DESIGN OF A COMPOSTING BIN TO CONVERT AUI’S BIOMASS TO AN ORGANIC FERTILIZER

April 2017
DESIGN OF A COMPOSTING BIN TO CONVERT AUI'S BIOMASS TO AN ORGANIC FERTILIZER

Capstone Final Report

Student Statement:
I affirm that I have applied ethics to the design process and in the selection of the final proposed design. And that, I held the safety of the public to be paramount and have addressed this in the presented design wherever may be applicable.

______________________________
Rim Toumi

______________________________
Dr. Abdelghani EL ASLI
Acknowledgements:

It’s with a grateful heart that I express my sincere gratitude to every person who helped me throughout my capstone project. First of all, I would like to thank my supervisor Dr. El Asli Abdelghani for trusting me and giving me the opportunity to realize this project. I also would like to thank him for his excellent supervision and his constant availability even outside the weekly meetings to help me, guide me, and encourage me to go forward. I would like to thank Dr. Naeem Nizar Sheikh for giving me helpful advises to begin my project. I also want to thank the ground and maintenance team, especially Mr. Jadid Mohamed, Mr. Ouzir Samir, and Mr. Bounasser Abdellatif for being very helpful in providing me with the needed information and assisting my project’s progress.

Finally, I would like to thank Dr. Fouad Berrada for taking from his time to assist to my capstone presentation and for giving important remarques to improve my work. I also want to thank Dr. Yassine Salih Alj for giving the capstoners clear and helpful guidelines and making this course an enjoyable one.
Table of Contents:

Acknowledgements ................................................................................................................. 3
Table of Contents ...................................................................................................................... 4
Tables and Figures .................................................................................................................... 6
Abstract ................................................................................................................................... 7
I. Introduction ........................................................................................................................... 8
II. Literature Review ................................................................................................................. 9
   1- The History Of Composting .......................................................................................... 9
   2- Modern Composting ....................................................................................................... 10
      2-1- The Advantages of Composting .............................................................................. 10
      2-2- The Biology of composting ..................................................................................... 11
      2-3 Composting Steps ...................................................................................................... 12
      2-4- Types of Composters ................................................................................................. 14
   3- The Status of Composting in the World ......................................................................... 17
      3-1- Composting in Morocco .......................................................................................... 17
      3-2- Composting in Europe ............................................................................................. 18
      3-3- Composting in the Universities ................................................................................. 19
III. Materials and Methods ..................................................................................................... 21
   1- The composting process .................................................................................................. 21
   2- Analysis of the waste flow in AUI .................................................................................. 22
      2-1 Types of AUI’s waste ................................................................................................. 22
      2-1-1 Al Akhawayn University’s yard waste .................................................................. 22
      2-1-2 Al Akhawayn University’s garbage ..................................................................... 23
   3- Design of the Composter ................................................................................................ 24
   4- Restrictions ....................................................................................................................... 28
5- Implementation of the composter…………………………………………………………29
6- Monitoring the composting process…………………………………………………32
6-1 Measuring the temperature…………………………………………………………32
6-2 Measuring the pH…………………………………………………………………….32
6-3 Measuring the moisture…………………………………………………………….33
IV. Results and Discussion…………………………………………………………34
1- Greenhouse Gas Emissions…………………………………………………………34
2- Temperature…………………………………………………………………………36
3- pH Values……………………………………………………………………………38
V- Composting Plan and Recommendations for Al Akhawayn University……38
1- Composter…………………………………………………………………………39
2- Needed Equipment…………………………………………………………………42
3- Waste Collection……………………………………………………………………44
4- Measuring the temperature…………………………………………………………45
5- Measuring the pH……………………………………………………………………45
6- Measuring Moisture…………………………………………………………………46
VI- Financial analysis………………………………………………………………46
1- Expenses……………………………………………………………………………46
1-1 Creating the composter……………………………………………………………46
1-1-1 on the small scale………………………………………………………………46
2- Savings……………………………………………………………………………….48
VII- Steeple Analysis…………………………………………………………………49
VIII- Conclusions and Future Work…………………………………………………51
IX- Appendix…………………………………………………………………………54
Tables and Figures:

Table 1: List of compostable and uncompostable materials……………………………14

Figure 1: Compost heap……………………………………………………………………15

Figure 2: Wooden compost bin………………………………………………………….15

Figure 3: Compost multi-bin……………………………………………………………16

Figure 4: Composting tumbler………………………………………………………….16

Figure 5: Food digestion cone…………………………………………………………..16

Figure 6: Eco-village in AUI……………………………………………………………..21

Figure 7: Garden waste in Eco-village AUI…………………………………………….23

Figure 8: Pilot study-composting tumbler………………………………………………25

Figure 9: Composter’s aeration holes…………………………………………………..26

Figure 10: Composter’s sharp sticks…………………………………………………..26

Figure 11: Construction of the composter…………………………………………….28

Table 2: Garden waste ratios…………………………………………………………….30

Figure 12: Bin of leaves…………………………………………………………………..30

Figure 13: Bin of grass………………………………………………………………….31

Figure 14: Ratios Calculator…………………………………………………………….31

Figure 15: Covered composting tumbler………………………………………………34

Figure 16: Greenhouse Gas Emissions Factors………………………………………..36

Figure 17: Graph of pH values Vs. Time days……………………………………….36

Figure 18: Graph of temperature Vs. Time days……………………………………37

Figure 19: Solar irradiations in Morocco………………………………………………42

Figure 20: AUI’s shredder………………………………………………………………43

Figure 21: Compost screen……………………………………………………………..44

Figure 22: general-purpose bi-metal thermometer…………………………………45
Abstract:

Composting is the acceleration of the natural process of breakdown of the organic material into a more stable organic substance. This paper focuses on the aerobic composting method. In the presence of oxygen, microorganisms consume organic matter and release heat and carbon dioxide; resulting in a compost. This document addresses a composting plan and recommendations for AUI. The issue has been raised since Al Akhawayn has centralized garden waste in different areas of its campus that is not properly invested. After analyzing the background, the waste stream, the restrictions and the methods that will be used; a composting tumbler has been made in order to convert AUI’s organic waste into compost. Processing 500kg of waste monthly will result in 4200kg of finished product yearly. This will allow the replacement of peat use in the nursery, which costs 20000MAD per year. If maintained, the compost will benefit the university in the ecological and the financial level. 7590MAD can be saved per year by using this organic fertilizer with a minimum cost.
Introduction:

Lately, the world has experienced a rise in the human’s interest to everything that is organic. According to Forbes, a high number of people begin to prefer food labeled as natural, organic or locally sourced despite their high price. Therefore, a wide range of people started their organic gardens. To make sure that their plants are getting enough amounts of nutrients, the soil should be properly conditioned without any chemical treatment. This agricultural system is called organic farming.

Organic farming started in the 20th century. This alternative agricultural system relies mainly on the following organic fertilizers.

Manure: is used as an organic fertilizer and is a mixture of animal feces and straw. This organic matter has been the main fertilizer in the past.

Green Manure: This popular practice in both the agricultural industry and in home gardening has numerous benefits for the soil. It involves turning a variety of plants into the soil for an extended period of time.

Bone Manure: also called bone meal, is a mixture of animal bones found in the kitchen waste. It is a slow-release organic fertilizer that contains a fair amount of phosphorus and protein.

Composting: it is a cheap and eco-friendly way to make a humus rich in nutrients to fuel plant growth and to restore vitality to depleted soil. It is a nature occurring organic fertilizer, since it is basically an acceleration of the nature’s process in itself, knowing that everything decomposes. Therefore, composting will be the subject of this capstone project, and it will be held in Al Akhawayn University. The purpose of this capstone
project is to implement a pilot study that involves the realization of an experimental 
composting system that is intended to be expanded on Al Akhawayn University level.

**Literature Review:**

1- The History Of Composting:

Composting is not only a modern age matter, this practice took place long time ago. The 
earliest records state evidence that before the introduction of modern sewage systems, the 
major fertilizers were animal manure and composts of garden and kitchen wastes.

Composting existed 10 000 years ago through the Akkadian empire which was located in 
modern day Iraq. When the citizens noticed that their plants grew better in area where there 
was manure they started putting manure in their soil. The history of composting also states 
that early farmers in Scotland, during the Stone Age, used to put manure and vegetable 
compost in their soil. Moving to Ancient Asia, there is evidence that the tools found in 
Neolithic sites in northern china contained similar features as those used by the Scottish 
farmers. Ancient writings and early Hindu texts show that the ancient Chinese farmers used to 
put cooked bones, silkworm debris and manure in their soil. The Greeks, Romans and 
Egyptians used composting too. They used to take straw from animal stalls and put it in the 
soil. Ashes, straw, stubble, chaff and grass were used to enrich the soil and animals’ blood 
was used as a fertilizer. In Egypt, after observing the worms’ composting abilities, Cleopatra 
enacted a law that states that anyone who removes earthworms from Egypt was punished by 
death. During the 12th century, the handbook Kitab Al Falah written by Ibn AL Awam gave 
detailed information about composting and the use of manure. In America, Native 
Americans were known by composting, and practiced it through three methods. The first 
method was sheet composting where, compostable materials were layered by soil. The second 
method was composting while planting, where the nutrients were the fish parts or other
animal parts. The third method was seed balls. In this method the seeds were balled in clay and compostable materials, which kept them moist, then they were thrown to plant the seeds. Composting was since then known as a money saver. In 1943, George Washington Carver said “Make your own fertilizer, compost can be done with little labor and practically no cash outlay”. Yet, composting was soon replaced in the early 20\textsuperscript{th} century. Justus Von Liebig, a German scientist, proved in 1840 that the plants can get nourishment from the chemicals. Therefore, the vegetables’ and animals’ waste mixture was replaced quickly by artificial fertilizers, and that was the beginning of the scientific method of farming. But like all the artificial solutions, fertilizers had their opponents.\textsuperscript{i}

2- Modern Composting:

In 1905 sir Albert Howard released the Indore method. After 30 years of research, Howard found the best modern compost. It involves alternating layers of green, manure and soil until reaching the desired height. The heap should be moist and turned regularly to meet the desired aerobic conditions, then the compost is ready in the span of three months. \textsuperscript{ii}

2-1- The Advantages of Composting:

Nowadays, composting is known for its numerous advantages which involve:

- Reducing yard and food waste make up 30\% of the waste stream and therefore diverting that waste away from the landfills.
- The plants from a well-done compost will look better, will produce better and will have a much greater ability to fight diseases.
- Adding organic matter to the soil improves moisture retention.
- Adding decomposed organic material to the soil feeds the soil’s organisms.
- Compost provides a balanced source of nutrients that helps the soil hold nutrients long enough so that the plants can use them.
- Composting saves money.
• Composting improves our diet, the plants will have fair amount of nutrients.

2-2- The Biology of composting:

Composting is a natural process. It involves all the spontaneous decomposition activities in nature, like the breakdown of leaves or the ageing of animal manure. However, this process takes a long time, that is where comes the importance of composting. Moreover, fresh organic material need to be composed before adding them to the soil, otherwise it may result in a change in the ecosystem.

A well made compost is dark brown and smells like the forest. It is composed from carbon, nitrogen, oxygen, and water. This four ingredients are mandatory for the composting organism to work effectively.

Carbon: brown material, provides for energy and the microbial oxidation of carbon produces the heat.

Nitrogen: such as fruits and vegetables are used to grow and reproduce more organisms to oxidize the carbon.

Oxygen: for oxidizing the carbon, the decomposition process.

Water: in the right amounts to maintain activity without causing anaerobic conditions.

The biology of a compost is easy to grasp. Beginning with the carbon cycle. Carbon compounds are the source or high metabolic activity, which increases the temperature during composting. Whereas the nitrogen balance decreases during the process along with a loss of CO₂ and H2O, which means a decrease in the carbon nitrogen (C/N) ratio. Bacteria that fix nitrogen to replace this loss. This activity occurs highly by the end of the decomposition and is influenced by the presence of ammonia and high temperatures.

The availability of oxygen is crucial too since our process is a biological oxidation. Therefore, the compost should be turned daily to supply O₂ and to allow the aerobic respiration. It is important to keep the percentage of oxygen in the compost from falling below 18%.
Another important composting factor is the temperature. Unlike the common belief that states that high temperatures are essential for good compost, excessively high temperature slow down the decomposition activity of the organic matters. Indeed, only few bacteria can perform above 70°C. The best-case scenario will be a varied temperature from 45 to 50°C. An adequate level of moisture is very important to maintain too. It lowers the structural strength of the organic latters and consequently speeds the decomposition process.

In a higher level of accuracy, the C/N ratio must be between 25 and 35. If the ratio is below 20, nitrogen is lost and ammonia is released, which leads to a bad smell in the compost. However, if the C/N ratio is above 40, the decomposition process slows down.

The size of the materials is an important factor too. For a fast and efficient decomposition, the size of the compostable materials should be between 1.3 and 5cm. If the materials are too big, it is important to reduce their size. The size should not be very small neither, otherwise this will cause a lack of aeration.

The following chemical reaction summarizes the composting process:

\[ \text{Organic waste} + O_2 \rightarrow \text{Compost} + CO_2 + H_2O + Heat \]

2-3 Composting Steps:

It is mandatory to be aware of the factors listed above and follow the next step in order to make a healthy compost:

1- Build a compost bin: its size will depend on how much compostable material we want to generate.

2- Choose the composter location: the area should be flat and sunny.

3- Alternate the layers: the first layer should contain twigs to allow air to get in. The second layer is a cover of leaves, then we alternate layers of carbon and nitrogen until the bin is full.
4- Maintain the compost bin: We should make sure that the materials are adequately wet and the compost should be mixed once a week to help the breakdown process.

This process can be easily performed without a mandatory agricultural experience. Indoor composting can be either a backyard composting, for this type we need a yard, fallen leaves or straw and grass clippings and food scraps. Or a worm composting (vermicomposting): A tiny yard or even an apartment will work, with enough food scraps.

Here is a list materials that are and those that are not compostable:
Table 1: List of compostable and uncompostable materials

2-4- Types of Composters:

As listed above, the first step of composting is making a compost bin. This step requires a full knowledge of the required size of compost and the material needed for the bin.

Here are some existing types of composting bins:

<table>
<thead>
<tr>
<th>Browns</th>
<th>Greens</th>
<th>Don't Compost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evergreen needles</td>
<td>Green leaves</td>
<td>Invasive weeds gone to see</td>
</tr>
<tr>
<td>Dried leaves</td>
<td>Garden waste</td>
<td>Meat/fish/bones</td>
</tr>
<tr>
<td>Paper egg cartons</td>
<td>Flowers</td>
<td>Fat/oil/grease</td>
</tr>
<tr>
<td>Paper towels/napkins</td>
<td>Vegetables</td>
<td>Dairy products</td>
</tr>
<tr>
<td>Dried grass clippings</td>
<td>Fruit peels</td>
<td>Cooked foods (attracts animals)</td>
</tr>
<tr>
<td>Shredded newsprint</td>
<td>Scraps</td>
<td>Pet waste</td>
</tr>
<tr>
<td>Bark</td>
<td>Coffee grounds</td>
<td>Plastics</td>
</tr>
<tr>
<td>Coffee filters</td>
<td>Tea leaves/bags</td>
<td>Metals</td>
</tr>
<tr>
<td>Straw</td>
<td>Egg shells</td>
<td>Glass</td>
</tr>
<tr>
<td>Sawdust (limited amnt.)</td>
<td>Flowers</td>
<td>Toxic material</td>
</tr>
<tr>
<td>Dryer/vacuum lint</td>
<td></td>
<td>Charcoal</td>
</tr>
<tr>
<td>Cardboard (cut into small pieces)</td>
<td></td>
<td>Chemical logs</td>
</tr>
<tr>
<td>Dead house plants</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shredded brown paper bags</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
- The first composter is as simple as compost heap. This is a traditional open-air heap. This type of composting used to exist in the past and can still be found in some gardens. It is usually a wide foot high heap that contains six layers of green garden waste and kitchen waste, placed over the brush core. Two layers of cow or chicken manure cover the layers. The heap type unlike the modern composting must be turned every 6 weeks.

Figure 1: Compost heap

- The second type of composters and the most common one is the wooden compost bin. This bin is easy to make. It can be made using four pallets and an additional one as a floor, stuck together using a metal pole. The pallets should contain gaps to allow aeration, then covered by a piece of plastic that will play the role of an isolator and will protect the compost from heavy rain too. This bin is suitable for a house garden, as it usually does not take a lot of space.

Figure 2: Wooden compost bin
- A type similar to the wooden bin but for higher quantities of compost is the multi-bin. In this bin, the compost should be turned every week first, and then left to mature for a month. This composter needs to be watered regularly too and its compost can be ready in few weeks. However, this kind of bin requires a lot of indoor space and a fair amount of effort.

- This type of composters is called a tumbler. It is easy to use because it can be turned easily. The materials inside it can then be mixed thoroughly, which allows the compost to be ready quickly. The tumbler generates high-quality compost, but is not as easy to make as the previous composters.

- The food digestion cone is a sophisticated type of composters. This type has a chamber buried under the ground where kitchen waste is gathered and decomposed. The digesters use the sun’s heat to fasten the process, therefore they should be put in a sunny area.
3- The Status of Composting in the World:

3-1- Composting in Morocco:

In Morocco, the agricultural growth has been significant in the last decades. However, this growth led to a huge consumption of chemicals and pesticides, along with a higher rate of organic waste production and a bad impact on the environment. Therefore, several composting initiatives have been introduced.

In 1995, the first use of composting technology has been promoted ENDA Maghreb (environment développement et action) started a research along with a laboratory composting experience with the help of different partners. After the success of the experience and a request from the urban commune of Sale Bab Lamrissa and the association Bou Regreg, ENDA started a composting project for that area with the financial help of the French embassy in Morocco. This experience is still operating since 1998, and processes a tone of household waste in a neighborhood in the commune of Sale Bab Lamrissa.

In order to bring the experience to a higher level, it was necessary to increase the capacity of the composting project in a way that it can serve a larger commune. Therefore, the first project of a co-treatment center (CCT) has been lunched in November 2000 in the commune of Tiflet. A unit of waste sorting and composting has been implemented in the same area.\textsuperscript{iv}

In 2010, the amount of methyl bromide consumed by the Moroccan agriculture was concern for Morocco; knowing that this pesticide depletes the ozone layer. To attack this issue, Morocco and the United Nations Industrial Development Organization (UNIDO) – the special agency of the United Nations for poverty reduction and environmental sustainably-partnered to start a composting technology to lower the organic waste.

In 2013, a composting unit was set in Agadir to put the compost technology into action.
The center contains a composting pilot unit to handle the process, as well as a laboratory to enhance the quality of the compost using non-chemical technologies."

Despite the experiences and initiatives done in Morocco, the production of compost is very limited. The rate of production is usually low and instable, and the principle customers are nurserymen and horticultural farms. However, in the recent years; a slight increase in the compost market has been noticed. The principle companies known for the production of compost in Morocco are AGRIFERTIL, ECOFERTIL, and Elephant Vert.

- Ecofertil is the first and the biggest composting company in Morocco. It is the pioneer of the Compost market in Morocco. Ecofertil exists since 1991. It was a partner in all the pilot experiences of bio agriculture in Morocco since 1996 and won 7 trophies in the national scale.

- Agrifertil is a company that started in 2007. It is specialized in the production of bio fertilizers and has a production unit in AL Jadida. The company launched a line of four products: Biofertil Compost, Nabat, Multifol and Samad. Agrifertil has equipped laboratories that ensure the quality of their product. Today their compost is sold in Agadir, Larache, the region of Fes-Meknes and Marrakech.

- Elephant Vert is a Swiss group that produces bio fertilizers in Morocco. It has three units of production in Morocco, Agadir, Meknes and Berkane. This company promotes the production of compost from biowaste and is aiming to expand its business in fifteen other cities in Morocco.

3-2- Composting in Europe:

In Europe, the European Compost Network (ECN) - European non-profit organization for recycling practices in composting and biological treatment of organic sources- launched more than 3000 composting plants for 72 members from 27 European countries. The organization assists member states to manage their organic waste for an emerging bio-based economy.
Multiple successful composting experiences emerged in Europe. One of the most spectacular achievements was in Hernani, which is one of the first towns in Spain’s province Gipuzkoa to promote the zero waste movement. The citizens of this small city managed to lower their household waste by 80 percent. Furthermore, composting classes have been implemented to educate the citizens about the home composting. Those who sign up to compost at home were granted with a 40 percent discount off the municipal waste management charges.

Another success story in the composting field but in a larger scale city is that of San Francisco. The city went from 42 percent to 60 percent recycled waste from 2001 to 2005. In 2006, a law was introduced to require the construction and demolition companies to recycle two thirds of the debris from steel and timber at a registered facility. In 2008, and after 70 percent decrease of waste diversion, the San Francisco supermarkets were no longer providing free plastic bags. In 2009, home composting was mandatory for the citizens and failing to do so was fined with a range from 100$ to 1000$. Today, San Francisco reached a decrease of 80% of organic waste sent to landfills, and 600 tones of organic waste is used to produce high quality compost in Vacaville facility. vi

3-3- Composting in the Universities:

In the universities-scale, the American Universities have been the leaders of the recycling and composting programs, the following universities are the leaders in this field:

• Pepperdine University: This university sends 22 percent of its waste to landfills and recycles the remaining 78 percent. Garden waste and food waste is composted and used as a fertilizer within the company.

• American University: It is a 100% free waste university. They compost all the paper towels in the campus areas, and recycle kitchen grease for electricity.

• College of Atlantic: The college has recycling outlets for bottles, cans, glass and paper. Also, food waste and napkins are used for composting.
• University of California Davis: 120 tons of items are recycled and 98% of its food waste has been composted since 2009. This university launched a program called the Bucket Program, where students collect food waste in their rooms. And in 2007, the university introduced the USA first zero waste athletic stadium.

• Harvard University: In 2011, Harvard joined the compost movement and reached a decrease of 103 tons of food waste sent to the landfills.

• Purdue University: Purdue follows the “recycle first, trash later” slogan, and composts animal waste and had reduced trash pickup to twice a week.\textsuperscript{vii}

3-4 Composting in Al Akhawayn University:

Al Akhawayn University has established campus models to emphasize the sustainability model as a part of its green strategy, yet, there is no concrete compost production in the University. AUI has an eco-village situated in a large area behind the ground and maintenance building. That place was constructed to hold agricultural activities using eco-friendly methods. Huge amounts of garden waste are shredded and centralized in a part of the eco-village. The waste is stocked in the form of large size bins, which are intended to produce compost. However, those bins are left to decompose naturally without any human interaction; which result in a very long composting process that can take over a year to produce a finished product.
III- Materials and Methods:

1- The composting process:

As stated in the literature review part, composting can be either aerobic or anaerobic. For this project, the composting method has been chosen to be aerobic for various reasons. First, the aerobic composting is fast since the microorganisms in it consume and decompose the organic matter quickly and more efficiently than the anaerobic one. Taking into consideration the project’s time limitation, the anaerobic method seems to be the best one. Second, anaerobic-composting needs to be done underground to prevent $O_2$ from getting into the compost, which makes the task more complicated. The aerobic-composting, however, works in an aboveground environment and requires no digging into the soil.

The process chosen is rapid composting process that takes from 14 to 21 days. This method requires daily turning of the compost in order to allow the microorganisms to get enough $O_2$ to accelerate their activity. Moreover, daily turning prevents the compost from overheating,
which kills the microorganisms and pushes the composting process to restart from the beginning. (Robert D. Raabe)

In order to track the progress of the compost and measure its quality, I measured the temperature, the pH, and the moisture of the compost at specific periods of time.

2- Analysis of the waste flow in AUI:

As stated previously, this project is a small scale composting system that aims to set the floor for Al Akhawayn to produce a high quality compost on the University level. In order to achieve this task, detailed information about the compost’s raw material need to be available. This will enable me to identify the combination of waste that will fit the best the compost, and to measure the degree of feasibility. Additionally, I will estimate the amount of waste that will be diverted from the landfills, which is one of the main advantages of composting. Therefore, with the help of dr. ElAsli, I gathered the needed data about the waste flow from the ground and maintenance staff.

2-1 Types of AUI’s waste:

2-1-1 Al Akhawayn University’s yard waste:

Al Akhawayn University is located within a large forest. The beautiful campus contains well-maintained gardens and trees that produce big amounts of yard waste. The ground and maintenance director estimates this waste to be close to an average of 300kg during the month of October and that the gardeners trim AUI yards 7 months a year. Assuming that the amount of yard waste collected during the 7 months is equal, we will end up with a total quantity of waste of 2100kg annually. Al Akhawayn University will be able to produce an estimation of 1470kg of compost per year if it comports its monthly waste
only, taking into consideration that the yield of production of compost is 70% of the original quantity (Michelle Dong. et al, 2014). Since AUI collects waste but doesn’t treat it since many years, the compost production can reach much more than 1470kg annually.

Figure 7: Garden waste in Eco-village AUI

2-1-2 Al Akhawayn University’s garbage:

Al Akhawayn University produces the equivalent of 3tons of waste per day. The waste is collected everyday from the trashcans distributed abundantly on different areas of the university then transported to landfills by the Ifrane’s garbage truck at 10pm. It has been
stated, on a previous composting project done at AUI by a group of American researchers, that the garbage of the university contains 25% plastic, 35% cardboard/paper, 25% food and 15% other percentage of volume.

AUI’s garbage contains an important percentage of food scraps, cardboard, and paper that we can use as additional sources of nitrogen and carbon. However, the garbage also contains plastic, cooked food, and other uncompostable materials. In order to include the garbage waste in the composting system, it is mandatory to sort carefully the types of waste mentioned previously; which will be a difficult and risky process. More on sorting of AUI’s garbage can be found in the recommendations chapter. Therefore, I decided to go with a composting system that only contains yard waste for now, in the hope that Al Akhawayn will implement a sorting process in the future.

3- Design of the Composter:

In order to implement the composting system, a composter has been designed on paper. It is a composting tumbler that provides the adequate conditions, to allow the production of high quality compost. The composter has a volume of 0.209m³ that can be converted to 127kg, with a radius of 28cm and a length of 85cm.
The tumbler kind of composters has been chosen because the turning action it requires provides the compost with a fair amount of air. As mentioned previously, bacteria need oxygen to keep up the respiration process that happens within aerobic systems. Additionally, putting the compost in a closed container is better in Ifrane where it snows for long periods of time. The tumbler will cover the compost from the snow and will help to retain the temperature inside.

The composter was made to allow a healthy composting process. Therefore, its design takes into consideration the following factors:

- Aeration: first of all, the composter designed is a tumbler that contains a cylindrical metal pipe on which 9 metallic slightly sharp sticks of a length of 27cm each have been welded. This allows turning the material inside the tumbler which allows air circulation. Additionally, 6 holes of a diameter of 2cm each were pierced on the upper
area of composter. Also, the composter contains a door that allows air entrance even when closed. Only half of the composter was filled to allow maximum aeration.

Figure 9: Composter’s aeration holes

Figure 10: Composter’s sharp sticks
- Temperature: The compost temperature may go from 20°C to 70°C. Therefore, the composter has to offer the adequate heat capacity. The material that meets the best this requirement is metal, known for its high capacity to retain heat. That is why our composter is metallic, and its interior has been painted with an anti rusting paint.

- Easiness of the task: In addition to produce high quality compost, this tumbler also aims to ease the task of composting. To do so, the composter contains a handle that has two control sticks from the two sides of the container to allow turning the axe inside the composter, which turns the components. Sharp metallic sticks have been welded on the axe to shred the composted materials and lower their size to accelerate the composting process. Additionally, the material of the composter is made of light metal to allow turning the tumbler easily upside down to remove the finish product. Furthermore, the composter is attached with metallic belts to keep it from falling down or moving during the turning action. The composter is put on a support to keep it stable and easy to reach.

After designing the composter and determining the conditions it should provide, comes the part of building it. The container is a cylindrical metallic barrel that I purchased from a scrap yard in Azrou. The axe, on which the sticks have been welded, is a metallic cylinder bought from the same place. After buying the main components, I brought them to a welder who built the composter following the design and respecting the requirements.
After being done with the constructions, the composter has been transported from Azrou to AUI’s annex. I chose that location because it has a free large space where garden waste was centralized. Additionally, the area is only visited by gardeners, which keeps the composter far from the people’s reach. The location is also near a basement that accommodates water sources and gardening tools, which can be very helpful in the composting process.

4- Restrictions:

As stated in the analysis of the waste flow part, the garbage of AUI is estimated by percent of volume to contain 25% plastic, 35% cardboard/paper, 25% food and 5% other. Although the cardboard, papers, and scraps of food can be compostable, they are not separated from the other garbage types. Therefore, to use this type of waste, a sorting process should be done on both the employees and the students level; which can be very difficult since this habit is not very common in our society. Additionally, the compost should not include cooked food, meat,
or fish as they contain pathogen, which may contaminate the compost. This makes the sorting process risky and requires precision and carefullness. Those variables make the idea of including food scraps and papers in the composting system neither realistic nor efficient.

The second restriction was the unavailability of a moisture level sensor. This fact prevented me from measuring precisely the percentages of moisture in the compost, which was an important variable in measuring the quality of the compost and calculating the C:N ratio. Another restriction was the time limitation. It is true that the period of time that I was given allowed me to implement a composting system with all the needed steps and to take the adequate measurements. However, if I had more time, I could analyze different types of compost differently and test which one of them would result in a better quality compost. Additionally, the yard waste data was hard to find and it took me a lot of time to find the information I needed, which shortened the amount of time I had.

5- Implementation of the composter:

After analyzing the waste flow of Al Akhawayn and determining the type and method of composting, comes the part of implementing the composter. Taking into consideration the restrictions related to the kitchen waste, I decided to compost the garden waste only. I looked for various ratios of garden wastes on internet to figure out the combination that would give me a ratio of approximately 30:1 as an ideal C:N ratio. The following ratio have been found on the official website of the university of Illinois.
Table 2: Garden waste ratios

From the table above, it can be deduced that mixing grass clippings with leaves would be the best combination. Therefore, I asked the gardening manager to gather fair amounts of grass and leaves in separate bins. I checked the two bins, watered them, and left them to decompose on the ground for four days in order to accelerate the decomposition process of my compost once in the composter.

Figure 12: Bin of leaves
The next step was filling the composter. I put two handfuls of grass versus one handful of leaves in two separate plastic bags, their masses were equal to 42.33kg of grass and 21.17kg of leaves. Then I calculated the total ratio of the mixture using the interface provided by Cornell Compost educational website.

After deciding the composition of the composting materials based on the total C:N ratio, I implemented the composter with the measured mixture, alternating the layers of grass clippings and leaves.
III-6- Monitoring the composting process:

III-6-1 Measuring the temperature:
Temperature is among the principal determinants of the quality of the compost. Therefore, I used a general-purpose thermometer that was available in the chemistry lab. To measure the temperature, I dug a hole into the composting material that was put in the composter and read the point of measurement then wrote it in a data sheet daily. In theory, the temperature should vary from 13°C to 70°C depending on the dominant bacteria present in the compost: Psychrophilic, mesophilic, thermophilic. (More on this can be found in the Results and discussions part).

The compost should not exceed 70°C and should be mixed if it does, otherwise it can become sterile as the microorganisms will be killed by the high temperature. (Robert D. Raabe)

6-2 Measuring the pH:
Measuring the pH is very important. It enables us to follow the process of decomposition. The compost contains microorganisms that work better under neutral to acid conditions. This occurs in a pH range of 5.5 to 8. The organic acids are formed during the initial stages of decomposition, which favors the growth of fungi and the breakdown of lignin and cellulose. At the last phase of the composting process, the compost becomes stable at a range of 6 to 8. In case the organic acids accumulate rather than breakdown, this should be a sign of an anaerobic process development. An unpleasant odor may occur and the nitrogen will be depleted. (Cornell Waste Management Institute, 1996) The compost should then be mixed to allow aeration and reduce acidity.

In order to measure the pH, a small quantity of compost was extracted from the middle of the sample. The quantity was then put in a baker that contains distilled water. The mixture was stirred using a magnetic mixer, then liquid was separated from the solid using a paper filter.
The final step was measuring the pH of the liquid using a pH probe, and taking note of the measurements.

6-3 Measuring the moisture:

Moisture is an important factor in aerobic composting, as microorganisms need water to live. The range of moisture should vary from 40 to 60 percent. If less, bacteria slow down; if more, air will be forced out of the compost which will turn the process into aerobic resulting in unpleasant odors. (Robert D. Raabe) Our compost is made of grass clippings and leaves. Those ingredients do not need a lot of water to attain the percentage of moisture needed. Therefore, I added water gradually at the beginning of the process until all the ingredients became moist. If the compost dries, water should be added while mixing the compost. The moisture level can be measured using a moisture level sensor, but since this tool is not available in AUI as stated in the restrictions part, I assumed the moisture using a general rule. I made sure that the compost felt damp to the touch with only a drop or two of water when squeezed.

In order to keep the maximum moisture of the compost, I covered the composter with a plastic bag.


IV - Results and Discussion:

This part includes the measurements and computations as well as discussions on the results of the methods discussed in Materials and Results part. The measurements presented in this part belong to seven days of recordings. The compost did not reach the stable state yet, however, it is important to mention that so far the results are proving that the composting process is on the right path.

1- Greenhouse Gas Emissions:

The three greenhouse gases produced by the composting process are the carbon dioxide (CO₂) methane (CH₄) and nitrous oxide (N₂O). These gases contribute to global warming by absorbing the radiations emitted by the earth and re-emitting them. Each one of those gases has a global warming capacity (GWC), as discussed in the literature review part. During the aerobic composting process, most of the generated CH₄ is oxidized with the presence of oxygen and the carbon in the compost is converted into CO₂; which has the least GWC. N₂O, on the other hand, has a big GWC, yet, only small amounts of it are produced during the
process. \( \text{CO}_2 \) is the principal greenhouse gas produced, and as the composting process increases, the carbon content in the material decreases.\(^{\text{xii}}\)

Greenhouse gas emissions can be used to track the evolution of the composting process. In the beginning of the aerobic process, high amounts of oxygen are available which results in high production of carbon dioxide and low amounts of methane (\( \text{CH}_4 \)). As the compost becomes closer to maturity, the oxygen concentration decreases and that of carbon dioxide increases. In order to calculate the emissions of those gases, I found the following equations provided by RTI international – an independent, nonprofit institute for research, development, and technical services to government and commercial clients worldwide- reported to U.S. Environmental Protection Agency.

\[
\begin{align*}
E_{\text{CO}_2} &= EF_{\text{compost,CO}_2} \times M_{\text{compost}} \\
E_{\text{CH}_4} &= EF_{\text{compost,CH}_4} \times M_{\text{compost}} \\
E_{\text{N}_2\text{O}} &= EF_{\text{compost,N}_2\text{O}} \times M_{\text{compost}}
\end{align*}
\]

Where:

- \( E_{\text{CO}_2} \) = \( \text{CO}_2 \) emissions (Mg \( \text{CO}_2/\text{yr} \))
- \( E_{\text{CH}_4} \) = \( \text{CH}_4 \) emissions (Mg \( \text{CH}_4/\text{yr} \))
- \( E_{\text{N}_2\text{O}} \) = \( \text{N}_2\text{O} \) emissions (Mg \( \text{N}_2\text{O}/\text{yr} \))
- \( EF_{\text{compost,CH}_4} \) = \( \text{CH}_4 \) emission factor for composted material (kg \( \text{CH}_4/\text{kg wet waste} \))
- \( EF_{\text{compost,N}_2\text{O}} \) = \( \text{N}_2\text{O} \) emission factor for composted material (kg \( \text{N}_2\text{O}/\text{kg wet waste} \))
- \( EF_{\text{compost}} \) = \( \text{CO}_2 \) emission factor for composted material (kg \( \text{CO}_2/\text{kg dry solids} \))
- \( M_{\text{compost}} \) = Annual mass of material added or fed to the compost process (Mg/yr, wet basis) = 63.5kg (the weight of the mass in the composter)

The emission factors of the gases has been provided by the same source (RTI international).
Figure 16: Greenhouse Gas Emissions Factors

\[
E_{\text{CO}_2} = 0.44 \times 0.0635 = 0.02794 \text{ Mg/yr} = 27.94 \text{ kg/yr}
\]

\[
E_{\text{CH}_4} = 0.004 \times 0.0635 = 0.00254 \text{ Mg/yr} = 25.4 \text{ kg/yr}
\]

\[
E_{\text{N}_2\text{O}} = 0.0003 \times 0.0635 = 0.00019 \text{ Mg/yr} = 1.9 \text{ kg/yr}
\]

In the same way, CO\textsubscript{2} emissions are related to pH. As it was mentioned before, as the decomposition process reaches advanced levels, the oxygen decreases and the carbon dioxide increases. Knowing that CO\textsubscript{2} contains an amount of acidity, the variation of pH can be explained. Indeed, as the composting process progresses, the CO\textsubscript{2} increases and the acidity increases too, so the pH decreases. After the first three days, CO\textsubscript{2} reaches its top value and starts decreasing afterwards, which causes the pH values to re-increase.

Figure 17: Graph of pH values Vs. Time days

2- Temperature:

The temperature was measured every day using a general-purpose thermometer. Measuring the temperature is an effective way to track the compost’s process. As the decomposition
process progresses, the temperature increases; however, it should not exceed 70°C, otherwise the aerobic microorganisms will become inactive. The amount composted in the pilot study is not large and the compost was turned daily, therefore, the temperature is not expected to reach high degrees.

![Graph of temperature Vs. Time days](image)

**Figure 18: Graph of temperature Vs. Time days**

During the initial stage of the process, the temperature varied between 20°C and 21°C. The dominant aerobic bacteria were the psychrophilic ones, who work in the lowest temperature range. In the second day, the temperature of the compost reached around 25°C, this caused the psychrophilic population died and was replaced by the mesophilic one. This type of bacteria provides a quicker decomposition of the organic matter and produces more heat and a quantity of acids and CO₂. During the seven days, the compost reached a temperature of 32°C as a highest value. The temperature is predicted to increase and settle during the next days.

When the temperature will reach around 40°C, the mesophilic bacteria will begin to die and leave the floor to the thermophilic bacteria who will take over. The temperature will stabilize during this stage, which will last no longer than 3 days due to the small size of the compost and the regular turning. Thermophilic bacteria decompose the largest amount of organic
matter, then decline and cause the temperature to decrease as well. (University of Illinois Extention)\textsuperscript{xii}

**2- PH Values:**

The pH values were measured daily for five days to follow the decomposition process. The ideal range of pH values goes from 5.5 to 8 when the system is in progress, then stabilizes in the range of 6.75 to 7.5.

![Graph of pH Values](image)

The graph shows that in the first day, the compost was acidic, which favors the growth of fungi and can be explained by the release of CO\textsubscript{2}. The pH reaches its peak in the third day with a value of 6.7. Starting the fourth day the pH declines slightly, which can be caused by the stabilization of CO\textsubscript{2} release.

**V- Composting Plan and Recommendations for Al Akhawayn University:**

As its title shows, this project is intended to implement a composting system for Al Akhawayn University on the large scale. To do so, the pilot study presented earlier has been made. The purpose of this initiative is to produce healthy and cheap compost all over the year.
1- Composter:

Since Al Akhawayn University is situated in Ifrane in the middle of the Atlas mountains at an elevation of 1665m which explains its cold weather. Ifrane experiences snow during the winter season and even the early spring sometimes, and a cool climate during autumn and summer. Knowing that the composting process can slow down or stop temporary because of low temperature, it seemed healthier and more time efficient for the compost to be put in a composting tumbler in order for it to be covered. The same solution is proposed for the larger scale composting system. The up-scaled version of the composting tumbler would be a large tumbler that has a capacity to carry 500kg of waste that can be converted to 0.821 m³. The optimal quantity was chosen to be 500kg because as stated in the Materials and Methods part, AUI produces an estimation of 2100 Kg garden waste per year, and taking into consideration the huge amount of untreated waste dispatched around the university, the composter can be easily filled with 500kg of garden waste each month.

The large tumbler will be a metal container painted with rustproof paint. Air will flow inside this container through multiple big size holes similar to those pierced in the pilot tumbler to allow the aerobic process to occur. In order to allow the composter to let enough O₂ in the composter, 1/3 of the composter needs to remain empty. Therefore, the tumbler will have a container of 1.084 m³. Implementing the composter with 500kg of waste monthly will result in 4200kg of compost annually.

The composter will contain an axe passing in the middle of it, and 27 large sticks in a cylindrical form will be attached to the axe to turn the compost. In order to accelerate the process, the compost should be mixed once a day, as stated in the Materials and Methods part.

Knowing that the composter will be of 1.084 m³ its estimated dimensions will be the following: a radius of 50cm, a length of 138cm.
As this task will require a certain physical force, it would be necessary to automate the turning process. A motor should be installed to turn the axe that will turn the compost. Since this project is all about saving the environment, it would be better to choose a motor that works using solar panels instead of electricity.

In the top of the tumbler, there would be a loading hopper that has a cover. The waste will be put easily inside the composter through that loading hopper using a skid loader or a front-end loader that the university already has.

On one side, the composter will contain a door from which the compost can be taken off when ready. The door will occupy the lower half of the composter’s side.

On the other side, a gear motor that works using solar panels will be installed.

On the backside of the tumbler, a medium size port will be pierced. That port will be used to insert a thermometer in it and monitor the temperature of the compost. A hosepipe can be inserted in that port too to add moisture to the compost.

It is preferable to put the composter in the backside of the annex, the same location of the smaller scale tumbler. That location is an empty large surface where garden waste was centralized. The tumbler will be far from the people’s reach there. Additionally, a basement that accommodates water sources and gardening tools is located in the same area, which can ease the composting process.

The tumbler has been designed using Edraw max software. Edraw is an all-in-one diagram software that provides simple ways to create different types of illustrations and designs. I chose it because it provided me with easy and sophisticated tools to create my tumbler.

Furthermore, this software offers a 30 days free trial, so I was able to make the design for free.
Temperature

2- The Motor:

This capstone project has an ecologic purpose, it aims to make of Al Akhawayn a sustainable university. Therefore, all the composting process components have been thought to achieve that goal. As mentioned in the last paragraph, the composter includes an axe that needs to be turned using a motor; whose power will be implemented using solar panels.

Knowing that the composter will have 27 stick to turn a value of 0.821m³ of compost, and with the help of Mr. Jadid the director of Grounds and Maintenance, we suggested that a motor of 2.2KW would be sufficient. The motor will be a motor redactor for practical purposes.

In order to estimate the number of solar panels that will be used, the following steps have been followed:

1- Computing the optimal power needed for the functioning of the motor:
\[ P_{\text{op}} = \frac{E_p}{I_{r}} \] where: \[ P_{\text{op}} \]: the optimal power needed

\[ E_p \]: the energy produced by the motor

: 2.2KWh

\[ I_{r} \]: the average solar irradiations in Ifrane

: 6 W/m\(^2\) per day

**Figure 19: Solar irradiations in Morocco**

So: \[ P_{\text{op}} = \frac{2200}{6} = 366.66 \text{W} \]

2- Choosing the solar panels:

The solar panels will be multicrystalline ones from the brand Yingli Solar, series YGE 72 CELL and their dimensions are 1960mm/ 990mm/ 40mm. This brand has been chosen because it provides a good quality for small prices.
Referring to the datasheet provided by the company, we estimated that 2 solar panels of a power of 218.8W each will be suitable. (the datasheet is included in the Appendix).

The panels will be installed in south direction at an angle of 45° with respect to earth to optimize their reception of sun radiations.

2- **Needed Equipment:**

In order to put the composter in action, Al Akhawayn already has a skid loader or a front-end loader to collect the waste dispatched all over the university. These same equipment will be used to load the waste into the composter. However, before doing so, the ingredients will need to be shredded. This step is important because the smaller the size of the waste, the faster the composting process. Our objective is to treat 500kg of waste per month, so the process needs to be accelerated. For this task, the university already has a shredder that can process waste from 4cm to 7cm. the shredder is in a perfect shape and will do the work efficiently.

![Figure 20: AUI’s shredder](image)

Figure 20: AUI’s shredder
I don’t think that any additional employee will be needed to achieve the task. One of the gardeners can collect the waste and centralize it in the area behind the Annex, and another one can measure the temperature, the pH, and the moisture at the same time, and will make sure that the compost will be turned once a day.

After the composting process is done, the compost will be collected from the door in the side of the composter. The product should then be screened, so Al Akhawayn should build a large horizontal screen like the one in the following picture.

![Figure 21: Compost screen](image)

3- Waste Collection:

The garden waste, which will be the main ingredient of the compost, is dispatched in different areas in AUI and in the backside of Al Akhawayn’s annex where the tumbler will be put. The university can begin by collecting the waste around to university and transporting it to the annex using a skid loader or a front-end loader it already has.

Relying on the calculations done in the Materials and Methodology part to calculate the idea ratio C:N of 30:1, the used garden waste will be the leaves and the grass clippings.
In addition to the yard waste which will be the main component of the compost, AUI can include kitchen waste and papers to it. However, it has been mentioned earlier that this operation will require a sorting process of the food and the other garbage produced. It is true that this task can be hard to implement since it is not part of our culture, yet, awareness campaigns can be launched in the university to inform the students and the employees about the advantages of composting. AUI can also add informative sessions for the employees to make sure they know which materials can be composted and therefore should be put separately in a trash can and not be mixed with cooked food or meat.

Another material that can be easily sorted is the printing paper. As we walk through the labs, we can notice the big amount of papers thrown in the trashcans. Flyers can be stick above each trashcan in the labs and indicate that the papers should be thrown separately in a different container that will be provided in each lab.

Adding the garbage waste to the compost will result in low waste amounts in Al Akhawayn and higher quality compost.

4- Measuring the temperature:

The temperature can be measured in this up-scaled tumbler through the port already mentioned. A general-purpose bi-metal thermometer will fit perfectly. An employee can measure the temperature daily to monitor the progress of the compost and turn the compost if it overheats.
Figure 22: general-purpose bi-metal thermometer

5- Measuring the pH:
This task can be achieved by taking a sample of the compost from the port of the tumbler, then put it in a baker that contains distilled water, stirring the mixture using a magnetic mixer, then separating the liquid from the solid using a paper filter, and finally measuring the pH of the liquid using a pH probe. This task can either be done by a lab technician, or as a lab assignment for students who take chemistry classes.

6- Measuring Moisture:
Al Akhawayn should purchase a moisture level sensor to monitor the moisture percentage of the compost. Similarly to the temperature measurements, the same employee can measure those two variables as well as the moisture by inserting the sensor from the port.

VI. Financial analysis:
This project aims not only to improve AUI on an environmental level, but also on a financial one. In order to estimate the gains and expenses of a composting system, a financial analysis is done. This part of the project includes:
1- Expenses:

1-1 Creating the composter:

1-1-1 on the small scale:

The initial composter was made using a barrel bought from a scrap yard in Azrou as a container. The axe was bought from the same place, and the other components of the composter were provided by the welder. The tumbler has the capacity to carry 127kg of waste when completely full, but for practical issues only its half have been filled.

<table>
<thead>
<tr>
<th>Expense:</th>
<th>Cost in MAD:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barrel + Axe</td>
<td>110</td>
</tr>
<tr>
<td>Other components</td>
<td>300</td>
</tr>
<tr>
<td>manpower</td>
<td>350</td>
</tr>
<tr>
<td>Paint</td>
<td>50</td>
</tr>
<tr>
<td>Transport</td>
<td>100</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>910</strong></td>
</tr>
</tbody>
</table>

1-1-2 On the large scale:

The composter that will operate on the university level is intended to process 500kg of waste. For quality issues, 1/3 of the composter needs to remain empty, so the composter has to have the capacity to contain 660kg of waste. The expenses for making this composter will depend on how AUI will make the compost. Al Akhawayn University has the ability to make it itself, however this will need welding and metallic components. This can be a little expensive but no exaggerated expenses.
Since the composter will contain 500kg of waste, it will be hard to turn it manually. As such, the tumbler’s axe will be turned using a motor attached to 2 solar panels of the brand Yingli solar.

No additional employees will be needed to maintain the composting system. AUI has a sufficient number of gardeners, one of them can do this task.

Collecting the garden waste in the university is already done on a regular basis by the ground and maintenance department. The equipment needed to achieve this task is available in AUI (skid loader, shredder, screen). The only thing left will be to transport the waste to the Annex.

In order to take the measurements necessary to keep track of the compost, the university is already equipped with the necessary tools, in the exception of the moisture sensor that needs to be purchased. A heavy duty moisture meter probe will fit.

2- Savings:

Al Akhawayn University uses peat for its nursery. Peat is an accumulation of organic materials that decompose in anaerobic conditions where water is abundantly available. This material can be replaced by compost. The university buys 5 tons of peat per year. Each kilogram costs 4MAD, so the university spends 20000MAD on peat per year. Knowing that implementing the composting system will produce 4200kg of compost per year, AUI will be saving an amount of: 4200kg * 4MAD = 16800MAD/year

We will need to subtract from it the initial investment, depending on how much the large scale composter will cost.
VI- Steeple Analysis:

*S for Societal:*
Composting is beneficial for the society for being a tool to raise awareness about the food waste, which can change the social habits. In school, composting can be used as an educational tool.

*T for Technological:*
Composting is an opportunity for Morocco to add the master of green technology to its records. It is important for Morocco to acquire the knowledge of the use of a rising tool in order to enhance its development.

*E for Economic:*
Composting will reduce the cost of send organic waste to landfills as well as the transportation fees to do so. Also, if composting is done in a governmental level, new job opportunities will be created, which will improve the economic status of Morocco.

*E for Environmental:*
The purpose of composting is environmental in the first place. Composting improves the structure of the soil and its fertility, increases moisture and nutrient-holding capacities in the soil and reduces the need for chemical fertilizers.

*P for Political:*
Composting will benefit the Moroccan government, who is constantly seeking development projects that improve the quality of living of the Moroccan citizens. Moreover, such a step will improve the status of Morocco among the other countries for the environmental value that composting has.
L for Legal:

Morocco is part of a total of 119 international environmental treaties, including:

- Convention on Biological Diversity Earth Summit, Rio 1992
- 1992 Amendment to protocol on substances that deplete the ozone layer (amendment to Montreal Protocol), Copenhagen 1992
- Basel convention on the dumping of hazardous wastes, Basel 1989
- Convention on Wetlands of International Importance, Ramsar, Iran 1971
- Kyoto Convention on reduction of greenhouse gas emissions Earth Summit, Kyoto 1997

E for Ethical:

From an ethical point of view, it is our duty as Moroccan citizens to protect our environment and preventing the food waste in our country. We should make a change in Morocco and composting is a great step toward it.
Conclusions and Future Work:

To conclude, this project converted Al Akhawayn’s organic waste into compost using a composting tumbler. The pilot study was made to test the composting process using actual AUI’s waste. Successful results have been found, which means that a larger scale bin would be efficient. Steps and recommendations have been given in the report; however, in order to continue the project, future work should be done on the university level.

The ground and maintenance staff should maintain the composting project since they are the ones who already had a composting initiative. The composter should be made and missing equipment should be purchased. Moreover, kitchen waste should be sorted in order to include it into the composting material. Finally, the whole university should be aware of the importance of compost, to participate in its continuity.
Works Cited:

i Carry on Composting, Home and Community Composting
http://www.carryoncomposting.com/142941469

ii David R. Hershey, Sir Albert Howard an The indoor Process, 1992
http://horttech.ashspublications.org/content/2/2/267.full.pdf

http://journals.sagepub.com/doi/pdf/10.1177/0734242X8300100118

iv ENDA Maghreb, Le traitement alternatif des déchets ménagers pour les petites et moyennes communes au Maroc

v United Nations Industrial Development Organization (UNIDO), High quality compost Towards a sustainable agro-industry in Morocco, 2013
https://www.feedingknowledge.net/home?p_p_id=1_WAR_feeding_knowledgeportlet& p_p_lifecycle=2&p_p_state=maximized&p_p_mode=view&p_p_cacheability=cacheLevelP age&1_WAR_feeding_knowledgeportlet_cmd=serveAttachment&1_WAR_feeding_knowledgeportlet_stepAttachmentId=17605&1_WAR_feeding_knowledgeportlet_calId=966 2&1_WAR_feeding_knowledgeportlet_mvcPath=%2Fcalls%2Fview_all_steps.jsp&1_W AR_feeding_knowledgeportlet_languageId=en_GB

vi Direction générale de l’environnement de la Commission européenne, Expériences réussies de compostage et de collectes sélectives, 2000

vii The Best Colleges, 2017
http://www.thebestcolleges.org/11-college-recycling-programs-that-put-all-others-to-shame/

viii Robert D. Raabe, Cooperative Extension University of California Division of Agriculture and Natural Resources

ix Michelle Dong. et al, Developing a Composting System for Al-Akhawayn University in Ifrane, Morocco, 2014

x Cornell Waste Management Institute, 1996
http://compost.css.cornell.edu/calc/2.html

xii University of Illinois Extention
http://web.extension.illinois.edu/homecompost/science.cfm

xiii Map of solar radiations in Morocco
Appendix:

Yingli Green Energy Holding Company Limited (NYSE: YGE), known as “Yingli Solar,” is one of the world’s leading solar panel manufacturers with the mission to provide affordable green energy for all. Deploying more than 60 million solar panels worldwide, Yingli Solar makes solar power possible for communities everywhere by using our global manufacturing and logistics expertise to address unique local challenges.

PROVEN PERFORMANCE AND VERSATILITY

Independently tested for proven product quality and long-term reliability. Millions of PV systems installed worldwide demonstrate Yingli’s industry leadership.

**Durability**
Durable PV modules, independently tested for harsh environmental conditions such as exposure to salt mist, ammonia and known PID risk factors.

**Advanced Glass**
Our high-transmission glass features a unique anti-reflective coating that directs more light on the solar cells, resulting in a higher energy yield.

**Extended Size**
Our large-format module facilitates system-level cost savings through reduced handling and installation times.

**PID Resistant**
Tested in accordance to the standard IEC 62804, our PV modules have demonstrated resistance against PID (Potential Induced Degradation), which translates to security for your investment.

Yingli Green Energy
Yingli Green Energy Holding Company Limited (NYSE: YGE), known as “Yingli Solar,” is one of the world’s leading solar panel manufacturers with the mission to provide affordable green energy for all. Deploying more than 60 million solar panels worldwide, Yingli Solar makes solar power possible for communities everywhere by using our global manufacturing and logistics expertise to address unique local challenges.
## YGE 72 CELL SERIES 2

### ELECTRICAL PERFORMANCE

<table>
<thead>
<tr>
<th>Module type</th>
<th>Parameters</th>
<th>Stabilized Power (STC, sun=1000W/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Power output $P_{mpp}$</td>
<td>W</td>
</tr>
<tr>
<td></td>
<td>Voltage at P $V_{oc}$</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>Current at P $I_{sc}$</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Open-circuit voltage $V_{oc}$</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>Short-circuit current $I_{sc}$</td>
<td>A</td>
</tr>
</tbody>
</table>

### GENERAL CHARACTERISTICS

- Dimensions (L / W / H): 1960mm / 940mm / 40mm
- Weight: 25 kg

### PACKAGING SPECIFICATIONS

- Number of modules per pallet: 26
- Number of pallets per 40’ container: 24
- Packaging box dimensions (L / W / H): 1960mm / 940mm / 40mm
- Box weight: 707 kg

### THERMAL CHARACTERISTICS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal operating cell temperature</td>
<td>NOCT</td>
</tr>
<tr>
<td>Temperature coefficient of $P_{mpp}$</td>
<td>%/°C</td>
</tr>
<tr>
<td>Temperature coefficient of $V_{oc}$</td>
<td>%/°C</td>
</tr>
<tr>
<td>Temperature coefficient of $I_{sc}$</td>
<td>%/°C</td>
</tr>
</tbody>
</table>

### OPERATING CONDITIONS

- Max. system voltage: 1000V
- Max. series fuse rating: 15A
- Limiting reverse current: 15A
- Operating temperature range: -40°C to 85°C
- Max. static load, front (e.g., snow): 5400Pa
- Max. static load, back (e.g., wind): 2400Pa
- Max. hailstone impact (diameter / velocity): 25mm / 23m/s

### CONSTRUCTION MATERIALS

- Front cover (material / thickness): low-iron tempered glass / 4.0mm
- Cell (quantity / material / dimensions / number of layers): 72 / multicrystalline silicon / 156mm x 156mm / 3 or 4
- Frame (material): anodized aluminum alloy
- Junction box (protection degree): IP65
- Cable (length / cross-sectional area): 100mm² / 4mm²
- Plug connector (type / protection degree): MC4 / IP65 or YT106 / IP65 or Amphenol H4 / IP65 or Phoenix Contact SUNCLIX/IP67

### QUALIFICATIONS & CERTIFICATES

- CE, CB, TÜV, SGS, IMQ, IEC, SGS, TÜV, VDE, SGS, TÜV, VDE, IEC, SGS, TÜV, VDE, IEC
- CEC, ZCS, MCCI, UL, SGS, TÜV, VDE, IEC, SGS, TÜV, VDE, IEC
- TUV-Certified: Module Class I, Power Plant Class I

---

*Yingli Partners:*

Yingli Green Energy Holding Co., Ltd.  
Tel: +86-312-2188055  
service@yingli.com  
YINGLISOLAR.COM

---

© Yingli Green Energy Holding Co., Ltd.  
DS_YGE72-35b_40mm_EU_EN_20160121_V04