Investigation of the applications of solar energy to AUI campus.

EGR 4402
CAPSTONE PROJECT FINAL REPORT

Spring 2017

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Investigation of the applications of solar energy to AUI campus.

Capstone Final Report

Approved by the supervisor

Dr. A. ElBoukili
Acknowledgment

First of all, I thank God who granted us health and guided us to a very thriving conclusion of this work.

Then, my profound thanks address my greatest supervisor: Mr. A. Elboukili for his wonderful orientation, guidance, help and compassion in bringing an extraordinary contribution without which this capstone research would not have been well accomplished. His knowledge, experience and advices provided me with a valuable help and high convenience to end up this work successfully.

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At last but not least, my parents, my decent support and cause of enjoyment and cheerfulness, the ones who all the time provided me with the very best of their life, who made me learn about the real meaning of life and its difficulties, the most incredible parents.

I praise all the people who helped by far or closely to the achievement of this capstone project.

I truly wish that this work can imitate the principles and the standards that you taught me all through my academic career at Al Akhawayn University.
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“The sun will be the fuel of the future”
Anonymous, 1876, Popular Science
Abstract:

The purpose of this capstone project is mainly to evaluate and investigate the applications of solar energy in AUI campus for the simple reason to reduce the cost of the electricity and also to develop the economic growth.

The point is to make use of the most abundant renewable energy source in Morocco, solar panels at the least cost possible, of course, without making bad use of the environment.

My project will be divided into two parts. In the first place, I will investigate how pn-junction and solar cells work, make the image of solar panels and solar arrays clear based on concrete data and then talk about the installations of solar panels; how they work, how they can be installed, their feasibility into AUI campus, their application to building 14 and finally how they promote a green campus.

Then, the second part is the analysis. There will be a comparison between AUI campus and a university in an advanced country like USA that is already using solar energy and find out where and when the solar panels are used. Then I will cover the financial evaluation, which consists of a comparison to the usual use of energy at AUI campus, efficiency study of the new use of solar panels and finally the calculation of annual savings and the payback period at the end.

Nobody denies the importance of solar panels nowadays, we are surely going to see how efficient they are. For this reason, the achievement of this capstone project will allow us to take care of our lovely environment in the most useful and economic way.
Introduction:

Objectives

Nobody can deny how electricity plays an important duty when it comes to the maintenance of our houses and our living environment. For this reason, it is high time to make wide decisions in order to minimize the electricity bill and protect our environment, especially in Ifrane, the cleanest city in Morocco. That is to say, my capstone project will have as aim to:

- To plan and implement an integrated installation on the execution of renewable energy.
- Know how solar panels are much efficient and how much money we may save if we use them, calculating the payback period.
- Independence next to the increasing price of electricity bill.
- The protection of our AUI campus.
- Sensitize people about the importance and the usefulness of solar panels.
STEPPLE ANALYSIS

**Societal:** there is a high demand in renewable energies and a high electricity expenditure

**Technological:** The incessant improvement of technology turns the software less complicated to execute

**Environmental:** decrease the environmental crash of energy and the natural trail in the world.

**Ethical:** keep away from the ravage of energy and promote reliability upon the environment.

**Political:** update the energy rule in the direction of the use of renewable energy.

**Legal:** The government of Morocco is making new energy strategies to encourage renewable energies

**Economical:** decrease the electricity monthly bill and produce revenues.
Chapter 1: Evaluating Solar PV systems Potential

1-1 What is a solar panel?

Figure 1: solar panels

Solar panels are devices that convert natural energy (mainly the sun) into electricity. They are in charge of collecting solar radiations and change them into electrical energy. Actually, solar panel is a collection of many solar cells that are known to be photovoltaic cells. The collection can be formed by connection them into parallel or series links depending on the energy needed.

The main element that makes up a solar well is known to be the photovoltaic cell which its role is to convert the sun rays into electricity.

Mainly, the majority of solar panels are constituted from solar cells that are made of crystalline silicone meaning "monocrystalline, polycrystalline, amorphous silicon, or hybrids".
1-2 Efficiency of solar panels:

The most efficient solar panels in the whole world are 40 to 50% efficient. Unfortunately, they are extremely expensive. One should balance between the efficiency of the solar panels and their costs.

Generally, most domestic solar panels are 10 to 25% efficient; people look for panels from which they expect the best return on savings rather just for their efficiency.

Figure 2: Silicon in nature
Larger space is needed for less efficient solar cells so as to produce the same amount of electricity like the efficient one.

Below is an illustration of the efficiency of very known but less efficient solar panels which more often brings in, a higher return on investment than the expensive ones.

Table 1: Famous solar panels

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model</th>
<th>Type</th>
<th>Module Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>SunPower</td>
<td>245-235</td>
<td>Monocrystalline</td>
<td>20.1%</td>
</tr>
<tr>
<td>SunEdison</td>
<td>Silvantis R-Series</td>
<td>Monocrystalline</td>
<td>17.7%</td>
</tr>
<tr>
<td>Yingli Solar</td>
<td>YL225C-24b</td>
<td>Monocrystalline</td>
<td>17.1%</td>
</tr>
<tr>
<td>REC</td>
<td>TwinpeakSeries</td>
<td>Monocrystalline</td>
<td>16.7%</td>
</tr>
<tr>
<td>Ja Solar</td>
<td>JAM6 48-220/SI</td>
<td>Monocrystalline</td>
<td>16.6%</td>
</tr>
<tr>
<td>Suntech</td>
<td>STP265/WEM</td>
<td>Polycrystalline</td>
<td>16.3%</td>
</tr>
<tr>
<td>Trina</td>
<td>PA05</td>
<td>Polycrystalline</td>
<td>16.2%</td>
</tr>
<tr>
<td>Jinko Solar</td>
<td>JKM265P</td>
<td>Multicrystalline</td>
<td>16.2%</td>
</tr>
<tr>
<td>Canadian Solar</td>
<td>CS6P</td>
<td>Polycrystalline</td>
<td>15.9%</td>
</tr>
<tr>
<td>Yingli Solar</td>
<td>YL205P-23b</td>
<td>Multicrystalline</td>
<td>15.8%</td>
</tr>
<tr>
<td>Solar World</td>
<td>SW 260</td>
<td>Monocrystalline</td>
<td>15.5%</td>
</tr>
<tr>
<td>Sharp</td>
<td>NU-U23F1</td>
<td>Monocrystalline</td>
<td>14.4%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------</td>
<td>-------------------</td>
<td>----------------</td>
<td>--------</td>
</tr>
<tr>
<td>Yingli Solar</td>
<td>YL 235 P-29b</td>
<td>Polycrystalline</td>
<td>14.4%</td>
</tr>
<tr>
<td>Kyocera</td>
<td>KD210GH-2PU</td>
<td>Polycrystalline</td>
<td>14.1%</td>
</tr>
</tbody>
</table>

Of course, as any other solar panel, its efficiency depends on many properties, here are some of them.

- Depends on the amount of energy over a given area.
- How far/close it is to the sun.
- Location of the solar panels.
- How big are the cells.
- Type of the solar cell.
- How much the sun affects the cell?
- Extent of solar energy that knockouts the earth

1-3 Doping of a semiconductor material

Talking about Silicon, it has many properties. The atom of silicon contains 14 electrons, grouped in three different shells (see below). The first two shells that contains two and eight electrons in row, are totally full. The outer shell, in contrast, holds four electrons. This way, the silicone tom will always look for ways to complete its outer shell. It will intervain electrons with four nearest atoms. This is known to be the crystalline structure which is extremely important for this kind of photovoltaic cell.
The only main issue with this crystalline silicon is that it is not a good conductor of electricity because its electrons can’t move around. To solve this issue, there are many impurities within the solar cell. Other atoms mix with the silicon atom for a given purpose. Solar panels do not work without theses impurities. Silicon may append with an atom of phosphorous which has five electrons in its last shell, it will bond with the atoms of silicon. In fact, this does not form a bond, but there exists a positive proton inside the phosphorous nucleus that holds it.

When we apply a certain energy to the silicon, if we heat it for example, the heat causes the electrons to disperse of their connection and leave their atoms. These electrons move around the crystalline lattice looking for a place to get attached to. These electrons, of course, hold an electrical current, and this is what we mean by doping.
When the silicon is doped with the phosphorous, what we get is of N-type (negative) for the reason of the prevalence of able electrons. This negative type silicon when doped is known to be a much better conductor than clean silicon.

On the other hand, the other part of the solar cell is doped with boron, which has three electrons in its last shell, and it is of a P type.

1-4 What is a Pn-junction/ how it works?

Previously, our two parts of silicon were neutral; what is more challenging is when we create an electric field so as for the cell to work. This electric field is created when both the N-type and P-type contact each other’s. Here is a closer look at how it works:

Figure 4: anatomy of solar cell/ pn junction
1-5 How does diode convert sunlight into electricity?

Exactly at the junction, the electrons at the P and N side mix together and constitute something which enables them to cross over each other. Ultimately, there is equilibrium, and an electric field unravelling the two sides which acts like a diode that permits the electrons to move from the P side to the N side.

When exposed to light, photons smash the solar cell, thus, the energy provided disrupt the electron couples. Then, each photon takes its specific direction. If this occurs to the near area of the junction, the electric field will make the electron move to the N side and the hole to the other side. Furthermore, if we offer an additional current path to the side of P so as to gather with the holes sent by the electric field, the electron movement offers the current and the cells field creates the voltage. If we multiply these last two, we will get the power.

1-6 What are the four generations of solar cells today?

Nowadays, we have found practically four generations of solar cells, expended below:

1st generation: it is the first generation photovoltaic cells and silicon is still presiding in the market because of its several advantages. These cells are classically made up of crystalline silicon cracker and they demand huge areas and spaces.
2nd generation of solar cells:

Known as (PECVD): which stands for Plasma Enhanced Chemical Vapor Deposition. Here again, four types of solar cells were introduced.

- Amorphous Silicon cells, their band breach was about 1.7 eV and they function like silicon.
- Polycrystalline Silicon are clean silicon grains, they work better than previous designs.
- Cadmium telluride (CdTe) cells are less expensive than silicon but not better than them when it comes to the efficiency.
- Copper indium gallium dieseline (CIGS): in this case, cells are put on glass or stainless steel and are a bit multifaceted...

They are presented below, respectively.
3rd generation of solar cells:

This generation differs from the others because of the inventive semiconductors that take place in here. Types of solar cells announced in this generation include many cells such as Nanocrystal solar cells; Polymer solar cells.…

4th generation of solar cells:

In this generation, polymers and nano particles were diverted so as to make a layer that can support electrons and protons to move with a voltage and a good current.

Below is an illustration of this fourth generation:
Chapter 2: Universities turning solar

Solar energy has improved massively during these last time, achieving more and more efficiency and becoming a more amiable option for many people. At its very first invention, the maximum reachable efficiency rate was 6%.

Today, the majority of cells have an efficiency rate of about 25%, others than can go till 40%.

As mentioned during my first part, Solar PV is considered dirt-free energy since it comes from a renewable resource which is the sun. Our planet is constantly receiving energy from the sun, so why not make use of it?

Overall solar is a very environmentally friendly solution in a society that uses colossal amounts of energy.

To make the image clear why I Thought of applying Solar at AUI Akhawayn university, I decided to mention three universities which are Brandeis, Harvard, and Stonehill that are making a lot of profit by using solar panels, and have more or less the same conditions of AUI campus.

2-1 Harvard University

Harvard university: this university turned solar on eight of its current buildings that mainly generate about 590,000 kWh/year. The university buys its energy generally from offsite sources and owns a wind turbine located in one of its big buildings. 17% of their electricity energy generally comes from renewable solar sources, which make them save a lot of money and thus the university turns green.

2-2 Stone Hill University

Stonehill College is so much known for its use of solar cells. It contains about 9,000 solar panels. This college save about $185,000/ year on energy costs with 20% efficiency.
Moreover, the panels are used far from the university, it is the university right if they try to make it less noticeable. Personally, I do not have the idea to make the solar panels not visible at AUI or hidden in campus, I think that it is so significant that students can physically recognize the link between the panels and the buildings.

2-3 Brandeis University

Brandeis University: here the panels are installed

On the roofs of the building. These panels came out to generate 10% efficiency per year. This plan is what I think should be the closest to my proposed project at Al Akhawayn university. This is a good place to start, and hopefully, if AUI falls in love with solar, the administration would then think to add more in each building.

Chapter 3: engineering study

3-1 Methodology

As mentioned earlier, the main purpose of this capstone is mainly to make a good use of solar panels at Al Akhawayn University and to try our best in order to turn green. For this reason, we will try to implement solar energy using solar panels to AUI campus and find out at the end how efficient the panels will be.
During the implementation of this capstone project, I tried to use the rule of elimination so as to determine the best building to apply my research on and to know the best location to place my panels at Al Akhawayn University. Through discussions with my supervisor from the beginning of the semester I was ordered to come up with a decision about which building to pick. Which building among the 41 buildings would be most beneficial to AUI. From the 41 building, the building choice was narrowed, the decision was based on many criteria summarized as follow:
Not only that, I chose the building 39 because it is opened the whole year, contrarily to some other buildings that are opened only in the fall or spring semesters.

At the beginning of my research, I was trying to install the solar cells on the roof of building 39, but my supervisor was not okay with it because it will grab a lot of difficulties and implications that will cost us a lot more than the project itself. We ruled this case out after because of aesthetics. Furthermore, it will mainly affect the architecture of the university and the campus appearance. I neglected the other buildings because they are not as big as the big buildings like building 38 or 39, those buildings are just too small to invest solar panels in them. Another criteria is the energy consumed over the whole year, and building 39 is one of the biggest buildings that consume a lot of energy and that is worth investing solar energy on.
Concerning the location, it has been found that the building 39 has a very large space in front of it, this area is never used. I thought of installing the panels there. Furthermore, this area is freshly directed to the sun. So, we will not be obliged touch the forest or cut the trees to find space.

3-4 Survey conducted:

Analysis of energy consumed in building 39:

During my research, I conducted a survey in order to know more about the energy consumption in building 39. To better know how people living there generate power during their daily lives. About six questions were asked. I also contacted the building of grounds and maintenance to have more exact information and I found out that there is on average 700000 kWh that is needed per year that the housing buildings consume; still, this is a huge number that should be analyzed.

The first question that was asked was whether the residents of building 39 properly close their French doors / windows/ doors in their rooms. Here is the results found:

It is the choice of the resident to control his / her heaters in their rooms. As a start, there is no insulation since there is a distinction between the warm and cold spaces.
Among 92 students, 25% of the residents’ doors or windows do not close properly, this is a serious problem because it affects the whole heating system of the building and its efficiency decreases with time. This means that there exists a kind of transition of cold air into the inside of the room.

The other question that was asked is at what degree you set your heaters to, there were three possible answers which are between 0 and 3, or between 3 and 6, or between 6 and 8. These were the results found.

As mentioned, the heaters can be adjusted to a certain number of heat needed. The maximum level of temperature is 8. Unfortunately, residents, most of them adjust them between 6 and 8, which is the maximum of what they can reach. Some of them just open the window when the room turns too hot, which causes a big loss of energy.

In addition to these questions, I asked the residents of building 39 to tell what time do they turn their light off when they want to sleep. Unfortunately, 100%, all of the interviewed residents turn it off after midnight. This result was a bit deceiving because the late time they sleep the more power they consume during the night.
Figure 10: At what time do you turn your light off when you want to sleep?

At last but not least, the two last questions that were asked were: do you turn on the light during the light? And how much power you think you consume during the day. I found these were important questions especially for my part coming concerning the energy audit and financial analysis and computation, I will rely on these results in order to make many assumptions. Below are the results gathered:

Figure 11: (do you turn on the light during the day)
Chapter 4: energy audit of the concerned building

4-1 definition and procedure:

By definition, the energy audit is known to be a kind of survey or inspection of the usage of the energy in a surface area. It is measured by people using professional tools or some background information.
A very detailed data collection of energy is really beneficial for my project. I should be gathering every single information about everything that works with electricity in building 39. This way, I may have a very close estimation about the monthly consumed energy in the whole building, so that I can start my project and the installation of solar panels. Every source of energy such us, the consumption of light bulbs, the consumption of heaters, refrigerators, kitchen machines, consumption of TVs…

Thanks to the department of grounds and maintenance that provided me with all information I need.

To begin, here is the general information about the building 39, its number of rooms, its number of residents, its area and finally the number of floors it contains.

<table>
<thead>
<tr>
<th></th>
<th># of rooms</th>
<th># of residents</th>
<th>Area(m²)</th>
<th># of floors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building 39</td>
<td>120</td>
<td>216</td>
<td>2000</td>
<td>5</td>
</tr>
</tbody>
</table>

To make the image clear, the number of residents change from one semester to another depending on the availability of preferred rooms. To another extent, if the number of the residents enrolling in this building is large, a double room can turn up to a triple room.
4-3 Energy audit

4-3-1 Lighting:

Since the building 39 is open the whole year and its main purpose is the satisfaction of its residents, it requires a good executive lighting system so as to generously improve energy usage by reassuring an efficient electrical lighting.

The building 39 uses three different lighting bulbs:

- The incandescent bulb (shown below), there are about 92 of them present in the stairs and in the hall of the building. They consume no more than 75 W each and they are on approximately eight hours per day. Concerning their consumption per day, it is about 55.2 kWh.
• The compact fluorescent lamp (shown below): there are about 51 of them present in the kitchens and stairs. They consume no more than 18 W each and they are on approximately nine hours per day. Concerning their consumption per day, it is about 8.26 kWh.

Figure 12: The compact fluorescent lamp

• The light spot: it is the most used one in the whole building. Used in the rooms of both girls and boys, and there are about 5 of them per individual room. About more than 600 spot is present in the building and they consume about 12 W and consume around 100.8 kWh per day.
4-3-2 heating system:

Because of its location in a cold city like Ifrane, building 39 is obliged to use many heating systems especially in snowy days. For this reason, the building needs to be well equipped to satisfy its residents. The heating system budget is expensive because of the obsolete material; we will try to find a way to diminish the energy consumption due to the heating and cooling. The building uses only the steam radiators that can quickly heat up the room in seconds. There are about 265 of them present everywhere in the building, in the rooms, in the kitchens and in the hall. Their rating per watt is about 1500 W each, and they work 12 hours a day during cold days. Here is an example taken from inside my friend’s room:

![Figure 12: steam radiator](image)

4-3-3 Other appliances:

Many other equipment are used in the building like the refrigerators, the electric iron, the washing machine, the toaster, the televisions, the kitchen fan, the microwave, the computer, the internet router and the cell phone chargers. Many details of these other appliances will be provided in details during the financial part.
Here are some examples of the other appliances that are used in the building:

Figure 13: Microwave

Figure 14: the television
Figure 15: refrigerator

Figure 16: toaster
Chapter 5: Energy Savings Enhancements & Feasibility study

5-1 Previous installation of solar panels at Al Akhawayn University

There is only one small building that uses the solar energy to satisfy its needs. In fact, unfortunately, it uses this kind of energy only for heating water. This building is the 19. The source of energy is not from these panels.

The installation of these panels was made in 2006, eleven years ago.

It is made up from sixty (60) solar panels each of 1.5 kW. Their investment cost was 250000 MAD. Concerning their energy, they have preserved about 24 404 kWh or more since the beginning of their installation.

5-2 Current source of energy of building 39

The current building 39 is considered to be a double wings habitation hall. It comprises new fresh technologies concerning power production. As a substitute of the old classical system of electricity, this building is doped of boilers that automatically transform energy absorbed from fuel into steam. The water that is heated shrubberies the boiler and is second handed for water boiling, the cohort of water, and the central heating also. What is good about this building is its thermostat dominant continuous controlled radiators.

5-3 Suggested panels from Morocco

I chose Jinko Solar as a supplier because it is a much known PV selling company present worldwide. It is a Chinese producer of PVs and a creator of solar panels. The firm began as a cracker manufacturer at the end of 2006 and received its IPO in 2010. Jinko Company has a combined business model engineering wafers, lockups and units. Its capacities at its very beginning were 5 GW, 4 GW and 6.5 GW. Jinko Solar has around 15,000 staffs working and 5 production locations.
In Morocco, it is present in Casablanca under two different stations. After contacting the company in Morocco, we agreed on everything, the price of the solar panels, the installation cost and the transportation cost. For them, each panel generates around 275 W each and their cost is about 2000 MAD. Here are its dimensions:

![Figure 17: dimensions of the proposed panels](image)

Here is to give an idea about their power:
Figure 18: power consumption of the chosen solar panels

Actually, in order to save space, we agreed on doing them the way shown in the part of solidworks after this.

5-4 modeling using Solidworks:

Taking into consideration that there is not enough free space next to the building 39, I tried to do the design of the panels using Solidworks and my designed was approved by the company, they are able to do the support in order to save space in the parking. Hence, it will not only be an installation of the solar panels, but also it will be a kind of covering the vehicles in the parking.

Here is what I thought of:
There will be four panels on every support in order to save a lot of space.

5-5 Feasibility study at AUI campus:

Obviously, Expending renewable energies as font for the electrical organization may significantly contribute to decreasing the bill of energy per month and make Al Akhawayn university as eco-friendly as possible. The answer that best outfits the energetic desires of building 39 is of course a PV system joined with large capacity batteries that will be explained afterwards. Fitting theses PV systems correctly is vital to grasp ideal power construction and have a supreme energy balance and economic payback. Consequently, a
perfect orientation must be implemented so as to attain both, the optimum control construction and the financial payback.

In a wide-ranging side, the perfect direction for these panels is definitely the south. Losses are between 15 to 25% were met for panels fronting the west or the east. But thanks to our recent discoveries, these losses were reduced over inverters that are capable to boost off the south directions.

This installation should be done during the sunny days (approximately from April to September) because of the high rate of efficiency during these times. Yet, when it is cold and the snow falls in Ifrane, there should be a reserve which is the classical old method; the electrical heating method. Even though Al Akhawayn University will not trust totally at 100 % the solar heating from the first time, but this resolution will decrease the electricity bills (significantly) during the sunny periods substantially.

Figure 19: PV Solar System
All in all, the best alternative then is making the use of the solar heating systems which are known to be an effective way to make hot water for buildings. The advantage of this scheme is that it is able to be used at any weather because they depend only on sunshine. For my case, I think it is more effective to make use of a solar heating system just like those inside campus. As far as my project is concerned, the structure’s pumps mingle a non-freezing high temperature transfer fluid over its amassers and a heat certain exchanger to evade the system’s bang due to the very freezing weather during the middle of the year. This procedure warrens the water that moves inside the building. Here is the system:

Figure 20: Active Solar Heating System

This scheme’s unit costs about 20,000 MAD.
5-6 The Sun in Ifrane

Using Meteonorm 7, it is a software that can count how many sunny days are per year in a certain location, it has been proved that the city of Ifrane has on average 5.5 kWh/m²/day, and because the city has about 6 sunshiny months each year which is equal to 180 days, formerly the quantity of energy each year is about 927kWh/m².

![Figure 21: Distribution of Solar Energy per meter square in Morocco](image)

This is to say that this capstone project will not only recover the energy funds, but it will similarly relief making of Ifrane a cleaner city, and Morocco an environment friendly nation.

I used Meteonorm 7, a software that calculates the radiation of the sun, the number of sunny days per year etc. here are screenshots from the software:
Figure 22: the sunshine duration at Ifrane city
Figure 23: the yearly temperature at Ifrane city
Figure 24: the daily global radiation at Ifrane city
Ifrane

Result informations
Uncertainty of yearly values: \( G_h = 4\% \), \( B_n = 8\% \), \( T_a = 0.3 \, ^\circ C \)
Trend of \( G_h \) / decade: 3.4\%  Variability of \( G_h \) / year: 3.4\%
Radiation interpolation locations: Satellite data (Share of satellite data: 100%)
Temperature interpolation locations: Midelt (99 km)

Figure 25: the radiations at Ifrane city
Ifrane

<table>
<thead>
<tr>
<th></th>
<th>Gh kWh/m²</th>
<th>Dh kWh/m²</th>
<th>Bn kWh/m²</th>
<th>Ta °C</th>
<th>Td °C</th>
<th>FF m/s</th>
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<td>February</td>
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<td>36</td>
<td>122</td>
<td>8</td>
<td>-1.2</td>
<td>3.2</td>
</tr>
<tr>
<td>March</td>
<td>182</td>
<td>55</td>
<td>183</td>
<td>11.1</td>
<td>0.1</td>
<td>3.3</td>
</tr>
<tr>
<td>April</td>
<td>184</td>
<td>52</td>
<td>186</td>
<td>13.2</td>
<td>2.3</td>
<td>3.4</td>
</tr>
<tr>
<td>May</td>
<td>206</td>
<td>79</td>
<td>188</td>
<td>16.8</td>
<td>5.9</td>
<td>3.3</td>
</tr>
<tr>
<td>June</td>
<td>240</td>
<td>61</td>
<td>255</td>
<td>22.6</td>
<td>8.2</td>
<td>3.1</td>
</tr>
<tr>
<td>July</td>
<td>247</td>
<td>60</td>
<td>268</td>
<td>26.1</td>
<td>8.7</td>
<td>2.9</td>
</tr>
<tr>
<td>August</td>
<td>230</td>
<td>52</td>
<td>271</td>
<td>24.9</td>
<td>9.2</td>
<td>3.0</td>
</tr>
<tr>
<td>September</td>
<td>174</td>
<td>52</td>
<td>195</td>
<td>20.5</td>
<td>8.8</td>
<td>3.0</td>
</tr>
<tr>
<td>October</td>
<td>141</td>
<td>43</td>
<td>174</td>
<td>15.6</td>
<td>6.5</td>
<td>2.9</td>
</tr>
<tr>
<td>November</td>
<td>102</td>
<td>33</td>
<td>153</td>
<td>9.8</td>
<td>1.6</td>
<td>3.2</td>
</tr>
<tr>
<td>December</td>
<td>87</td>
<td>32</td>
<td>135</td>
<td>6.8</td>
<td>-0.8</td>
<td>3.3</td>
</tr>
<tr>
<td>Year</td>
<td>1968</td>
<td>598</td>
<td>2283</td>
<td>15.1</td>
<td>3.9</td>
<td>3.1</td>
</tr>
</tbody>
</table>

Result informations
Uncertainty of yearly values: Gh = 4%, Bn = 8%, Ta = 0.3 °C
Trend of Gh / decade: 3.4%  Variability of Gh / year: 3.4%
Radiation interpolation locations: Satellite data (Share of satellite data: 100%)
Temperature interpolation locations: Mideit (99 km)

Figure 26: the exact data table

Calculations I need:

From the above screenshots from meteonorm 7, it has been shown that there are about 8 sunny months in Ifrane
Table 3: data about the weather in Ifrane

<table>
<thead>
<tr>
<th>Month</th>
<th>Daily Sunshine duration (hour)</th>
<th>Monthly sunshine duration</th>
<th>Global radiation(kwh/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>march</td>
<td>7</td>
<td>210</td>
<td>160</td>
</tr>
<tr>
<td>April</td>
<td>7</td>
<td>210</td>
<td>180</td>
</tr>
<tr>
<td>May</td>
<td>8.3</td>
<td>249</td>
<td>200</td>
</tr>
<tr>
<td>June</td>
<td>10</td>
<td>300</td>
<td>240</td>
</tr>
<tr>
<td>July</td>
<td>11</td>
<td>330</td>
<td>244</td>
</tr>
<tr>
<td>August</td>
<td>10.2</td>
<td>306</td>
<td>230</td>
</tr>
<tr>
<td>September</td>
<td>8.2</td>
<td>246</td>
<td>170</td>
</tr>
<tr>
<td>October</td>
<td>7</td>
<td>210</td>
<td>130</td>
</tr>
</tbody>
</table>

Chapter 6: financial study

6-1 electricity bill chart

<table>
<thead>
<tr>
<th>Time of the Day</th>
<th>Unit Price (MAD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Time</td>
<td>1.3277</td>
</tr>
<tr>
<td>Normal Time</td>
<td>0.9274</td>
</tr>
</tbody>
</table>

Figure 27: Electricity bill chart
6-2 lighting

Al Akhawayn University mostly uses fluorescent bulbs, the CFCs, incandescent lump and pressure sodium lamp.

<table>
<thead>
<tr>
<th>Type of lamp</th>
<th>Quantity</th>
<th>Rating/watt</th>
<th>Hours used/day</th>
<th>Consumption/day (kwh)</th>
<th>Consumption/year (kwh) (11 months, 330 days)</th>
<th>Average yearly cost (MAD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incandescent bulb</td>
<td>92</td>
<td>75</td>
<td>8</td>
<td>55.2</td>
<td>18216</td>
<td>24045.12</td>
</tr>
<tr>
<td>Compact fluorescent lamp</td>
<td>51</td>
<td>18</td>
<td>9</td>
<td>8.262</td>
<td>2725.8</td>
<td>3598.056</td>
</tr>
<tr>
<td>Light spot</td>
<td>600</td>
<td>12</td>
<td>14</td>
<td>100.8</td>
<td>33264</td>
<td>43908.48</td>
</tr>
</tbody>
</table>

Table 4: data table of lighting
* Peak time

**Results:**

Total lighting energy consumption/ year: **54205.8 kWh**

Total lighting cost/year: **71551.65 MAD**

**6-3 heating:**

<table>
<thead>
<tr>
<th>heater</th>
<th>quantity</th>
<th>Rating/ watt (W)</th>
<th>Working hours/day</th>
<th>Consumption/day (KWH)</th>
<th>Consumption/year (KWH)</th>
<th>Average yearly cost(MAD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>heater</td>
<td>265</td>
<td>1500</td>
<td>12</td>
<td>4770</td>
<td>858600</td>
<td>789912</td>
</tr>
</tbody>
</table>

- (normal time) **Results:**
  - Total energy consumed (heaters)/ year: **858600 kwh**
  - Total price in MAD: **789912**
6-4 Other appliances:

<table>
<thead>
<tr>
<th></th>
<th>Quantity</th>
<th>Rating/ watt (W)</th>
<th>Working hours/day</th>
<th>Consumption/day(KWH)</th>
<th>Consumption/year (KWH) (330 days)</th>
<th>Average yearly cost (M AD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refrigerator</td>
<td>180</td>
<td>124</td>
<td>24</td>
<td>535.68</td>
<td>176774.4</td>
<td>162632.44</td>
</tr>
<tr>
<td>Electric iron</td>
<td>120</td>
<td>1000</td>
<td>1</td>
<td>120</td>
<td>39600</td>
<td>36432</td>
</tr>
<tr>
<td>Washing machine</td>
<td>80</td>
<td>500</td>
<td>2</td>
<td>80</td>
<td>26400</td>
<td>24288</td>
</tr>
<tr>
<td>toaster</td>
<td>120</td>
<td>750</td>
<td>0.25</td>
<td>22.5</td>
<td>7425</td>
<td>6831</td>
</tr>
<tr>
<td>Television</td>
<td>100</td>
<td>135</td>
<td>6</td>
<td>81</td>
<td>26730</td>
<td>24591.6</td>
</tr>
<tr>
<td>Kitchen fan</td>
<td>4</td>
<td>180</td>
<td>3</td>
<td>2.16</td>
<td>712.8</td>
<td>655.76</td>
</tr>
<tr>
<td>Microwave</td>
<td>130</td>
<td>1500</td>
<td>0.5</td>
<td>97.5</td>
<td>32175</td>
<td>29601</td>
</tr>
<tr>
<td>appliance</td>
<td>250</td>
<td>150</td>
<td>6</td>
<td>225</td>
<td>74250</td>
<td>68310</td>
</tr>
<tr>
<td>------------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td>Home</td>
<td>27</td>
<td>10</td>
<td>24</td>
<td>6.48</td>
<td>2138.4</td>
<td>1967.3</td>
</tr>
<tr>
<td>internet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>router</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>oven</td>
<td>6</td>
<td>280</td>
<td>2</td>
<td>3.36</td>
<td>1108.8</td>
<td>1020.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>96</td>
<td>96</td>
</tr>
<tr>
<td>Cell</td>
<td>250</td>
<td>30</td>
<td>10</td>
<td>75</td>
<td>24750</td>
<td>22770</td>
</tr>
<tr>
<td>phone</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>charger</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5: data table of other appliances

**Results:**

Total energy consumption of other appliances: **412064.4 kWh**

Its cost: **379099.18 MAD**

6-5 Recapitulation

<table>
<thead>
<tr>
<th>appliance</th>
<th>Total energy consumption (kwh)</th>
<th>total in MAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighting</td>
<td>54205.8</td>
<td>71551.65</td>
</tr>
<tr>
<td>Heating</td>
<td>858600</td>
<td>789912</td>
</tr>
<tr>
<td>Other appliances</td>
<td>412064.4</td>
<td>379099.18</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1324870.2</td>
<td>1240562.83</td>
</tr>
</tbody>
</table>

Table 6: recapitulation of results found
6-6 Installation cost

It is so true that the installation of photovoltaic panels is not very common in Morocco, suppliers are rarely present. Luckily, Jinko solar, the company from where I am going to buy the solar panels also makes the installation itself. They will take into consideration how much money will be paid concerning the panels and thus reduce a bit for us the installation cost. As being informed, the price of the installation cost for individuals goes from 10000 MAD to 100000 MAD to cover the needs of the whole building and the electricity consumption. This price includes the solar balance sheet and the layer of the panels. All in all, the installation will cost around **75000 MAD** and will take about 24 to 48 hours for installation.

6-7 number of panels needed for the project

Number of panels needed to do my project is as follows:

The Wattage of 1 panel is 275W

The Yearly energy then becomes

\[ = 0.275 \times (210+210+249+300+330+306+246+210) = 566.775 \text{ kwh/panel} \]

The efficiency of the panels is 20%, so here is how many panels we will need:

\[ 1324870.2 \times (20\%) / 566.775 = 467 \text{ panels needed.} \]
The total area needed for my project

Area needed for these panels:

1 panel $\rightarrow$ 1.63 m²

467 panel $\rightarrow$ 761 m² area needed

6-9 total cost for the project and the payback period

For the panels

- money needed to buy the total panels

  2000(per panel)*467=934000 MAD

- For the installation cost 75000 MAD

- Total cost for the project is 1009000 MAD Payback period =

(934000+installation cost)% 1240562.83 = 0.81

Around 8 years payback period.
These are the savings per year:

Table 7: the savings per year

<table>
<thead>
<tr>
<th></th>
<th>ENERGY</th>
<th>COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAVINGS</td>
<td>20% (1324870.2)</td>
<td>264974.04*0.92</td>
</tr>
<tr>
<td></td>
<td>= 264974.04</td>
<td>= 243776.11</td>
</tr>
</tbody>
</table>

**Conclusion**

Thomas Edison once said “I’d put my money on the sun and solar energy.” Of course, he said that based on pure evidence and experiences. It is unbelievably true how much solar energy can save millions of dirhams depending on the amount of kWh per year. My capstone project aimed just one building among 41 buildings in the university, and the savings were tremendous, how about if we could install and apply the solar panels in all the other buildings of Al Akhawayn University. The sun is the only maintainable source of energy in the world, so why don’t we use it and make especially when fossil fuels are finite, at a time or another. On the other side, unfortunately, a lot of toxic gases are harming our environment every single day of our lives. It is true that Climate change our days is not given that much importance, very few people are paying attention to it. The usage of solar panels is definitely the ultimate solution to these phenomenon. There is a fact about these
panels which underlines that casing only 1% of the whole desert of the world with panels may afford about one fifth of the planet’s electricity, how huge is this. It is high time to make a better use of the free energy so as not only to save money and energy but also to be environmentally friendly which is much more important than anything else. In addition, when solar panels duos with greenhouses, its plants can also raise vegetables and fruits and that is by making use of the evaporators of water. On the other hand, even if my project budget may be a bit expensive, one should look in the very long run and how much power and energy we can save. What has been stated all above is just the theoretical part, it is high time, to my view, to move to the practice and to the application.
References

- "How to Install an Exterior Solar Panel." DIY. Ed. DIY Rowan Network. DIY
Appendices

Appendix A: Modeling of solar panels