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Calculations

2. Calculations and design

2.1. General information

The farm produces dairy products. It is divided into two parts: a working area on the left Figure 29 and a house on the right (green roof).

As mentioned before the farm is 5 kilometers far away from Călugăreni's terms (Neamt county, Romania).

Figure 29: General overview of the farm

Location: Bacâu, Neamt County (Romania)

Coordinates: 47°04'19.2"N 25°56'06.1"East

Elevation: 864 m above sea level

The energy what the farm requires can be divided into two parts: Electrical and Heat needs.

The production part of the farm is used the whole week, while the house is kept for use during weekends by the owner. We see that two clearly different parts exist, the production area of the farm, and the house itself.

The method for sizing the installation, will be choosing for the least favorable month, this means the month when the solar irradiation is the lowest throughout the year.

2.2. Sizing process guideline

Before jumping right into the calculation process, a guide will be established in order to make easier to follow the whole process.

The process for sizing the installation will be as follows:

1. **Calculating the power needed for the installation**
2. **Measuring the wind and sun resources**
3. **Small wind turbine sizing**
4. **Photovoltaic installation sizing**
5. **Sizing of the battery system**
6. **Inverter and regulator**
7. **Connection lines between elements**
8. **Protections**
9. **Others**

The exact reasons why certain elements were chosen etc… has been exposed on previous chapters of this case study, so in case of doubt about some of the aspects about to be exposed check part 1.5 and 1.6, where the reasons are deeply explained.

Calculations also will be included in this section, such as emissions to the atmosphere saved thanks to the installation. The distance needed between the solar panels, the selection of the type of solar panel etc..

2.3. Power needs of the installation

The installation consumptions can be divided into two parts: Consumptions related to production and consumptions related to the house. All consumptions of the farm are considered to be AC.

The production part consumes the most; it has two elements, an electrical boiler and a refrigeration device. The boiler is used along the year used for the production of dairy products, boiling milk and other elements for the elaboration of different products. The fridge is in continuous use to preserve the dairy products.

- **Electrical boiler:** Power: 2000W
- **Industrial fridge**: Power: 750W

On the other part, the house has a basic electrification degree. It has the following elements:

- **Fridge**: Power: 150W
- **Cleaning machine**: Power: 1000W
- **Electrical stove**: Power: 2000W
- **Lights**: Power: 40W Amount: 20
- **Power sockets**: Power: 3450W Amount: 10
- **Water pump**: Power: ½ CV≈367,5W

Also the house has heating system which is used in winter during the three coldest months.

Now that we have the power needs we will need now the Wh/day that the installation consumes every day. This is needed for the sizing of the power generation system. A series of factors will be used, so the installation is not oversized, these factors are taken from the Spanish regulation ITC-BT-25 [26]

For the amount of hours of use for each element a combination of collected data from the owner, studies of use [27][28] and own consideration has been followed.

We know the **boiler** is used all around the year for a total of **2100h/year**. The rest of the elements need to be studied in order to determine the amount of hours they are used.

- **Fridge and Industrial fridge:** Around 8 hours every day. And they work 7 days/week
- **Cleaning machine:** Considering that the house is used on weekends. 1 hour/day and 2 days/week of use.
- **Electrical stove:** 2 hours of use a day for 2 days/week
- **Lights:** 6 hours of use during the low light parts of the day
- **Power sockets:** A maximum of 2 hours a days for the weekend
- **Water pump:** 3 hours of use per day.

Let's take a look then at Table 4 to see all the previously mentioned information together.

	Power (W)	Hours	F.Simult	F.Use	Days/week	Weeks/year	Wh/year:	Wh/day
Boiler	2000	5,753424			7	52,1428571	4199999,52	11506,848
Ind.Fridge	750	8			7	52,1428571	2190000	6000
C.machine	1000	1			2	52,1428571	104285,714	285,714286
Elec.Stove	2000	2	1	0,75	2	52,1428571	312857,143	857,142857
Fridge	150	8	1	1	7	52,1428571	438000	1200
Lights	800	6	0,3	0,75	2	52,1428571	112628,571	308,571429
Wat.Pump	367,5	3	1	0,7	2	52,1428571	80482,5	220,5
Sockets	34500	2	0,2	0,25	2	52,1428571	359785,714	985,714286
						Total:	7798039,16	21364,4909

Table 4: Power consumed by the farm daily

We can see at the upper table the factors we previously mentioned, let's define them, for the better understanding, what they are used for:

- **Factor of simultaneity:** It represents, of all the total elements of the same type, for example the 20 lights, the amount of them that on a normal use can be simultaneously connected. For example for the 20 lights applying the 0,3 factor we get that maximum around 6 lights are connected at the same time
- **Factor of use:** This factor states the percentage of the total power used on a normal basis.[26]

Note that for the Lights and the Sockets the power has been multiplied by the total amount of plugs and light points to be present in the house.

In Table 4 can be seen what will be used in the following chapters for the sizing of the installation, the **total Wh/ year** in blue and the **total Wh/day** in orange. These are the values of the annual and daily energy requirements.

The power consumption from the production part (**Boiler+Ind.Fridge**) represents more than 75% of the all total consumption of the farm.

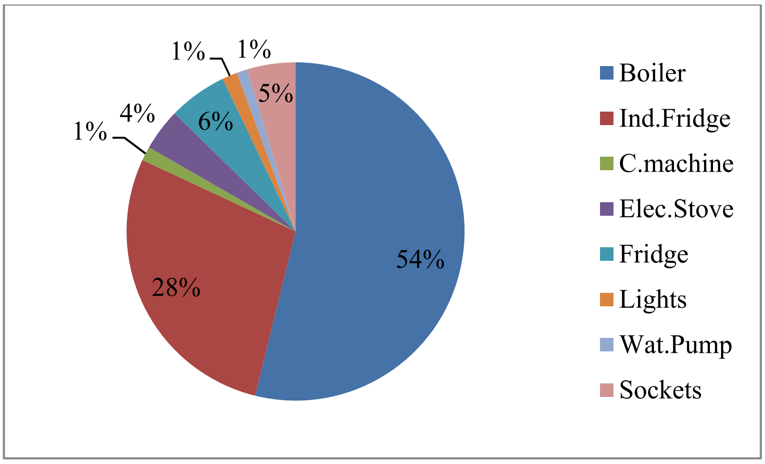

Figure 30: Daily consumption by the different elements

2.4. Measuring the sun and wind resource

Now we need to know the potential energy we can use from the sun and wind, so we can size the installation.

The sun resource is the most abundant energy resource on the earth [29]. Measuring the irradiation along the year on a certain area can be done through different databases available for the different countries and regions.

In this case study the free access database PVGIS financed by the European Union will be the one is used to estimate the solar resource available monthly for the location of the farm.

Monthly Solar Irradiation

PVGIS Estimates of long-term monthly averages

Location: 47°4'19" North, 25°56'6" East, Elevation: 864 m a.s.l.,

Solar radiation database used: PVGIS-CMSAF

Optimal inclination angle is: 36 degrees
Annual irradiation deficit due to shadowing (horizontal): 0.5 %

Month	H_h	H_{opt}	$H(50)$	I_{opt}	T_{24h}	N_{DD}
Jan	1210	1990	2140	64	-4.8	678
Feb	1910	2760	2880	56	-4.2	576
Mar	3370	4260	4290	45	0.5	499
Apr	4290	4740	4560	31	6.4	257
May	5310	5310	4920	18	12.1	124
Jun	5390	5130	4670	11	15.4	81
Jul	5650	5530	5070	15	17.5	65
Aug	4970	5350	5080	27	17.4	113
Sep	3620	4420	4400	41	12.8	226
Oct	2520	3670	3840	55	6.0	414
Nov	1500	2480	2680	64	2.7	572
Dec	1010	1750	1910	66	-2.5	699
Year	3410	3960	3870	36	6.6	4304

Figure 31: Monthly irradiation values. Source: PVGIS.

Hh: Irradiation on horizontal plane (Wh/m2/day)

Hopt: Irradiation on optimally inclined plane (Wh/m2/day)

H(50): Irradiation on plane at angle: 50deg. (Wh/m2/day)

Iopt: Optimal inclination (deg.)

T24h: 24 hour average of temperature (°C)

NDD: Number of heating degree-days (-)

We can see at Figure 31: Monthly irradiation values. Source: PVGIS.Figure 31 the different irradiation values for the different angles. The one we will use from this point will be the column of ***H(50)*** these are the amount of solar energy arriving at the installed angle of the installation: 50º

It can be seen that PVGIS itself suggests an optimal average angle to obtain the maximum output without changing the solar panels’ angle. The reasons for choosing this angle have been already stated on previous chapters.

PVGIS also gives graphs representing the irradiation for the different angles we choose, see Figure 32. We can see that at 50º degrees we get a bit more of power at winter, which is the critical period where earth receives the least sunlight.

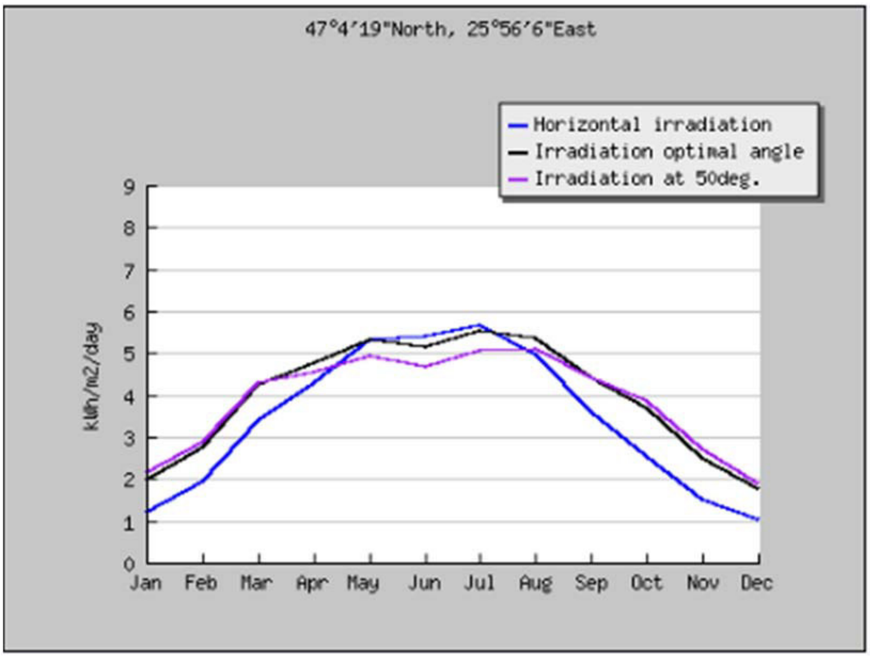

Figure 32: Irradiation along the year for the different angles. Source: PVGIS.

PVGIS gives a view of the obstacles and possible shadows that can occur along the year. The sun in winter hits the earth at a much sharper angle than in summer, this makes that the total amount of sun hours in winter is much less. Therefore, studying the losses due to possible objects blocking the solar panels from the sunlight is especially important in places like cities etc… In the case study the panels are situated high and facing south, so no losses due to shadows are considered.

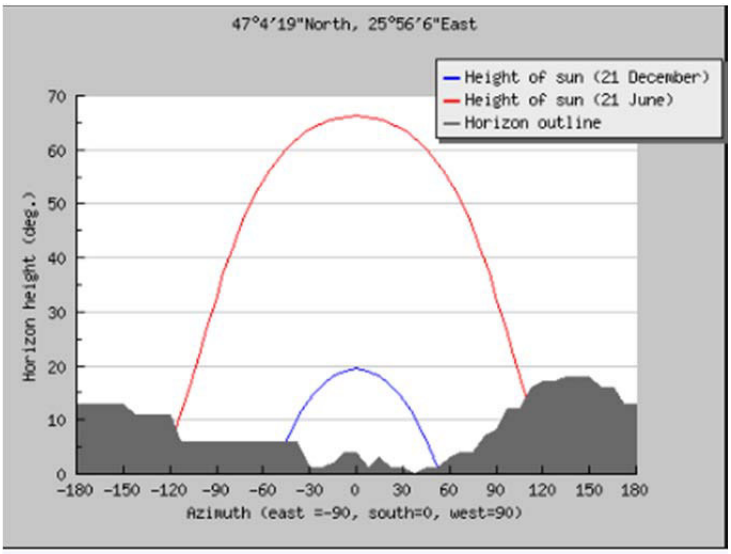

Figure 33: Yearly solar path. Source: PVGIS.

Wind resource availability on the other hand, is much harder to determine because it does not only change on a global level, but wind heats up at the equator and rises to move to one direction and goes to the opposite in colder regions, but also changes due to local geography (montains, valleys, sea present or not etc..).

All this makes wind a hard thing to quantify and more importantly predict. Although now every country more or less disposes of its own wind atlas, e.g. http://atlaseolico.idae.es/ for Spain. A deep study of the area is needed to measure the wind frequency and speed.

For measuring the power produce by the small wind turbine the speed of the wind and the amount of hours it blows are needed.

A rose of wind is a common graph that displays the speed of the wind, its direction and frequency (amount of hours). On Figure 34 we can see the rose wind for the village of Calugareni. It is noticed that wind blows mostly from South-West direction.

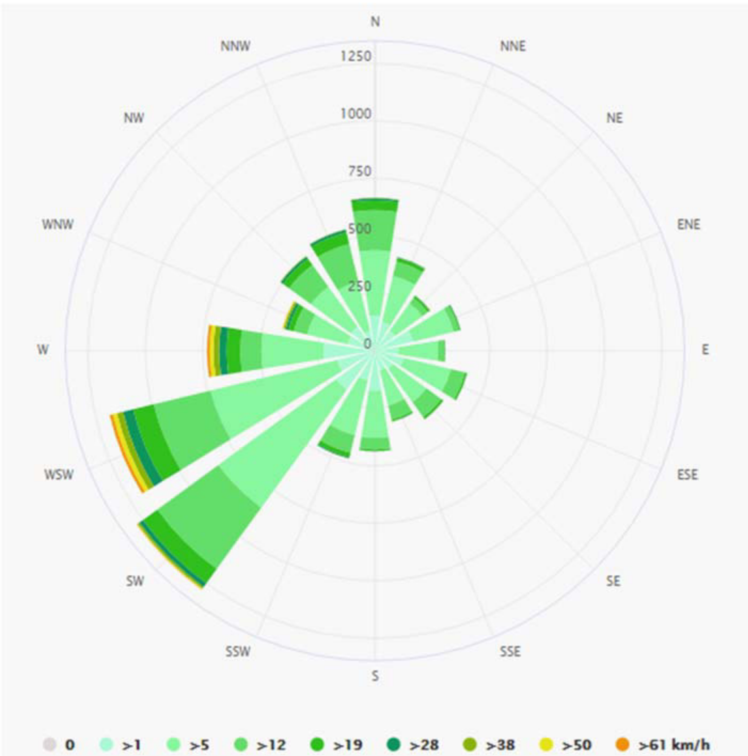

Figure 34: Rose of wind for Calugareni. Source: Meteoblue.

Compiling all data from the graph we get:

Spd (km/h)	Spd(m/s)	Hours/year
0	0	79
1	0,27777778	2147
5	1,38888889	4078
12	3,33333333	1677
19	5,27777778	471
28	7,77777778	162
38	10,5555556	79
50	13,8888889	44
61	16,9444444	26

Table 5: Wind speed and hours. Source: Own creation

The wind speed velocity mostly groups around the speed of 1,38 m/s, this means that most of the time the wind speed is quite low. Considering that a lot of small wind turbines have a cut-in-speed lower than that value, the speeds are not ideal.

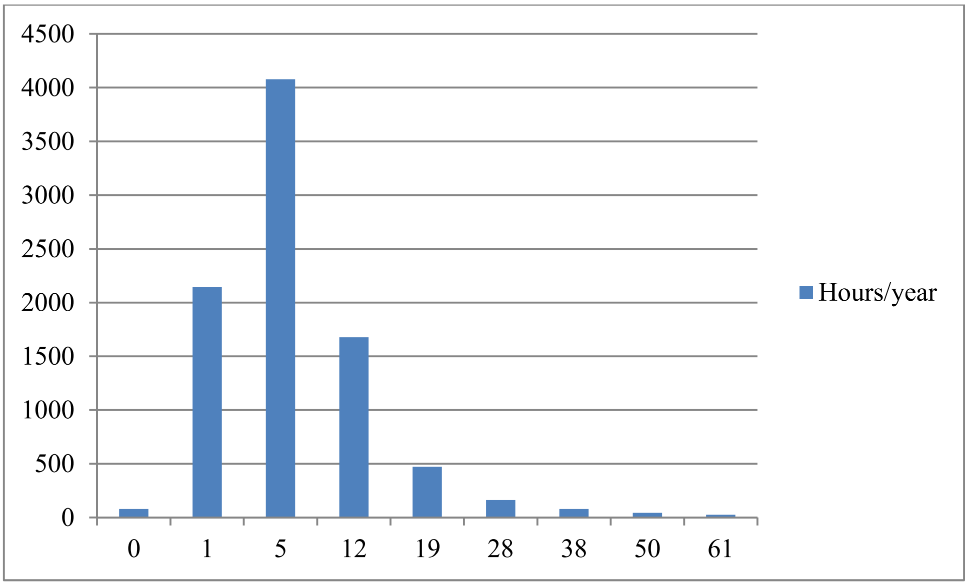

Figure 35: Hours/year vs speed of wind. Source: Own creation

Therefore, now we dispose all the tools needed to size the hybrid installation.

2.5. Small wind turbine sizing

The chosen small wind turbine is a E30 PRO by the Spanish company ENAIR. It has the following characteristics:

Number of blades	**3**
Power output	3000W
Working voltage	48V
Weight	125 kg
Swept area	11,34 m^2
Cut-in-speed	1,8 m/s
Nominal speed	11 m/s
Power control	Passive by centrifugal change of pass angle

Table 6: Small wind turbine characteristics

For further information about the small wind turbine check the annex.

So now let's calculate the annual production of the wind turbine using the data provided by the manufacturer. Every turbine has a different Cp (power coefficient) that depends on a series of variables: tip speed ratio, the attack angle, number of blades, wind speed etc… So the manufacturer normally gives out those coefficients or directly gives the power production.

The equation for calculating the power produce by the turbine is:

$$Poutput = \frac{1}{2} * Cp * \rho * A * v^3 \qquad \textbf{(4)}$$

Cp: Power coefficient

P: Air density, at 15ºC is around 1,255 kg/m^3 at sea level

A: The area swept by the wind turbine

V: the speed of the wind

In this case the manufacturer gives the power generated at a certain speed directly. See Table 7, the yearly production and daily production from the wind turbine can be seen. Average production could go higher or lower depending on different factors such as: Height at which the wind turbine is installed, wind change along the year etc…

			CUT-in-Speed: 1,8m/s		
Speed (km/h)	Speed(m/s)	Hours/year	Power	Wh/year	
0	0	79	0	0	
1	0,27777778	2147	0	0	
5	1,38888889	4078	0	0	
12	3,33333333	1677	180	301860	
19	5,27777778	471	300	141300	
28	7,77777778	162	1200	194400	
38	10,5555556	79	2000	158000	
50	13,8888889	44	2250	99000	
61	16,9444444	26	2500	65000	
			Total	959560	Wh/year
				2628,93151	Wh/day

Table 7: Power production of the turbine. Source: Own creation

Most of the production from the wind turbine comes due to low speed wind. As mentioned before by installing the wind turbine higher the power output is expected to go up.

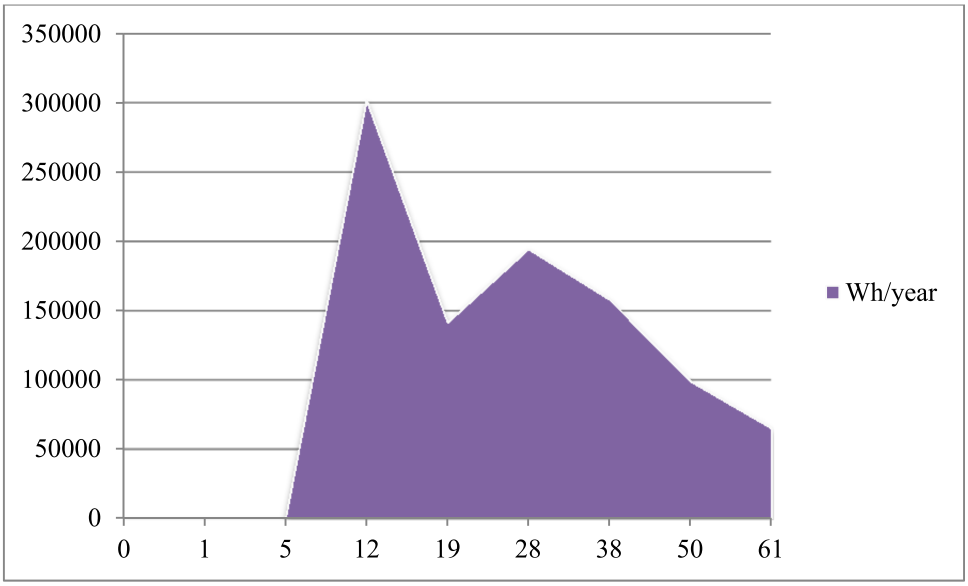

Figure 36: Production by wind speed

The power production achieved by the wind turbine will be taken from the daily energy needs from the farm, so we can size the photovoltaic installation on the next chapter correctly with no oversizing.

$$\boldsymbol{Pneeds = Pneedstotal - Pturbine = 21364{,}4909 - 2628{,}93151 = 18735{,}5607\ Wh}$$

2.6. Photovoltaic installation sizing

For choosing the amount of panels for our photovoltaic power generation installation we need to calculate the minimum power to install, it takes into account the losses of all the systems and the least favorable month.[7]

The Performance rate (PR) takes into account all losses from the system. All elements composing the system have a performance rate, although it is usually high, the accumulation of losses from all the elements have a significant effect, especially on off-grid systems.

$$Pr = 1 - \left(Lossorient + Lossshade + Lossdirt + Losscable + (1 - Perfinv) + (1 - Perfreg + 1 - Perfbat)\right) \quad \textbf{(5)}$$

Where:

Loss$_{orient}$: Losses due to orientation of the panels. In this case the panels face south, so it is considered 0.

Loss$_{Shade}$: Losses due to other objects projecting a shadow over the panels. Considered 0 due to being on the roof and an open area (no nearby objects)

Loss$_{dirt}$: Losses by dirt. It is considered to be around 5%.

Loss$_{cable}$: Losses due to joule effect on the wiring. In this case they are considered to be around 5%

Perf$_{inv}$: Performance of the inverter. For the chosen model it is 95%.

Perf$_{reg}$: Performance of the charge regulator. For the chosen model it is 98%.

Perf$_{battery}$: Performance of the battery system.

$$\boldsymbol{Perfbat = (1 - Kb) * (1 - \frac{Ka*N}{DOD})} \quad \textbf{(6)}$$

Where:

Kb: These are the losses while charging and discharging the battery system. It is considered about 5%.

Ka: Self-discharge value of the battery system. For a stationary Lead acid type, the value is $5 * \frac{10^{-3}}{\text{day}}$

N: Autonomy days of the battery system. For this installation 5 days are considered.

DOD: Maximum depth of discharging for the battery system. To protect it and maximize its life period. For this case study the DOD is 0.6.

$$Perfbat = (1 - 0{,}05) * \left(1 - \frac{5 * 10^{-3} * 5}{0{,}6}\right) = 0{,}910417$$

Putting all the data together we obtain the performance rate of the whole system:

$$PR = 1 - \big(0 + 0 + 0.05 + 0.05 + (1 - 0.95) + (1 - 0.98 + 1 - 0.910417)\big) = 0.740417$$

Now that we have the **PR** we can correct the power needed by the installation ("**Pneeds**" previously mentioned):

$$Pneeds_{pr} = \frac{Pneeds}{PR} = \frac{18735{,}56}{0{,}740417} = 25304{,}065\ Wh$$

In numerous bibliographies, a security factor is present [7]. This factor is used for safety reason to make sure that the demand is covered, it changes from source to source, in this case study the Security Factor (SC) is **1,1** which has been used.

Also, photovoltaic degrade over time, different technologies differ on degradation over time, also the location on the globe influence[30] a **1%/year** of production loss. So we need to oversize the installation, so in a **20-year**-period it will be still able to produce enough energy.

$$Pneeds_{PRSC} = Pneeds_{PR} * Factor_{degrad} * Factor_{security} \quad (7)$$

Where:

$Factor_{degrad}$: There is a 20% of loss over 20 years. The factor will be 1,2.

$Factor_{security}$: It is 1,1.

$$Pneeds_{PRSC} = 25304{,}065 * 1.2 * 11 = 33401{,}36\ Wh$$

The panel chosen is a monocrystalline solar panel, model **TM-M672320/340** from the company **Tamesol**. The characteristics of the panel are the following:

Maximum Power at STC:	**340 W**
Optimum Operation Voltage (Vmp):	37.76 V
Optimum Operating Current (Imp):	9.00 A
Open Circuit Voltage (Voc):	46.80 V
Short Circuit Current (Isc):	9.46 A
Module Efficiency:	17.51 %

Table 8: Solar panel characteristics.

Solar irradation changes along the day, a common concept is used in photovoltaics, that is Peak Sun Hours (PHS). PHS is the amount of hours of **1000 W/m^2** irradiation received on a day. It is used to calculate the minimum power to install

$$Pinstall = \frac{Pneeds_{PRSC}}{PSH_{month}} \quad \textbf{(8)}$$

The PSH what we will take is from the least favorable month, which is December (see Figure 31). The irradiation values are from the **H(50)**, due to the fact, that that is the angle of installation.

PSH$_{\textbf{December}}$: 1,910 Kw/m^2

$$Pinstall = \frac{Pneeds_{PRSC}}{PSH_{december}} = \frac{33{,}40136\ Kwh}{1{,}910\ \frac{Kw}{m^2}} = 17{,}487Kw$$

Now the amount we need, considering the maximum power output for the panels is 340W.

$$Number_{panels} = \frac{Pinstall}{Power\_panel} = \frac{17487\ W}{340\ W} = 51.43\ panels \approx 52\ panels$$

We chose the closest higher integer from the previous equation is the amount of panels to install of the photovoltaic installation.

2.7. Sizing of the battery system

Since the system is off-grid, as we already mentioned previously, we will need an energy store system to accumulate the excess energy.

The battery system will work at 48 V to reduce the amount of losses and lowering the current (less joule effect losses due to lower current) due to the higher voltage, to be able to install thinner cables.

The equation to calculate the amounts of Ah needed is:

$$Cbatsystem = \frac{1{,}1 * N * Id}{DOD * Per_{BatInvReg}} \quad \textbf{(9)}$$

Where:

Cbatsystem: It is the capacity needed to install in Ah

N: It is the autonomy of the battery system. Considered to be 5 days.

Id: It is the daily need from the power consumption of the farm

$$Id: \frac{Pneedstotal}{48\ V} = \frac{21364.69\ Wh}{48\ V} = 445.09\ Ah$$

DOD: It is the depth of discharge. In this case study it is considered to be 0,6.

$Perf_{BatInvReg}$: It is the combined performance of the battery system, regulator and inverter.

$$Perf_{BatInvReg} = \mathrm{Perf_{Bat}} * \mathrm{Perf_{Inv}} * \mathrm{Perf_{Reg}} = 0.910417 * 0.95 * 0.98 = 0.84759$$

Then:

$$Cbatsystem = \frac{1.1 * 5 * 445.09}{0.6 * 0.84759} = 4813.638\ Ah$$

The chosen battery is the model 12 CS 11P, from the company Rolls. It is a deep cycle lead acid battery, a block type battery of 12 V rated voltage per module.

Since the autonomy of the system is expected to be of around 5 days, we can consider a discharge rate of 120 hours for the battery system. The lower we discharge the battery system the higher is the capacity.

Weight dry	**100 kg**
Weight wet	123 kg
Number cells and plates	11 plates/ cell and 6 cells
Capacity 100 hours	503 Ah
Capacity 72 hours	475 Ah
Capacity 24 hours	371 Ah

Table 9: Characteristics of the 12 CS 11 P battery

For the 12 CS 11P model the capacity for a 100 hour discharge is :

$Cbat_{100HourRate}$ =503 Ah

Then the number of batteries in parallel needed will be:

$$Number_{BatteriesParallel} = \frac{Cbatsystem}{Cbat_{100HourRate}} = \frac{4813.638\ \text{Ah}}{503\ \text{Ah}} = 9.5698 \approx 10\ \text{batteries}$$

But the voltage we are working with is of 48 V so we will need 4 batteries in series, due to the fact that the battery chosen is a 12 V block.

So the total number of batteries as a whole will be:

$$NumberTotal = Number_{BatteriesParallel} * Number_{BatteriesSeries} = 40\ batteries$$

3. Choosing the inverter and charge regulator

3.1. Charge regulator

The charge regulator and inverter are from the company **Victron Energy**.

Let's begin choosing the charge regulator. The parameters that will define the amount of the regulators we will have to install will depend on the characteristics of the solar panels we chose (the wind turbine has its own regulator).

The parameters we will use from the solar panels are (see Table 8) :

Vosc: The open circuit voltage from the solar panels, Vosc=46.80 V.

Isc: It is the solar panel's short-circuit current. It is the maximum current that on normal operation, the solar panel could give. The value in the table is: Isc= 9.46 A

Victron Energy provides a group of solar charge regulators that can be connected at 12,24,36 and 48 V. The ones we will discuss are the **SmartSolar MPPT 150/85**, **150/100**, **250/85** and **250/100**. The first number stands for the maximum PV open circuit voltage and the second one the rated current of the regulator, e.g 150 V and 85 A.

Then:

$$Voltage_{safety} = Factor_{security} * Vosc \quad \textbf{(10)}$$

$$Current_{safety} = Factor_{security} * Isc \quad \textbf{(11)}$$

Factor$_{\textbf{security}}$: Is a security parameter to be sure we protect the regulator. The factor is normally defined as a 25% increment over the normal value[7]

$$Number_{PanelsSeries} = \frac{Voltage_{Reg}}{Voltage_{safety}} \quad \textbf{(12)}$$

$$\boldsymbol{Number_{PanelsParallel}} = \frac{\boldsymbol{Current_{Reg}}}{\boldsymbol{Current_{safety}}} \quad \textbf{(13)}$$

Therefore applying all this data we get the maximum number amount of panels we can connect in series and parallel for the values of the charge regulators.

Voltage	Max.Num.Panels.Serie	Num.Panel.Serie
250	4,273504274	4
150	2,564102564	2
Current	Max.Num.Panels.Parall	Num.Panel.Parallel
85	7,188160677	7
100	8,456659619	8

Table 10: Maximum number of panels series and parallel

We have 52 panels to install, thus we know the amount of charge regulators we will need for every model:

$$Number_{Regulators} = \frac{52 \;\; Panels}{Num.Panel_{Serie} * Num.Panel_{Parallel}} \quad \textbf{(14)}$$

Applying the upper equation we get the panels we will need:

Model	Num.Panel.Regulator	Num.Inverters
150/85	14	3,714285714
150/100	16	3,25
250/85	28	1,857142857
250/100	32	1,625

Table 11: Number of charge regulators

Looking at Table 11, we see that the models 250/85 and 250/100 are the ones that allow us to use the less amount of inverters, then we will choose the model 250/85 (cheaper than 250/100) and we will need two of them.

The connection scheme for the panels will be 28+24. One group of 28 panels and 24 panels are connected to a charge regulator. The regulators are connected in parallel to the battery system.

SmartSolar Charge Controller 250/85	
Battery Voltage	12/24/48 V
Rated charge current	85 A
Maximum PV open circuit voltage	250 V
Maximum efficiency	99%

Table 12: Charge regulator operative characteristics

3.2. Inverter sizing

For the election of the inverter, we need to know the power that can be simultaneously connected from the consumption side. In order not to over-size the election of the amount of inverters needed, there is a criterion for considering how high the simultaneously connected power can be:

Boiler	2000W
Fridge + Industrial Fridge	900 W
Electrical Stove	2000 W
Cleaning machine	1000W
Power socket	3450 W* 0.5=1725 W
Lights	800 W*0.3*0.75=180W
Total Simultaneous power:	**7805 W**

Table 13: Simultaneous connected power

The factors applied are:

- **Power sockets**: A factor of use of 50% percent of the total power capability of the socket for one socket is considered. The unlikely scenario of all the consumptions connected at the same time justifies the application of this factor
- **Lights**: A factor of simultaneity of 30% for all the lights is applied. And a factor of use of 75% for power use for the lights.

$$Power_{SimultaneousSEC} = Power_{Simultaneous} * Factor_{Security} \quad \textbf{(15)}$$

Factor$_{\textbf{Security}}$: is the same coefficient previously used for the charge regulator election, is a factor of 1.25 to secure the safety operation of the inverter.

$$Power_{SimultaneousSEC} = 7805\ W * 1.25 = 9756.25\ W$$

The inverter is also from the company **Victron Energy**, the one chosen is the model **Phoenix 48/5000**. Works at 48 V from the battery side and has a power output at 25ºC of 5000VA. The output is a sinusoidal wave of 230 V to feed the consumptions.

$$Number_{Inverters} = \frac{Power_{SimultaneousSEC}}{Power_{inverter}} = \frac{9756.25}{5000} = 1.95125 \approx 2\ Inverters$$

As the simultaneous connected power can be very high, we chose the biggest inverter **Victron Energy**, it is the one that allows us to only use two of them, with the rest we will need more than 2 inverters.

4. Connection between lines

The connection cables that will be defined in this section will be the following ones:

- Solar panels-Combiner box
- Combiner box-Charge regulator
- Charge regulator-Battery system
- Battery system- Inverter
- Inverter- Consumption

Cables for the wind turbine:

- Wind turbine- turbine charge regulator
- Turbine charge regulator- Battery system

To size the connection between the different elements, the maximum current that could flow through the conductor (it means if the conductor is physically able to conduct the current without burning) and the voltage drop along the line will be taken into account.

The cables used for this sizing are the ones from the **Prysmian**'s catalog for photovoltaic installation, **TECSUN (PV) PV1-F.** The catalog disposes of a series of colors: Red, blue and black. The insulation cover of the cables is **HEPR 120° C**, cables at a rated voltage of **0.6/1 kv.**

The color helps with the installation process, red and blue will be used for the positive and negative on the solar panels strings respectively, for the rest of the installation red and black cables will be used for positive and negative.

The suggested installation method for all cables will be on a tube with two pairs of cables inside, named installation **type B1** for the outside line and **type F** for inside ones by the Spanish norm **UNE 20460–5–523**[31]. These methods are just suggested and not definitive, it is used to give a better and more real view on how the installation will behave. Maximum tolerated current for each cable section will be taken from the **table A.52-1 bis** which is from the previous normative.

The equations used to calculate the cable section needed in function of the voltage drop is the following:

For single-phase and direct current:

$$S\ (mm) = \frac{2*L*I}{c*(V_a - V_b)} \quad \textbf{(16)}$$

For single-phase and alternating current:

$$S(mm) = \frac{2*L*P}{c*e*V^2} \quad \textbf{(17)}$$

- **L**: the length of the conductor itself in meters.
- **I**: the current circulating through the cable in Ampers.
- **P**: the power transported on the line in Watts.
- **C**: electrical conductance of copper. At 20º C being 56 m/**Ω***mm^2
- **Va**: the voltage at the beginning point of the conductor in Volts.
- **Vb**: the voltage at the end of the conductor in Volts.
- **E**: the voltage drop of the line, is a non-dimensional parameter.
- **V**: the voltage at the alternating current line between a phase and the neutral, which is 230 V.

The maximums and recommended voltage drops used in this case study are the ones considered in the Spanish legislation (IDAE) [32]

Voltage drop (%)	Allowed value (REBT)	Recommended Value
Solar panels-Charge regulator/Inverter	3 %	1%
Charge regulator-Battery system	1%	0.5%
Battery system-Inverter	1 %	1%
Inverter-Light points	3%	3%
Inverter- Appliances	5%	3%

Table 14: Voltage drop values. Source: IDAE

First, let's start the selection of the proper conductors for the DC[20] part of the installation, which starts from the solar panels and ends at the inverter:

[20] Direct current

- **DC part of the installation:**

Line Panels-Combiner box and line from combiner box-Regulator:

The selectivity of the cables for the panel-combiner box and the junction box-regulator will be so the total voltage drop of both lines is within the range of the ones stablished in Table 14.

$$Voltage\ drop_{PanelRegulator} = Voltage\ drop_{PanelCombiner} + Voltage\ drop_{CombinerboxRegulator} < 1\% = 0.01 \quad \textbf{(18)}$$

The section of the conductor for the Solar panel-Combiner line will depend mostly on the distance from the positive pole of the panel to the combiner as all panels are arranged in strings of the same amount of panels 4

The minimum conductor's width will be of **6 mm²** on the DC to lower the voltage drop on that part because the voltage lowers the losses, which are higher due to joule effect (higher current). On the other hand, the installation process is easier.

Voltage drop of the string-panels to combiner						
N.Strings	Distance (m)		Cable width (mm)	Current string (A)	Voltage drop (%)	
	minimum	maximum				
1	1	5	6	9	0,00035468	0,00177342
1	5	9	6	9	0,00177342	0,00319215
1	9	13	6	9	0,00319215	0,00461089
1	3,53	7,53	6	9	0,00125203	0,00267077
1	7,53	11,53	6	9	0,00267077	0,0040895
1	11,53	15,53	6	9	0,0040895	0,00550824
1	1	5	6	9	0,00035468	0,00177342
1	5	9	6	9	0,00177342	0,00319215
1	9	13	6	9	0,00319215	0,00461089
1	3,53	7,53	6	9	0,00125203	0,00267077
1	7,53	11,53	6	9	0,00267077	0,0040895
2	11,53	15,53	6	9	0,0040895	0,00550824

Table 15: Voltage drop at solar strings. Source: Own.

In Table 15 we can see the voltage drops for the different strings. The red color symbolizes the positive cable of each string and the blue one the negative one. The length of every cable changes depending on the string position on the roof.

Considering that the combiner box for each group of panels will be installed at a maximum distance of **1 m** (the closest possibly). The distances between the negative (blue) and positive (red) will be of **4 m** which is the width of 4 panels in series:

$$Distance_{NegativePositive} = Width_{panel} * 4 \quad \textbf{(19)}$$

Width panel: Taken from the manufacturer datasheet **0.996** m

$$Distance_{NegativePositive} = 0.996 * 4 = 3.984\, m \approx 4\, m$$

The distance between superior lines of panels will be the minimum distance of 1 m plus the minimum distance we will need to leave to avoid shadowing (check **Distance between panels on roof installation** for more information)

$$Distance_{UpperPanels} = MinimumDistance + Distance_{AvoidShadowing} \quad \textbf{(20)}$$

Minimum distance: The distance to the group's combiner. The minimum distance is **1** m.

Distance$_{\textbf{AvoidShadowing}}$: The distance to avoid shadowing. Calculated as **2.53** m.

$$Distance_{UpperPanels} = 1 + 2.53 = 3.53\, m$$

The current is the highest one on normal use, that is the **Impp** (current at maximum output at STC[21]) of the solar panel (check annex for **TM-M672320** datasheet)

Now it is needed to check that the selected diameter of cable is able to support the short-circuit of the string, that will be the maximum current that can be tolerated on normal operation process.

Cable section (mm^2)	Maximum tolerated current for under tube installation (A)*	Maximum expected current (A)
6	46	9.62

Table 16: Thermic criterion for the selected cables. Source: Own

*The maximum tolerated current of the conductor is the one considered for an under tube installation for the selected sections (type B1 installation taken from table 52-B1/A.52-1 bis 40º C, insulator XLPE 2[31]).

Now let's see the line Combiner box-Regulator:

	Cables combiner to regulator				
Group	Lenght (m)	Current (A)	Conductor mm	Volt.drop	V.drop Panel-Combiner
1	12	54	35	0,00437781	0,009886049
2	12	63	35	0,00510745	0,010615684

Table 17: Voltage drop from the combiners to the charge regulators. Source: Own

[21] Standard Conditions

Considering that the Combiner box is installed at a maximum of **1 m** away from both groups of the panels. We obtain at

	Cables combiner to regulator				
Group	**Lenght (m)**	**Current (A)**	**Conductor mm**	**Volt.drop**	**V.drop Panel-Combiner**
1	12	54	35	0,00437781	0,009886049
2	12	63	35	0,00510745	0,010615684

Table 17 the voltage drop on the line and the sum of voltage drop from the panels (the worst scenario, when the string is with the highest voltage drop) to the junction box.

Thermic criterion for the combiner box-regulator line:

Group	**Nominal current (A)**	**Conductor (mm)**	**Maximum tolerated current (A)***
1	54	35	137
2	63	35	137

Table 18: Maximum current for the line combine-regulator

*Current corrected for the suggested installation method **B1**.

We can see that the chosen section is able to withstand the nominal operation of the line.

Being the total voltage drop for the compound line solar panel-regulator, the sum of the line with the highest voltage drop, plus the voltage drop for the cable from the combiner to the charge regulator.

Where:

$$Voltage\ drop_{PanelRegulator} = Voltage\ drop_{PanelCombiner} + Voltage\ drop_{CombinerboxRegulator} < 1\% = \mathbf{0.01} \quad \mathbf{(18)}$$

For **group 1** $Voltage\ drop_{PanelsToRegulator} = 0.00550824 + 0.004377 = 0{,}009886049$

For **group 2** $Voltage\ drop_{PanelsToRegulator} = 0.00550824\ +\ 0.0051 =\ 0{,}010615684$

The voltage drop for the total line are within the ranges of **1%** as the recommended voltage drop. To easier the installation process all solar panels cables will be the same section, therefore all cables will be **6 mm^2** on the solar panels to combiner side. For the line from the combiner box to the charge regulator, the chosen section is **35 mm^2**.

	N.strings	Total cable lenght (m)
Group 1	1	6
	1	14
	1	22
	1	11,06
	1	19,06
	1	27,06
Group 2	1	6
	1	14
	1	22
	1	11,06
	1	19,06
	2	27,06
		Total: 198,36*2 cables= **396.72**

Table 19: Total meters needed for section 6 mm^2

Group	Total cable lenght (m)
1	12* 2 cables
2	12* 2 cables
	Total: **48**

Table 20: Total meters needed for section 35 mm^2

Line charge regulator- battery system:

The highest power that the line connecting the charge regulators with the battery system will be the one coming from the solar panel system. The maximum PV[22] power output for 48V of the model **SmartSolar 250/85**, is 4900W (taken from the datasheet).

Therefore considering that there are 2 charge controllers in parallel the total maximum power coming from the PV to the battery system will be **9800 W**. Remind that the chosen system's voltage for the battery, regulator and inverter is **48 V**.

$$\text{For each regulator line } Imax_{perRegulatorBattery} = \frac{4900\ W}{48\ V} = 102.08\ A$$

Where the maximum distance is considered for the installation from the charge regulators to the battery system is **2 m**:

[22] PV: Photovoltaic

Cable regulator-battery				
Power (W)	Lenght (m)	Current (A)	Section (mm)	Voltage drop
4900	2	102,083333	35	0,004340278

Table 21: Voltage drop for the line connecting the charge regulator with the battery system. Source: Own

Let's check if the cable can withstand the current:

Nominal current (A)	Section (mm)	Maximum tolerated current (A)*
102.0833	35	174

Table 22: Maximum tolerated current for the line regulator-battery system

*For the installation method **F**.

We can see that the chosen section of **35 mm** is able to withstand the current.

The voltage drop at the connection regulator-battery is lower than the recommended value of **0.5%**. The selected conductor diameter is of **35 mm** ^{2}.

	Total cable length (m)
Connection charge regulator-battery system	2*2 pair of cables
	Total: **8**

Table 23: Total meters needed for section 35 mm^2

Line battery system to inverters:

The maximum power it will support is from the maximum simultaneous connected power from the power consumes (see Inverter sizing for more information about the criteria followed for calculating the maximum simultaneous connected power).

$$Power_{SimultaneousSEC} = 9756.25\ W$$

$$Imax_{BatteryInverter} = \frac{9756.25\ W}{48\ V} = 203.55\ A$$

The maximum recommend distance from the battery system to the inverters **2 m**.

Cable battery- Inverter				
Power (W)	Lenght (m)	Current (A)	Section (mm)	Voltage drop
9756,25	2	203,255208	35	0,008641803

Table 24: Voltage drop from battery system to inverters. Source: Own

The voltage drop falls right within the recommended value from Table 14.

But examining the thermic criteria for the cable we can see that it is not able to withstand the current that will pass through it, so we need to take a bigger cable section.

Nominal current (A)	Section (mm)	Maximum tolerated current (A)*
203.255	35	174

Table 25: Tolerated current for 35 mm cable cross section

*Type **F** installation

It can be clearly seen that the cable is not capable of handling the nominal current for the line. A new section of **70 mm** is chosen.

Section (mm)	Nominal current (A)	Maximum tolerated current (A)*
70	203.255	269

Table 26: New section maximum current values.

*Type **F** installation

The voltage drop for the new conductor line section is:

Cable battery- Inverter				
Power (W)	**Lenght (m)**	**Current (A)**	**Section (mm)**	**Voltage drop**
9756,25	2	203,255208	70	0,004320902

Table 27: Voltage drop for 70 mm section.

Where we can see that the voltage drop values are within the recommended ones, lower than **1 %**. Therefore the definitive cable section will be of **70 mm** for the battery-inverter line.

	Total lenght (m)
Battery-Inverter	2* 2 cables
	Total: **4**

Table 28: Total length needed for 70 mm^2

- **AC part of the installation**:

Line Inverter to distribution panel:

The installation of distribution panel from where the two branches will emerge, one goes to the production area to feed the boiler and industrial fridge and the other one goes to feed the house consumptions. The distribution panel locates the protection of the lines, as well, and is located at a maximum of **1 m** from the inverter.

The section needed for the connection inverter will be the minimum that can support the current, considering that previously was stated that the minimum recommended section is of **6 mm**:

Power (W)	Nominal current (A)	Max tolerated current cable (A)*	Lenght (m)	Section (mm)	Volt. Drop
9756,25	42,41847826	46	1	6	0,00109779

Table 29: Line inverter to distribution panel. Source: Own

We can see that the section **6 mm^2** is able to support the current, so there is no need to oversize it more.

Line distribution panel to consumption:

For this part two lines are needed to be sized:

- Line to the production area

- Line to the house

The maximum recommended voltage drop for both lines is **3%** of a phase-neutral voltage of **230V**. The distances to the production area and the house from the small house, where the inverters are located, is of **50 m** and **14 m** respectively.

The section takes into the account the previous data and the following formula is used $S(mm) = \frac{2*L*P}{c*e*V^2}$ **(17)** :

For the production part:

$$S(mm) = \frac{2 * 50 \ * 2750}{56 * 0.03 * 230^2} = 3.094 \, mm$$

Where:

P: The power of the boiler plus the industrial fridge, which is **2750 W**.

For the house part:

$$S(mm) = \frac{2 * 14 * 7006}{56 * 0.03 * 230^2} = 2.207 \, mm$$

Where:

P: Is the power from the previously calculated maximum simultaneous connected power minus the power from the production part, that is: **P= 9756 W-2750 W= 7006 W**

At **TECSUN-PV-PV1-F** catalogue we can see that the closest cross sections are **4 mm** and **2.5 mm** respectively. But the selected diameter for both of them will be **6 mm** to make the installation process easier. Therefore the voltage drops we obtain are:

	Section (mm)	Voltage drop
House	6	0,011036941
Production	6	0,01547169

Table 30: Voltage drop on the consumes.

We can see that the voltage drops are well within the tolerated values for both cases. Lastly we need to see if the selected cables are able to withstand the maximum nominal current, considering that they are installed under tube (Type **B1** installation [31]):

Line	Section (mm)	Nominal current (A)	Maximum tolerated current (A)*

House	6	30.46	46
Production	6	11.956	46

Table 31: Maximum current for AC consume lines

*Type **B1** installation

We see in Table 31 that they are able to withstand it. Therefore the selected section will be **6 mm**.

	Length needed (m)
Inverter-Distribution	1
House	14
Production area	50
	Total: 65* 2 cables= 130

Table 32: Total length needed from distribution to consumption.

- **Wind turbine line sizing:**

The maximum power output from the wind turbine is maximum **3000W**, the working voltage of the turbine is of **48V.**

The allowed and recommended voltage drops for the wind turbine line connection are the same of that previously stated for the solar panel.

Line from wind turbine to charge regulator:

As we stated in the final solution description, the wind turbine should be installed around **10 m** away from the house, then considering that the charge regulator of the turbine will be installed where the other charge controllers are (the ones from the PV system) a total distance of **20 m** from the turbine to the regulator can be considered.

Wind turbine to Charge regulator					
Power (W)	Voltage	Current (A)	Section(mm)	Length (m)	Voltage drop
3000	48	62,5	95	20	0,0097901

Table 33: Voltage drop for the Wind turbine-Regulator line.

For a **95 mm** size cable the voltage drop is right within the recommended value, lower than **1%** total drop. Now let's see if the cable supports the nominal current along the cable:

Nominal current (A)	Maximum tolerated current (A)*
62.5	327

*Type **F** installation

It can be clearly seen that the cable is able to withstand the current.

Line from charge regulator of the wind turbine to battery system:

Where the voltage drop will be, considering that the charge controller is installed at a maximum of **2 m** from the battery system.

Charge regulator to battery system					
Power (W)	**Voltage**	**Current (A)**	**Section(mm)**	**Length (m)**	**Voltage drop**
3000	48	62,5	25	2	0,003720238

Table 34: Voltage drop from the regulator to the battery system.

The maximum tolerated current from the cable will be:

Nominal current (A)	Maximum tolerated current (A)*
62.5	140

Table 35: Tolerated current for the cable charge regulator of the turbine to the battery system.

The total amount needed of cable will be of:

	Length needed (m)	
Turbine-regulator	20	
	Total:	20*2 cables=40

Table 36: Total length needed of section 95 mm.

	Length needed (m)	
TurbRegulator-Batt	2	
	Total:	2*2 cables=4

Table 37: Total length needed for section 25 mm.

5. Protections

5.1. Fuses

The chosen fuses are **gPV** fuses by the company **SOCOMEC**, that is constructed according to **IEC 60269 standard**. With a rated breaking voltage of **1000 VDC** for the models from **1** to **600 A (**taken from the fuse datasheet**)**.

For the selection of the correct nominal current for the fuse it is needed to introduce the following equations:

For the protection of the cable system the fuse must meet the following criteria:

$$Ib \leq In \leq Iz \quad \textbf{(21)}$$

$$I_2 \leq 1.45 * Iz \quad \textbf{(22)}$$

Where:

Ib: The design current for the circuit

In: The the nominal current assigned to the protection device. Caliber.

Iz: The maximum tolerated current by the conductor.

I_2: The current where the activation of the device is guaranteed. For fuses made following the **IEC 60269** norm, the guaranteed activation current is **I_2=1.6*In**.

The short-circuit current along the lines must be calculated to see if the fuse device is able to protect against the short circuit currents:

$$Isc = \frac{Voltage\ at\ that\ line\ part}{\Sigma Resistances} \quad \textbf{(23)}$$

$$Breaking\ Capacity > Iscmax \quad \textbf{(24)}$$

$$Iscmin > Ia = I_{f5} \quad \textbf{(25)}$$

Where:

Iscmax: The maximum short-circuit current expected on the line.

Iscmin: The minimum short-circuit current expected on the line.

Ia: The current point is when the I/t graphic for the cable and fuse device cut. The mentioned graphic is not available, the $\mathbf{I_{f5}}$ current at which, after 5 seconds pass, the fuse opens, will be taken.

The short-circuit currents along the circuit depend on the short-circuit coming from the solar panels. A security factor will be defined to oversize the short-circuit and to make sure that it protects the cable even the currents are lower in practice.

$\mathbf{Factor_{security}}$: 1.25

For circuit breakers the following equations must be accomplished:

$$Breaking\ capacity > Iscmax \quad \textbf{(26)}$$

$$Iscmin > Ia \quad \textbf{(27)}$$

$$Iscmax < Ib \quad \textbf{(28)}$$

Where:

Ia: The current of activation of the magnetic device.

Ib: The current that corresponds to the value $\mathbf{(I^2t)_{adm}}$ of the conductor line measured on the circuit breaker graphic for (I^2t). The tolerable value for the conductor is:

$$(I^2 * t)_{Maxcable} = k^2 * S^2 \quad \textbf{(29)}$$

Let's choose the fuses for the system:

- **PV string to combiner fuse:**

We know that the strings of the panels are formed of 4 panels connected in series. The connection lines of all panels to the combiner are **6 mm** cross section.

Nominal current (A)	Current rating of fuse	Maximum tolerated current (A)*
9.46	12	46

Table 38: Fuse string to combiner

*For the suggested installation method **B1**

Where:

$$9.42 < 12 < 46 \ \ \text{Valid}$$

$$I_2 = 1.6 * 12 = 19.2\ A$$

And:

$$1.45 * Iz = 66.7 \geq I_2 = 19.2 \quad \text{Valid}$$

The short-circuit currents of the chosen panel looking at **Tamesol** datasheet for the model is **TM-M672340**:

Isc: 9.46 A

The fuse should not cut the line when the string is on short-circuit mode, so as we see in Table 38 the **Isc** was considered the design current for the line.

The fuse should cut the line in the situation when the strings of panels connected in parallel starts to feed the string (in case of fault at that string), instead of supplying the consumption.

	N.Voltage (V)	Rpanel	Isc (A)	LineLength (m)	Section (mm)	pCopper	R.Panel-Combiner
String	151,04	15,9661734	9,46	15,53	6	0,02	0,04622024

Table 39: String and line short-circuit characteristics

Where:

N.voltage: The total voltage of 4 panels connected in series. In volts.

Rpanel: Which is the internal resistance of the panel at short-circuit instant.

$$\text{Rpanel} = \frac{\text{N. voltage}}{\text{Isc}} = \frac{151.04}{9.46} = 15.966\ \Omega$$

LineLength: The longest line installed for the different strings. Where in this case is **15.53 m**, which is the farthest string.

pCopper: The conductance of copper at 20ºC temperature. In Ω*mm^2/m.

R.Panel-combiner: The resistance of the line connecting to the farthest string to the combiner. The following equation is used:

$$Resistance = \rho_{copper} * \frac{L}{Section} \quad \textbf{(30)}$$

Then the short-circuit for each group will differ considering the worst case scenario, for **Group 1** the fuse should protect the line of one string in case of 5 other strings short-circuited to it.

For **Group 2** the worst case scenario is 6 strings short-circuit to a single string. The total short-circuit current form each group will be:

$$Isc_{group} = (N-1) * Isc * Factor_{security} \quad \textbf{(31)}$$

Then:

R5panels	3,19323467 Ω	R6panels	2,66102889 Ω
Group 1		Group 2	
Iscmax	Iscmin	Iscmax	Iscmin
59,125	58,2814101	70,95	69,7386871

Table 40: Short current for the farthest string on each group.

The chosen fuse has a breaking capability of **30 kA** and a **If5** of **30 A**.

For group 1:

$$30000\ A \gg Iscmax = 59.125\ A \quad Valid$$

$$Iscmin = 58.2814 > If5 = 30\ A \ \ Valid$$

For group 2:

$$30000\ A \gg Iscmax = 70.95\ A \text{ Valid}$$

$$Iscmin = 69.738 > If5 = 30\ A \text{ Valid}$$

- **Lines combiner box to regulator fuses:**

The short-circuit possibilities in this part of the installation is that of short-circuit current to each array through the line connecting the combiner for each group and each group array regulator.

	N.Voltage	Rarray	Isc	LineLenght	Section	pCopper	R.Comb-Reg
Group 1-Regulator	151,04	2,66102889	56,76	12	35	0,02	0,006122449
	N.Voltage	Rarray	Isc	LineLenght	Section	pCopper	R.Comb-Reg
Group 2-Regulator	151,04	2,28088191	66,22	12	35	0,02	0,006122449

Table 41: Line from combiner to junction box characteristics.

Where the maximum expected short-circuit currents for both groups are the following:

Group 1		Group 2	
Iccmax	Iccmin	Iccmax	Iccmin
69,7386871	69,5813288	81,1309466	80,9180566

Table 42: Maximum and minimum Isc for both group arrays.

The chosen Fuse rating will be between the nominal current for each group **Isc** and the maximum tolerated current for the cable section of **35 mm**.

	Nominal current (A)	Fuse current rating (A)	Max tolerated current (A)*
Group 1	56.76	63	174
Group 2	66.22	80	174

Table 43: Fuse rating line from combiner to regulator.

*Installation method type **F**

The activation fuse will activate at:

$$I_2 = 1.6 * 80 = 128\ A \text{ and } I_2 = 1.6 * 63 = 100.8$$

$$1.45 * 174 = 252.3\ A$$

We see that for **group 1**:

$$I_2 = 127A \leq 1.45 * Iz = 252.3 \text{ Valid}$$

And for **group 2** :

$$I_2 = 128 < 1.45 * Iz = 252.3 \text{ Valid}$$

The fuse can handle the maximum possible short-circuit, knowing that the chosen model are: two fuses of **63** and **80 A** rating and fuse size **NH1**.

Looking at

Group 1		Group 2	
Iccmax	Iccmin	Iccmax	Iccmin
69,7386871	69,5813288	81,1309466	80,9180566

Table 42 we get the **Isc**:

Group 1 $Iscmax = 81.13\ A\ < Breaking\ capacity = 50000A$ Valid

$$If_5 = 225\ A > Iscmin = 81.11\ A\ \ Not\ valid$$

Group 2 $Iscmax = 69.738\ A < Breaking\ capacity = 50000\text{A}$ Valid

$$If5 = 300\ A > Iscmin = 69.72\ A\ \ Not\ valid$$

We can see that the fuses are capable of dealing with the maximum short-circuit currents due to the high breaking capability of the fuses, but they do not meet the second condition.

Although on other type of installation an addition protection measure should be installed to cover this weakness, in this case we see that the own conductor are capable of dealing with the **Iscmin** without passing the tolerance limit for the installation type suggested. So no extra protection is needed.

- **Line regulator to battery :**

Now for the lines connecting the two charge regulators to the battery system. The voltage changes to **48V** and so does the current. The maximum short-circuit what the line can suffer is when the battery system's reverse current circulates along the line in a short circuit between the line and the battery system.

	N.Voltage	Lenght	Section	Rreg-bat	Rtotalreg-bat
Regulator-Battery	48	2	35	0,00102041	0,000510204

Table 44: Line from the regulators to battery characteristics.

Where:

Rtotalreg-bat: Is the sum of both **Rreg-bat**, that is the resistance of the line of each of the two charge regulators to battery lines:

$$RTotal_{RegBat} = \frac{1}{\left(\frac{1}{R_{RegBat}} + \frac{1}{R_{RegBat}}\right)} \quad \textbf{(32)}$$

The **maximum short-circuit current** is the one that occurs at the union point of both lines from the charge regulators to the battery system.

The **minimum short-circuit current** is the one at the base of the charge regulator for each line, from the reverse current of the battery system.

	Regulator-Battery system			
	Psc	Inominal	Iscmax	Iscmin
Group 1	58080	102,083333	1512,5	1202,636917
Group 2	58080	102,083333	1512,5	1202,636917

Table 45: Maximum and minimum short circuit currents.

Where:

Psc: The Short-Circuit power output of the battery system:

$$Psc = VoltageBattery * Isc_{C1hour} * 10\ batteries\ in\ parallel = 48 * 121 * 10 = 58080\ W$$

Isc: **Iscmax** with security factor and the **minimum Isc** without it.

$$Iscmax = Factor_{security} * \frac{Psc}{48\ V} = 1.25 * 1210 = 1512.5\ A$$

The chosen fuse for the two lines is the following:

Nominal current (A)	Fuse current rating(A)	Max tolerated current (A)*
102.08	125	174

Table 46: Fuse caliber for the line from regulator to battery.

*Method **F** of installation

Where:

$$I_2 = 1.6 * In = 1.6 * 125 = 200\ A$$

$$1.45 * Iz = 252.3 > I_2\ Valid$$

The short-circuit protection from the fuse:

$$Breaking\ capacity = 50000\ A \gg Iscmax\ \ Valid$$

$$If5 = 500A < Iscmin\ for\ both\ lines\ \ \ Valid$$

- **Line from battery system to inverter:**

The union line between the battery system and the inverter presents the following characteristics:

	N.Voltage	Length (m)	Section (mm)	Rbat-inv
Battery-Inverter	48	2	70	0,00102041

Table 47: Connection line between batteries and Inverter characteristics.

Where the maximum and minimum **Isc** are the following:

Battery system-Inverter			
Psc	**Inominal**	**Iscmax**	**Iscmin**
58080	203,255208	1512,5	1208,77

Table 48: Expected short-circuit currents at the line.

The **Iscmin** is the one at inverter level and the **Iscmax** will be the one at battery level, where Iscmax has been calculated:

$$Iscmin = \frac{Psc}{(48\ V * +R_{BatInv}))}$$

The chosen fuse will be the following:

Nominal current (A)	Caliber of the fuse (A)	Maximum tolerated current (A)*
203.255	250	269

Table 49: Fuse rating for the line battery-inverter.

*Type **F** installation

Where:

$$I_2 = 1.6 * 250 = 400\ A$$

$$1.45 * Iz = 269\ A < I_2\ \ No\ Valid$$

The protection against short-circuit:

$$Isc_{max} \ll Breaking\ capacity = 33000\ A\ \ Valid$$

$$If_5 = 800\ A\ < Iscmin\ \ Valid$$

- **Line from Inverter to distribution panel fuse:**

Where :

Cable inverter-distribution panel					
Power (W)	Voltage	Inominal	Section (mm)	Length (m)	RInvDist
9756,25	230	42,4184783	6	1	0,00297619

Table 50: Characteristics of the line from the Inverter to the distribution panel.

The Isc are:

Psc	Voltage	Iscmax	Iscmin
58080	230	315,652174	314,7155206

Table 51: Isc at the Inverter to distribution panel.

Let's choose the needed fuse:

Nominal current (A)	Fuse current rating (A)	Max tolerated current (A)*
42.4184	50	57

Table 52: Fuse rating

*For **E** type installation

Where:

$$I_2 = 1.6 * 50 = 80\ A$$

$$1.45 * Iz = 82.65 > I_2\ \ Valid$$

Now the short circuit protection from the fuse:

$$Iscmax = 100.095 \ll Breaking\ capacity = 50000\ A\ Valid$$

$$If_5 = 150\ A < Iscmin\ \ Valid$$

Further protection from a circuit breaker is needed:

- **Lines from distribution panel to consumption:**

The characteristic of the lines going to the electrical consumptions are:

	Power	Length	Current	Section	ResistanceLine
Home	7006,25	14	30,4619565	6	0,04166667
	Power	**Lenght**	**Current**	**Section**	**ResistanceLine**
Production	2750	50	11,9565217	6	0,14880952

Table 53: Lines from the distribution panels to the consumptions, characteristics.

The short-circuit will be the one at the distribution panel, which is the **Iscmax**, and the minimum **Isc** at the end of the line due to the resistance of the line itself.

	Iscmax	Iscmin
House	314,715521	241,730212
Production	314,715521	219,24368

Table 54: Isc in the consumption lines.

Where the **Iscmax** is the one at the distribution panel level, and **Iscmin is** the one at the end of each line:

$$Iscmin_{linesAC} = \frac{Psc}{\left(48\ V * (1 + RInverterDist + RLine)\right)}$$

Then the chosen fuse will be the following:

Nominal current (A)	Fuse rating (A)	Max tolerated current (A)*
30.46	32	46
11.95	15	46

*Installation type **B1**

For the house the fuse rating of **32 A** fuse size is 14x51 and **15 A** fuse size is 10x38 for the production part.

$$I_{2house} = 1.6 * 32 = 51.2\ A\ \ and\ I_{2production} = 1.6 * 15 = 24\ A$$

Then:

$$Iz * 1.45 = 66.7\ A\ \ \boldsymbol{Valid\ for\ both\ of\ them}$$

The fuses have a breaking capacity of **30 kA** for the **15 A** rated fuse and **10kA** for the **32 A** one. So as we can see they are much higher than the **Iscmax** so they are valid.

On the other protection condition:

For the production part $If_5 = 45\ A < Iscmin_{withoutsecurityfactor} = 219.24\ A \quad Valid$

For the house part $If_5 = 80\ A\ < Iscmin_{Withoutsecurityfactor} = 241.73\ A\ \ Valid$

- **Line to the wind turbine protection**

The maximum tolerated currents for the battery system to turbine charge regulator and for the line from the charge regulator to the turbine are the reverse current of the short-circuit with the battery system:

Nominal current (A)	Fuse rating (A)	Max tolerated current (A)*
62.5	80	327*
62.5	80	140*

Figure 37: Lines from battery system to wind turbine currents.

*Type **F** installation

$$I_2 = 1.6 * 80 = 128\ A$$

$$Iz * 1.45 = 140 * 1.45 = 203\ A > I_2\ \ \boldsymbol{Valid\ for\ both\ lines}$$

Now the protection against short currents:

Wind turbine to Charge regulator					
Power (W)	**Voltage**	**Current (A)**	**Section(mm)**	**Length (m)**	**ResistanceLine**
3000	48	62,5	95	20	0,003759398
Charge regulator to battery system					
Power (W)	**Voltage**	**Current (A)**	**Section(mm)**	**Length (m)**	**Resistanceline**
3000	48	62,5	25	2	0,001428571

Table 55: Lines from battery system to wind turbine characteristics.

And:

Wind turbine to regulator			
Psc	Voltage	Iscmax	Iscmin
58080	48	1510,34237	1203,75496
Battery system to regulator			
Psc	Voltage	Iscmax	Iscmin
58080	48	1512,5	1208,27389

Table 56: Expected Isc currents at the lines of the wind turbine.

$$Breakin\ capacity = 50000\ A \gg Iscmax\ \ Valid\ for\ both\ lines$$

$$If_5 = 300\ A < 1023.75\ A\ and\ < 1208.27\ A\ \ Valid\ for\ both\ lines$$

5.2. Grounding

The grounding should guarantee that the contact voltage when a defect occurs is of **24 V**, this in addition to the differential protection at the house and production area considering a sensibility of **30 mA** from the protections (following the Spanish legislation) .

$$R_{GroundingDC} = \frac{24\ V}{0.03\ A} = 800\ \Omega$$

The grounding for the DC can be made through a TN-S connection to ease the installation. It will connect to the grounding the neutral and masses of the solar panel, the masses of the combiner boxes, wind turbine mass and its charge controller and the charge regulators for the PV system.

Let’s see the sizing of a vertically disposed plate for the installation of the grounding:

$$R_{Grounding} = \frac{0.8 * \rho}{L} \quad \textbf{(33)}$$

P: The resistivity of the terrain. For this case a farming terrain not to humid, the parameter will be **10 Ωm**

L: The perimeter of the plate.

$$L = \frac{150 * 0.8}{800} = 0.15\ m$$

The plate is 2 mm wide.

6. Others

6.1. Selection of solar panel model

The selection of panels will be between a series of panels considered to be installed. The models considered are the following by the manufacturer companies:

Tamesol:

Three models from the family **TM-M672** 320, 325 and 340 W

AE Solar GmbH:

Two models: **AE305P6-72** of 305 W and **AE310P6-72** power output 310 W

The prices for the solar panels are taken from **Enfsolar**'s database [33]

Power to install (W)	Panel model	Price of panel (€/Wp)	Power panel	Monthly irrad (Wh/m^2)	Panels needed	Price (€)
33401,3822	TM-M672320	0,378	320	1910	55	6.652,80 €
33401,3822	TM-M672325	0,378	325	1910	54	6.633,90 €
33401,3822	TM-M672340	0,378	340	1910	52	6.683,04 €
33401,3822	AE305P6-72	0,39	305	1910	58	6.899,10 €
33401,3822	AE310P6-72	0,39	310	1910	57	6.891,30 €

Table 57: The comparison of solar panels. Source: Own

In Table 57 we can see the difference in price among the different models. We can reject the models from the **AE Solar Gmbh** company, since they are more expensive than the ones from the **Tamesol** family of monocrystalline.

Selecting between the three types of panels from the same family is not just about money, we have to take into account that the amount of the panels are pretty high, the difference in price among the three of them are pretty low, that the model that needs the least amount of panels to supply the needed power is also preferable (due that the installation will be on the roof).

But the definitive factor for selecting the panel model is the amount of charge controllers depending on how we organize them.

The considered charge regulators as we stablished before are the models **SmartSolar 250/100**, **250/85**, **150/100** and **150/85**. For more information about the calculation process see Charge regulator.

	Panel parameters		Regulator characteristics							
	Vosc	Icc	Voltage		Current		Series		Parallel	
TM-M672320	46,62	8,94	250	150	85	100	4	2	7	8
TM-M672325	46,67	9,07	250	150	85	100	4	2	7	8
TM-M672340	46,8	9,46	250	150	85	100	4	2	7	8

Table 58: Number of panels in parallel and series by charge regulator. Source: Own.

In Table 58 we see that the regulator allows the same amount of panels in parallel and series connection for the three types of panels, dividing the maximum amount of panels each regulator can take, thus we obtain the number of regulators needed:

Amount of Regulators					
Number panels	250/100	250/85	150/100	150/85	
55	1,71875	1,96428571	3,4375	3,92857143	TM-M672320
54	1,6875	1,92857143	3,375	3,85714286	TM-M672325
52	1,625	1,85714286	3,25	3,71428571	TM-M672340

Table 59: Amount of regulators needed by solar panel model. Source: Own

Watching Table 59 we would select the model **TM-M672325** as it is the cheapest one, and needed two **SmartSolar 250/85** as the other two but the problems comes when organizing the panels **TM-M672320** and **TM-M672325** due that the number of panels needed for each model is 55 and 54 respectively.

The problem is that we cannot organize the numbers 55 and 54 in combinations that give an integer number using only two regulators with the proposed models: e.g for the 55 panels group.

Possible combinations would be 32+23, 31+24, 30+25 and 29+28 doing the basic math of diving the previous numbers between the maximum allowed of panels possible in series by each charge regulator we can see we never get an integer number.

So if we choose those two models we would need three charge regulators even it sounds unintuitive.

But the model **TM-M672340**, which needs 52 can be organized in two groups of 28+24 that can use only two regulators, which is the cheapest solution. Therefore the chosen model for the installation is the model **TM-M672340** of 340 W.

7. Distance between panels on roof installation

Although normally on roof installation the solar panels are installed at the same angle as the roof, and there is no separation between panels is needed, in this case the panels are suggested to be installed at a 50º degree angle, which is 5º more than the roof angle of around 40-45º. Then a separation is needed between the panels to avoid shadowing.

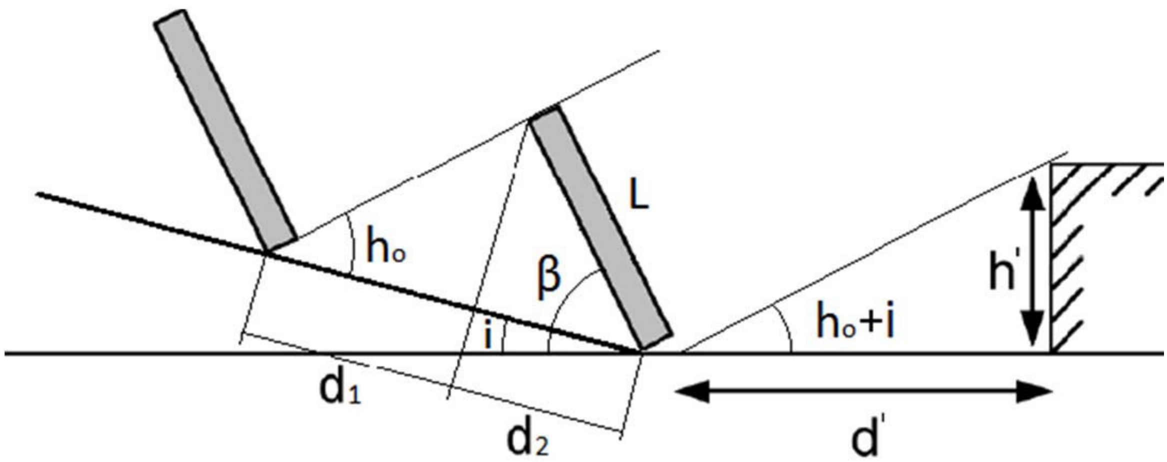

Figure 38: Distance to avoid shadowing in inclined installation. Source: IDAE[32]

The following calculation process:

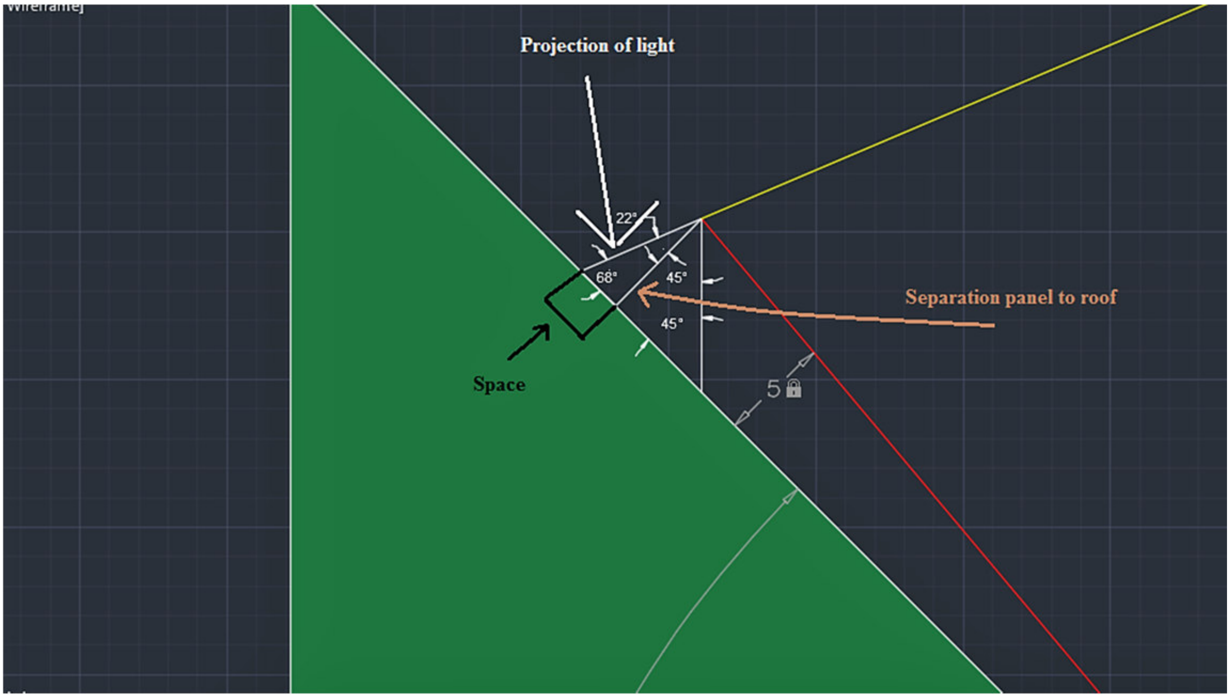

Figure 39: Light projection in winter on the panels. Source: Own creation

The explanation of Figure 39:

Yellow line: Represents the sunlight in winter (the worst scenario) where the light presents a 23º angle with the ground (horizontal axis).

Red line: Represents the solar panel. The chosen model is 1,956 m long. The panel is at a 5º degree with the roof surface and at a 50º angle with the horizontal axis.

Projection of Light (PL): The distance that the light travels since it "touches" the solar panel and ends at the roof surface.

Space (d): The minimum distance to separate the upper panel to avoid shadowing.

Separation panel to roof (SPR): The vertical distance of the highest part of the solar panel in respect to the local axis located on the roof surface.

The calculation of the minimum space needed will be as follows:

$SPR = Panel_{Lenght} * \sin PanelToSurface \ (mm)$ **(34)**

Being:

PanelToSurface: The angle between the panel and the surface is **5º**.

PanelLength: 1956 mm

$$SPR = 1956 * \sin 5° = 170.47 \ mm$$

We calculate now the previously stated Projection of the light:

$$PL = \frac{SPR}{\sin 68°}\ (mm) \quad \textbf{(35)}$$

$$PL = \frac{170.47}{\sin 68°} = 183.857\ mm$$

Now to finish the minimum space needed to be left between the solar panels :

$$Space = PL * \cos 68° \quad \textbf{(36)}$$

$$Space = 183.857 * \cos 68° = 68.874\ mm \approx 70\ mm$$

The angle of the roof is between 45 to 40 degrees. Therefore the minimum space needed should be bigger for safety reasons.

Then the total space measured from the base of the first line of panels is:

$$Space_{total} = Space + Panel_{lengthsurface} \quad \textbf{(37)}$$

Being $\text{Panel}_{\text{lengthsurface}}$: The projection of the first line of panels' length upon the roof surface:

$$Panel_{lengthsurface} = Panel_{length} * \cos(Angle_{panel} - Angle_{Roof}) \quad \textbf{(38)}$$

$$Panel_{lengthsurface} = 1956\ mm * \cos(50° - 45°) = 1948.55\ mm$$

$$Space_{total} = 70\ mm + 1948.55\ mm = 2018.55\ mm$$

Then:

$$Space_{totalSecurity} = Space_{total} * Factor_{Security} \quad \textbf{(39)}$$

Factor$_{\textbf{Security}}$= 1.25

$$Space_{totalSecurity} = 2018.55\ mm * 1.25 = 2523.19\ mm \approx 2523\ mm = 2.523\ m$$

Budget and economic analysis

8. Economical aspects of the project

On previous chapters of this case study we defined the total amount of needed elements for the hybrid installation, being the amount of elements needed for the installation:

TM- M672340	52 Panels
Enair E30PRO 48V	1 turbine + regulator
SmartSolar 250/85	2 charge regulators
Phoenix 48/5000	2 inverters in parallel
Batteries 12CS-11PS	40 blocks

Table 60: Elements to install at the hybrid system.

For the different calculations we will do in this chapter, the following parameters are needed to be defined:

Discount Rate: The gain or loss on an investment over a specified time period, expressed as a percentage of the investment's cost. For this case a discount rate of **5%** has been taken

O&M: Being the maintenance and operation of the system. For off-grid systems the annual O&M of **2%-6%** of the initial capital cost is taken , for this case study a rate of **2% .**

Investment period: The period of time taken into consideration when calculating the NPV and IRR of the investment. A period of 20 years has been taken.

8.1. Budget of the installation

The cost of the elements inTable 60 will be :

	Price.exVAT(€)	PriceVAT(€)
Panels	6.683,04 €	7.952,82 €
Wind turbine	5.880,16 €	6.997,39 €
Inverters	5.086,00 €	6.052,34 €
Charge regulators	1.413,45 €	1.682,00 €
Battery system	37.830,08 €	45.017,80 €
	Total price:	67.702,35 €

Table 61: Price with VAT of the system elements.

As we can see in off-grid systems the need of battery systems hugely increments the price. Now for the **Balance of System** (BOS) investment, that the price includes:

Mounting system, installation, cables, infrastructure, transformer, grid connection, planning and documentation and any other elements.

For the off-grid system the transformer and grid connection will not form the part of the investment, as they are not needed. So taken data from ground-mounted PV systems in Germany [34] the cost for mounting is of **75 €/Kwp**, Installation and DC-cabling costs are around **50 €/Kwp** and infrastructure is **40€/Kwp**. Finally the compound cost of transformer, switchgear and planning is of **60€/Kwp**, so the price for planning and documentation is of **20€/Kwp.**

Engineering and construction is around **370 Euros/Kwp** and Fees and permitting, are around **160 €/Kwp**

Considering the wind turbine as part of the installed photovoltaic system we get that:

Installed power (kW)	Price/Kwp (€/Kwp)	Price (€)
20.68	715	14786

Table 62: BOS and additional cost.

A funding for the installation can be asked from the funding program **Casa verde** (Green house in English) for a total of 6000 Lei (**1500 €**) funding.

The total initial investment will be:

Elements price	BOS+ others	Funding	Total (€)
67702.35	14786	-1500	80988.35

Table 63: Total initial investment

The yearly **O&M** cost is: **1619.767 €.**

Comparing the renewable solution to the standard connection to the electrical grid, it can be seen:

The distance between the closest connection point to the medium voltage (MV) network is 2 km far away (this distance is only the horizontal distance, not the upwards distance, due that the farm is located on a higher position respect to the closest population core)

The prices for a typical connection from an MV network, considering that the infrastructure required to connect the farm to the network is not installed:

- From MV to the location: $\mathbf{57900\ €/\mathit{km}}$
- The price of the transformer from 20/0.4 Kv, 63kVA: $\mathbf{10500\ €/\mathit{Piece}}$

Prices were given by **E·ON** company responsible of the installation of the electrical infrastructure in the area, the partner of **General Electric**. The prices are just estimated, and probably in the case scenario where the traditional grid connection was chosen, the price could be higher due to the difficulties on the whole line installation along the area (uphill, forest, mud etc…)

Therefore the initial investment from the connection to the normal grid will be a total of:

$$TotalPrice_{StandardConnection} = 2\ km * 57900 \frac{€}{km} + 10500 \frac{€}{piece} = \mathbf{126300}\ €$$

We can see that the price is higher than the proposed installation for this case study.

8.2. Payback, IRR and NPV

The payback from the installation is calculated with the following formula:

$$Payback\ period = \frac{Initial\ investment}{Anual\ cash\ flows} \quad \textbf{(40)}$$

Where the annual cash flows will be from the saving from not used diesel generator:

$$CashFlow = LitresDieselSaved * PriceDiesel - O\&M \quad \textbf{(41)}$$

Where the yearly litres of diesel saved (see Air pollution and greenhouse gas emissions) are:

Litres Diesel Saved=9357,647 Litres

Price Diesel: The average of diesel price in Romania is around **1€/liter**.

$$CashFlow = 9357.648 \frac{€}{Year} - 1619.76 \frac{€}{year} = 7737.88\ €/year$$

Therefore the Payback period will be:

$$Payback\ period = \frac{80988{,}35\ €}{7737.88\ \frac{€}{Year}} = 10.466\ Years$$

NPV and IRR:

The equation for the **Net Present Value** is:

$$NPV = -I_o + \sum_{t=1}^{n} \frac{CashFlow}{(1+DiscountRate)^t} \quad \textbf{(42)}$$

Where:

Io: Is the initial investment

N: is the investment period

A **positive NPV** means that the inversion is profitable and should be accepted, because we will get a profit because the return rate is higher than the discount rate

A **NPV=0** means that it should be accepted with conditions, since it does not bring neither benefit nor loss.

A **negative NPV** should be rejected

As for Internal Return Rate (**IRR)**:

It is the rate when NPV equals to zero.

$$NPV = -I_o + \sum_{t=1}^{n} \frac{CashFlow}{(1+IRR)^t} = 0 \quad \textbf{(43)}$$

A **positive internal rate** means, that IRR is bigger than the discount rate, it would mean that the return rate from the inversion is greater than the discount rate considered, and you gain profit from the investment you have invested in. The project should be accepted.

An **equal IRR** would mean that you neither lose neither win money, the project should be accepted.

When the **IRR is smaller** than the Discount rate, it means, that the inversion is not profitable, should be discarded.

The NPV for the project is of **7088.42 €** and a IRR of **6%** which is higher than the considered Discount rate of **5% (**see Table 64)

	SAVINGS	COST	PROFITABILITY		
	FuelPriceSaved (€/year)	O&M (€/year)	Cash-Flow	Cumulative Cash-Flow	NPV (€)
0			- 88.988,35 €		
1	9357,648	1619,76	7.737,89 €	7.737,89 €	-77.732,32 €
2	9357,648	1619,76	7.737,89 €	15.475,78 €	-71.048,04 €
3	9357,648	1619,76	7.737,89 €	23.213,66 €	-64.682,06 €
4	9357,648	1619,76	7.737,89 €	30.951,55 €	-58.619,22 €
5	9357,648	1619,76	7.737,89 €	38.689,44 €	-52.845,09 €
6	9357,648	1619,76	7.737,89 €	46.427,33 €	-47.345,92 €
7	9357,648	1619,76	7.737,89 €	54.165,22 €	-42.108,61 €

8	9357,648	1619,76	7.737,89 €	61.903,10 €	-37.120,70 €
9	9357,648	1619,76	7.737,89 €	69.640,99 €	-32.370,31 €
10	9357,648	1619,76	7.737,89 €	77.378,88 €	-27.846,12 €
11	9357,648	1619,76	7.737,89 €	85.116,77 €	-23.537,38 €
12	9357,648	1619,76	7.737,89 €	92.854,66 €	-19.433,81 €
13	9357,648	1619,76	7.737,89 €	100.592,54 €	-15.525,65 €
14	9357,648	1619,76	7.737,89 €	108.330,43 €	-11.803,60 €
15	9357,648	1619,76	7.737,89 €	116.068,32 €	-8.258,78 €
16	9357,648	1619,76	7.737,89 €	123.806,21 €	-4.882,76 €
17	9357,648	1619,76	7.737,89 €	131.544,10 €	-1.667,51 €
18	9357,648	1619,76	7.737,89 €	139.281,98 €	1.394,63 €
19	9357,648	1619,76	7.737,89 €	147.019,87 €	4.310,96 €
20	9357,648	1619,76	7.737,89 €	154.757,76 €	7.088,42 €
				154.757,76 €	7.088,42 €

Discount Rate:	0,05	**IRR:**	6%

Table 64: NPV and IRR of the system.

Project plans

9. Project Plans

Figure 40: Distribution plan

On Figure 40 is showed an aerial view of the farm, and the suggested installation location for the system:

In red the location of the solar panels.

In orange the location of the wind turbine.

In green the location of the different elements (charge regulators, inverters) and the battery system.

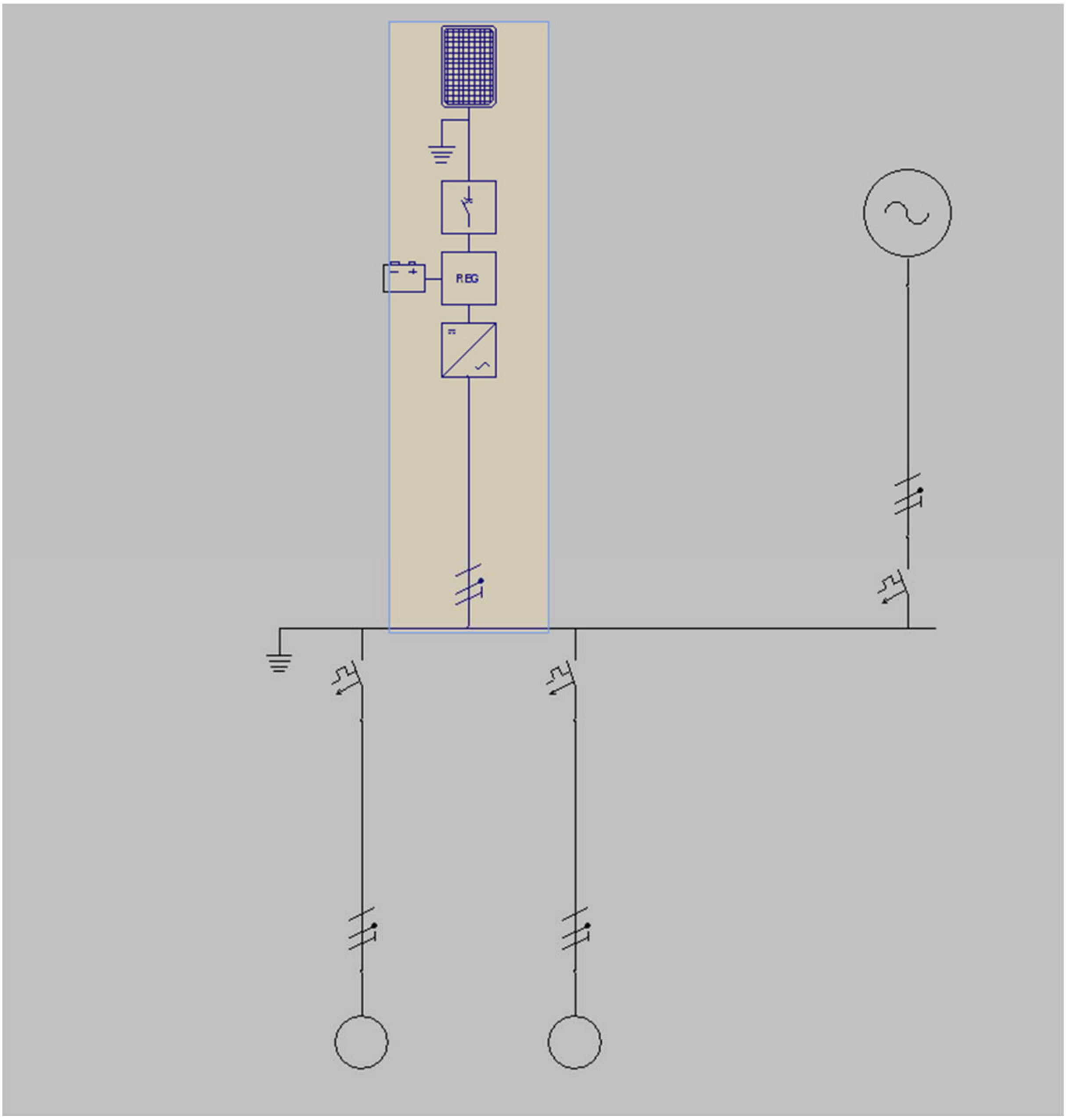

Figure 41: Electric scheme of the installation including generator.

REPORT OF THE CASE STUDY ON RENEWABLE ENERGIES TO LOCAL DEVELOPMENT TRANSNATIONALLY IMPLEMENTED

Study concerning optimization of photovoltaic lighting system in Margineni village

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Bacau, April 2017

Contents of the project

Memory of the project

1. Introduction

This case study presents of a photovoltaic lighting system installation that could supply power to public lighting, and a new development which presents the design of a photovoltaic system with a centrally managed system on a street where currently there is not any lighting system in operation in Margineni village.

1.0.1. Data about the village:

Figure 1: Margineni

- Margineni is a commune in Bacau County, Romania.
- The commune's members are: Margineni, Barati, Trebes, Padureni, Poiana, Blidaru, Budului Valley, Podis and Serpeni.
- Coordinate: 46°35'19''N 26°48'23''E
- Population: about 9400
- Specific Climate
  - Avarage temperature: 9,2°C
  - Warmest month, July
    avarage temperature: 21,2 °C
  - Coldest month, January
    avarage temperature: 4,1 °C
  - Thermal amplitude annual: 25,2 °C
  - Avarage value of precipitation: 542mm/year
  - Prevailing winds: North and Northwest
  - The average value of speed wind: 2.1 m/s
  - The annual average of sunshine: 2000 hours

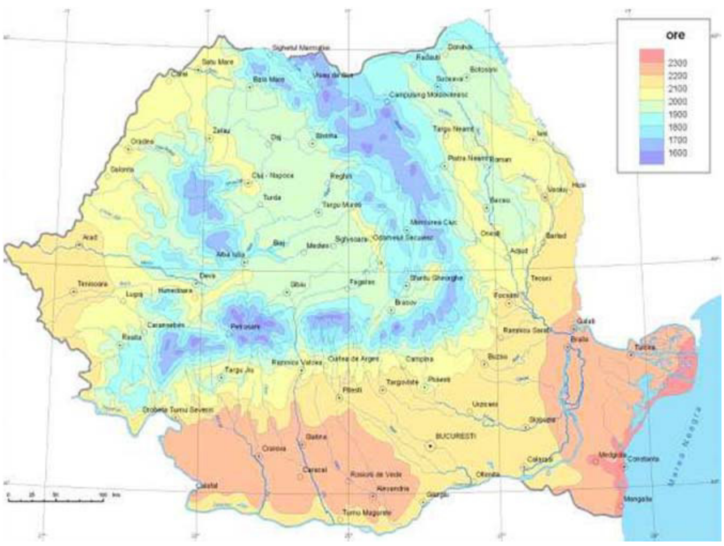

Figure 2: Hours of sunshine in Romanina

1.0.2. Data about the street:

The street where I have designed the photovoltaic lighting system in this case study is an access street to the workstation (pumping and chlorination) of the Regional Water Company in Margineni village.

Width: 4m

Length: 150 m

Figure 3: Map view from the street in Margineni

<u>Regional Water Company (CRAB S.A.):</u>

The company manages the drinking water supply, domestic sewage as well as the industrial run off from Bacau County according to the regulations of the water supply and sewerage.

In 2011 the S.C. Regional Water Company Bacau obtained certification of the integrated system of quality, environmental management and health and safety at work in compliance with the requirements of international standards.

This company is very important for Bacau County, therefore it is also important that transport is safe and controlled between the workstations. Currently it is neccessary to install a lighting system to this street.

In order for the design to be successful, we need to know everything about the public lighting system in the village, and to analyze the possibilities to choose the best solution.

1.0.3. Photovoltaic lighting system

The solar panels / or photovoltaic cells – directly convert the radiation energy of the Sun into electricity. The construction elements compose of photoelectric solar cell semiconductor material, which generates an electrical signal when exposed to light radiation. The principle of operation is as follows:

When photons of light from the semiconductor crystal surface after absorption with the crystalexcite valence electrons, the electrons are in a higher energy level (conduction band), the free charge carriers are formed. The charge is carried to an external load passing creating a closed circuit and thus electricity is generated. The solar panels directly provide electrical power, which is converted by means of inverter power voltage.

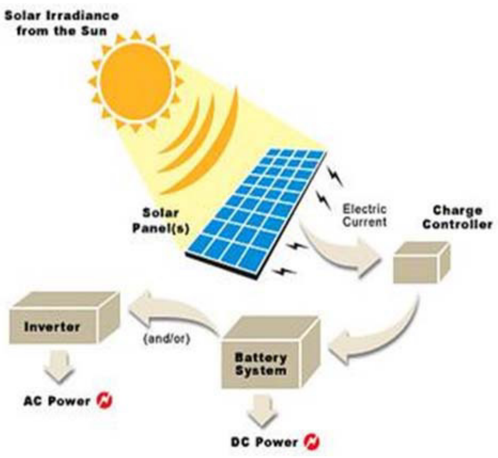

Figure 4: Operating principle of a PV system

Nowadays photovoltaic lighting systems are very popular because, owing to its use of solar energy, we can produce light, thereby solving the issue of street lighting. The most modern technology available is the LED (Light Emitting Diode) street lighting installation. The reason for the popularity is the energy saving. Compared to conventional street lighting, the photovoltaic system can save up to 50 or 80% energy.

The core of LED as the light source is that light is not created by means of a filament or gas discharge as in traditional incandescent lamps or compact fluorescent tubes, but through integrated semiconductors (diodes).

LED in the public lighting:

- More than 50 000 hours of life
- A small amount of waste
- There is no flicker of light close to natural light effect
- Low energy consumption (50-80% reduction) and high brightness
- Low power dissipation, low heat generation
- Power without delay, immediately lighting.


Figure 5: LED lamp

1.0.4. The importance of the control system

LEDs are energy efficient by design. Simply using LED lamps or fixtures can help a facility to meet updated system and energy codes while reducing electrical consumption and cost. For the same reason it is possible to control any light source – to maximize energy savings, extend system life, enhance flexibility, increase productivity, and provide a safe and comfortable environment for the inhabitants.

A wide range of controls are available – from a single switch or dimmer to a centralized lighting control system – to provide maximum flexibility, as well as measurement and reporting tools to help effectively analyze the energy savings being achieved with the lighting and control installation. Easy-to-install wireless controls facilitate simple retrofit, reducing installation and programming costs and improving the return on investment (ROI).

Regardless of the control system to be chosen, it is critical to work with a manufacturer who can guarantee compatibility and performance, eliminating many of the common concerns and issues that are seen with LED installations.

Maximizing savings, life, and performance

Dimming LEDs, similar to the process with fluorescent sources, save energy at a roughly 1:1 ratio. This means that if you dim LEDs down to 50% of their light output, you save nearly 50% of the associated energy. While it is true that LEDs are already very efficient compared to almost any other light sources, you save even more energy by dimming them.

Dimming LEDs also makes run cooler, extending the life of the electronic components in the driver, as well as the phosphor in the LEDs. This will potentially double or triple the useful life of the LED lamp or module. Research is ongoing to better quantify the relationship of dimming LEDs and lifetime extension.

LED lighting provides linear energy savings relative to dimming levels.

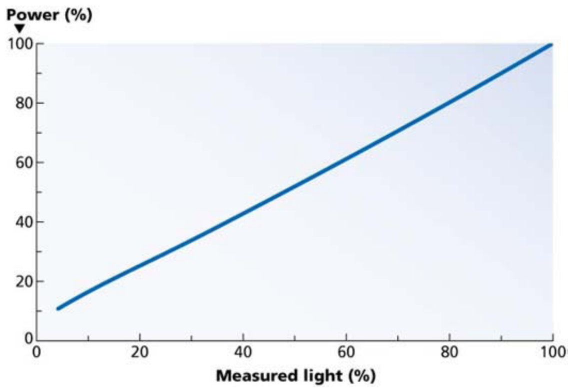

Diagram1: Linear straight between power and lighting

New constructions enable the use of either LED lamps or LED fixtures and offer a wide variety of control options. Retrofit applications are often limited to LED lamps, and the control options will be limited as well. Defining the application will determine how to think about the other factors in a LED-based lighting and control system.

The basis of these lamps have integral drivers that determine whether they are dimmable, and if so, the dimming performance. LED fixtures can vary from cove lights to downlights and usually have an external driver. Some fixture manufacturers offer different driver options (fig. 6) on the same fixture to support different control technologies or applications (such as dimmable vs. non-dimmable). It may even be able to specify an optimal drive from another manufacturer that includes the desired feature set.

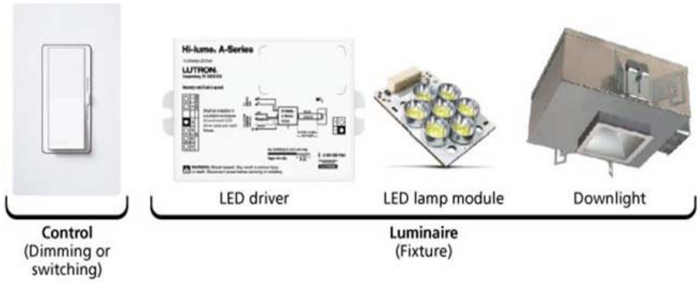

Figure 6: Fixture and control system

In the case of luminaires, a driver that meets the project requirements has to be chosen.

It is necessary to check with the driver or fixture manufacturer to be confident that the right product is chosen - drivers are available that can dim LEDs from 100% to 1% light, offering smooth and continuous dimming for both constant-current and constant-voltage sources. The long-life benefits of LEDs will be reduced if the driver is not designed for an equally long life.

Control type to LED product operation

There are many types of controls and control systems from high voltage (traditional phase control or reverse phase control) to low voltage (0-10V, DMX, DALI) and even some new entries with embedded wireless connectivity in the lamp/fixture.

While there have been a variety of control technologies available for years, the proliferation of LED lighting has caused many applications to move away from the typical control choices used for standard incandescent loads. Additionally, the inherent controllability of LEDs makes it likely that more applications will incorporate controls. Therefore, training on available control technologies, such as 0-10V, forward or reverse phase, EcoSystem, or others, it will be necessary to ensure the proper pairing of the controls with fixtures that support that technology.

High peak current in LED lamps that occurs on each half-cycle of the AC line voltage can also damage dimmers.

A holistic approach to LED control can help meet and exceed customer expectations. Technologies are improving, control options are expanding, literature and general knowledge is increasing, and LEDs can now be effectively used in virtually any type of commercial application. By choosing the right manufacturer and considering key issues, it will be easier than ever to provide customers with a LED lighting and control system that meets energy-saving, performance, and aesthetic expectations.

1.0.5. Current photovoltaic lighting system in Margineni:

- Total amount: €3.5 million
- The system's installation date: October, 2015.
- The length of the public lighting network in Margineni commune: 70.12 km and 1606 pillars.
- Each lighting pole is a standalone system.
- The investment is not made throughout the village as there are some streets where traditional street lighting is currently operating, or where public lighting is non-existent.

In the commune of Margineni two classes of lighting can be identified in harmony with the two categories of the lighting of road traffic, which is as follows:

ME3a type: with important traffic

- train length: 15,25 km
- 510 sytstems
- width of the roadway: 7m
- alternating poles bilateral arrangement
- min. distance between 2 poles on the same side: 60m
- where alternating bilateral → unilateral → arrangement is not allowed min. distance between 2 successive poles: 30m
- max. mounting height body lighting: 8m above the roadway
- max. length of the mounting bracket to the body luminaire shall not exceed 2m
- maintenance factor: 0,85 (cleaning, lighting twice a year)

ME5 type: with little traffic

- trail length : 54,85 km
- 196 system
- width of the roadway: 7m
- alternating poles unilateral arrangement
- min. distance between 2 poles: 50m
- max. height mounting body lighting: 8m above the roadway
- max. length of the mounting bracket to the body luminaire shall not exceed 2m
- maintance factor: 0,85 (cleaning, lighting twice a year)

The main characteristics of body lighting IP66 ME3a, and ME5 type are:
(IP66 is a notanion, which means: fully protected against dust and powerful water jets and against immersion in water)

	ME3a	ME5
Type	TECEO 1	
Casing	aluminium	aluminium
Lens	heat treated glass, flat or curved	heat treated glass, flat or curved
Degree of protection	IP66 minimum	IP66 minimum
Protection from impact	minimal IK08	minimal IK08
Minimum net flow of lighting	6400lm	4300lm
Driver power supply	12-14V	12-14V
Color temperature of light	3000-4500 K	3000-4500 K
Maximum total consumption	80 W	60 W
Minimum duration	50000 h	50000 h
Possibility of assembling	vertically and horizontally	vertically and horizontally
Vertical adjustment	0°-15°	0°-15°
Operating temperature	-30°C - +35°C	-30°C - +35°C
Maximum weight	12 kg	12 kg
Producer	Energobit Schreder Lighting	

Table 1: Main characterictics of the two different road categories

1.0.5.1. Teceo 1 type

Maximum energy savings

A minimal total cost of ownership was the driving force behind the development of the Teceo range. It is equipped with LEDs and various dimming and remote management options for a dramatic reduction in energy consumption. It offers a very competitive alternative to luminaires equipped with traditional light sources such as high-pressure sodium lamps.

Figure 7: Teceo1 lamp

Lensoflex®2

Teceo luminaires are equipped with second generation LensoFlex®2 photometric engines that have been specifically developed for lighting spaces where the wellbeing and safety of people using the environment is essential.

This system is based upon the additional principle of photometric distribution. Each LED is associated with a specific lens that generates the complete photometric distribution of the luminaire. It is the number of LEDs in combination with the driving current that determine the intensity level of the light distribution.

Figure 8: Teceo1 lamp

Performance and flexibility

The Teceo luminaires are equipped with photometric engines composed of modular quantities of LEDs so that they can offer a wide range of lumen packages. They can also be equipped with a variety of drivers and dimming options.

The Teceo luminaires can be adjusted on-site for optimal photometric performance. This flexibility ensures that the light distributions are specifically adapted to the real needs of the area to be lit.

Figure 9: Teceo1 lamp

Smart lighting

The Teceo luminaires can integrate the Owlet range of control solutions to operate either in stand-alone mode, in an autonomous network or in an interoperable network.

Dimming scenarios and light-on-demand features equipped with sensors can adapt the lighting to the real needs of the place and the time to ensure safety and well-being in the most sustainable way.

Figure 10: Teceo1 lamp

Futureproof

Using state-of-the-art technology, Teceo luminaires have been designed to fulfil the FutureProof concept. The photometric engine is IP 66 sealed to protect the LEDs and lenses from coming into contact with the outside environment and so maintain photometric performance over time.
The optical unit can be easily removed, allowing real on-site replacement at the end of its service life in order to take advantage of future technological developments.
This easy and rapid procedure reduces maintenance costs and contributes to reducing the total cost of ownership.

At the forefront of sustainability

The Teceo 1 luminaire can take advantage of its very low power consumption to be supplied with solar energy to offer an even more sustainable lighting solution. The Teceo 1 solar version – equipped with a driver specifically designed for this application – provides high efficacy which enables the panel size and battery capacity to be reduced, thus minimising the total cost of ownership.
The Teceo 1 solar version is the perfect tool to answer energy efficiency concerns and to offer a performing LED lighting solution for off-grid applications. The Teceo solar version range is suitable for both 12V and 24V batteries. It can provide a LED lumen package from 2,200 up to 9,000lm to meet the lighting needs of numerous applications such as car parks, bike paths, secondary roads, residential streets.

Teceo 1

LENSOFLEX®$_2$							Lifetime
Number of LEDs	Neutral white (4000K)	16 LEDs	24 LEDs	36 LEDs	40 LEDs	48 LEDs	100.000 h
Current: 350mA	Nominal flux (lm)*	2400	3600	4800	6000	7200	90%
	Power consumption (W)	18	27	36	44	53	
	Solar version - 12V	✓	✓	✓	✓	✓	
	Solar version - 24V	✓	✓	✓	✓	✓	
Current: 500mA	Nominal flux (lm)*	3100	4700	6300	7900	9500	
	Power consumption (W)	26	38	51	63	75	
	Solar version - 12V	✓	✓	✓	-	-	
	Solar version - 24V	✓	✓	✓	✓	✓	
Current: 700mA	Nominal flux (lm)*	4000	6100	8100	10200	12200	80%
	Power consumption (W)	36	55	71	90	107	
	Solar version - 12V	✓	-	✓	-	-	
	Solar version - 24V	✓	-	✓	-	-	

Table 2: Data of Teceo1 type

1.0.5.2. Technical data

Components:

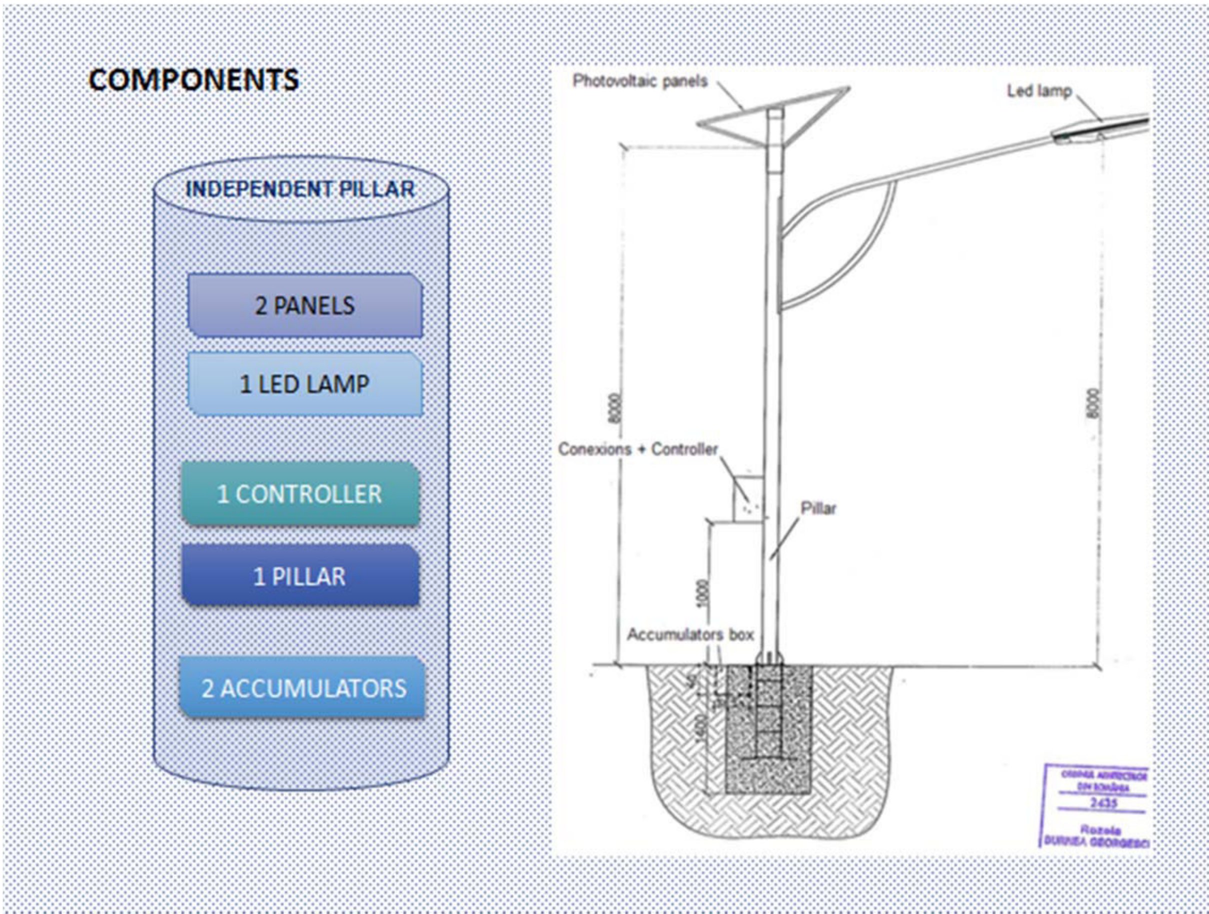

Figure 11: Components of the photovoltaic system

<u>Photovoltaic module in normal operating conditions:</u>

- Max power: 172W
- Max Voltage: 26,7V
- Max current: 6,7to
- Short-circuit current: 6,95
- Number of cells/module: 60pieces
- Cell type: polycrystalin
- Cell size: 156*156mm
- length*width*height: 1700*50*1000 mm
- The bypass diodes include connections
- The maximum supported load: 5400 N/m^2

Controller:

- Operating Voltage: 12V
- Input voltage: 47 V
- Voltage output: max. 34 V
- Max. output current: 20A
- Operating temperature: -25°C –+55°C
- System monitoring and control of electrical parameters
- Voltage and current adjustment
- Automatic load reconnection
- Short-circuit protection

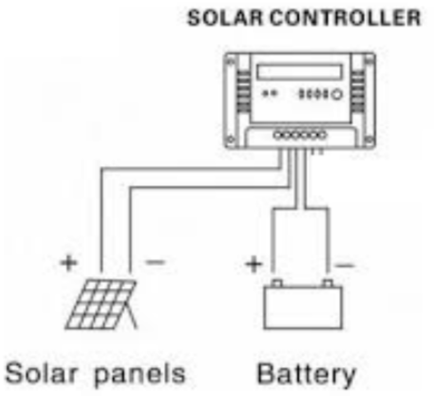

Figure 12: Controller

Battery

- No maintenance
- Technology: deep cycle
- Electrolyte: acid sulfate
- Normal voltage: 12V
- Normal capacity: 100Ah
- Operating temperature: -20°C – +40°C
- Weight: 30 kg
- Size: 350*200*250 mm
- Explosiom safety valve

Figure 13: Battery

Pillar

- Material: steel OL37
- Mounting: base plate clamped with anchors on insulated concrete foundation
- Anticorrosive painting or galvanizing
- Height: max 8,0 m
- Wind resistance: 150km/h
- Accessory:
  - Mounting box controller
  - Battery mounting box
  - Anchors embedded in the foundation

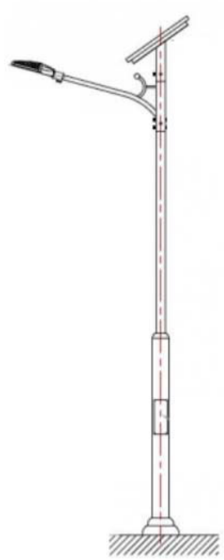

Figure 14: Pillar

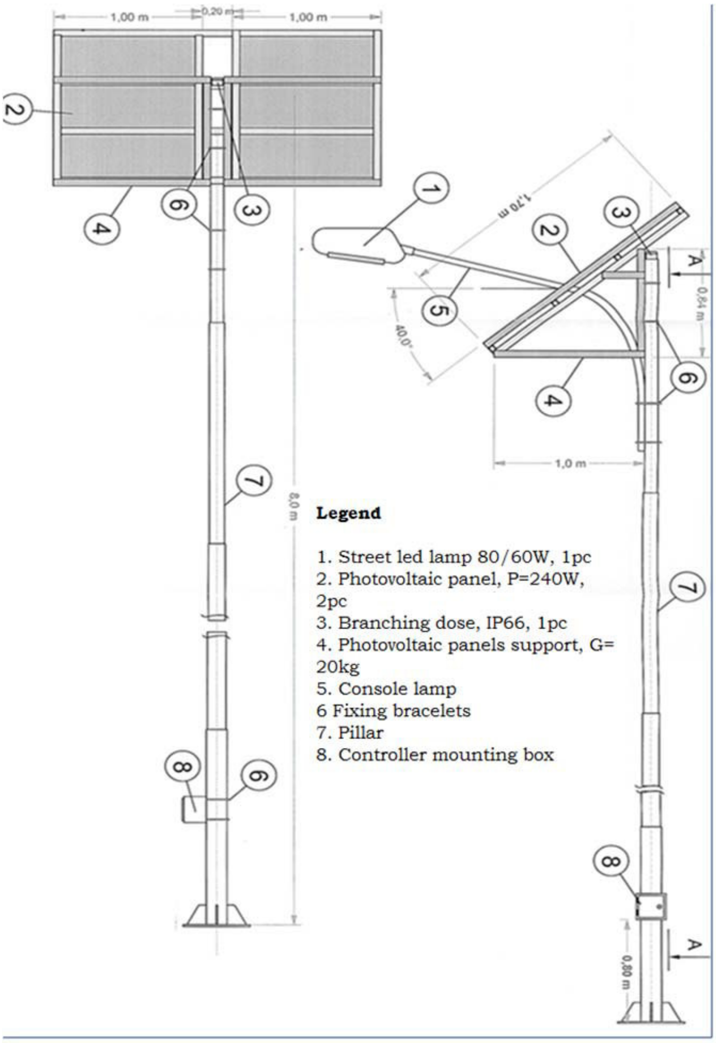

Figure 15: Structure

The main advantages and disadvantaged of the photovoltaic lighting system are the following:

Advantages

- Low cost of ownership
- It does not emit pollutants during operation
- The Sun as an energy source is available everywhere
- Energy saving

Disadvanteges:

- High production costs
- Long payback period
- Relatively low efficiency
- Pollutants that must be neutralized at the end of the life cycle

1.1. State-of-art in the problem domain

Reducing operating and energy consumption costs of public lighting is being promoted today. The operators, primarily municipalities, are considering a solution in this regard that the outdated lamps should be replaced with new, more energy-efficient light sources and luminaires. Unfortunately, this reconstruction program will usually provide technical solutions to investors in which energy efficiency is placed above all other technical aspects, and so lighting levels required by public lighting standards are often not met, the streets and squares are already under-lit.

In conformity with the 24 hour change of daylight, the highly changeable traffic, the variable meteorological conditions and some extreme situations on the roads, the intensity of street lighting should change in a dynamic manner. New technical devices and methods that are offered by technical progress will be necessary obviously for the realization of adaptive lighting.

A lighting control system as an intelligent network based lighting control solution that incorporates communication between various system inputs and outputs related to lighting control with the use of one or more central computing devices. Lighting control systems are widely used on both indoor and outdoor lighting of commercial, industrial, and residential spaces. Lighting control systems serve to provide the right amount of light where and when it is needed.

Further cost reduction potential of intelligent control system.

On the one hand, in Margineni village the replacement of the previous high-performance luminaires also resulted in cost savings thence the photovoltaic lighting system works well, and it saves significant energy and money for the village, but there are some streets where the lighting system is traditional, or there is no street lighting at all.

On the other hand, if we want to control lighting, it is neccessary to know whether the fixtures from the current system are dimmable or not. The current system in Margineni works with Teceo1 type from Schreder manufacturer. This type of fixture is non-dimmable because each lighting pole is a standalone one, therefore it is neccessary to choose a new type which can work in a controlled system.

The goals are to:

- increase energy savings,
- enhance energy efficiency,
- increase Energy Security,
- reduce energy import dependence,
- reduce environmental damage.

1.2 Design alternatives to be considered

There are a number of questions that inevitably occur:

- What happens when a new network or lamp is replaced? (If a lamp is replaced, what will be the technical condition of the network?)
- How much distance is needed for proper lighting? (40-50-60m, the distance from the road network is 4-7 m).
- Can the actual technology provide approppriate solutions for this specific situation?

During the design the following aspects should be taken into account:

- the column distances,
- points of light heights,
- road layout,
- road category.

In Margineni, there are two road categories:

- ME3a: important traffic
- ME5: little traffic

In the design it is necessary to determine the categories of road.

1.2.1. Potential products which are able to work in a controlled system:

Pegaso is produced by SPI Tecno. The Pegaso type has different versions of strength, from which the appropriate parameters must be selected, which are the following:

<u>Lighting type of roads:</u>

- Pegaso 24: for roads ME5 and ME6, speed 30km/h
- Pegaso 36: for roads ME4b, speed 50Km/h
- Pegaso 48: for roads ME3b, speed 90Km/h
- Pegasus 48+: for roads ME2b, speed 130km/h

<u>Height of the posts:</u>

- Pole height: 6 m Pegaso 24
- Pole height: 8 m Pegaso 36, Pegaso 48
- Pole height: 10 m Pegaso 48
- Pole height: 12 m Pegasus 48+

Cross reference:

- SAP70W lamp with replaceable Pegaso24 / 40W-48W
- SAP100W lamp with replaceable Pegaso24 / 55W - 65W
- SAP150W lamp with replaceable Pegaso36 / 80W - 100W
- SAP150W lamp with replaceable Pegaso48 / 80W - 100W
- SAP250W lamp with replaceable Pegaso48 / 110W-190W
- SAP400W lamp with replaceable Pegaso48 + / 125W-355W
- SAP400W lamp with replaceable Pegaso48 + / 150W-330W

Advanteges of Pegaso:

- energy savings of up to 60%,
- Saving with remote control by up to 75%,
- low maintenance,
- easy accessibility to the led housing,
- perfect uniformity of light due to the asymmetric lenses,
- it does not contain hazardous substances.

1.2.2. Types of control systems

The dimming systems have two main groups: **analogue and digital.**

Analogue

Analogue dimming covers all dimming systems that do not transform the dimming signal into bits and controls the lighting in analogue manner.

Phase dimming

Phase dimming systems dim the lights by altering the supply voltage.

Leading & trailing edge dimming

Before LEDs, halogen lamps were dimmed with wall dimmers. These kinds of dimmers can still be used. But dimmers, drivers and LED-modules must be compatible with each other.

This type of controlling is accomplished without any need for an additional control wire. It involves connecting a dimmer in series between one of the mains wire and the equipment.

The dimmer cuts part of the mains voltage sinusoidal waveform to a greater or lesser extent in order to dim luminous flux even from 1% to 100% (this value depends on the dimmer and the driver).

Depending on how the driver makes the mains voltage cut, it is possible to distinguish between two types of dimming:

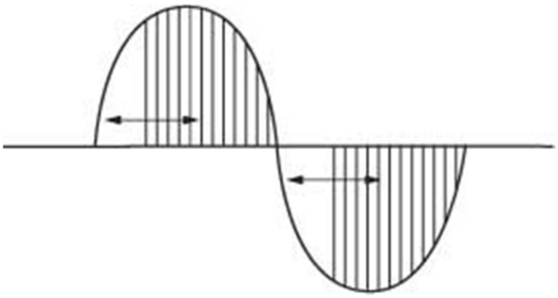

Figure 16: Leading-edge dimming

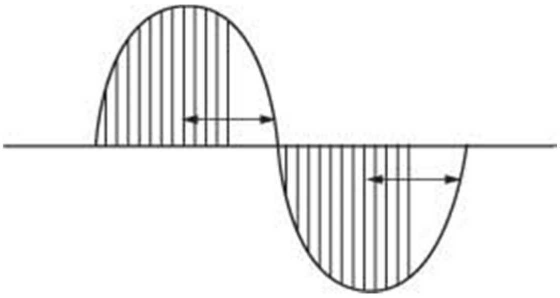

Figure 17: Trailing edge dimming

Dimming cut-off takes place in the wave on its ascending side, from the beginning (phase cut-off at ignition). This is traditionally used in halogen lamps supplied through electromagnetic transformers.

Dimming is achieved by cut-off in the wave on its descending side, from the end cutting backwards (phase cut-off at switch off). This way of dimming causes less interference than leading-edge dimming.

There are dimmers and equipment that support both types of dimming, and others that support only one type.

<u>1-10V regulation</u>

The 1-10V system enables dimming of the luminous flux from around 1…10% to 100%. This is done by sending an analogue signal to the equipment over an additional, two-wire control line. These control wires have positive and negative polarities respectively and that must be kept in mind when wiring up the system.

The analogue signal has a direct voltage value of between 1V and 10V. 1V – or short circuiting the fixture's input control – gives the minimum light level, while 10V – or leaving the input control circuit open – gives out the maximum light level.

The International Standard IEC 60929 defines the regulation curve. The regulation curve represents the relationship between the control line voltage and the luminous flux. It reflects a practically linear relationship in the range of 3V to 10V.
To get a response adapted to that of the human eye it is possible to use logarithmically controlled potentiometers.

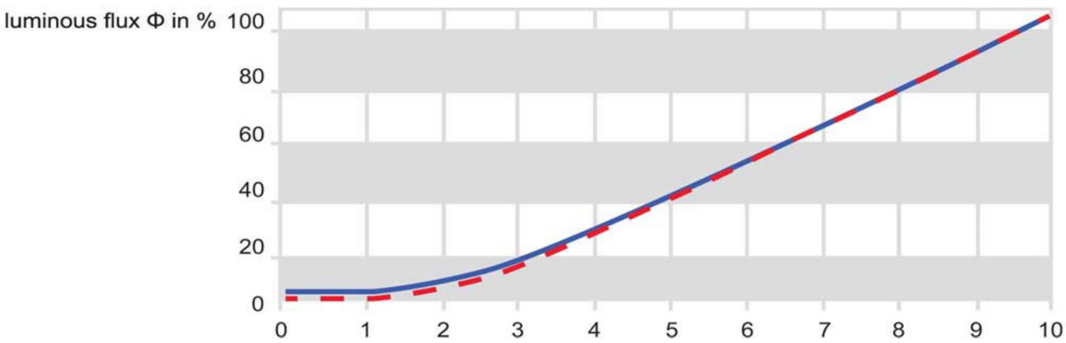

Diagram 2: Regulation curve by IEC 60929

These luminaires result in power control of 1-10V brightness. The driver supplies a current to the controller through equipment control terminals. The controller current must be from 10µA to 2mA. The maximum control line current is obtained with a voltage of 1V and the minimum with a voltage of 10V.

<u>Touch Control Push Button</u> (analogue but can be connected to a digital systems)

Touch Control is a system that enables the simple and economic dimming of luminous flux. It uses the mains voltage as a control signal applying it with a standard push button on a control line without any need for specific controllers. The Touch Control system enables users to carry out the basic functions of a regulation system with a power-free pushbutton. Depending on how long the button is pressed, it is possible to switch the light on or off or dim it. Switching the light on or off is done by short, sharp pressing or "click". If the button is pressed for a longer time, it is possible to dim the luminous flux between the maximum and minimum levels alternately.

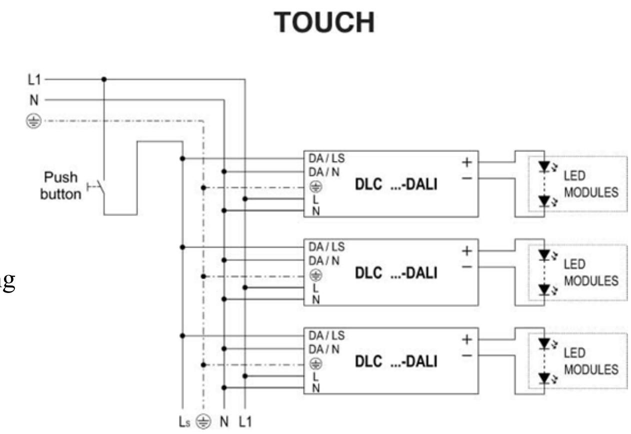

Figure 18: Touch dimming

Digital

Digital dimming covers all dimming systems that transform the dimming signal into bits and controls the lighting in digital format.

DALI Regulation (digital)

As revealed by the meaning of the acronym, **D**igital **A**ddressable **L**ighting **I**nterface, DALI is a digital and addressable communication interface for lighting systems.

This is an international standard system in accordance with IEC 62386, which ensures compatibility and interchangeability between different manufacterers' equipment.

It is a bi-directional dimming interface with a master-slave structure. The information flows from the controller, which operates as the master, to the control gears that only operate as slaves. The latter carries out the orders or responds to the information requests received.

Digital signals are transmitted over a bus or two-wire control wire. These control wires can be negatively and positively polarized, though the majority control gears are designed polarity free to make connection indifferent.

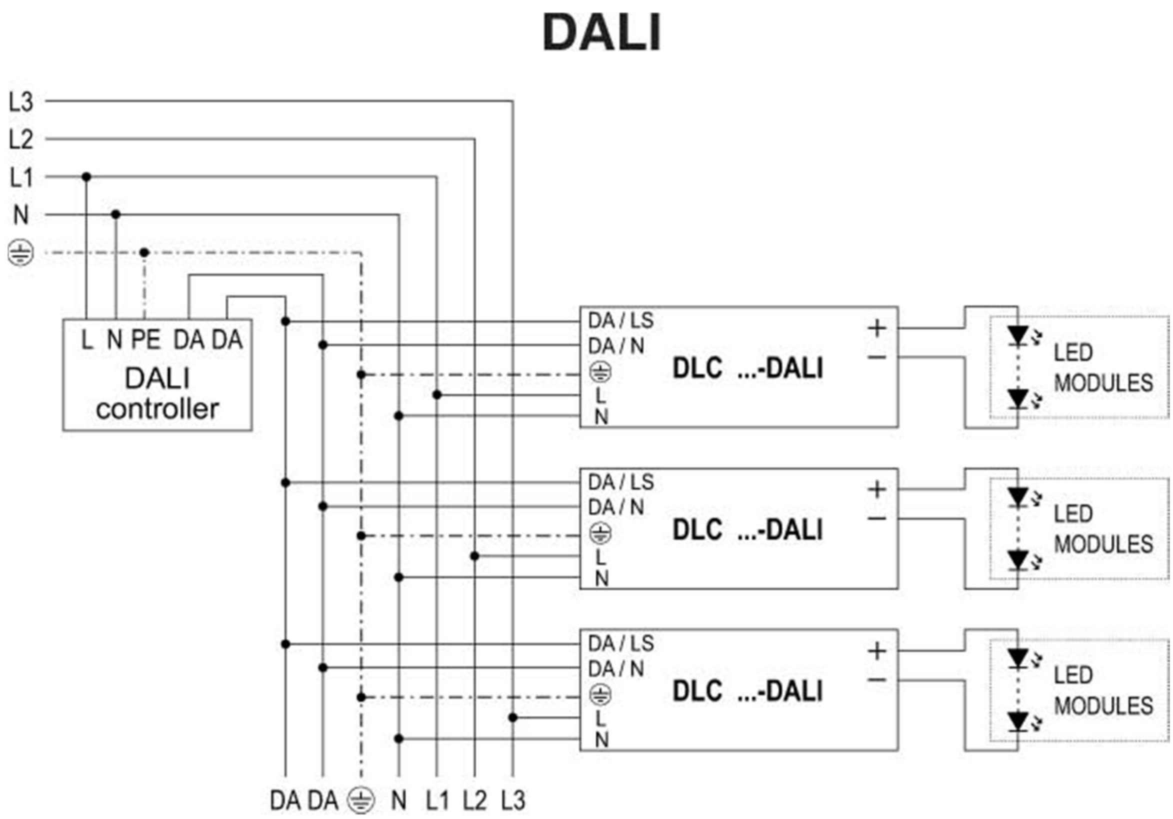

Figure 19: DALI dimming

Consequently, the DALI interfaces offer wiring simplicity in addition to great flexibility when it comes to designing the lighting installation.
The maximum voltage drop along the control line must not exceed 2V with the maximum bus current of 250mA. Therefore, the maximum wiring distance allowed depends on the cable cross section, but it must never exceed 300m in any case.

Wireless dimming options
The principle aim of lighting control is to reduce energy consumption and therefore the cost of annual energy budget is significantly reduced. Different mechanisms of control meet the desire of human and the operating conditions which are required. Utilizing photocell control enables automatic turning the street light fixtures on at sunset and off at sunrise. It is an efficient, simple, economic and common method of lighting control.

GSM wireless controller

Applying a GSM wireless controller in addition to photocell control will increase the capability of the system by monitoring the state of the light fixtures and controlling the switching. It allows to operate certain lamps and turn off others, or to dim the lights when the pedestrian and vehicular movement decreases. GSM is an open, digital cellular technology used for transmitting mobile voice and data services. It is a modern method in street lights controlling, especially because of its ability to cover long distances and increase the charging time for the batteries remotely for the Light Fixtures.

This approach can be used particularly by the municipalities and remote control centres often use GSM networks, and light fixtures will be controlled by computers. The determination of when light should be turned on or off will depend on the level of environmental light brightness such as the reduction of light intensity during low light brightness.

Applying this technology for public lighting, energy savings would be incredible, as well as resulting in far less light pollution. If the public lights were fitted with solar panels, making the system self-powering, the system would be more efficient. The utilization of light sensors provides a simple yet effective way for the automatic regulation of lighting power according to ambient light conditions thus enabling the system be turned on out of strict time schedules (e.g. during cloudy daytime).

The implementation of the proposed system could be further improved in the future by using modern simulation environment. The whole system is controlled by a PIC microcontroller.

The design has passed through several stages such as: selecting the practical components of the overall block diagram, purchasing these components, designing an external frame, mounting the photovoltaic solar panel, connecting it to the charge controller, interfacing GSM with PIC microcontroller and installing the LED lighting fixtures. Using LEDs lamps with GSM control system is a modern way in saving energy.

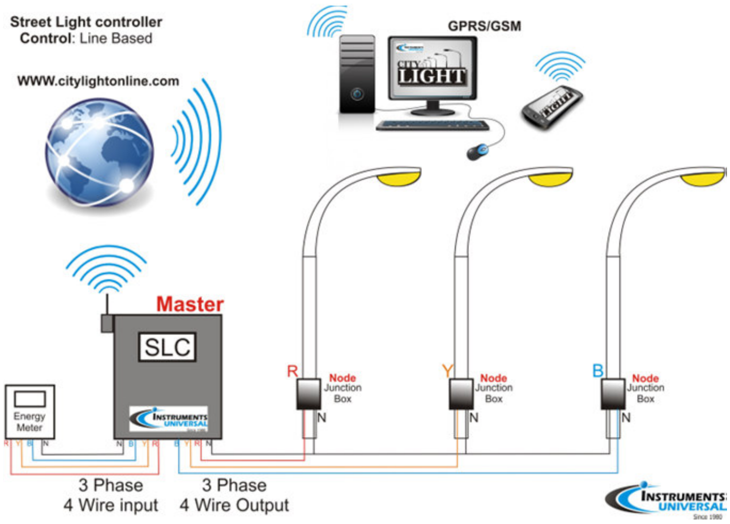

Figure 20: The structure of the GSM control system

Dimming interface	Advantages	Disadvantages
AC wiring (phase-cut)	No addition wiring required Can use existing phase-cut dimmers	Added circuitry in power supply Cannot dim smoothly to zero May exhibit flickering
Analog input (0-10V)	Can use existing 0-10V lighting controls Can dim smoothly down to zero Simple implementation in driver	Requires additional control wiring Requires controller
Logic control	Very simple form of dimming	Only suitable for two-level brightness
Digital input (DALI)	Standard for control of multiple luminaires Can include luminaire monitoring capability	Requires additional control wiring Requires controller
Digital input (DMX)	Standard is focused on theatre/stage lighting Can offer comprehensive control – pan, tilt, zoom, colour, image effects	Requires additional control wiring Requires controller Noise sensitive, no monitoring capability
Wireless	No additional wiring required Can offer comprehensive features	Driver and controller are more complex Wireless signals have limited range

Table 3: Advantages and disadvantages of different control systems

1.3 Description of the final solution

The street, which is the main factor in this case study, is an access street with low traffic.

The street in question has little traffic thus it belongs to the ME4b category.

Of the above described Pegaso products the registered and most appropriate type for the ME4b category is the Pegaso 36.

Therefore the most appropriate choice is the Pegaso 36 system by SPI Tecno producer.

1.3.1. LED Lamp- Pegaso 36

Pegaso is an innovative product with performance modular and stand alone mode or controlled. The structure is a single cast aluminum incorporating the radiator 250W to dissipate the heat produced by the LEDs, a feature essential to ensure the product life of at least 103.000 hours of continuous operation. Much attention has been paid to the design of the electronic power supply and the LED drive design to ensure the product's lifespan. The asymmetrical lens can be detected in many types adapted to the geometry of the road, the height and spacing of the poles. 4000K versions are available on request for quantity. The IP66 - Insulation class I or II.

Technical data:

- Case: Die cast aluminium 250W painted with thermohardened polyester powders, offering high resistance to rust and external atmospheric agents. The opening of the lamp is faciliated by two latches and the cover is kept by a hinge at the tip.
- LED: high power used 2 or 3 W
- LED printed circuit board: Metalcore (Aluminium)
- Diffuser: Asymmetric lens
- Input voltage: 24Vdc
- Power Supply: 48V 130W (no electrolytic capacitors)
- Class: I or II.
- Installation: Pipe diameter: 60=68mm
- Operating temperature range: -25°C - +50°C
- Humidity range: 10% - 90%
- Weight: 8,2 kg
- Height: 8m
- Distance between two columns: 30m
- Net flow of lighting: 5580 lm
- Nominal consumption: 50W
- Color temperature of light: 3000 K
- Illumination angle: around 130°

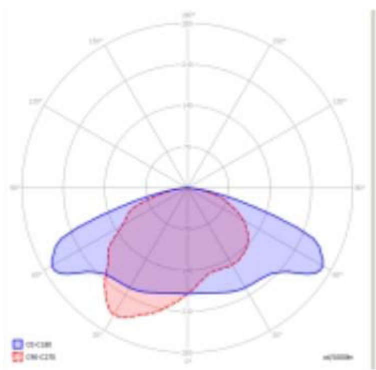

Figure 21: Illumination angle of Pegaso 36

1.3.2. Solar panel- Shinetime Solar XTP6-60-240

Electrical data:

- Peak Power Watts: 175 W
- Nominal Voltage: 27,7V
- Nominal Power Current : 6,32A
- Open Circuit Voltage: 34,1V
- Short Circuit Current: 6,75A
- Irradiance: 800W/m2

Operating Conditions:

- Maximum system voltage: 1000VDC
- Max series fuse rating: 15A
- Operating temperature range: -40°C - +85°C
- Max. static load front: 5400Pa
- Max static load back: 2400Pa
- Max hailstone impact: 40mm/4,5m/s

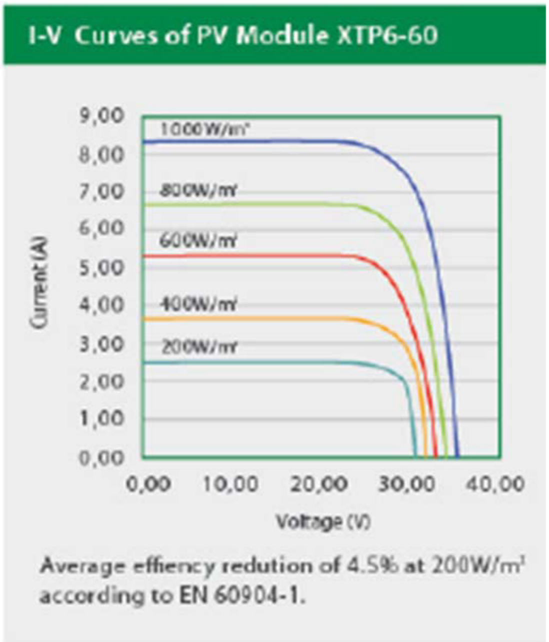

Figure 22: Curves of PV module

Mechanical data:

- Solar cells: Polycrystalline 156*156mm (6 inches)
- Cells orientation: 60 cells (6*10)
- Module dimension: 1640*992*40mm
- Weight: 19,5 kg
- Glass: High transparency low-iron tempered solar glass 3,2mm (0,13inches)
- Frame: Silver colour anodized aluminium alloy
- Junction Box: IP65 rated
- Cable: Photovoltaic technology cable: 4,0mm^2 (0,003 inches^2), 900mm (35,4 inches)
- Connector: MC4 Compatible /IP65

1.3.3. Photovoltaic charge regulator: WRM-15

- MPPT recharge
- Wide voltage range on PV module input VPAN 0- 100V
- Maximum PV module power 250W for 12V battery and 500W for 24V battery
- Integrated blocking diode
- For sealed/GEL, flooded lead acid batteries and lithium-ion batteries (from Rev 1.9)
- Charge voltage compensated in temperature
- 12V / 24V battery voltage auto-detect
- 18 programs for load management
- 48 LCD symbols for user interface
- Low battery protection
- Over-temperature protection
- Protection for battery polarity inversion
- Overload protection on output
- IP20 metal box

WRM-15 is a complete solution for the realization of off-grid PV systems to power supply road signs systems, lighting systems, small low voltage systems and for the recharge of batteries inside caravans. This model of charge regulator has got a circuit of search of the maximum PV module's power (MPPT): regardless of battery voltage and its charge state, WRM-15 always makes the PV module work in its point of maximum power maximizing the energy extracted from the module and loaded into the battery. PWM charge regulators want PV modules with No. 36 cells for the recharge of 12V batteries and PV modules with No. 72 cells for the recharge of 24V batteries. This planning obligation is no more necessary with MPPT circuit where we can use the cheaper PV modules used in grid connected systems (with a number of cells different from 36 or 72) also in PV off-grid systems. You can also use amorphous PV modules that are normally not suitable to PWM charge regulators.
The several programs of load management, selectable by the user, make WRM-15 the complete solution in several applications; i.e. to power supply video cameras that have to work only during the day, or to power supply flashing systems / road signs that have to work only during night, or to power supply lighting systems that have to work only for a certain number of hours during the night. WRM-15 detects the day/night state according to the PV module's voltage; therefore it is not necessary to connect further sensors to the regulator. A wide display shows the working status of the regulator either through simple and intuitive icons either displaying the values of recharge current, battery voltage, energy produced**.**

General description

WRM-15 is a photovoltaic charge regulator for leaden electrochemical batteries either sealed (SEAL) or flooded lead acid (FLOOD). In fig. 1 there is a scheme of principle of WRM-15. A charging program for lithium-ion batteries with integrated Battery Management System (BMS) was introduced with firmware version 1.9. It is absolutely forbidden to connect

WRM15 lithium-ion battery without a BMS because it protects the battery from unsafe operating conditions that can lead the battery to explosion or to burn up.

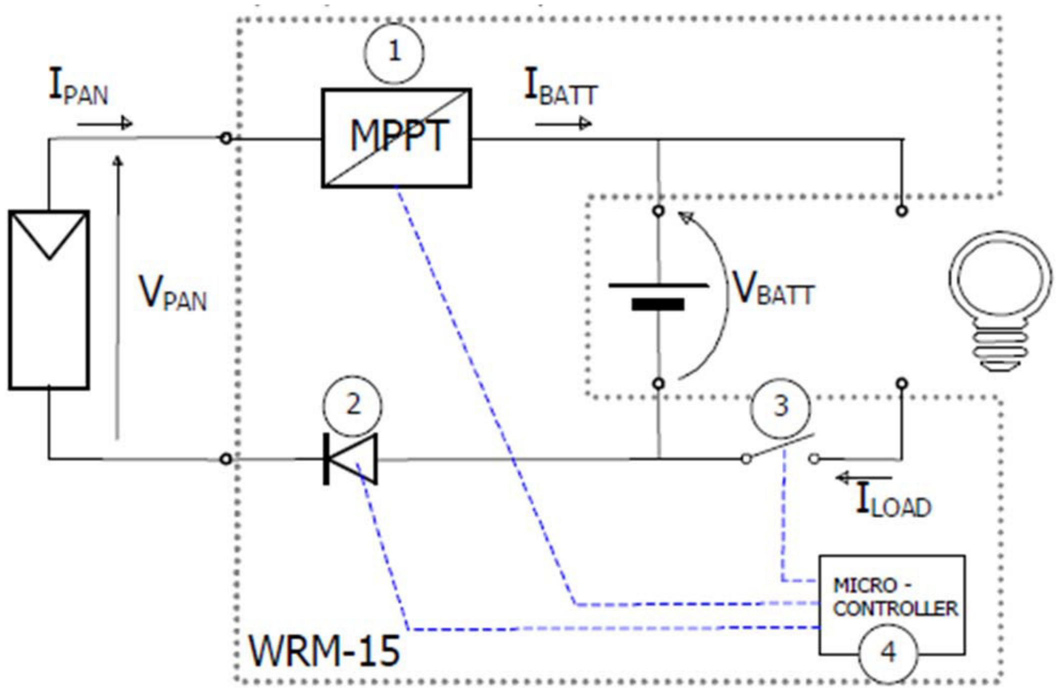

Figure 23: General structure of charge regulator

5- Recharge circuit: it adapts VPAN and IPAN (respectively voltage and current of the photovoltaic module) so to search the condition in which the power that is given by the PV module is maximum, thus realizing the MPPT (*Maximum Power Point Tracking*). In addition, it manages the battery recharge by reducing the current sent towards the battery when the voltage VBATT exceeds its recharge voltage (Vch).

6- Series diode: it prevents the PV module from absorbing current from the battery during night when it is not lighted.

7- Circuit for the load control: it turns the load on/off according to the program that has been set from the user and it provides load detachment in case of low battery / overload / short-circuit on the load.

8- Microprocessor: it controls the whole circuit, it measures currents and voltages of PV module / battery / load and it shows them on the display.

WRM-15 charge regulator, thanks to the recharge circuit with MPPT, allows using a wide range of photovoltaic modules ensuring the optimum exploitation of the power. The PV module has to be chosen according to the nominal voltage of battery and respecting the constraints of the panel input of WRM-15: maximum voltage 100V and maximum panel power 250W with 12V battery and 500W with 24V battery.

1.3.4. Battery - FIAMM 12FGL27

Applications and advantages:
The batteries are designed for optimum performance and to protect against network disturbances. They are ideal for:

- Emergency lights
- Signage
- Security & Alarm Systems
- Industrial & Continuity Process
- UPS Applications
- Minor Traction
- Storage systems for renewable energy.

- VRLA AGM and gas recombination technology, with 99% of the internal gas recombined
- No maintenance; no topping up
- Not dangerous for transport by air / sea / rail / road
- 100% Recyclable

Data:

- Nominal voltage: 12V (2x)
- Weight: 9kg
- Dimension: 166*175*117*125mm
- Grids: obtained by gravity casting alloy with calcium lead-highly pure tin
- Separators: completely absorbed electrolyte separators in glass fibre (AGM) high microporosity
- Terminal attack: fi threaded insert that guarantees high conductivity and allows easy installation
- Polar Sealing: high reliability, specially designed to prevent infiltration of acid in a wide temperature range
- Unidirectional safety valve: enables gas in excess to go out when overcharged
- Device antifi amma: prevents sparks or flames inside the battery
- Container and lid designed with thick walls in ABS for a high mechanical resistance
- Self-discharge: <2% per month

Figure 24: Battery

Co-funded by the Erasmus+ Programme of the European Union

1.3.5. Remote control

The remote control is the ability to communicate with a SmartCity with some devices capable of creating large databases and counters and reduce light intensity with a variety of gas, electricity, water and street lights and various sensors. Its ease and versatility makes it particularly suitable for preparing a proprietary network that on the one hand is connected to the Internet and other peripherals through a transceiver radio frequency 868 MHz. The operator interface thanks to OrionView is able to communicate with all the devices on the network. The example below clarifies the case of public lighting.

Figure 25: Remote control

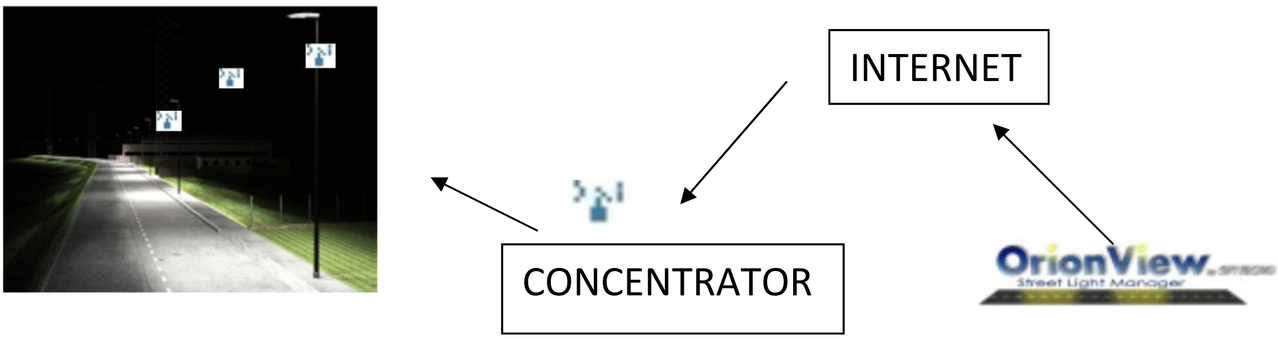

Figure 26: Network Connection

OrionView

The platform allows OrionView with a few clicks of the mouse and from any computer connected to the Internet to plan your electric bill while controlling the consumption of public lighting systems.
The system is a tool that installs OrionView and returns to the operators of public lighting system the ability to exercise the role of a real manager and could intervene in a completely automated manner. The system is able to send e-mails to pre-established lists of people of "Warnings" in the event of a fault; in this way it will reverse the current situation which is always the citizen that alarms the operator.

1.3.6. Pole - GLS Hline-T panel support and battery box

The technological development of the GLS HLINE street lamp is more widespread among the classical photovoltaic columns.

- High reliability and durability
- Gel silicon battery tecnology with long service life
- Up to 250 hrs of autonomy without Sun
- Remote evolved features
- Automatic dimming
- Smart city functionalities
- Full customizable design

- Pole and panels support material: hot deep galvanized steel
- Pole total Height: up to 12,5m
- Height of light: up to 10m
- Battery box placement: at the head
- Maximum number of batteries: 2
- Battery box material: steel galvanized thin steel
- Type of anchor: foundation with bolts

Figure 27: Pillars

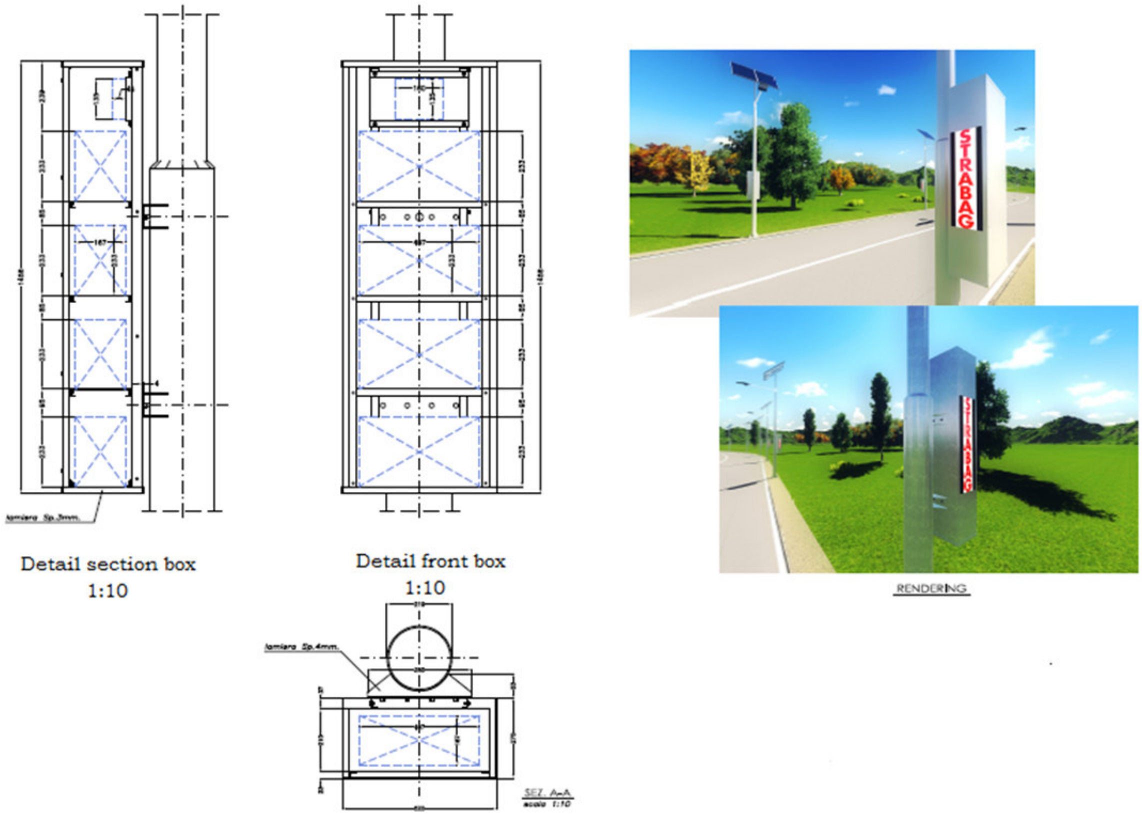

Figure 28: The structure of the battery box

1.3.7. All components and their numbers in summary

The street length is 150m, while the distance between 2 columns is 30m. 150/30=5, therefore it is neccessary to install 5 columns for adequate lighting.

Led lamp: 5 pieces

Solar panel: 5 pieces

PV charge regulator: 5 pieces

Battery: 10 pieces (5x2)

Remote control: 5 pieces

Pole and pole support: 5 pieces

Battery box: 5 pieces

1.4 Impact of the project for the rural development

1.4.0.1. Impacts of the photovoltaic lighting system for the rural development

The installation of such systems is widespread in urban areas, along the motorways, and in underdeveloped peripheral rural areas.
Although the commissioning of such systems in urban regions (and in developed rural regions or in areas having the potential to develop) can be justified, in certain aspects, innovative developments in economically backward rural areas have relatively higher marginal utility. In resource-deficient rural regions any (sustainable) development especially investment in innovative activities is higly benefical, even if the direct job-creation ability is negligible.

The regional impacts of different photovoltaic systems, with special regard to investments of innovative nature, are of utmost significance. On the basis of urbanity and rurality, no difference can be revealed with regard to the currently available amounts of alternative energy including that of solar energy. Rural development must focus on the development of self-sufficiency in rural regions, an essential component of which is to accentuate the role of alternative energy production. There is a strong correlation between rural development and decentralized energy production. Decentralized energy production implies the use of local raw materials, local labour force and local investments and according to many, building a (green) country starts with villages.

In terms of energy utilization efficiency, the worst situation is to be found particularly in rural regions. It is an issue of great importance to supersede the approach to thinking solely in the context of large-scale supply systems. Instead, it is essential to create balance between small-scale power plants and large-scale supply systems. One aspect of the above balance is represented by the commissioning of PV systems, i.e. the emergence of local power stations in rural areas. Energy rationalization, while safeguarding environmental sustainability, also ensures sustainable economic development, therefore PV systems can certainly be regarded as developments congruent with community interests.

An outstandingly important aspect to be taken into account in relation with rural developments is to ensure that the deployment of PV systems do not result in land-use restrictions. In this context, a favourable situation is created by the fact that photovoltaic energy production can be combined with several other production methods (soil strength reinforcement, recultivation, pasturing, apiculture, vine-culture, horticulture, etc.). The demand for land brought into use by investments may as well reach high levels but owing to the aforementioned particularity, such high demand does not pose any barriers to investments and in view of the rapid pace of innovations, the future is likely to see a significant decrease in specific land-use demand.

These systems exert their effects typically through the diversification of the economic activity of a specific region while they can also enhance its prestige and offer further opportunities, such as:

- the emergence of renewable energy production locally, its development,
- partial or total replacement of local energy sources (energy consumption of business enterprises and residential energy consumption) with renewable energy,
- effective communication avenues to reach out to a given region's environmental consciousness and commitment to sustainability,
- involvement of local entrepreneurs in community developments based on local energy production,
- possibilities of setting up exhibition sites for events dedicated to renewable energy sources,
- modernization of energy utilization in a region, strengthening self-sufficiency,
- systems contribution to the demonstration of environmental education in a specific region and enhancing the efficiency of such education.

Local residents may need to consider providing support to solar energy utilization/production by offering special funds for this purpose. As a result, they could realize additional income (or more money is left in their pocket), which, in turn, will boost the region's internal demand. By the promotion of the local multiplication of the aforementioned case (equipped with a complex system of development tools), the revenue remaining with the region may increase. In this respect, small-scale, decentralized electricity production deserves special attention or, perhaps special assistance. Introduction to best-practices in solar PV parks may significantly enhance their spread and social acceptance and encourage both investors and governments providing space for installation to carry out partly similar developments. Unpredictable energy policy poses an increasingly serious obstacle to the expansion of photovoltaic parks in spite of all the positive examples of such developments throughout Europe.

In parallel with opportunities, there are a number of problems to work on. Economic sustainability of local governments seems to be unstable, while at the same time settlements pay particular attention to local economic development. Elements of sustainability do not carry equal weight in the task-orientation concepts of local governments. In the context of regional development, energy production-related projects may typically become successful if they are viewed as elements constituting a part of a well-designed complex system of development and if no short-term high returns are expected. In view of the technology - intensity of innovative industries, also solar PV systems require only a low level of labour force participation while at the same time both the local governments and the the spread of renewable energy sources, including also the expansion of photovoltaic systems, depends predominantly on the changes in the pattern of fossil fuel energy markets, therefore, the success of a PV park and its impact on a region pose serious external risks in the short to medium-term.

The primarily indirect economic impacts of the projects could be significant. A well organised system of regional energy production is able to change consumption habits and trends and serve as a template for neighboring municipalities and areas.

Another issue of concern is that members of local communities do not seem to be ready for the adoption of alternative and innovative solutions, thus, it is not only the shaping of public perception of PV systems but also the development of assistance schemes may become necessary. After the use of energy generated by PV systems has become common among local governments, entrepreneurs and local residents, at the time of constructions, business undertakings engaged in the execution of the relevant work processes will see a temporary upswing. Another problem is that the aforementioned businesses are not necessarily (typically not) local undertakings either.

STRENGTHS	OPPORTUNITIES
• Massive development, the majority of potential participants are affected positively • Innovative economic presence in the region, potential spin-off. • The only future is local, regional, small-scale autonomous energy production and supply solutions, renewable energy sources and energy saving. It is based on lifestyle. • Long-term sustainable operation • Innovative solutions • Cheaper local energy	• Local-level developments, innovations, incubation • Strengthening local capacity • Dynamically developing sector (very rapid innovation) • Installation of operating joint development of the region • The objectives of EU development policy • Special local segment of construction (Transient) Development • diversification of the structure • broader vision of the energy industry and the region foundation • The establishment of an alternative energy demonstration
WEAKNESSES	**DANGERS**
• Low not only international, but domestic visibility. • Poor cooperation and competition. • Landscape effect (negative). • Market coverage and operation in the region is up to suppliers (including component manufacturing). • Energy storage unresolved. • E-on network connection limitations.	• Energy Policy support is uncertain. • No substantive receptivity by the insufficient regional and income situation • Lack of information • The opportunity to gain competitive advantage is low

Table 4: Analysis of the impacts of PV systems for rural development.

1.4.1 Environmental impacts

Visual pollution

The design of a PV park requires special emphasis to be placed on specific factors, such as the selection of the appropriate land used for the construction, the assessment of environmental impacts, e.g., landscape effects, visibility in terms of the local landscape and natural heritage. Furthermore, it becomes necessary to ensure that the local community can formulate its views on the installation of the intended power plant. In case there are nature conservation areas in the neighbourhood, landscape effect and the impact of visual pollution become of paramount importance in the development of a PV park. A PV park located in the vicinity of landscape or natural heritage areas is likely to be detrimental to landscape enjoyment. The solar park must be prevented from becoming a feature overpowering the landscape.

CO_2 emission

Atmospheric concentration of carbon dioxide is rapidly increasing with an annual growth rate amounting to 2 ppm (parts per million).
Energy consumption of a settlement and its CO_2 emission depend on several factors most important of which are the climate, the type of buildings, the used energy carriers, the structure of the economy, the size of the population, the modes of transport, and the leadership of business involved in photovoltaic system development and installation as well as the behaviour of citizens. We can influence the factors in a short time, however, most of them can only be influenced in a longer term.

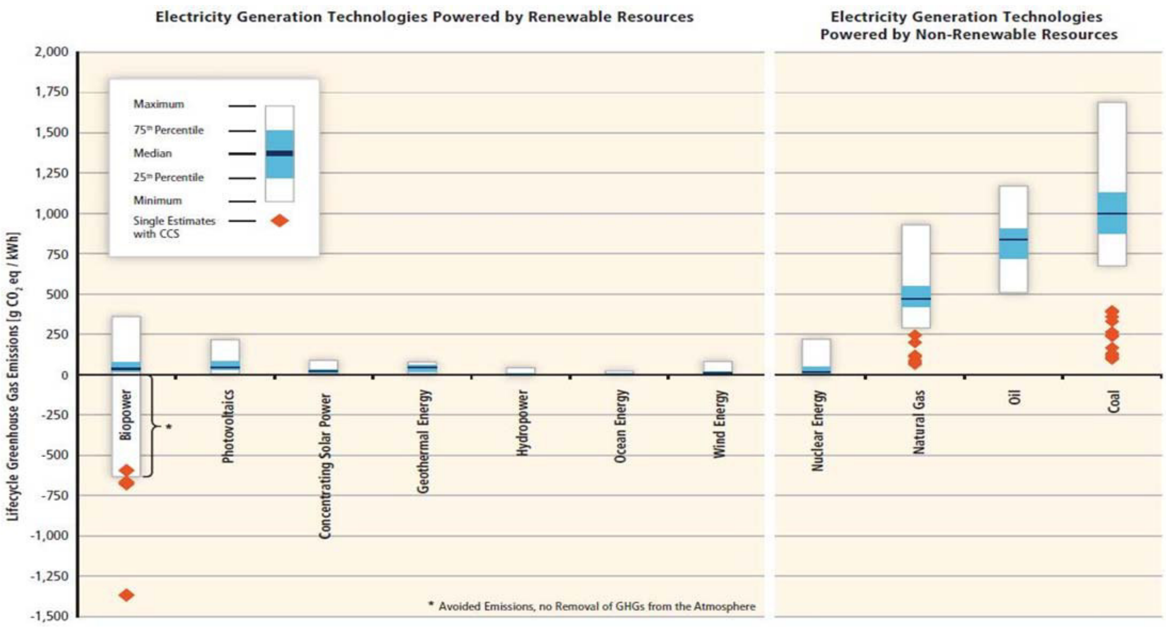

Diagram 3: CO_2 emissions

Waste production and management

During their 20 to 30 year long lifetime photovoltaic panels do not produce either waste or pollution. Installed battery lifetime is around 15 years.

In that time any component or equipment replacement will be treated adequately by the approved recovery and recycling managers.

Advantages

- No direct sunlight (Even overcast weather)
- Solar systems can easily place the existing roof structures
- Does not require soil and civil engineering work
- No interference with other existing infrastructure
- It does not require a building permit
- Silent operation
- Maintenance-free
- Cost-effective way of reducing CO_2 emissions
- The system is carried out by a single investment. From then on the system provides clean energy in a predictable manner for a minimum of 25 years. Since energy is produced by means of renewable energy the price depends on the investment.
- Maintenance is minimal, noiseless operation, since (unlike wind power plants) contains no moving parts.
- The world's economies are environmentally conscious and advanced (EU, USA, Japan) governing the transfer price of renewable energy brought explosive growth. The countries need to switch a higher proportion of the population to renewable energy sources.
- Investment promises high yields, but the risk is almost negligible.

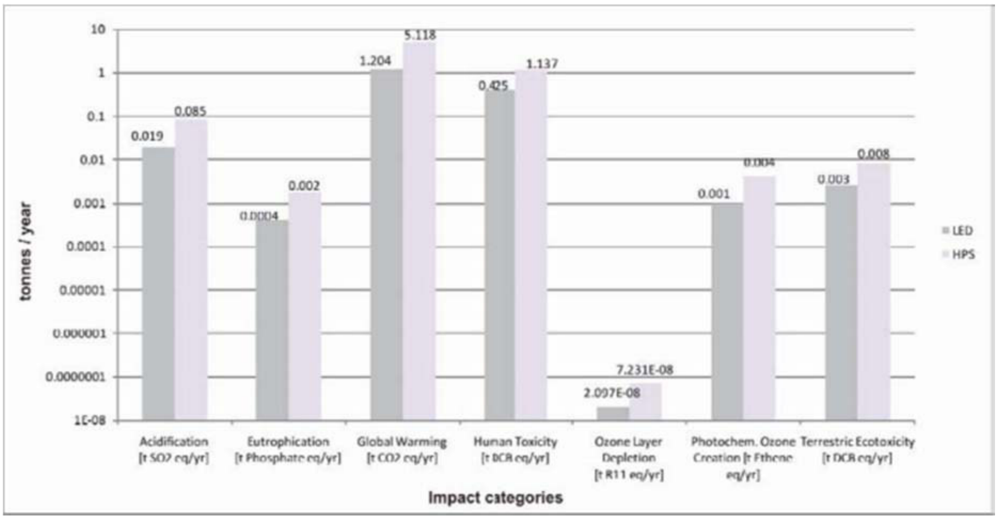

Diagram 4: Impacts compraison, HPS vs LED
HPS: High- Pressure Sodium

1.4.2 Social and rural impact

Energy security

The photovoltaic installation presented contributes to improved energy security by having a positive impact on rural electrification, energy autonomy and sovereignty.

- Rural electrification: The installation carried out can generate electricity in a rural area where there is no main grid, and the cost of extension and connection of the network represents a major investment.
- Energy independency and sovereignty: The installation that contributes to decentralized energy production contributes to energy supplier independence and autonomy. Also, this type of installation affects the direct control of the generation and energy consumption that affects greater autonomy.

The change in the intensity of the publicity parallels the public expansion of infrastructure, professionalization and structural changes.

The public impact is likely to be vast thus the development of positive attitudes is now indispensable. In addition to interaction based on social connections to the public is also effective to increase, but less than the strength of inquiries related decision making at the result, that "a relatively small -" privileged "or" medium-sized "- groups are more efficient than large ones.
Local governments have a greater impact on the population. During the development of a municipality much will depend on the decision-makers, city managers, local networks, stakeholders' interests, and personal competences.

Controlled system:

An intelligent network of street lights spread out across a city or town also offers communications improvements. Systems which can assist with many of the normal functions of a living city, including parking and traffic flow, are available. Street lighting systems can monitor traffic flow, and offer alternative routing based on weather, construction and changes to traffic signal timing. Intelligent street lights can also monitor air quality and other environmental conditions to improve information flow and enable municipalities to take action to benefit the lives of their citizens. Intelligent lighting systems can also improve the emergency response to dangerous developments by assisting with traffic control, providing information about the location of an incident and reducing response time.

Designation of social indicators	Expected effects
Human health	Minimal effects (see detailed in life-cycle analysis)
Quality of life	Due to the sense of independence for the supply system, no or minimal effect
Education, qualification, knowledge	Positive effect, involvement of students into research tasks for the purpose of disseminating results
Public awareness, approach, presenting good examples	Positive
Mitigation of social disparities	Negative impact: Access to PV systems is possible mainly for wealthy people and savings resulting from the use of such systems also contribute to their costbenefits, thus creating possibility for a further increase in social disparities
Enhancement of co-operation between social actors, strengthening cohesion	Positive impact: see e.g. outputs of current IPA
Prevention of migration (job creation)	Exerting no impact: the job-creation effect of PV systems does not appear in the given region (see detailed in the chapter about regional impacts)
Energy poverty alleviation	Positive impact: renewable energy is not yet fully exploited but it is gradually becomes incorporated in the energy system

Table 5: The effects of social and rural impacts

As we can see in Table 5 the potential social impacts are various. We can find factors where PV use has not or negative influence on the society, especially in the mitigation of social inequality. However it can positively affect cooperation. In a widely social sense the use of PV combined with good cooperation among actors can become a good-example, having positive effects on settlement marketing.

1.5 Conclusions

The photovoltaic LED lighting systems in most countries are in developing stage from the point of view of infrastructure and economics, but the prices are getting reasonable as the market demand rises higher for this kind of technologies, which make it more affordable. LEDs lamps have a longer lifespan, up to 50,000 hours. This is approximately 50 times longer than the classic incandescent bulb and 10 times longer than the compact fluorescent lamps. Used 10/12 hours a night, a LED module can approximately last up to 11 years.

This project of intelligent streetlight system is a cost effective, practical, eco-friendly and the safest way to save energy. It efficiently saves the energy by replacing the conventional bulbs by LEDs and by automatic switching/dimming of LEDs as and when required. The main drawbacks of this system are the initial cost and maintenance. However, large scale implementation of this proposed system will definitely reduce the overall cost of the project by a great extent.

By using these approaches to develop an intelligent lighting system, a higher control and energy efficiency and also a more environmental friendly systestem can be obtained. The overall efficiency begins at the design with LEDs, compared with the classical lighting systems. At this point the lighting system energy consumption is significantly lower and with greater energy efficiency as the system functions only when it is needed.

Intelligent lighting control and energy management system is a perfect solution for energy saving, especially in public areas.

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[16] Module 2- Chapter 1- part 1-3

[17] Module 2- Chapter 2- part 1-2

[18] Module 2- Chapter 2- part 2-3

Calculations

2. Calculations and design

2.1 Size of the photovoltaic system

Measured by the autonomy of the solar photovoltaic system, it has an early pre-identification: the strength of the body, the height of the installation, and the pair of illuminating columns. In this stage the body size is shown as a user of electric energy in batteries.

In Romania the average length of the system in public lighting program is **4000** hours/year.

Certain aspects are likely to be criticised for instance that in winter when the photovoltaic lighting system is expected to work long hours the duration of sunshine hours is low.

Calculations are fully available on the site http://re.jrc.ec.europa.eu/pvgis/ apps4/URpvest.php for Bacau production system using energy photovoltaic installed power of 1 kWp shows a daily average production of electricity for December is 1.37 kWh, at an angle inclination of 35°.

	Fixed system: tilting 35 grd. orientation: 0 degrees			
Months	Ed	EM	HD	HM
January	1,59	49,2	1,91	59,1
February	2,44	68,3	3,00	52,3
March	3,69	114	4,78	148
April	4,08	122	5,50	165
May	4,41	137	6,07	188
June	4,51	135	632	190
July	4,68	145	660	204
August	4,58	142	643	199
September	3,82	114	5,22	157
October	3,12	967	4,10	127
November	2,00	601	2,51	75,2
December	1,37	42,4	1,6	31,8
Year	3,36	102	4,52	137
Total one year		1230		1650

Table 6: The average quantity of electricity produced by photovoltaic system

The meaning of the notations is:

- -E_d : average production of electricity daily from the given system (kWh);
- -E_m: average monthly production of electricity (kWh);
- H-$_d$: average amount of daily global irradiation per square meter received by the given modules (kWh/m^2);
- -H_m: average amount of global radiation per square meter received by the modules of the system (kWh/m^2).

Electricity demand for the LED lighting with an installed power **of 50W at 24 V**, which function in Bacau in the shortest day in December between - 16.40 and 7:40 for 15 hours is 750 Wh.

Battery capacity (Ah = Wh/V) is calculated as follows:

$$\mathbf{C_a = C_s \times A / G_r \times T}$$

where: Ca is the capacity of the battery in Ah; C_s - capacity electric power stored in the Wh; A-autonomy in days; G_r -the percentage of battery discharge; T-voltage in V.

In the case of regular use for photovoltaic lighting system, choose autonomy and a grade of 75% download result following capacity battery:

Ca = 750 Wh x 1 day / 0,75 x 24 V = 41,6 Ah

I have chosen 2 batteries of 30 Ah (12V)

As it was previously seen for a system of 1kWp photovoltaic panels with an installed power of 1kWp located optimally to the south at an angle of inclination of 35° produces daily and 1.37 kWh in our case we need 750 Wh. Therefore, give an installed power of the photovoltaic panels 547 Wp.

Optimization of the photovoltaic lighting system can be achieved by reducing the intensity of the **noase** (dimming) during the night, in the low-traffic times as shown in Figure 29.

In this period, changing to a lower class of enlightenment (in our case from the class ME4b) but with the standards related to the new lighting classes was framed.

Through this optimization the amount of energy used may be by lighting body by over 60% and thus reduce the cost of the photovoltaic system.

In our situation we can use a photovoltaic panel with 240 Wp.

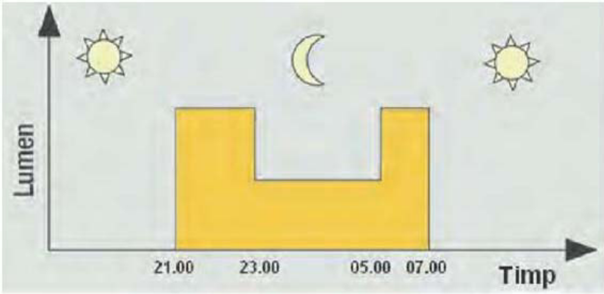


Figure 29: Periods identified in the course of the night to reduce the intensity of the bright part of the body.

From 21:00 till 23:00: 100% lighting mode→ 5580 lm

From 23:00 till 5:00: 50% lighting mode→ 2790 lm

From 5:00 till sunrise (7:00): 100% lighting mode→ 5580 lm

Public lighting program is **4000** hours/year (avarage). One day: 4000/365 ≈ 10 hours, but this data varies according to the seasons, but the avarage is 10 hours/day and I use this data in my calculations.

Without lighting control system: 4000h/year → lamps works at 100%.

With lighting control system, the lamps work between 23:00 and 05:00 (6 hours) at 50%. This in one year is: 2190 hours at 50%, which means that with a lighting control system we can save 1095 hours of lighting/per year from which, depending on the control system, tuning reduction also results. The 50% reduction of light in 6 hours/day results in a total of 27% reduction.

For the design and selection of a lamp type, an important criterion called lamp efficacy should be considered. In most cases, a more efficient light source can be substituted for a less efficient source with little or no loss in visibility or colour rendition. The total annual cost savings help to decrease the size of the photovoltaic system.
Lamp efficacy $\mathbf{E_F}$ is measured in lumens per watt (lm/W) and defined as follows:

$$\mathbf{E_F = F_L/P_L}$$

where $\mathbf{F_L}$is a luminous flux in lumen (lm) and $\mathbf{P_L}$ lamp power. Table 7 shows luminous efficacy of different types of lamps. If a lamp produces more lumens from each watt of electrical energy input, it is more efficient.

Lamp Type	Conversion Efficacy (Lumens per Watt)	Life (Hours)
Incandescent	14	800
Low Voltage Halogen	20	2000 to 5000
Mercury Vapor	40 to 60	22000
Fluorescent	64 to 90	7000
Metal Halide	70 to 90	12000
High Pressure Sodium	90 to 125	25000
Low Pressure Sodium	120 to 200	20000
LED Lamps	100 to 150	50000

Table 7: luminous efficacy of different types of lamps

$$E_F = 5580 lm/50W$$
$$E_F = 111,6\ lm/W$$

The street has small vehicular and pedestrian movement at night, so selecting Illumination value (**E**= 4 lux) is enough based on the second classification in Table 9. The standard unit for illumination (**E**) is lux, which is equal to lm/m^2.

Illumination E in (lux)	Environments
1	full moon
4-10	street lighting
100-1,000	workspace lighting
10,000	surgery lighting
100,000	plain sunshine

Table 8: Lux data

Road and area classification	E_{ave} in (lux)
Local Residential Roads (Local-Low)	4
Residential Collector Road (Collector-Low)	6
Employment Collector Road (Collector-Low)	6
Arterial Roads (Major-Low)	9
Rural Local Residential (Local-Low)	4
Rural Collector Road (Collector-Low)	6
Low Density Residential	3

Table 9: Classifications of roads, and the lux values

The existing distance between two columns (***a***) of the street about the Pegaso 36 type is 30 meters. Therefore, **a** should be selected 30 m in this study in order to use the same posts (columns). The street length: 150 m → 150/30=5.5 columns are need for adequate lighting.

Budget and economic analysis

Co-funded by the Erasmus+ Programme of the European Union

3. Economical aspects of the project

The full economic value of the investment required for a LED lighting project must be determined using standard analysis techniques. These devices are already widely used in industry to analyze energy efficiency and are easy to apply to LED lighting. Calculations are based on a life cycle analysis and provide a more realistic assessment of the long-term economic value of the LED lighting system.

LED lighting systems have a very long service life of over 50,000 hours, and new challenges for maintenance are new for local governments. Overall, significant cost savings can be achieved in maintenance operations, so LED luminaires will no longer require frequent bulb replacement, which is otherwise required for conventional light bulbs. This is somewhat offset by the more frequent cleaning of the lamps, which can be particularly needed in places where there is great contamination. Intelligent LED lighting can self-test: self-regulation can have a significant impact on the lighting network maintenance as it enables the automatic notification of the luminaire in case of faults.

The costs of the proposed system include the initial costs of the components, and components replacement costs, while the system maintenance costs should be done by the department of electricity in Margineni municipality. The existing hanging columns will be used for the proposed system. Initial costs include PV modules, batteries, charge controllers, lighting units and other accessories used in the installation. The life cycle period of the system is taken to be the life cycle period of the component that has a maximum life time. In this analysis, it is 24 years for the PV system. The life time of the battery is dependent mainly on number of charge-discharge cycles which in turn depends on value of depth of discharge of the battery (DOD) assumed. In this analysis a typical value of 12 years is considered as a life time of battery where a DOD is assumed to be 80%. The lifetime of the used LED lamps are 12 years on the basis of 10 hours of operation per night.

The life times of the other components of the system such as charge controllers and management system generally take values greater than 20 years. Because the cost of each is small in comparison with the other components, in this analysis a 24 years life time is considered for each. Therefore, batteries and lamps should be replaced once during this period.

3.1. Budget of the installation

The installation price proposed for the photovoltaic system (1 set) with the proposed elements (the prices are realistic):

Components	Costs
Solar Panel	€400
Charge Controller	€100
Battery (2x)	2x€700
Led lamp	€200
Remote Control	€200
Accessoires	€200
Total cost (1 system)	**€2500**
Total cost for the whole street	**5x€2500 = €12500**

Table 10: The price of the components

On the street, which is the main character in my case study, today has no lighting system.
I start from a comparison of a traditional grid connected electric power and solar power system, which shows the difference from a financial point of view.

Used data:

- Lamps power: 100W; 50W
- Night hours: 10h; 7h
- Price of energy in Romania: €0,097

<u>A normal high pressure sodium fixture's power for street lighting is **100W**</u>

5 fixtures are needed for the street:

5x100W =500W=**0,5kW**

With effective night hours of 10h, the total annual consumed energy is:

365 night/year x 10 h/night * 0,5 kW = **1825 kWh.**

Then, the annual total cost of the consumed energy is:

18255kWh * 0.097 Euro/kWh ≈ **€177.**

<u>The power of the proposed LED lamp (Pegaso 36) is **50W**</u>

5 fixtures are needed for the street:

5x50W =250W=**0,25kW**

With effective night hours of 10h, the total annual consumed energy is:

365 night/year x 10 h/night * 0,25 kW = **912,5 kWh.**

Then, the annual total cost of the consumed energy is:

912,5kWh * 0.097 Euro/kWh ≈ **€88,5.**

This data was calculated without using the control system.
With an average reduction in brightness per night, not 10 hours/night, just 7 hour/night:

365 night/year x 7 h/night x 0,25kW= **638,75 kWh**

638,75 kWh x 0,097Euro/kWh ≈ €**62**

The price of a normal high pressure sodium fixture is about €800, which is much cheaper than the photovoltiac LED system (2500Euro), but the energy used by the normal system is more, which is an important aspect of the environment and economics.

Installing a photovoltaic system for the street instead of the current existing one according to Table 10, the total cost of the proposed system is (€2500). Therefore, the proposed lighting system of the Street is an economical one comparing to the annual total cost of the consumed energy of the traditional lighting system.

	Traditional system	**Photovoltaic controlled system**
1 piece	€800	€2500
5 piece	€5600	€12500
Energy price/year	€177	€62
Maintance/year	€80	€15
Total cost in the 1st year	€5857	€12577
Total cost in the 2nd year	€257	€77

Diagram 5: Recovery diagram

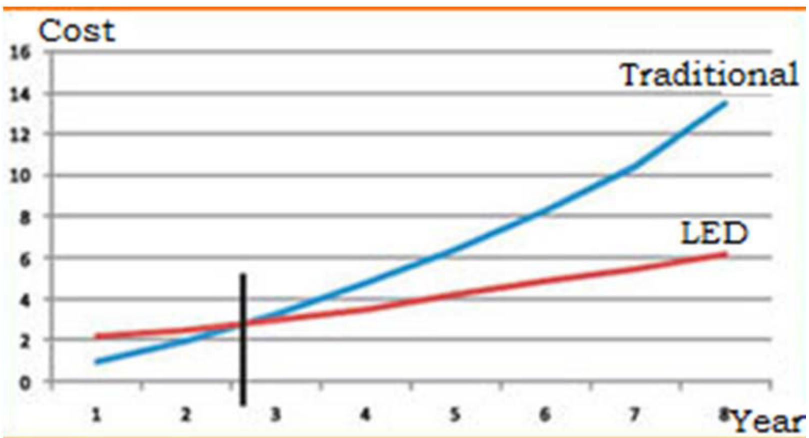


Table 11: Compraison of prices

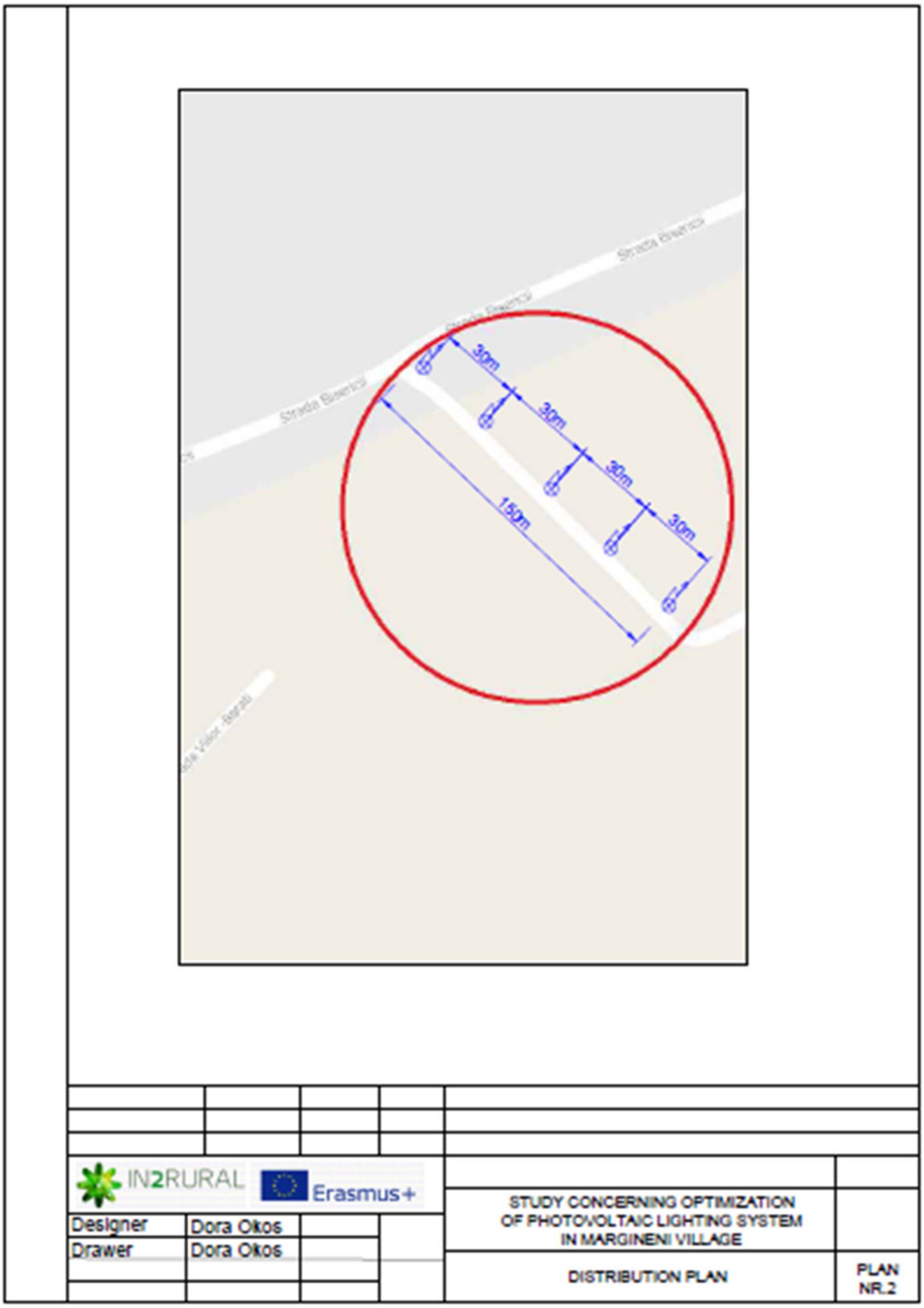
Project plans

4.1. Location of the installation

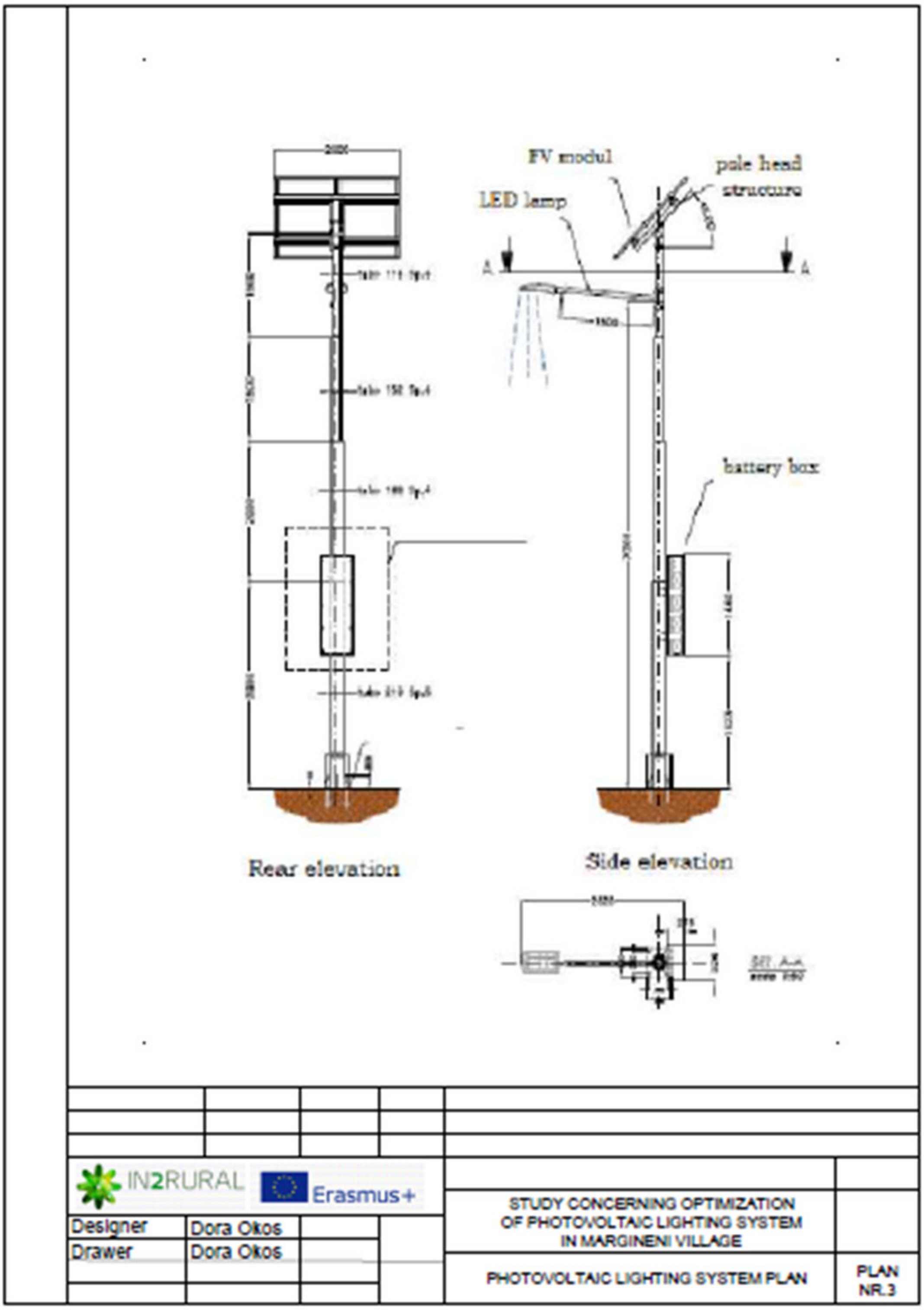
IN2RURAL Erasmus+			
Designer	Dora Okos	STUDY CONCERNING OPTIMIZATION OF PHOTOVOLTAIC LIGHTING SYSTEM IN MARGINENI VILLAGE	
Drawer	Dora Okos	LOCATION PLAN OF THE INSTALLATION	PLAN NR.1

4.2. Distribution plan

The locatation of the system on the street.



Photovoltaic lighting system plan



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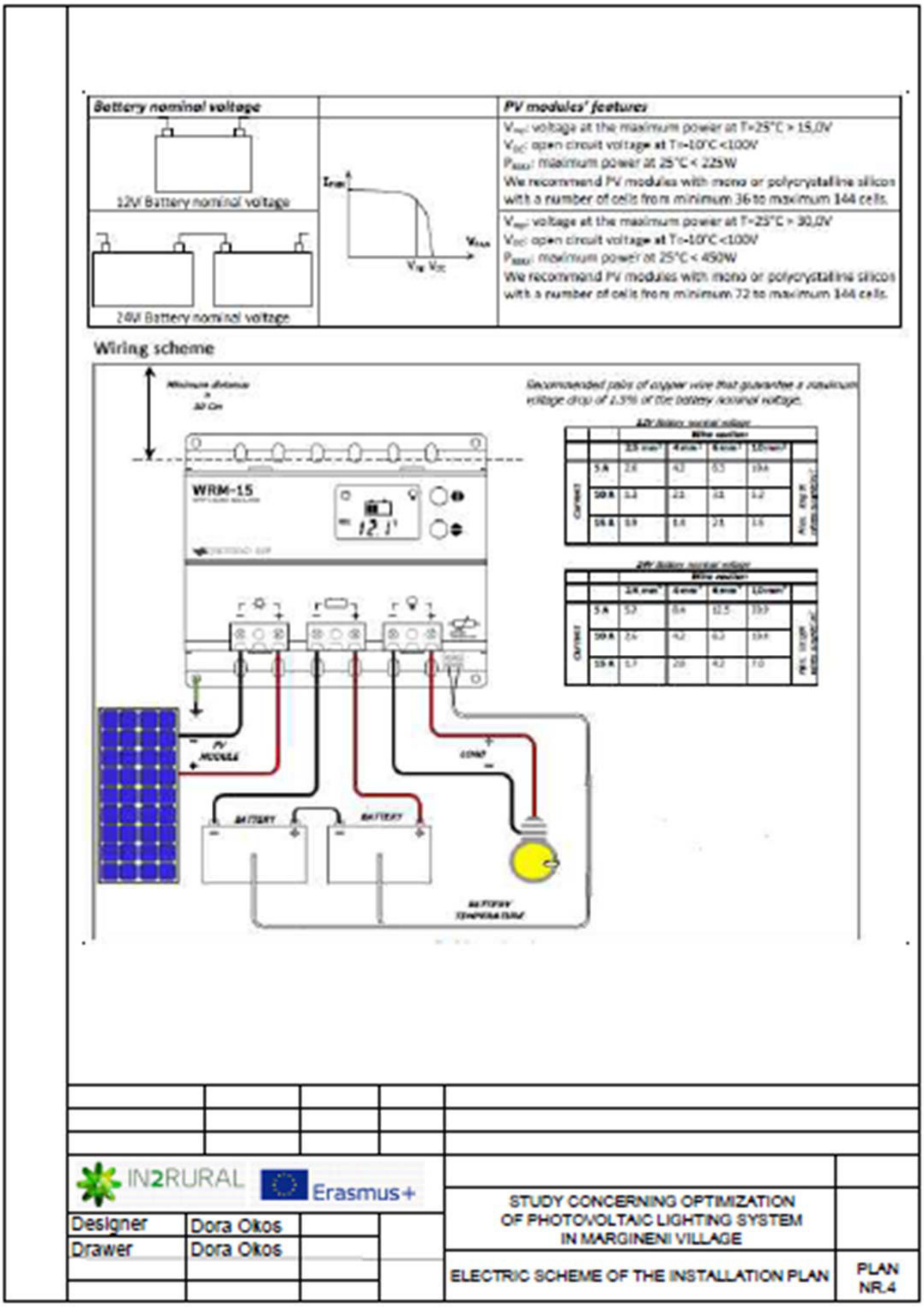
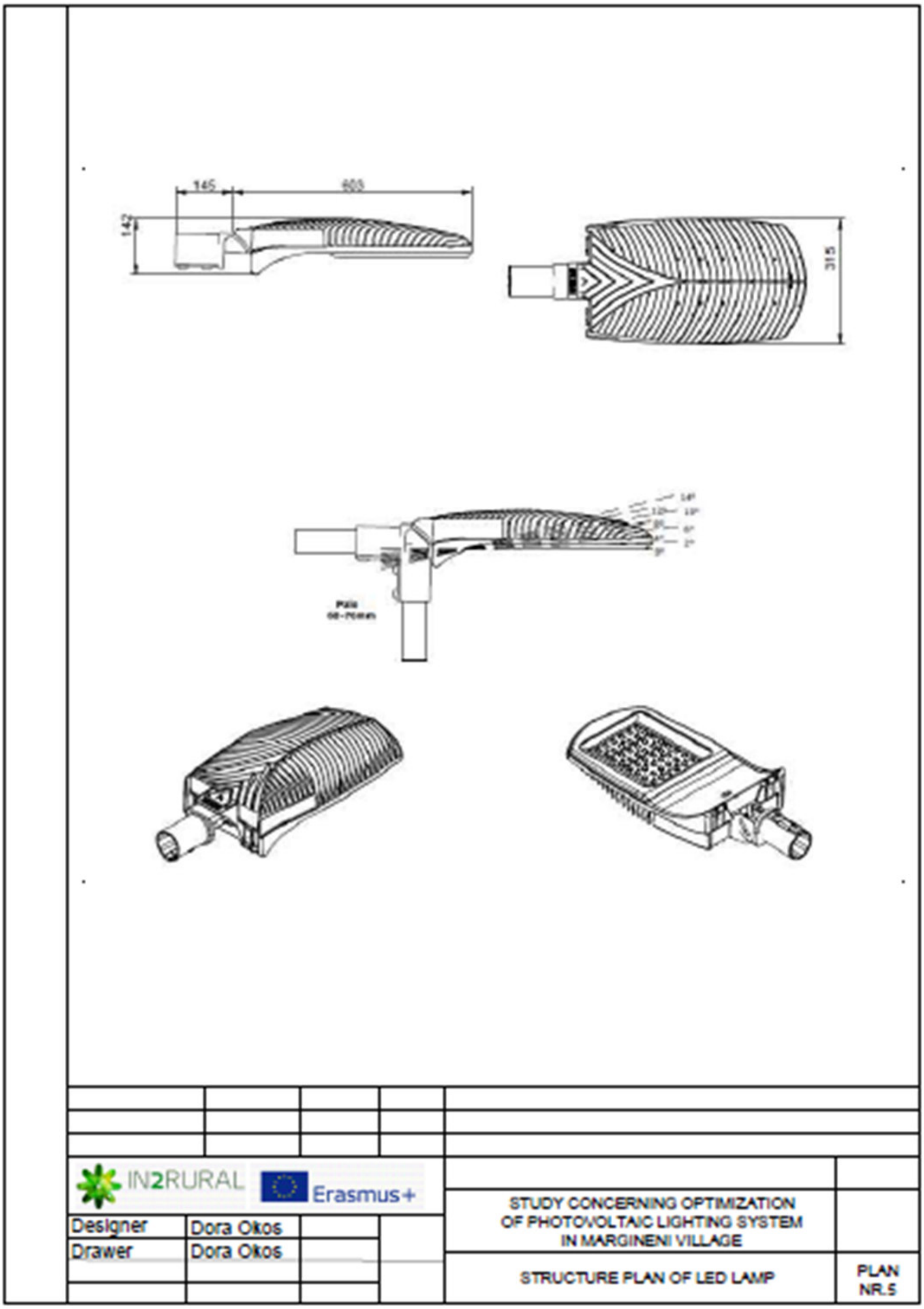
4.3. Electric scheme of the installation

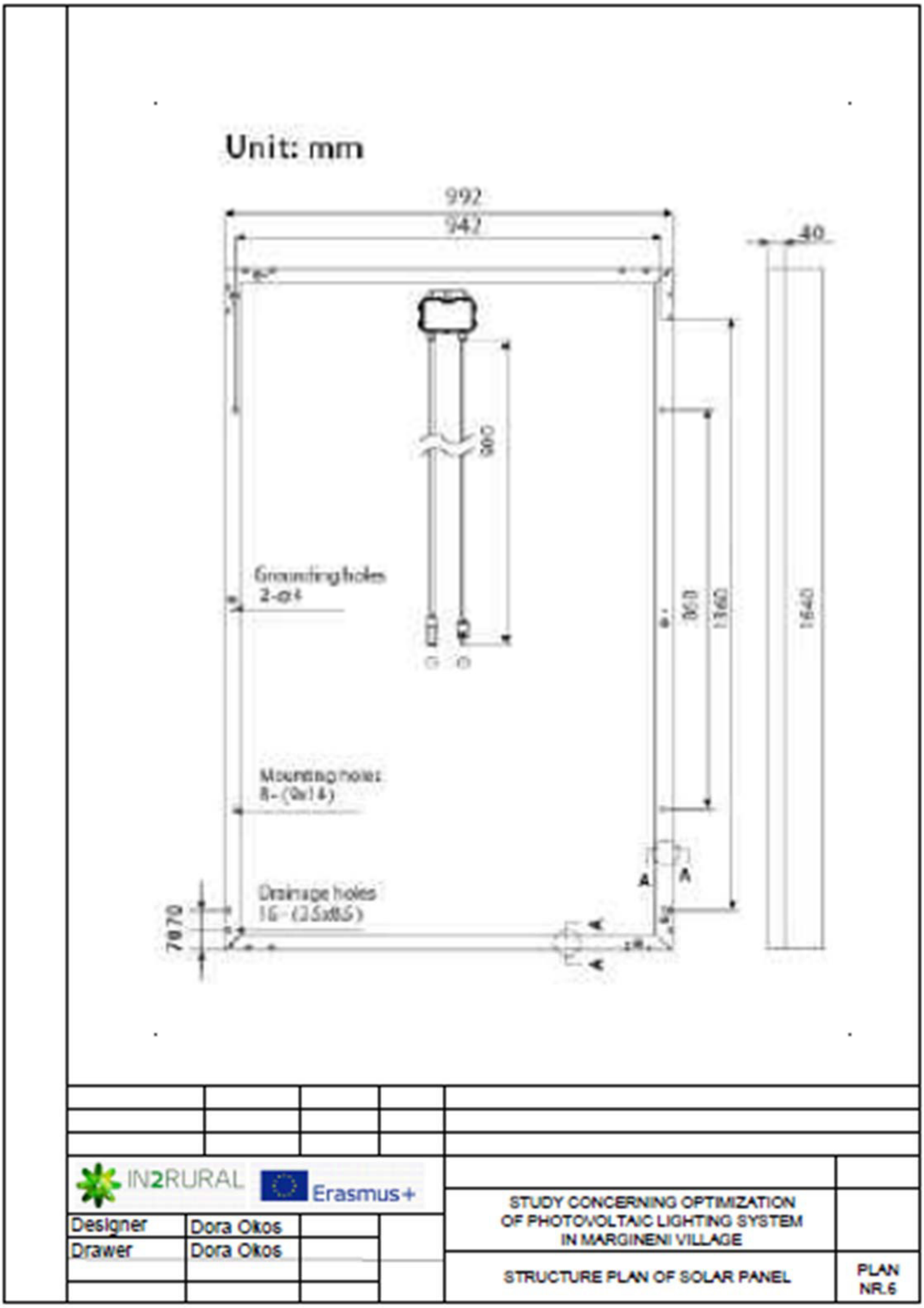


4.4. Structure plans of the Elements/illmunated area

The structure of the LED Lamp



Structure of the Solar panel



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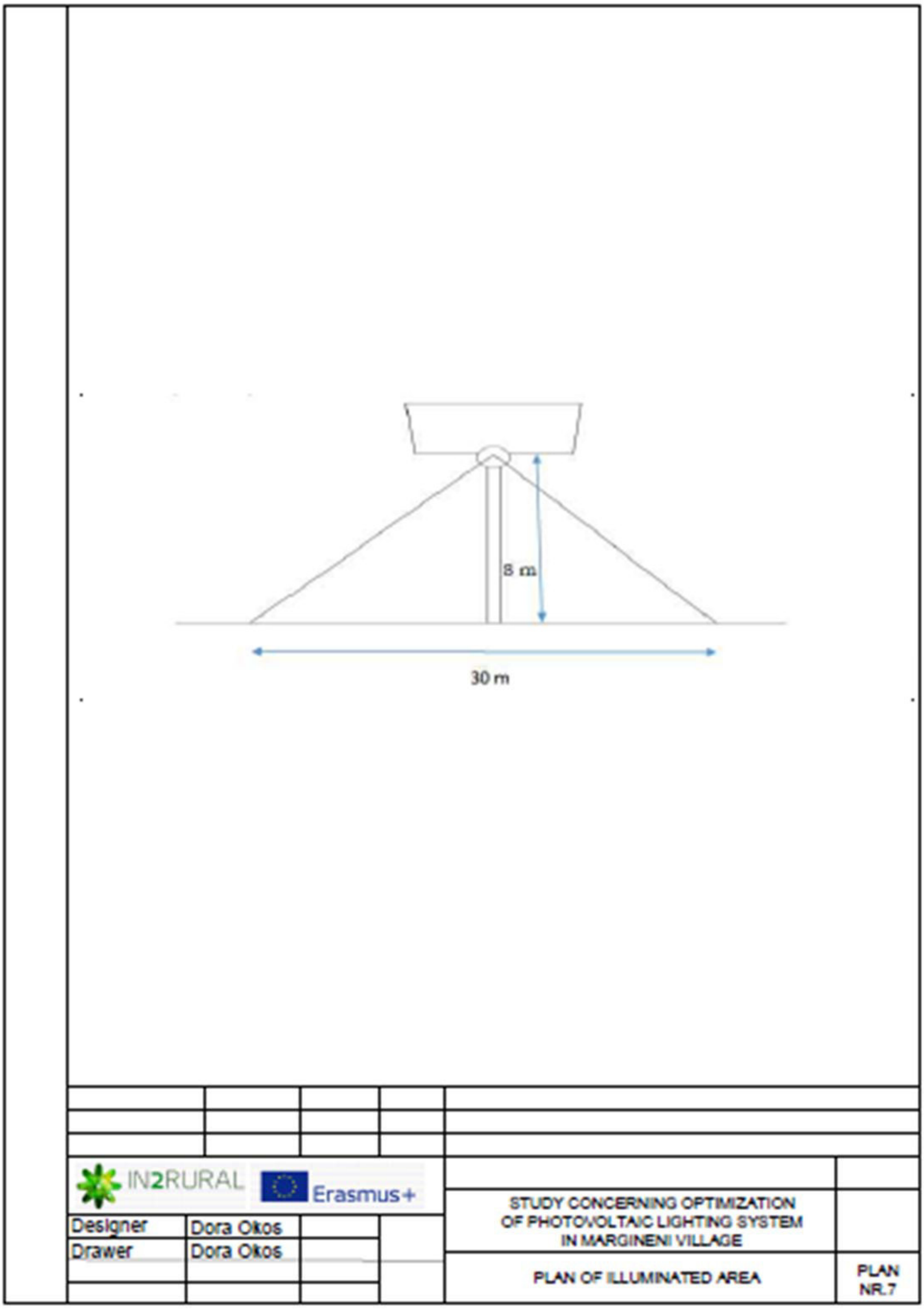
Plan of illuminated area



REPORT OF THE CASE STUDY ON RENEWABLE ENERGIES TO LOCAL DEVELOPMENT TRANSNATIONALLY IMPLEMENTED

Development of renewable energy models for children education

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Jose Segarra Murria, UMANS
Zsuzsanna Kray, UMANS

Case study tutor: Carmen Ibáñez Usach

Renewable energies tutor: Jose Segarra Murria
Rural development tutor: Vicent Querol
English tutor: Imre Baják
Professional supervisor: Zsuzsanna Kray

UMANS
Castellon de la Plana, April 2017

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Memory of the project

1. Introduction to the project

This case study concentrates on children education on renewable energies.
There are a lot of renewable energy sources but this case study focuses on three main types.
In this case study, three models will be designed and their respective pedagogical guides will be prepared. Firstly, three different types of models will be analysed: hydraulic energy, eolic energy and photovoltaic energy each of them focused on a type of energy transformation process.
For each model selected from the literature reviewed, different features will be presented and studied: an initial design of each model will be included, the materials and components needed will be listed, a description of the process will be done and, finally, the steps to build it will be explained.
Finally, three new models will be designed concerning three types of energy transformation (hydraulic, eolic and photovoltaic energy).

As published by Kandpal and Broman [1]: “Another dimension of energy education, in general, and renewable energy education, in particular, that merits immediate attention is to ensure continuity and consistency in the inputs given at different levels.”
Due to the relevance of energy education, focus on energy education is a matter of high priority.

In order to make renewable energy sources be a big part in the global energy supply mix, large scale dissemination of different types of renewable energy technologies are needed.
It follows that the number of well-trained specialists who design, develop, repair, install, manage, and reserve renewable energy systems is increasing.
Large scale renewable plants (such as electric power generation using solar, wind, waves, tides, ocean thermal gradients, mini hydro, etc.) provide employment opportunity similar to conventional power plants.
Therefore, to meet the labour requirement of both the above types of potential renewable energy applications, it is essential that educational efforts in this area should take the job requirement of both types of applications into account.

So the renewable energy education is very important to provide trained manpower for huge energy systems is available along with skilled entrepreneurs for planning, development and treatment of renewable energy based decentralized systems. This way these energy systems are available along with skilled entrepreneurs for planning, development and treatment of renewable energy based decentralized systems.

This section includes precedents of this project. The development of renewable energy technologies has been emphasized in many countries previously. The main goal is to promote development. These energy supply opportunities will be very important in the future to face the global energy demand. Significant progression has been done in numerous technologies such as: photovoltaic and thermal applications, wind power, etc. in mid nineteen seventies. In turn, the total contribution of non-hydro renewable energy technologies is restricted yet.

In the last three decades, many education programmes have started whose topic is to promote the use of renewable energy in several countries worldwide. After the oil crisis of the nineteen seventies, a huge number of countries commenced academic projects in the field of renewable energy because many people worried about global climate alteration, and demanded the development of different renewable energy technologies. In that sense, huge progress was made related to these energies in, children education and energy training programmes.

Thus, as referred by Kandpal and Broman [1]: "The role of a renewable energy education programme should be educative, informative, investigative and imaginative. Renewable energy teaching and more broadly the energy tuition has to have the entire population as its target audience."

It is essential to create the awareness of future generations in order to enhance the relevance of protecting the environment, energy related challenges are perceived by humanity (for example: climate change problems, and that high prices and the depletion of fossil fuels, etc.).
It is necessary to make students be aware of the disadvantages of the different non-renewable sources and of the advantages of renewable energy sources, and also to inform them about renewable energy technologies and the institutional and environmental issues related to their development and utilization.
It is important to encourage children, and to focus on the enforcement and development of several ways to create energy solutions, make a lot of efforts towards the use of renewable energies. The world needs more and more energy, rising global energy postulate which has to be fulfilled. Furthermore, it is essential to focus on efficient and effectual applying of renewable sources of energy.

Renewable energy education in schools will have to be issued at mass level on a global scale. Therefore, both formal and informal ways of tuition should be substantially applied for this goal.
The formal education involves in direct communication (face to face), and commands given in universities, schools, colleges and so on.

This is a long term controlled strategy which ensures necessary skills knowledge through an organized system of education.
The informal mode means that the use of mass communication media to learn from institutions which do not impart organized instructions.
This mode helps to such people who have never gone to schools, such people who would like to study and are interested in improving themselves, their skills and knowledge.

As pointed by Kandpal and Broman [1]:
"Thus a judicious mix of formal and informal routes of education will have to be used for imparting renewable energy education. Since the adoption of renewable energy technologies

requires active participation of common public, it is important to take initiatives that improve public understanding in this regard."

The present energy educators main task is the apportion of appropriate education to students about energy related complex issues, furthermore, to stimulate them to ferret about corresponding solutions.
"Concerted efforts should be made to improve the knowledge and appreciation of school students about renewable energy sources and technologies."
Kandpal and Broman mentioned in their book [1].

In the world a lot of groups labour school curriculum. For example, Victorian Solar Energy Council in Australia began a renewable energy education programme in different schools.
This education programme contains different packages created in this topic, which help experimental work. Packages involve different types of games and several activities about renewable energy. It is possible to build simple experimental devices.
A new course was launched at the Moscow Institute of New Technologies in Education.
Students should introduce design of energy systems and different development plans and should be able to follow this project.
Florida Solar Energy Centre in the United States of America, which plays an important role in the field of energy education at school level, has done significant work.
The renewable energy education programmes and suitable consciousness initiatives at school level are very impressive in changing the behaviour of the students.
The familiarization with the basics of renewable energy resources and technologies is very essential in the science curriculum of schools.

As regards to variety and flexibility: renewable energy education has to be imparted at several levels.
Appropriate quality and amount of teaching-learning resource materials should be done attainable at all levels of renewable energy education, in formal and informal programmes as well, furthermore, from elementary school level to university level.
The appropriate allocation of available resources (for example: materials, books, etc) is very important. The sharing of electronic audio-visual resource materials is easier between respective teachers than books from libraries.
[1]

It is quoted from Rietbergen J. and Hadjemian N. 's book [2]:
"Renewable energy technologiess are energy-providing technologies that utilize energy sources in ways that do not deplete the Earth's natural resources and are as environmentally benign as possible. These sources are sustainable in that they can be managed to ensure they can be used indefinitely without degrading the environment (Renewable Energy Association, 2009).2 By exploiting these energy sources, RETs have great potential to meet the energy needs of rural societies in a sustainable way, albeit most likely in tandem with conventional systems."
[2]

Renewable energy derives from natural resources such as sunlight, wind, rain, tides, watercourses, which are naturally replenished.

In 2006 renewable energy from all sources accounted for only about 8% of global energy production. Nuclear made up another 6% of global energy production. This left about 86% of global energy originating from fossil fuels, which were both non-renewable, and also the main reason of global climate change and a number of other, contrary impacts on the environment.

As it was written by Nemethy S., Dinya L., Gergely S. and Varga G.

"The production and use of renewable energy (with particular emphasis on bio-energy, solar power and wind energy) is the key for all aspects of sustainability, including economical viability. Agricultural lands occupy 37% of the earth's land surface. Agriculture accounts for 52% of methane and 84% of global anthropogenic nitrous oxide emissions."

The reduction of harmful greenhouse gases is needed, the best way to reduce these gases is to replace the fossil fuels for energy processing by agronomical feedstocks (such as dung, crop residues and dedicated energy crops).

In agriculture it has a lot of opportunities to develop combined production structures which include organic, chemical-free crop production, the application of bio-energy forests and biological filters, the consumption of biologically cleaned waste water, free from heavy metals etc.

The goal is to decrease the global warming. The application of bio energy plants has a lot of advantages and positive effects. For example, if renewable energy from dedicated bio energy crops (such as biological filters) were used, it may help to increase the soil carbon sequestration. This way the dedicated bio energy crops could reduce the effects of global warming.

In this method complete ecological cycles can be created, which utilize all energy sources in an optimal way and minimize waste production.

[3]

1.1. State-of-art in the problem domain

Renewable energy education is a comparatively recent issue.

In order to conclude that the educational efforts are effectual and successful, different issues must be properly answered.

The specialist who works in this field, needs appropriate knowledge and skills, furthermore, has to be creative and to be able to create corresponding solutions for special situations.

This area is new, so specialists have to be aware of their responsibility, furthermore, they should be able to create green solutions.

The environmental consciousness is increasing year after year. It is typical that all of the potential energy solutions are controlled in a severe way. They will have short- and long-term effects on sustainable development and environment considerations.

All the energy resource technology combinations would be environmentally sustainable, it is very important.

It is essential that children can learn on renewable energy education related to different energy resource-technology combinations which have environmental and ecological implications (which need appropriate inputs).
Environmental education creation is a key towards students. Children will be able to look for and find possible energy supply options which satisfy increasing global energy demand.
Huge efforts towards environmental education.
It would be good if the pupils could make proposals for useful measures towards minimizing the negative environmental impacts of the energy solutions chosen by the consumers.
This is very important because it is needed that appropriate inputs for equal environmental education and energy education are ensured in a synergistic manner.

The renewable energy education has another aspect the effectiveness of which needs attention for getting a suitable job.
According to Kandpal and Broman: "At present, particularly in the case of post graduate level programmes, it is being noticed that energy education programmes are not always able to attract the best talented students thus, to some extent, reflecting its employment potential."

The unemployment and under-employment is a similar big problem too.
The renewable energy programmes and education offer a lot of job opportunities, therefore it is very necessary.
This programmes proffer self-employment to children.

In most of the renewable energy education programmes, the entire content in its entirety of breadth and depth is often not included.
Courses need to be optimized so that they contain both a broad range of information and an in-depth analysis of the information given.
For example, if a single introductory course (of about 45 contact hours) is expected to provide inputs on all different renewable energy sources such as solar, wind, hydro, etc., only basic concepts (knowledge and understanding level) could be introduced in the lesson and detailed treatment (designs, analysis, evaluation, etc.) may not be possible.
Consequently, even after efficient accomplishment of such a course the children are just aware of several possible technological options renewable for harnessing energy sources.
Unfortunately, students are not able to obtain competence for their design, production, achievement, evaluation, etc.
In the past, regrettably, it has caused problems. Knowledge of employees is not enough to work and make an appropriate, successful strategy for huge size sustainable dissemination of renewable energy systems.
In fact, unfortunately, in many cases, their efforts have resulted in distorted prioritization and non-judicious allocation of scarce resources and funds.

The analysis of the renewable energy courses and teaching programmes is guided by the expertise of available educators.

[1]

The dissemination and development of the corresponding renewable energy technologies, will need collaboration of experts and well-trained staff in the whole world.
Workforce development is one of the critical factors referring to renewable energy technology dissemination and development.

As pointed by Kandpal and Broman [1]:
"This necessitates that sincere efforts be made in the area of renewable energy education and training to provide the required technical manpower at all levels."

As it was written by Kandpal and Broman [1]:
"Unavailability of human resource with required knowledge and skills is often identified as one of the key reasons for poor dissemination of renewable energy technologies."

The traditional fuels are not able to produce modern energy services, for example mechanical power and electricity limits their capability to develop other aspects of life (it involves employment and children education).
Unfortunately, traditional fuels can not produce appropriate energy which would be usable. Therefore energy producing of traditional fuels is useless and ineffectual.
As a result of this, they need a huge efforts and also substantial time to gather. The local resource stocks frequently reduce so they should be derived from further outside.

As it was written in Rietbergen J. and Hadjemian N. 's book [2]:
"This significantly reduces the time available for productive activities. If managed ineffectively, such resources use can also degrade the environment and create negative spillover effects in other sectors. Given the cultural practices in many rural areas, these impacts are often most felt by women and children."
Although, there are some methodological difficulties which create concrete connection between energy poverty and rural development. It is a common concept the name of which is "energy ladder".
Societies that depend on traditional energy activities are placed at the bottom rung of the energy ladder.
The energy ladder is moved up by modern energy services.
The societies which have full access to modern energy services, they are found at the top of the energy ladder and experience superior levels of economic development and higher income levels.
[2]
Finnish rural schools have formed huge efforts to ensure educational equality in rural areas which have a considerable number of population.
Unfortunately, in the past several decades, a lot of rural schools have been closed in several countries. The reason was that these schools had high costs, furthermore, it was not so cheap to get along kids from very small town to bigger schools. It caused a significant problem.
Authorities decided to close rural schools. The small school involves just fifty pupils in this region. The children who are aged seven to twelve and one to six take part in primary school (or sometimes people define these preschools) in these rural areas. Usually there are few

teachers in the classroom in these small schools. This teaching has a special name "multigrade or multiage teaching". [4]
Concrete details are referred from Hyry-Beihammer and Autti [4]: "In the last two decades, sixty-five percent of small Finnish comprehensive schools have been closed.
Many rural schools had serious financial problems.
From 1990 to 2010, 2,117 comprehensive schools were closed in Finland."
Although, many rural schools have been closed, fortunately, new schools have been built in this region.
After World War II, the school-age population was extremely big, and the shipping process and routes were undeveloped yet. In the 1950s, towns in this area spread all over the municipalities. An unexampled growth in the number of village schools started, therefore, more new schools buildings were needed in this rural area.
Until the 1950s the number of schools frequently increased. [4]

The energy maintenance and the sequestration of carbon dioxide can go different ways to contribute to the solution of this problem, but the application of renewable energy sources must increase dramatically worldwide, in order to produce ecologically and energetically self sustaining societies. These societies are built on such a difficult system which involves ecological and inartificial progresses.
[3]

1.2. Design alternatives to be considered

1.2.1. Electric power generation from hydraulic sources

In this section, three models where hydraulic energy is transformed into electric energy are analysed which are developed for children.

1.2.1.1. Electric power generation from hydraulic sources option 1.

1.2.1.1.1. Initial design of the model

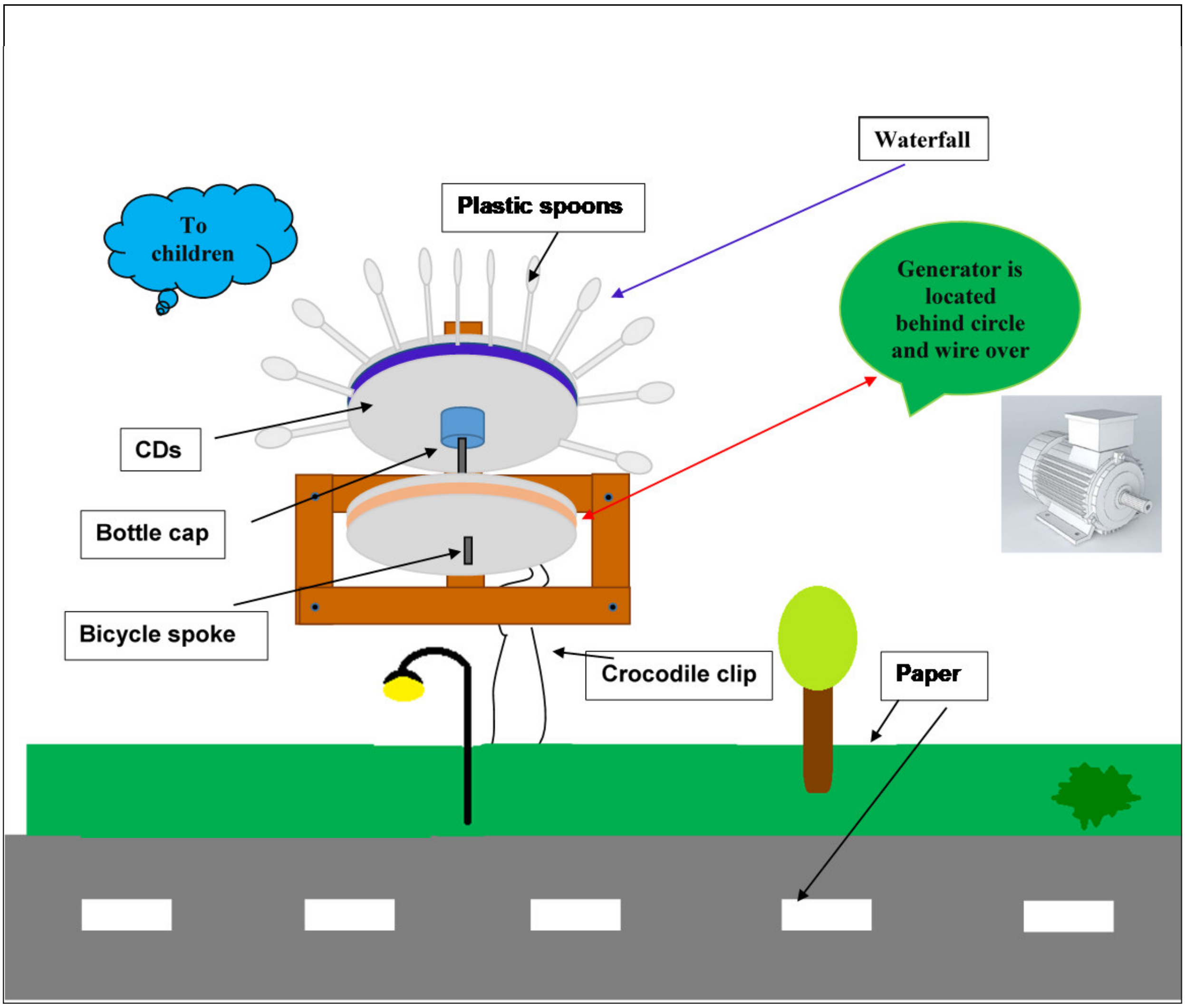
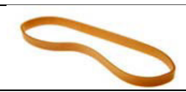


Figure 1. : H 1. Drawing

1.2.1.1.2. List of materials and components

Table 1. : H 1. List of materials

• Two the biggest size woods (the same sizes) ☛ Sizes: Length: 24 cm 2,5 cm wide 2 mm thick On the top of wood there is a hole which is of 2 mm diameter • Two medium sized woods (the same sizes) ☛ Sizes: Length: 21 cm 2,5 cm wide 4 mm thick There is a hole in the middle of wood (also of 2 mm diameter) • Two small size woods (the same sizes) ☛ Sizes: Length: 11 cm 2,5 cm wide 4 mm thick In this case: on the top of the wood and at the bottom part of wood there is a hole (also 2 mm diameter) These holes are located at 2 mm distance from the edge of wood.	
• Four CDs (Compact Disk) ☛ Sizes: Diameter: 12 cm Thickness: 1,2 mm	
• One circular styrofoam ☛ Sizes: Diameter: 11,5 cm 11.5 Thickness: 3 mm	
• Bicycle spoke ☛ Sizes: Length: 13 cm Diameter: 2 mm	
• Generator (motor) Twelve Volt motor worm ☛ Sizes: Approximately 4cmx2cm	
• Two plastic bottle caps ☛ Sizes: Outer diameter: 21 mm	

Height : 16 mm	
• Sixteen disposable plastic teaspoons ☛ Sizes: Length: 14 cm	
• Jar rubber (rubber band)	
• Water shut-off valve ☛ Sizes: Length: 4cm Diameter: 0,8 cm	
• Two crocodile clips (black and red) Sizes: Length: 20 cm	
• LED diode Sizes: Approximate length: 3 cm	
• Four small screw nails Sizes: Length: 1 cm	
• Two longer screw nails Sizes: Length: 3 cm	
• One two litre plastic bottle (with pouring water)	
• Screwdriver	
• Small piece of metal slab (platen) Sizes: Length: 4 cm Width: 2 cm	
• Glue gun	
• Superglue	
• Decoration: Two straws (Height: 5cm), colourful papers (brown, black, green, pink), table tennis ball	

• Artificial grass (width: 3 cm, Length:10 cm)	
• Sheets of wood Sizes: Length: 60 cm Width: 60 cm	

1.2.1.1.3. Description of the process

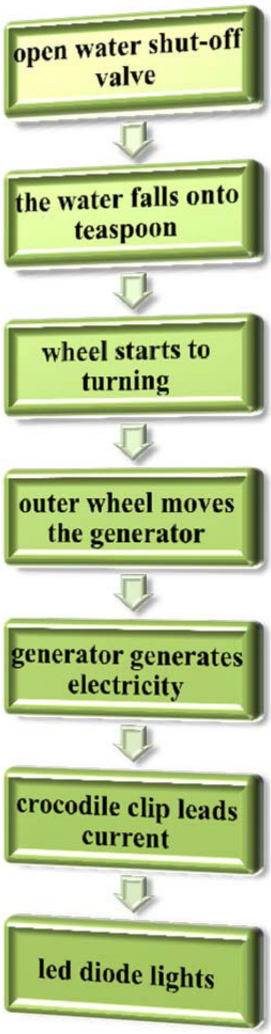


Figure 2.: The description of the process in a few words

1.2.1.1.4. Steps to build the model

- Drill the holes in the wood pieces (diameter: 2 mm).
- Two pieces of small size wood (length: 11 cm) and two pieces of medium size wood (length: 21 cm) were screwed together in rectangle form with four small screw nails.
- Drill a hole in the two biggest size piece of wood (length: 24 cm) which was located 2 mm distance from the edge of the wood. Diameter: 2 mm
- One-one the biggest size wood (length: 24 cm) was screwed to (the middle) one-one pieces of the medium size woods (length: 21 cm) (with two longer screw nails).
- The lines (diameter) have to be drawn equal distance each other using a ruler. Exactly sixteen lines are drawn in CD.
- Use a glue gun to draw eight lines.
- Disposable plastic spoons have to be installed in sixteen pieces of glue streaks in the same direction.
- Glue has to suited in top of the disposable plastic spoons, and CD is laid into the spoons (softly push).
- Holes have to be drilled (diameter: 2mm) in the middle of the two plastic bottle caps.
- Glue has been suited in the inner edge of the two plastic bottle caps then it is put in the middle of the CD (so the top of the plastic bottle caps would be up), then glue is placed in the outer edge of the plastic bottle caps).
- Bicycle spoke has been attached to the wood and the plastic bottle caps (through propeller), use a superglue.
- We make sure that all things moving together with propeller. If it works, we can go on to the next step.
- Hole has to be drilled (diameter: 3mm) in the middle of the previous two CDs and the styrofoam.
- The two CDs and the styrofoam have to be sticked together (by superglue), the styrofoam was located in the middle, between the two CDs.
- The prepared object must be put to the bicycle spoke, it was fixed with superglue.
- Cut the unnecessary (pieces) parts of the bicycle spoke.
- The propeller was fixed by superglue, put the wood and into the bicycle spoke. This is necessary so that the propeller should not fall down. Then we turn this structure to check whether it works or not. It was excellent, so we continued.
- Put jar rubber between the two CDs and the styrofoam.
- Fixed the generator to wood with the platen (metal slab). Drilled two holes in the wood which will hold the generator (engine).
- The generator has a little black part (wheel), so put the jar rubber into the little black part of the generator. It will generate energy. Furthermore, needed two screws to put.
- Drilled a hole in the 2 litre plastic bottle which has the same diameter as the diameter of the water shut-off valve.
- Connected the crocodile clip to the generator, and the other part of the crocodile clip was connected to the led diode.

- Turned this wheel, the led diode lighted, so it created energy.

The decoration of this model:

- Lamp in the road: Lead a wire (crocodile clip) through black colour straw. The led diode was located on the top of the straw.
- The road: use big grey paper and cut streaks from white paper.
- Bush: fold a few green papers, and cut streaks and (glue gun).
- Hedgehog: cut black paper and pink paper (superglue).
- Tree: Big straw was bought (height: 5 cm), cut unnecessary part of straw. Cut a little brown paper and stick to the straw.
- Crown of tree: table tennis ball was bought (normal size ping-pong ball), and cut from green paper appropriate size piece, stick together the paper and the ball. Stick together the ball and the straw.
- Artificial grass which was 3 cm wide and 10 cm long.
- This model and decoration were located in cut sheets of wood (60x60cm) which was painted to green colour.

1.2.1.1.5. Pedagogical explanation

Fill the two litre plastic bottle with water. Open the water shut-off valve (this is a switch which enables the water to fall, otherwise it does not allow the water to fall) and see the water fall into spoons. This way, the propeller starts to rotate. As one of the wheels is connected to the generator it generates electricity. The crocodile clip is conducting the created electricity. Crocodile clip leads the energy to the led diode.
If the water falls frequently, the electricity is constant. Otherwise if the water falls discontinuously the electricity is not constant, the power generation is defective. [5]

1.2.1.2. Electric power generation from hydraulic sources option 2.

1.2.1.2.1. Initial design of the model

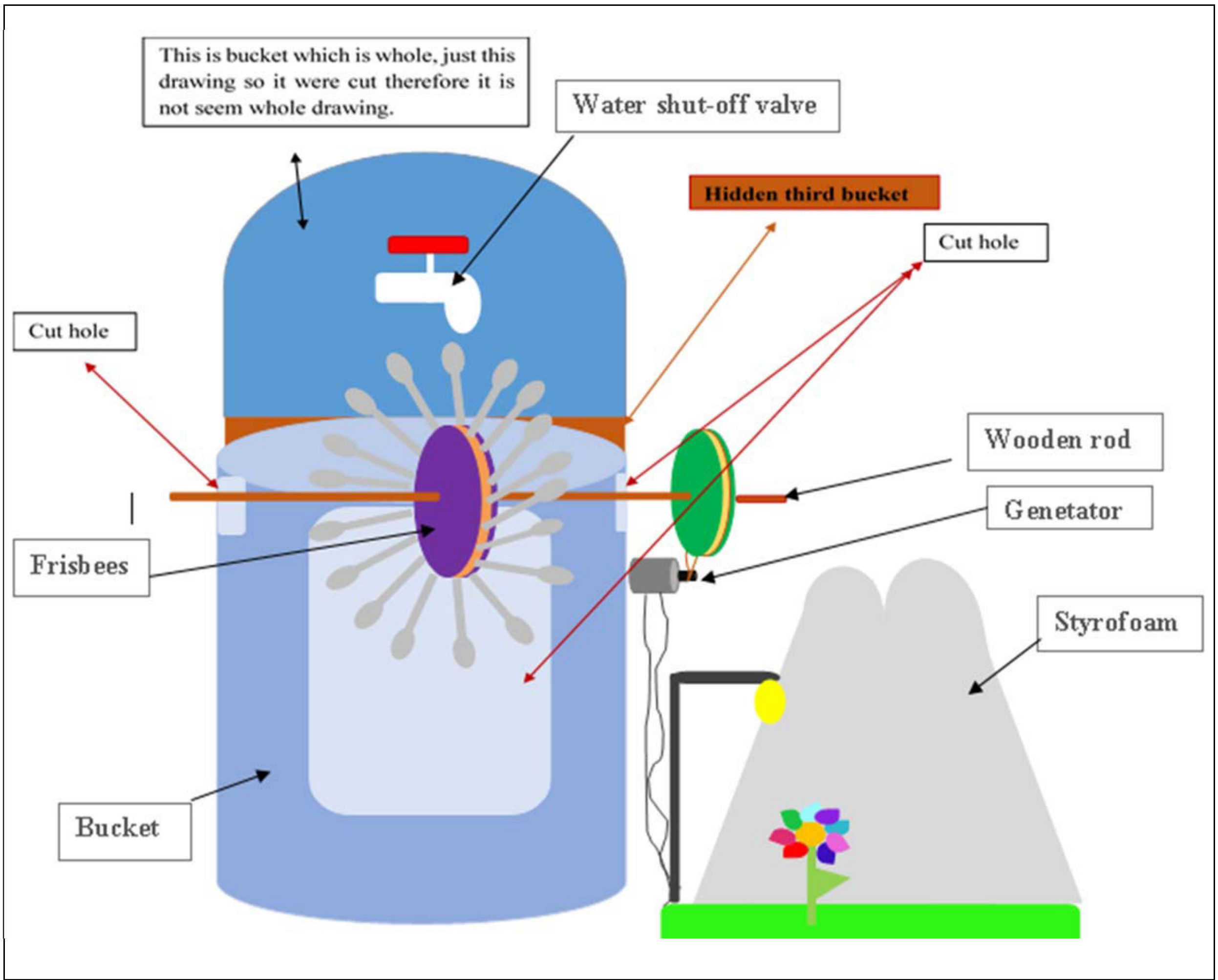
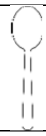
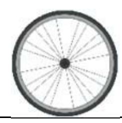


Figure 3. : H 2. Drawing.

1.2.1.2.2. List of materials and components

Table 2. : H 2. List of materials

• Three plastic buckets Sizes: Tonnage: 20 litre Diameter: 35 cm Height: 33 cm	
• Water shut-off valve Sizes: Length: 2cm Diameter: 1 cm	

• Cylindrical wooden rod Sizes: Diameter: 2 cm Length: 45 cm	
• Corkwood (whose form is circular) Sizes: Height: 2 cm Diameter: 9 cm	
• Ten disposable plastic spoons Length: 6 cm	
• Two plastic frisbees (bigger) Sizes: Diameter: 9 cm Height: 0,5 cm • Two plastic frisbees Sizes: Diameter: 6 cm Height: 0,5 cm	
• Sponge (second circle) Sizes: Diameter: 6 cm Height: 2 cm	
• Rubber band	
• Crocodile clip Sizes: Length: 30 cm	
• Generator (motor)	
• Led diode	
• Bicycle spokes (cut small pieces)	
• A small piece of metal slab (platen) (curved, semi-circular form) Sizes: Length: 4 cm Width: 2 cm	

• Two small screws Sizes: Length: 1 cm	
• Superglue	
• Glue gun	
• Cut sheet of wood (base board) Sizes: Length: 100 cm Width: 100 cm	
• Artificial grass Sizes: Length: 40 cm Width: 20 cm	
• Colourful (green, yellow, red) papers	
• Straw	

1.2.1.2.3. Description of the process

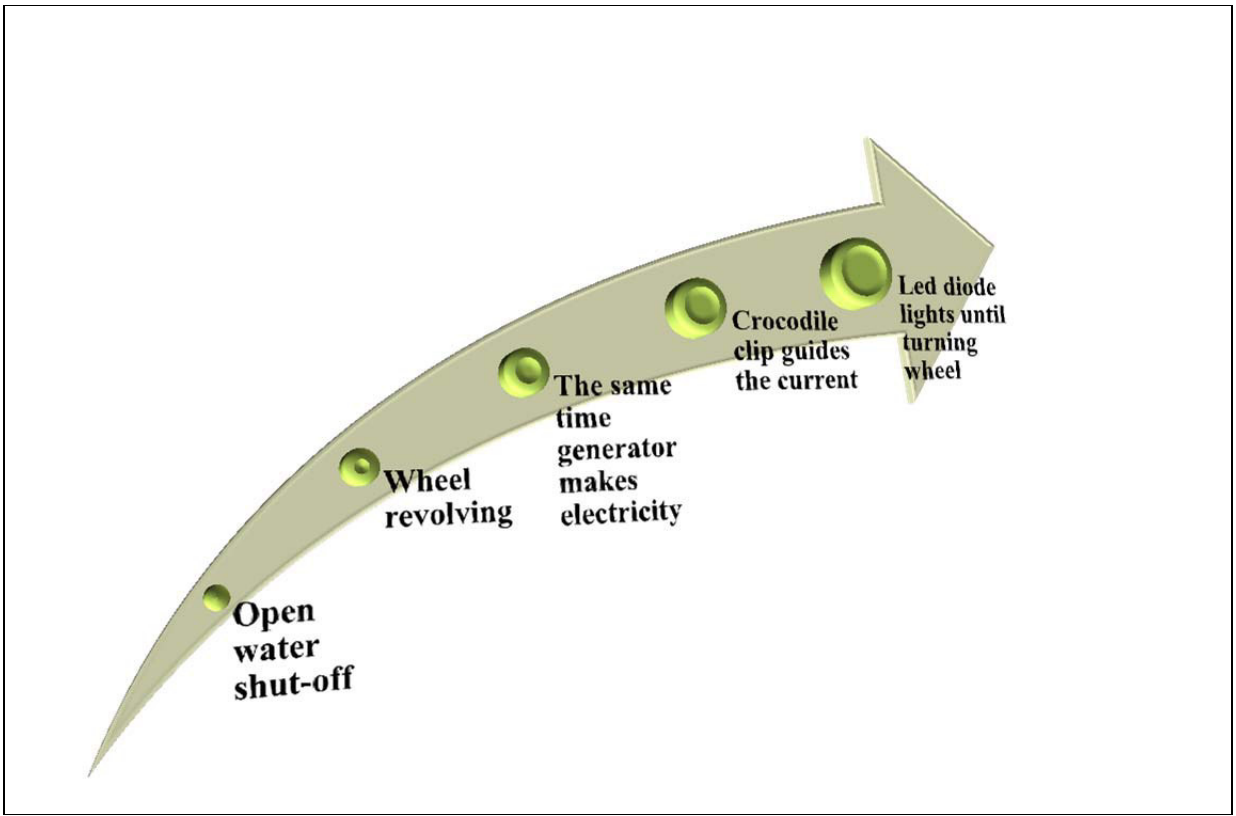


Figure 4.: The description of the process in a few words

1.2.1.2.4. Steps to build the model

- Turn one of the plastic buckets (with head down) and put the second plastic bucket into this plastic bucket. Drill a hole (the diameter of which is 1 cm) in the side of the upper plastic bucket. Put the water shut-off valve into this hole. Use superglue to avoid it from moving. If this step is finished, fill the plastic bucket with water.
- Take out the third plastic bucket's ear because it is not necessary.
- Cut two holes in the middle of the plastic bucket. These two holes are placed symmetrically. The details of both of the holes are: 5 cm long, 3 cm wide. Both of the holes have the same parameters.
- The third hole bisects the two previous holes. Cut the third hole which is 20 cm long and 10 cm wide.
- Cut (use a knife or a similar appropriate device, a pencil sharpener drawing tool can even be used) the end of ten spoons to get a sharp form.
- The corkwood of circular shape has these dimensions: height: 2 cm, diameter: 10 cm. Insert ten plastic spoons to around the corkwood. Thrust into corkwood. The distance is 3,1 cm between the ten plastic spoons. Each spoon is 3,1 cm far from another spoon. Stick this structure between two pieces of frisbee together (use super glue).
- Also stick the sponge between two pieces of frisbee together. This is the circle which will be put in the jar rubber.
- As the cylindrical wooden rod has diameter (which is 2 cm), therefore a hole will be drilled (the diameter of which is 2,3 cm) exactly in the middle of the circular corkwood (first circle) and also drill a hole (diameter: 2,3 cm) in the middle of the second circle.
- If the previous step is completed, put this corkwood in the middle of the cylindrical wooden rod. Fix this structure with superglue.
- Drill a hole (diameter 2,3 cm) in the middle of the sponge.
- Also drill a hole (which also size is 2,3 cm) in the middle of the two pieces of frisbee.
- Stick the sponge between two pieces of frisbee (use superglue).
- Put the created second circle into one side of the wood, furthermore stabilize it with glue gun.
- Lay the cylindrical wooden rod with structures (with two circle) into the plastic bucket.
- Drill two holes (the diameters are: 0,4 cm) under the smaller circle. The distance between the holes are 2 cm.
- Fix the generator (motor) with a curved small piece of metal slab (platen) into the plastic bucket.
- Fix the rubber band (jar rubber) to the generator's small moving part, furthermore also fix it into in the middle of the smaller circle.
- Connect the crocodile clip to the generator.
- Lead the wire of the crocodile clip to the led diode under the artificial grass.
- Fix the led diode into the bicycle spoke (before we cut 5 cm long bicycle spoke), which will be painted black.

- Stick the end of the bicycle spoke and the base board together with superglue.
- The wooden base board is 100 x 100 cm.
- Artificial grass: Use superglue to stick together he artificial grass and the cut sheets of wood (base board).
- Flowers: create some flowers. Cut a short line streak from green paper and cut a circle from yellow paper and cut petals from different colour papers. Flower stalks: use straw (cut the unnecessary parts, length: 2 cm)
- Mountain: Use styrofoam painted in grey. Cut the styrofoam mountain form.

1.2.1.2.5. Pedagogical explanation

The first step is to switch on the water shut-off valve. If the container is full of water, the water will start to flow.

When the water falls into plastic spoons, this wheel will start to turn.

The smaller circle is connected to the generator which generates electricity.

The crocodile clip plays one of the most important roles in this process because the crocodile clip leads energy to the led diode.

Consequently, the led diode starts to light. [6]

1.2.1.3. Electric power generation from hydraulic sources option 3.

1.2.1.3.1. Initial design of the model

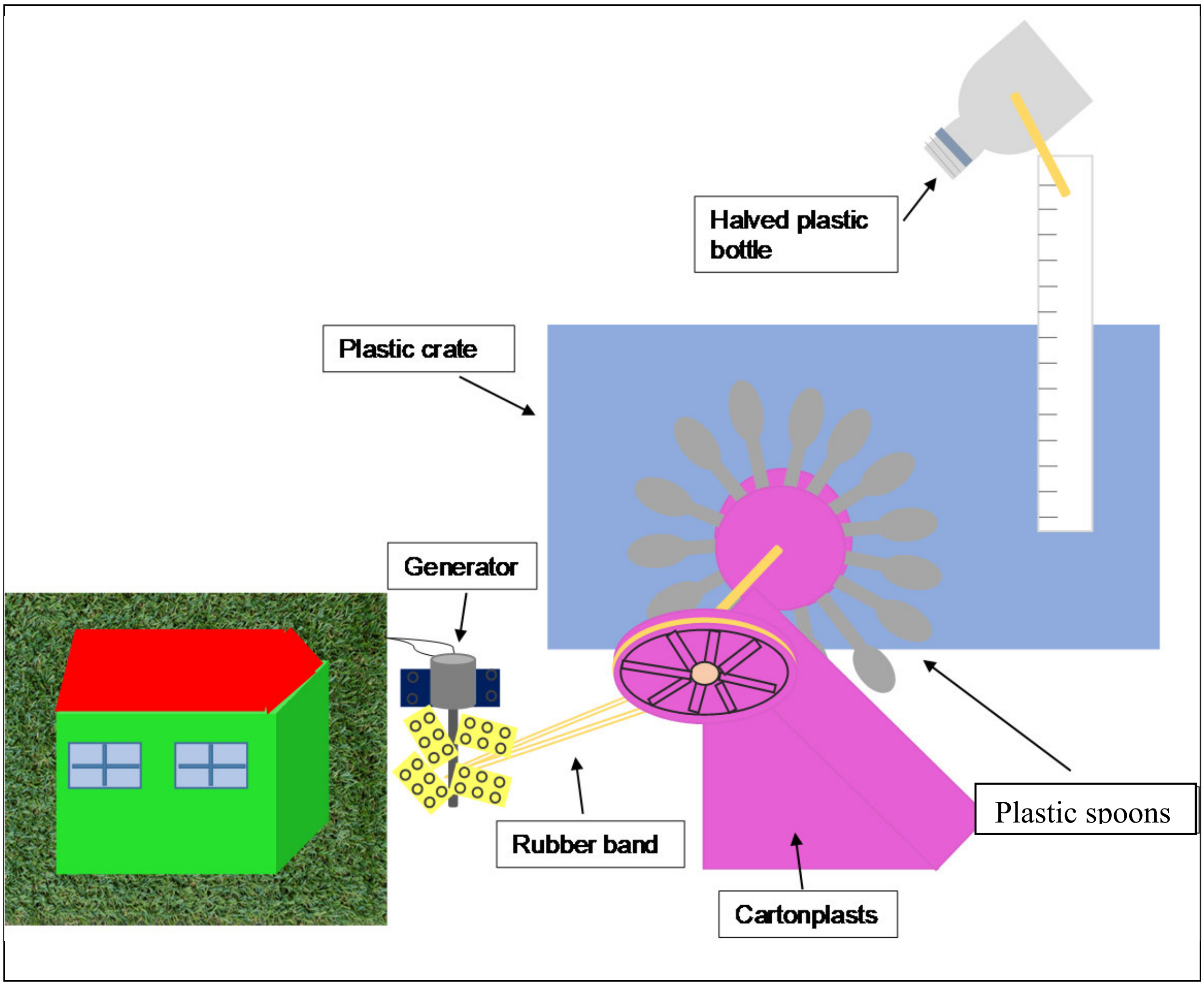
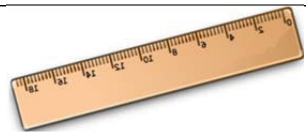
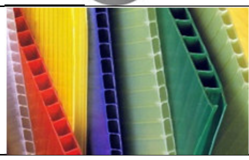


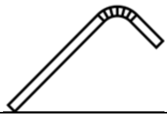
Figure 5. : H 3. Drawing.

1.2.1.3.2. List of materials and components

Table 3. : H 3. List of materials

• Ruler Sizes: Length: 30 cm Width: 3 cm	
• 1 litre plastic bottle (halved)	

• Bamboo skewers (broken)	
• Plastic crate Sizes: Length: 30 cm Width: 10 cm	
• Sixteen disposable plastic spoons	
• Six cartonplasts Sizes: A4	
• Cylindrical wooden rod Sizes: Length: 20 cm Diameter: 1 cm	
• Semi-circular small piece of metal slab (platen) (curved) Sizes: Length: 2 cm Width: 1 cm	
• Superglue	
• Generator (motor)	
• Led diode	
• Two jar rubbers (rubber band)	
• Two styrofoams (circle) Sizes: Diameter: 10 cm	
• Four Legos (Rectangle form) Sizes: Length: 2 cm Width: 1 cm	
• Lego rod Sizes: Length: 5 cm	
• Crocodile clip Sizes: Length: 15 cm	

• Lego piece (which holds the generator) (Bigger than the previous four pieces of Lego) (Rectangle form) Sizes: Length: 4 cm Width : 2cm	
• Small plastic house	
• Two straws (painted black and brown)	
• Table tennis ball (painted green)	
• The basis is styrofoam (painted green) Sizes: Length: 55 cm Width: 25 cm	
• Tempera paint (different colour)	

1.2.1.3.3. Description of the process

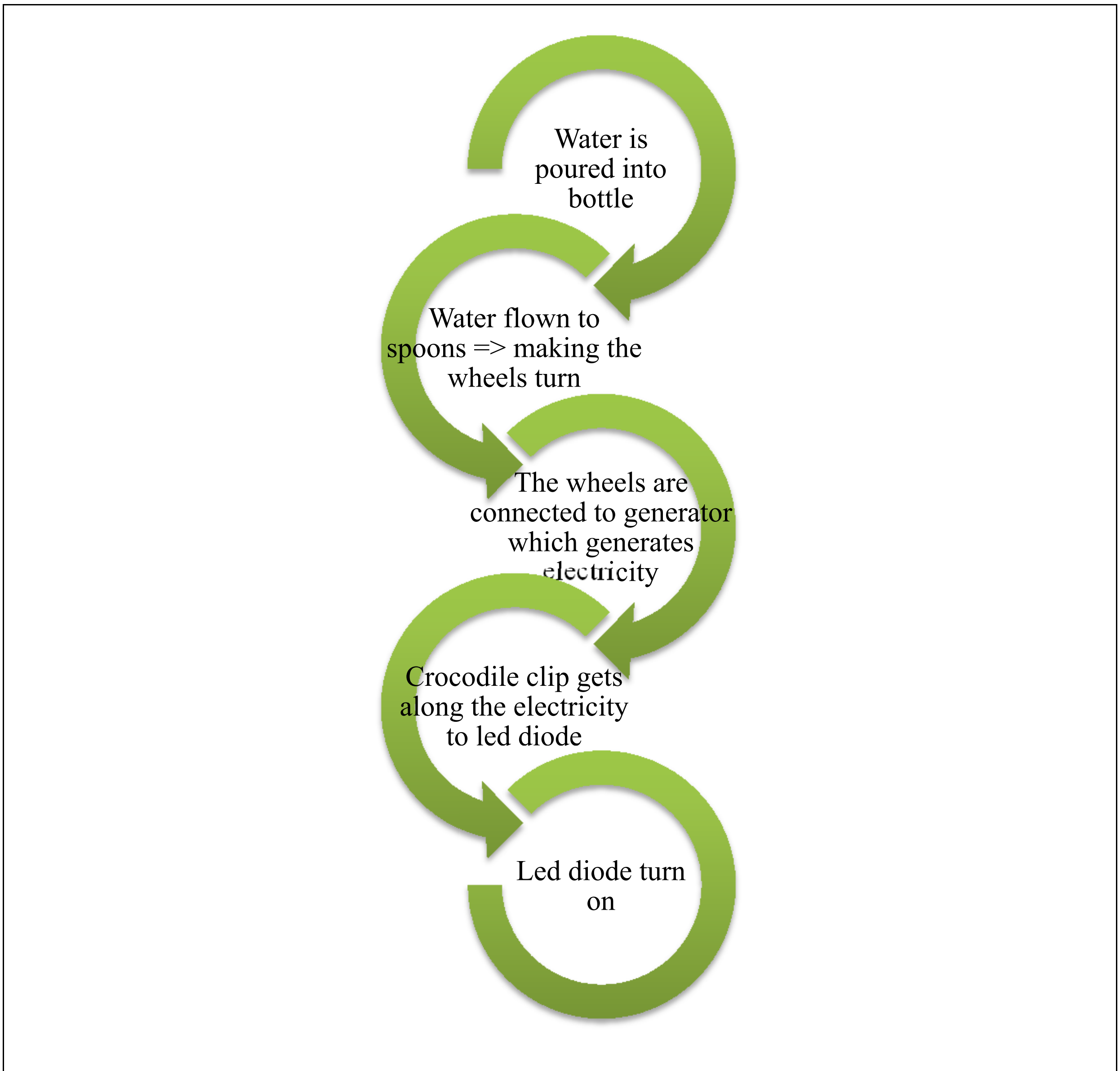


Figure 6.: The description of the process in a few words

1.2.1.3.4. Steps to build the model

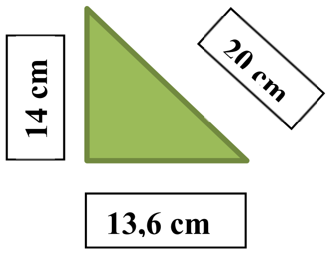
- Firstly, place the plastic crate in the basis and fix the ruler in one side of the plastic crate using superglue.
- Have a one litre plastic bottle halved and punch two holes (the diameter of which is 1 cm) in the middle of it thrust the halved bamboo skewers (which are 5 cm long) into the bottle. Furthermore, thrust it into ruler.

Fix half plastic bottle into ruler. The half plastic bottle incline 45° so the water will flow 45°.

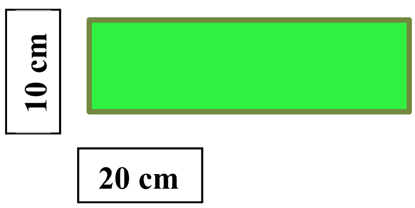
- Cut four circle forms (which are same sizes) from A4 size cartonplast.

The diameter is 14 cm.

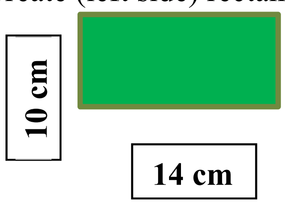
- Carve (or cut) sixteen plastic spoons to sharp form with a knife or a similar appropriate gadget, a pencil sharpener drawing tool can even be used.
- Thrust this plastic spoons into the styrofoam (the form is circular). The styrofoam diameter is 10 cm, therefore thrust the plastic spoons into the styrofoam with a distance of 1,96 cm between them.
- Then if these plastic spoons are fixed in the styrofoam, stick the whole styrofoam circle and the two circle formed cartonplasts together (with superglue).
- Stick another styrofoam circle between the two cartonplasts.
- Drill two holes in the middle of the two circles. The diameter is 1 cm.
- Put the two circles on the cylindrical wooden rod. Place two circles at the two edges of the cylindrical wooden rod. Later fix these two circles with superglue.
- Draw wheel spokes in the outer edge of the two circles. It will be more lifelike.
- Build quadrilaterals from the rest of the cartonplast.
- Firstly, make two right triangles. Their sizes are the same.



- Cut (right side) rectangle.



- Create (left side) rectangle.



- Stick these previous four pieces together with superglue. Then stick this quadrilateral (which is made from cartonplasts) on the basis (styrofoam).
- Put the prepared propellers on this quadrilateral. The small semi-circular piece of metal slab (curved) helps with fixing. Stick this metal slab (with the propeller in it) and the quadrilateral together.

- Put the Lego cubes (four pieces) on the Lego rod and place the two jar rubbers to this Lego rod and one of circles.
- Suit the generator on the end of the Lego rod and we fix it with superglue.
- Put the bigger Lego piece (the sizes of which are: 4 cm length and 2cm width) under the generator. This Lego piece holds generator.
- Stick the Lego rod to the basis (styrofoam) as well as this bigger Lego piece.
- Then connect the crocodile clip to the generator. Another end of the crocodile clip is connected to led diode.
- Make the lamp following these steps: halved straw (length: 5 cm) and lead the crocodile clip (with the led diode) into the straw. Stick this straw on the basis and paint the straw black colour (with tempera paint).
- The small plastic house which is stuck on the basis next to the Lego structure was bought.
- Half another straw, and make the tree from the straw. Firstly, paint the tree brown colour, and paint the table tennis ball green. Stick the green table tennis ball and the brown straw together. Put this element next to the small plastic house.
- Paint the cartonplast pink colour.

1.2.1.3.5. Pedagogical explanation

Pour water from a big plastic bottle (for example: from a 2 litre plastic bottle) to the halved small plastic bottle, and the water will flow to the plastic spoons which will start to turn (initially slowly). Two circles start to turn. As one of the circles is connected to the Lego rod (which is the generator), and the crocodile clip is also connected to the motor which leads the energy to the led diode, the led diode will light while the water is flowing. This is the way of generating electricity from water. [7]

1.2.2. Electric power generation from eolic sources

In this section, the analysis of three models in which eolic energy is transformed into electricity is included.

1.2.2.1. Electric power generation from eolic sources option 1.

1.2.2.1.1. Initial design of the model

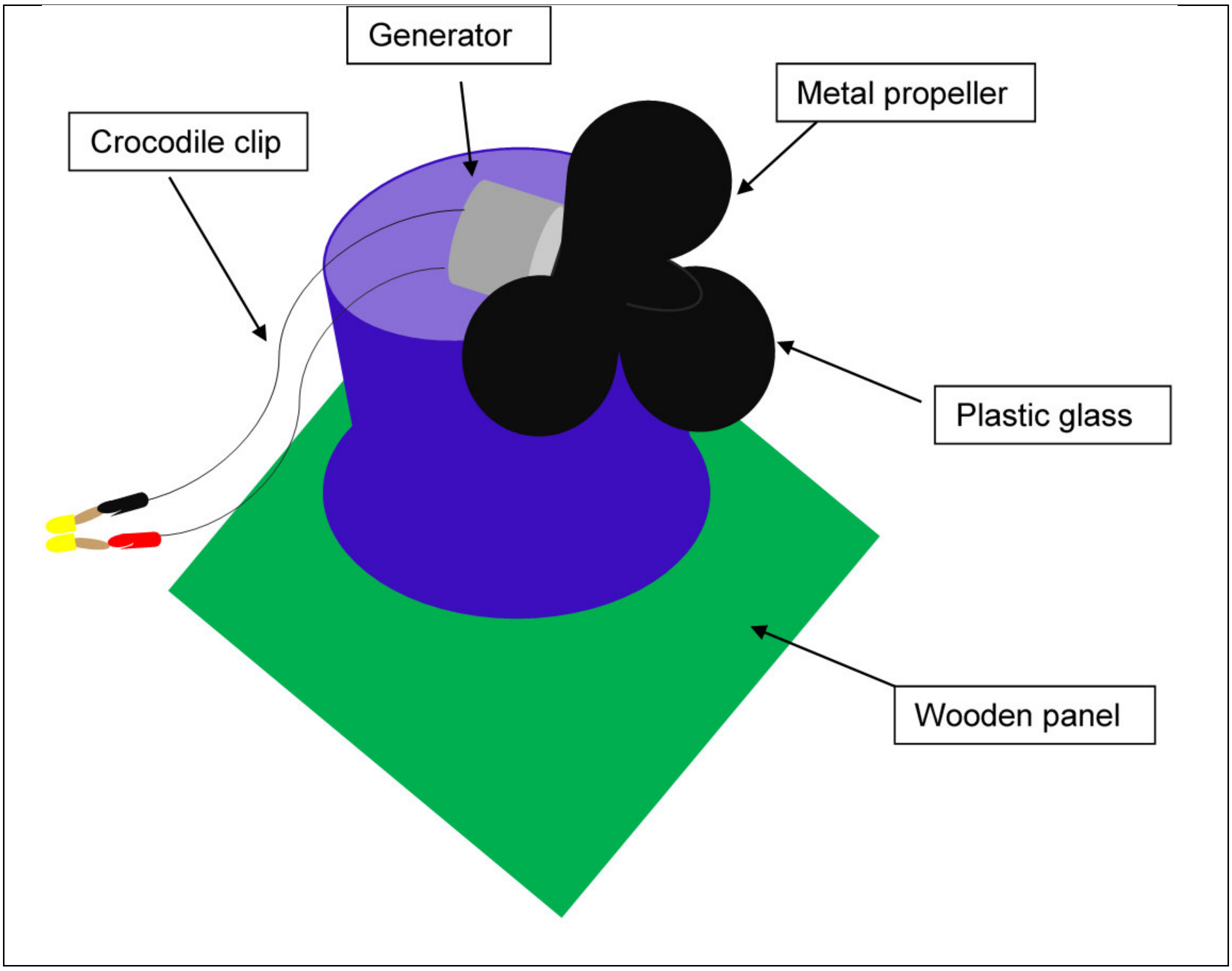
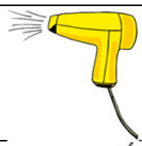


Figure 7. : E 1. Drawing

1.2.2.1.2. List of materials and components

Table 4. : E 1. List of materials

• Basis: wooden panel Cube shape Every side is: 10 cm	
• Generator (motor) Sizes: Diameter: 4 cm Length: 2 cm	
• Two led diodes Sizes: Length: 4 cm	
• Crocodile clip Sizes: Length:15 cm	
• Metal propeller (from a mini size ventilator, this is the turbine) Sizes: Diameter: 10 cm	
• Disposable plastic glass Sizes: Tonnage: 2 dl Length: 98 mm Diameter up/down: 71/45 mm Material: PS Quantum: 2,4g	
• Glue gun	
• Tempera paint (green, blue colour)	
• Hair dryer	
• Soldering	

1.2.2.1.3. Description of the process

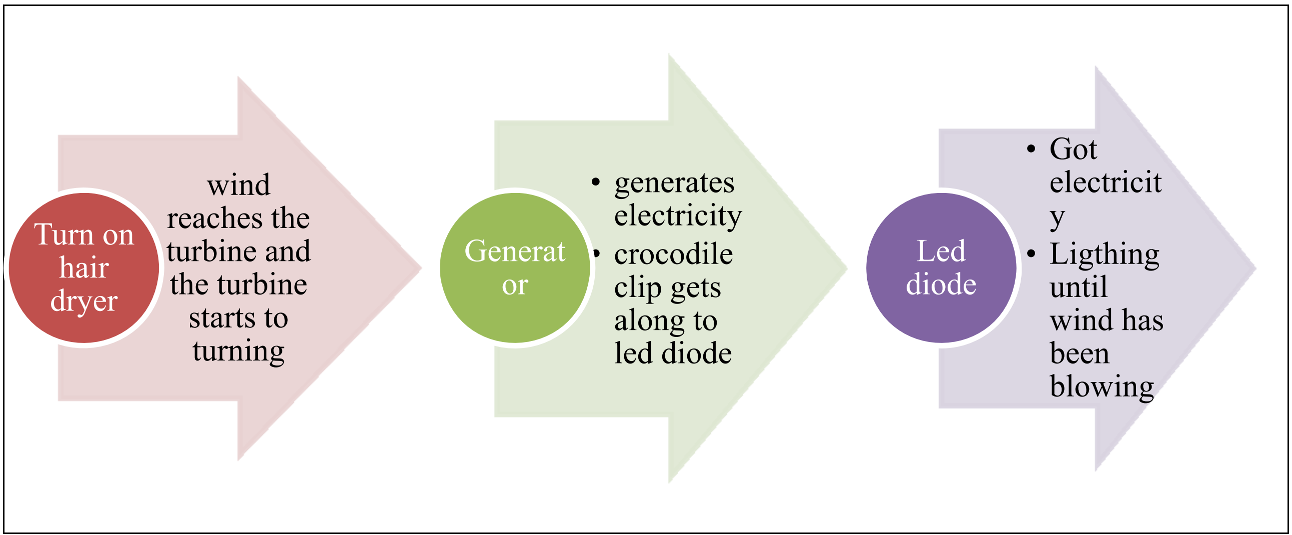


Figure 8.: The description of the process in a few words

1.2.2.1.4. Steps to build the model

- Firstly, stick the side of the disposable plastic glass into the wooden panel (which will be the basis) with the glue gun.
- Secondly, stick the generator to the top of the plastic glass (with glue gun).
- Put the metal propeller (namely, this is the turbine) to the generator and twist together.
- The rotor part of the wind energy model is finished.
- Solder end of crocodile clip (smaller end) into generator (motor).
- Take two led diodes and fix them to the crocodile clip by soldering.
- Paint the wooden panel green and paint the disposable plastic glass blue colour.
- When all previous steps are finished, finally, the hair dryer will be used in front of this structure to activate the system.

1.2.2.1.5. Pedagogical explanation

When the wind reaches the wind turbine (namely propeller), it starts to turn. The generator (which is located in the rotor) also turns together with the turbine. While the generator is turning it creates electricity. When the generator generates electricity, the crocodile clip leads this created electricity to the led diode. Due to that, the led diode starts to light. While the wind turbine is turning the led diode is lighting. [8]

1.2.2.2. Electric power generation from eolic sources option 2.

1.2.2.2.1. Initial design of the model

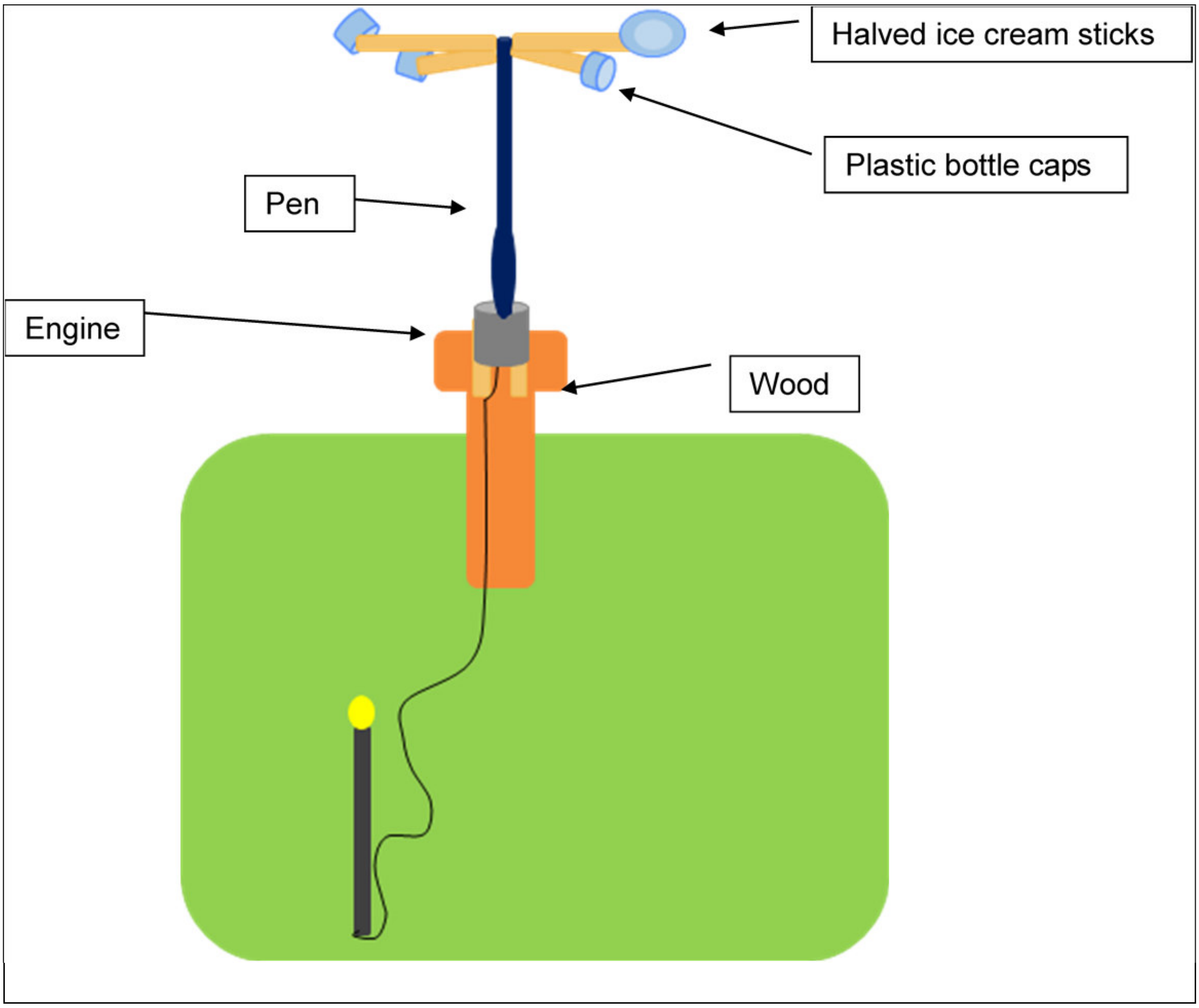


Figure 9. : E 2. Drawing.

1.2.2.2.2. List of materials and components

Table 5. : E 2. List of materials

• Four ice cream sticks	
• Four plastic bottle caps	

• Pen	
• Superglue	
• Wood panel Sizes: Length: 10 cm Width: 5 cm Thickness: 1 cm	
• Wood panel (bigger) Sizes: Length: 25 cm Width: 6 cm Thickness: 1 cm	
• Wood panel (the most biggest, which is the basis) Length: 25 cm Width: 12 cm Thickness: 1 cm	
• Generator	
• Crocodile clip	
• Straw	
• Hair dryer	
• Tempera paint	
• Secateurs	
• Led diode	
• The basis is green paper (A4)	

1.2.2.2.3. Description of the process

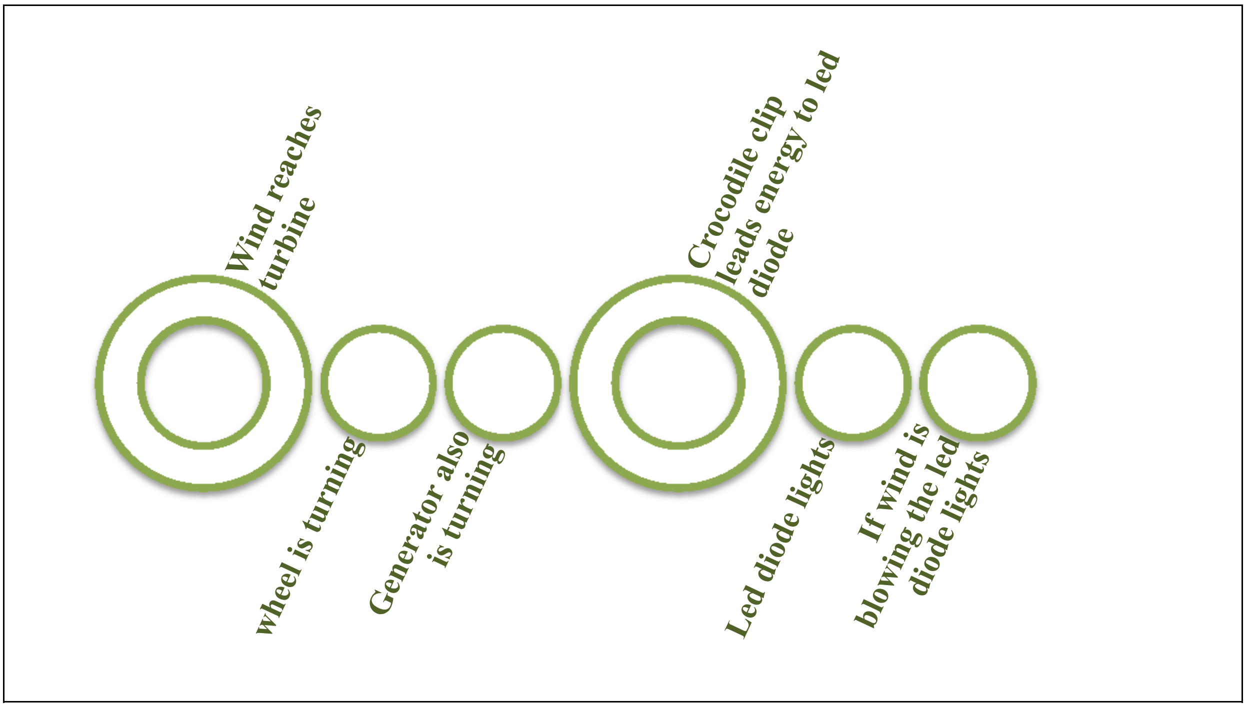


Figure 10.: The description of the process in a few words

1.2.2.2.4. Steps to build the model

- Two ice cream sticks have to be halved by secateurs.
- Stick each ice cream stick to a plastic bottle cap.
- The pen is taken apart.
- Suit the agglutinated ice cream stick to the pen with superglue. The turbine has been made.
- Stick the bigger wood panel to the biggest panel.
- Stick the small wood panel to the top of the bigger wood panel (use superglue)
- Stick two pieces of ice cream stick on the top of the small wood panel.
- The generator is stuck with two pieces of ice cream sticks together, to the small wood panel.
- The crocodile clip is connected to the generator.
- Drill a small hole to one side of the straw (where the crocodile clip is lead).
- Stick the crocodile clip to the wooden panel and stick the straw there.
- Connect the led diode to the crocodile clip. Paint the straw black as lamps (streetlight).
- Suit the propeller into the generator.
- Use a hair dryer.

1.2.2.2.5. Pedagogical explanation

When the hair dryer is turned on, wind is created. When wind reaches the wind turbine (propeller), the wheel starts to turn. The wind turbine will be turned by the wind. The generator is connected to the crocodile clip, which leads created current to the led diode. When the current reaches the led diode, it starts to light. The motor generates electricity. [9]

1.2.2.3. Electric power generation from eolic sources option 3.

1.2.2.3.1. Initial design of the model

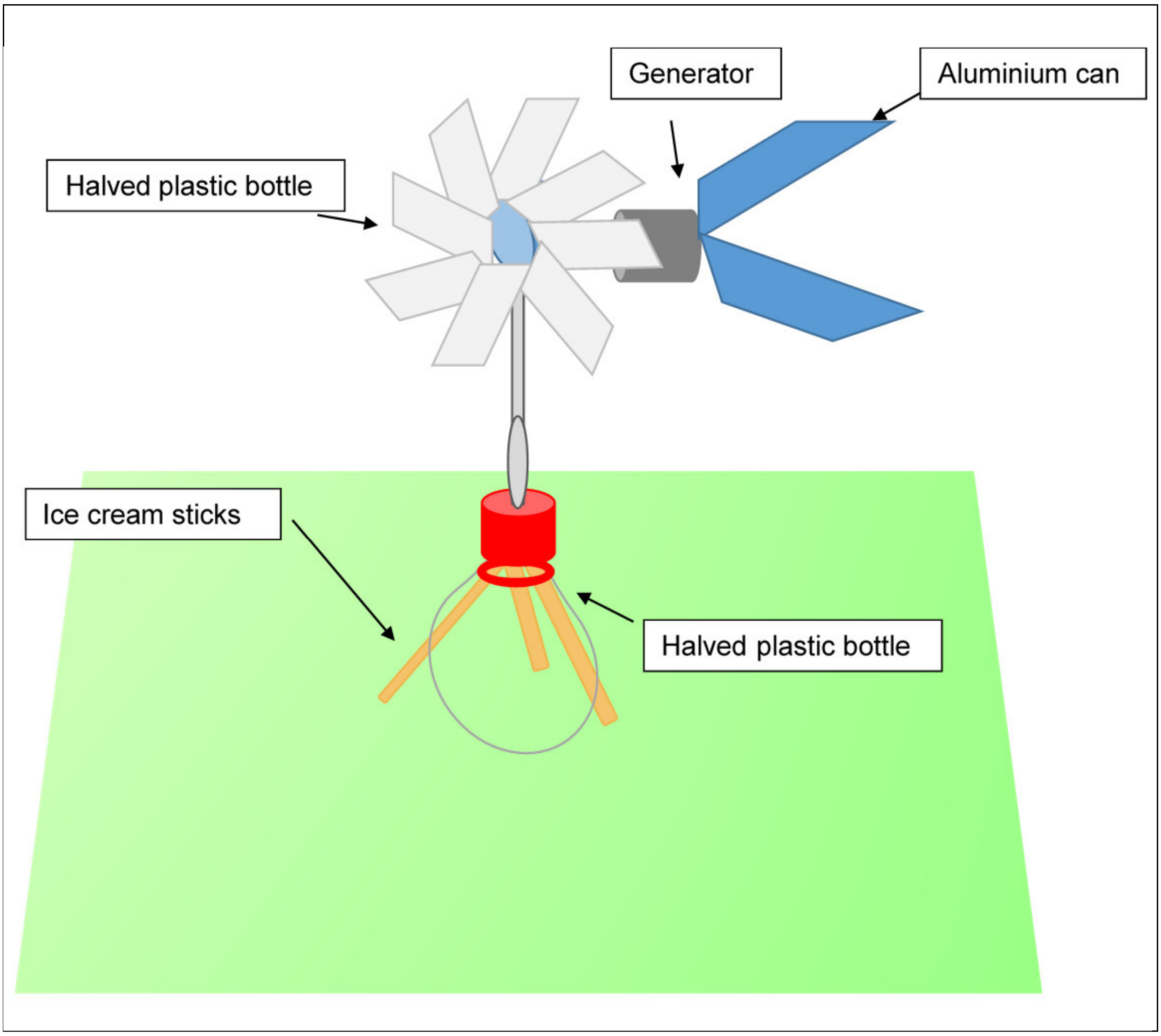


Figure 11. : E 3. Drawing.

1.2.2.3.2. List of materials and components

Table 6. : E 3. List of materials

• Two half litre plastic bottles	
• Two plastic bottle caps	
• Metal wire Sizes: Length: 15 cm Diameter: 1 cm	
• Superglue	
• Sharp knife	
• Scissors	
• Hair dryer	
• Drill	
• Pen (pen refill, grip of pen)	
• Aluminium can	
• Generator	
• Crocodile clip	
• Wood panel Sizes: Length: 25 cm Width: 20 cm Thickness: 3 cm	
• Led diode	
• Two ice cream sticks	

1.2.2.3.3. Description of the process

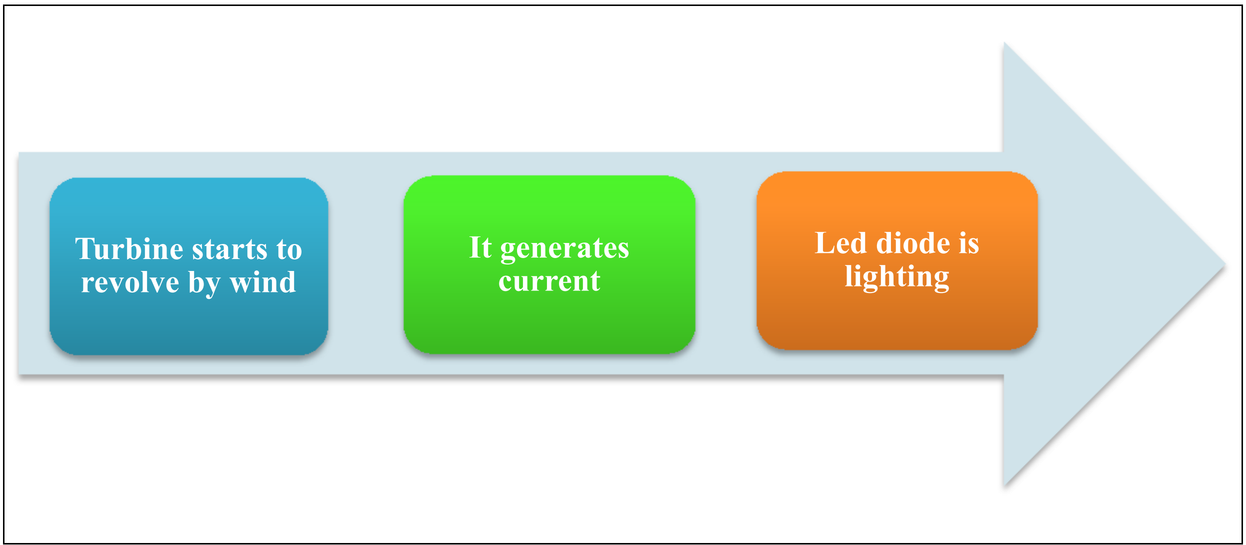


Figure 12.: The description of the process in a few words

1.2.2.3.4. Steps to build the model

- Cut the half litre plastic bottle in smaller pieces (with the sharp knife).
- Cut the small half litre plastic bottle in eight pieces. It will be a mini propeller (with appropriate scissors).
- Drill a hole in the middle of the plastic bottle cap with the drill (diameter is 0,5 cm).
- Fix the metal wire in the middle of the plastic bottle cap with superglue.
- The pen is taken apart.
- The pen refill is halved by scissors.
- Drill a hole in the grip of the pen.
- The pen refill is transfixed in the grip of the pen.
- The previous structure is suited in the pen.
- The metal wire (with the plastic bottle propeller) is inserted through the grip of the pen (where the hole was drilled).
- Crook the metal wire. The goal is to fix this structure together. When it is fixed, cut the unnecessary parts.
- Cut both ends of the aluminium can with the knife.
- The aluminium can is crooked to the flat form.
- Drill a hole in the middle of the aluminium can.
- Cut small parts from the aluminium can.
- Fix the generator in the turbine (using superglue).
- Fix the aluminium can in the generator wire with superglue.
- Fix the crocodile clip to the generator and connect it to the led diode with superglue.
- Another half litre plastic bottle is halved.

- Two ice cream sticks are halved. Stick three halved ice cream sticks with the halved plastic bottle.
- A hole is drilled in the middle of the plastic bottle cap (diameter is 2 cm).
- The pen is suited in the middle of the plastic bottle cap (with superglue) and screw it the in plastic glass.
- This structure is fixed in the wooden panel with superglue.

1.2.2.3.5. Pedagogical explanation

Wind causes the turbine to turn, while the hair dryer is working. When this propeller is turning, the generator helps to generate electricity. As there is a crocodile clip connected to this motor, therefore, the crocodile clip leads the created energy (current) to the led diode, and due to that, the led diode lights.[10]

1.2.3. Electric power generation from photovoltaic sources

This part of the case study deals with three options of photovoltaic energy transformed into electric energy.

1.2.3.1. Electric power generation from photovoltaic sources option 1.

1.2.3.1.1. Initial design of the model

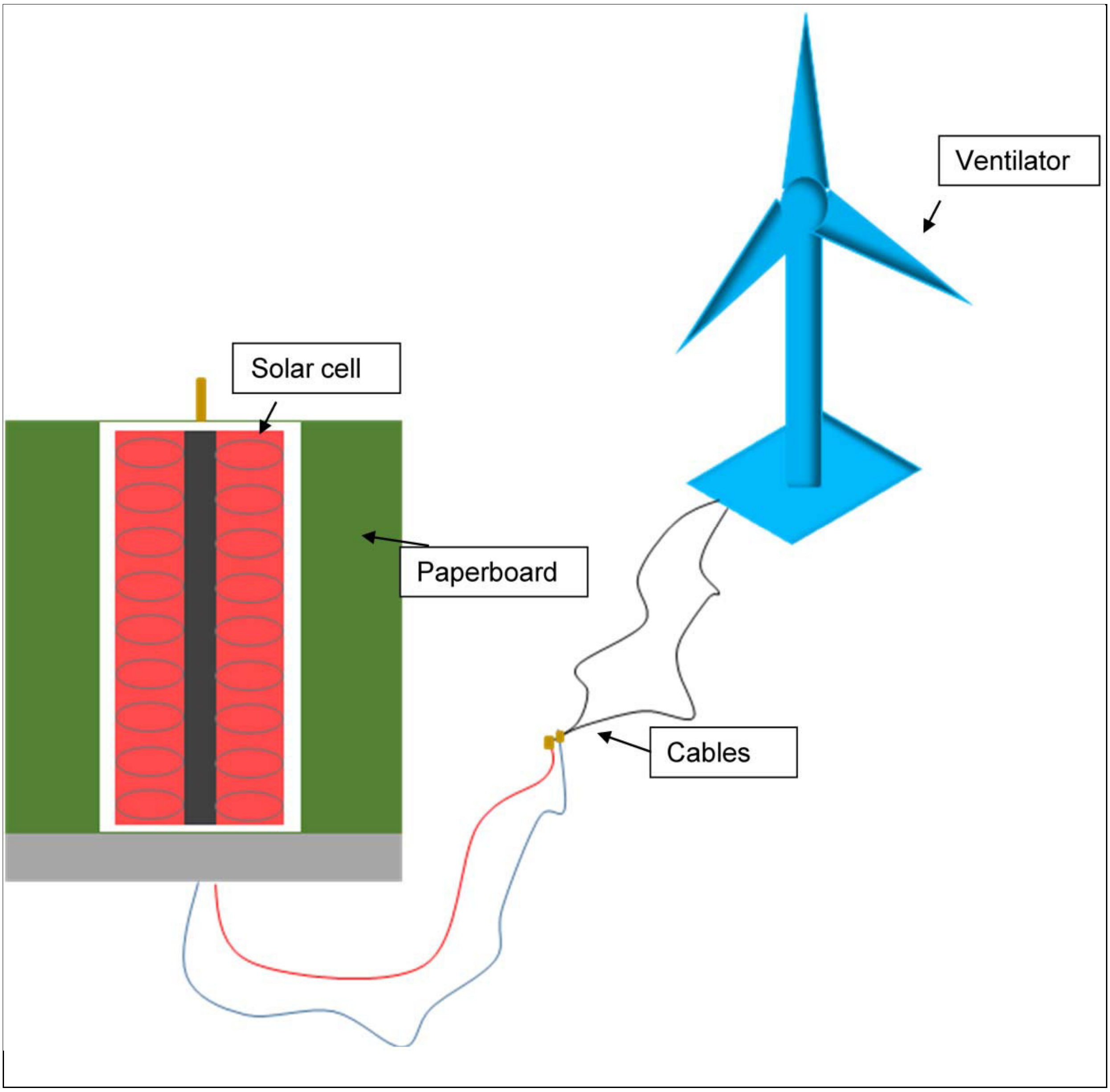
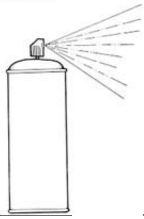


Figure 13. : P 1. Drawing.

1.2.3.1.2. List of materials and components

Table 7. : P 1. List of materials

• Flat paper pizza box (paperboard, lid of a box) Sizes: 16x16cm	
• Aluminium foil	
• Thin aluminium wire	
• Two electrical cables	
• Small duct tape (scotch tape isolated, insulating tape)	
• Superglue	
• Scissors	
• Small solar panel (bought from eBay) Sizes: Length: 17 cm Width: 6 cm	
• Ventilator Size: Height: 22 cm	
• Battery	
• Four toothpicks	
• Toothpaste	
• Copper sulphate	
• Saline solution (water with salt)	

• Lemon juice	
• Steel shavings	
• Synthetic enamel (coloring spray)	
• Small brush	

1.2.3.1.3. Description of the process

Figure 14.: The description of the process in a few words

1.2.3.1.4. Steps to build the model

- Firstly, cut the appropriate size (17x17cm) from the aluminium foil and create two pieces of little cubes form the part which is longer than the original size.
- Stick the aluminium foil to the paper pizza box (paperboard) with duct tape.
- The two toothpicks are located at the opposite side of the rectangle form paper board (which is just simple pizza box).

- One of the toothpicks is located in the middle of the side of the paper board and another piece of toothpicks is located at the other side of the paperboard, and the edge of this side.
- Cut the aluminium foil with scissors.
- Two toothpicks are suited under the two pieces of small aluminium foil.
- Then the toothpicks are fixed to the aluminium foil pieces using insulating tape.

- Use synthetic enamel (coloring spray) in the middle of the aluminium foil (in rectangle form). This is red colour.
- The solar panel is fixed in the paper board.
- The next step is the proper leading of the cables.
- Two cables are connected into the two ends of the cable of the solar panel.
- The two cables are fixed with insulating tape.
- Toothpaste is mixed with saline solution in one glass.
- The solar panel is painted with the earlier created solution using a small brush.
- The aluminium foil is painted green colour using a small brush.
- The previous wet surface is sprinkled thoroughly with some steel shavings.
- The ventilator put on the table.
- The full charged battery is suited to the two ends of the cables of the ventilator.
- When it is put to the ventilator cables, the ventilator turns because of the current.
- The battery is put aside next to this ventilator.
- The ventilator cables are connected to the two cables of the solar panel.

1.2.3.1.5. Pedagogical explanation

Use this photovoltaic model (solar panel cells) if the Sun has been shining but just exclusively in this case. The solar cell is like sandwich. It has a negative and a positive part. The negative side is blue and the positive side is red. When sunshine reaches the top of the small solar panel, the solar panel produces energy from the Sun rays. This energy is led by the cables (which are connected to this small solar panel). The other end of the cables are connected to the small ventilator. These cables get along the energy to the ventilator. So energy is created. The turbine of the ventilator works (it is turning) while the sun shines, so the ventilator got current. [11]

1.2.3.2. Electric power generation from photovoltaic sources option 2.

1.2.3.2.1. Initial design of the model

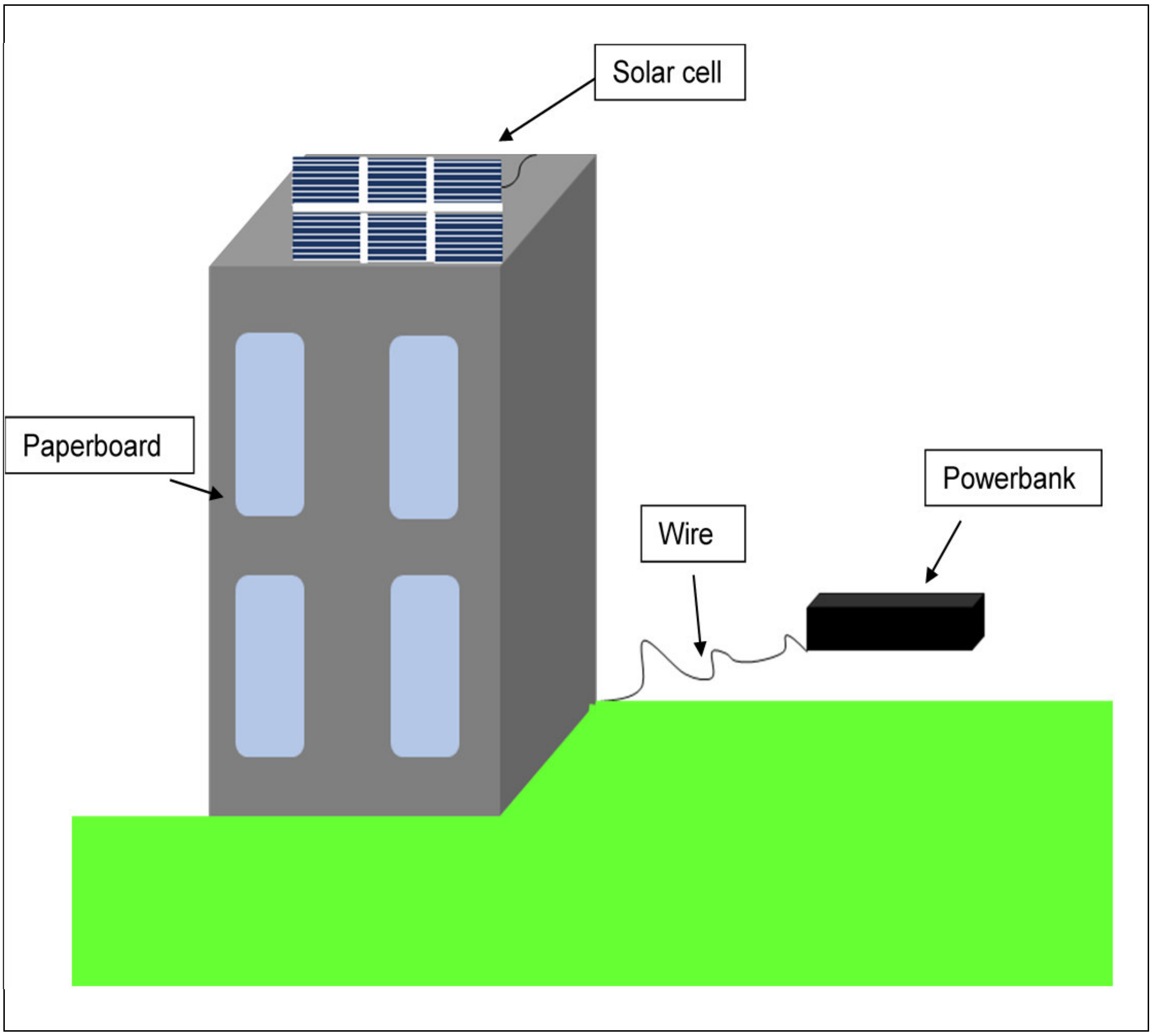


Figure 15. : P 2. Drawing.

1.2.3.2.2. List of materials and components

Table 8.: P 2. List of materials

• Multi-meter	
• Transparent nail polish	
• Old phone charger	
• Wire Sizes: Length: around 1 meter	
• Two component glue	
• Ten small solar cells (bought from eBay)	
• Two plastic pieces	
• Soldering	
• Paper box Sizes: Width: 10 cm Length: 20 cm	
• Superglue	
• Colourful papers	
• Tempera	
• Power bank	

1.2.3.2.3. Description of the process

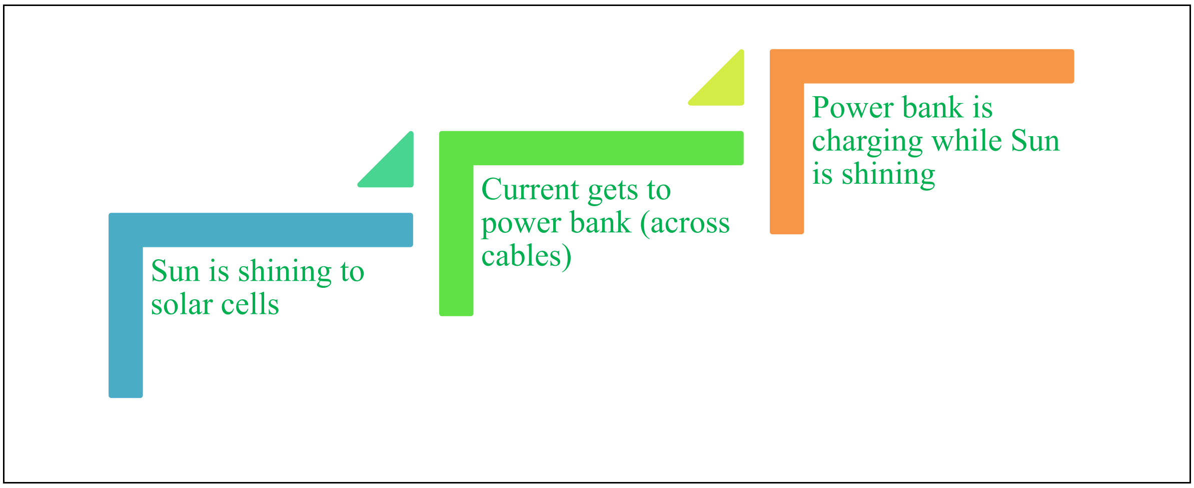


Figure 16.: The description of the process in a few words

1.2.3.2.4. Steps to build the model

- Firstly, the solar cells are covered by transparent nail polish.
- This is really the cheapest method.
- This material helps to protect small solar cells from the corrosion of the batteries due to the Sun.
- Solder the negative and the positive wires at the two ends of the solar cells using soldering.
- The two component glue is mixed, and a small amount of glue is placed on each solar cell. As these solar cells are very fragile, do this step carefully.
- Put the solar cells between the two plastic pieces.
- Press very gently to connect the glue with the two pieces of plastic.
- The cable (from the old phone charger) is put on the solar panel.
- This cable is connected to the power bank, so the power bank is charged directly.
- The last step is to fix the structure to the top of the paper box using superglue.
- The paper box is a small size storey house.
- The paper box is painted grey colour.
- Cut little cubes from the colourful papers.
- These will be the windows on the storey house which will be blue colour.
- The grass can be built by using green paper.

1.2.3.2.5. Pedagogical explanation

As solar cells are similar to a simple sandwich, therefore the solar cells have two types. It has negative type silicon (the colour of which is blue) and also has positive type silicon (whose part is red).
When sunlight reaches the top of the solar cells. Firstly, photons carry the created energy, then photons give this energy to the electrons. The electrons use this energy to get to the negative-type layer, furthermore, electrons escape out into the circuit. Flowing around the circuit, the electrons charge the power bank. [12]

1.2.3.3. Electric power generation from photovoltaic sources option 3.

1.2.3.3.1. Initial design of the model

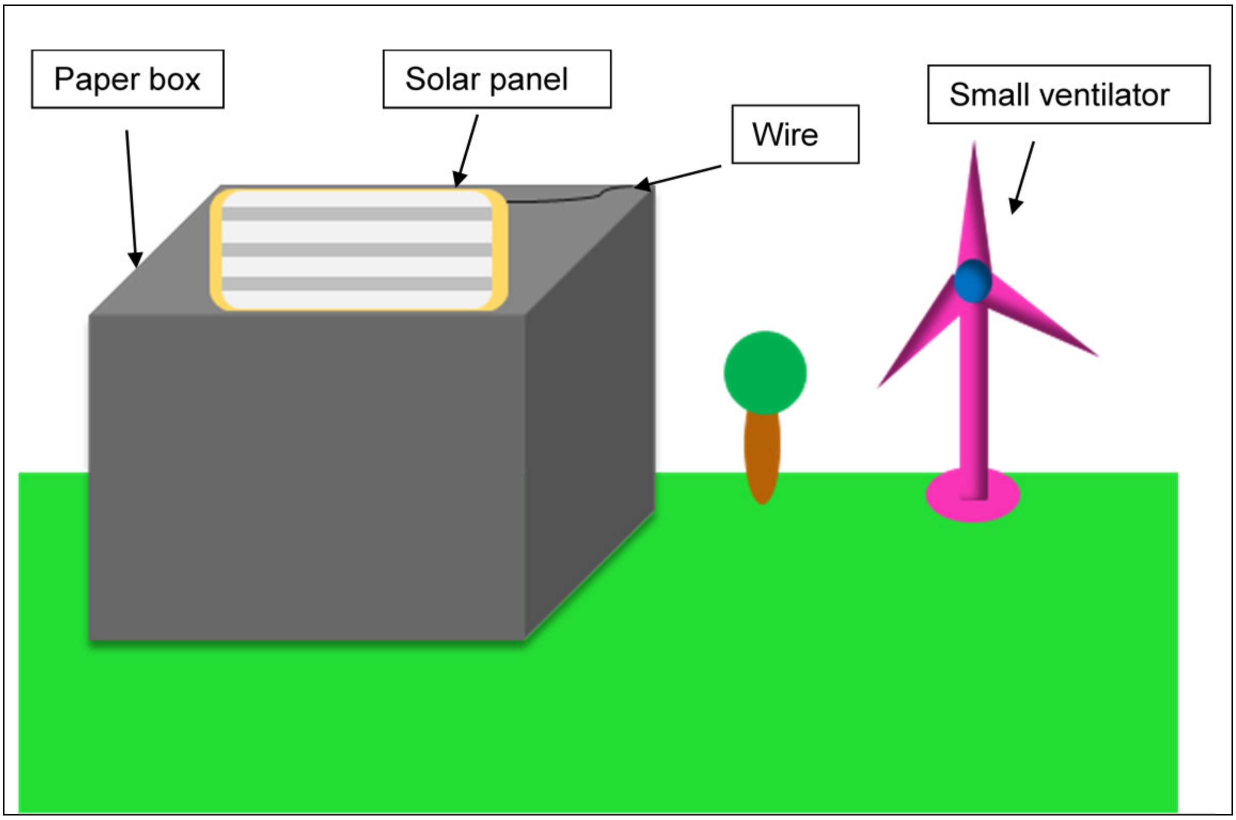


Figure 17. : P 3. Drawing.

1.2.3.3.2. List of materials and components

Table 9. : P 3. List of materials

• Tabbing wire
• Set of gloves
• Solar cell
• Masking tape
• Dab of solder
• Flux
• Two cables
• Small size ventilator Size: Height: 10 cm
• Colourful papers
• Soldering
• Ice cream stick
• Ping pong ball
• Tempera
• Superglue
• Paperboard Sizes: Length: 15 cm Width: 15 cm

1.2.3.3.3. Description of the process

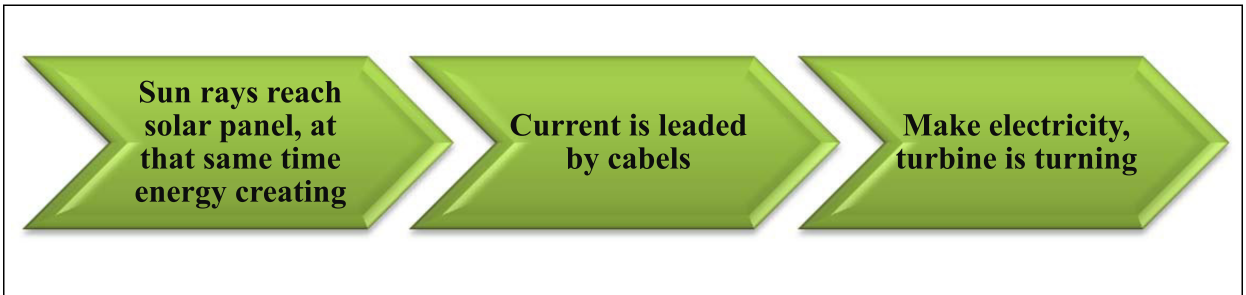


Figure 18.: The description of the process in a few words

1.2.3.3.4. Steps to build the model

- In order to pre tab each of the twelve cells, you need to cut eighteen ten inch pieces of tabbing wire and six five and a quarter inch pieces.
- Then enroll the tabbing wire from the spool.
- Have a pair of gloves before soldering these pieces of tabbing wire to the cell straighten each piece out with your thumb.
- It will make the job easier when you start to solder.
- Use set of gloves to prevent unwanted fingerprints on the solar panel.
- Solar cells are extremely fragile, therefore, making solar cells is a very careful and slow process.
- The best way to remove them from their stack is to pick them up from their paper.
- Place them near the edge of the table.
- The solar cell is placed on the workbench.
- The workbench is one of the square pieces of wood that protects the cells during shipment (carrying).
- The cell is fixed on the workbench.
- It will not slide around during the pre tabbing process.
- The masking tape is used very carefully so that it would be removable easily, about ten millimeters from the edge of the solar cell.
- It is placed perpendicular to the two traces. Solder the tabbing wire.
- Pre tabbing has been finished.
- Apply a couple of coats of flux to the traces on the cell.
- Take one of the ten inch pieces of tabbing wire and it is placed about an eighth of an inch from the edge of the cell.
- Apply a little dab of solder and hold it in place.
- Flux is used on the top of the tabbing wire before soldering it.
- Place about three eighths of an inch of solder on soldering iron.
- Spread the solder right on the top of the tabbing wire carefully and gently.
- The solder spread about halfway down the cell.
- Apply another three eighths of an inch of solder and spread it down the other half.
- Make sure there are no bumps or excess build up of solder.
- Repeat this process for the bottom trace: place a dab of solder to hold the tabbing wire in place, and more flux to the top of the wire.
- Carefully spread 3/8” of solder along the top of the tabbing wire, then, stop halfway and repeat.
- Then smooth out any excess build up of solder.
- Two pieces of cable is connected to this solar panel using soldering.
- The cables also are connected to the ventilator.
- Making the environment: Tree is created: the ice cream stick was stuck with the ping pong ball.

- The ping pong ball is painted the green and the ice cream stick is painted brown using tempera.
- The paper board is like a flat.
- The paper board is painted grey using tempera.
- Paint the ventilator pink colour.
- The A4 size green colour paper is suited in place.

1.2.3.3.5. Pedagogical explanation

Sunlight reaches the solar cells. Inside a solar cell, there are two wafer-thin layers of silicon crystal like a sandwich. When sunlight hits the top silicon layer, it ‘excites’ the electrons and gives them enough energy to move. The electrons begin to flow from the top layer to the bottom. The cables which are connected to the solar cells and the cables of the ventilator help to lead energy to the ventilator. Photovoltaic solar cell generates DC (direct current).[13]

1.3. Description of three new models

1.3.1. Description of the hydraulic model

In this section some explanations will be introduced. It might save money if instead of the sixteen disposable plastic spoons just twelve plastic spoons are applied. The appliance of sixteen plastic spoons is unnecessary because twelve plastic spoons is enough to work the hydraulic model. The ruler, the cartonplasts and the plastic crate is not necessary therefore these materials are negligible as it can be seen at the third hydraulic model's case. Instead of bicycle spoke we can use wooden rod. It is better to avoid the use of cartonplast or a very big size wood.

I would choose a plastic piece instead of green colour paper, because it is a harder material than simple paper.

This solution is of very low price. The materials are easily available. Only the wooden rod and the two plastic rods may cause a little problem but this price is very low. So it is possible to obtain easily.

We do not have to think about how we can obtain the appropriate materials, because we can collect them from children who do not have to pay for these materials.

1.3.2. Description of the eolic model

The metal propeller is very high-priced therefore we need to avoid this device. The metal propeller is not such a material which would be easy to access. Instead of this device, it is better idea to use a CD as a propeller. Of course it is needed to cut the CD into three pieces. This is a very cheap way to build a propeller. However, the second and third eolic model propeller is very inexpensive too.

Everybody has scissors, therefore if kids can bring them to the workplace, it is the best way. So this way it is not necessary to buy scissors.

It is needles to buy disposable plastic glass because if somebody does not need this he/she can bring it to the workplace.

1.3.3. Description of the photovoltaic model

In this case this model also has a reasonable price. We can buy the small solar panel from eBay. The price only 1 euro. So this is very cheap.

It is better to apply a small size paperbox instead of a big size one (for example in case of the second photovoltaic model). If tempera is used to paint the paperboard grey, it looks pretty good to children.

1.4. Impact of the project on the rural development

The future generations would get awareness of renewable energy technologies.

The renewable energy education and training of renewable energy technologies is useful because it will give enough knowledge to kids. Teach kids to protect the environment, and they will use these energies instead of fossil fuels (for example: natural gas and oil etc.)

In these few paragraphs the antecedents of the impacts of the use of renewable energy technologies on rural development are introduced. The potential of renewable energy technologies to power rural development has been understood for many decades. Nevertheless, it is lately that huge efforts have been made to mobilize the resources to accomplish this potential and there is still a long way to proceed.

In September 2000, it was the first time that there was a connection between clean sources of energy and rural energy access. This connection was expressly prepared in the form of the United Nations General Assembly. This general assembly has obligation to a global companionship to reach a series of goals and targets, known as the Millennium Development Goals (MDGs), by the year 2015.

Reducing rural poorness through rural development is very essential to achieving these goals, furthermore, confirming this is the need for expanding the availability of new and modern energy services.

Modern energy services have a lot of advantages, they have benefits such as mechanical power, natural gas, electricity, clean cooking fuels, which consent to human prosperity. One of the goal is ensuring environmental sustainability which really promotes renewable energy technologies. The Millennium Development Goals, expressly remarks the relevance of modern energy services for rural development.

Some affordable environmental interferences have advantages and benefits, for example the use of an improved stove with traditional fuels. This able to decrease acute respiratory infection by 25 per cent among young kids and babies.

As reffered by Rietbergen J. and Hadjemian N. [2]:

"Movement up the energy ladder can occur within various aspects of rural life: agriculture, household cooking, household lighting, heating. It seems logical to assume that increased access to modern energy services (moving up the energy ladder) can catalyse rural development (measured in increased income). In fact, there is a co-dependent relationship: access to modern energy services can increase incomes (if used productively) and an increase in income can make modern energy services more affordable."

The decentralized nature of some renewable energy technologies allows them to be corresponded with the specific needs of different rural areas.

The opportunity of the acceptance of renewable energy technologies is essential for the success of traditional national grid-based rural electrification programmes. It is very important to reach small rural areas, communities in developing countries.

If the people would apply the cleaner use of traditional fuels in rural areas, it would be better because these use of fuels has positive impact to health. As these fuels improve health, for example they reduce acute respiratory infection and conjunctivitis, generally caused by indoor pollution. As these fuels do not pollute, therefore they have a good impact in rural areas.

The required time to household activities can be reduce with access to electricity.

Improved education to children and health to people who live in rural areas, combined with more time to undertake non-energy related activities, are important goals in themselves.

It is cited from Rietbergen J. and Hadjemian N.'s book [2]:

"However, access to modern energy services also have the added value of helping local populations to engage in income-generating activities. Demand for services associated with RETs can help generate local economic activity based on these technologies, in addition to the means to power local industry."[2]

1.4.1. Environmental impact

Children learn about renewable energy technologies and renewable energy sources, including their works and building of renewable energy desktop models. Fortunately, it has positive impacts to the environment, as they will obtain and have enough knowledge about types of the renewable energy. They will apply this knowledge in their job in the future.

As kids will be able to build these models in real, they will cause a lot of positive impact to the world. The use of the renewable energies is an opportunity for the future, therefore it has a lot of good impacts. These are clean energies therefore they do not pollute the environment as they do not emit toxic gases.

If the future generations apply more renewable energy technologies, it will have positive impact on our world. They create energy and so on.

It is invoked from Rietbergen J. and Hadjemian N.'s book [2]:

"Applications of renewable energy technologies for productive activities vary from mechanical wind-powered water pumping to motorized milling machines for grinding grain. Radio services can provide farmers and fishermen with weather forecasts and telecommunication services can provide growers with information on crop prices (World Bank, 2004b). As noted by Steger (2005: 213), these applications can lead to job creation and improved livelihoods, both of which can contribute to significant increases in productivity in rural areas."

In fact, the network extension is not the most cost-effective means of expanding access to rural areas. It is the specific of rural areas that the population density is extremely low. Unfortunately, it has greater technical losses too, because these transmission networks frequently increase.

By contrast, off-grid systems served by renewable energy technologies can be the best opportunity.

1.4.2. Social and rural impact

Kids and women mostly will have more time for education, leisure and economic activity which is also positive impact.

Fortunately, it has other wider health benefits which can occur too. If they used more efficient technologies food and water accessibility would improve.

The domestic use of renewable energy technologies has really big impact on livelihoods in rural areas. Furthermore, the greater access to energy for domestic use also has remarkable impact on rural communities.

Clean water is provided by the application of electric water pumps, which also helps to decrease a lot of efforts (which are needed) for collection.

It is also a social impact that in rural health clinics and hospitals, the operation of medical equipment and the refrigeration of vaccines could be achieved by renewable energy sources.

If television and radio would be available for rural people it can cause improvement in the field of education and entertainment (which is also very important to every people, mainly children).

It would be better if the people who live in rural areas applied electric lighting. Electric lighting is better than old kerosene lanterns. The electric lighting provides more light than old lamps. The people could work more easily if they use these lamps. It would offer good options, for example safety, better security, comfort and more study time. The more study time means that they could learn easily for example at night. [2]

Social capital's goal is to understand the role of a school in the community.

Providing education to all civilians is the main goal of the Finnish basic education. The geographic residence or socioeconomic background does not matter in this viewpoint.

As we can read in a book which was written by Autti O. and Hyry-Beihammer E. K. [4]: "Rural schools (in this article also village schools) have formed a meaningful part of this effort to ensure educational equality, providing good basic education possibilities in sparsely populated rural areas. These schools have also been the heart of their villages' social life."

Unfortunately, many rural schools were closed by the government in rural areas.

In the late 1960s a lot of small schools were closed. The reason for closing them was the decline of birth rates.

The closures of the small rural schools was experienced in a lot of places, for example: mainly it was experienced in Finland, furthermore, in the United Kingdom and Scandinavian countries.

Fortunately, at the end of the 1970s the situation became better related to small rural schools, when the current comprehensive school system was founded and educational equality was meant to ensure equal educational opportunities for all citizens (Kalaoja & Pietarinen, 2009).

Every student can get appropriate education that corresponded to his or her prerequisites and expectations. [4]

I will cite from Autti O. and Hyry-Beihammer E. K. 's book [4]: "The Finnish state ended additional funding for small schools in 2006, which led in turn to municipalities' closing local schools to solve financial problems. The effects were visible in the 2006 figures for school closures: A record 186 schools were reported closed (Official Statistics of Finland, 2007)"

1.4.3. Pedagogical Guide

In the following pages a pedagogical guide is going to be presented in the topic of how to use the three mock-ups in our teaching method, what is the pedagogical goal of each renewable energy class and some didactic tips and tricks are listed in this chapter.

The concrete construction steps of mock-ups are presented in 2.2 Construction guide chapter.

The subchapters follow the same structure in order to facilitate the work of teachers, youth workers and instructors.

1.4.3.1. Domestic Water Heater Mock-up

Goal of the class

Firstly, the workshop aims to let the participants experiencing the heating power of the Sun. Moreover; the goal is to gain a deeper understanding of domestic hot water producing system. Last but not least, it is important to understand the dependence of humanity on energy sources, as well as the unpredictability of renewable energy sources.

As an output, a mock-up of homemade water heating system (Figures 14) will be produced by groups of the participants.

Pedagogical goal

The pedagogical goal is double. Once, deepening the knowledge on hot water producing systems, second is improving the manual skills and chic of participants through tinkering and working with do-it-yourself crafts.

Keywords

#Thermosiphon, #Domestic hot water, #Water heating, #DIY craft

Age

The suggested age of students is 9-12 years. With more scientific explanation and more individual (craft)work, older students can enjoy the class also.

Group (number of participants)

The ideal is forming groups of 3-6 students, or as much as can work comfortably around one table.

Time

Duration of the class: 2h
Preparation time: 2h
Results in (time): 1.5-5h

Location, classroom requirements

Craftworks are preferably done in classroom or in equipped workshop. To test the thermosiphon mock-up in real life conditions, direct sunshine is needed. Thus, if does not enter enough sunshine into the classroom, it is recommended to place the ready mock-ups outside and adjust the inclination hourly in order to make the thermosiphon system facing directly to the Sun.

Concrete goal of the class

We are aiming to build a mock-up of a domestic water heater system, made of recycled materials, materials from the household and some basic materials collected from specific stores.

Working mechanisms of the real life cases:

Domestic water heater systems are usually placed on the roof of houses or other buildings, facing to the South. They collect the sunbeams, the glasshouse effect multiplies its heating power, the water temperature is increasing, warmer water is lifted up and that starts the circulation in the whole system. After a few hours the water tank is accumulating more and more hot water, less and less cold water, thus the average temperature is increasing.We are going to make a model working on the same thermosiphon mechanism (see Figure 14).

There are three main parts of the model.

- Box

The box serves to encase the tubes filled with water and to collect and accumulate the heat. For this reason it is isolated from five sides, has a layer of aluminium in order to reflect the rays of the Sun and is covered by plastic glassware (or polymethyl methacrylate) favouring the greenhouse effect inside the box, thus allowing to reach the highest temperature possible. Inside the box the tubes are interconnected and the two main thick tubes have two outputs: one where the colder water enters on the bottom of the box, and one where the warmer water exits, close to the top of the box. Between the two, many thin tubes ensure the connection.

- Tubes

There are two types of tubes: a thin one (type 1) and a thick one (type 2). The thin tubes serve to distribute the best possible the water and ensure big surface for heat catching. The thermosiphon effect raises the hot water through these thin tubes. The thick tubes connect the thin tubes and the container on two ways: from the bottom part of the container to the bottom part of the box brings the colder water, from the upper side of the box to the upper side of the container brings the warm water.

- Container

The container serves to store the water. It is suggested to isolate well with foam rubber or even better with multilayer insulation. Serious temperature differences can be detected after some hours compared to the initial temperatures (and also between the upper layer of water and the layer at lower level inside the container). It is the result of the thermosiphon effect, in real life cases it happens the same way. On the top, the container should be covered with a removable tap in order to avoid heat losses and staying able to measure temperature throughout the experiment. Be careful by touching the water! The temperature can increase until 60°C. It has to be mentioned that it is the usual temperature of (electric) boilers.

Preparation before the class

- Buy the specific material and collect the rest from your household
- Check the tools (availability, status, condition)
- Suggested: prepare your own thermosiphon system before the class in order to have your own experience on the topic
- Check tips and tricks
- Optional: if you have the opportunity to introduce the topic on the previous class, you can give some handouts or suggest some videos or links to the students to be observed; favouring this way that they come prepared to the class.

Lesson Plan

- Arrange the workshop or classroom. Distribute materials, tools and handouts if any
- Start the class
  - Introduce the topic starting from global problems and highlighting the importance of nature awareness and renewable energies. You can use interactive methods, like brainstorming or mind mapping to reveal the existing knowledge of students.
  - Provide the students with accident prevention instructions. Depending on their age and abilities you may prepare some material for them (for instance if they are not prepared to use a drill, drill the holes on their material before).

- Environmental background
  - You might start with listing the different impacts, how the Sun influence our life (light, heat) and its' consequences (sunburnt skin, drying, discolouring clothes, etc.)
  - You may bring other examples or experiments to prove the power of the Sun
  - Turn to the topic of renewable energy usage of Sun. The two most common ways are:

  - Producing electricity with the help of photovoltaic panels
  - Heating domestic water up
- Tell your students, that they are going to see how the heating power of Sun can be multiplied and used for heating water up.

• Start constructing the pilot model (see *2.2 Construction guide* steps)
- There is a possibility to arrive to the class with two teacher's models:
  - One that is readily built up, this one we can put under the Sun at the beginning of the class. Note the temperature of the water in the container, the ambient air temperature and the time. During the class check it, note down the measured temperatures and adjust the inclination hourly.
  - The other teacher model would be in particles to make easier the explanation towards the class.
- You might show first to students your ready model in order to let them know how the result should be by the end of the workshop
- Dismount your model or take your second teacher's model
- Go step-by-step, show them the first steps at your desk and tell them to replicate it on their own models in groups. Raise their attention to the importance of cooperation and task sharing inside the group (and on class level too).
- Go around the tables and observe students' work. In case of need of help, give them a hand and encourage them to solve some of the challenges individually.
- When one section is done, go with the next steps of the *2.2 Construction guide*. Show them the next steps at your desk and then let them to repeat the steps on their own model.
- When a group is ready, go out to the school garden or place the mock-ups under the Sun for testing.

• Testing the model
  It's time to try in real life our thermosiphon system.
- Bring the box outside.
- Place the mock-up towards the Sun, precise inclination in order to reach the highest possible exposure.
- Set water container at a higher position then the box. Fill up with water; let the tubes to be filled up. By moving and slightly shaking the mock-up, ensure that no air stays in the system. Make sure you fully cover both sinkers.
- Measure the temperature in the container and measure the ambient temperature too, note it down, including the time.
- Come back in one hour and measure the same temperatures, note them down.
- Adjust the angle of the box to the position of the Sun.

• Conclusions
- Encourage your students to derive their conclusions based on the data they have
- Help them by asking the following questions: How many degrees difference you measured in total? When was the temperature the highest? Why? Could it increase

further somehow? How? What helped to reach this temperature? Have you used fossil energies to reach this temperature increase?
- Optional: you can start an open conversation or give as homework to redact a text about domestic water heater systems. Would they like to use it when they are going to be adults? Would they encourage their parents to install it on their house? If they consider it a good solution for the climate change caused global problems, what do they think, why don't use everybody these systems? What else is missing?

Extra information for teachers, instructors, tips and tricks

- It is worthy to do the activity during the morning hours, then the water has time to heat up, we can reach higher temperatures.
- Your students may check the water temperature between the upper and lower levels of water inside the container
- If it is not a sunny day, we can encourage the students to repeat the experiment another day and take notes of the results
- We can explain to the students, real water heating systems are working on this effect. The main differences are: size (thus the volume of water), more professional isolation techniques, etc. It can be mentioned as a similarity that none of the systems work if there is no direct sunshine.
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1.4.3.2. Photovoltaic Energy in Domestic Lighting

Goal of the class

The workshop is aiming to let the participants experiencing the solar radiation energy of the Sun and to learn how we produce electricity with the help of photovoltaic panels. The goal is to gain a deeper understanding of photovoltaic energy systems on mock-up and domestic levels. Last but not least, see the dependence on energy sources and the unpredictability of renewable energy sources. As an output, a mock-up of a house equipped with photovoltaic panels will be produced by groups of the participants (Figures 28). The mini photovoltaic cells produce electricity that will be symbolically used for two purposes, once, for lightning (as, buildings need lighting inside) second for mechanical energy and elevation (as in real life we need to lift up people or material to a higher point too).

Pedagogical goal

The pedagogical goal is triple. Once, deepening the knowledge on photovoltaic system usage, second, learn basics of electricity, third is improving the manual skills of participants through working with electric appliances, tinkering and working with do-it-yourself crafts.

Keywords

#photovoltaic, #solar cell, #electricity, #solar energy

Age

The suggested age of students is 14-16 years. With more preparation from the teacher's side, younger students can enjoy the class also.

Group (number of participants)

Groups of 3-6 students, or as much as can work comfortably around one table.

Time

Duration of the class: 3h
Preparation time: 2h
Results in (time): immediately (in case of a sunny day = enough sunlight)

Location, classroom requirements

Craftworks are preferably done in classroom or in equipped workshop. To test the photovoltaic system in real life conditions, direct or at least abundant sunshine is needed (depending on the PV cells used). Thus if does not enter enough sunshine into the classroom, it is recommended to place the ready mock-ups outside and test the results there.

Concrete goal of the class

We are aiming to build a mock-up of a house that symbolize a real one in life that is equipped with photovoltaic cells providing electricity inside the house and outside serves as a lift. In our example, inside the house – as in real life too – we use electricity for lighting that four LED bulbs are representing. Outside of the house, there is going to be a "lookout", and we can elevate the small piece with the help of the motor and thread.

Working mechanisms of the real life cases:

Naturally, in reality we use much larger photovoltaic panels (as an average we can say 2m x 1m) and we need inverters to convert the variable direct current output of a photovoltaic panel into frequency alternating current that can be used by a local network. As we are going to see in our example, the solar cells will likely/only function in direct sunlight. It is similar to the real life cases, where electricity is not produced for example during the night. To sort out the energy needs during the night or cloudy days, in most of the installations batteries ensure the energy storage. In our model, we are not going to use inverters, neither battery in order to keep it simple for demonstration.

Along the next points we are going to look through the model's elements and see how they can help us to reach our pedagogical goal.

Do-it-Yourself (DIY) part

The wooden made house is serving as a close-to life example, but might be different depending on personal fancy. In our example inside the house there is darkness and the walls are covered by aluminium foil in order to reflect the LEDs' light. The roof of the house is at angle of 35-45° as in real life (this is the usual inclination for solar panels). In real life they are usually facing to the South, however our mock-up will function the best when it faces directly to the Sun.

Wooden craftwork requires accuracy in manual work, attention and caution from students. Working with saw, drill and cutting pliers develop the motor abilities and increase focusing capacity.

In our example, we aim rural schools with this workshop. Students from rural areas are still more connected to nature and craftworks, however, in urban areas of Castellón province students maybe need more help from the adult. For these students it is a good practice to bring closer manual work to them, in some cases, only by touching and working with different materials (wood, metal, plastic, etc.) can activate the different parts of their brain and can help students with learning difficulties.

Electrician work

One of the main aims of this workshop is teaching about electricity and familiarizing students with basic electricity rules as parallel or serial connection, working mechanisms of switches, LED lights and resistors, as well as the usage of soldering iron and tin.

This part of the class will require some previous knowledge in the topic; therefore depending on the age and knowledge of students, we may split the class into several parts and focus on one element at once.

From the electricity part of the workshop, students will understand better how renewable energies – in this case the Sun energy – can be converted to electricity. Also, they are going to learn about the electricity usage inside the house, consumption and the potential of electricity producing solar cells.

Caution: Your students need to pay particular attention when using the saw, the drill, the soldering iron to avoid injuries and accidents. As they are going to work with 6 V solar cells, the danger of electric shock is <u>not</u> occurring.

Preparation before the class

- Buy the specific material and collect the rest from your household
- Check the tools (availability, status, condition)
- Suggested: prepare your own photovoltaic system before the class in order to have your own experience on the topic
- Check tips and tricks
- Optional: if you have the opportunity to introduce the topic on the previous class, you can give some handouts or suggest some videos or links to the students to be observed; favouring this way that they come prepared to the class.

Lesson Plan

- Arrange the workshop or classroom. (Distribute materials, tools and handouts if any)
- Start the class
  - Introduce the topic starting from global problems and highlighting the importance of nature awareness and renewable energies. You can use interactive methods, like

brainstorming or mind mapping to reveal the existing knowledge of students on photovoltaic topics.
- Provide the students with accident prevention instructions. Depending on their age and abilities you may prepare some material for them beforehand (for instance if they are not prepared to use the drill, drill their holes before).

- Environmental background
  - You might start with listing the different impacts, how the Sun influences our life (light, heat) and its' consequences (sunburnt skin, drying, discolouring clothes, etc.)
  - You may bring other examples or experiments to prove the power of the Sun
  - Turn to the topic of renewable energy usage of Sun. The two most common ways are:
    - Producing electricity with the help of photovoltaic panels
    - Heating domestic water up
  - Tell them that on this class you are going to see how we can generate electricity with the help of photovoltaic panels.

- Start the construction of the pilot model (see *2.2 Construction guide* steps)
  - You may find worthy to arrive to the class with two teacher's models:
    - One that is readily built up, this one we can put under the Sun at the beginning of the class and see what is the goal at the end of the workshop
    - The other teacher's model would be in particles to make easier the explanation towards the class.
  - You might show first to students your ready model in order to let them know how the result should be by the end of the workshop
  - Dismount your model or take your second teacher's model
  - Go step-by-step, show them the first steps at your desk and tell them to replicate it on their own models in groups. Raise their attention to the importance of cooperation and task sharing inside the group (and on class level too).
  - Go around the tables and observe students' work. In case of need of help, give them a hand and encourage them to solve some of the challenges individually.
  - When one section is done, go with the next steps of the *2.2 Construction guide*. Show them the next steps at your place and then let them to repeat the steps on their own model.
  - When a group is ready, go out to the school garden or place the mock-ups under the Sun for testing.

- Testing of model

It's time to try in real life our photovoltaic system.
  - Bring the mock-up outside.
  - Place the roof (so the solar cells) facing directly to the Sun (perpendicular to the light rays, in order to reach the highest possible exposure)
  - Move one switch to ON
  - If you did everything well, one LED switches on

- Repeat the same with the other switches and LEDs
- If there is enough (sun)light, you can switch on all the LEDs
- Observe if there are any differences among the LEDs (strength of light or anything else)
- Move the fifth (3 stage) switch to one direction and then try to the other direction as well.
- Observe how the figure lifts up to the "lookout" and how turns back to the ground level.
- Try whether there is enough sunshine to make all of them functioning.
- Observe what happens if you slowly start to move the roof away from the sunshine. Move it to the shadow until none of the LEDs lights or the motor has not enough power to lift the piece. You might try it inside the classroom too.

- Conclusions
  - Encourage your students to derive their conclusions based on the experience they observed
  - Help them by asking the following questions: How much sunlight is needed to have all the LEDs switched on? And for the elevator? What would happen if we removed one solar cell?
  - Optional: you can start an open conversation or give as homework to redact a text about domestic water heater systems. What are the most common (electricity) consumers in our homes? Could they imagine to live in an off-grid (so solar energy powered) house? If they consider it a good solution for the climate change caused global problems, what do they think, why don't use everybody these systems? What else is missing in their opinion?

Extra information for teachers, instructors, tips and tricks

- It is worthy to do the activity during the morning hours, then there is going to be enough light around daytime
- If it is not a sunny day, we can encourage the students to test the model another day and take notes of the results
- We can explain to the students, that real photovoltaic systems are working on the same effect. The main differences are: size (of the panels), usage of batteries and inverters, etc. It can be mentioned as a similarity that none of the systems work if there is not enough sunshine.

1.4.3.3. Aeroelevator

Goal of the class

The workshop is aiming to let the participants experiencing the power of wind energy. The windmill is going to turn its axis and this energy is going to be transformed into potential energy: the small piece is going to be lifted up.

As an output, a mock-up of a windmill (Figures 35) is going to be built by groups of the participants.

Pedagogical goal

The pedagogical goal is double. Once, deepening the knowledge on wind energy systems, second, improving the manual skills of participants through working with craftwork.

Keywords

#wind energy, #wind mill, #elevator

Age

The suggested age of students is 6-12 years.

Group (number of participants)

Groups of 3-6 students, or as much as can work comfortably around one table.

Time

Duration of the class: 1-2h
Preparation time: 1h
Results in (time): immediately (in case of a windy day, if not, by blowing the blades)

Location, classroom requirements

Craftworks can be done in classroom or outside as well. To test the windmill in real life conditions, steady wind is needed blowing from one direction. If it is not a windy day, we can try by blowing the blades or – as a less ecological solution, but serving the test of the experiment – by using a fan.

Concrete goal of the class

We are aiming to build a mock-up of a windmill that symbolizes in classroom conditions the power of wind energy.

This model is very simple, guaranteeing success in the classroom, uses recycled material and costs practically nothing. In the windmill we did not plan any electrical part in order to make it understandable and feasible by younger students. This model is going to symbolize as the potential in as well the barriers of renewable energies. For these reasons we have chosen this mock-up, providing a solution for schools that aims to teach about renewable energies but dealing with limited budget and/or time.

Working mechanisms of the real life cases:

The most well-known usage of windmills is/was the classical grain mills and the mills used for water pumping. In the latter case water is pumped out from a well with the use of the windmill connected with a piston, thus the rotational movement is turned into vertical movement. The same effect is symbolized in our example with the exception of lacking the piston. In our model the water is lifted up vertically.

Along the next points we are going to look through the model's elements and see how they can help us to reach our pedagogical goal.

Do-it-yourself (DIY)

The big plastic bottle serves for being used as the tower and foundation. The small one serves to hold the axis. The blades of the windmill are the well known origami-style paper windmills [1] [2] that are turning quite easily even in case of low wind speed. The clip is stuck to the axis and it is used as the "barrel" of the well of the symbolic wind energy based water pump.

Creation of the windmill is quite easy, the only critical point can be when cutting the plastic bottle and we have to warn the students to pay attention when using the cutter or scissor.

Creating something moving is motivating for students; moreover if it is functioning well, it increases the self-confidence. Working with paper, plastic and tools develops the motor and focusing capacity.

Preparation before the class

- Buy or collect the material from your home
- Check the tools (availability, status, condition)
- Suggested: prepare your own eolic system before the class in order to have your own experience on the topic
- Check tips and tricks
- Optional: if you have the opportunity to introduce the topic on the previous class, you can tell a story about old windmills or wind-connected water pump systems; favouring this way that they come packed with curiosity to the class.

Lesson Plan

- Arrange the workshop or classroom (distribute materials, tools and handouts if any).
- Start the class
  - Introduce the topic of wind energy by starting from global problems and highlighting the importance of nature awareness and renewable energies. You might use interactive methods or ask students what they are associating to from the word "wind"
  - Provide the students with accident prevention instructions. Depending on their age and abilities you may prepare some material for them beforehand (for instance if they are not prepared to use the cutter or scissor, cut their bottles before).

- Environmental background
  - You might start by interviewing students, how they feel on a windy day? What are the typical windy places (seashore, big plains or high mountains without vegetation)? How wind is/used to be used in sailing, shipping? Where have they seen modern wind turbines?
  - You may bring other examples or experiments how and why humankind started to use windmills in the history (mill grains, pump water and irrigate).