AL AKHAWAYN UNIVERSITY IFRANE

School of Science and Engineering

The Design of a Biogas System for Adghagh Village

Capstone Design

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**Executive Summary:**

As part of the bachelor in engineering and management science, Al Akhawayn University gives the chance to the students to apply all the engineering materials learned during the academic life of an undergraduate student in a project called capstone design. Through the capstone design project the student is able to do an engineering project with the supervision of an engineering professor from the engineering and science school. My capstone design project is the design of a biogas system in the region of Adghagh.

The choice of this project as a capstone design project is not accidental. I had opted for such project, which is the biogas system because first I'm fascinated by the renewable energy field in terms of the methods and the tools used on it and also I'm planning to start a postgraduate program on this domain.

This report will show and illustrate the work that I have done during capstone project: the implementation of the biogas system in the region of Adghagh with the supervision of Dr. Albachir Seydou Niandou.
**Acknowledgments:**

I wish to express my sincere thanks to Dr. Albachir Seydou Niandou, my academic supervisor for his efforts and contribution during the capstone design. Dr. Albachir Seydou Niandou had helped a lot in my capstone design project: the design of the biogas system in the region of Adghagh since he is mastering the field which is the renewable energy and all the methods and tools used in this field.

Also I am grateful to everyone who contributed to my work; I thank them for their time and efforts they have taken in helping me including my family and all the engineering and science school staff.
1. Introduction:

1.1 General Context:

The rural population in developing countries such as Morocco is heavily dependent on one of the most important type of renewable energy, the biomass for his daily life needs like cooking and heating. This heavily dependency of the biomass energy which means all the organic materials that of plant origin, animal or fungal origin that can become a source of energy by combustion has several drawbacks on the local environment like deforestation reduction soil fertility and global environment such as the climate change. In addition to the environmental drawbacks of the direct use of biomass there are also several risks, faced, especially by the women and the children in the collection of biomass and also the health problems essentially due to the fumes generated by the biomass combustion.

To overcome all the different drawbacks and negative impacts in all fields associated with the classical use of biomass energy many research and studies had been conducted all over the world to find a solution to this problem. The domestic biogas system is an opportunity to improve the living conditions of the poorest families, while preserving the environment.

Biogas is the gas produced by the fermentation of animal or vegetable organic materials in the absence of oxygen. Recently, the use of domestic biogas method has been widespread, especially in many African countries such as Mali, Morocco, and Rwanda. The Moroccan government had lunched and encourages many projects related to biogas in order to find a clean and renewable source of energy in order to satisfy the huge needs in terms of the energy supply.
1.2 Project Objectives:

Our project intends to design a biogas system that takes as input the biomass in order to produce the biogas that could be used by the local society (Adghagh village) for heating, cooking, and producing electricity. The design of the biogas system should take into consideration the biogas potential of the middle Atlas region in order to achieve a high efficiency.

The overall aim of this project is divided into 3 major parts:

The First part will be dealing with the literature review of the project, including a biogas background, Environmental Performance Index, and also the biogas potential of the Middle Atlas region.

The second part is the part in which we will be dealing with the design of the biogas system including the design of the digester, the pipeline connection related to the digester, the mechanism used to produce the biogas and the maintenance actions that should be performed by the farmers.

In the third and the last part we will discuss the results of using the biogas system in the Adghagh village by conducting a financial analysis, the energy calculation of the biogas system, listing the advantages of the biogas system from different prospective, and the socio-economic impacts of the biogas system in the region of Adghagh.
1.3 STEEPLE Analysis:

STEEPLE analysis is a strategic tool used to assess and evaluates the different factors that affect a renewable energy project. Based on the STEEPLE Analysis we could improve the project from several perspectives. There are mainly 7 factors related to the STEEPLE Analysis which are: technology, societal, ethics, political, legal, environment, and economical.

The figure below shows the different factors affecting the project:

- **Technology**: The use of biomass to produce the biogas
- **Societal**: The increase in terms of the energetic needs. The biogas is non-polluting and can be applied in farms, food industry, or in the municipal landfills.
- **Ethics**: The use of biomass to produce biogas is a tool to recycle waste.
- **Political**: The biogas is a renewable form of energy which means that this form is a perfect solution to satisfy the daily needs.
- **Legal**: The biogas is clean form of energy and can be used by everyone.
- **Environment**: The biogas is a renewable form of energy and could be used to recycle the daily organic waste.
- **Economical**: The use of biogas will help the local society to reduce the spending related to energy since this biogas required only the biomass.

*Figure 1: STEEPLE Analysis of biogas*
2. Literature Review:

21: The biogas:

2.1.1: The substance:

Biogas is a gas fuel mixture produced by the natural fermentation of the biomass in the absence of oxygen. Its main component combustible is methane representing 50% to 70% of the total volume. In addition to the methane the biogas contains carbon dioxide, sulfide, oxygen and the water vapor.

<table>
<thead>
<tr>
<th>Components</th>
<th>Formula</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>CH₄</td>
<td>50-70% of the volume</td>
</tr>
<tr>
<td>Carbone dioxide</td>
<td>CO₂</td>
<td>25-45% of the volume</td>
</tr>
<tr>
<td>Water vapor</td>
<td>H₂O</td>
<td>2-7% of the volume</td>
</tr>
<tr>
<td>Sulfide</td>
<td>H₂S</td>
<td>0.002-2% of the volume</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>N₂</td>
<td>&lt; 2% of the volume</td>
</tr>
<tr>
<td>Ammoniac</td>
<td>NH₃</td>
<td>&lt; 1% of the volume</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>H₂</td>
<td>&lt; 1% of the volume</td>
</tr>
</tbody>
</table>

2.1.2- The process:

The formation of the biogas is essentially due to the activity of several microbes. The chemical process of the biogas formation required 4 steps involved consecutively:

Environmental requirements in four steps involved consecutively:

The Hydrolysis: microorganisms secreting enzymes that breaks down the organic matter, such as carbohydrates, lipids, glucose and pyridines.

The Acidogenesis: the fermentative bacteria convert the hydrolysis products into acetate, carbon dioxide, hydrogen and fatty acids. The Acetogenesis: volatile fatty acids and alcohols are oxidized into acetate, hydrogen and carbon dioxide prior to methane conversion. This process is closely related to Methanogenesis.
The Methanogenesis: unicellular microorganisms produce methane from the acetate, hydrogen, and the carbon dioxide. This is the longest step in the process of the biogas production, and it is influenced by the feed rate the temperature and the ph.

The biogas formed can be purified to remove the carbon dioxide and the hydrogen sulfide in order to have bio methane.

The bio methane has similar characteristics of the natural gas (butane) and its main roles.

2.1.3 Efficiency and productivity:

In order to have a bio digester that operates in normal way and reach the maximum efficiency each family where the biogas system is implemented should have 4 oxen or 8 sheep in order to produce at least 40 kg of wastes per day.

This is a table that shows the biogas production depending on the waste origin:

<table>
<thead>
<tr>
<th>Waste origin</th>
<th>M3 biogas/ Kg of waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle</td>
<td>0.023-0.040</td>
</tr>
<tr>
<td>Sheep</td>
<td>0.041-0.059</td>
</tr>
<tr>
<td>Chicken</td>
<td>0.065-0.116</td>
</tr>
<tr>
<td>Human</td>
<td>0.030-0.050</td>
</tr>
</tbody>
</table>
From the table above we could notice that the waste from chicken origin has the highest efficiency in terms of the biogas production compare to the other waste origin such as human, cattle and sheep.

2.2 Comparison between the biogas and the natural gas:

The biogas produced by the natural fermentation of the organic waste using a biogas system could be considered as the best alternative to the heavily dependency on the classical use of biomass (combustion). The biogas have approximately similar characteristics as the natural gas used to satisfy the daily needs if the local society in terms of cooking and heating. The table below shows the characteristics of the biogas and the natural gas. The biogas studied contains around 61% of methane, 35% of carbon dioxide, and 4% of other materials.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Natural gas</th>
<th>Biogas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calorific power ((kWh/m3))</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>Density (kg/m3)</td>
<td>0.7</td>
<td>1.2</td>
</tr>
<tr>
<td>Ignition temperature (°C)</td>
<td>650</td>
<td>700</td>
</tr>
<tr>
<td>The maximum propagation speed of the flame in air (m/s)</td>
<td>0.39</td>
<td>0.31</td>
</tr>
</tbody>
</table>
2.3 The situation of biogas in Morocco:

Morocco with a youth population (28% of the total population less than 15 years old) and with many huge projects such as infrastructure, tourism projects, and the rural electrification makes the energetic needs of the kingdom continue to increase in a sustained manner (around 7-8% of increase in terms of the electricity consumption).

To overcome this problem, Morocco should find some solution related to the source of energy such as the renewable energy. One of the most efficient solutions is the biogas based on the biomass energy. The biogas is a renewable form of energy non-polluting and can be applied in farm, food industry or in the municipal landfills.

For this reason, the Moroccan government had started and encouraged many projects in different regions of the kingdom related to the biogas production.

- The national energy strategy RE development aims, in addition to wind and solar energy, to profit from the biogas potential of the kingdom.
- Several studies and projects initiated by the National Agency for Renewable Energy Development and the Energy Efficiency (ADEREE) related to the biogas energy.
- Communal (FEC) with the technical assistance of GIZ (projects PEREN et AGIRE) and the World Bank.

There is also a program called “the Moroccan program related to biogas”: 
Tableau 4: Moroccan program related to biogas

<table>
<thead>
<tr>
<th>National strategy</th>
<th>PNDM</th>
<th>PNA</th>
<th>National de lutte</th>
</tr>
</thead>
<tbody>
<tr>
<td>ER (programme national des déchets ménagers)</td>
<td>(programme national d’assainissement)</td>
<td></td>
<td>(programme national de lutte contre le Réchauffement Climatique)</td>
</tr>
</tbody>
</table>

- • 42% of the electrical power will provided by renewable energies including biogas source in 2020
- • 90% of collected wastes
- • 60% of Reduction of pollution in urban areas
- • Rehabilitation of 300 landfills and recycling 20% of collected wastes
- • Reduction of 53 tons of CO2 in 2030
- • 260 cities targeted
- • 60% of Reduction of pollution in urban areas

2.4 Environmental performance index:

One of the most important indexes that should be taken into consideration before the design and the implementation of any environmental project especially for the renewable energy project is EPI (the environmental performance index).

The Environmental Performance Index (EPI) is an index created to assess, compare and improve the effectiveness of environmental policies.

After poor results in 2012, Morocco seems to have improved in ecology. In any case that reveals the latest newly released Environmental Performance Index. In an 81st place out of 178 ranked countries, the Kingdom has increased over the last ten years, but should make more efforts. Out of 178 countries in the world, Morocco is the most efficient 81st in the
management of the environment, reveals the 2014 Environmental Performance Index (EPI) recently released by US universities Yale and Columbia. He received a score of 51.89 / 100, improving by 6.66% over the last decade.

From analyzing the ranking of Morocco based on the environmental performance index we could conclude that the kingdom represent a real place where the environmental project, especially the project related of renewable energies such as the biogas project could be implemented efficiently and effectively.

This is two figures showing the ranking of Morocco and the detailed view of EPI of the kingdom.

![Figure 3: The environmental performance index ranking of Morocco](image_url)
2.5 The biogas potential of the middle Atlas region:

Nobody denies the huge potential of biogas in middle Atlas region due essentially to livestock waste compared to the other regions of the kingdom.

According to the annual report of breeding cattle and poultries published by the minister of agriculture the middle Atlas region is one of the most important regions of the kingdom in terms of breeding cattle and sheep. This region has an energy mobilized potential of the manure of a cattle and poultries of 90594-115934. This is a map (figure 4) that illustrates the potential mobilizable of the manure of cattle and poultries in Morocco.
This potential of middle Atlas region could be exploited in the construction and the implementation of biogas project. Since the raw material required in the biogas production, which is the biomass, is abundant we could easily implement a biogas system in Adghagh which is part of the middle Atlas region. The implementation of such system will be beneficial for the local society from different prospective: environmental, energetic and economical prospective and also we help the population of Adghagh to recycle their waste in clean and daily basis.
2.6 The Village of Adghagh:

The village of Adghagh is small situated in the Middle Atlas, eleven Kilometers from the city of Ifrane. This village covers approximately 23 500 square kilometers containing mountains areas and indecisions forests. The Adghagh is the home to the Descendent of three Berber families: Ait Lahcenou Brahim, Ait Hassou, and Ait Amerou Aissa. The local society in the village of Adghagh is heavily depending on the classical used of biomass (combustion) in order to satisfy their daily needs in terms of heating and cooking. This method of biomass combustion has several drawbbacks in the local environment due to the CO2 and CH4 emissions and also this method could be the main cause of many health problems for women and children due to the fumes generated by the combustion of biomass.

Figure 6: The Village of Adghagh.

In terms of the climate characteristics, the village of Adghagh has approximately similar characteristic as the city of Ifrane in terms of the average high temperature, the daily mean temperature, average low temperature, the monthly sunshine hours , and the wind speed.
The table below shows the temperature characteristic of the village of Adghagh.

**Table 5: The temperature characteristics of Adghagh village and the average monthly sunshine**

<table>
<thead>
<tr>
<th>Month</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average high °C</td>
<td>8.7</td>
<td>9.9</td>
<td>11.5</td>
<td>13.2</td>
<td>17.0</td>
<td>22.8</td>
<td>28.4</td>
<td>28.9</td>
<td>24.3</td>
<td>18.7</td>
<td>12.5</td>
<td>9.7</td>
</tr>
<tr>
<td>Daily mean °C</td>
<td>4.3</td>
<td>5.2</td>
<td>6.6</td>
<td>8.0</td>
<td>11.8</td>
<td>15.9</td>
<td>21.2</td>
<td>21.4</td>
<td>17.9</td>
<td>12.5</td>
<td>7.8</td>
<td>4.7</td>
</tr>
<tr>
<td>Average low °C</td>
<td>-0.8</td>
<td>0.5</td>
<td>1.4</td>
<td>2.8</td>
<td>6.0</td>
<td>9.4</td>
<td>13.7</td>
<td>13.9</td>
<td>11.0</td>
<td>6.6</td>
<td>2.9</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Mean monthly sunshine hours

|       | 180 | 169 | 214 | 214 | 211 | 263 | 302 | 340 | 317 | 258 | 227 | 175 |
Methodology:

3.1: The Design of the Digester:

Nobody denies that digester is the most important part in the biogas system. This digester is a physical structure where chemical and microbial reactions take place and it has several names such as anaerobic reactor. It main function is to provide and ensure all the conditions required for the production of the biogas using the biomass in terms of the temperature, the air and the water needed.

Figure 7: Complete picture of a modern and sophisticated biogas system
The Size:

One of the most important characteristics of the biogas system that should be taken into consideration before the design is the size of the system. This characteristic is mainly dependent on many factors:

1. The quantity and the origin of the waste used in the digester in order to produce the biogas. For the case of Adghagh village the average quantity of the feed stock is approximately 24 Kg per day for each family and in terms of the origin of the waste we will use the cow dung since this origin is abundant in Adghagh village and has a high efficiency in terms of the biogas produced.

2. An important factor that could affect the choice of the size of the biogas system is the objective of treating organic waste (the production of energy/ the production of fertilizer). For our project the main goal of using the biogas system is to produce the biogas which would be used by the local society to satisfy the daily needs for heating and cooking.

3. Another factor affecting the size of the biogas system is the demand and the consumption of the natural gas in the region where the system would be implemented.

4. The wind speed and direction and the air temperature in seasons of the year would affect the size of the biogas system chosen. Concerning the region of Adghagh the wind speed varies between 3Km/h and 25km/h and in terms of the temperature the table below shows the temperature characteristics of the region of Adghagh:
Table 6: The temperature characteristics of Adghagh village and the average monthly sunshine

<table>
<thead>
<tr>
<th>Month</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average high °C</td>
<td>8.7</td>
<td>9.9</td>
<td>11.5</td>
<td>13.2</td>
<td>17.0</td>
<td>22.8</td>
<td>28.4</td>
<td>28.9</td>
<td>24.3</td>
<td>18.7</td>
<td>12.5</td>
<td>9.7</td>
</tr>
<tr>
<td>Daily mean °C</td>
<td>4.3</td>
<td>5.2</td>
<td>6.6</td>
<td>8.0</td>
<td>11.8</td>
<td>15.9</td>
<td>21.2</td>
<td>21.4</td>
<td>17.9</td>
<td>12.5</td>
<td>7.8</td>
<td>4.7</td>
</tr>
<tr>
<td>Average low °C</td>
<td>-0.8</td>
<td>0.5</td>
<td>1.4</td>
<td>2.8</td>
<td>6.0</td>
<td>9.4</td>
<td>13.7</td>
<td>13.9</td>
<td>11.0</td>
<td>6.6</td>
<td>2.9</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Mean monthly sunshine: 180 169 214 214 211 263 302 340 317 258 227 175

In order to determine effectively the size of the biogas system, we had developed a mathematical equation that should be achieved in order to have a high efficiency in terms of the biogas production:

\[
\text{Digester size (m}^3\text{)} = \text{Daily feed-in (m}^3\text{ day}^{-1}\text{)} \times \text{Retention time (day)}
\]

Where:

Digester size: can be defined as the size of the stomach tank in addition to the size of the gas collector.
Daily feed-in; is the size of the mixture of the organic waste used in the production of the biogas with the water. The size of daily feed-in could be fixed or varied depending on the frequency of the production. This is a table that summarizes the biogas system size and the average daily feedstock:

<table>
<thead>
<tr>
<th>Biogas system Size (m³)</th>
<th>Daily Feedstock (Kg)</th>
<th>Daily Water (litres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>6</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>8</td>
<td>48</td>
<td>48</td>
</tr>
<tr>
<td>10</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>15</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>20</td>
<td>120</td>
<td>120</td>
</tr>
</tbody>
</table>

Based on the different characteristics of the Adghagh village in terms of the temperature, wind speed, monthly sunshine hours, and the daily feedstock we had opted for biogas system of size 4m³. This sizes match perfectly the general characteristic of the region and will help the local society to produce an important amount of the biogas every day. In the first stage of our project we are targeting a sample size of 40 families in Adghagh village in order to check first the efficiency of the system, if the project reach the objectives fixed we will target another 40 family in the same region.
Generally, the 24 kilograms of biomass should be complimented with the same amount of water (24 litters) every day in order to reach high efficiency.

**Type of the Digester:**

Since the biogas is had been considered as one of the most clean and efficient form of renewable energy, many forms and types of digester had been developed during the last century. In terms of the flow, we will choose the continuous digester which is a type of digester that requires a daily loading and residual management. This digester is named as continuous digester since to every day load corresponds to a standard quantity of biomass. The choice of this type of digester flow could be justified by the fact that each family of sample in the region of Adghagh could produce 24 kg of feedstock per day which is the daily loading required for biogas system of size $4m^3$. In terms of the retention time the continuous digester required between 14-40 days but this period (the retention period) could be reduced using an agitator or a heater in order to accelerate the process of the biogas production. The most important advantages of using this digester compare to other digester like the batch digester is that a single unit allows a permanent supply of the products such as the biogas and the fertilizer.

In terms of the design of the digester, we will opt for a fixed dome digester since this form of digester allows a high daily production of biogas and its cheaper compare to the other form of digester. The form of digester is the most important form of digesters due to its simplicity in terms of the structure. It is composed mainly of two spherical domes, inlet pit, outlet pit and an inspection opening.
The fixed dome digester should be completely entombed underground to allow the digester to operate in an optimal way. The temperature inside the digester should be under a constant temperature change with a tolerance range of ± 2 °C.

Concerning the dimension our fixed dome digester we will follow some equations related to the digester in order to find the optimal values such as the digester volume, the inner and the outer radius of the dome, the volume of the upper and the bottom sphere, the volume of the gas storage, the effective gas volume, and the maximum gas volume.

The total digester volume is expressed by the following equation:

\[ V = 2.09 R_1^3 + 0.687 R_1 \]
a. The values of $R_1$, $R_2$, and $h$

\[4m^3 = 2.09R_1^3 + 0.687R_1^3\] 
by solving this equation we find that

$R_1 = 1.14 \text{ m}$

$R_2 = 1.5 \text{ m}$

$h = 0.46 \text{ m}$

b. The volume of the upper and the bottom sphere:

$V_1 = 2.09R_1^3 = 3.01 \text{m}^3$

$V_2 = 0.687R_1^3 = 0.99 \text{m}^3$

$V = 4 \text{ m}^3$

C. The volume of the gas-storage and the height of the gas-storage:

The gas storage for the fixed dome digester should exceed 25% which means that:

$V_{\text{gas}} = 1 \text{m}^3$

Concerning the height of the gas storage we should solve the equation:

$1.047h^3 - 3.581h^2 + 1.0015 = 0$

$h_{\text{gas-storage}} = 0.57 \text{ m}$

D. The maximum gas production:
Concerning the maximum gas production per day is calculated using the following equation

The maximum gas production per day (m3) = daily feeding (Kg) * gas production per kg of dung (Liters/kg)

\[24 \text{ (kg)} \times 50 \text{ (liters/kg)} = 1.2 \text{ m3}\]

f. The effective gas volume \(V_{\text{eff \_ gas}}\)

The effective gas volume = 50% of the gas produced every day

\[V_{\text{eff \_ gas}} = 50\% \times 1.2 \text{ m3} = 0.6 \text{ m3}\]

g. The maximum gas volume:

Maximum gas volume \(V_{\text{max \_ gas}}\) = volume of storage \(V_{\text{gas}}\) + the effective gas volume \(V_{\text{eff \_ gas}}\)

\[V_{\text{max \_ gas}} = 1 \text{ m3} + 0.6 \text{ m3}\]

Figure 9: Picture of fixed dome with the different dimensions.
**The Construction Materials:**

In addition to the design of the biogas system, the materials used for the construction of the system are crucial in terms of the biogas production. For this reason we should choose the best quality in the market in terms of the different materials used in the construction of our biogas system.

The table below summarizes the materials used for the construction of our biogas system of size 4 m³.

*Table 8: The different construction materials used for a biogas system of size 4 m³*

<table>
<thead>
<tr>
<th>Materials</th>
<th>Biogas system 4 m³</th>
<th>unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>50</td>
<td>sack</td>
</tr>
<tr>
<td>Cement</td>
<td>13</td>
<td>sack</td>
</tr>
<tr>
<td>Paint</td>
<td>1.5</td>
<td>liter</td>
</tr>
<tr>
<td>Bricks</td>
<td>1000</td>
<td>piece</td>
</tr>
<tr>
<td>Inlet pipe</td>
<td>2</td>
<td>piece</td>
</tr>
<tr>
<td>Elbow</td>
<td>5</td>
<td>piece</td>
</tr>
<tr>
<td>socket</td>
<td>4</td>
<td>piece</td>
</tr>
<tr>
<td>Water drain</td>
<td>2</td>
<td>piece</td>
</tr>
<tr>
<td>Gas stove</td>
<td>2</td>
<td>piece</td>
</tr>
</tbody>
</table>
In terms of the cement, we should choose the best quality of the Portland cement in the market and the sacks of the cement shouldn't have direct contact with the floor in order to avoid absorption of the moisture.

For the sand it should be very clean and we should avoid the use of dirty sand which will decrease the strength of the biogas system. Course and granular sand will be used for concrete work and the fine sand for plastering work.

### 3.2 Pipeline connection:

Nobody denies the importance of a sophisticated and modern pipeline connection associated with the bio digester in order to achieve a high efficiency. As everyone knows the biogas contains the water vapor. This water vapor passes through a pipe some of it condenses and transforms into liquid (water) and this liquid will represent an obstacle for the gas flow.

In order to overcome this problem we should install a water trap to make the water able to escape.

This water trap should be attached to the biogas pipes at any low point where the water could be easily collected.

![Figure 10: The comparison between a normal pipeline connection and an ideal one.](image)
In terms of the structure the water trap is composed of T-joint linking a small tube down from the main tube into a container of water. Generally this container is a plastic water bottle.

In terms of the mechanism the gas produced is prevented from escaping due to the pressure of the water. For this reason the level of water shouldn't exceed 15 cm, which is approximately, equal to 15mbar.

![Figure 11: A picture of water trap](image)

### 3.3 Mechanism:

Concerning the mechanism used in the production of the biogas using a simple installation:

First, the biomass is introduced in the installation via pumping a viscous or liquid matter. Most of installations used in the biogas production operate in daily based in order to satisfy the quotidian needs of energy. The biomass is introduced several times in the bio digester and at the same time an equivalent

The subtract is heated and stirred for several days with a minimum temperature of 37°C in order to provide all the necessary conditions for the microbial activity required in the biogas production. Generally all the steps of the biogas production take place in the same bio digester but in some modern and sophisticated installations we could find separated compartments used only for the hydrolysis, which is the first step for the biogas production.
The biogas produced during the fermentation phase is accumulated below of the subtract. It is stocked after in the gas storage tank at low pressure.

After a retention period which varies depending on the type of digester used, the biomass is transformed intro digestate which is a gooey mixture of brown color that could be used by the farmers as fertilizer. In addition to the digestate the biogas is formed also and then forwarded to gas engine that will purified and remove the carbon dioxide and hydrogen in order to produce the bio-methane that could be used for producing electricity and for heating.

This is a picture of sophisticated biogas system where we could find the digester, the gas storage tank, the post-digester and the gas engine used to produce electricity based on the biogas.

Figure 12: Schema of a different component of a sophisticated biogas system.
3.4 Maintenance:

The biogas system faced many problems and issues that could affect negatively the production and the efficiencies of those systems.

This is some common problem of the biogas systems:

<table>
<thead>
<tr>
<th>Common problems</th>
<th>% of biogas plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leakage of gas storage</td>
<td>38%</td>
</tr>
<tr>
<td>Problems related to pipeline connection</td>
<td>26%</td>
</tr>
<tr>
<td>Problems related to tubing and valves</td>
<td>23%</td>
</tr>
<tr>
<td>Problems related to low gas in the winter</td>
<td>13%</td>
</tr>
</tbody>
</table>

In order to ensure an optimal performance of the biogas system the farmer should know the importance of any component of the system including the digester, the pipeline connection and perform a periodical maintenance of the system in order to achieve a high efficiency.

The maintenance operations vary depending on the types and the production of the biogas system. In general, the maintenance operations could be summarizing in:

First, loading and unloading the biogas system depending on the production frequency and the nature of the biomass (generally, this actions should take place every day or every 20 days for the case of batch digester)
Second, the maintenance of the curve where the digester is implemented is very crucial. For this reason a completed drain should be performed by the farmer one to two times per year.

Third, the masonry and the metallic parts of the system should be verified periodically in order to avoid any problem that could affect the efficiency of the system.

Fourth, in addition to the maintenance operations related to the digester, the farmer shouldn’t neglect the pipeline connection of the system. For this reason the user of the biogas system should perform a daily verification of the traps, tubing and the water trap or any time where there is problem in terms of the gas flow through the pipeline connection.

The farmers should carry lot about some routine and daily repair work related to the biogas system such as painting of drum to avoid the risk of gas leakage.

**Result:**

4.1 financial analyses:

Nobody denies that the financial analysis of the project is an essential way to evaluate the efficiency of the project. The financial analysis of the project deals with the different types of the cost (direct or indirect) related to the realization of the project.

Considering our project which is the implementation of the biogas system in the region of Adghagh we had perform a financial analysis of a biogas system of size 4 m³ which is implemented in the region of Adghagh.

For the four financial analyses we will consider two major types of cost: the direct cost and the indirect cost.
**The direct Cost:**

Concerning the direct cost associated construction of the curve need for the biogas system and the cost of the digester this is a table that summarizes the different direct costs:

**Table 10: The different cost associated with the implementation of biogas system**

<table>
<thead>
<tr>
<th>The material</th>
<th>The cost (DH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reinforcement + Rubble</td>
<td>1750</td>
</tr>
<tr>
<td>Top concrete</td>
<td>600</td>
</tr>
<tr>
<td>Cement</td>
<td>500</td>
</tr>
<tr>
<td>concrete mixture</td>
<td>300</td>
</tr>
<tr>
<td>Glance</td>
<td>4300</td>
</tr>
<tr>
<td>Insulation</td>
<td>2700</td>
</tr>
<tr>
<td>tarpaulin</td>
<td>1100</td>
</tr>
<tr>
<td>Sealant</td>
<td>1300</td>
</tr>
<tr>
<td>The digester</td>
<td>2500</td>
</tr>
</tbody>
</table>

**The Indirect Cost:**

In addition to the direct cost associated with the construction of the curve needed for the biogas system and the cost of the digester, we could identify an type of cost which is the indirect cost associated with the construction of the biogas system.

Those indirect costs are the cost associated with the maintenance operations of the biogas system performed periodically by the farmers and without forgetting the cost of the labors worked during the digging of the curve. It’s difficult to have an exact number of this type of
cost since the maintenance and labor costs could vary depending on several factors and reasons.

4.2 advantages of using biogas system in the region of Adghagh:

The biogas as a form of renewable energy has several advantages in the regions where this type of energy is implemented. This form of renewable energy which is based on the exploitation of organic waste has many advantages that could be classified based on 4 aspects:

![Advantages of Biogas System](image.png)

Figure 13: Advantages of Biogas system from different prospective.

In terms of energy: Biogas is form of renewable energy that can be exploited in several manners:

The biogas energy could be used as energy source for heating and hot water production, as tool for electricity production and also as an alternative fuel for vehicles.

From an environmental prospective: Biogas energy is a tool that could be used to recycle organic waste and thus avoid pollution and nuisances on the local environment. Also the production of biogas based on the organic waste will help to decrease the CO\textsubscript{2} and CH\textsubscript{4} emissions, which are very harmful for the environment. Moreover, residual products from the biogas production could be used as fertilizer in agriculture.
From an economic prospective: Biogas present many advantages for the local society especially for farmers, who can develop economically and energetically their agricultural waste (plant or animal source). Also the use of biogas energy as main source of energy will help the local society to decrease his spending related to energy needs since the biogas plants need only the organic waste as input.

And from technical prospective: biogas technology can be easily installed on a small scale for a better adaptation to the national context, as is the case in several countries mostly during the last thirty years.

**4.3 Energy calculation of the biogas system:**

The calculation of energy produced by the biogas system is a key term to know the expected biogas production in the Adghagh region and at the same time to evaluate the efficiency of the systems. According to Tamera which is a peace research village with the goal of becoming "a self-sufficient, sustainable and duplicable communitarian model for nonviolent cooperation and cohabitation between humans, animals, nature" there are 4 major equations that could be used to calculate the energy produced by the biogas system:

The first formula:

\[ \text{Total gas produced (m}^3) = \text{Total cow dung (Kg)} \times 0.05 \]

The second formula:

\[ \text{Total energy (mega joules MJ)} = \text{Total gas produced (m}^3) \times 19 \]

We had conducted our analysis on a sample of 40 families of the region and we had expected a daily waste production of 24 kg. The table below shows the energy calculation expected for each family and for our sample selected in the region of Adghagh:
Table 11: the energy production of a biogas system of size $4\, m^3$

<table>
<thead>
<tr>
<th>Cow dung (Kg)</th>
<th>Total gas produced ($m^3$)</th>
<th>Total gas produced ($m^3$)</th>
<th>Total energy (MJ) for each family</th>
<th>Total energy (MJ) for the sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>For each family</td>
<td>for each family</td>
<td>for sample</td>
<td>family</td>
<td>sample</td>
</tr>
<tr>
<td>1</td>
<td>0.05</td>
<td>2</td>
<td>38</td>
<td>1520</td>
</tr>
<tr>
<td>12</td>
<td>0.6</td>
<td>24</td>
<td>456</td>
<td>18240</td>
</tr>
<tr>
<td>24</td>
<td>1.2</td>
<td>48</td>
<td>912</td>
<td>36480</td>
</tr>
</tbody>
</table>

From the results we could notice that for an optimal waste production which is approximately 24 Kg we could generate thanks to the biogas system $1.2\, m^3$ and 920 MJ for each family in the region of Adghagh. This amount of energy produced by the biogas system of size $4\, m^3$ would help the 40 families where the system is implemented to reduce their daily and monthly spending related to energy and at the same time the system would recycle in clean and proper way the organic waste.

In addition to the energy expressed in MJ we could also convert the biogas produced into electrical energy. Before converting the gas produced into electrical energy we should know that 65% of energy is lost as heat or other mechanical loss and only 35% would be converted into electrical energy following the two equations:

The third equation:

$$\text{Total energy (KWh)} = \frac{\text{Total energy (MJ)}}{3.6}$$
The fourth equation:

**Electrical energy (KWh) = Total energy (KWh) \times \frac{35}{100}**

<table>
<thead>
<tr>
<th>Cow dung (kg)</th>
<th>Total energy (MJ) for each family</th>
<th>Total energy (MJ) for the sample</th>
<th>Total energy (KWh) for each family</th>
<th>Total energy (KWh) for the sample</th>
<th>Electrical energy (KWh) for each family</th>
<th>Electrical energy (KWh) for the sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>38</td>
<td>1520</td>
<td>10.56</td>
<td>422.23</td>
<td>3.696</td>
<td>147.78</td>
</tr>
<tr>
<td>12</td>
<td>456</td>
<td>18240</td>
<td>126.67</td>
<td>5066.67</td>
<td>44.33</td>
<td>1773.34</td>
</tr>
<tr>
<td>24</td>
<td>912</td>
<td>36480</td>
<td>253.34</td>
<td>10133.34</td>
<td>88.67</td>
<td>3546.67</td>
</tr>
</tbody>
</table>

From the table above we could notice that the biogas system of size 4 m³ that take as input 24 kg of cow dung per day could produce up to 88.67 Kwh for each family where the biogas system is implemented for an optimal production. This amount of electrical energy will help the local society of Adghagh to satisfy their daily needs that requires electricity and at the same time would be a perfect solution to the lack of electricity in many parts of the Village of
Adghagh. There are mainly two approaches used to generate electricity based on the biogas produced by the biogas system:

The first approach is the use of a duel fuel generator that should be linked to the biogas system through an air mix. This type of generator requires diesel in order to work.

![Figure 14: Duel fuel generator](image1)

The second approach more renewable and clean compare to the first approach which is the use of 100% biogas generator. The 100% biogas generator doesn't require any form of fuel to operate in optimal way but it is costly and at the same it requires some specific maintenance tools that are very expensive.

![Figure 15: 100% biogas generator](image2)
4.4 The socio-economical impact of the biogas system in the village of Adghagh:

in order to determine and evaluate the impact of the biogas system we should conduct an SEA (socio-economical analysis) in the village of Adghagh. The SEA is a modern method that uses economic science and sociology in order to evaluate the socio-economical impacts of a project on specific population. The SEA contains 4 major stages: aims of the SEA, setting the scope of the SEA, identifying and assessing impacts, interpretation and conclusion drawing.

The flow chart below shows the different stages of the SEA:

![Flow chart of the different stages of SEA]

**Figure 16: the different stages of SEA**

**Stage 1: Aim of the Sea**

During the stage 1 of the socio-economical analysis we fix the aim of the SEA. Concerning our project which is the design of the biogas system in the village of Adghagh, the aim is
evaluating the different socio-economical impacts of the biogas system in the local population of the Adghagh village.

**Stage 2 : setting the scope of the SEA**

The second stage of the SEA is the setting of the scope of the socio-economical analysis. During this stage of SEA we are defining the boundaries of our socio-economical analysis. The boundaries of our projects are: the time period covered is one month, the geographical area of study is the Adghagh Village where the biogas system will be implemented, and the population is the 40 families in the village of Adghagh.

**Stage 3 : identifying and assessing impacts**

The third step in the socio-economical analysis is identifying and assessing impacts. Concerning our project we are focusing more on the economical impacts of the biogas system in the village of Adghagh. The table below shows the estimated spending related to energy for each family before and after the implementation of the biogas system in the village of Adghagh.

Table 13 : The expected spending of each family before and after the implementation of the biogas system

<table>
<thead>
<tr>
<th>The time</th>
<th>The spending before the implementation of the system for each family (DH)</th>
<th>The spending per day before the implementation of the system for each family (DH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>one day</td>
<td>60</td>
<td>45</td>
</tr>
<tr>
<td>2 day</td>
<td>120</td>
<td>86</td>
</tr>
<tr>
<td>One week</td>
<td>420</td>
<td>350</td>
</tr>
<tr>
<td>One month</td>
<td>1800</td>
<td>1250</td>
</tr>
</tbody>
</table>
**Stage 4 interpretation and conclusion:**

The last stage is the interpretation and the conclusion. From the results of the previous stage we could notice that the biogas system would help a lot the local society of Adghagh to decrease their daily spending related to energy since the biogas system requires only the organic waste as input and also the biogas system would help the families to recycle their waste in a daily basis in a clean and proper way.

**Recommendations:**

Before the implementation of the biogas system in the region of Adghagh we had conducted a survey among the farmers of the region in order to have recommendations and expectations regarding the biogas system.

**Data collecting:**

The survey was conducted on 40 families in the region of Adghagh where the biogas system will be implemented. During this survey we had as objective to know and determine the expectations and recommendations of the farmers regarding the biogas system. The survey has one question which is what are the characteristics that should be taken into consideration for the implementation of persistent and efficient biogas system in the farms of Adghagh region? we had opted for one question in order to simplify the classification of the results into major categories.

**Data analysis:**

Based on the results of the survey, we had classified those results into three major categories of recommendations:

The first category is the characteristics that are considered by the farmers as critical (the first order) that the biogas system should have.
The second type is the characteristics of the second order required before the implementation of the biogas system in the region of Adghagh.

The last type is the characteristics and the features that could be considered as the third order importance for a persistent and efficient biogas system.

Figure 17: The first order characteristics required for an efficient the biogas system:

Figure 18: The second order characteristics required for an efficient the biogas system.
Figure 19: The third order characteristics for the biogas system in the region of Adghagh.

**Recommendations:**

In addition to the recommendations based on the survey conducted among the farmers in the region of Adghagh there are many recommendations that should be taken into consideration before the design and the implementation of the biogas system in the region of Adghagh:

1. The collaboration with the local authorities is one of the most important factor that could help achieving our objectives. This collaboration will help to get the authorization to start designing and implementing our biogas system in the region of Adghagh.

2. The collaboration with the Moroccan organizations operating in the renewable energy field in order to get all the necessary information related to the biogas potential in the region of
Adghagh and also to have clear idea about the different biogas projects that had been realized in the kingdom.

3. The maintenance of the biogas system is the most important key to achieve a high efficiency in terms of the biogas system. For this reason we should teach the farmers of the village of Adghagh some basic maintenance actions that should be performed periodically.
**Conclusion:**

Nowadays, many countries around the world faced real problems related to the shortage of energy sources and huge dependency on non-renewable energy sources (oil, diesel, and fossils). Morocco is one of those countries that are searching for solutions and alternatives to satisfy the energy needs of the society. To overcome the problems related to the energy needs the kingdom should move toward sustainable and renewable source of energy such as the biogas energy.

The approach of using the biogas as the main source of energy especially in the rural areas has proved his efficacy in the different continents of the world and several countries had started and lunched biogas plants project. for example , the implantation of the biogas plants in the European countries had be increased in the last years due to the several advantages of those plants and also the local government encourage farmers to adopt biogas plants as main source of energy by giving financial subversion .

Table 14: the number of biogas plants in some European countries.

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of bio-farms</th>
<th>Number of biogas plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>21575</td>
<td>368</td>
</tr>
<tr>
<td>Spain</td>
<td>32195</td>
<td>32</td>
</tr>
<tr>
<td>Germany</td>
<td>23003</td>
<td>7515</td>
</tr>
<tr>
<td>Denmark</td>
<td>2677</td>
<td>62</td>
</tr>
</tbody>
</table>

The aim of this project is to design and implement a biogas plant in the region of Adghagh, which will help the local society to overcome the problem of the dependency on the fossils and the fuel as main source of energy. The biogas system, which is composed, of a simple digester (containing two tank: stomach tank and the gas storage tank) and pipeline connection will produce the bio-methane using the biomass which is abundant in this region.

The results of the financial analysis, the survey conducted among the farmers of the region, and the several advantages of the biogas plants shows that this project will be beneficial for the local societies from financial prospective since the project will not cost lot in terms of the implementation, from energetic prospective the use of biogas plant will help the region to overcome the problem of dependency on fossils and fuels, also the biogas plant will be beneficial from an environmental prospective since the use of this form of renewable energy will valorize the organic waste and will reduce significantly the CO$_2$ and CH$_4$ emissions.
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References:


Culhane, T. (n.d.). Biogas Digester What is a biogas digester and how to build it? Module for a decentral autonomous energy supply. 1, 7, 8, 9, 10.


