$

The heat production from biogas by microturbine depends on several factors, such as the quality and quantity of biogas, the size and efficiency of the microturbine, and the heat recovery system. According to a report by EPA, microturbines typically have a total system efficiency of 60 to 70 percent, which means that they can convert 60 to 70 percent of the biogas energy into electricity and useful heat1. The amount of heat produced by a microturbine can be calculated by subtracting the electrical output from the total energy input.[66]

Assuming that a microturbine has an efficiency of 33 percent and an electrical output of 9.31 kW and that the biogas has an energy content of 6 kWh/m^3, then the heat production from 1 m3 of biogas by the microturbine would be:

Heat production (kWh) = Electrical output (kW) - Biogas volume (m^3) ×Biogas energy content (kWh/m^3) × Microturbine efficiency (%) (3.14)

Heat production (kWh) = 9.31 Kw -1 m^3 × 6 kWh/m3 ×0.33 = 7.33 kWh

The amount of cooling produced by an absorption chiller can be calculated by multiplying the heat available for cooling by the coefficient of performance (COP) of the chiller. according to a study by Mohammed Saeed et al., a single-effect absorption chiller using lithium bromide as refrigerant can have a COP ranging from 0.6 to 0.82. For example, assuming that a single-effect absorption chiller has a COP of 0.65 and that it uses the heat available for cooling from 1 m3 of biogas by a microturbine as described above, then the cooling production from biogas by microturbine would be:[67]

Cooling production (kWh) = Heat available for cooling (kWh) × COP (3.15)

Cooling production (kWh) = 7.33 kWh ×0.65= 4.7 kWh

The following table lists the potential of electricity, heat, cold in the studied areas

Table 3.5: The quantities of electricity, heat and cold in (Ghardaia, Ouargla, and El menia)

Studied states	Biogas (1000m³)	Electricity(MWh)	Heat(MWh)	Cold(MWh)
Ghardaia	13463,31	26657,36	98686,11	64145,97
El Menia	5261,61	10418	38567,64	25068,97
Ouargla	28949,75	57320,51	212201,69	137931,1

The energy produced from the micro-turbines with biogas is about 27% electricity and 73% of the heat. As for the cold, the percentage of COP controls it. The heat produced by a microturbine can be used for various purposes, such as space heating, water heating, cooling, drying, etc. The use of heat recovery systems can increase the overall efficiency and economic benefits of biogas power generation.

3.6. Economic return

3.6.1. Analysis of the economics of a CCHP energy supply system

Investments in trigeneration distributed energy systems need to be thoroughly analyzed. Enterprises should receive both the required investment income and the efficiency of energy conservation from the economic benefits that accrue to them. The system operation expenses, operating incomes, and associated financial indicators will all be analyzed in this part.

3.6.2. A CCHP system's cost analysis

Initial investment K_0 the gas turbine systems, absorption chillers, and heat boilers are the major investments for CCHP systems. The control system and biogas fuel system are typically included in the pricing of a gas turbine.

The microturbine itself, a biogas purification system, heat recovery equipment, power electronics, and control systems are the typical components of a microturbine-based CCHP system. Costs associated with site preparation, installation, and permits should also be taken into account [68]. Typically, the initial investment cost for a CCHP system with a microturbine can range from 120,000$ [69].

Because fuel costs are the highest, the operation of a system will be significantly influenced by the price of gas. For the sake of simplicity, the calculation models only take into account the quantity of gas consumed by a device, not the overall consumption during the operation process.

The yearly fuel cost (C fu) and operation and maintenance costs (C ma) make up the majority of the operation costs of trigeneration systems.

$$C_{fm}= C_{fu}+ C_{ma} \quad (3.16)$$

$$C_{fu}= (3600×W×H×P\quad)/(\eta×\delta) \quad (3.17)$$

Where W is the generation power in kW, H is the annual hours of operation of the equipment and it is 8760h, p_f is the fuel price in $/m^3$,Where it is equal to 0.3$/m^3$[70] , since we obtained it from the biomass, but we added the costs of extracting it from biomass and transferring biogas to the project capital $k_0$$\eta$is generation efficiency in % and δ is the fuel calorific value in kJ/m^3 where is 23000kj/m^3 .the cost maintenance We estimated it approx 10,000$. [71] [72].

3.6.3. Analysis of system revenue

For CCHP energy supply systems, there are two types of economic revenues (R al) after the system is put into operation: electricity revenues (R e) and cooling and heating revenues (R c and R h).

$$R_{al} = Re + Rc + Rh \qquad (3.18)$$

First, the first revenue of a project investment is electricity revenue:

$$R_e = W ×H ×P = G×P \qquad (3.19)$$

Where, G is the generation capacity in kWh and P e is the electricity price in and is approx 0.19 $/kWh. [73]

The second revenue of a project investment is cooling and heating revenue. To compare each system easily, we can take the maximum cost of production cooling and heating in a system as a reference price.

$$R_h= (Q_h×*3600×24×P_h)/ 10^6 \quad (3.20)$$

$$R_c= (Q_c×d×3600×24×P_c)/ 10^6 \quad (3.21)$$

Where **Q_h** and **Q_c** are the heating and cooling supplies in Kw respectively **d**is the annual supply day; and **Ph** and **Pc** are the price of heating and cooling in $/kJ,and they are 0.25$/kJ for both.[71][72]

Table 3.6: revenue and the costs of the system

The costs of the system	
C_{fu}	35,000 $
C_{ma}	10,000 $
C_{fm}	45,000$
Analysis of system revenue	
Re	46,603 $
Rc	6,083$
Rh	9,352 $
Ral	62,038 $

3.6.4. Economic evaluations' financial indicators

The main focus of investment project evaluations is economic effects. The wide range of economic effect evaluation indicators reflects the various project economics theories. Incorporating the requirement for an economic assessment of a CCHP system, this part chooses three key indicators: Investment payback duration, internal rate of return, and net present value for economic study.

A) NPV:

NPV stands for Net Present Value, and it is a financial metric used to assess the profitability of an investment or project. It measures the difference between the present value of cash inflows and the present value of cash outflows over a specified time period, considering the time value of money. [74]

$$NPV = \sum_{t=1}^{n}[C_{Ft}/\ (1+r)^{t}\ ]-\ K_0\ ] \quad (3.22)$$

Where:

- (C_{Ft}) represents the expected cash flow at time t where equals 17,038$
- (**r**) is the discount rate or the required rate of return. 4%
- (**t**) is the time period.15 year
- (**K_0**) is the initial investment or cash outflow at time 0.

B) Payback period:

a) Static investment payback period T_J does not consider the time value.

$$T_J = K_0 / A_t \quad (3.23)$$

$$A_t = R_{al} - C_{fm} \quad (3.24)$$

Where A_t is annual net income in $

b) Dynamic investment payback period T_D considers the time value and is the time when cumulative NPV is equal to zero.

$$T_D = [T_D - 1] + |NPV_{T_D-1}| / [A_{T_D}] \quad (3.25)$$

Where $[T_D-1]$ is the last year in which cumulative NPV is negative (in the year T_D, cumulative net present value is greater than zero); $|NPV_{T_D-1}|$ is the absolute value of NPV until the year $[T_D-1]$; A_{T_D} is net income inthe year [T_D].[72]

C) Internal rate of return IRR

IRR, or Internal Rate of Return, is a financial metric used to evaluate the profitability of an investment or project. It represents the rate at which the net present value (NPV) of cash flows from the investment equals zero. In other words, it is the discount rate that makes the present value of cash inflows equal to the present value of cash outflows. [74]

$$\sum_{t=0}^{n} A_t\,(1+IRR)^{-t}=0 \quad (3.26)$$

Table 3.7: results of Economic evaluations' financial indicators

Economic evaluations financial indicators	
NPV	204581,8 $
T_J	7.04 year
A_t	17,038 $
T_D	6.51 year
IRR	7 %

We estimated the life of the project to be about 15 years, and the recovery year was about 7 years. Note that the previous economic indicators were expected, as the NPV index reached ($204,581.8), which is positive, and the IRR index reached 7%, which is greater than 4% = (r). All this indicates that this project has a promising and economically profitable future.

3.7. The environmental impact of biogas

The sources of biogas are natural sources such as the sources taken in this study, such as livestock manure, household waste, and palm waste. Biogas can help reduce emissions from waste, which is the second biggest source of methane emissions. One of the best available recycling options for bio-waste is anaerobic digestion for biogas production [75].Capturing methane in biogas can provide reductions in the emissions of greenhouse gases, production of renewable energy and management of waste disposal [76].Using this methane as a fuel dramatically reduces its climate impact by converting it into CO_2, which is up to 34 times less potent as a greenhouse gas. [77]

The percentage of methane in natural gas can vary, but it typically ranges from 70% to 90%. Methane is the primary component of natural gas and is considered its main combustible element. [78] And according to different sources, the percentage of methane in biogas is approximately 60%

to 65%by volume, with most of the remainder being carbon dioxide and small amounts of other gases. [79]

To determine the CO_2 emissions from the combustion of 1 cubic meter (m^3) of biogas or natural gas, we need to consider the methane content and the combustion reaction. The stoichiometric combustion of methane can be represented by the following equation:

$$CH_{4\,(g)} + 2O_2 \rightarrow CO_{2\,(g)} + 2H_2O$$

In this reaction, one molecule of methane (CH_4) produces one molecule of carbon dioxide (CO_2) upon complete combustion. However, the composition of biogas can vary significantly. If we assume that the biogas contains 60% methane (CH_4) by volume, the remaining 40% will consist of other gases, including carbon dioxide. And it also contains natural gas 90% methane (CH_4) by volume and 10% impurities.in this case, the calculation can be done as follows:

1$m^3$of biogas contains 0.6 m^3 of methane (60% methane content) and 0.9 m^3 of methane for natural gas (90% methane content)The methane (CH_4) component will produce an equal volume of carbon dioxide (CO_2) upon complete combustion.Therefore, 0.6 m^3 of methane will produce 0.6 $m^3$of carbon dioxide for bio gas .and 0.9 m^3 of methane will produce 0.9 m^3 of carbon dioxide. Soreplacing biogas with natural gas will reduce CO_2 emissions by 0.3 cubic meters per cubic meter used.

Table 3.8: The table shows the amount of CO_2 reduced if we use biogas instead of natural gas

Studied states	biogas (m^3)	reduced emissions of CO_2(m^3)
Ghardaia	13463,31	4038,993
El Menia	5261,61	1578,483
Ouargla	28949,75	8684,925

The percentage of CO_2 reduced by about 30%, all of this strengthens the environmental yield. Compared to natural gas, biogas has a number of environmental advantages. It is a more environmentally responsible way to meet our energy needs because it is produced from organic waste sources, is renewable, emits fewer greenhouse gases, has the ability to recover nutrients, and encourages local energy generation.

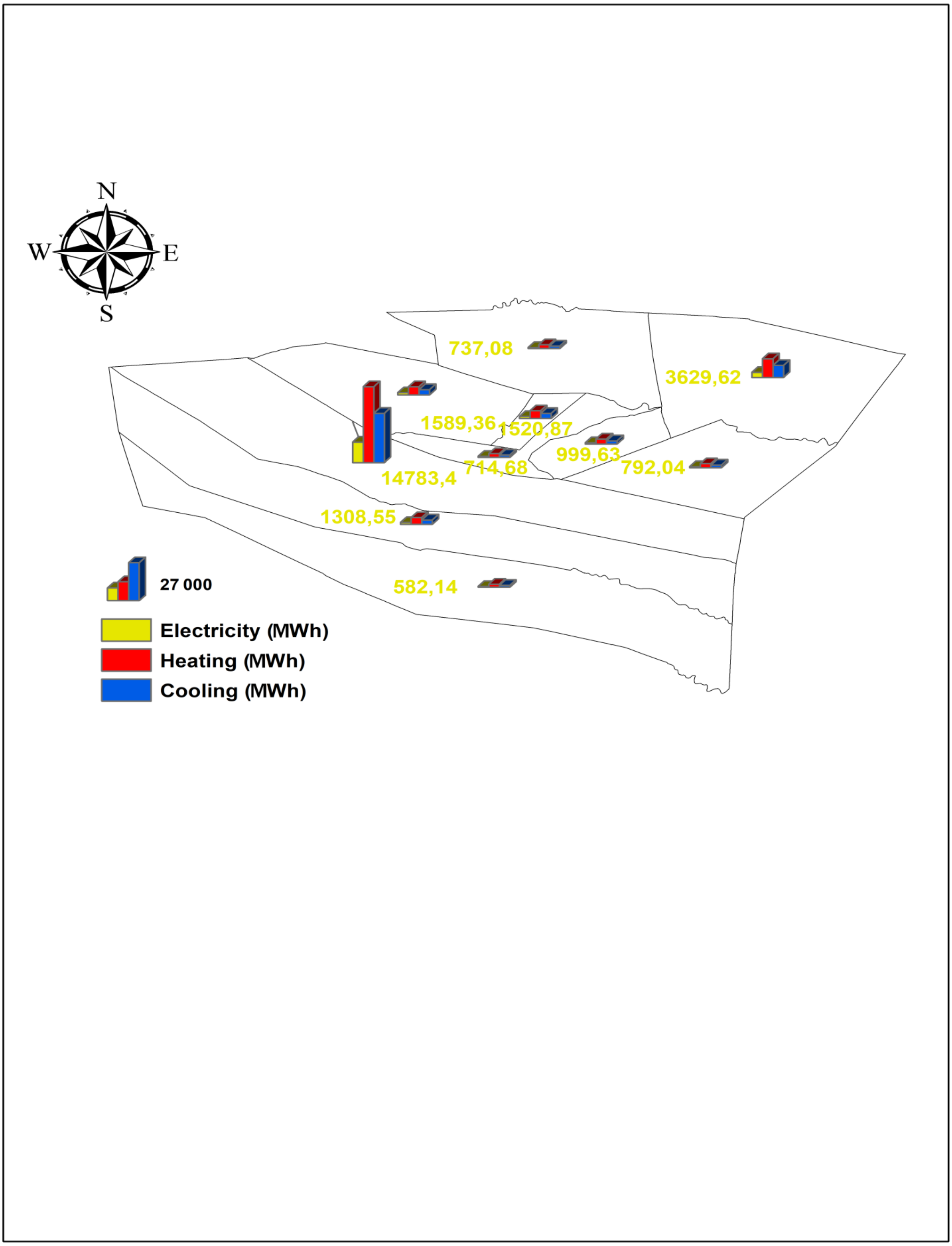

Figure3.6: Distribution of electricity production, cooling and heating in the state of Ghardaia

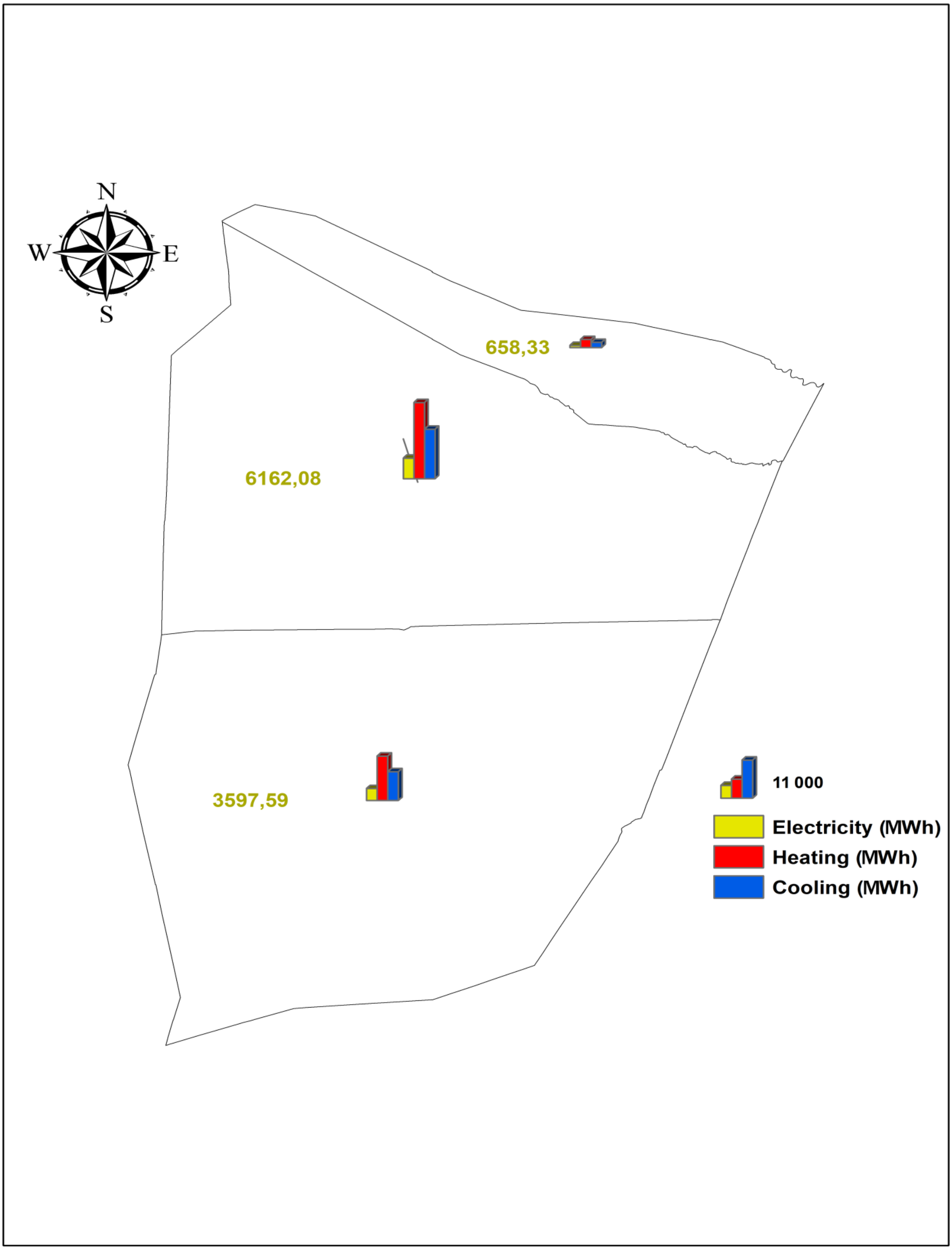

Figure3.7: Distribution of electricity production, cooling and heating in the state of El-Menea

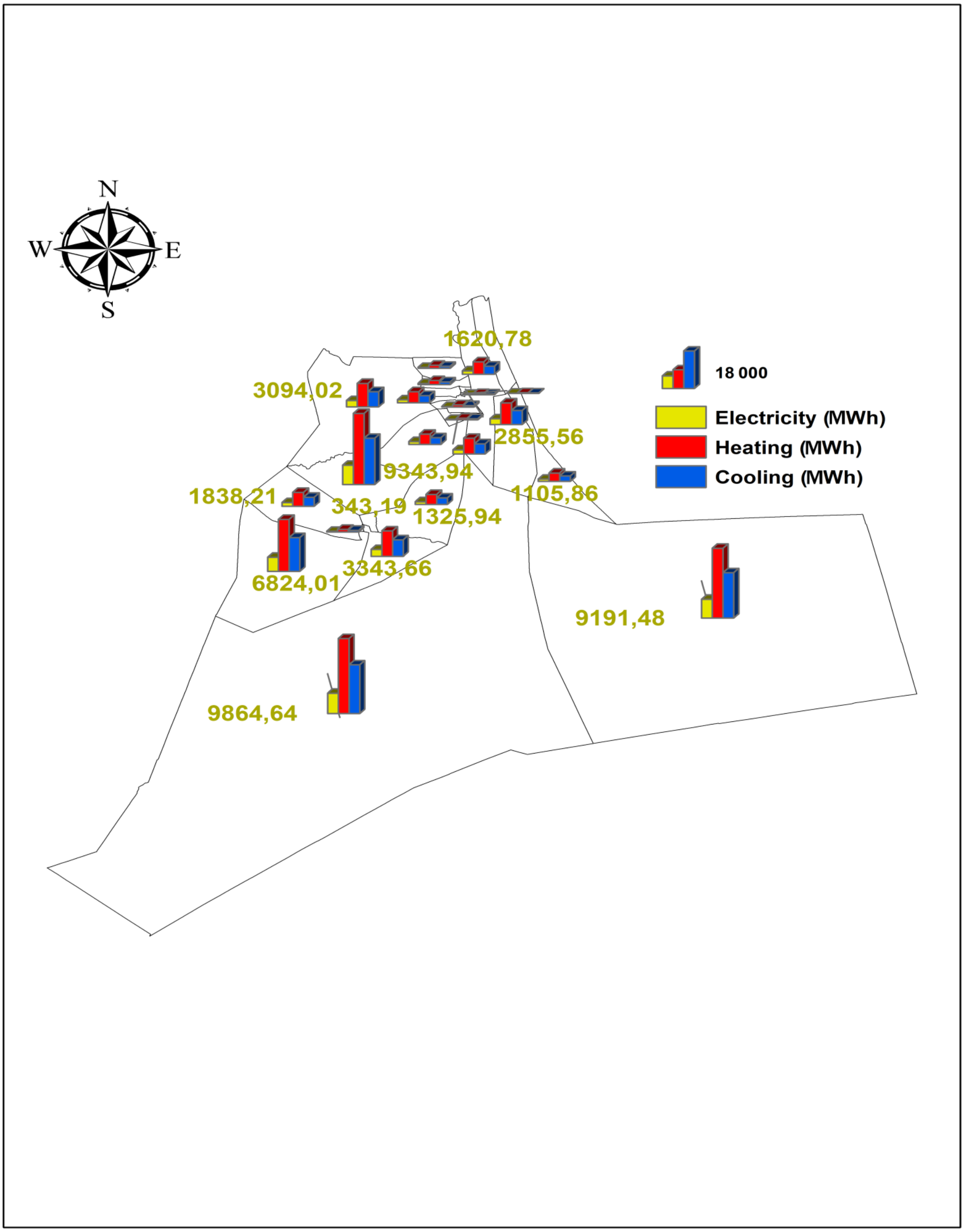

Figure3.8: Distribution of electricity production, cooling and heating in the state of Ouargla

3.8. Conclusion

In conclusion, the implementation of a CCHP microturbine system fueled by biogas offers numerous advantages in terms of electricity, heat, and cold production, as well as economic and environmental benefits. By utilizing biogas, a renewable energy source derived from organic waste, the system reduces reliance on fossil fuels, leading to lower greenhouse gas emissions and helping combat climate change.

The microturbine system efficiently converts biogas into electrical power, which can be used on-site or fed back into the grid, potentially reducing electricity costs. Its compact size and modular design make it suitable for decentralized energy generation, minimizing transmission losses and optimizing resource utilization. Moreover, the CCHP microturbine system simultaneously produces heat and cold, meeting various thermal energy demands. Waste heat generated during electricity production can be recovered for heating purposes, while absorption chillers can provide cooling, especially in commercial and residential buildings.

From an economic perspective, implementing this system with biogas can lead to significant cost savings. Its high energy efficiency and utilization of biogas as a low-cost or free fuel source result in reduced energy bills. Additionally, the system's ability to generate electricity, heat, and cold simultaneously improves overall energy efficiency and enhances economic returns.

In terms of the environment, the use of biogas in the CCHP microturbine system significantly reduces greenhouse gas emissions compared to conventional energy sources. By diverting organic waste from landfills and utilizing it for energy production, the system helps mitigate methane and CO_2 emissions, a potent greenhouse gas. Moreover, its integrated production of electricity, heat, and cold reduces the need for separate energy systems, leading to overall energy savings and a smaller carbon footprint.

In summary, the implementation of a CCHP microturbine system fueled by biogas offers a sustainable and efficient solution for generating electricity, heat, and cold. Its economic benefits include cost savings and optimized resource utilization, while its environmental benefits include reduced greenhouse gas emissions and waste diversion. Overall, this system represents a promising approach to meet energy needs while addressing economic and environmental challenges.

Conclusion general

Conclusion General

Biomass to biogas conversion is a promising and sustainable solution for energy production and waste management. By harnessing the natural process of anaerobic digestion, organic materials such as agricultural residues, food waste, and dedicated energy crops can be transformed into biogas, a renewable energy source primarily composed of methane and carbon dioxide. This process offers several significant benefitsHe also contributed to determining the distribution of electricity, cooling and heat production in the studied states (Ghardaia - El Menea - Ouargla). In geographical maps

In this study, we made an overview of biomass and its conversion into biogas and its most important sources and we also studied the evaluation of biomass and biogas so that is evaluating the potential of biogas in the regions of **Ghardaïa, Ouargla, and El-Menea**reveals promising opportunities for sustainable energy production, waste management, and agricultural development. These regions possess specific characteristics that make them suitable for biogas projects, and careful assessment is crucial for maximizing their potential.

- Firstly, the abundance of agricultural activities in **Ghardaïa, Ouargla, and El-Menea** provides a significant source of biomass feedstock for biogas production. The presence of agricultural residues, such as crop waste, animal manure, and organic byproducts, can be effectively utilized in anaerobic digestion processes to generate biogas. This offers an opportunity to convert these organic materials into a valuable energy resource while simultaneously addressing waste management challenges.
- Secondly, the regions experience favorable climatic conditions, with high solar radiation and relatively warm temperatures. This climate contributes to the efficient operation of anaerobic digesters, as the microorganisms responsible for biogas production thrive in warmer environments. The availability of sunlight can also support the growth of energy crops, such as sorghum or maize, which can be specifically cultivated for biogas production, further enhancing the biomass supply.

Additionally, the local context of **Ghardaïa, Ouargla, and El Menea**, including the presence of agricultural communities and potential energy consumers, is conducive to the development of decentralized biogas systems. These systems can be integrated into existing farms, agro-industrial facilities, or local communities, allowing for efficient utilization of biogas within close proximity to the source of biomass. This decentralized approach promotes energy self-sufficiency, reduces transmission losses, and fosters local economic development.

After extracting the potential of biogas, we discussed the study of the production of electricity, cold and heat using the CCHP system using biogas. And economic and environmental returns.Whereis utilizing Combined Cooling, Heating, and Power (CCHP) systems, specifically employing microturbines fueled by biogas, offers significant advantages for electricity generation and heating and cooling needs while providing favorable economic returns.

CCHP systems integrate the simultaneous production of electricity, heating, and cooling, resulting in higher overall efficiency compared to separate systems. By harnessing the waste heat generated during electricity production, CCHP systems can effectively utilize this heat for heating and cooling purposes, thus maximizing energy utilization and reducing energy waste. Microturbines, as a compact and reliable technology, have emerged as a viable option for CCHP applications.

When fueled by biogas. the combustion of biogas in microturbines produces electricity, while the exhaust heat can be utilized for heating or cooling through absorption chillers or heat exchangers.

Implementing a CCHP system with microturbines and biogas has varying financial benefits. The most important factors are the cost and availability of the biogas feedstock. The fuel expenses for the microturbines can be kept to a minimum if there is a dependable and affordable source of biogas, which helps to ensure economic viability. The cost reductions brought about by the energy efficiency of the CCHP system should also be taken into account. The device might potentially minimize energy prices because it reduces the need to buy electricity from the grid by producing electricity locally.Byeliminating the need for separate heating and cooling systems, the use of waste heat for heating and cooling further increases cost savings.Nevertheless, the economic indicators **IIR** and **NPV** indicated the efficacy of this project and its promising return on profit and energy returns.

Finally, the environmental return of producing electricity, heating, and cooling from biogas in reducing CO^2 emissions is significant. It provides a sustainable alternative to fossil fuel-based energy sources, reduces greenhouse gas emissions, mitigates climate change, and supports the transition to a low-carbon economy. Promoting the widespread adoption of biogas technology, coupled with supportive policies and investments, can contribute to achieving environmental sustainability and combating climate change.

Annex

Annex chapter II:

Tables A.1: Production of biomass and biogas from municipal waste

Ghardaia

Municipalites	Population	Waste kt/year	Organicwaste kt/year	Biogas m³
Ghardaia	142540	41,62168	28,17787736	5635,57547
Guerrara	82983	24,231036	16,40441137	3280,88227
Bounoura	61946	18,088232	12,24573306	2449,14661
Metlili	61750	18,031	12,206987	2441,3974
Berriane	46437	13,559604	9,179851908	1835,97038
El Atteuf	21750	6,351	4,299627	859,9254
Daya Ben Dahoua	19631	5,732252	3,880734604	776,146921
Zelfana	12733	3,718036	2,517110372	503,422074
Mansoura	4605	1,34466	0,91033482	182,066964
Seb Seb	3138	0,916296	0,620332392	124,066478
TOTAL WILAYA	457513	133,593796	90,44299989	18088,6

El-menia

Municipalites	Population	Waste kt/year	Organicmatter kt/year	Biogas m³
El Menia	43476	12,694992	8,50564464	1701,12893
Hassi F'hel	5921	1,728932	1,17048696	234,097393
Hassi Gara	22177	6,475684	4,38403807	876,807614
TOTAL WILAYA	71574	20,899608	14,1490346	2829,80692

Ouargla

Municipalites	Population	Waste kt/year	Organicwasts kt/year	Biogas m³
Ouargla	162708	47,510736	32,16476827	6432,95365
Rouissat	77010	22,48692	15,22364484	3044,72897
Sidi-Khouiled	18836	5,500112	3,723575824	744,715165
Ain-Beida	27261	7,960212	5,389063524	1077,8127
Hassi-B-Abdallah	7267	2,121964	1,436569628	287,313926
N'goussa	22002	6,424584	4,349443368	869,888674
Hassi-Messaoud	52046	15,197432	10,28866146	2057,73229
El-Borma	8210	2,39732	1,62298564	324,597128
Touggourt	52902	15,447384	10,45787897	2091,57579
Nezla	71232	20,799744	14,08142669	2816,28534
Zaouia abidia	28265	8,25338	5,58753826	1117,50765
Tibesbest	43060	12,57352	8,51227304	1702,45461
El megarine	18480	5,39616	3,65320032	730,640064
Sidi slimane	10048	2,934016	1,986328832	397,265766
Témacine	27313	7,975396	5,399343092	1079,86862
Balbat amer	18569	5,422148	3,670794196	734,158839
El hadjira	18760	5,47792	3,70855184	741,710368
Al alia	9939	2,902188	1,964781276	392,956255
Taibet	32698	9,547816	6,463871432	1292,77429
Bennaceur	14979	4,373868	2,961108636	592,221727
M'nager	16444	4,801648	3,250715696	650,143139
Total Wilaya	738029	215,504468	145,8965248	29179,305

Tables A.2: Production of biomass and biogas from animal manure (cows, camels, sheep and goats)

Ghardaia

Municipalities	Bovin (head)	Mature (kt/year)	Biogas (m^3)
Ghardaia	497,00	4,0816125	306,120938
Guerrara	1174,00	9,641475	723,110625
Bounoura	192,00	1,5768	118,26
Metlili	284,00	2,33235	174,92625
Berriane	218,00	1,790325	134,274375
El Atteuf	428,00	3,51495	263,62125
Daya Ben Dahoua	479,00	3,9337875	295,034063
Zelfana	193,00	1,5850125	118,875938
Mansoura	100,00	0,82125	61,59375
Seb Seb	798,00	6,553575	491,518125
TOTAL WILAYA	4363,00	35,8311375	2687,33531

Municipalities	Camels (head)	Mature (kt/year)	Biogas (m^3)
Ghardaia	192,00	1,5768	118,26
Guerrara	936,00	7,6869	576,5175
Bounoura	261,00	2,1434625	160,759688
Metlili	9145,00	75,1033125	5632,74844
Berriane	98,00	0,804825	60,361875
El Atteuf	247,00	2,0284875	152,136563
Daya Ben Dahoua	101,00	0,8294625	62,2096875
Zelfana	239,00	1,9627875	147,209063
Mansoura	241,00	1,9792125	148,440938
Seb Seb	72,00	0,5913	44,3475
TOTAL WILAYA	11532,00	94,70655	7102,99125

Municipalities	Sheep(head)	Mature (kt/year)	Biogas (m^3)
Ghardaia	18716,00	10,930144	142,091872
Guerrara	59812,00	34,930208	454,092704
Bounoura	5367,00	3,134328	40,746264
Metlili	152635,00	89,13884	1158,80492
Berriane	18176,00	10,614784	137,992192
El Atteuf	5821,00	3,399464	44,193032
Daya BenDahoua	35276,00	20,601184	267,815392
Zelfana	13729,00	8,017736	104,230568
Mansoura	6789,00	3,964776	51,542088
Seb Seb	10899,00	6,365016	82,745208
TOTAL WILAYA	327220,00	191,09648	2484,25424

Municipalities	Goats (head)	Mature (kt/year)	Biogas (m^3)
Ghardaia	25720,00	15,02048	195,26624
Guerrara	9892,00	5,776928	75,100064
Bounoura	5070,00	2,96088	38,49144
Metlili	65411,00	38,200024	496,600312
Berriane	4946,00	2,888464	37,550032
El Atteuf	5770,00	3,36968	43,80584
Daya BenDahoua	23247,00	13,576248	176,491224
Zelfana	3789,00	2,212776	28,766088
Mansoura	4221,00	2,465064	32,045832
Seb Seb	5522,00	3,224848	41,923024
TOTAL WILAYA	153588,00	89,695392	1166,0401

El menia

Municipalities	Cows(head)	Mature (kt/year)	Biogas (m^3)
El Golia	512,00	4,2048	315,36
Hassi F'hel	0,00	0	0
Hassi Gara	0,00	0	0
TOTAL WILAYA	512,00	4,2048	315,36

Municipalities	Camels (head)	Mature (kt/year)	Biogas (m3)
El Golia	3504,00	28,7766	2158,245
Hassi F'hel	434,00	3,564225	267,316875
Hassi Gara	2530,00	20,777625	1558,32188
TOTAL WILAYA	6468,00	53,11845	3983,88375

Municipalities	Sheep (head)	Mature (kt/year)	Biogas (m^3)
El Golia	56999,00	33,287416	432,736408
Hassi F'hel	5203,00	3,038552	39,501176
Hassi Gara	17578,00	10,265552	133,452176
TOTAL WILAYA	79780,00	46,59152	605,68976

Municipalities	Goats (head)	Mature (kt/year)	Biogas (m^3)
El Golia	26792,00	15,646528	203,404864
Hassi F'hel	3298,00	1,926032	25,038416
Hassi Gara	16322,00	9,532048	123,916624
TOTAL WILAYA	46412,00	27,104608	352,359904

Ouargla

Municipalities	Cows (head)	Mature (kt/year)	Biogas (m³)
Ouargla	144	1,1826	452,098125
Rouissat	04	0,03285	3257,0775
Sidi-Khouiled	07	0,0574875	142,8975
Ain-Beida	07	0,0574875	1632,85031
Hassi-B-Abdallah	45	0,3695625	608,54625
N'goussa	14	0,114975	4381,16344
Hassi-Messaoud	140	1,14975	4620,76313
El-Borma	00	0	4506,81469
Touggourt	0	0	691,081875
Nezla	0	0	0
Zaouia abidia	31	0,2545875	0
Tibesbest	1	0,0082125	0
El megarine	0	0	210,650625
Sidi slimane	0	0	153,984375
Témacine	33	0,2710125	0
Balbat amer	19	0,1560375	944,848125
El hadjira	0	0	512,46
Al alia	0	0	1233,72281
Taibet	417	3,4246125	1054,485
Bennaceur	84	0,68985	462,569063
M'nager	53	0,4352625	697,24125
Total Wilaya	999	8,2042875	25563,2541

Municipalities	Camels (head)	Mature (kt/year)	Biogas (m³)
Ouargla	734	6,027975	452,098125
Rouissat	5288	43,4277	3257,0775
Sidi-Khouiled	232	1,9053	142,8975
Ain-Beida	2651	21,7713375	1632,85031
Hassi-B-Abdallah	988	8,11395	608,54625
N'goussa	7113	58,4155125	4381,16344
Hassi-Messaoud	7502	61,610175	4620,76313
El-Borma	7317	60,0908625	4506,81469
Touggourt	1122	9,214425	691,081875
Nezla	0	0	0
Zaouia abidia	0	0	0
Tibesbest	0	0	0
El megarine	342	2,808675	210,650625
Sidi slimane	250	2,053125	153,984375
Témacine	0	0	0
Balbat amer	1534	12,597975	944,848125
El hadjira	832	6,8328	512,46
Al alia	2003	16,4496375	1233,72281
Taibet	1712	14,0598	1054,485
Bennaceur	751	6,1675875	462,569063
M'nager	1132	9,29655	697,24125
Total Wilaya	41503	340,843388	25563,2541

Municipalities	Sheep (head)	Mature (kt/year)	Biogas (m^3)
Ouargla	18565	10,84196	140,94548
Rouissat	13814	8,067376	104,875888
Sidi-Khouiled	1555	0,90812	11,80556
Ain-Beida	3554	2,075536	26,981968
Hassi-B-Abdallah	1917	1,119528	14,553864
N'goussa	16876	9,855584	128,122592
Hassi-Messaoud	16991	9,922744	128,995672
El-Borma	7308	4,267872	55,482336
Touggourt	2299	1,342616	17,454008
Nezla	3267	1,907928	24,803064
Zaouia abidia	7889	4,607176	59,893288
Tibesbest	1867	1,090328	14,174264
El megarine	2676	1,562784	20,316192
Sidi slimane	1963	1,146392	14,903096
Témacine	3883	2,267672	29,479736
Balbat amer	2568	1,499712	19,496256
El hadjira	9580	5,59472	72,73136
Al alia	15860	9,26224	120,40912
Taibet	6686	3,904624	50,760112
Bennaceur	2242	1,309328	17,021264
M'nager	4517	2,637928	34,293064
Total Wilaya	145877	85,192168	1107,49818

Municipalities	Goats (head)	Mature (kt/year)	Biogas (m³)
Ouargla	31455	18,36972	238,80636
Rouissat	10329	6,032136	78,417768
Sidi-Khouiled	1754	1,024336	13,316368
Ain-Beida	2962	1,729808	22,487504
Hassi-B-Abdallah	2335	1,36364	17,72732
N'goussa	26281	15,348104	199,525352
Hassi-Messaoud	18942	11,062128	143,807664
El-Borma	10477	6,118568	79,541384
Touggourt	3550	2,0732	26,9516
Nezla	6910	4,03544	52,46072
Zaouia abidia	3404	1,987936	25,843168
Tibesbest	3688	2,153792	27,999296
El megarine	4934	2,881456	37,458928
Sidi slimane	3332	1,945888	25,296544
Témacine	13840	8,08256	105,07328
Balbat amer	9264	5,410176	70,332288
El hadjira	11969	6,989896	90,868648
Al alia	27373	15,985832	207,815816
Taibet	10361	6,050824	78,660712
Bennaceur	3488	2,036992	26,480896
M'nager	7042	4,112528	53,462864
Total Wilaya	213690	124,79496	1622,33448

Tables A.3: Production of biomass and biogas from palm waste

Ghardaia

Municipalites	palm	Palmwast (kt/year)	Biogas (m3)
Ghardaia	160048,00	4,0012	740,742156
Guerrara	224427,00	5,610675	1038,70426
Bounoura	52216,00	1,3054	241,668702
Metlili	182365,00	4,559125	844,030811
Berriane	54039,00	1,350975	250,106002
El Atteuf	53620,00	1,3405	248,166765
Daya Ben Dahoua	81832,00	2,0458	378,738954
Zelfana	94152,00	2,3538	435,758994
Mansoura	44120,00	1,103	204,19839
Seb Seb	48626,00	1,21565	225,053285
TOTAL WILAYA	995445,00	24,886125	4607,16832

EL-menia

Municipalites	Palm	Palmwast (kt/year)	Biogas (m^3)
El Golia	150085,00	3,752125	694,630901
Hassi F'hel	86296,00	2,1574	399,399462
Hassi Gara	86184,00	2,1546	398,881098
TOTAL WILAYA	322565,00	8,064125	1492,91146

Ouargla

Municipalites	Palms	Palmwast (kt/year)	Biogas (m³)
Ouargla	304919	7,622975	1411,24136
Rouissat	127102	3,17755	588,259832
Sidi-Khouiled	54501	1,362525	252,244253
Ain-Beida	218086	5,45215	1009,35653
Hassi-B-Abdallah	180817	4,520425	836,86628
N'goussa	184977	4,624425	856,1198
Hassi-Messaoud	61436	1,5359	284,341167
El-Borma	0	0	0
Touggourt	13820	0,3455	63,962415
Nezla	176339	4,408475	816,140977
Zaouia abidia	117624	2,9406	544,393278
Tibesbest	136000	3,4	629,442
El megarine	195621	4,890525	905,382893
Sidi slimane	164506	4,11265	761,374895
Témacine	214184	5,3546	991,297098
Balbat amer	183213	4,580325	847,955567
El hadjira	111043	2,776075	513,934765
Al alia	64035	1,600875	296,369989
Taibet	34390	0,85975	159,165518
Bennaceur	24711	0,617775	114,368686
M'nager	61490	1,53725	284,591093
Total Wilaya	2628814	65,72035	12166,8084

Annex chapter III:

Tables A.4: Production of electricity, heat and cold from biogas

Ghardaia

Municipalites	Biogas (1000m³)	electricity(MWh)	heat(MWh)	cold(MWh)
Ghardaia	768,1153671	1520,868427	5630,29	3659,685667
Guerrara	1833,14048	3629,618149	13436,92	8733,997815
Bounoura	360,9482068	714,6774495	2645,75	1719,737731
Metlili	7466,365348	14783,40339	54728,46	35573,4977
Berriane	372,2645504	737,0838098	2728,70	1773,65445
El Atteuf	504,8647767	999,6322578	3700,66	2405,428228
Daya Ben Dahoua	802,7052519	1589,356399	5883,83	3824,489173
Zelfana	400,0208371	792,0412574	2932,15	1905,899278
Mansoura	294,0088729	582,1375683	2155,09	1400,805275
Seb Seb	660,8829768	1308,548294	4844,27	3148,776943
TOTAL WILAYA	13463,31667	26657,367	98686,11	64145,97226

El Menia

Municipalites	Biogas(1000m³)	electricity(MWh)	heat(MWh)	cold(MWh)
El Menia	3112,159805	6162,076414	22812,13	14827,88539
Hassi F'hel	332,4899639	658,3301284	2437	1584,148433
Hassi Gara	1816,966364	3597,5934	13318	8656,93624
TOTAL WILAYA	5261,616132	10417,99994	38567,65	25068,97006

Ouargla

Municipalites	Biogas(1000m³)	electricity(MWh)	heat(MWh)	cold(MWh)
Ouargla	928,38916	1838,210537	6805,09	4423,310153
Rouissat	3446,46789	6824,006432	25262,61	16420,69628
Sidi-Khouiled	173,32795	343,1893408	1270,49	825,8210174
Ain-Beida	1688,71852	3343,662662	12378,31	8045,899371
Hassi-B-Abdallah	669,668802	1325,944227	4908,67	3190,637006
N'goussa	4719,16051	9343,93782	34591,45	22484,44027
Hassi-Messaoud	4982,13978	9864,636773	36519,08	23737,405
El-Borma	4642,163	9191,482749	34027,05	22117,58564
Touggourt	737,643021	1460,533182	5406,92	3514,500175
Nezla	80,8962103	160,1744964	592,97	385,429994
Zaouia abidia	106,492419	210,8549905	780,59	507,3831324
Tibesbest	45,1213941	89,34036033	330,74	214,9808822
El megarine	270,061768	534,7223006	1979,55	1286,709293
Sidi slimane	195,342656	386,7784582	1431,86	930,7100829
Témacine	156,950119	310,761236	1150,44	747,788843
Balbat amer	1047,9616	2074,96396	7681,56	4993,013024
El hadjira	677,315653	1341,084993	4964,72	3227,070429
Al alia	1562,63707	3094,021408	11454,13	7445,184343
Taibet	1442,2037	2855,563329	10571,35	6871,379535
Bennaceur	558,516563	1105,862795	4093,93	2661,052164
M'nager	818,5766	1620,781667	6000,17	3900,108209
TOTAL WILAYA	28949,7544	57320,51372	212201,70	137931,1049

Bibliographical References

Bibliographical References

[1]A Review of Biomass Briquette Binders and Quality ParametersObi, Okey Francis;Pecenka,Ralf; Clifford, Michael J. Energies; Basel Vol. 15, N° 7, (2022): 2426.
[2]The 2nd International Conference on Natural Resources and Life Sciences (NRLS)IOP Conf. Series: Earth and Environmental Science 293 (2019)A review: Biomass-based fuel pellet usage in biomass gasifier-an optimization on non-wood material

[3]Darby, Thomas. "What Is Biomass Renewable Energy". Real World Energy. Archived from the original on 2014-06-08. Retrieved 12 June 2014.
[4]Office of Energy Efficiency & Renewable Energy Forrestal Building 1000 Independence Avenue, SW Washington, DC 20585 https://www.energy.gov/eere

[5]Akia, Yazdani, Motaee, Han, and Arandiyan. A review on conversion of biomass to biofuel by nanocatalysts. Biofuel Research Journal 1 (2014) 16-25.

[6]Book Green Energy and Technology Madhumi Mitra Abhijit Nagchaudhuri Editors Practices and Perspectives in Sustainable Bioenergy A Systems Thinking Approach

[7]SciVerse ScienceDirect Renewable and Sustainable Energy Reviews Thermochemical conversion of biomass – Eco friendly energy routes N.L. Panwar a,∗, Richa Kothari b, V.V. Tyagi c

[8]VENKATA PRABHAKAR SOUDHAM ,Department of ChemistryUmeå University, Sweden 2015Biochemical conversion of biomass to biofuelsPretreatment–Detoxification–Hydrolysis–Fermentation

[9]Jennings,S.Conversion of biomass resource to useful forms of energy and other products. 2008.

[10]"Biomass Gasification." 2001. Renewable EnergyTechnologies: http://www.cogeneration.net/biomass_gasification.htm.(accessed on 3 February 2023)

[11]Value-Added Chemicals FromAnimal Manure. Washington State University.2003:http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14495.pdf>. (Accessed on 11 February 2023)

[12]Escobar, J.C., et al., Biofuels: environment, technology and food security.

Renewable and Sustainable Energy Reviews, 2009. 13(6-7): p. 1275-1287.

[13]Khiari, K., Contribution à 39;étude des propriétés thermo-physiques desbiocarburants de seconde génération et leur influence sur le comportement desmoteurs, 2016, Ecole des Mines de Nantes.

[14].Datta, A. and B.K. Mandal, A comprehensive review of biodiesel as an

alternative fuel for compression ignition engine. Renewable and Sustainable Energy Reviews, 2016. 57: p. 799- 821

[15].Chen, H. and X. Fu, Industrial technologies for bioethanol productionfrom lignocellulosic biomass. Renewable and Sustainable Energy Reviews,2016. 57: p. 468-478.

[16].Elshahed, M.S., Microbiological aspects of biofuel production: current status and future directions. Journal of advanced research, 2010. 1(2): p. 103-111.

[17].Hassan, M.H. and M.A. Kalam, An overview of biofuel as a renewable

energy source: development and challenges. Procedia Engineering, 2013. 56: p. 39-53.

[18].Gaurav, N., et al., Utilization of bioresources for sustainable biofuels: areview. Renewable and Sustainable Energy Reviews, 2017. 73: p. 205-214

[19].Dai L, Liu R, Si C. A novel functional lignin-based filler for pyrolysis and feedstock recycling of poly (L-lactide). Green Chem 2018;20:1777–83.

[20].Noorollahi, Y., et al., Biogas production potential from livestock manure in Iran. Renewable and Sustainable Energy Reviews, 2015. 50: p. 748-754.

[21]."Deadly floods hit Algerian oasis". BBC News. 2008-10-02. Retrieved 12 February 2013.

[22].ONS Ghardaia

[23].Budget-Ouargla, 2019.

[24].ONS-Ouargla, 2019.

[25]."60590: El Golea (Algeria)". ogimet.com. OGIMET. 5mai 2023. Retrieved10mai 2023.

[26].ONS. Statistiques sur l'environnement, Collections Statistiques n° 177 / 2015.

[27].Kehila , Agence National Caractérisation des déchets ménagers et assimilés dans les zones nord et aride d'Algérie. RetrievedNovember 22, 2018, 2016.

[28].l'environnement-Ouargla, D.d., 2021.

[29].DSA –Ghardaia

[30].SoterisKalogirou, Jan Baeyens, John Wheeldon , Biofuels and BioenergyEdited by, Ir. HuiliZHANG July 2020, Pages 29-37

[31].Ardebili, S.M.S., Green electricity generation potential from biogas produced by anaerobic digestion of farm animal waste and agriculture residues in Iran. Renewable Energy, 2020. 154: p. 29-37.

[32].L'agriculture-Ouargla, D.d., 2021.

[33].Makkawi,Y,et al., Fast pyrolysis of date palm (Phoenix dactylifera) waste in a bubbling fluidized bed reactor. Renewable Energy, 2019. 143: p. 719-730.

[34].Ashur, M.M., S.M. Aldulaimi, and I.M. Bengharbia, Biogas Production from Date Palm Trees Residues. 2019.

[35].RECIOUI, Etude prospective de la récupération d'énergie en Algérie, 2016, Université DjillaliLiabès de Sidi Bel Abbès.

[36].AND, l'agence nationale des déchets. 2011. http://and.dz/indicateurs-dechets-en-algerie(accessed on 28April 2023).

[37].Igliński, B., R. Buczkowski, and M. Cichosz, Biogas production in Poland—Current state,potential and perspectives. Renewable and Sustainable Energy Reviews, 2015. 50: p. 686-695.

[38].Ali, M.M., et al., Mapping of biogas production potential from livestock manures andslaughterhouse waste: A case study for African countries. Journal of Cleaner Production,2020. 256: p. 120499.

[39].Lammers, P., et al. "Economic and environmental evaluation of an agricultural waste biogas-to-energy project using life cycle assessment." Journal of Industrial Ecology, vol. 23, no. 5, 2019, pp. 1091-1103.

[40].Compower.AB Externally Fired MicroturbineET 10. Available online: http://compower.se/index.html (accessed on 3April 2023).

[41].Pink GmbH Absorption Chiller PC 19 Data Sheet. Available online: http://www.pink.co.at/inc.download.php?dlf=325 (accessed on 03march 2023).

[42].Gallert, C., Winter, J., & Imhoff, J. F. (2015). Anaerobic digestion. In Environmental Biotechnology (pp. 111-146). Springer, Cham.

[43].Hassan, S. H., Cetecioglu, Z., &Yesil, H. (2015). A review on anaerobic bioconversion of microalgal biomass for bioenergy and other bioproducts. Renewable and Sustainable Energy Reviews, 50, 1170-1185.

[44].C.Maravelias, D. Kaliampakos, D. Papadopoulos, "Evaluation of biogas-fueled micro gas turbine-based cogeneration systems for small scale applications," Energy Conversion and Management, vol. 127, pp. 387-397, 2016.

[45].W. Wang, X. Li, L. Chen, and Y. Dai, "Performance analysis of a biomass-fired cogeneration plant with a cooling system," Energies, vol. 13, no. 3, 2020. DOI: 10.3390/en13030554]

[46].N. K. Selvaraj and R. K. Mohamed, "Recent advancements in biogas-based cogeneration systems," Renewable and Sustainable Energy Reviews, vol. 116, 2019. DOI: 10.1016/j.rser.2019.109440

[47].Da Costa Gomez, C. Biogas as an energy option: An overview. In The Biogas Handbook; Woodhead PublishingLimited, 2013; pp. 1–16. ISBN 9780857090119. Available online: http://linkinghub.elsevier.com/retrieve/pii/B9780857094988500014 (accessed on 3 January 2023).

[48].Capstone Turbine Corporation (CPST). Biogas Renewable Energy Solutions. Available online: https://www.capstoneturbine.com/solutions/renewable-energy (accessed on 15mai 2023).

[49].Clarke Energy. Biogas|CHP|Cogeneration|Combined Heat and Power.Available online: https://www.clarke-energy.com/biogas/ (accessed on 01mai 2023).

[50].Al-Sulaiman, F.A.; Hamdullahpur, F.; Dincer, I. Trigeneration: Acomprehensive review based on prime movers. Int. J. Energy Res. 2011, 35,233–258. [CrossRef]

[51].Jradi, M.; Riffat, S. Tri-generation systems: Energy policies, prime movers,cooling technologies, configurations and operation strategies. Renew. Sustain.Energy Rev. 2014, 32, 396–415. [CrossRef]

[52].Baina, F.; Malmquist, A.; Alejo, L.; Fransson, T.H. Effect of the fuel type onthe performance of an externally fired micro gas turbine cycle. Appl. Therm.Eng. 2015, 87, 150–160. [CrossRef]

[53].Baina, F.; Malmquist, A.; Alejo, L.; Palm, B.; Fransson, T.H. Analysis of a

high-temperature heat exchanger for an externally-fired micro gas turbine. Appl. Therm. Eng. 2015, 75, 410–420. [CrossRef]

[54].J.Villarroel-Schneider.Performance Analysis of a Small-Scale Biogas-Based Trigeneration Plant: An Absorption Refrigeration System Integrated to an Externally Fired Microturbine.Published: 10 October 2019

[55].Ghaem, S. Modeling and Analysis of Hybrid Solar-Dish Brayton Engine; KTH Royal Institute of Technology:Stockholm, Sweden, 2012. Available online: http://www.diva-portal.org/smash/get/diva2:564523/fulltext01(accessed on 19 September 2017).

[56].KTH Royal Institute of Technology. Operating Instruction Manual-MicroGas Turbine ET10; KTH Royal Institute of Technology: Stockholm, Sweden,2010.

[57].Shao, Y.; Huang, S.; Chen, B.; Xiao, H.; Jiang, R.; Qin, F.G.F.Performance Evaluation Indexes of DistributedCCHP Systems. Energy Procedia2017, 142, 2415–2422. [CrossRef]

[58].Dincer, I.; Rosen, M.A. Exergy Analysis of Absorption Cooling Systems.Exergy 2013, 115–131. Availableonline:http://linkinghub.elsevier.com/retrieve/pii/B9780080970899000085 (accessed on 29 Mai 2023).

[59].Sun, Z.G.; Wang, R.Z.; Sun, W.Z. Energetic efficiency of a gas-enginedriven cooling and heating system. Appl. Therm. Eng. 2004, 24, 941–947.

[60].Moran, M.J.; Shapiro, H.N.; Boettner, D.D.; Bailey, M.B. Fundamentals of Engineering Thermodynamics, 8th ed.;Wiley: Hoboken, NJ, USA, 2014; ISBN1118832302, 9781118832301

[61].Dincer, I.; Rosen, M.A. Exergy and Energy Analyses. Exergy 2013, 21–30.Availableonline:http://linkinghub.elsevier.com/retrieve/pii/B9780080970899000024 (accessedon05 march2023).

[62].Dincer, I.; Rosen, M.A. Exergy Analysis of Absorption Cooling Systems.Exergy 2013, 115–131. Availableonline:http://linkinghub.elsevier.com/retrieve/pii/B9780080970899000085 (accessed on 02 march 2023).

[63].Dincer, I.; Rosen, M.A. Exergy Analysis of Cogeneration and DistrictEnergy Systems. Exergy2013,285,302.Availableonline:http://linkinghub.elsevier.com/retrieve/pii/B9780080970899000139 (accessed on 3 February 2023).

[64].Energy ReportsVolume 8, Supplement 16, December 2022, Pages 774-7867th International Conference on Advances on Clean Energy Research, ICACER 2022 April 20–22, 2022, Barcelona, SpainTechnologies for biogas to electricity conversion

[65].I. Tou, S. Igoud et A. Touzi Laboratoire de Biomasse, Centre de Développement des Energies Renouvelables, B.P. 62, Route de l'Observatoire, Bouzaréah, Alger Production et Valorisation – Biomasse, (2001) 103-108

[66].United States Environmental Protection Agency August 2013Renewable Energy Fact Sheet:Microturbines

[67].U.S. Department of Energy (DOE): The DOE website offers valuable resources on CCHP systems, renewable energy, and microturbines. Visit their website at www.energy.gov to access publications, case studies, and technical reports.

[68].''Bofeng Yan'' Gas-fired Combined Cooling, Heating and Power (CCHP) in Beijing: A Techno-economic analysisNorth China Electric Power University, Changping District, Beijing 102206, China 2016

[69].gohari.h.d 'The micro turbine renewable energy combustor (MiTREC). Staffordshire Centre for Renewable and Sustainable Engineering .2020

[70].Biogas Cost Reductions to Boost Sustainable Transport - IRENA. https://www.irena.org/News/articles/2017/Mar/Biogas-Cost-Reductions-to-Boost-Sustainable-Transport

[71].Jean-Ann James 'Water, Air Emissions, and Cost Impacts of Air-Cooled Microturbines for Combined Cooling, Heating, and Power Systems: A Case Study in the Atlanta Region December 2016Engineering 2(4):470-480DOI:10.1016/J.ENG.2016.04.008

[72].Richard A. Brealey, Stewart C. Myers, and Franklin Allen."Principles of Corporate Finance"

[73].https://ar.globalpetrolprices.com(accessed on 20 February 2023).

[74].R. Venkatachalam, "Understanding Internal Rate of Return: A Beginner's Guide" published in The Journal of the Society of Management Accountants of Canada 2013

[75]. Methane Strategy recognises pivotal role of biogas and biomethane in.... https://www.europeanbiogas.eu/methane-strategy-recognises-pivotal-role-of-biogas-biomethane-in-reducing-eu-methane-emissions-in-agricultural-waste-sectors/.(accessed on 07Mai 2023).

[76].M. R. Atelge,'' Biogas Production from Organic Waste: Recent Progress and ... - Waste and Biomass Valorization volume 11, pages1019–1040 (2020)

[77].Tim Juliani, director of corporate climate engagement, WWF '' Is Biogas a "Green" Energy Source?'' Blog Posts | WWF 24 September 2020

[78].Facts about Methane | UNEP - UN Environment Programme.

[79].IEA (2020), Outlook for biogas and biomethane: Prospects for organic growth, IEA, Paris https://www.iea.org/reports/outlook-for-biogas-and-biomethane-prospects-for-organic-growth, License: CC BY 4.0(accessed on 10mai 2023).