Clean Energies Based Refurbishment of the Heating System
of Al Akhawayn University Swimming Pool

Capstone Design

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## Glossary

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GHG</td>
<td>Greenhouse Gas</td>
</tr>
<tr>
<td>ar</td>
<td>As Received</td>
</tr>
<tr>
<td>daf</td>
<td>Dry And Fresh</td>
</tr>
<tr>
<td>CV</td>
<td>Calorific Value</td>
</tr>
<tr>
<td>HHV</td>
<td>Higher Heating Value</td>
</tr>
<tr>
<td>LHV</td>
<td>Lower Heating Value</td>
</tr>
<tr>
<td>COEF</td>
<td>Carbon Content Coefficients</td>
</tr>
</tbody>
</table>
Abstract

This project presents an engineering evaluation and a cost effectiveness study of the replacement of old diesel boilers by a new biomass boiler with an economizer for water and space heating of Al Akhawayn University swimming pool located in the cold Middle Atlas region. This biomass boiler is a new green technology that could use olive pits as well pellets from oak trees from the forest of the region. Infrared thermography has been used to evaluate the current heat losses in the building for better energy efficiency. In addition to the evaluation of the extra energy saving that results from reducing water evaporation through the addition of a pool cover. The calculations and simulation results show the possibility for as much as 59.3 % annual savings on energy cost and a pay back period of the initial investment of only 4.8 years. The new system also allows a reduction of 23 593 Kg on CO\textsubscript{2} emissions, which is 40 % less than the initial CO\textsubscript{2} emissions.
1. Introduction

1.1 General Context

During the last decade, the world is trying to find an adequate solution to reduce the greenhouse emissions that destroy the protective layer of ozone. One of the major causes of global warming is the overconsumption of fossil fuel, major energy source, to support the huge number of demands that will lead to a lack of availability in the near future.

The best solution is the use of green technology including biomass. Biomass is a biological material derived from agricultural residues and crops, woody and herbaceous materials, in addition to organic wastes. Biomass energy production is the magical key to replace fossil fuel in many domains. This project will be a study of the use of olive pits as biomass energy in order to replace the diesel used in the boilers that heat Al Akhawayn swimming pool water. The purpose of this project is to emphasize the performance of the heating system and the energy savings due to the use of biomass energy.

1.2 Project Objectives

As it has been mentioned earlier, the main objective of this project is the engineering evaluation of replacement of old diesel boilers by a new biomass boiler. In terms of energy savings, the detailed objectives of the study are the following:

- Evaluate the proposed biomass boiler,
- Evaluate the calorific value produced by olive pits,
- Determine the annual energy consumptions of the boilers,
- Calculate CO\(_2\) emissions,
- Analyze the energy savings due to the use of a thermal cover,
- Compare the alternative of using oak as a biomass source.
1.3 STEEPLE Analysis

STEEPLE Analysis is a strategic decision model that evaluates the seven factors that affect a project’s environment and lead to the improvement of a company decision-making. The STEEPLE Analysis factors that should be taken into consideration are the following: societal, technology, environment, ethics, political, legal, and economical.

The figure below evaluates this capstone project potential impact:

**Societal**: Population growth leads to the increase of fossil fuel energy demand. Biomass is an alternative to replace fossil fuel and can be adapted to the behavior change of the society.

**Technology**: The use of biomass heating systems.

**Environment**: Biomass heating systems is an eco-friendly system that use renewable energies. In addition to the fact that it is a neutral carbon cycle.

**Ethics**: Decrease the energy consumption in order to preserve the environment.

**Political**: Fossil fuel costs are increasing and its production will not be sufficient for the future generation, so biomass is the alternative found that costs less.

**Legal**: Biomass is not a dangerous resource, so it can be used be everybody.

**Economic**: Biomass heating system reduce the energy consumption and generate important cost savings.

*Figure 1.3: STEEPLE analysis of Biomass*
1.4 Problem Statement
Nowadays, fossil fuel is considered as the main energy source which is used in all the sectors. Fossil fuel is not a clean energy and is one of the main causes of greenhouse gas (GHG) emissions. Due to the growth population, fossil fuel has a higher demand that causes to its cost increase. The challenge is to find an eco-friendly energy source that can replace fossil fuel and be less expensive, as it is the case for biomass. Diesel boilers used to heat swimming pool water are known as being very pollutants since they emit a large amount of carbon dioxide to the atmosphere and consume thousand liters of diesel by year. Al Akhawayn University chose to replace its diesel boilers by biomass boiler in order to take part of the environment protection and guarantee the sustainable energy.

2. Literature Review
2.1 The Use of Biomass in the World
Biomass energy is an old way to produce heat energy that was neglected in the past. Due to the increase of the greenhouse gas emissions, experts decided to bring back this alternative.

Biomass is an eco-friendly energy source for the energy sector; it is mainly used for electricity generators and power engineering plants [26]. The biomass energy produced is known as being the least capital-intensive renewable energy source because of the optional self-contained production, which explains its annual worldwide production of 220 billion Mg of dry mass [7,16]. Biomass incineration process consists on the conversion of chemical energy contained in the biomass into thermal energy, and the carbon dioxide emissions are not harmful to the atmosphere since it is a carbon neutral cycle since the carbon taking out is then returned to the ground [7, 20, and 29]. Biomass conversion does not allow CO₂ content to be highly emitted in the atmosphere since it is a renewable process [30-33]. Any kind of renewable energy source contributes in some ways to the protection of the environment and decreases the use of fossil fuel in industrial sectors [3-15].
The difference between biomass and fossil fuels is that biomass has a closed cycle that consists on taking carbon out of the atmosphere while it is growing, then returns it once it is burned so it is a carbon neutral. While burning fossil fuels release carbon dioxide in the atmosphere that leads to a climate change.

Figure 2.1: The biomass carbon cycle fundamentally differentiates biomass from fossil fuel [39]

2.2 Biomass Energy in Morocco

Renewable energies occupy an increasingly important role in the global energy mix. The Morocco is no exception to this trend and has the advantage of enjoying a rich potential relative to other countries. The optimal exploitation of its rich potential will reduce energy dependency and ensure the stability of the country.

Morocco has a large biomass deposit to be exploited:

- Forest wood (9 million hectares of forests), stems and leaves after harvesting,
- Agroindustry byproducts such as, olive pomace and vegetable water from the 16 000 traditional mills and 14 modern mills (40 000 tons of olive oil are extracted annually on average).

Figure 2.2: Biomass Sources [4]
By-products of sweets (13 candies),
Almonds shells, argan seeds,
Household waste,
Seaweed.

Morocco has even set up a legal framework to support its energy approach “Recueil des Lois relatives à la protection de l’environnement” [34]. It figures among the referred types:

- **Law No. 13-03 on the fight against air pollution**

This law, promulgated by Dahir No. 1-03-61 10 Rabii I in 1424 (12 May 2003), is designed to prevent, reduce and limit emissions of air pollutants that can affect the health of humans and in particular to the general environment. It defines the means to fight against air pollution, sanctions procedures for damage or serious pollution and incentive measures for investment in projects for the prevention of air pollution.

**Under section 4 of the Act:**

It is forbidden to release, to issue or deny, allow the release, emission or discharge into the air of pollutants such as toxic or corrosive gases, fumes, vapors, heat, dust, odors beyond the amount or authorized by the standards set by regulation concentration (Decree No. 2009-286 of December 8, 2009 setting standards for air quality and the procedures for air monitoring and Decree No. 2-09-631 of July 6, 2010 laying down emission limit values pollutants into the air from stationary pollution sources and methods of controlling these emissions.

**2.3 Proposed Biomass Boiler**

Al Akhawayn University has launched several years ago a process to improve its environmental impact. To do so, the university decided to replace its old fuel boilers by a biomass boiler that will produce energy to heat the university swimming pool water. This new energy provider is the Italian company "Pasqualicchio", which operates biomass boilers since few
years. In order to do so, the company will provide 437,500 kg of olive pits annually. In this way Pasqualicchio proposes a solution to Al Akhawayn University to replace the fossil fuel used today.

The chosen biomass boiler is the CSB Marina 500 that will produce 580 kW of power.

*Operating layout taken from the Pasqualicchio Catalog:* As it is described in the catalog, “the fuel stored in the hopper is made to advance intermittently into the combustion chamber thanks to a system made up from two worm screws that turn with different speeds and which are separated by a safety valve (Safety Lock System). The flame develops inside the combustion chamber with the aid of combustion agent air blown by a fan. The flame together with the combustion fumes produce the heat supplied to the water present inside the boiler body. The energy is transferred to the heat-carrying fluid in two ways: by irradiation due to the flame and convection, i.e. thanks to the energy level of the fumes just developed by combustion. It is the fumes, which before being expelled from the flue, that are obliged to follow a certain pathway in the body of the boiler, known as the “smoke 3-pass”, during which they transfer heat to the water it contains. This operation allows an excellent heat exchange with the heat carrier fluid, which translates into an increase in efficiency and a decrease in fuel consumption. The management of the entire machine is controlled by an electronic heat regulator, which makes operation completely automatic” [23].
Figure 2.3.2: CSB Marina 500 Operating Layout [23]
Technical Specification:

Table 2.3: Technical Specifications of the biomass boiler [23]

<table>
<thead>
<tr>
<th>Model</th>
<th>CSB Marina 500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chimney [kW]</td>
<td>660.04</td>
</tr>
<tr>
<td>Nominal Power [kW]</td>
<td>580.00</td>
</tr>
<tr>
<td>Chimney [kcal/h]</td>
<td>569000</td>
</tr>
<tr>
<td>Nominal Power [kcal/h]</td>
<td>500000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>CSB Marina 500</th>
</tr>
</thead>
<tbody>
<tr>
<td>A [mm]</td>
<td>2680</td>
</tr>
<tr>
<td>B [mm]</td>
<td>2140</td>
</tr>
<tr>
<td>C [mm]</td>
<td>4170</td>
</tr>
<tr>
<td>D [mm]</td>
<td>1100</td>
</tr>
<tr>
<td>E [mm]</td>
<td>1770</td>
</tr>
<tr>
<td>F [mm]</td>
<td>420</td>
</tr>
<tr>
<td>G [mm]</td>
<td>1890</td>
</tr>
<tr>
<td>H [mm]</td>
<td>1870</td>
</tr>
<tr>
<td>I [mm]</td>
<td>960</td>
</tr>
<tr>
<td>L [mm]</td>
<td>620</td>
</tr>
<tr>
<td>M [mm]</td>
<td>2170</td>
</tr>
<tr>
<td>N* [mm]</td>
<td>3330</td>
</tr>
<tr>
<td>O [mm]</td>
<td>980</td>
</tr>
<tr>
<td>P [mm]</td>
<td>1370</td>
</tr>
</tbody>
</table>

Figure 2.3.3: CSB Marina 500 Dimensions [23]

Dimension combustion chamber (Lu*La*Al) [mm]: 2100 900 605
Chimney [mm]: 350
Weight [kg]: 3300
### Fuel

<table>
<thead>
<tr>
<th>Type</th>
<th>Pellets, Wood chips, Wood, Maize, Olive pit, Olive pomace, Sawdust</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tank Capacity [Lit/kg-Pellet]</td>
<td>740 / 480</td>
</tr>
</tbody>
</table>

### Hydraulics

<table>
<thead>
<tr>
<th>Water connection system [Inches]</th>
<th>DN 80</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal pressure [bar]</td>
<td>3</td>
</tr>
<tr>
<td>Water capacity [Lit]</td>
<td>1315</td>
</tr>
</tbody>
</table>

*Notes: (*) the values have been calculated taking a fuel with calorific value below 5 [kW * h/kg] as a reference.*

### 3. Olive Pits

Biomass can be converted to heat energy by using biochemical and thermo chemical conversions methods. The most applied process used for biomass fuels is the combustion that is known for its reliability and cheap cost.

During this process, the biomass starts by losing its moisture at 100°C or more using heat released from other particles. Once the dried particle heats up, volatile gases are released as CO, CH₄, in addition to other gaseous components, which represent 70% of the heating value. At the end, ash remains while char oxidizes.

#### 3.1 Olive pits characteristics

Olive biomass is an agricultural biomass fuel extracted from the olive oil industry. The remaining residues after the virgin olive oil extraction process are olive pomace. This olive pomace usually contains olive pits, olive skin, and some pomace oil in addition to wastewaters. Then, the olive pits are separated from the vegetable parts (olive skin and pomace oil) and waste waters to keep only the solid form that can be burned directly.
Direct burning is the most common way to obtain energy from the dry olive pits. Once it burns, the olive biomass energy stored is transformed to release heat. During its combustion, olive biomass releases a considerable amount of energy due to its high calorific value. The advantage of olive biomass is that it can be used in direct combustion, and replace fossil fuel supplied to boilers.

3.2 Olive pits properties

- **Basis of analysis:**

The basis of analysis consists on the proximate analysis of olive pits, in other words, the percentage content of each of ash (A), moisture, calorific value (CV) and Sulphur (S).

There are three types of weight units:

- As received (ar): original olive pits weight percentage (wt%) including ash and total moisture;
- Dry: wt% from the dry material including ash;
- Dry and ash free (daf): wt% excluding all moisture and ash.

- **Ash:**

The amount of ash depends on the ash formation temperature:

\[
DryAshContent(\text{wt\%}) = \frac{arashcontent(\text{wt\% ar}) \times 100}{100 - watercontent (\text{wt\%})}
\]

- **Water content on wet base (ar):**

There is a difference between the water content of the material, as it is available and at the moment of the analysis.

- **Volatiles and fixed carbon (wt\%):**

<table>
<thead>
<tr>
<th></th>
<th>( C(fixed) = 100 - ash(ar) - watercontent - volatiles (ar) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>ar</td>
<td>( C(fixed) = 100 - ash(dry) - volatiles(dry) )</td>
</tr>
<tr>
<td>daf</td>
<td>( C(fixed) = 100 - volatules(daf) )</td>
</tr>
</tbody>
</table>

- **Olive pits composition:**

- Carbon (C),
- Hydrogen (H),
✓ Oxygen (O),
✓ Nitrogen (N),
✓ Sulphur (S),
✓ Chlorine (Cl),
✓ Fluorine (F),
✓ And bromine (Br).

⇒ \( ar = C + H + O + N + S + Cl + F + Br + ash + watercontent = 100 \)
⇒ \( dry = C + H + O + N + S + Cl + F + Br + ash = 100 \)
⇒ \( daf = C + H + O + N + S + Cl + F + Br = 100 \)

Table 3.1.1: Calorific Value (MJ/kg) [25]

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ar</td>
<td>dry</td>
</tr>
<tr>
<td><strong>Fuel Properties</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proximate Analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moisture content</td>
<td>wt%</td>
<td>6.08</td>
</tr>
<tr>
<td>Ash content</td>
<td>wt%</td>
<td>1.62</td>
</tr>
<tr>
<td>Volatile matter</td>
<td>wt%</td>
<td>77.01</td>
</tr>
<tr>
<td>Fixed carbon</td>
<td>wt%</td>
<td>15.29</td>
</tr>
<tr>
<td><strong>Ultimate Analysis</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon</td>
<td>wt%</td>
<td>49.59</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>wt%</td>
<td>6.28</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>wt%</td>
<td>0.42</td>
</tr>
<tr>
<td>Sulphur</td>
<td>wt%</td>
<td>0.05</td>
</tr>
<tr>
<td>Oxygen</td>
<td>wt%</td>
<td>35.92</td>
</tr>
<tr>
<td>Total (with halides)</td>
<td>wt%</td>
<td>100</td>
</tr>
<tr>
<td><strong>Calorific Values</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net calorific value (LHV)</td>
<td>MJ/kg</td>
<td>18.78</td>
</tr>
<tr>
<td>Gross calorific value (HHV)</td>
<td>MJ/kg</td>
<td>20.3</td>
</tr>
<tr>
<td>HHV Milne</td>
<td>MJ/kg</td>
<td>20.83</td>
</tr>
<tr>
<td><strong>Ash Properties</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ash composition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SO3</td>
<td>wt% (ash)</td>
<td>0.56</td>
</tr>
<tr>
<td>P2O5</td>
<td>wt% (ash)</td>
<td>2.46</td>
</tr>
<tr>
<td>SiO2</td>
<td>wt% (ash)</td>
<td>30.82</td>
</tr>
<tr>
<td>Fe2O3</td>
<td>wt% (ash)</td>
<td>6.58</td>
</tr>
<tr>
<td>Al2O3</td>
<td>wt% (ash)</td>
<td>8.84</td>
</tr>
<tr>
<td>CaO</td>
<td>wt% (ash)</td>
<td>14.56</td>
</tr>
</tbody>
</table>
The calorific value (CV) is expressed as Higher Heating Value (HHV), which is the calorific value under laboratory conditions, and Lower Heating Value (LHV), which is the calorific value in boiler plant. The difference is caused by the produced vapor of water heat.

The higher heating value of combustion of biomass can be calculated by using the following formula:

\[ HHV_d = \frac{HHV}{1-M} \quad HHV = HHV_d \times (1 - M) \]

Where M represents the moisture, and HHVd is the gross heating value of dry biomass that can be calculated using the Milne formula:

\[
HHV_d (MJ/Kg) = 0.341 \cdot C \text{ (wt\% dry)} + 1.322 \cdot H \text{ (wt\% dry)} - 0.12 \\
\quad \quad \quad \cdot O \text{ (wt\% dry)} - 0.12 \cdot N \text{ (wt\% dry)} + 0.0686 \cdot S(\text{wt\% dry}) \\
\quad \quad \quad - 0.0153 \cdot \text{ash(\text{wt\% dry})}
\]

\[
HHVd (MJ/Kg) = 0.341 \cdot 52.8 \text{ (wt\% dry)} + 1.322 \cdot 6.69 \text{ (wt\% dry)} - 0.12 \\
\quad \quad \quad \cdot 38.25 \text{ (wt\% dry)} - 0.12 \cdot 0.45(\text{wt\% dry)} + 0.0686 \\
\quad \quad \quad \cdot 0.005(\text{wt\% dry)} - 0.0153 \cdot 1.62(\text{wt\% dry})
\]

\[ HHV_d = 22.18\text{MJ/Kg} \]

Then, knowing that the wet moisture of olive pits is 50%:

\[ HHV = HHVd \times (1 - M) = 22.18 \frac{MJ}{kg} \times (1 - 0.5) \]

\[ HHV = 11.09 \text{MJ/Kg} \]
Concerning the lower heating value, its calculation formula is as below:

\[ LHV(MJ/Kg) = HHV \times (1 - M) - 2.447 \times MH2O \]

Where the constant 2.447 represents the water latent heat vaporization at the temperature 25°, unit (MJ/Kg).

\[ LHV(MJ/Kg) = 11.09 \times (1 - 0.5) - 2.447 \times 0.1 \]
\[ LHV(MJ/Kg) = 5.30 \text{ MJ/Kg} \]

In order to proceed to the annual energy consumption calculation of the swimming pool water heating, we need to refer to the following table to have more details:

<table>
<thead>
<tr>
<th>Energy Used</th>
<th>Power (kW)</th>
<th>Heating Power value (kwh/L)</th>
<th>Average Cost (MAD/L)</th>
<th>Annual Quantity (L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel</td>
<td>395.35</td>
<td>9.2</td>
<td>6</td>
<td>175000</td>
</tr>
</tbody>
</table>

Using the information from the table, the annual energy consumption of the swimming pool water heating can be calculated using the following formula:

\[ AnnualDieselEnergyConsumption_{Swimmingpool}(MJ) = Diesel \text{ Heating Value} (\text{kWh/L}) \times \text{Annual Diesel Quantity} (L) \]

\[ AnnualDieselEnergyConsumption_{Swimmingpool}(MJ) = 9.2 \left(\frac{kWh}{L}\right) \times 175000(L) \]

\[ AnnualDieselEnergyConsumption_{Swimmingpool}(MJ) = 1610000 \text{ kWh} \times 3.6 \]
\[ \text{(Conversion Process)} \]

\[ AnnualDieselEnergyConsumption_{Swimmingpool} = 5796000MJ \]
For this project, an amount of 437500 Kg is required as biomass fuel, which means that the total energy that will be produced by olive pits using the heating value calculated previously:

\[
\text{AnnualBiomassEstimationEnergyProduction}_{\text{Swimmingpool}} (MJ) = LHV \left( \frac{MJ}{Kg} \right) \times \text{RequiredBiomassQuantity} (Kg)
\]

\[
\text{AnnualBiomassEstimationEnergyProduction}_{\text{Swimmingpool}} (MJ) = 5.30 \left( \frac{MJ}{Kg} \right) \times 437500 (Kg)
\]

\[
\text{AnnualBiomassEstimationEnergyProduction}_{\text{Swimmingpool}} = 2318750MJ
\]

### 3.3 CO₂ Emissions

Fossil fuels are intensive greenhouse gas emission intensive that release a high amount of carbon dioxide when combusted. Climate change is one of the biggest concerns nowadays, for this reason the CO₂ emissions emitted once the fossil fuel is combusted should be calculated [12].

CO₂ emissions from fossil fuel combustion is calculated using the following formula:

\[
\text{CO}_2 \text{emissions}_{FossilFuel} = \text{Quantityoffuelcombusted} \times \text{COEF}
\]

The calculation method of CO₂ emission coefficient (COEF) may differ depending on the availability of fossil fuel data:

1. The first method can be based on the fossil fuel chemical composition:

   o The quantity of fuel combusted expressed in mass unit:
\[ \text{COEF(unitmass)} = \frac{\text{Weightedaverage mass fraction of carbon in type of fuel} (tC/mass unit of the fuel)}{} \times 44 \div 12 \]

- The quantity of fuel combusted expressed in a volume unit:

\[ \text{COEF(volumeunit)} = \frac{\text{Weightedaverage mass fraction of carbon in type of fuel} (tC/mass unit of the fuel)}{} \times \frac{\text{Weighted density of type of fuel (Mass unit/volume unit of fuel)}}{} \times 44 \div 12 \]

2. The second method can be based on net calorific value and CO₂ emission factor of the type of fuel:

\[ \text{COEF} = \frac{\text{Weighted average net calorific value (NVC) of the fuel in} \left( \frac{\text{GJ}}{\text{mass or volume unit}} \right)}{\text{Weighted average CO₂ emission factor of the type of fuel}} \times \frac{\text{mass unit of the fuel}}{\text{volume unit of the fuel}} \]

By using the first method calculation:

\[ \text{CO₂ emissions}_{\text{FossilFuel}}(\text{Kg}) = \text{Quantity of fuel combusted} \times \frac{\text{Weighted average mass fraction of carbon in type of fuel} (tC/mass unit of the fuel)}{} \times 44 \div 12 \]

Knowing that the used oxidation factor for oil and oil products is about 0.99, meaning that 99% of the carbon present in the fuel is oxidized while only the rest, 1%, remains unoxidized. Al Akhawayn University consumes 175000 L/year of diesel, which is the equivalent of 1100.74 petroleum barrels:

*Conversion process: 1 Petroleum Barrel = 158.984 liters*
⇒ Number of Petroleum Barrel consumed annually = \frac{175000L \times 1}{158.984L}

Number of Petroleum Barrel consumed annually = 1100.74 Petroleum Barrels

Using the biomass as a source for the swimming pool water heating, it will cause the use of 60% of the actual number of petroleum barrels:

Number of Petroleum Barrel consumed annually = 0.6 \times 1100.74 Petroleum Barrels

Number of Petroleum Barrel consumed annually = 660.4 Petroleum Barrels

The CO₂ emission coefficient of diesel known as volatile distillate oil can be calculated using the table 3.3 below:

Table 3.3: Heat Contents & Carbon Content Coefficients of Various Fuel Types [37]
The Carbon emission coefficient is calculated as follow:

\[
\text{COEF} \left( \frac{\text{KgC}}{\text{PetroleumBarrel}} \right) = \text{HeatContent} \left( \frac{\text{MillionBtu}}{\text{MetricTon}} \right) \times \text{Carbon (C) Content coefficients} \\
\text{COEF} \left( \frac{\text{KgC}}{\text{PetroleumBarrel}} \right) = 5.83 \left( \frac{\text{MillionBtu}}{\text{MetricTon}} \right) \times 19.95 \left( \frac{\text{KgC}}{\text{MillionBtu}} \right)
\]

\[
\text{COEF} \left( \frac{\text{KgC}}{\text{PetroleumBarrel}} \right) = 116.31 \left( \frac{\text{KgC}}{\text{MetricTon}} \right) \times 1 \text{MetricTon} \times \frac{1}{7.88 \text{barrels}}
\]

(Conversion process: 1 Metric Ton of crude oil = 7.88 barrels)

\[
\text{COEF} = 14.76 \left( \frac{\text{KgC}}{\text{PetroleumBarrel}} \right)
\]

After finding the value of COEF, the calculation of the CO\(_2\) emission can be made for the current situation –use of diesel- and the new alternative –biomass & diesel as a back up plan.-

➢ **Diesel:**

\[
\text{CO}_2\text{emissions}_{(\text{Diesel})} = \text{Quantity of fuel combusted} \times \text{Weighted average mass fraction of carbon intype of fuel (tC/mass unit of the fuel)} \times \text{Weighted density of type of fuel (Mass unit/volume unit of the fuel)} \\
= \frac{44}{12}
\]

\[
\text{CO}_2\text{emissions}_{(\text{Diesel})} = 1100.74 \text{PetroleumBarrel} \times 14.76 \left( \frac{\text{KgC}}{\text{PetroleumBarrel}} \right) \times 0.99 \times \frac{44}{12}
\]

\[
\text{CO}_2\text{emissions}_{(\text{Diesel})} = \textbf{58976.33 KgC}
\]

⇒ The use of diesel boilers result to a CO\(_2\) emission amount of 58976.33 Kg in the atmosphere.
Biomass & Diesel:

\[
\text{CO}_2\text{emissions}_{(\text{Biomass + Diesel})} = \text{Quantity of fuel combusted} \times \text{Weighted average mass fraction of carbon in type of fuel (tC/mass unit of fuel)} \times \text{Weighted density of type of fuel (Mass unit/volume unit of fuel)} \times \frac{44}{12}
\]

\[
\text{CO}_2\text{emissions}_{(\text{Biomass + Diesel})} = 660.4 \text{Petroleum Barrels} \times 14.76 \left( \frac{\text{KgC}}{\text{Petroleum Barrel}} \right) \times 0.99 \times \frac{44}{12}
\]

\[
\text{CO}_2\text{emissions}_{(\text{Biomass + Diesel})} = 35383.44 \text{KgC}
\]

⇒ The use of the biomass boiler results to a CO\textsubscript{2} emission amount of only 35383.44 Kg in the atmosphere.

Carbon dioxide emission savings:

\[
\text{CO}_2\text{Emission Savings} = \text{CO}_2\text{emissions}_{(\text{Diesel})} - \text{CO}_2\text{emissions}_{(\text{Biomass + Diesel})}
\]

\[
\text{CO}_2\text{Emission Savings} = 58976.33 \text{Kg} - 35383.44 \text{Kg}
\]

\[
\text{CO}_2\text{Emission Savings} = 23593 \text{Kg}
\]

⇒ Replacing the current diesel boilers by the new biomass boiler that will use diesel, as a back up plan in case the temperature of the water is not the desired one, will result to a carbon dioxide savings of 23593 Kg. This saving represents less harm to the atmosphere and will contribute to the protection of the environment.

3.4 Economic Benefits

The use of the new biomass boiler will certainly decrease the energy bill. As a part of our project, the biomass boiler chosen “CSB Marina 500” has a power of 580 kW and costs 9586 €, which is approximately 104842.78 MAD (1€=10.94 MAD). This machine works independently; it just needs to be configured, so no workers needed. The company “Pasqualicchio” will do the olive pits transportation without
charging any fees. The biomass mass boiler requires a yearly maintenance that will cost around 2200 MAD/year; this maintenance includes cleaning the flue and boiler. The biomass boiler has a lifetime of 20 years and a salvage value of 30% at the end of its lifetime.

### Diesel consumption to heat the swimming pool water (2013-2014)

<table>
<thead>
<tr>
<th>Period</th>
<th>Quantity (Liter)</th>
<th>Cost (not including VAT)</th>
<th>Total Cost TTC</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013-2014</td>
<td>175000</td>
<td>941702</td>
<td>1,035,873.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Energy Subtitled</th>
<th>Annual consumption of diesel per Liter</th>
<th>Annual consumption of diesel per Kw</th>
<th>Required biomass fuel per Kg</th>
<th>Annual cost of biomass fuel (MAD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel</td>
<td>175000</td>
<td>10 KW/LITRE</td>
<td>4 KW/KG</td>
<td>Rate: 1 MAD/Kg</td>
</tr>
<tr>
<td>Biomass</td>
<td>175000</td>
<td></td>
<td>437500</td>
<td>437,500.00</td>
</tr>
</tbody>
</table>

| Total diesel annual energetic cost (MAD) | 941,702.00 |
| Total biomass annual energetic cost (MAD) | 437,500.00 |
| Annual savings (MAD) | **504,202.00** |
| Annual saving (%) | 53.54% |
| Overall cost of operation | **400,000.00** |
| Return on investment (Year) | 1 |
4. Swimming Pool Cover Installation

Indoor swimming pools loose most of its energy due to the evaporation.
Indoor pools require room ventilation in order to control the indoor humidity caused by the evaporation. The ventilated air emitted needs to be conditioned, so it is explicitly added to the energy costs.

Swimming pool cover minimizes the evaporation amount, which automatically means reducing the heated water costs by saving around 50%–70%.

4.1 Types of pool covers

Swimming pool covers exist in three different types that are mainly made of different materials like UV stabilized polyethylene, vinyl, or polypropylene. Those covers are opaque or transparent, light or dark colored.

The first type and lowest pool cover cost is the bubble cover, which is similar to bubble packing material but with a
thicker grade of plastic that contains UV inhibitors. The second type of cover is the vinyl cover which is a heavier material but has a longer life expectancy. The last type is the insulated vinyl cover which is a thin layer of flexible insulation sandwiched between two layers of vinyl.

For an indoor heated swimming pool, the use of a thermal cover on the surface of the water during off hours helps to save energy by preventing the evaporation of water if the pool dehumidifying device or any other system did not operate properly during that time. In addition to that, the evaporative heat loss costs decrease because they are avoided since the water will not evaporate anymore.

Besides the energy savings, the use of a pool cover has many other benefits:

✓ Reduction of the amount of make-up water needed by 30-50%,
✓ Reduction of chemical consumption by 35-60%,
✓ Cut cleaning time since the cover keeps dirt and debris out of the swimming pool.

All covers are adapted to prevent evaporation. Indoor pools do not have very important convection losses because the air is warmer than the water and radiation losses are very limited.

4.2 Method of use

The manufacturers propose different way to cover swimming pools. The simplest known method is the manual one that consists on pulling the cover on and off, folding it and placing it somewhere out of the way or buy a pool cover reel where the cover can be manually rolled up.

Semi-automatic cover works electrically using a motor driven reel that roll and unrolls the cover; however, it needs someone to guide both processes.

Contrary to the semi-automatic cover, the automatic one does not require someone to guide the cover and uncover process; it has a push of a button that does the work. But it is the most expensive cover.
In order to choose which one is the best option for the project, the cost should be compared taking into consideration the cost of labor for the manual and semi-automatic covers.

The cover installation can be built into different ways as described below:

- Integral mounting in the pool [2,38]:

- Flush mounting in the wall of the pool [2,38]:

- Outdoor mounting [2,38]:
4.3 Technical Assessment

Al Akhawayn University heated indoors swimming pool is not equipped with a thermal cover. We therefore propose to install one. In order to have a functional thermal cover, its dimensions should be well studied. Sometimes, it is better to divide the cover into several parts to manipulate it easily since it has to be rolled and unrolled several times a day. Therefore the design of the facility should be taken into consideration. Since Al Akhawayn University swimming pool is an Olympic one, neither the outdoor mounting and integral mounting are adequate because the landscape should be preserved, so the priority is given to the flush mounting in the walls of the swimming pool.

Using one of the manufacturers’ website [38], a cost estimation of the semi-automatic cover could be made.
Figure 4.3.1: Swimming pool cover criteria [38]
<table>
<thead>
<tr>
<th>FORME BASSIN POUR VOLET</th>
<th>Rectangle</th>
</tr>
</thead>
<tbody>
<tr>
<td>TYPE DE CONSTRUCTION</td>
<td>Piscine en béton ou coffrage perdu</td>
</tr>
<tr>
<td>VOLET COMPLET</td>
<td>Volet avec mécanique et lames</td>
</tr>
<tr>
<td>TYPE DE VOLET IMMERGE</td>
<td>Volet immergé discret moteur dans l’axe</td>
</tr>
<tr>
<td>LARGEUR PISCINE POUR VOLET</td>
<td>X</td>
</tr>
<tr>
<td>LONGUEUR DU BASSIN (EN METRES)</td>
<td>50</td>
</tr>
<tr>
<td>LARGEUR DU BASSIN (EN METRES)</td>
<td>21</td>
</tr>
<tr>
<td>LARGEUR PISCINE POUR VOLET EN L</td>
<td>X</td>
</tr>
<tr>
<td>LONGUEUR AU PLUS LARGE (EN METRE) UNIQUEMENT BASSIN EN L</td>
<td>X</td>
</tr>
<tr>
<td>TYPE EскаLIER</td>
<td>Sans escalier</td>
</tr>
<tr>
<td>LARGEUR DE L’ESCAlier</td>
<td>Sans escalier</td>
</tr>
<tr>
<td>COULEUR DES LAMES DU TABLIER</td>
<td>Blanc</td>
</tr>
<tr>
<td>FINITION DES LAMES (DANS LES ARRONDIS)</td>
<td>Finition angle vif 90°</td>
</tr>
<tr>
<td>TYPE D’ANGLE DU BASSIN</td>
<td>Angles vifs ou 90°</td>
</tr>
<tr>
<td>NOMBRE D’ANGLES</td>
<td>4</td>
</tr>
<tr>
<td>POUTRE</td>
<td>Avec poutre blanche</td>
</tr>
<tr>
<td>SUPPORT DE POUTRE</td>
<td>Avec support sur paroi</td>
</tr>
<tr>
<td>CAILLEBOTIS</td>
<td>Caillebotis Bois exotique 1000x930mm</td>
</tr>
<tr>
<td>CLOISON DE SÉPARATION</td>
<td>Avec mur séparateur en dur</td>
</tr>
<tr>
<td>HAUTEUR DE LA CLOISON DE SÉPARATION</td>
<td>Hauteur 180cm</td>
</tr>
<tr>
<td>SUPPORT DE CLOISON</td>
<td>Support équerre sur arase</td>
</tr>
<tr>
<td>TRANSPORT ET LIVRAISON VOLET</td>
<td>Enlèvement par vos soins</td>
</tr>
<tr>
<td>CHARIOT ÉLÉVATEUR</td>
<td>Sans chariot élévateur (Prévoir 4 personnes lors du déchargement)</td>
</tr>
</tbody>
</table>

⇒ Prix TTC : **1 260 000 MAD** (1200 MAD/m²)

Figure 4.3.2: Swimming pool cover cost estimation [38]
Since the swimming pool cover has huge dimensions, it will be divided into two so that it can be transported. In addition to that, they will be installed on the two opposite length sides (one up, other down).

➤ **Method 1:**

The water evaporation calculation from a swimming pool surface depends on: the temperature in the water and the temperature in the air, the actual humidity of the air and the velocity of the air above the surface [8].

![Figure 4.3.3: Water evaporation process [8]](image)

The amount of evaporated water is calculated using the following formula:

\[ g_s = \Theta A (x_s - x) / 3600 \]

or:

\[ gh = \Theta A (x_s - x) \]

where:

- \( g_s \): amount of evaporated water per second (kg/s)
- \( gh \): amount of evaporated water per hour (kg/h)
- \( \Theta \): evaporation coefficient = \((25 + 19 v)\) (kg/m\(^2\)h)\>>Empirical equation that cannot be derived from first principles.
- \( v \): velocity of air above the water surface (m/s)
- \( A \): water surface area (m\(^2\))
- \( x_s \): humidity ratio in saturated air at the same temperature as the water surface (kg/kg) (kg H\(_2\)O in kg Dry Air)
- \( x \): humidity ratio in the air (kg/kg) (kg H\(_2\)O in kg Dry Air)

Most of the heat required for the evaporation is taken from the water itself. To maintain the water temperature heat must be supplied.

The heat supplied can be calculated as:

\[ q = h_{wge} g_s \]
Where

- \( q \) = heat supplied (kJ/s, kW)
- \( h_{we} \) = evaporation heat of water (2270 kJ/kg)

Concerning Al Akhawayn University swimming pool with water temperature 27°C, the saturation humidity ratio is calculated by interpolating 27°C in the table 4.3:

**Table 4.3: Humidity Ratio**

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Saturation Pressure of Water Vapor (Pa)</th>
<th>Maximum Humidity Ratio (( kg_w/kg_a ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>609.9</td>
<td>0.003767</td>
</tr>
<tr>
<td>5</td>
<td>870</td>
<td>0.005387</td>
</tr>
<tr>
<td>10</td>
<td>1225</td>
<td>0.007612</td>
</tr>
<tr>
<td>15</td>
<td>1701</td>
<td>0.01062</td>
</tr>
<tr>
<td>20</td>
<td>2333</td>
<td>0.014659</td>
</tr>
<tr>
<td>25</td>
<td>3130</td>
<td>0.019826</td>
</tr>
<tr>
<td>30</td>
<td>4234</td>
<td>0.027125</td>
</tr>
</tbody>
</table>

By using interpolation, at 27°C:

\[
x_s = \frac{(27 - 25) \times (0.027125 - 0.019826)}{(30 - 25)} + 0.019826 = 0.0227456 kg/kg
\]
With an air temperature of 27°C and 65% relative humidity, the humidity ratio can be found using the Mollier diagram which indicates 0.013 kg/kg.

(The Mollier diagram represents the relationship between water vapor content of air and heat content that helps to measure the relative humidity ratio.)

Figure 4.3.5: Mollier Diagram [8]
For a 50 m * 21m swimming pool and 0.1m/s velocity of air above the surface, the evaporation can be calculated as follow:

\[
g_s = \frac{(25 + 19(0.1\text{m/s})) * ((50\text{m} * 21\text{m})) * \left(0.0227456\frac{kg}{kg} - 0.013\frac{kg}{kg}\right)}{3600}
\]

\[
g_s = 0.076\frac{kg}{s} g_h = 275\frac{kg}{h}
\]

The heat supply required to maintain the temperature is calculated as follow:

\[
q = \left(2270\frac{kJ}{kg}\right) * (0.076\frac{kg}{s})
\]

\[
q = 172.52\text{ kW}
\]

<table>
<thead>
<tr>
<th>Average water temperature of the swimming pool</th>
<th>27º C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saturation humidity ratio</td>
<td>0.0227456 kg/ kg air</td>
</tr>
<tr>
<td>Ambient average pool temperature</td>
<td>25º C</td>
</tr>
<tr>
<td>Humidity ratio in the air</td>
<td>0.013 kg/kg air</td>
</tr>
<tr>
<td>Relative humidity percentage</td>
<td>65%</td>
</tr>
<tr>
<td>Floor area of the swimming pool</td>
<td>1050 m²</td>
</tr>
<tr>
<td>Annual hours of inactivity</td>
<td>3910 h/year (11.5 h / day)</td>
</tr>
</tbody>
</table>

The cover proposed will save around 65% of heat water, which means that the heat loss will be:

\[
g_h = 275\frac{kg}{h} - \left(275\frac{kg}{h} * 0.65\right) = 96.25\frac{kg}{h}
\]

Then:

Hourly Losses: 96.25 kg/h * 680 Wh/kg * 0.86 kcal Wh = 56 287 kcal/h

Using the rule of three, the annual savings are:
\[
\frac{3910 \text{ hour}}{\text{year}} \times \frac{56287 \text{ kCal}}{1 \text{ hour}} = 220,082,170 \text{ kCal} \times \frac{0.001163 \text{ kWh}}{\text{year}}
\]
\[
= 255,955.56 \text{ kWh/year}
\]

Any evaporation of water requires adding the new amount of water and heating it, which means consumption of energy shall be equal to:

\[
g_h \frac{Kg \text{ H}_2\text{O}_{\text{evaporated}}}{h} \times \text{inactivity hours} \times \frac{h}{an} \times (T_{\text{final water}} - T_{\text{initial water}})^\circ \text{C} \times \frac{1 \text{ kWh}}{860 \text{ kCal}}
\]

\[
= \frac{96.25 \frac{Kg \text{ H}_2\text{O}_{\text{evaporated}}}{h}}{h} \times \frac{3910}{an} \times (27 - 10)^\circ \text{C} \times \frac{1 \text{ kWh}}{860 \text{ kCal}}
\]
\[
= 7439.23 \text{ kWh/year}
\]

The total savings obtained due to the compensation of the loss of water in the basin will be:

\[
255955.56 + 7439.23 = 263394.79 \text{ kWh/year}
\]

Improved boiler efficiency:

\[
\eta = 88\% + \left(\frac{7439.23 \times 100}{255955.56}\right) = 90.91\%
\]

Thermal energy saving:

\[
\frac{263394.79 \text{ kWh}}{\text{year}} \times 1.11 = 292368.22 \text{ kWh PCl/year} = 28834.41 \frac{L}{\text{year}}
\]
(1.1: constant diesel factor for conversion to PCI)

On the other hand, the dehumidification heat pump will operate less frequently because it must operate during the off hours to remove the evaporated water contained in the ambient air of the pool; the estimated annual savings would be:

\[
\frac{96.25 \text{ Kg H2O}_{\text{evaporated}}}{h} \times 3910 \frac{h}{\text{year}} \times 1 \frac{kWh}{1.95 \text{ H2O}_{\text{condensed}} Kg} = 192993.59 \frac{kWh}{\text{year}}
\]

Therefore, the total savings obtained are the following:

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Savings (kWh/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler</td>
<td>292368.22 (kWh PCI)/year</td>
</tr>
<tr>
<td>Dehumidification pump</td>
<td>192993.59 kWh/year</td>
</tr>
<tr>
<td>Total savings</td>
<td>485361.81 kWh/year</td>
</tr>
</tbody>
</table>

4.4 Annual Savings

<table>
<thead>
<tr>
<th>Energy</th>
<th>Energy Saving</th>
<th>Average Cost</th>
<th>Annual Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>192993.59 kWh/year</td>
<td>1.37 MAD</td>
<td>264493.54 MAD/year</td>
</tr>
<tr>
<td>Diesel</td>
<td>292368.22 kWh PCI/year</td>
<td>6 MAD/L</td>
<td>173006.46 MAD/year</td>
</tr>
</tbody>
</table>

Total Annual Savings 437500 MAD/year
$\Rightarrow$ Estimated investment:

As mentioned before, the estimated investment for a semi-automatic thermal cover, 50 x 21 m, is 1 260 000 MAD, which has a depreciable lifetime of 5 years.

$$(1 \ 260 \ 000 \ MAD) / (252 \ 000 \ MAD/ \text{year}) = 5 \text{ years}$$

$\Rightarrow$ Method 2 (Verification):

According to Boelter and al.[2], unoccupied indoor swimming pool evaporation can be calculated using the following formula:

For $\Delta x < 0.008$, $E = 5.71 \Delta x$

$0.008 < \Delta x < 0.016$, $E = 4.88(-0.024 + 4.05795 \Delta x)$

$\Delta x > 0.016$, $E = 38.2 (\Delta x)^{1.25}$

Using the previous $\Delta x$ calculation,

$$\Delta x = \left(\frac{0.0227456 \text{ kg}}{\text{kg}}\right) - \left(\frac{0.013 \text{ kg}}{\text{kg}}\right) = 0.0097$$

$$E = 4.88(-0.024 + 4.05795 \times 0.0097)$$

$$E = 0.0749 \text{ kg/s}$$

By comparing both method 1 and 2, it is shown that the evaporation rate is around 0.075 kg/s

5. Oak vs. Olive pits as a biomass source

Al Akhawayn University has a large oak forest of 45 hectares surface area where woody plants and organic materials are found. The possible biomass production from an oak forest depends on the following factors:

$\Rightarrow$ The height,

$\Rightarrow$ The diameter,

$\Rightarrow$ The density (units/area) of the trees.
From the previous parts, it is known that the new biomass boiler needs 437 500 Kg annually to heat the swimming pool water.

Each one-kilogram of olive pits produces 4 kW of energy, while each one-kilogram of oak produces 2.635 kW of energy. Using the rule of three:

\[
\begin{align*}
4 \text{ kW} & \Rightarrow 437 \text{ 500 Kg of olive pits annually} \\
2.635 \text{ kW} & \Rightarrow ? = \textbf{287 873.75 Kg of oak annually}
\end{align*}
\]

From the previous calculation, it is shown that 287 873.75Kg of oak is needed annually to heat the swimming pool water.

\section*{5.1 Oak components}

The primary net productivity of aboveground biomass produced in an oak forest is 435g/m²/year [23], from this data, the annual biomass possible production from Al Akhawayn University oak forest can be calculated as follow:

\[
\text{Annual Oak Biomass Production} \text{ At } \text{Al Akhawayn University} (Kg) = \text{Area} \times \text{Biomass Net productivity}
\]

\[
\begin{align*}
\text{Annual Oak Biomass Production} \text{ At } \text{Al Akhawayn University} (Kg) & = 45 \text{ Hectare} \times (0.435 \frac{kg}{m^2} \times \frac{1 \text{ m}^2}{0.0001 \text{ Hectare}}) \\
\end{align*}
\]

\text{Annual Oak Biomass Production} \text{ At } \text{Al Akhawayn University} = \textbf{195750 Kg} (Which is lower than the needed amount 287 873.75 Kg)

After the calculation of the possible oak production from Al Akhawayn university forest, it is shown that there is not plenty of oak production to satisfy the biomass boiler needs. If the oak has to be used, a part of the diesel should be used also in order to heat the water at the desired temperature.
5.2 Oak Calorific Value

Table 5.2: The oak components characteristics

<table>
<thead>
<tr>
<th>Components</th>
<th>Oak (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>49.7</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>5.4</td>
</tr>
<tr>
<td>Oxygen</td>
<td>39.3</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0.1</td>
</tr>
<tr>
<td>Sulfur</td>
<td>0.1</td>
</tr>
<tr>
<td>Ash</td>
<td>0.51</td>
</tr>
<tr>
<td>Moisture</td>
<td>30</td>
</tr>
</tbody>
</table>

In order to have the energetic value produced by Al Akhawayn University oak forest, the corresponding heating value HHV and LHV [24] should be calculated:

\[
HHV_d = \frac{HHV}{1 - M} \quad HHV = HHV_d \cdot (1 - M)
\]

Where M represents the moisture, and HHVd is the gross heating value of dry biomass that can be calculated using the Milne formula:

\[
HHV (MJ / Kg) = 0.341 \cdot C (wt\% dry) + 1.322 \cdot H (wt\% dry) - 0.12 \\
\quad \cdot O (wt\% dry) - 0.12 \cdot N (wt\% dry) + 0.0686 \cdot S(wt\% dry) \\
\quad - 0.0153 \cdot ash(wt\% dry)
\]

\[
HHVd (MJ / Kg) = 0.341 \cdot 49.7 (wt\% dry) + 1.322 \cdot 5.4 (wt\% dry) - 0.12 \\
\quad \cdot 39.3 (wt\% dry) - 0.12 \cdot 0.1(wt\% dry) + 0.0686 \cdot 0.1(wt\% dry) \\
\quad - 0.0153 \cdot 0.51(wt\% dry)
\]

\[
HHVd = 19.36 \text{ MJ/Kg}
\]
Then, knowing that the wet moisture of oak is 30%:

\[
HHV = HHV_d \times (1 - M) = 19.36 \frac{MJ}{Kg} \times (1 - 0.3) \\
HHV = 13.55 \text{ MJ/Kg}
\]

Concerning the lower heating value, its calculation formula is as below:

\[
LHV (MJ/Kg) = HHV \times (1 - M) - 2.447 \times MH2O
\]

Where the constant 2.447 represents the water latent heat vaporization at the temperature 25°, unit (MJ/Kg).

\[
LHV(MJ/Kg) = 13.55 \times (1 - 0.3) - 2.447 \times 0.1 \\
LHV\left(\frac{MJ}{Kg}\right) = 9.24 \text{ MJ/Kg}
\]

For this project, an amount of 195750 Kg can be produced, which means that the total energy that will be produced by oak using the heating value calculated previously:

\[
\text{Annual Oak Biomass Estimation Energy Production}_{\text{Swimming pool}} (MJ) \\
= LHV \left(\frac{MJ}{Kg}\right) \times \text{Required Biomass Quantity}(Kg)
\]

\[
\text{Annual Oak Biomass Estimation Energy Production}_{\text{Swimming pool}} (MJ) \\
= 9.24 \left(\frac{MJ}{Kg}\right) \times 195750(Kg)
\]

\[
\text{Annual Biomass Estimation Energy Production}_{\text{Swimming pool}} \\
= 1808730 \text{ MJ}
\]

⇒ Using those results, it seems that Al Akhawayn University swimming pool consumes 5796000 MJ of energy per year (calculated earlier in the Biomass
section), while the annual estimated energy production of biomass is about 1808730 MJ, which is the equivalent of 31.21% of the diesel annual energy consumption. This percentage can be explained as the possibility of reducing the use of diesel by 31.21%, in other words, 31.21% of the annual diesel energy consumption can be produced from the biomass that is a green renewable energy. And the 68.79% is still going to be used as diesel.

5.3 CO2 Emission

Using the oak biomass as a source for the swimming pool water heating, it will cause the use of 68.79% of the actual number of petroleum barrels that has been calculated earlier in the biomass section:

\[
\text{Number of Petroleum Barrel consumed annually} = 0.6879 \times 1100.74 \text{ Petroleum Barrels}
\]

\[
\text{Number of Petroleum Barrel consumed annually} = 757.2 \text{ Petroleum Barrels}
\]

- **Oak Biomass & Diesel:**

\[
\text{CO}_2 \text{ emissions}_{(\text{Oak Biomass}+\text{Diesel})} = \text{Quantity of fuel combusted} \times \text{Weighted average mass fraction of carbon in type of fuel (tC/mass unit of the fuel)} \times \text{Weighted density of type of fuel (Mass unit/volume unit of the fuel)} \times \frac{44}{12}
\]

\[
\text{CO}_2 \text{ emissions}_{(\text{Oak Biomass}+\text{Diesel})} = 757.2 \text{ Petroleum Barrel} \times 14.76 \left(\frac{\text{Kg C}}{\text{Petroleum Barrel}}\right) \times 0.99 \times \frac{44}{12}
\]

\[
\text{CO}_2 \text{ emissions}_{(\text{Oak Biomass}+\text{Diesel})} = 22129.02 \text{ Kg C}
\]

⇒ The use of the biomass boiler results to a CO\textsubscript{2} emission amount of
only 2,518.45 Kg in the atmosphere.

\[
CO_2 \text{ Emission Savings} = CO_2 \text{ emissions}_{(\text{Diesel})} - CO_2 \text{ emissions}_{(\text{Oak Biomass+Diesel})}
\]

\[
CO_2 \text{ Emission Savings} = 58976.33 \text{ Kg} - 22129.02 \text{ Kg}
\]

\[
CO_2 \text{ Emission Savings} = 36847.33 \text{ Kg}
\]

Replacing the current diesel boilers by a biomass boiler that works with oak as a source and will use diesel, as a back up plan in care the temperature of the water is not the desired one, will result to a carbon dioxide savings of 36847.33 Kg. This saving represents less harm to the atmosphere and will contribute to the protection of the environment.

### 5.4 Biomass pellet making machine

Once the oak has been harvested, it needs to be converted to pellets. To do so, a biomass pellet-making machine should be purchased. This machine should convert about 200/300 Kg pellets[25]. The yield per hectare varies between 600 kg in a semi-fructification and 3200 kg at a full fructification.

![Biomass pellets making machine](image)

Figure 5.4.1: Biomass pellets making machine [40]
Figure 5.4.2: Biomass pellets making machine components [40]

Table 5.4.2: Biomass pellets making machine components [40]

<table>
<thead>
<tr>
<th>No.</th>
<th>Description of machine</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hammer mill</td>
</tr>
<tr>
<td>2</td>
<td>Cyclone</td>
</tr>
<tr>
<td>3</td>
<td>Screw conveyor</td>
</tr>
<tr>
<td>4</td>
<td>Pellet mill</td>
</tr>
<tr>
<td>5</td>
<td>Cyclone</td>
</tr>
<tr>
<td>6</td>
<td>Air lock</td>
</tr>
<tr>
<td>7</td>
<td>Cooler</td>
</tr>
<tr>
<td>8</td>
<td>Screener</td>
</tr>
<tr>
<td>9</td>
<td>Fan</td>
</tr>
<tr>
<td>10</td>
<td>Fan</td>
</tr>
<tr>
<td>11</td>
<td>Bag dust collector</td>
</tr>
</tbody>
</table>
6. Thermal Performance

A building thermal performance is the energy transfer process between the concerned building and its surroundings. It enables the effectiveness determination of a building design to improve designs in order to realize energy efficient buildings. Various heat exchange are possible in a building as it is illustrated below.

![Figure 6.1: Heat exchange processes between a building and its surroundings [35]](image)

Heat flows and heat transfer by conduction happen through walls, roof, ceiling, floor. Even the presence of a human occupant results to a heat add, in addition to the use of equipment and lights.

![Figure 6.2: Heat exchange due to human occupant[35]](image)
A building thermal performance depends on several factors such as:

- Design variables (Building shape, walls, windows, roof orientation…)
- Material properties (Density, conductivity, specific heat, transmissivity…)
- Weather (Ambient temperature, humidity, wind speed, solar radiation…)
- Building’s usage date (Equipment, lighting, air exchanges, internal gains due to occupants…)

![Diagram](image)

**Figure 6.3: Heat balance in buildings[35]**

The previous diagram (Figure 6.3) shows different factors that might affect the heat balance of a building. These factors influence on the building performance can be studied using different software.

For this project, a building geometry has been modeled through Sketch up and converted to Gbxml file to use it in Design Builder, in addition to that its thermal properties have been simulated using Energy Plus software. Since Ifrane is not available on the site-specific weather database of the software, Midelt has been chosen because it has the closest temperatures.
The heating design simulation was run to investigate the building’s behavior under extreme weather.

Calculation results are typically used to size heating systems and their components such as:

- **Ceilings**: Sum of heat gains to the zone from ceiling inner surfaces.
- **Walls**: Sum of heat gains to the zone from external wall inner surfaces.
- **Ground floors**: Sum of heat gains to the zone from ground floor inner surfaces.

Figure 6.4: Different Sketch Up screenshots showing different side of building 13 (Swimming Pool Building)
• **Doors and Vents:** Sum of heat gains to the zone from door and vent inner surfaces (Since the doors are mainly made of glass, they have been considered as windows).

• **External Infiltration:** heat gain through air infiltration (non-unintentional air entry through cracks and holes in building fabric).

• **Glazing:** the total heat flow to the zone from the glazing, frame and divider of exterior glazing excluding transmitted short-wave solar radiation.

Heating design calculations are carried out under Steady State conditions (stable temperatures over a several-hour period), which means that thermal mass effects are ignored. The calculations assume worst-case conditions including no solar gains, no internal gains (lighting, equipment, occupancy, etc) and design conditions for wind speed and direction. The resulting “design heat loss” (the sum of all heat flows out of a building) is further multiplied by a “sizing factor” to determine the “design heating load” (the capacity of heating equipment required to offset all heat losses).

From the resulting graph, we can notice that the external surfaces such as walls and ceilings, glazing and ground floors are always exposed to the atmosphere which explains the negative sign in the heat balance value because it applies heat from cold to hot. And those results clearly show the urgent need of isolation of such components to minimize the heat loss.
Figure 6.5: Heating design simulation from Design Builder
7. Thermal Study

7.1 Review purpose
Locate and analyze abnormal overheating on the water heating system installation of the swimming pool equipment and edges/windows/doors of the swimming pool room using a thermal imaging camera.

7.2 Control principle
The camera is sensitive to infrared radiation and receives the energy emitted by hot surfaces. It converts the stream of electromagnetic energy received into an electrical signal to reproduce a thermal image viewable called thermogram.
To locate the fault, a photograph of the area, which has been photographed, is attached to the report.
The calibration of the camera, and the auditor measurement capture conditions allow the camera to measure accurately the objects surfaces’ temperatures. The comparison of measured temperatures and the rated temperature of the material help to propose feasible recommendations.

7.3 Intervention conditions
Only viewable equipment (open, visible, sufficient perspective...) were examined by infrared thermography.

7.4 Used equipment

<table>
<thead>
<tr>
<th>Camera model</th>
<th>FLIR T200_Western</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camera serial</td>
<td>402004399</td>
</tr>
<tr>
<td>Lens</td>
<td>FOL 18mm</td>
</tr>
<tr>
<td>IR resolution</td>
<td>200×150</td>
</tr>
</tbody>
</table>

7.5 Examination Results
Among the examined equipment by infrared thermography, only those with abnormal heating are subject to a summary sheet containing the following information:
- Designation, nature and location of the equipment,
- Thermal image (thermogram) of the equipment subject to a hotspot,
- Real-image of this equipment,
- The measurement parameters,
- Measured temperatures,
- Analysis of the probable causes of this heating,
- Recommended actions,
- Prioritize actions to be undertaken.

7.6 Thermograms

7.6.1 Inside the swimming pool room

➢ Air ventilation

![Thermogram images](image.png)

<table>
<thead>
<tr>
<th>Measurements</th>
<th>°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sp1</td>
<td>28.9</td>
</tr>
<tr>
<td>Sp2</td>
<td>32.0</td>
</tr>
<tr>
<td>Li1 Max</td>
<td>32.2</td>
</tr>
<tr>
<td>Li1 Min</td>
<td>28.8</td>
</tr>
<tr>
<td>Average</td>
<td>30.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameters</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Emissivity</td>
<td>0.95</td>
</tr>
<tr>
<td>Refl. temp.</td>
<td>20 °C</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Text annotations</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor temperature</td>
<td>28.9 °C</td>
</tr>
<tr>
<td>Maximum</td>
<td>Maximum temperature coming/leaving from the ventilator</td>
</tr>
</tbody>
</table>
Ceiling edges

<table>
<thead>
<tr>
<th>Measurements</th>
<th>°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bx1</td>
<td>Max 26.1</td>
</tr>
<tr>
<td></td>
<td>Min 20.0</td>
</tr>
<tr>
<td></td>
<td>Average 23.4</td>
</tr>
<tr>
<td>Sp1</td>
<td>20.2</td>
</tr>
<tr>
<td>Sp2</td>
<td>26.1</td>
</tr>
</tbody>
</table>

Parameters

- Emissivity: 0.95
- Refl. temp.: 20 °C

Note

Most of the heat losses are found at the ceiling corners as it is the case in this picture. The ambient temperature varies between 27°C and 28°C, while in the corner the temperature is about 20°C. This temperature difference may cause a room temperature decrease.
**Recommendation:**

The use of an interior insulating crown molding on the ceiling junctions where there are heat loss problems. Interior crown modeling is a pre-fabricated foam insulator which is installed in the ceiling junction to decrease the heat loss by using the conductivity heat transfer from better insulated portions of the wall to transfer it.
to the ceiling junctions that have an insulated problem [27]. As a proposition, the crown molding chosen is of polystyrene type and will be fixed in the junction using polyurethane foam and sealed using latex acrylic caulking.

Figure 7.6.1.2: Insulating crown molding components[17]

- **Windows**
Measurements

<table>
<thead>
<tr>
<th></th>
<th>Max</th>
<th>28.1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min</td>
<td>22.0</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>23.1</td>
</tr>
</tbody>
</table>

Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emissivity</td>
<td>0.95</td>
</tr>
<tr>
<td>Refl. temp.</td>
<td>20 °C</td>
</tr>
</tbody>
</table>

Note

The windows in the swimming pool room are double glazed, which help to keep the cold temperatures on the outside from affecting the climate on the inside. However, we notice an important heat loss through the existing windows.
### Measurements

<table>
<thead>
<tr>
<th></th>
<th>Max</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Bx1</td>
<td>27.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min</td>
<td>22.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>25.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sp1</td>
<td>22.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Parameters

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Emissivity</td>
<td>0.95</td>
</tr>
<tr>
<td>Refl. temp.</td>
<td>20 °C</td>
</tr>
</tbody>
</table>

### Note

Another perspective of the heat loss caused by the windows.

---

![Image of measurements and diagrams]
**Recommendations:**

The swimming pool windows are already double-glazed, however; the outside temperature affects the inside temperature that causes a very important heat loss. In order to solve this problem, the possible solution will be a secondary glazing, which means, to add a second layer of either glass or plastic to the windows. This alternative is cost effective that saves around 10% of the energy. In addition, it is very discreet and slim.

**Figure 7.6.1.3:** Secondary glazing installation[28]

**Figure 7.6.1.4:** Outer frame details of the secondary glazing installation[6]
Doors

Recommendations:
In order to decrease the heat loss to the maximum, the three doors in the swimming pool should be replaced by “energy guard triple-pane high performance glass” doors, which offer a maximum energy savings. This new type of insulated door incorporates three double-strength glass layers that has a winter heat loss by 68%, and a summer heat gain of 69%, with a solar heat gain coefficient of 0.14 compared to standard clear insulated glass [32].
7.6.2 Swimming pool heating system

- Plate heat exchanger

**Recommendations:**

The plate heat exchanger can be insulated using a removable insulation jacket in order to reduce energy loss. Insulation jackets are made of Velcro and are very easy to put and remove.

![Removable insulation jacket](image)

**Figure 7.6.2.1: Removable insulation jacket [14]**
Polyvinyl chloride pipes

**Recommendations:**

PVC material is often used for plumbing pipe since it resists to corrosion. However, PVC pipes need to be insulated to avoid loosing degrees of water temperature. The alternative is the use of tubular sleeve insulation that is made of neoprene foam.

![Figure 7.6.2.2: Tubular sleeve insulation](image)
Swimming pool underground walls

Recommendations:
The walls of the swimming pool are made of reinforced concrete that is not insulated. This high heat loss is due to the fact that the pool water is 27°C, and also due to the connection to the hot water tank which is not insulated neither. The best solution is to isolate the swimming pool walls and the tank to reduce the heat acting on the walls. The pool walls can be insulated using EPE foam with aluminum foil and polystyrene.

![Figure 7.6.2.3: EPE foam [9]](image)
Boiler’s chimney

Recommendations:
One of the chimney boilers is not insulated and causes a huge heat loss as it is shown in the thermogram maximum temperature. A cladding insulation should be used in order to decrease it.

Figure 7.6.2.4: Cladding insulation [13]
7.7 Approximation of heat loss calculation

Table 7.7.1: Dimensions

<table>
<thead>
<tr>
<th>Dimensions (m)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>57.69</td>
</tr>
<tr>
<td>Width</td>
<td>28.65</td>
</tr>
<tr>
<td>Eave height (h’)</td>
<td>2.72</td>
</tr>
<tr>
<td>Ridge height (h)</td>
<td>9.43</td>
</tr>
</tbody>
</table>

Those dimensions were found using the application “Google Earth Pro” since those data are not available, so the dimensions are not very accurate.

- **Length:**

![Figure 7.7.2: Google Earth Pro screenshot showing the length of the swimming pool room [10]](image)
- **Width:**

  Figure 7.7.3: Google Earth Pro screenshot showing the width of the swimming pool room [10]

- **Ridge height:**

  Figure 7.7.4: Google Earth Pro screenshot showing the eave height of the swimming pool room [10]
Eave height:

Figure 7.7.5: Google Earth Pro screenshot showing the ridge height of the swimming pool room [10]

Table 7.7.2: U-value (heat loss measure)

<table>
<thead>
<tr>
<th>Material</th>
<th>U-value (W/m²°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walls (Brick)</td>
<td>2.6</td>
</tr>
<tr>
<td>Roof (Wood + Corrugated asbestos)</td>
<td>5.35</td>
</tr>
<tr>
<td>Floor (Tile)</td>
<td>2</td>
</tr>
<tr>
<td>Double glazed wood windows</td>
<td>2.5</td>
</tr>
<tr>
<td>Double glazed metal doors</td>
<td>3.2</td>
</tr>
</tbody>
</table>

Table 7.7.3: Design temperature

<table>
<thead>
<tr>
<th>Design temperature (°C)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum outside ambient temperature</td>
<td>-2</td>
</tr>
<tr>
<td>Required inside temperature</td>
<td>27</td>
</tr>
</tbody>
</table>
First, the temperature lift should be calculated:

\[ \text{Temperature lift} = \text{Inside ambient temperature} - \text{Minimum outside temperature} \]

\[ \text{Temperature lift} = 27 - (-2) = 29^\circ C \]

Then, the general formula to calculate the total heat loss of the swimming pool room is as the following:

\[ \text{Total surface heat loss} = \text{roof loss} + \text{walls loss} + \text{floor loss} + \text{windows loss} + \text{doors loss} \]

\[ \text{Roof Area (double pane)} = 2 \times 813 = 1626m^2 \]

\[ \text{Walls Area} = \text{Total walls area} - \text{windows area} - \text{doors area} \]
\[ = 739.9 - 290 - 165 = 284.9m^2 \]

\[ \text{Total walls area with windows and doors} = 2 \times (L \times h') + 2 \times \left[ (L \times h') + \left( \frac{L \times h'}{2} \right) \right] = 739.9 m^2 \]

\[ \text{Windows Area} = 290 m^2 \]
\[ \text{Doors Area} = 165 m^2 \]

\[ \text{Floor Area} = \text{Total floor area} - \text{Swimming pool area} \]
\[ = (L \times l) - \text{Swimming pool Area} = 1652.8m^2 - 1050 m^2 \]
\[ = 602.8 m^2 \]
\[ \text{Swimming pool Area} = 1050 m^2 \]

Then, the calculation of heat loss through surface:
Heat loss through surface = Area * Uvalue

Roof Heat Loss = 1626 * 5.35 = 8699.1 W
Walls Heat Loss = 284.9 * 2.6 = 740.74 W
Windows Heat Loss = 290 * 2.5 = 725W
Doors Heat Loss = 165 * 3.2 = 528 W

Floor Heat Loss = 602.8 * 2 = 1205.6 W

Total surface heat loss = 8699.1 + 740.74 + 725 + 528 + 1205.6 = 11898.44 W

However, there are air leak at the edges of windows and doors, so an allowance should be made. Normally the range of allowance varies from 20% to 60% depending on the structure conditions and the type [36]. Assuming 43% of allowance for heat loss due to the ventilation and air leaks:

Total heat loss = 11898.44 * 0.43 = 5116.3 W

In order to decrease this heat loss of 5119.5 W, the recommendations made earlier should be taken into consideration.

Table 7.7.4: Heat loss in different parts of the pool building

<table>
<thead>
<tr>
<th></th>
<th>Roof</th>
<th>Walls</th>
<th>Windows</th>
<th>Doors</th>
<th>Floor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Loss (W)</td>
<td>8699.1</td>
<td>740.74</td>
<td>725</td>
<td>528</td>
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Figure 7.7.6: Graph representing different heat loss in the pool building
8. Boiler Economizer

To benefit more from the installation of the new biomass boiler, a boiler economizer can be added to it in order to improve efficiencies and cost savings. A boiler economizer is a heat exchanger device that exhausts waste heat from the boiler in order to preheat the feed-water that will be used to make steam or return it to the water circuit, in addition to heat the sanitary water (hot water for showers). The captured heat loss reduces the amount of fuel required, which means less fuel expenses and fewer GHG emissions. The boiler heating circuit provides less heat to produce hot water or steam since the boiler economizer already preheats the feed/return water; which explain the fact that the boiler operates at a higher efficiency (improvement of 3-7%).

Boiler economizer has different shapes:

- Cylindrical:
  - Compact
  - Lightweight, providing ease of installation
  - Hinged stainless steel access doors
  - Stainless steel internal exhaust gas bypass

Figure 8.1: Cylindrical Economizer [25]

Total cost: $24 200 = 239 172.23 MAD
Rectangular:

- Individually removable fin tubes
- Stainless steel interior shell
- Hinged full face access door
- Stainless steel internal exhaust gas bypass
- 10 gauge carbon steel, seal-welded exterior

Total cost: $23,280 = 230,079.73 MAD

Purchasing one of those equalizers will help increasing the average efficiency and reduce the fuel costs, in addition to the reduction of the exiting exhaust temperatures.
to the atmosphere to 65.5°C – 148.9°C. The average turnkey payback will vary between 12-18 months with an annual return on investment of 75-100% [39].

9. Construction phase

The new boiler installation requires the construction of a new local that should be close enough to the heating system installation of the swimming pool water in order to be linked to the water pipes.

Figure 9.1: Google Earth Pro screenshot showing the construction area of the new building [10]
Inside the new local an isolated room will be reserved only for the boiler as it is shown in the construction plan below:

Figure 9.2: New local construction plan

Figure 9.3: Boiler room construction plan
Then concerning the olive pits storage silo of volume 284 m³ and capacity of 150 tones, it will have the following dimensions:

In order to charge the boiler, a flexible extractor should be linked from the silo to the biomass boiler.
The construction phase has already started by putting the slab at the same level as the sloping ground.

Figure 9.6: Construction phase of the new local
## 10. Equipment depreciation

### 10.1 Biomass boiler

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<tr>
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<th>Cost of Asset</th>
<th>Salvage Value</th>
<th>Estimated Asset Life</th>
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Depreciation Expenses = \((\text{Cost of Asset} - \text{Salvage Value}) / \text{Estimated Asset Life}\)

\[
3669.4973 \text{ MAD}
\]

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### 10.2 Pool cover

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<td>Estimated Asset Life</td>
<td>20 Years</td>
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**Depreciation Expenses** = \((\text{Cost of Asset} - \text{Salvage Value}) / \text{Estimated Asset Life}\)

\[\frac{1260000 - 252000}{20} = 50400\text{ MAD}\]

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## 10.3 Economizer

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**Depreciation Expenses** = \((\text{Cost of Asset} - \text{Salvage Value}) / \text{Estimated Asset Life}\)

\[
(230079 - 92031.6) / 20 = 6902.37 \text{ MAD}
\]

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### 10.4 Biomass pellet making machine

| Cost of Asset | 985895 MAD |
| Salvage Value | 443652.75 MAD |
| Estimated Asset Life | 20 Years |

**Depreciation Expenses**:

\[
\text{Depreciation Expenses} = \frac{(\text{Cost of Asset} - \text{Salvage Value})}{\text{Estimated Asset Life}}
\]

\[
= \frac{(985895 - 443652.75)}{20}
\]

\[= 27112.113 \text{ MAD}
\]

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11. Financial analyses

11.1 Olive pits financial analysis

**Initial investment**

- Cost of biomass boiler: MAD 104,842.00
- Cost of economizer: MAD 230,079.00
- Cost of isolation materials and installation: MAD 333,000.00
- Cost of swimming pool cover: MAD 1,260,000.00
- New Local construction fees: MAD 165,000.00
- Pool cover earthmoving work and installation: MAD 252,000.00
- Total: MAD 2,344,921.00

Unexpected and unforeseen event (7% of the total initial investment): MAD 164,144.47

**Total of initial investment**: MAD 2,509,065.47
Net annual savings
- Olive pits use: MAD598,373.00
- Economizer energy saving: MAD153,452.66
- Isolation energy savings: MAD42,769.00
- Pool cover energy savings: MAD437,500.00
**Total**: MAD1,232,094.66

Annual Expenses (11 months over 12)
- Olive pits: MAD437,500.00
- Diesel in case of back up need (2 months): MAD180,000.00
**Total**: MAD617,500.00

**Total annual savings**: MAD614,594.66

*Base line years to payout*: 4.08 years

Comparing the total initial investment and net annual savings:

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<th>Profit/Loss</th>
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<td><strong>MAD3,072,973.30</strong></td>
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⇒ In less than 5 years, the new equipment will pay back its original cost and generate additional incomes.
## 11.2 Oaks financial analysis

### Initial investment

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<tbody>
<tr>
<td>Cost of biomass pellet machine maker</td>
<td>MAD985,895.00</td>
</tr>
<tr>
<td>Cost of biomass boiler</td>
<td>MAD104,842.00</td>
</tr>
<tr>
<td>Cost of economizer</td>
<td>MAD230,079.00</td>
</tr>
<tr>
<td>Cost of insulation materials and installation</td>
<td>MAD333,000.00</td>
</tr>
<tr>
<td>Cost of swimming pool cover</td>
<td>MAD1,260,000.00</td>
</tr>
<tr>
<td>New local construction for the biomass</td>
<td>MAD165,000.00</td>
</tr>
<tr>
<td>New local construction for the biomass making machine (10m*8m)</td>
<td>MAD200,000.00</td>
</tr>
<tr>
<td>Pool cover earthmoving work and installation</td>
<td>MAD252,000.00</td>
</tr>
<tr>
<td>Agricultural Service</td>
<td>MAD293,625.00</td>
</tr>
<tr>
<td>Total</td>
<td>MAD3,824,441.00</td>
</tr>
</tbody>
</table>

Unexpected and unforeseen event (7% of the total initial investment)  
MAD267,710.87

**Total of initial investment**  
MAD4,092,151.87

### Net annual savings

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oak use</td>
<td>MAD136,529.00</td>
</tr>
<tr>
<td>Economizer energy saving</td>
<td>MAD153,452.66</td>
</tr>
<tr>
<td>Insulation energy savings</td>
<td>MAD42,769.00</td>
</tr>
<tr>
<td>Pool cover energy savings</td>
<td>MAD437,500.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>MAD770,250.66</strong></td>
</tr>
</tbody>
</table>

### Annual Expenses (11 months over 12)

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Olive pits</td>
<td>MAD96,230.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>MAD96,230.00</strong></td>
</tr>
</tbody>
</table>

### Total annual savings

MAD674,020.66

### Base line years to payout

6.07 years

Comparing the total initial investment and net annual savings:
<table>
<thead>
<tr>
<th>Year</th>
<th>Costs</th>
<th>Benefits</th>
<th>Profit/Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 1</td>
<td>MAD4,092,151.87</td>
<td>MAD674,020.66</td>
<td>-MAD3,418,131.21</td>
</tr>
<tr>
<td>Year 2</td>
<td>0</td>
<td>MAD674,020.66</td>
<td>MAD674,020.66</td>
</tr>
<tr>
<td>Year 3</td>
<td>0</td>
<td>MAD674,020.66</td>
<td>MAD674,020.66</td>
</tr>
<tr>
<td>Year 4</td>
<td>0</td>
<td>MAD674,020.66</td>
<td>MAD674,020.66</td>
</tr>
<tr>
<td>Year 5</td>
<td>0</td>
<td>MAD674,020.66</td>
<td>MAD674,020.66</td>
</tr>
<tr>
<td>Year 6</td>
<td>0</td>
<td>MAD674,020.66</td>
<td>MAD674,020.66</td>
</tr>
<tr>
<td>Year 7</td>
<td>0</td>
<td>MAD674,020.66</td>
<td>MAD674,020.66</td>
</tr>
</tbody>
</table>

Total: MAD4,092,151.87 MAD4,718,144.62 MAD625,992.75

In less than 7 years, the new equipment will pay back its original cost and generate additional incomes.

**Figure 11.2: Column chart representing annual cost savings of each use of olive pits and oaks**

From the financial analysis, it has been shown that the use of olive pits and the energy saving equipment alternatives are a better compared to oak use as
biomass. The combination with olive pits is more profitable and its payback period is less of 5 years, in addition to the fact that it has an annual cost savings of 614 594.66 MAD.

12. Conclusion

Detailed knowledge of environmental damage is essential to progress towards a rational use of energy by taking into account the potential harm. This knowledge should help to locate the balance between the benefits of energy and its "adverse effects" on the environment, and thus determine the optimum level of energy consumption. It is also a policy instrument of choice towards the most environmentally friendly energy systems.

The determination of the "equilibrium point" is a difficult exercise given the great complexity of interactions between human activities and environment: health impact, climate change, and relations between local and global risks.

Al Akhawayn University wants to use renewable energies to respect the environment. For this reason, the university changed the current diesel boilers that heat the swimming pool water by a new biomass boiler that use olive pits as a source. The main goal of this project is to banish the use of diesel that harms the environment and find an eco-friendly alternative which will cost less.

The study revealed that the use of olive pits, as a biomass source, is a very good energy producer that will reduce carbon emissions. For a better profitability other equipment as economizer, isolation, and pool cover have been studied to see how much energy can be saved. It results that the combination of those equipment and the use of olive pits turn to be a very effective long-term investment that can save 614 594 MAD per year after a return on investment of nearly 5 years.
13. References


[7]. DZIEWANOWSKA M., DOBEK T. Analysis of the level of co and CO2 emission during the process of combustion of biomass containing leaves of various trees species. ActaAgrophysica 8, (1), 53, 2006 [In Polish].


[30]. STOLARSKI M., SZCZUKOWSKI S., TWORKOWSKI J. Biofuels obtained from energetic perennials biomass. Energetyka 1, 77, 2008 [In Polish].

[31]. STRZELCZYK F., WAWSZCZAK A. The effectivity of the biomass as energy-fuel. RynekEnergii 5, 51, 2008 [In Polish].


Appendix A: CSB Marina

Description:

- CSB Marina is a cutting-edge facility designed to enhance the marina experience through innovative technology.
- The facility is equipped with state-of-the-art features to ensure safety, comfort, and efficiency for marina users.

Features:

- Safety and emergency systems
- Automated security measures
- Efficient fuel delivery system

Equipment:

- Automated fuel dispensers
- Safety lock systems
- Automated security measures

Accessories:

- Standard accessories
- Optional accessories

Feed:

- Pellets
- Castor
- Blood meal
- Fish meal
- Gravy
- Seaweed

- CSB Marina 94K, 750L
- CSB Marina 94K, 1000L
- CSB Marina 94K, 125L
- CSB Marina 94K, 2000L

- CSB Marina 94K, 750L
- CSB Marina 94K, 1000L
- CSB Marina 94K, 125L
- CSB Marina 94K, 2000L

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CSB Marina » Further details regarding components

**Hopper**
Positioned on the side or rear, they have a truncated inverted pyramid shape for the CS versions and truncated-cone shape for the CSB versions. These have different sizes and are mounted on all models. The hopper is adapted depending on the generator power band. For the floor-standing boilers, which have the smallest size mounted, a larger hopper can be requested.

**Turbulators**
It is an optional, also applicable successively, and is made up from helical steel bars. These modify the inner shape of the shell and tube in a way that the hot fumes lengthen their pathway inside the boiler body before reaching the flue, thus transferring a larger amount of heat to the water.

**Level sensor**
Signals the reserve status of the fuel in the hopper. The boiler stops if it is not refilled. The sensor prevents complete emptying of the fuel conveying unit, saving the customer from annoying boiler re-start operations.

**Domestic Hot Water Module**
It is an optional that allows the production of domestic hot water for models up to 99. The coil is realised in finned copper to increase the heat exchange surface and has been designed to be installed also after purchase of the boiler.

**Damper**
It has been studied to solve any excessive draft problems, which would negatively affect burner operation. This type of solution guarantees normal operations of the machine also in the case of non-standard operating. In this way, it reduces the excessive consumption of fuel and improves efficiency of the entire boiler.

**Burner**
It is the point where there is the effective generation of thermal energy obtained through the combustion of the material, previously stored in the silo and transported inside the burner through the double screw system. It constitutes the base of every boiler in the CS and CSB ranges and is formed from a thick external steel casing that encloses a cavity inside which the combustion agent air and secondary air are appropriately conveyed. The upper base is made up from refractory material, which guarantees perfect isolation, while the “heart” of the entire structure where combustion takes place, is completely in cast iron.

**Mixer**
Supplied as per standard on all products in the CSB range. It is necessary for omnivorous boilers operating with large piece size biomass fuel and fine fuels such as sawdust. The system is composed of a mechanical arm positioned inside the hopper and is managed through a motor connected to a reducer, directly by the electronic control board, which governs its operating times. It moves the material stored inside the silo in a way to prevent “bridges”, which can prevent arrival inside the combustion chamber.

**Blower for automatic Ignition**
It is possible to automate switch-on, making use of the potentiality of the control unit, requesting the installation of the blower as an optional, which on blowing air at a very high temperature onto the biomass fuel, contained in the burner, triggers combustion.
# Appendix B: Design Builder Weather Data

<table>
<thead>
<tr>
<th>Weather Condition</th>
<th>Max DB Temperature (°C)</th>
<th>WB Temperature of Max DB (°C)</th>
<th>Min Night Design Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling Design Weather (0.4% based on dry-bulb temp.)</td>
<td>34.1</td>
<td>16.3</td>
<td>20.1</td>
</tr>
<tr>
<td>Cooling Design Weather (1% based on dry-bulb temp.)</td>
<td>33.0</td>
<td>15.5</td>
<td>19.0</td>
</tr>
<tr>
<td>Cooling Design Weather (2% based on dry-bulb temp.)</td>
<td>31.0</td>
<td>15.5</td>
<td>17.0</td>
</tr>
<tr>
<td>Cooling Design Weather (0.4% based on wet-bulb temp.)</td>
<td>30.2</td>
<td>16.8</td>
<td>16.2</td>
</tr>
<tr>
<td>Cooling Design Weather (1% based on wet-bulb temp.)</td>
<td>29.6</td>
<td>17.0</td>
<td>14.6</td>
</tr>
<tr>
<td>Cooling Design Weather (2% based on wet-bulb temp.)</td>
<td>27.6</td>
<td>17.0</td>
<td>13.6</td>
</tr>
<tr>
<td>Cooling Design Weather (0.4% based on dew-point temp.)</td>
<td>22.5</td>
<td>15.1</td>
<td>8.5</td>
</tr>
<tr>
<td>Cooling Design Weather (1% based on dew-point temp.)</td>
<td>22.0</td>
<td>14.1</td>
<td>6.0</td>
</tr>
<tr>
<td>Cooling Design Weather (2% based on dew-point temp.)</td>
<td>21.3</td>
<td>13.2</td>
<td>7.3</td>
</tr>
</tbody>
</table>

**Annual Weather**

| Hourly Weather Data | MARESBLANCA_NOVESPER_MIEC |