Professional Bachelor Electromechanics

SUSTAINABLE ENERGY REDUCTION, PRODUCTION AND MANAGEMENT AT PXL-TECH WITH A PHOTOVOLTAIC INSTALLATION

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Bachelor project academic year 2014-2015

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The student takes full responsibility for this dissertation. Dissertation supervision and process coaching does not eliminate incomplete information and/or inaccuracies which have been taken into account in the final evaluation, but which have not been modified in the final version of the dissertation.

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I. Summary

This research paper is focused on the analysis of an installation of solar panels for the PXL-Tech building.

With this project research PXL-Tech building can obtain more independence from the main electrical grid by generating it's own electricity in order to feed a part of it's electrical need.

Moreover, with the implantation of this project, PXL-Tech building will suffer a positive change into a "greener" and more environmentally friendlier building.

The research for this project has been made following different steps. First of all the analysis of the electrical consumption and building's physical characteristics has been made to know the resources that can be taken into account.

Then, the election of the solar panels and the rest of the components (inverters, cables etc) has been made with different softwares and different criteria in order to get a project as detailed as possible.

Finally the economic analysis will lead the reader to know if the installation is profitable or not, which is the most important thing when making an installation like this.

Also, for going deeper in the research, an analysis on the efficiency and an economic analysis for part of the installation of the use of solar trackers has been made.

Moreover, changing completely the topic of photovoltaics, certain ways for improving the heating system have been analised.

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II. ii. Acknowledgements

First and foremost I would like to thank the people who have helped and supported me during this project. I would like to acknowledge the help of teachers mr Vanheusden and mr Vandormael because they helped me when I needed and they gave me the best advice and recommendation for improving and making the project better.

I would like to express my very great appreciation to the whole team of PXL-Tech for making our stay in Belgium much easier.

I wish to thank all the people that I have met here in Belgium for leaving a mark for the rest of my life during this Erasmus experience.

Eskerrik asko danoi benetan.

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1. Introduction

In recent years, the environment and the earth are becoming popular topics because of the climatic change. The climate on earth is starting to change and humankind has a special fault on this. The abuse of fossil fuels and the excessive CO_2 emissions pollute the earth and this has to be cut.

Furthermore, the dependence on fossil fuels for having electricity is really high. The customers are made to pay the prices that big electricity and oil companies want.

That is why the renewable energies are a good and a real option to avoid these two main problems mentioned above.

Therefore, PXL-Tech wants to develop its building into an energetically self-sufficient building. The idea consists of reducing the electrical consumption that the building has and generating its own electrical need and hot water as far as possible. For generating its own electrical supply, a photovoltaic system is designed and for obtaining hot water, a geothermal system has been designed in order to provide PXL-Tech with as much power as possible.

The bachelor project "Sustainable energy reduction, production and management at PXL-Tech is divided in two main parts: the geothermal part for obtaining hot water and the photovoltaic part for obtaining electric power.

In this report the photovoltaic part is going to be explained. It focuses on obtaining electricity from solar panels, without the need of the main electric grid. For this, an analysis of the building's physical characteristics is firstly made. Then, knowing the consumption of the electricity is crucial for the election of different panels. Finally, after making the choice of all the components, a final map is done with all the panels on it, in order to make it more visual.

This project describes and analyses the study for making the PXL-Tech building a self-sufficient building. Different kinds of panels will be analysed for the solar installation in order to make a deeper analysis. Moreover, different inverters will be also analysed, from different companies, to make a detailed analysis. Finally, an economic analysis will be done, in order to know if it will profitable installing the solar panels.

It is expected the photovoltaic installation to be profitable and worthwhile. All the installation of the solar panels, inverters and other components will cost some investment and with the saving of electricity this new installation will generate, we will be able to calculate the profitability of the whole system.

So with this hypothesis, a clear research question is deduced: Will be profitable a photovoltaic system for PXL-Tech building?

IV. 2. Literature review

ELECTRICAL CONSUMPTION

Firstly, before making the choice of the panels, the electrical consumption of PXL-Tech building needs to be analysed. For that, the electric bills of last 3 years, 2012, 2013 and 2014 have been studied.

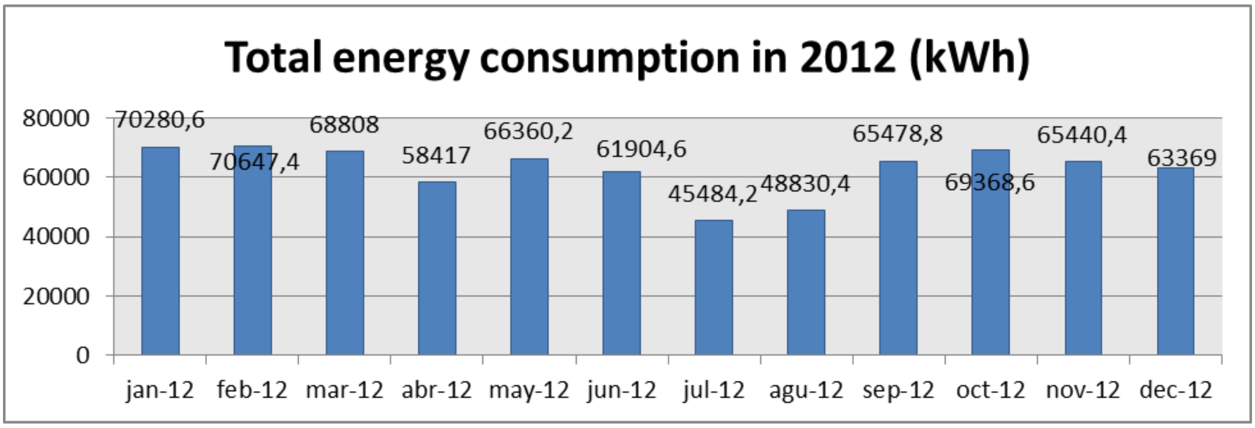
To fully understand the following tables, some definitions have to be clear:

- Kilowatthour (kW·h): it is the power produced by solar panels.
- Kilowattpeak (kWp): t is the power of the photovoltaic installation, the power tah solar panels generate under standard conditions, corresponding to the power that a panel generates during best days of the year.

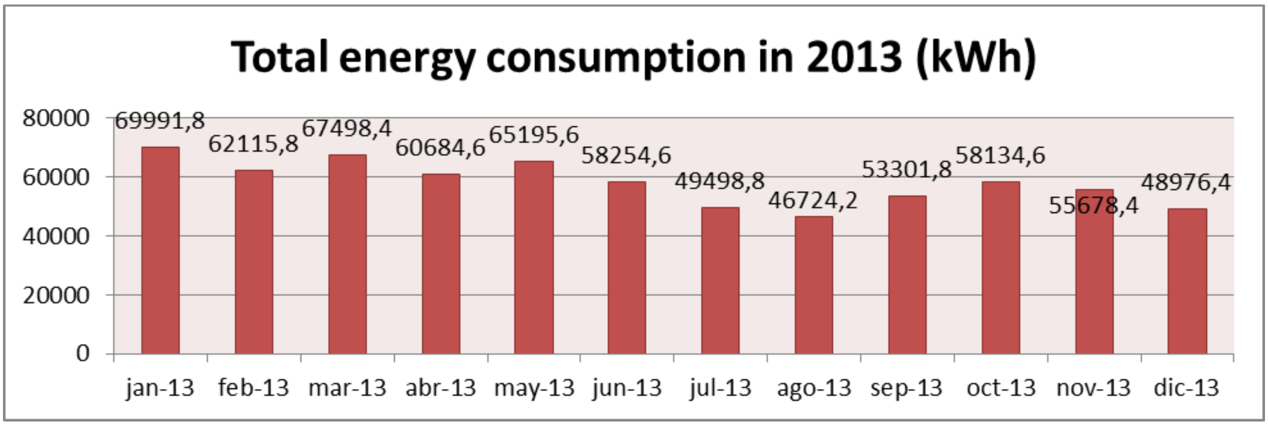
As can be seen in the following graphics [Graph1, Graph2 and Graph3] the total energy consumption of the building has been draw.

In the vertical axis the energy consumption is placed, whereas in the horizontal axis the time is located, divided per month for a whole year.

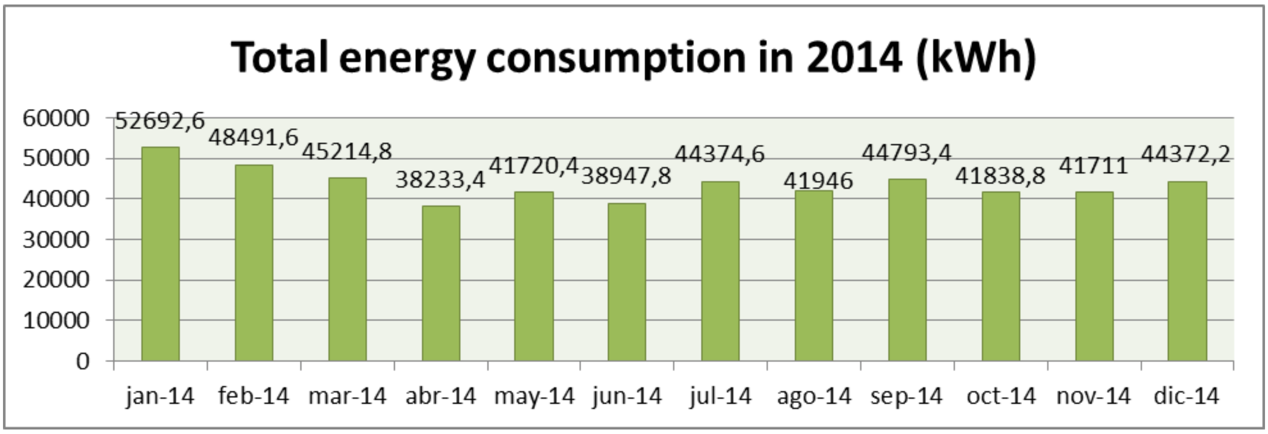
As there can be seen, the total consumption of the building has decreased from 2012 to 2014, as well as the peak power.



Graph. Nº 1: Total energy consumption of PXL-Tech building in 2012



Graph. Nº 2: Total energy consumption of PXL-Tech building in 2013

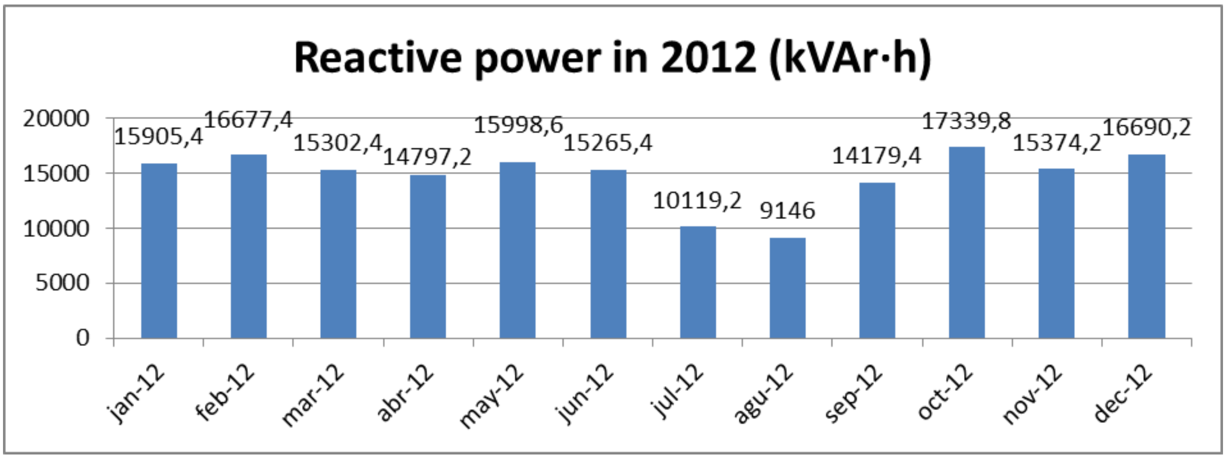


Graph. Nº 3: Total energy consumption of PXL-Tech building in 2014

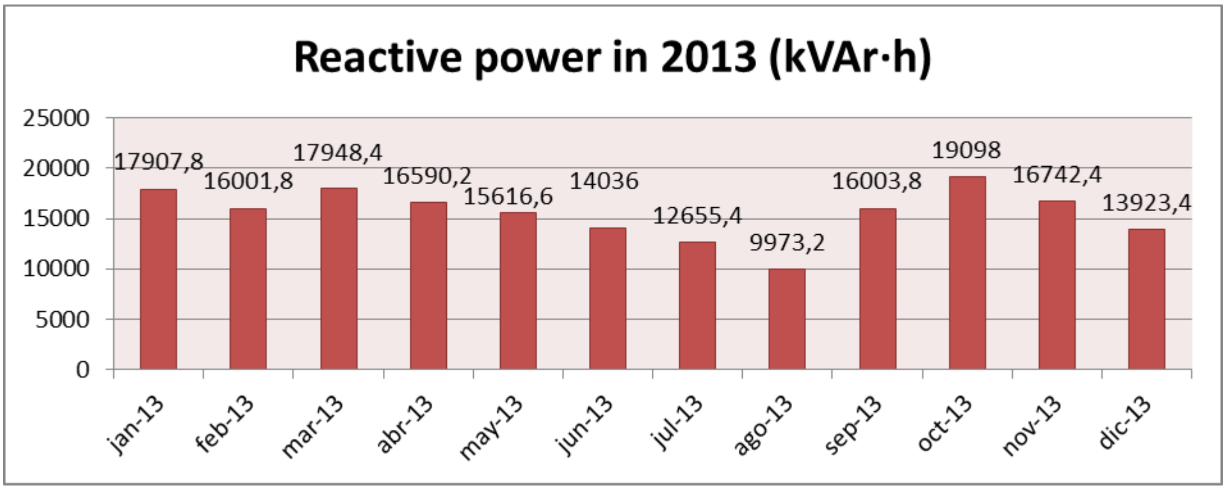
As can be seen, in three years, January is the month in which the consumption is highest, whereas the vacation period of July and August is the lowest.

As far as the reactive power is concerned [Graph4, Graph5 and Graph6], varies from 2012 to 2014.

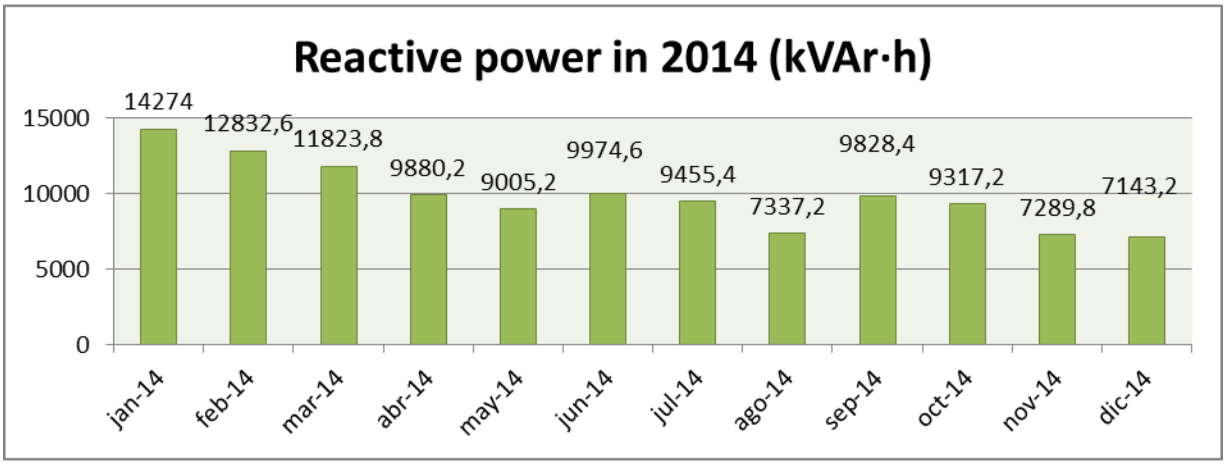
It increases in 2013 comparing with 2012, but next year, in 2014, decreases quite a lot.



Graph. Nº 4: Total reactive power of PXL-Tech building in 2012



Graph. Nº 5: Total reactive power of PXL-Tech building in 2013

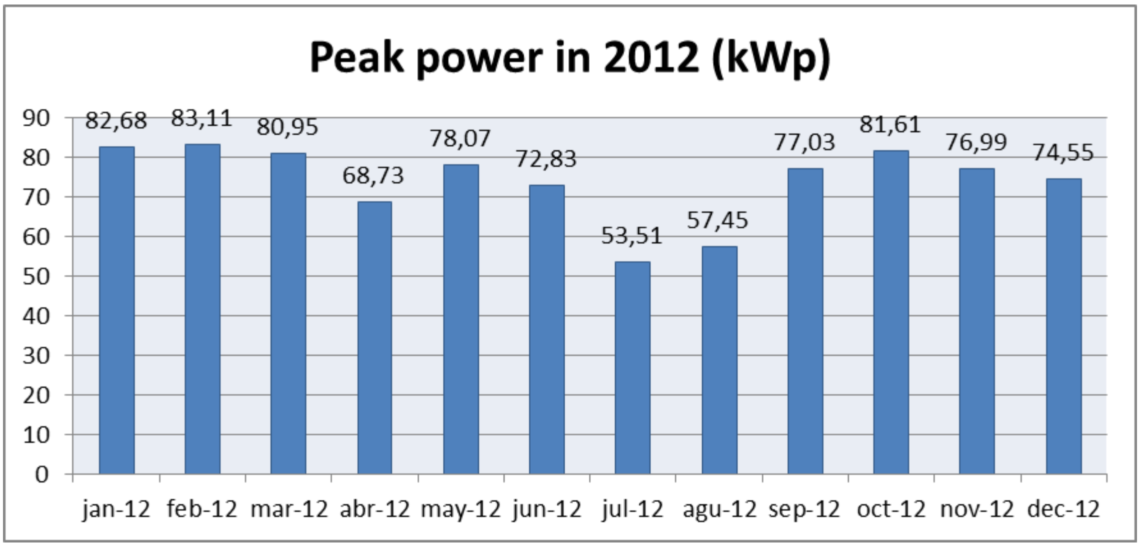


Graph. Nº 6: Total reactive power of PXL-Tech building in 2014

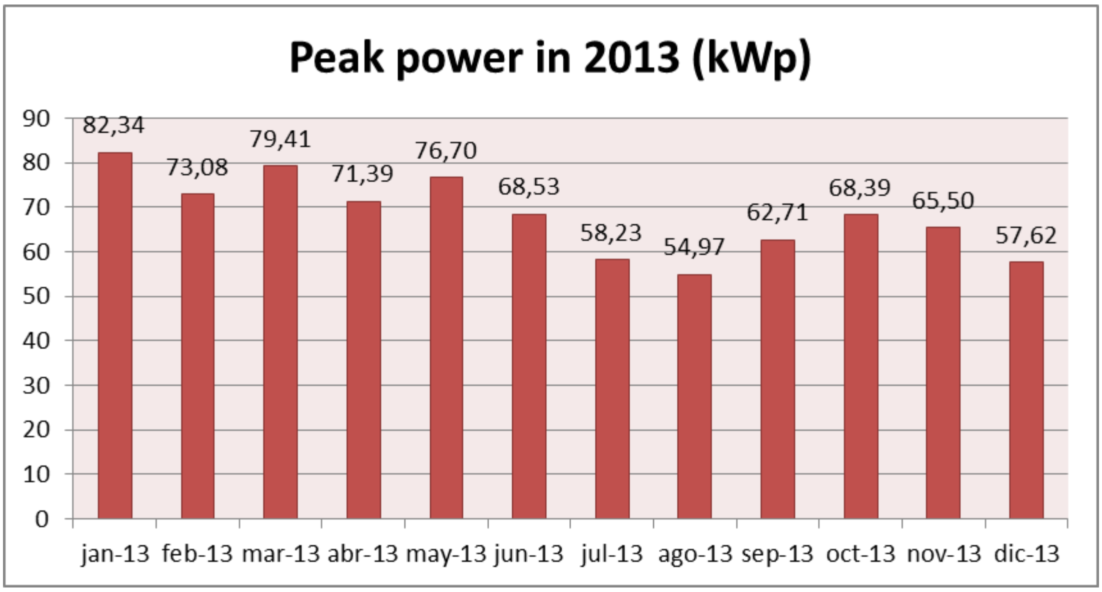
As can be seen in the following graphics [Graph7, Graph8], the peak power consumption of the building has been draw.

In the vertical axis the power consumption is placed, whereas in the horizontal axis the time is located, divided per month for a whole year.

As there can be seen, the total peak consumption of the building has decreased from 2012 to 2014, as well as the peak power



Graph. Nº 7: Peak power of PXL-Tech building in 2012 per month



Graph. Nº 8: Peak power of PXL-Tech building in 2013 per month

For the estimation of the whole cost of electricity, we have assumed that it will cost 15 € cent per kW·h (15 €cent. / kW·h). So, adding all the monthly costs, this is the yearly cost of the whole electricity:

Paid in 2012	113.158,38 €
Paid in 2013	104.408,25 €
Paid in 2014	78.650,49 €

Table. Nº 1: Yearly cost of electricity

As the consumption has decreased during the years, the total cost of the electricity will also decrease.

ANALYSIS OF THE BUILDINGS PHYSICAL CHARACTERISTICS

First of all, the available surface on which solar photovoltaic panels can be placed has to be known. For that, a research on the maps of the building and surroundings for different possible placements has been made:

Note: To make the calculations of the different surfaces, there will be subtracted 10% of the total surface.

Above the expansion of the atrium: In some years' time, the big room which is currently on the ground floor, will be in built until third floor, so, then, the conventional roof and the roof of the expansion of the atrium will be at same level. Therefore, this surface can be taken into account for using it as a possible placement for the panels:

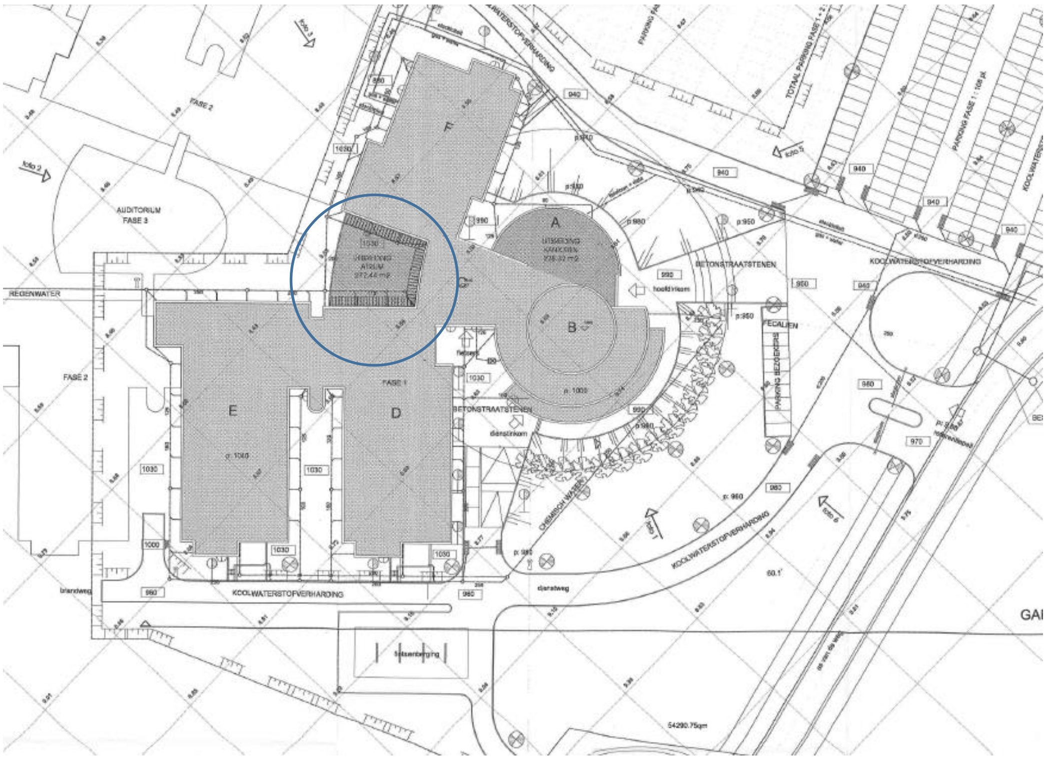


Figure 1: Location of the atrium

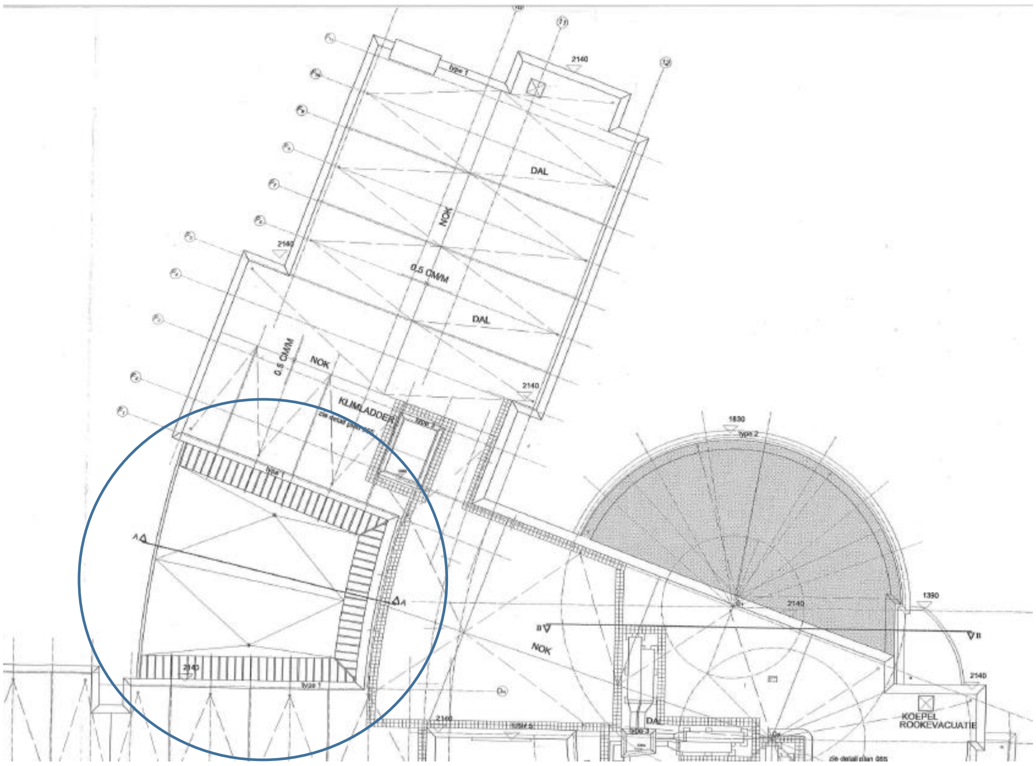


Figure 2: Location of the atrium

Brief sketch:

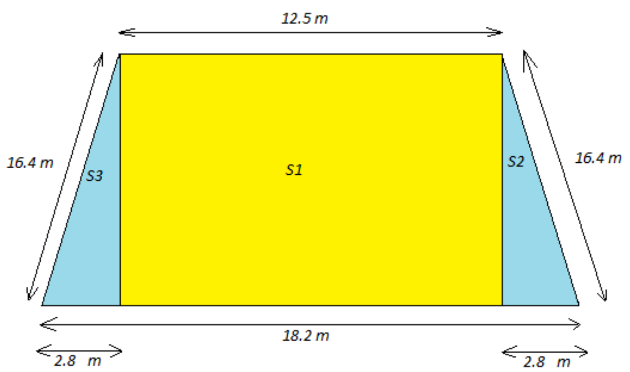


Figure 3: Brief sketch of the atrium

$$h^2 = k^2 + k^2 \Rightarrow k = \sqrt{h^2 - k^2} \Rightarrow \boldsymbol{k} = \sqrt{16.4^2 - 2.8^2} = \mathbf{16.15\ m}$$

Surface 1 = S1 = (18.2 – 2.8 – 2.8) · 16.15 = **201.87 m²**

Surface 2 = Surface 3 = $2 \cdot \frac{2.8 \cdot 16.15}{2} = \mathbf{45.22\ m^2}$

Total area: 201.87 + 45.22 = **247.09 m²**

If 10% is substracted in order not to use the borders of the roof:

$$247.09 - (247.09 \cdot 0.1) = 222.38\ m^2 \approx \mathbf{222\ m^2}$$

1. <u>The part of the roof that sticks out in the cafeteria</u>: This surface, even if it looks quite small at first, has a really good orientation towards the sun. Placing some panels here would be a good option, not only because of the good orientation, but also because of the fact that the roof belongs to PXL-Tech.

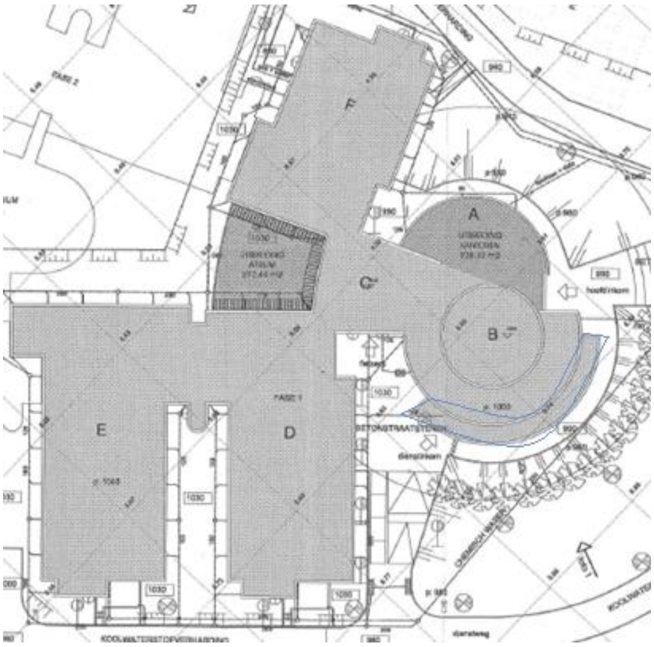


Figure 4: Location of roof of cafeteria

Brief sketch:

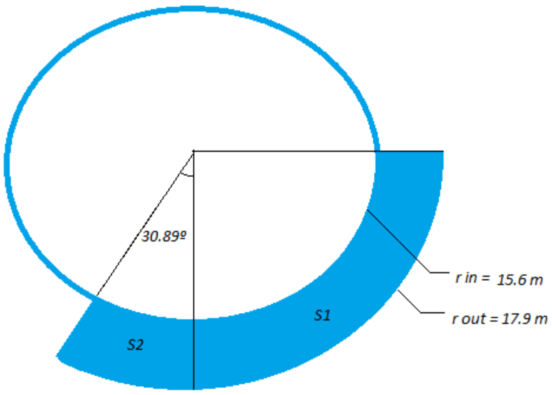


Figure 4: Brief sketch of surface of roof of cafeteria

$$\boldsymbol{S1} = \frac{\pi \cdot {r_{out}}^2}{4} - \frac{\pi \cdot {r_{in}}^2}{4} = \frac{\pi \cdot 17.9^2}{4} - \frac{\pi \cdot 15.9^2}{4} = \boldsymbol{60.51\, m^2}$$

S2= 90º → 60.51m^2
30.89º → X m^2
X = 20.77 m^2

Total area: 60.51 m^2 + 20.77 m^2 **= 81.28 m^2**

If 10% is subtracted in order not to use the borders of the roof:

81.28 m^2 – (81.28 m^2 · 0.1) = **73.152 m^2 ≈ 73 m^2**

2. Bicycle parking: Even if this area seems to be quite small, it will be analysed. Nowadays some trees shadow the parking, but in some years time, with a new train line that will go across the PXL-Tech faculty's belongings, these trees will disappear. Then, this available area will be quite interesting to place some solar panels, mainly because the orientation and secondly because it is a PXL-Tech faculty's area.

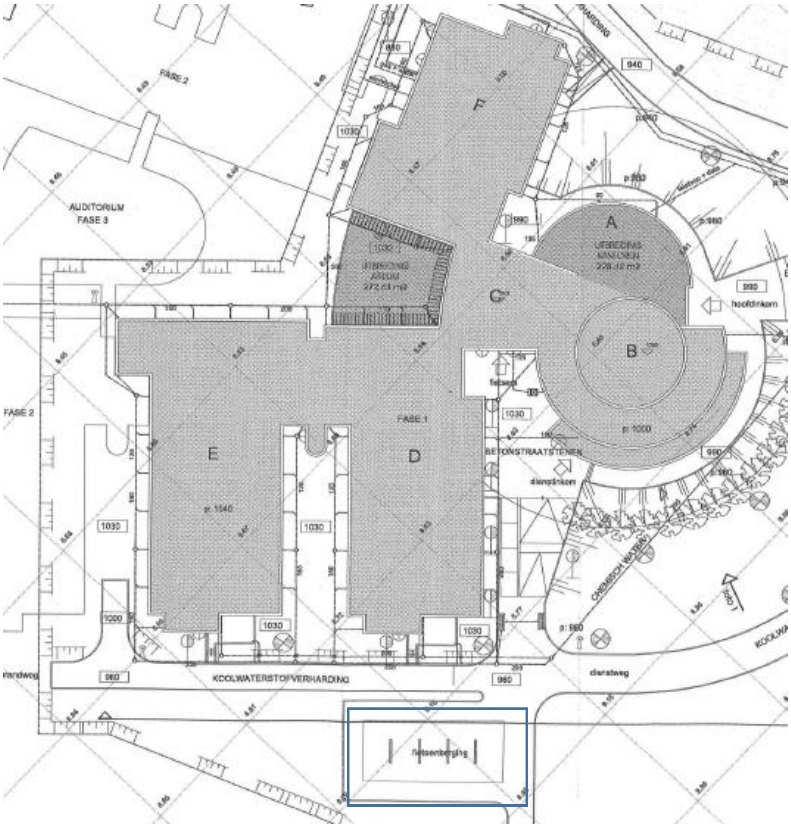


Figure 5: Location of roof of bycicle parking

Brief sketch:

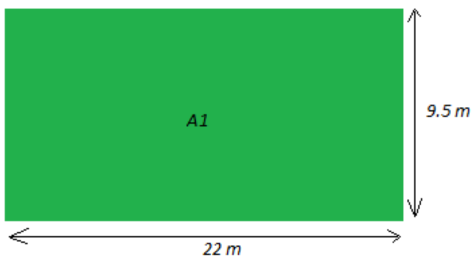


Figure 6: Brief sketch of roof of bycicle parking

$$\boldsymbol{A1} = 22 \cdot 9.5 = \boldsymbol{209\ m^2}$$

If 10% is subtracted in order not to use the borders of the roof:

209 m^2 – (209 m^2 · 0.1) = **188.1 m^2 ≈ 188 m^2**

3. <u>Big parking to the right of the entrance + Parking Bezoekers/Visitors:</u> Another suitable option will be covering the parking which is to the right of the main entrance and the parking area for visitors. This will be quite interesting because there would be a lot of available area, but there has to be done some investment, previous to the installation of the panels.

In all the previous cases, panels were able to install almost without any previous investment. But in this case, covering the parking like in supermarket parking will provide PXL-Tech building more available installing area.

Also, the orientation and the placement of both of the car parks are quite good. They do not have any object that will shadow the panels nearby, very important fact when placing solar panels.

In the end of the results, has been made an economic analysis of placing solar panels with trackers in this area.

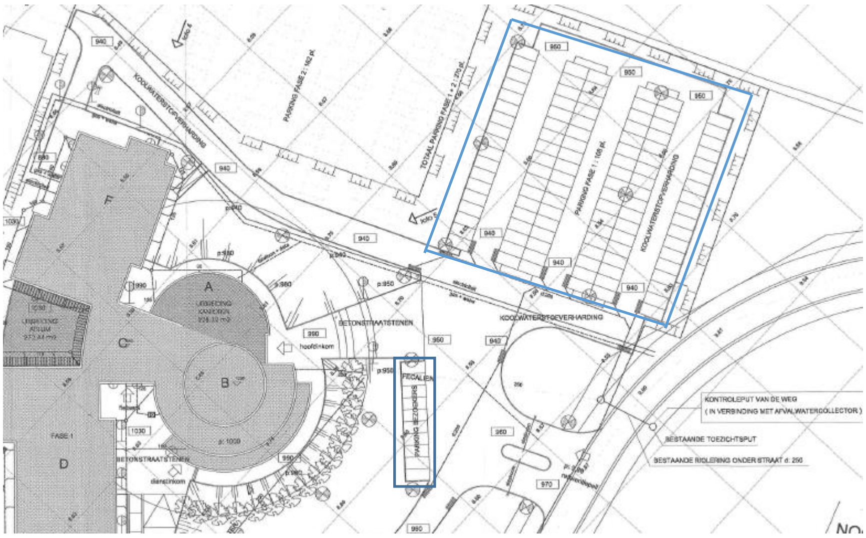


Figure 7: Location of visitors an big parking

Brief sketch:

Big parking to the right of the entrance:

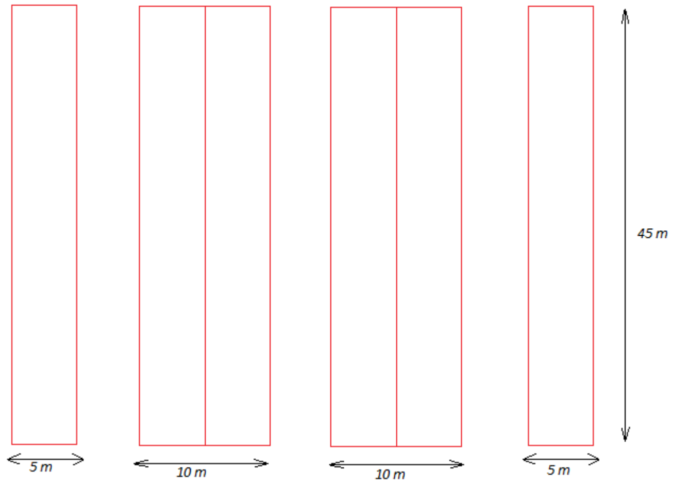


Figure 8: Brief sketch of big parking

$$\boldsymbol{Total\ area} = (5 \cdot 45) + (10 \cdot 45) + (10 \cdot 45) + (5 \cdot 45) = \mathbf{1350}\ \boldsymbol{m^2}$$

If 10% is subtracted in order not to use the borders of the roof:

$$1350 - (1350 \cdot 0.1) = \mathbf{1215}\ \boldsymbol{m^2}$$

Parking Bezoekers/Visitors:

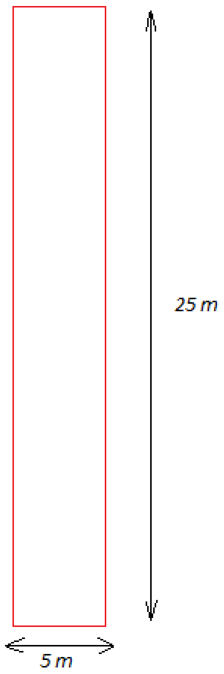


Figure 9: Brief sketch of visitors parking

$$\boldsymbol{Total\ area} = 5 \cdot 25 = \mathbf{125}\ \boldsymbol{m^2}$$

If 10% is subtracted in order not to use the borders of the roof:

$$125 - (125 \cdot 0.1) = \mathbf{112.5}\ \boldsymbol{m^2} \approx \mathbf{112}\ \boldsymbol{m^2}$$

4. <u>Fields outside, which will be able to use:</u> In the fields outside the PXL-Tech buildings will be possible to place solar panels, but has to be kept in mind that the train will be crossing these fields. That is why needs to be known which area will be used and which one will be able to use:

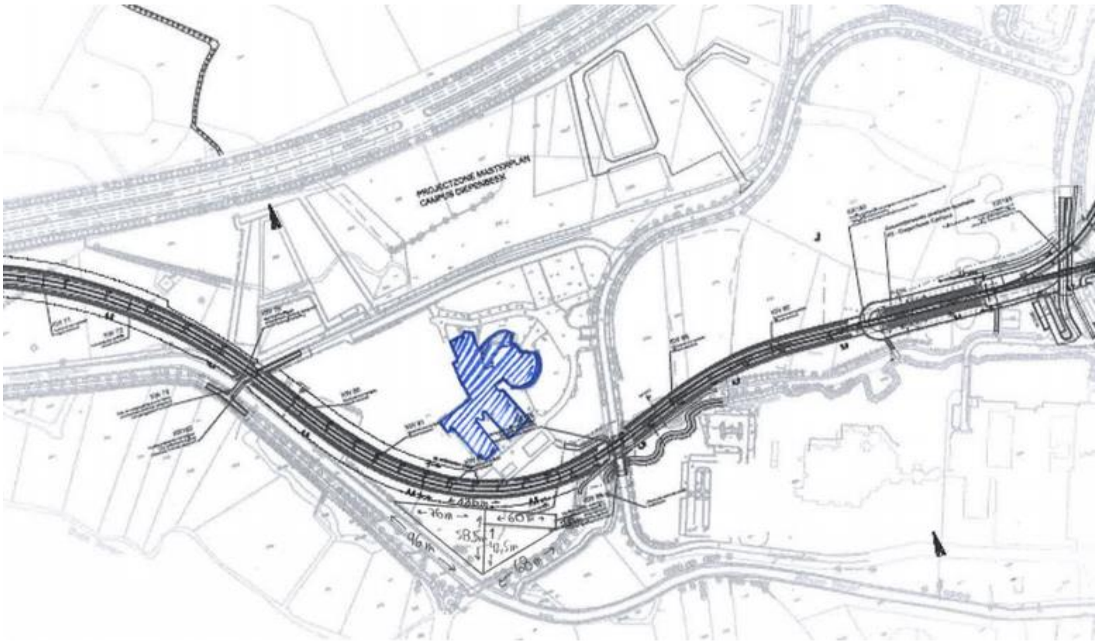


Figure 10: Location of available surface outside

Figure 11: Location of available surface outside

Scale: 1 cm = 40 m

Brief sketch:

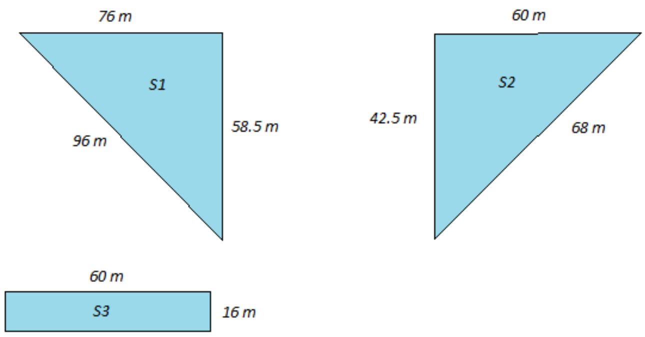


Figure 12: Sketch of available surface outside

$$S1 = \frac{76 \cdot 58.5}{2} = 2228.7\ m^2$$

$$S2 = \frac{60 \cdot 42.5}{2} = 1275\ m^2$$

$$S3 = 60 \cdot 12 = 720\ m^2$$

Total area: 2228.7 + 1275 + 720 = **4223.7 m^2**

If 10% is subtracted in order not to use the borders of the roof:

$$4223.7 - (4223.7 \cdot 0.1) = \mathbf{3801.33\ m^2}$$

5. <u>Extra available roof surface:</u> After having a walk through the roof, has been seen that optimizing the available area will be helpful for the installation. Placing the panels in the roof will be really helpful for avoiding problems with paper work, because the field/area of the roof is property of PXL University, so PXL does not need the permission of anybody else for installing the panels.

As can be seen on the next picture, there will be four available surfaces in the roof, taking into account the surface that the green roof will take away for solar panel use.

Figure 13: Location of extra surface in the roof

These four available areas consist of:

1. Surface 1: 17.85· 7.14 = 127.45 m^2 , subtracting %10 =**114.7 m^2**
2. Surface 2: 9.28 · 5.71 = 52.98 m^2 , subtracting %10 = **47.7 m^2**
3. Surface 3: 7.14 · 8.57 = 61.2 m^2, subtracting %10= **55.07 m^2**
4. Surface 4: 7.14 · 5.71 = 40.77 m^2, subtracting %10= **36.7 m^2**

Available area: 114.7 + 47.7 + 55.07 + 36.07 = **253.54 m^2**

If 10% is subtracted in order not to use the borders of the roof:

$$253.54\ m^2 - (253.54\ m^2 \cdot 0.1) = \mathbf{228.06\ m^2}$$

6. Available surface in southern façade: As the southern façade is the façade in which the sun strikes most of the time and as the wall is a part of the PXL-Tech building, so it is not necessary to receive permission to build on it.
Maybe will not be profitable placing the panels with a sun tracker, because of the difficult installation, but at least, is an available extra surface.

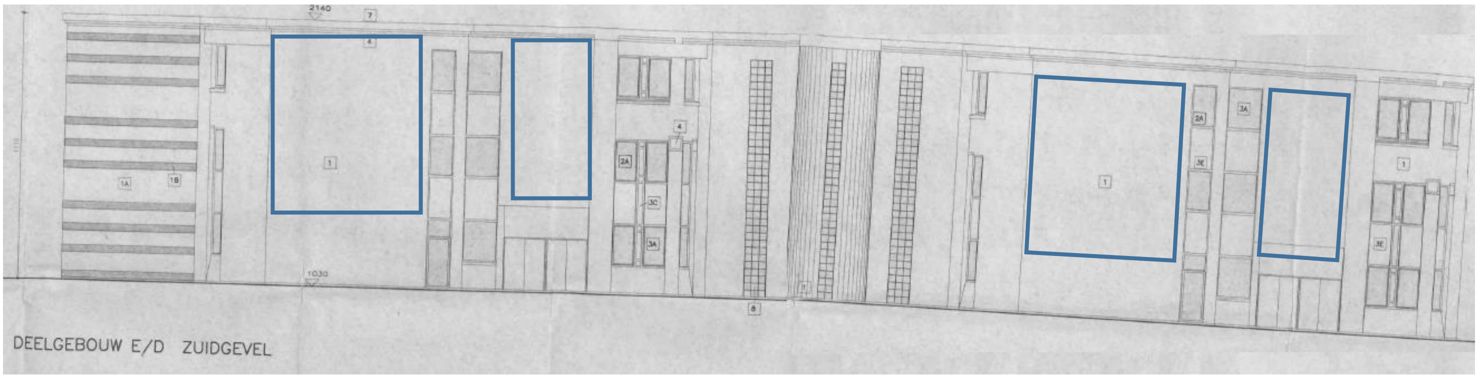


Figure 14: Location of extra surface in the southern façade

Brief sketch:

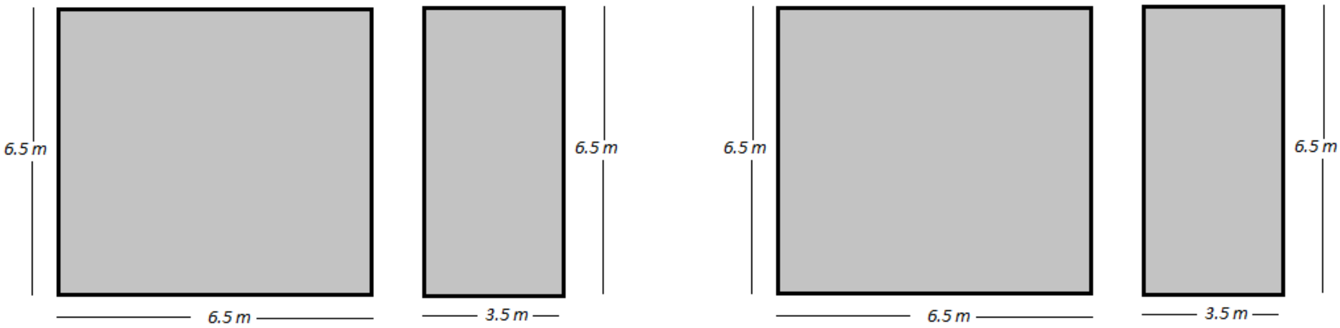


Figure 15: Sketch of extra surface in the southern façade

$$\boldsymbol{Total\ area} = 2 \cdot (6.5 \cdot 6.5) + 2 \cdot (6.5 \cdot 3.5) = \boldsymbol{130\ m^2}$$

If 10% is subtracted in order not to use the borders of the roof:

$130\ m^2 – (130\ m^2 \cdot 0.1) =$ **117 m^2**

- <u>Total available area</u>: **222 m^2 + 73 m^2 +188 m^2 + 1215 m^2 +112 m^2 + 3801.33 m^2 + 228.06 m^2 + 117 m^2 = 5956.39 m^2**

1. <u>Available area for Geothermal issue:</u> Here the area that will be good for using with geothermal resources has been calculated.

Brief sketch:

Figure 16: Location of extra surface in the outer field

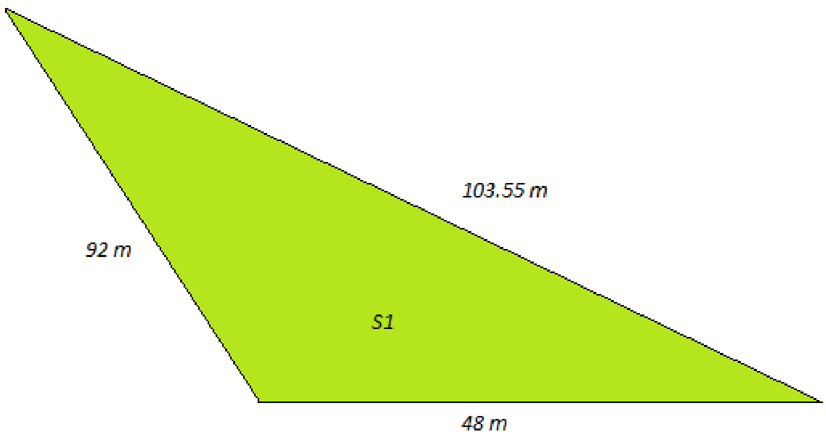


Figure 17: Sketch of extra surface in the outer field

$$P = \frac{a+b+c}{2} = \frac{92+103.55+48}{2} = 121.77$$

$$S1 = \sqrt{p \cdot (p-a) \cdot \ (p-b) \cdot \ (p-c)} =$$
$$= \sqrt{121.77 \cdot (121.77-92) \cdot (121.77-48) \cdot (121.77-103.55)}$$
$$= \mathbf{2207.59\ m^2}$$

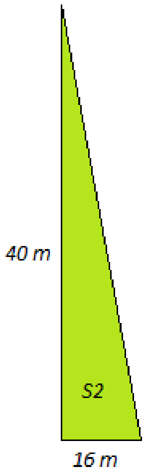


Figure 18: Sketch of a part of extra surface in the outer field

$$\boldsymbol{S2} = \frac{40 \cdot 16}{2} = \boldsymbol{320\ m^2}$$

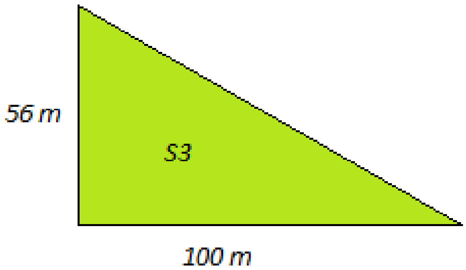


Figure 19: Sketch of a part of extra surface in the outer field

$$S3 = \frac{56 \cdot 100}{2} = \boldsymbol{2800\ m^2}$$

Total available surface: 2207.59 m^2 + 320 m^2 + 2800 m^2 = **5327.59 m^2**

If 10% is subtracted in order not to use the borders of the roof:

5327.59 m^2 – (5327.59 m^2 · 0.1) = **4794.83 m^2**

V. 3. Method

CHOICE OF PV PANELS

According to the book “Planning and installing photovoltaic systems. A guide for installers, architect and engineers” (by Deutsche Gesellschaft Für Sonnenenergie), the required photovoltaic area for 1kW peak (1 kWp) is approximately 10 m^2. This approximation will vary depending on the different type of solar panel used, as we will see in this next picture:

Cell material	Required PV area for $1kW_p$
Mono-crystalline	$7m^2$–$9m^2$
High performance cells	$6m^2$–$7m^2$
Polycrystalline	$7.5m^2$–$10m^2$
Copper indium diselenide (CIS)	$9m^2$–$11m^2$
Cadmium telluride (CdTe)	$12m^2$–$17m^2$
Amorphous silicon	$14m^2$–$20m^2$

Figure 20: Relation between required area for 1kWp for different cell materials

Firstly, the area that the panels will take when we use different kind of cell material has to be calculated. For that which will be the consumption that solar panels will provide has to be known. Linked with this, it is important to know the desire to reduce electrical consume that PXL-Tech building has. The objective of PXL-Tech is to reduce one third the electrical consumption for the future, so, if the consumption in 2014 was 524336,6 kW·h, it will be reduced to 349557,73 kW·h, approximately 350000kW·h.

As we have been told, the relation between 1 kWp and 1 kW·h is the next: 1kWp = 850 kW·h, so the total kWp of 350000 kW·h will be 411.76 kWp.

Now, is going to be crucial to know which the limit of kWp is, in order to know if the government will provide us with a subsidy or not. This limit is now set in 250 kWp, so if you remain under this value, the government will provide you a 93€ subsidy per every 1000 kW·h.

In order to get this subsidy, the maximum installed kWp will logically be 250 kWp.

So, if PXL-Tech building will install 250kWp in solar panels and we know that the consume will be 411.76 kWp, the solar panel installation will provide the 60.71% of the whole need of electricity. This will suppose a saving of 47748,64€ per year (according to the consume of 2014).

In order to know the area that will be used by each type of solar cell, the table above will be used

	Model	Max power (Wp)	Nº of panels needed	Length (m)	Width (m)	Area of panel (m^2)	Total panel surface (m2)
Monocrystalline	Sanyo HIT-N235SE10	235	1064	1,58	0,798	1,261	1341,32
High performance cells	SunForte PM096B00	327	765	1,559	1	1,631	1246,72
Polycrystalline	Solarworld SW 250	250	1000	1,675	1,001	1,677	1644,80
Copper indium diselenide (CIS)	Avancis PowerMax® SMART	120	2083	1,587	0,664	1,054	2196,35
Cadmium telluride (CdTe)	Calyxo CX3 80	80	3125	1,2	0,6	0,720	2250
Amorphous silicon	Du Pont DA145	145	1724	1,4	1,1	1,540	2656,17

Table. Nº 2: Required amount of panels and surface for each type of panels

So, now it is known the total panel surface that will take each cell type.

Related with this, we the minimum distance between two panels has to be known, in order not to make shadow one to others.

$$d_{min} = l \cdot (\cos\beta + \frac{\sin\beta}{\tan H})$$

- l: Length of panel (m).
- β: Inclination angle (34º).
- H: (90-latitude)-23.5º

With this, it is able to calculate the minimum distances for each panel type:

	Model	Minimum distance between panels length (m)	Minimum distance between panels width (m)
Monocrystalline	Sanyo HIT-N235SE10	4,48	2,01
High perfomance cells	SunForte PM096B00	4,42	2,63
Polycristaline	Solarworld SW 250	4,75	2,52
Copper indium diselenide (CIS)	Avancis PowerMax® SMART	4,50	1,67
Cadmium telluride (CdTe)	Calyxo CX3 80	3,40	1,51
Amorphous silicon	Du Pont DA145	3,97	2,77

Table. Nº 3: Required minimum distance between two panels

Now the relation between the available area, the used area and the irradiation will be shown:

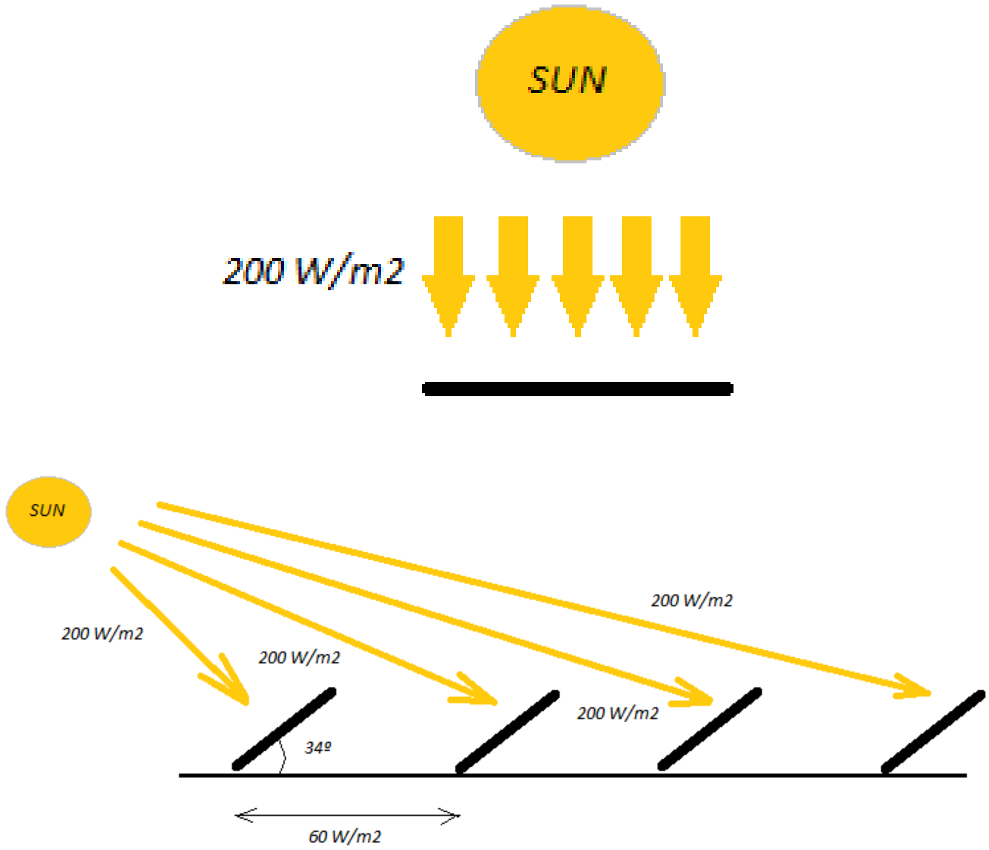


Figure 21: Solar radiation brief sketch

The sun hits the panels with the power of 200 Watts per square meter. This is so if the distance between the panels is taken into account, this means that the 200 W/m^2 will not be "real" for the whole used surface and the whole available area.

The total available area will be higher than the total used area, because all the available surface with solar panels will not be covered.

MONOCRYSTALLINE

	Available (m^2)	Nº of panels	Used (m2)	Relation (Available/Used)	Radiation (W/m^2)	Real radiation for the used area (W/m^2)
Southern façade	117	92	116,012	1,00851636	200	198,3111111
Field outside	3801,33	548	691,028	5,500978253	200	36,35716973
Extra roof + bike	416	100	126,1	3,298969072	200	60,625
Atrium	222	55	69,355	3,200922789	200	62,48198198
B + Visitors parking	185	45	56,745	3,260199136	200	61,34594595
Big car park	1215	288	363,168	3,34555908	200	59,78074074
TOTAL	5956,3	1128	1422,408			

Table. Nº 4: Required number of panels per zone and real radiation for the used area for MONO panels

POLYCRYSTALLINE

	Available (m^2)	Nº of panels	Used (m2)	Relation (Available/Used)	Radiation (W/m^2)	Real radiation for the used area (W/m^2)
Southern façade	117	69	115,713	1,011122346	200	197,8
Field outside	3801,33	294	493,038	7,710014238	200	25,94028932
Extra roof + bike	416	85	142,545	2,918376653	200	68,53125
Atrium	222	45	75,465	2,941761081	200	67,98648649
B + Visitors parking	185	36	60,372	3,06433446	200	65,26702703
Big car park	1215	234	392,418	3,096188248	200	64,59555556
TOTAL	5956,3	763	1279,551			

Table. Nº 5: Required number of panels per zone and real radiation for the used area for POLY panels

As the table show, some of the “real radiation for the used area” are correct, such as the Atrium, B+Visitors parking , Extra roof + bike and Big car park because are around 60 in both cases.

For the Southern façade this will not work because there will not be any separation between the different rows of panels (because they will be one over the other).

Regarding the field outside, the value is too low, but this is because there can be placed more panels there. There were problems with the scale and maps during the calculations, because the only map that was available with the path of the future train was too small and 1 cm were 40 m in real life, so it was not able to place the panels as accurate as wanted.

ANALYSIS BETWEEN NORMAL SOLAR PANELS AND SOLAR PANELS WITH SOLAR TRACKER

A solar tracker is a machine which chases the path of the sun. With this, the radiation that hits the panel remains perpendicular, so the efficiency increases considerably.

The solar tracker is attached to the solar panel, in order to rotate the panel. This rotation can be done differently:

It can be done in one axis, or it can rotate in two axis.

The solar trackers that rotate just in one axis are cheaper and simpler than other trackers, but, at the same time, the tracking is less precise, therefore, it will get more energy than solar panels without trackers, but it will get less than panels with more advanced trackers.

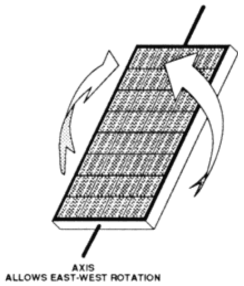


Figure 22: Picture of single axis solar tracker

The next table and graphic show the difference on the efficiency between single-axis tracker solar panels and solar panels without trackers.

In the vertical axis the output power is shown (in Watts) whereas the time of the day is shown in the horizontal axis (in hours).

As the single-axis tracker's line is higher than fixed solar panels, can be deduced that the output power they give is higher for the same conditions, that is why, single axis trackers are more efficient than fixed solar panels.

TABLE I: FIXED VS SINGLE-AXIS [1].

HOUR	POWER FOR FIXED MOUNT(mW)	POWER FOR SINGLE-AXIS(mW)
0800	20.664	62.403
0900	39.780	67.473
1000	44.176	77.212
1100	70.616	93.772
1200	88.110	110.430
1300	104.960	137.160
1400	125.334	130.754
1500	105.342	120.335
1600	86.172	103.096
1700	70.620	89.910
1800	46.494	65.625

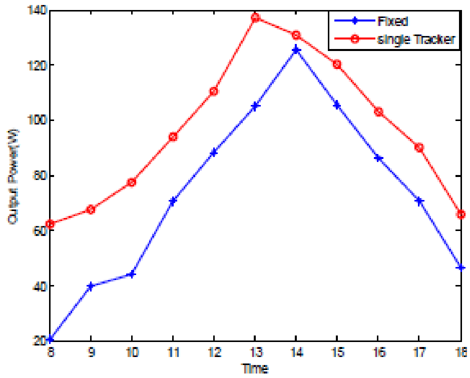


Table. Nº 5 & Graphic Nº9: Fixed vs. single axis tracker graphic comparison

Otherwise, double axis rotating solar trackers make a more precise tracing of sun's path, so it increases the electricity generation up to a 35% more comparing with a solar panel without any tracker.

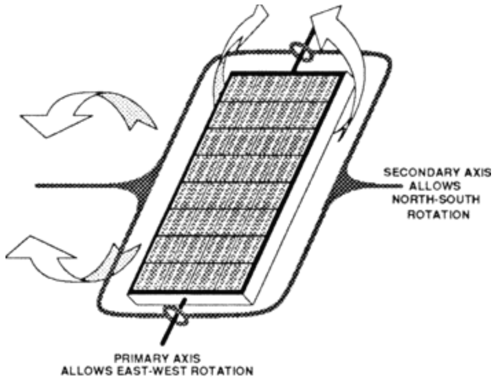


Figure 23: Picture of double axis solar tracker

TABLE 2 .FIXED VS DUAL-AXIS [2].

HOUR	POWER FOR FIXED MOUNT(W)	POWER FOR DUAL-AXIS(W)
0700	14.575	38
0800	23.987	49.728
0900	43.876	52.701
1000	47.94	54.9519
1100	52	52.974
1200	57.6666	59.6156
1300	57.96	58.0488
1400	56.412	56.5687
1500	54.6883	55.3151
1600	48.174	54.8562
1700	36.96	52.3698
1800	27.72	52.668
1900	12.69	33.22

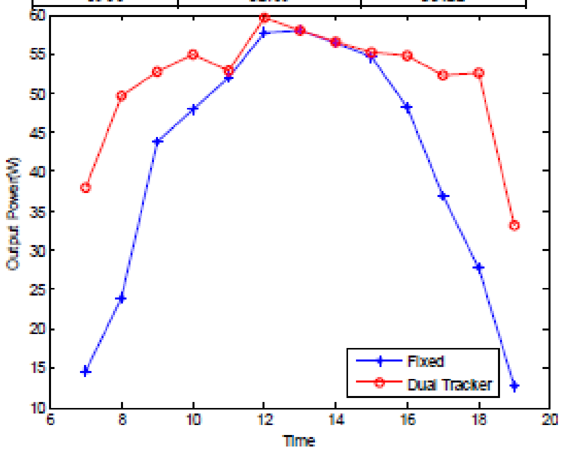


Table. Nº 6& Graphic Nº10: Fixed vs. dual axis tracker graphic comparison

Regarding the type of tracker, they can also be classified as bright spot trackers and pre-programed astronomic trackers.

The bright spot trackers work with a sensor which indicates which point in the sky is the brightest and therefore, where the panel must point to.

Pre-programed astronomic trackers rotate the panel following the solar equations, which allow knowing in which point the sun will be for each hour. For the rotation bidirectional DC motors are used, one in each axis.

The bright spot trackers are easier to use and to programme, because the algorithm is simpler. Moreover, this mechanism provides small production gains in cloudy days. Regarding the pre-programed astronomic trackers are more robust than other trackers, what means more reliability when using. The bad aspect of this kind of trackers is that the algorithms are too huge and complicated.

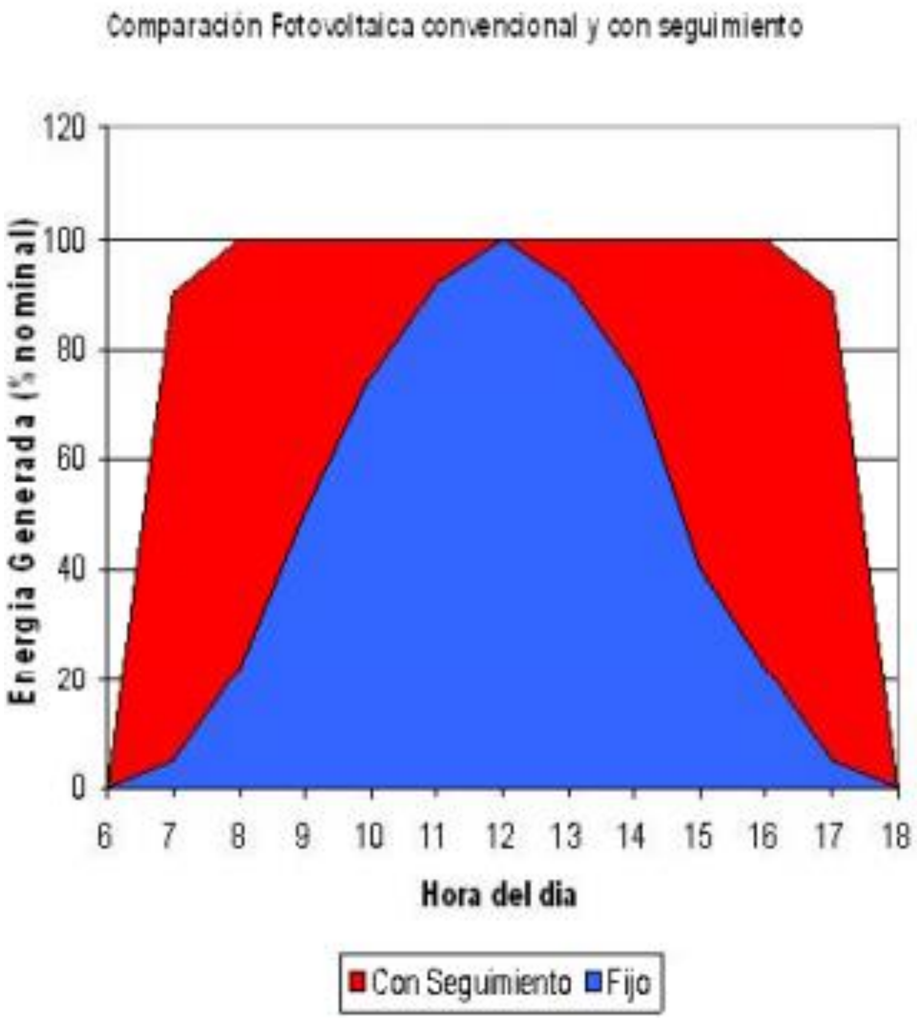


Figure 23:Difference between fixed solar panel and panel with tracker

Wind speed results:

Regarding the wind speed results, in order to prove panels' resistance, different values of wind speed have been taken into account. These wind speed datas have been taken from three weather stations nearby PXL-Tech building and from PXL-Tech's weather station.

Basing on the Kleine Brogel Air Base's results, which were the most accurate. As a result, the PV system should be able to cope with the wind speed of 24 m/s and the most common wind direction will be SW.

To ensure the whole safety, this value over dimensioned, therefore, the value to bear in mind was 30 m/s.

CONNECTION BETWEEN DIFFERENT PANELS AND INVERTER

In this part the different connection between the solar panels will be analysed, and after knowing this, the choice of the inverter will can be done.

For all this, two special software have been used. The first is called Fronius Solar Configurator. As far as it is made and configured by Fronius (solar inverter manufacturer), this software is reliable and trustable, but the main disadvantage is that it only contains Fronius solar inverters.

The second software is called PVSYST and it allows the user to do the sizing of the modules and inverters for their installation.

The possible configuration and the choice of the inverter for two different solar panel types have been analysed: Monocrystalline and polycrystalline.

Each inverter has been chosen for a power slightly higher than the placed panels, just in case. The inverters have been chosen for more or less endure the power of 5 panels more than designed, for safety.

Now the possibilities of connection between the panels, using first Fronius Solar configurator and afterwards PVSYST, will be analysed, for monocrystalline and polycrystalline panels.

FRONIUS SOLAR CONFIGURATOR

MONOCRYSTALLINE PANEL

Regarding the **monocrystalline panels**, Sanyo HIT-N235SE10 panel has been chosen, according to the references in which showed that was one of the best panels for placing here.

The pictures above show the placement of the different solar panels throughout all PXL-Tech building and surroundings:

1. Southern façade:

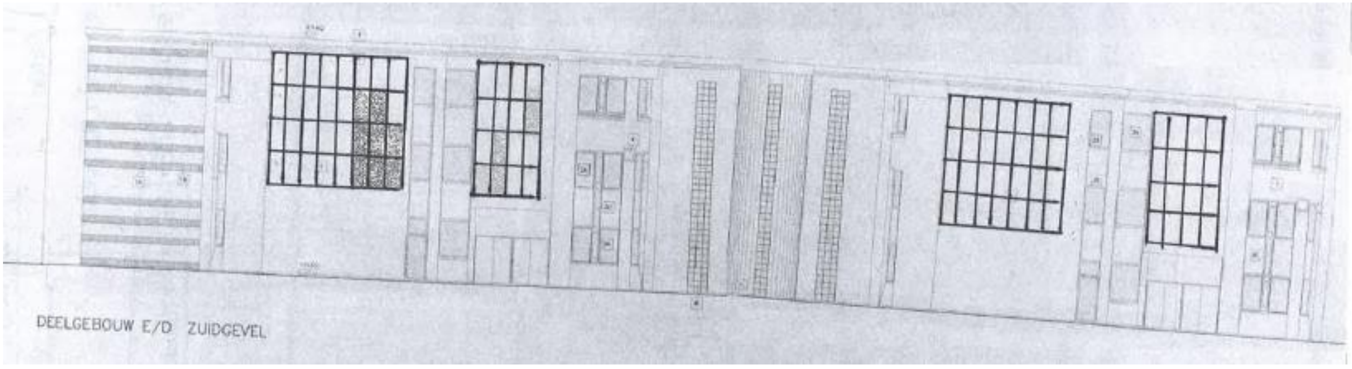


Figure 24: Final location of monocrystalline panels in southern façade

In the southern façade, the available area is 117 m^2, so, as the size of the panel is known,the amount of panels there can be placed can be calculated. In the picture above, the placement of panels has been done on scale.

For doing this placement of panels, as the size of the panels is known and there are available maps of the PXL-Tech building, a drawing of the panel has been painted on the maps of the building. All, the panels and the maps, are on scale. Nevertheless, in the oral presentation the maps will be shown.

In this southern façade a total amount of 92 Sanyo HIT-N235SE10 panels can be placed.

Regarding the connection between panels, Fronius Solar Configurator showed us which the appropriate connection would be for each inverter:

The panels in the southern façade will be connected in 8 strings, in which there will be 12 modules per string.

In the first step of the Fronius Solar Configurator, the configuration of the panels will be determined: 8 strings with 12 modules per string. There will be shown the total power and the total PV power / max. DC power inverter. The inverter that has been chose is Fronius Symo 20.0-3-M (20000W).

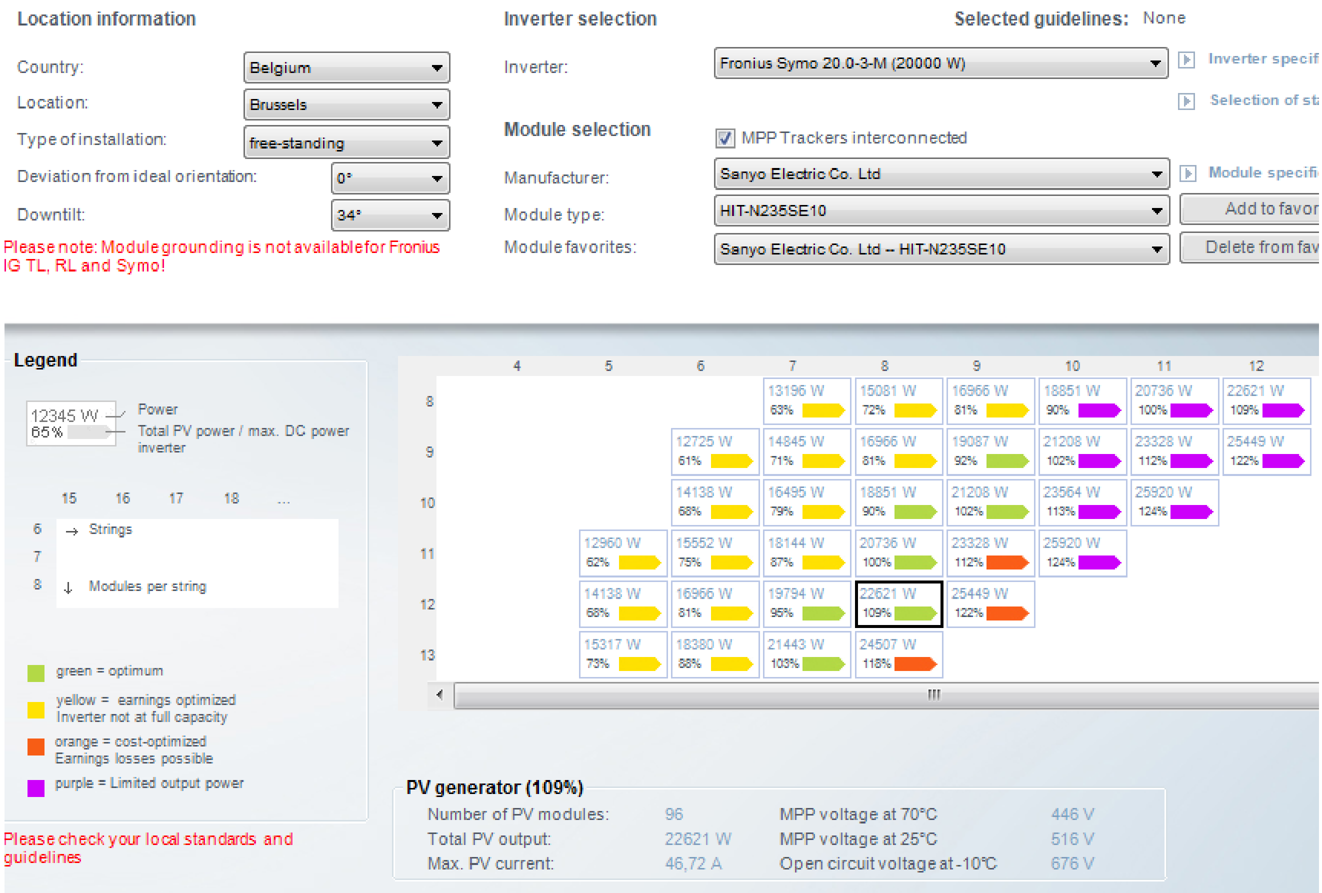


Figure 25: Configuration of the panels

In the second step, the string cable length, the distance to the inverter and the distance to the main grid connection will be determined:

Figure 26: Configuration of the cables

- String cable length has been set to 19 meters:12·length of panel (1.58 m) = 18.96 m ≈ 19m
- The cable length to the main electrical grid has been set to 85 meters, which is the distance from the southern façade to the point in the northern façade.

Automatically the software calculates the section of each cable, and by using these cables, the power losses that the system will have. Therefore, the total loss with these cables will be 133.29 Watt, 0.68% of the total power installed.

2. <u>Fields outside, which will be able to use:</u>

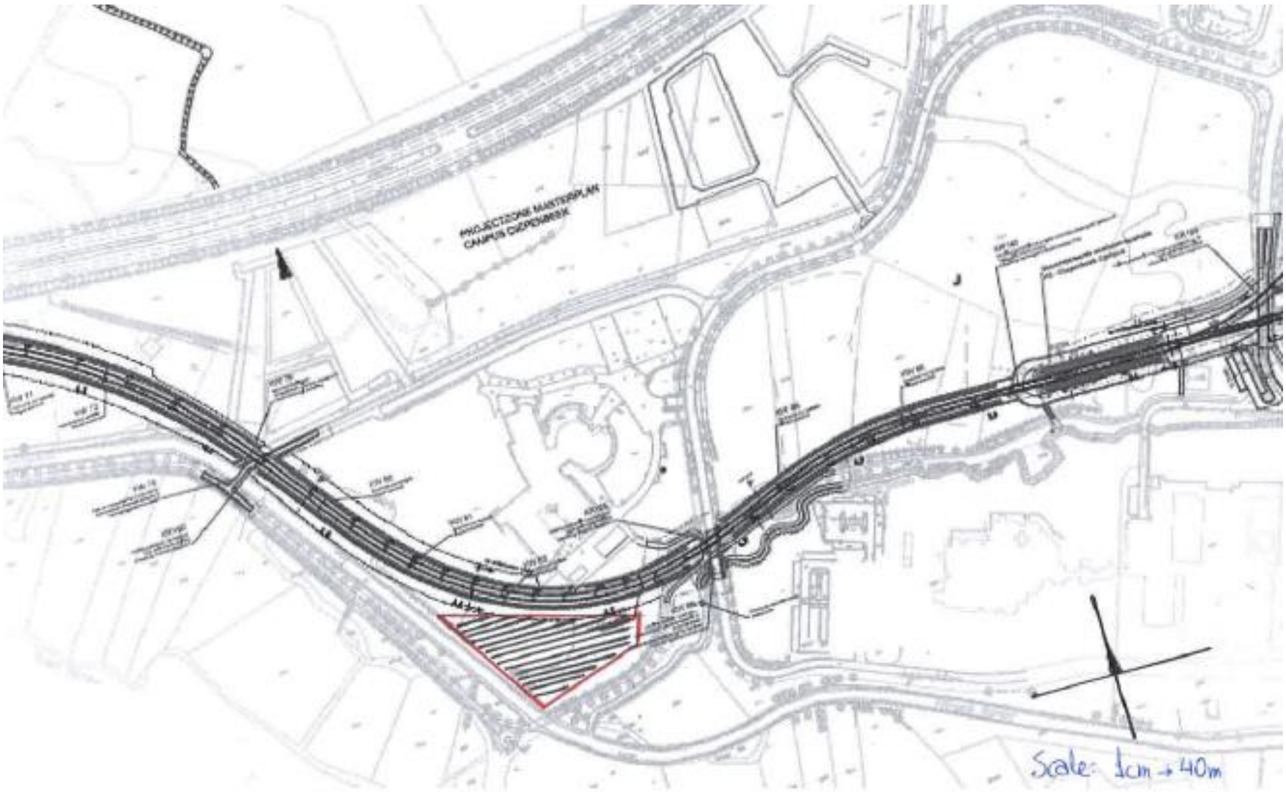


Figure 27: Final location of monocrystalline panels in field outside

This is the distribution of the panels in the field:

	On map	Real scale
1st row	6 mm	15 panels
2nd row	9 mm	22 panels
3rd row	12 mm	30 panels
4th row	15 mm	37 panels
5th row	18 mm	45 panels
6th row	21 mm	53 panels
7th row	25 mm	63 panels
8th row	24 mm	60 panels
9th row	22 mm	55 panels
10th row	21 mm	53 panels
11th row	17 mm	43 panels
12th row	13 mm	32 panels
13th row	10 mm	25 panels
14th row	6 mm	15 panels

Table. Nº 7: Relation of panels size

There are 3801.33 m^2 available for placing solar panels. There will be 548 panels in total. For this there will be used two big inverters: **two** Fronius CL 60.0 (60000 Watt). **So the procedure shown below must be done twice**.

The distribution of the panels will be 31 strings of 9 modules each string. For this configuration, the total power will be 65744 Watt and the total PV power / max. DC power inverter will be %102.

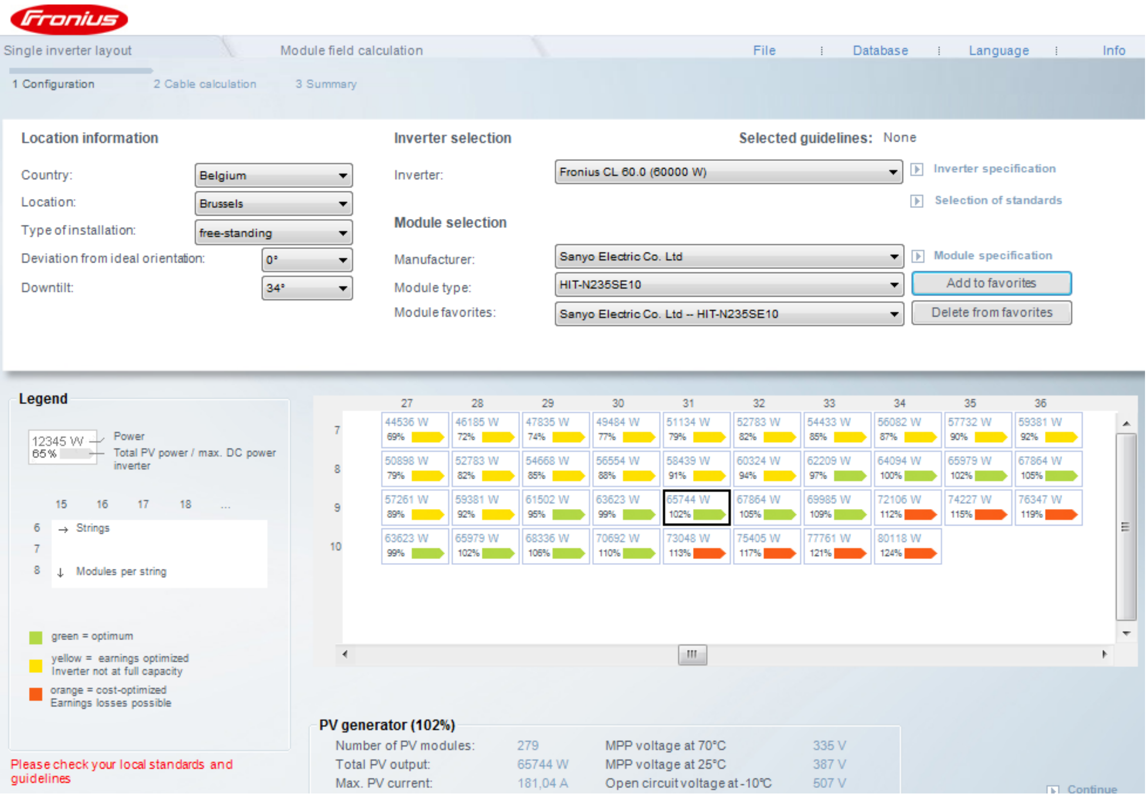


Figure 28: Configuration of the panels

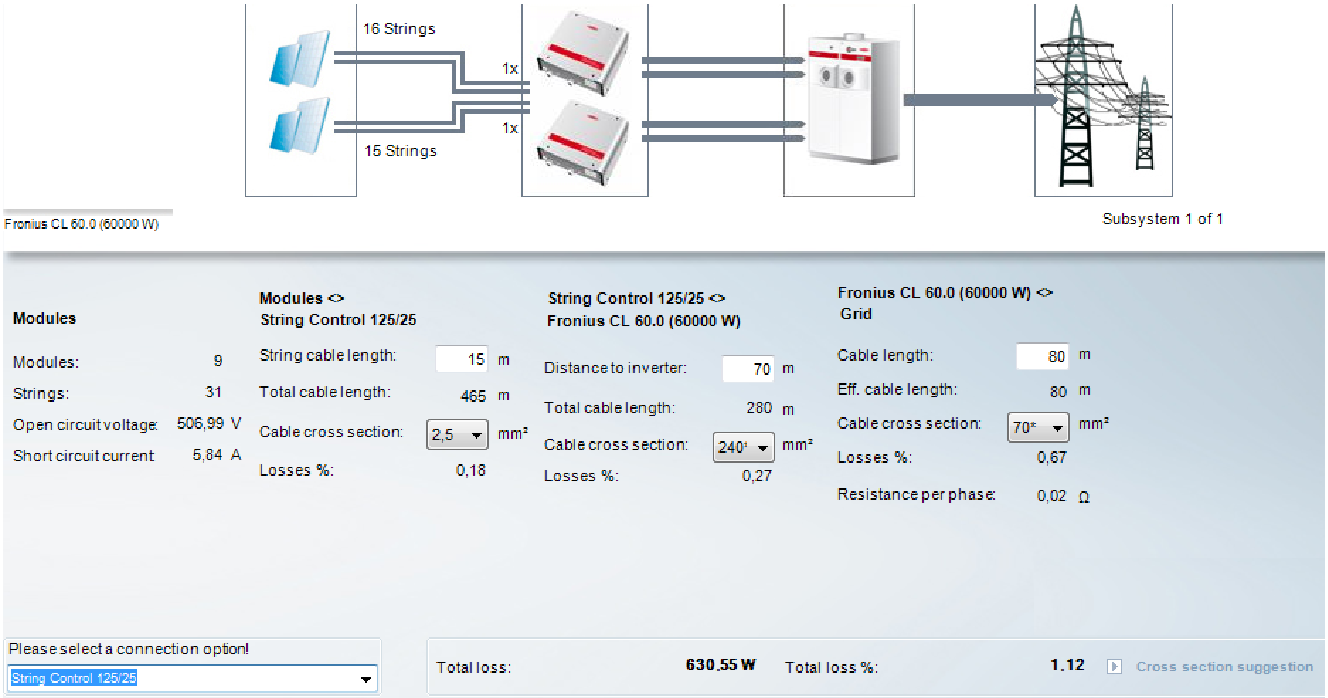


Figure 29: Configuration of the cables

String cable length has been set to 15 meters: 9·length of panel (1.58 m)=14.22 m ≈ 15m

- The distance to the inverter has been set to 70 meters: A good place for placing the inverter might be the any of the two stairs of the southern façade, in order to install both inverters in the same place. Then, the panel that is further is at 70 meters.
- The cable length to the main electrical grid has been set to 80 meters, which is the distance from the inverter to the point in the northern façade.

Automatically the software calculates the section of each cable, and by using these cables, the power losses that the system will have. Therefore, the total loss with these cables will be 630.55 Watt, 1.12% of the total power installed.

3. <u>Extra available roof surface + bicycle park roof:</u>

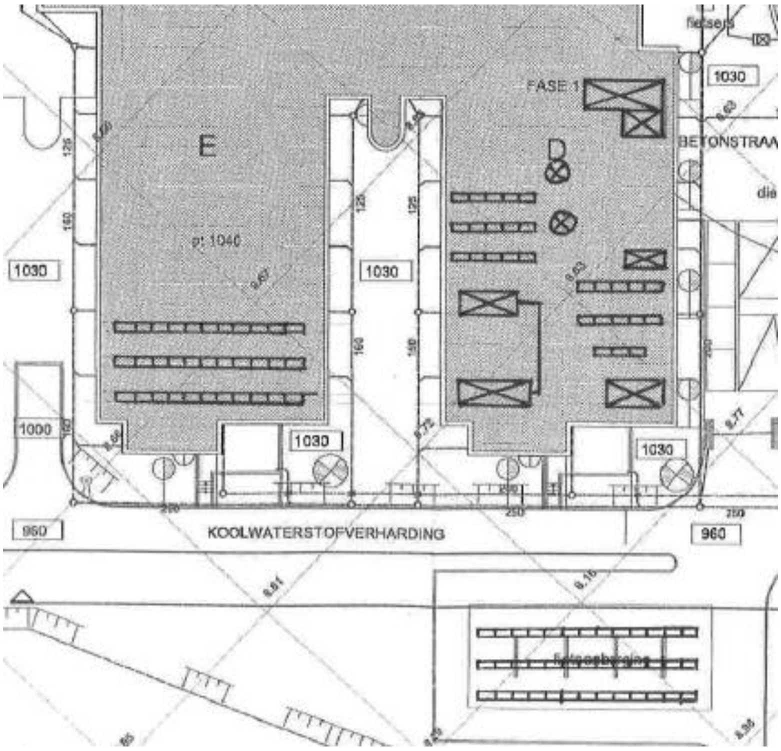


Figure 30: Final location of monocrystalline panels in bycicle parking

The available total surface here will be 188 m^2 + 228 m^2 = 416 m^2. Taken into account the area each panels takes, and the minimum distance between each panel, the total amount of panels that can be placed is 100 panels.

The connection between the panels will be 13 strings of 8 panels in serial connection per string.

The total power of this part of installation is going to be 24507 Watt, and the the total PV power / max. DC power inverter will be 95%.

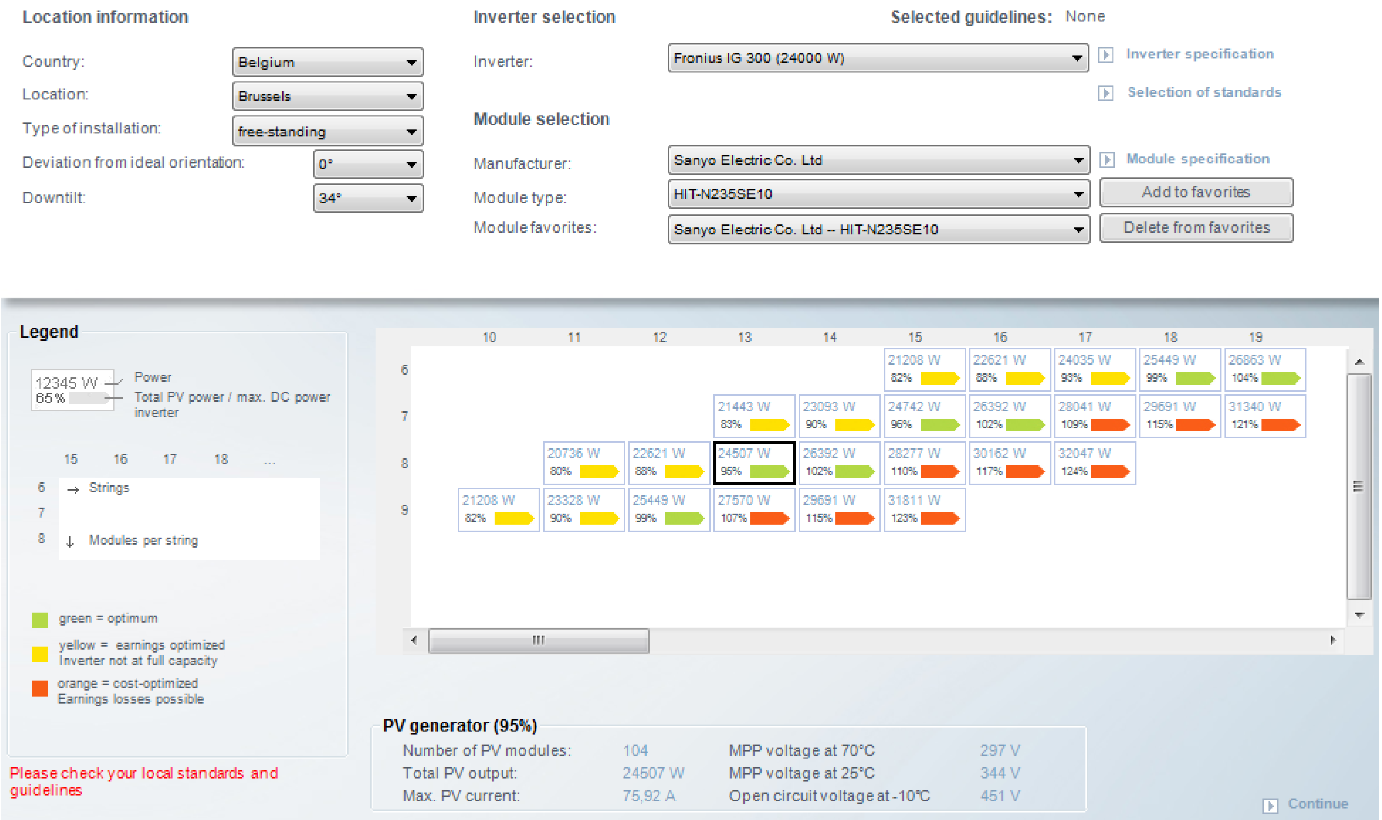


Figure 31: Configuration of the panels

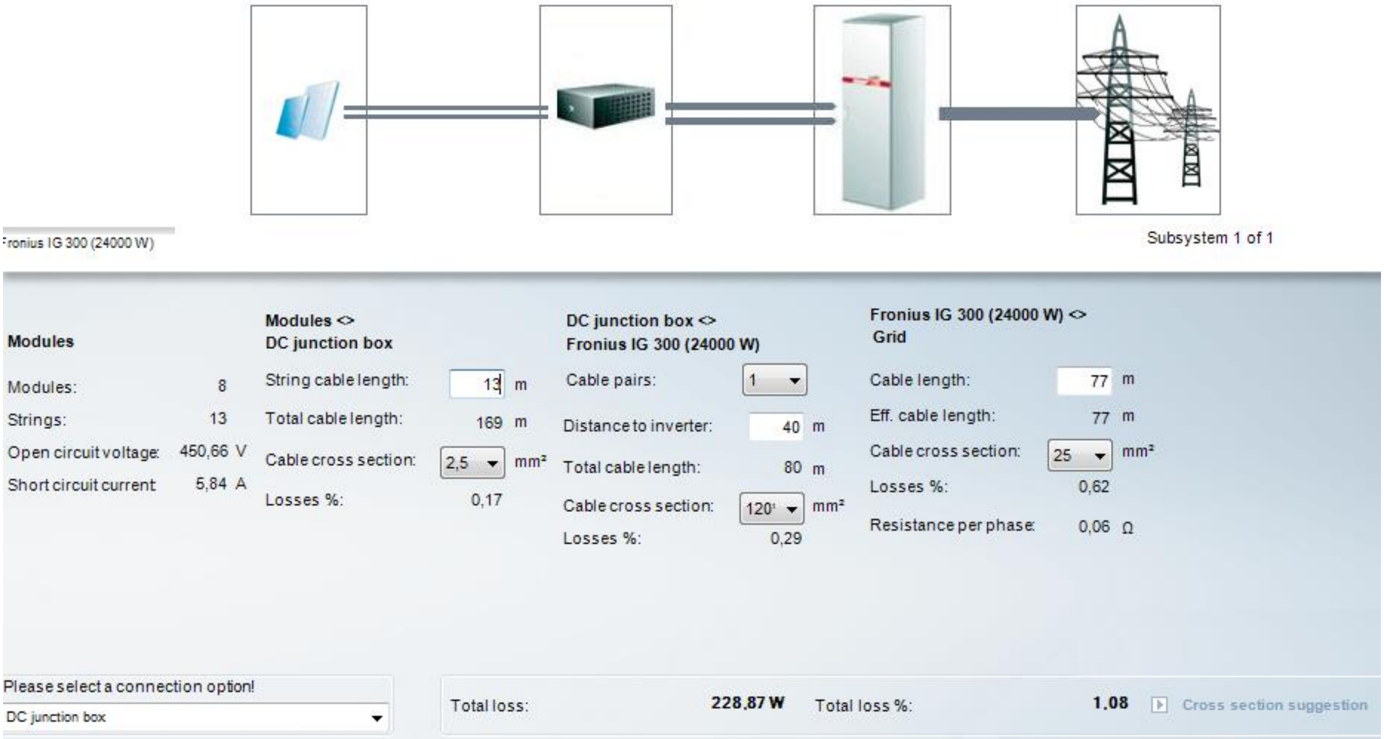


Figure 32: Configuration of the cables

- String cable length has been set to 13 meters:8·length of panel (1.58 m) = 12.64 m ≈ 13m
- The distance to the inverter has been set to 40 meters: A good place for placing the inverter might be the any of the two stairs of the southern façade, in order to install this inverters in the same place of others.
- The cable length to the main electrical grid has been set to 77 meters, which is the distance from the inverter to the point in the northern façade.

The area of each cable has been set automatically by the software, as shown in the screenshot above. By using these given areas, the total energy loss will be 228.67 Watt, 1.08% of the whole installation.

4. Atrium:

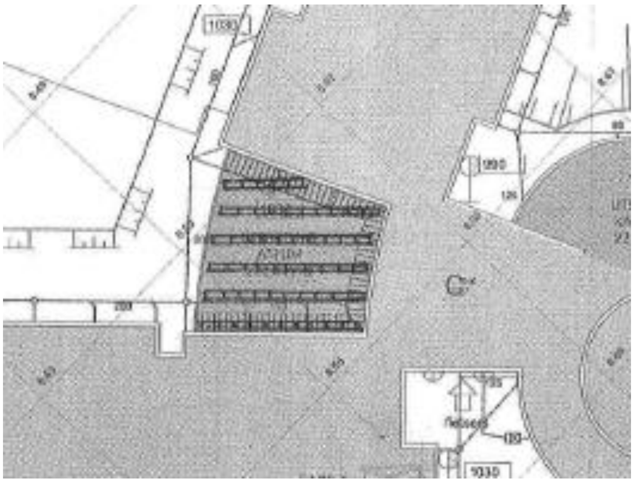


Figure 33: Final location of monocrystalline panels in atrium

There are 222 m^2 available in the Atrium. In 222 m^2 there can be placed 55 Sanyo monocrystalline panels. Regarding the connection of the panels, there will be 7 strings with 8 modules each string.

For this configuration, converter Fronius IG Plus 150 (12000 Watt) will be used.

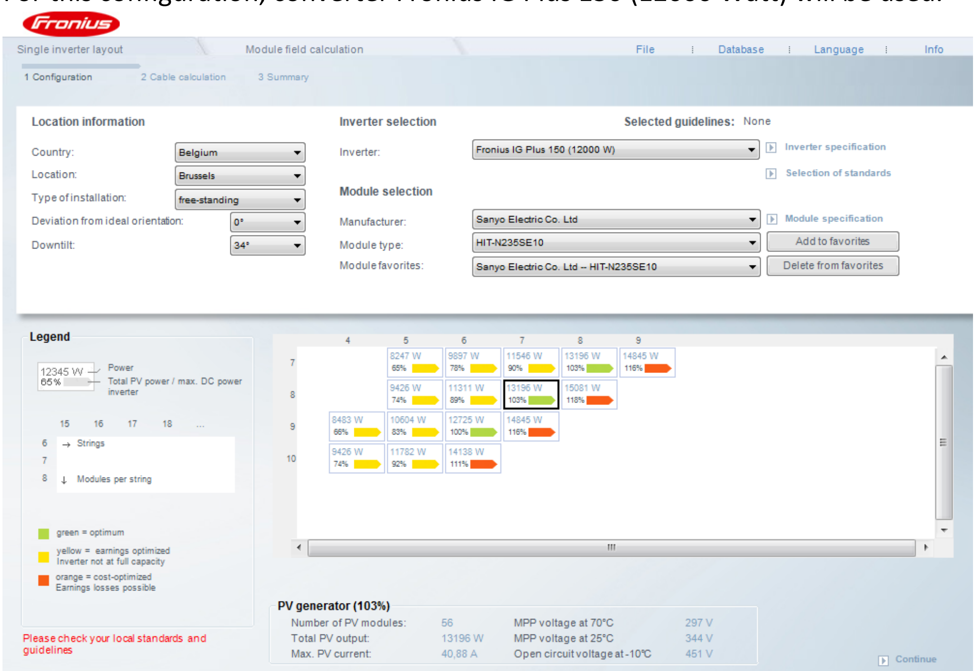


Figure 34: Configuration of the panels

In this case, the total power of this part of installation is going to be 13196 Watt, and the total PV power / max. DC power inverter will be 100%.

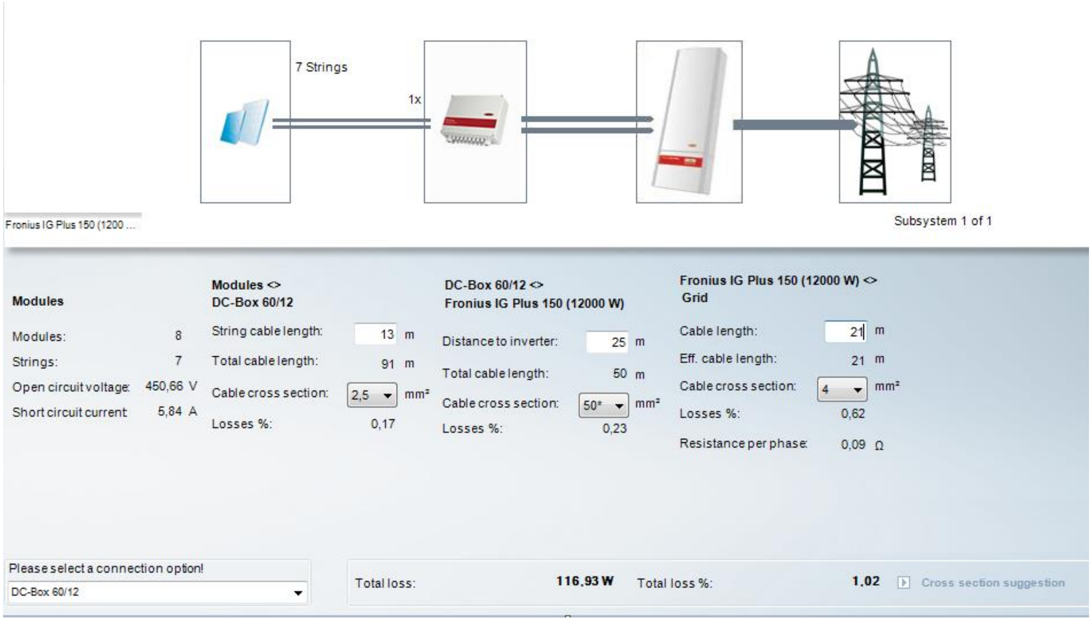


Figure 35: Configuration of the panels

- String cable length has been set to 13 meters:8·length of panel (1.58 m) = 12.64 m ≈ 13m
- The distance to the inverter has been set to 25 meters: A good place for placing the inverter might be the ”laagspaningsboard”, close to the atrium in the second floor. In this case, the panel that is further is at 25 meters.
- The cable length to the main electrical grid has been set to 21 meters, which is the distance from the atrium to the point in the northern façade.

The area of each has been set automatically by the software, as shown in the screenshot above. By using these given areas, the total energy loss will be 116.93 Watt, 1.02% of the whole installation.

5. Building B and parking for visitors:

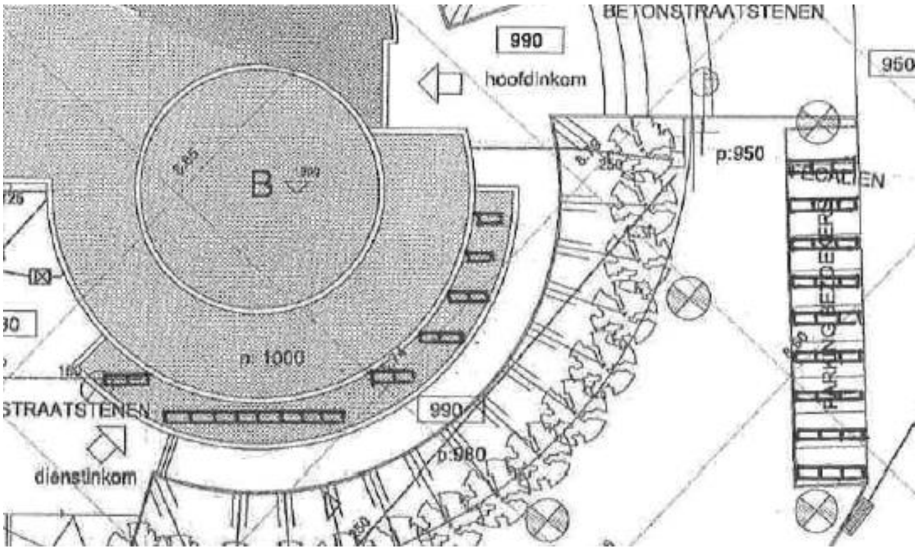


Figure 36: Final location of monocrystalline panels in atrium

There are 185 m^2 available with the surface in building B's roof and the visitors parking.

In this available surface there is the possibility to place 45 panels. For this 45 panels will be used the Fronius IG Plus 120 (10000 Watt).

The configuration that this inverter allows, in order to get a high efficiency, will be 6 strings, with 6 modules each string. This will be the maximum that the inverter will endure. In this case we will place 45 panels, and the maximum will be 45, so there will not be any problem.

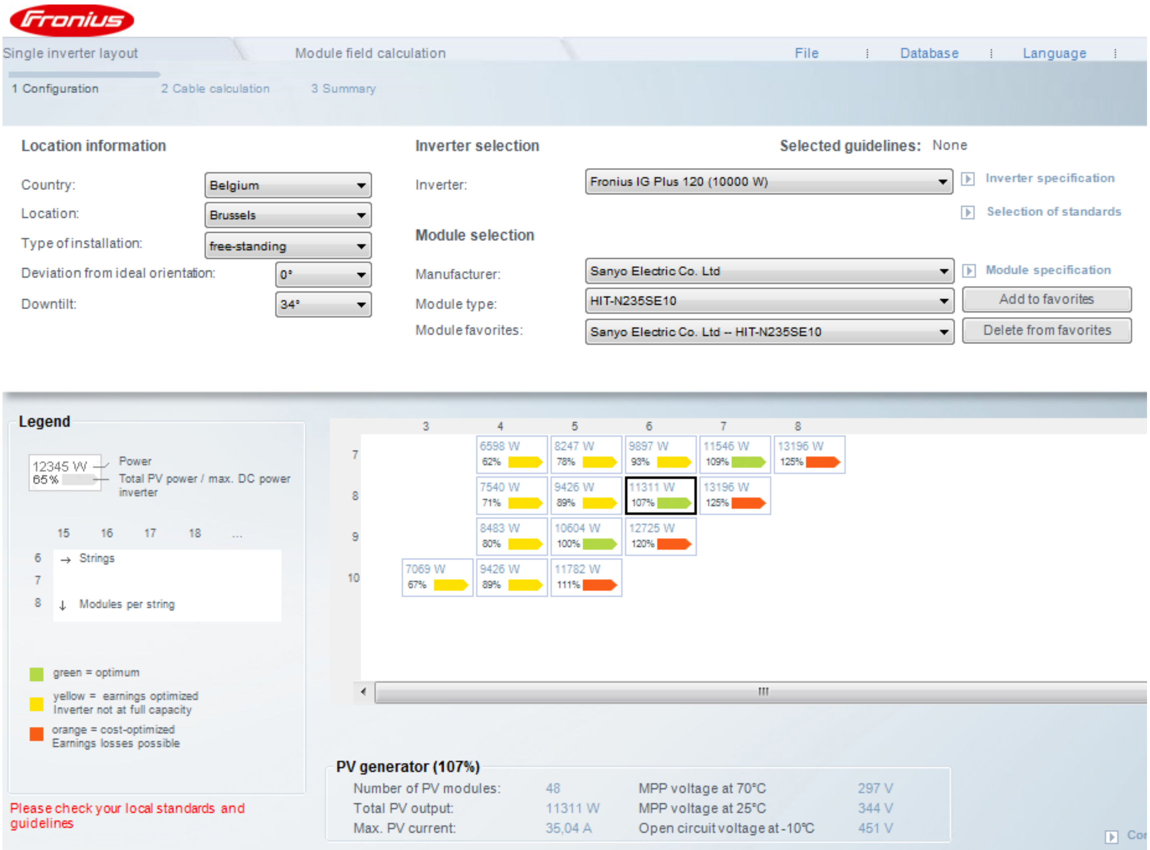


Figure 37: Configuration of the panels

In this case, the power will be 11311 Watt, and the total PV power / max. DC power inverter will be 107%.

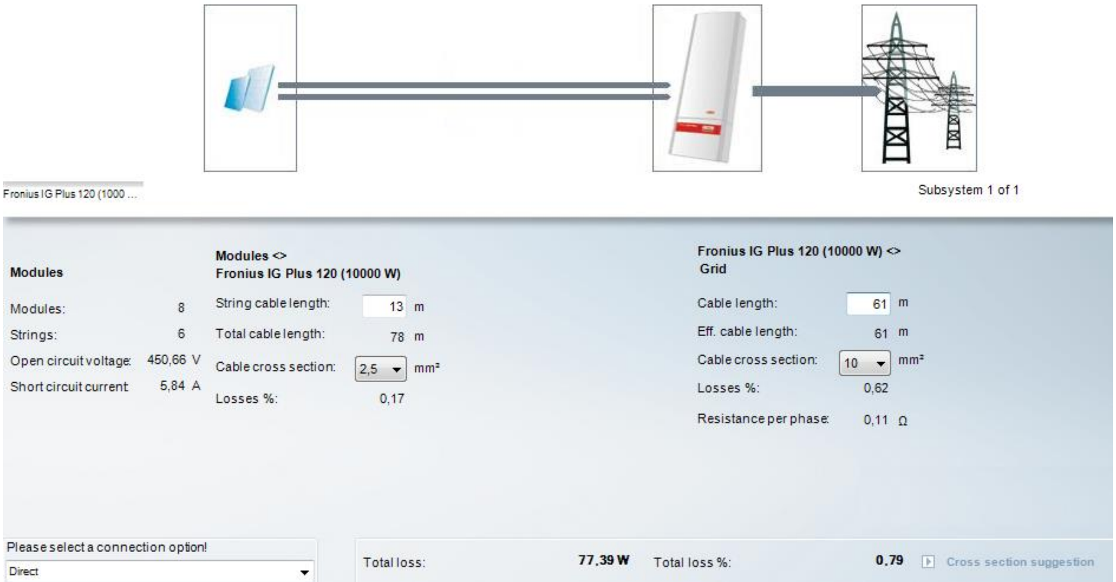


Figure 38: Configuration of the panels

- String cable length has been set to 13 meters:8·length of panel (1.58 m) = 12.64 m ≈ 13m
- The cable length to the main electrical grid has been set to 61 meters, which is the distance to the point of the electric grid cable that is nearest.
- A good place to place the inverter would be in “traphal”, close to the main entrance.

The area of each has been set automatically by the software, as shown in the screenshot above. By using these given areas, the total energy loss will be 77.39 Watt, 0.79% of the whole installation.

6. <u>Big car park:</u>

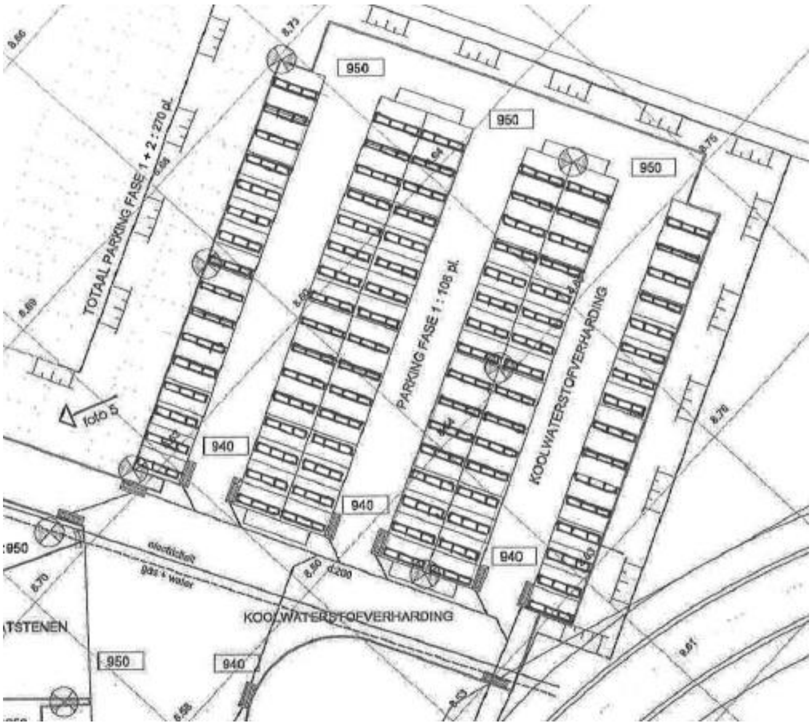


Figure 39: Final location of monocrystalline panels in big parking

There are 1215 m^2 available for placing panels in the big car park. Taking into account the size of the panels and the minimum distance between two rows, the total amount of panels that can be placed is 288.

With this, the configuration that will be used is 29 strings of 10 modules each. With this converter Fronius CL 60.0 (60000 Watt) can be used. The power of the installation would be 68336 Watt and the total PV power / max. DC power inverter will be 106%.

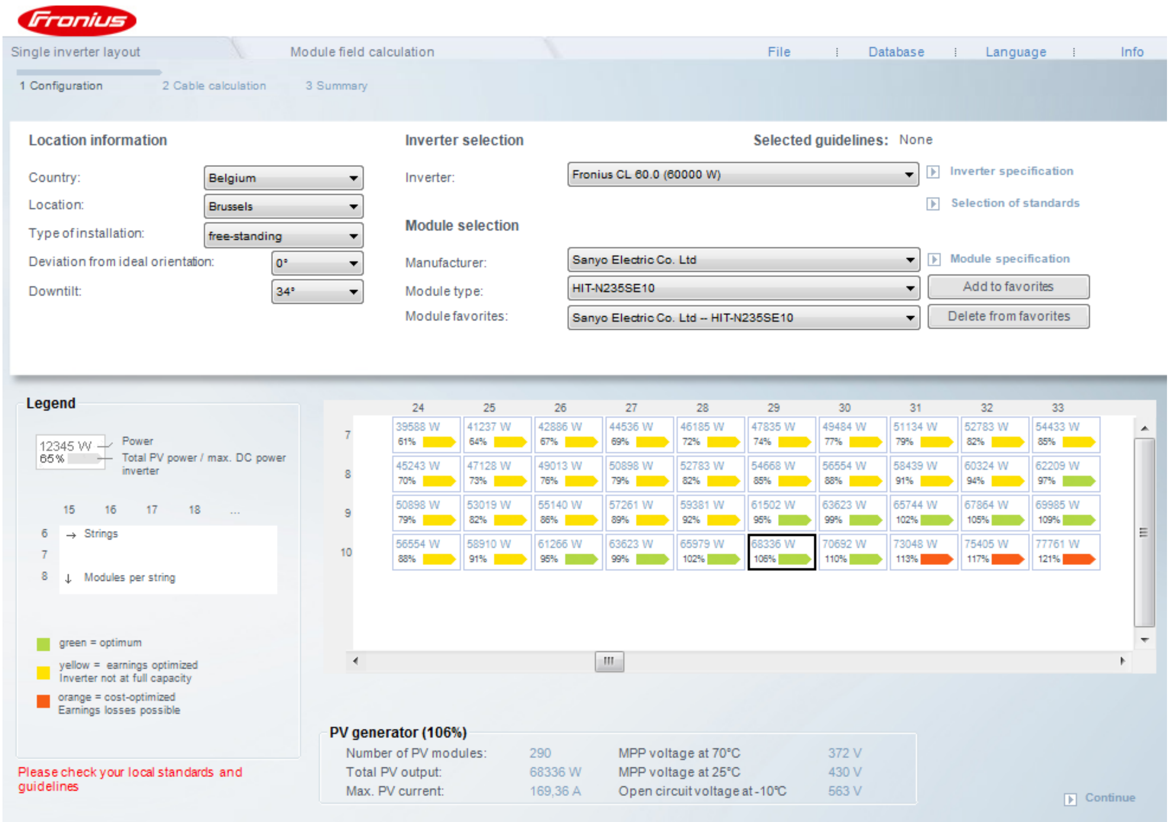


Figure 40: Configuration of the panels

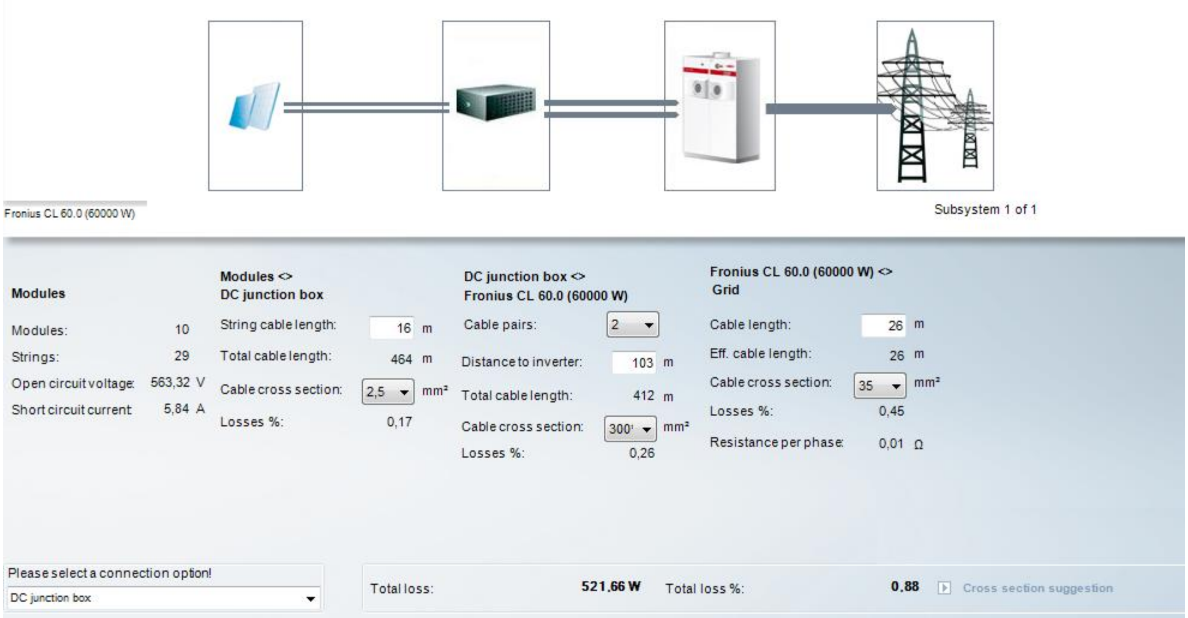


Figure 41: Configuration of the cables

- String cable length has been set to 16 meters:10·length of panel (1.58 m) = 15.8 m ≈ 16m
- The distance to the inverter has been set to 103 meters: A good place for placing the inverter might be the " traphal", close to the main entrance in the second floor. In this case.
- The cable length to the main electrical grid has been set to 26 meters, which is the distance from the atrium to the point of the cable that is nearest.

With this configuration and cable cross section, the total loss will be 521.66 Watt, 0.88% of total loss.

POLYCRYSTALLINE PANEL

Now, the placement and connection-configuration of **polycrystalline** solar panels, and with this, we will make the choice of the inverter will be analysed.

Regarding the polycrystalline panels, the module SolarWorld SW 250 poly has been chosen. This has been chosen because it is, among the polycrystalline panels, the best for placing in this area.

1. <u>Southern façade:</u>

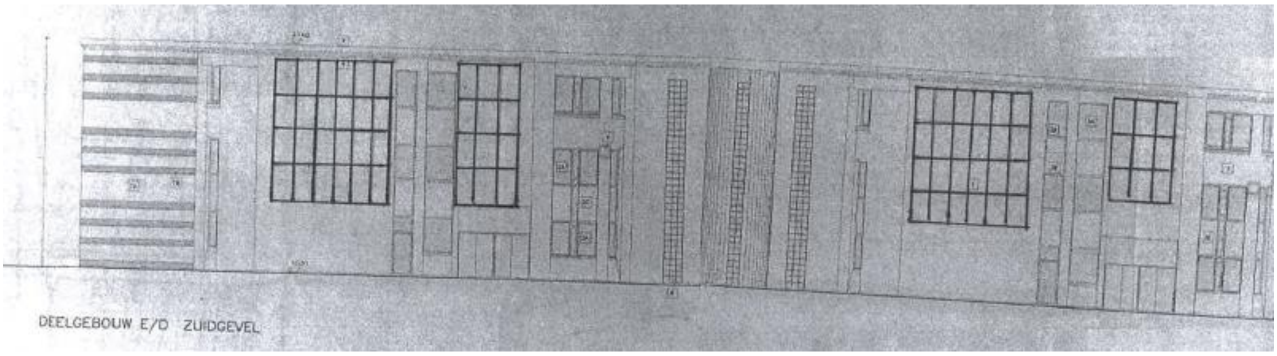


Figure 42: Final location of polycrystalline panels in southern façade

In the southern façade there are 117 m^2 available for placing the panels, and as the size of the solar panel is known, there can be placed up to 69 panels.

The connection-configuration of the panel will consist of 6 strings, with 12 modules each string.

For this configuration, the chosen inverter will be a Fronius Symo 17.5-3-M (17500 Watt).

The power will be 18007 Watt, and the total PV power / max. DC power inverter will be 96%.

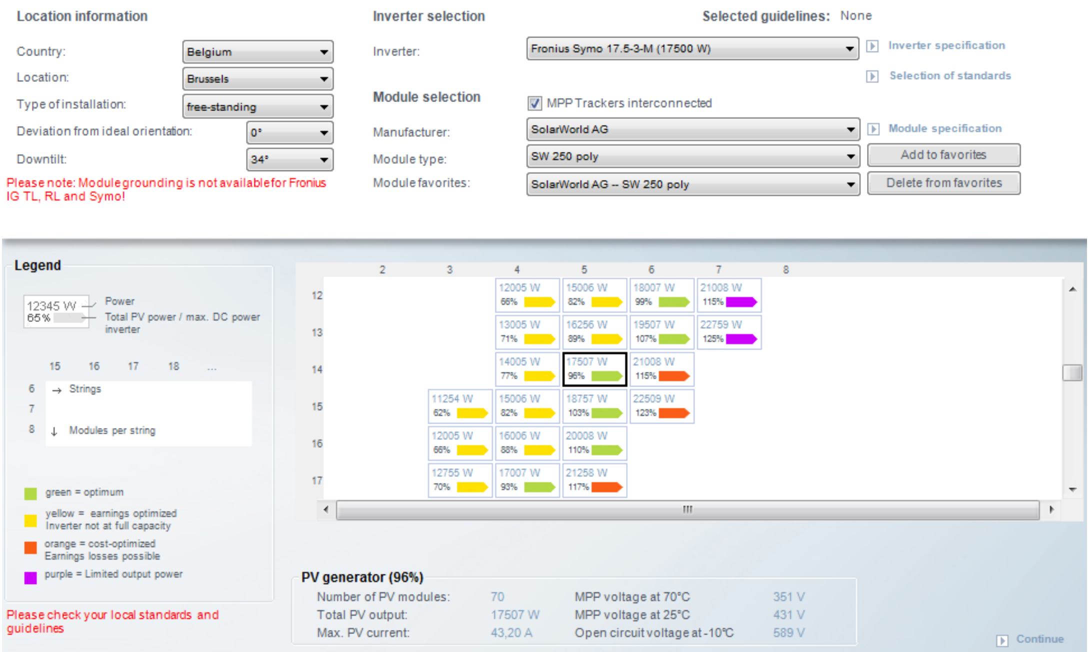


Figure 43: Configuration of the panels

Figure 44: Configuration of the cables

- String cable length has been set to 21 meters: 12·length of panel (1.675 m) = 20.1 m ≈ 21 m.
- The cable length to the main electrical grid has been set to 77 meters, which is the distance to the point of the electric grid cable that is closest, in the northern façade.
- A good place to place the inverter would be in stairs of the southern façade because it is a closed area, with not much people transit, and the sound will not disturb.

With this configuration and cable cross section, the total loss will be 117.19 Watt, 0.82% of total loss.

2. Fields outside, which will be able to use:

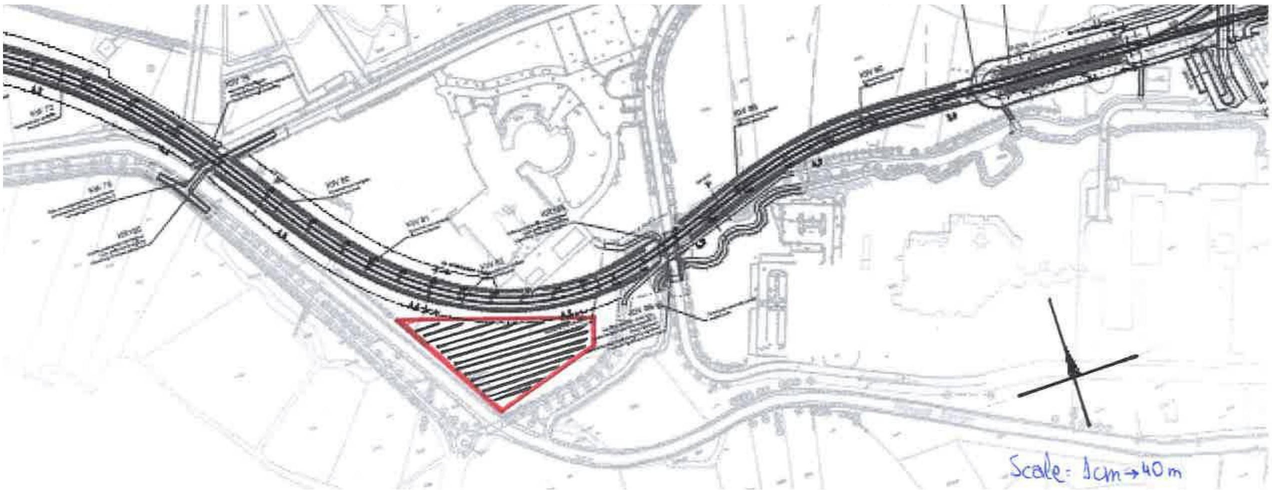


Figure 45: Final location of polycrystalline panels in outern field

	On map	Real scale
1st row	7 mm	11 panels
2nd row	10 mm	15 panels
3rd row	13 mm	20 panels
4th row	17 mm	26 panels
5th row	20 mm	31 panels
6th row	23 mm	36 panels
7th row	23 mm	36 panels
8th row	22 mm	34 panels
9th row	18 mm	28 panels
10th row	15 mm	23 panels
11th row	11 mm	17 panels
12th row	7 mm	11 panels
13th row	4 mm	6 panels

Table. Nº 8: Relation of panels size

In this outern field there are 3081.33 m^2 that can be used for placing panels. In this surface can be placed a total amount of 294 SolarWorld polycrystalline panels, taking into account their size and distance between each row.

The configuration that will be used for these panels will be 14 strings with 8 panels per string.

For this configuration the best inverter is going to be Fronius Agilo 75.0-3 (75000 Watt). It has to be said that the inverter will notwork in full efficiency point because it has been designed for a little bit more of power. Even if it will not work on it's full capacity (it will be overdimensionated), it will work on 94% of it's capacity, which is quite high.

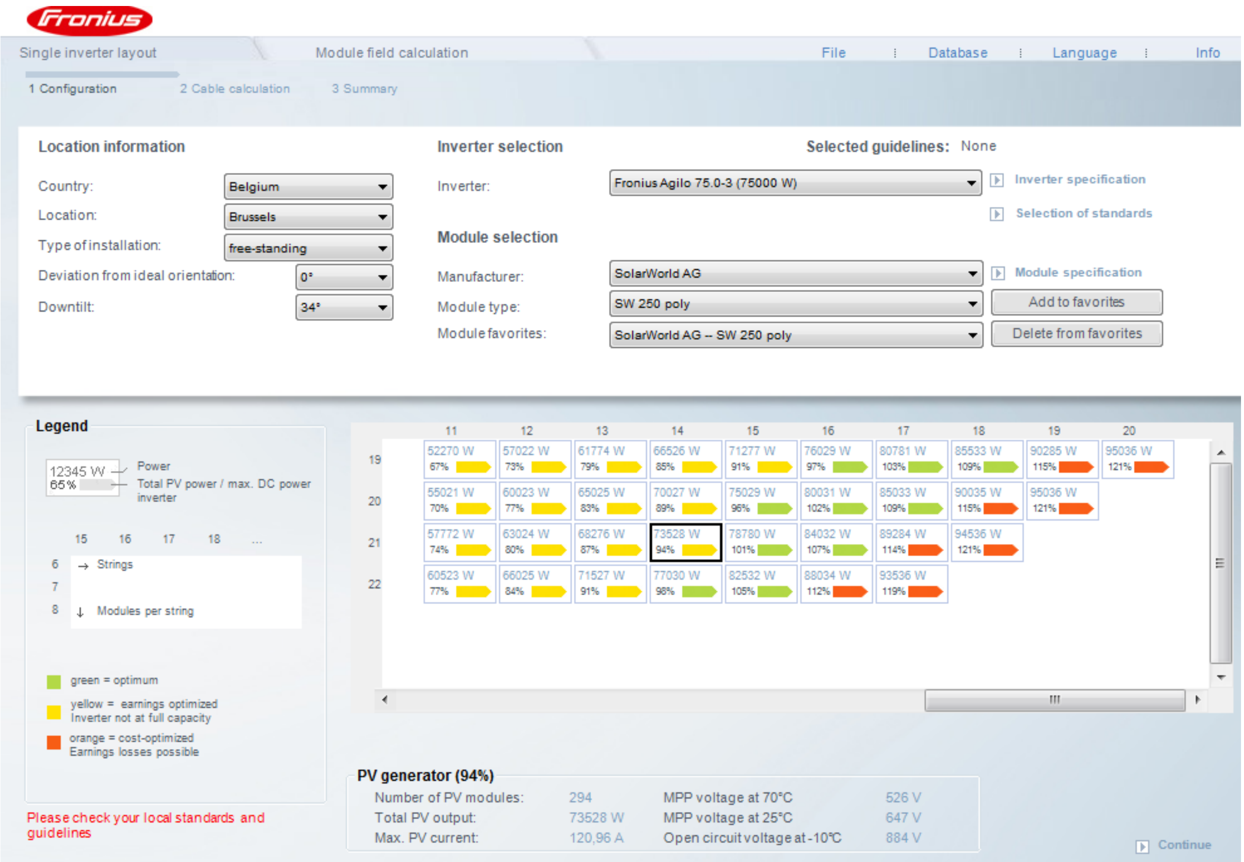


Figure 46: Configuration of the panels

As the picture above shows, the inverter will not work in full capacity, but it will be almost there, so it is not such a bad option.

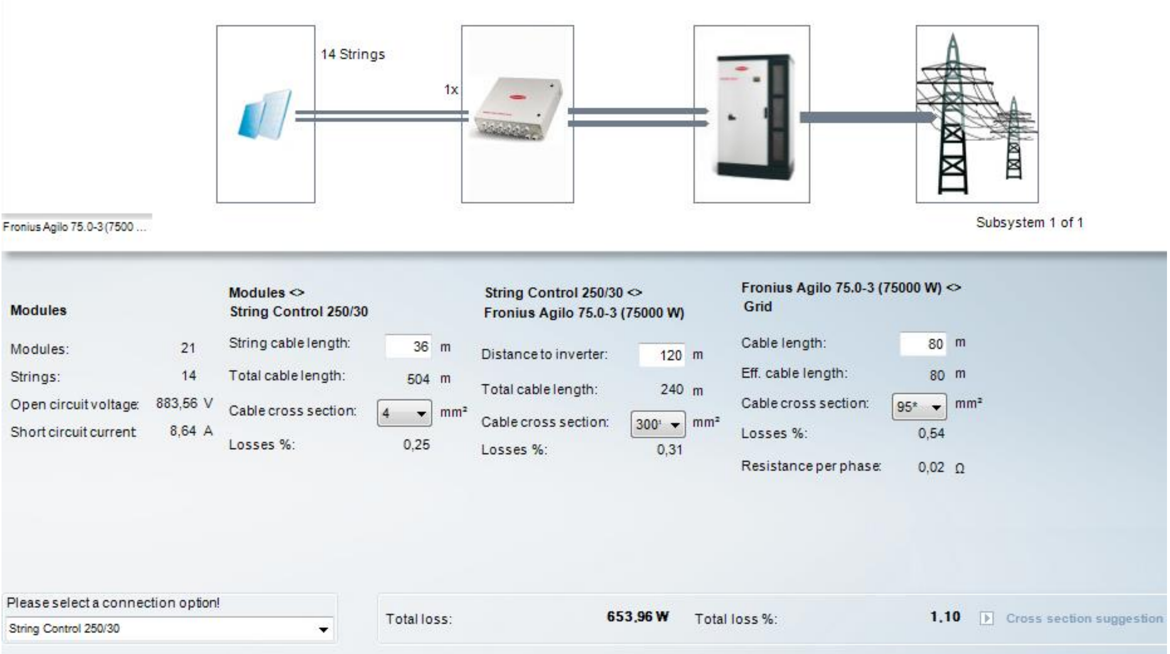


Figure 47: Configuration of the cables

- String cable length has been set to 36 meters: 21·length of panel (1.675 m) = 35.17 m ≈ 36 m.
- The cable length to the main electrical grid has been set to 80 meters, which is the distance to the point of the electric grid cable that is closest, in the northern façade.
- The distance to the inverter has been set to 120 meters: A good place for placing the inverter would be in stairs of the southern façade because it is a closed area, with not much people transit, and the sound will not disturb. Here, there is the possibility to join most inverters together.

3. <u>Extra available roof surface + bicycle park roof:</u>

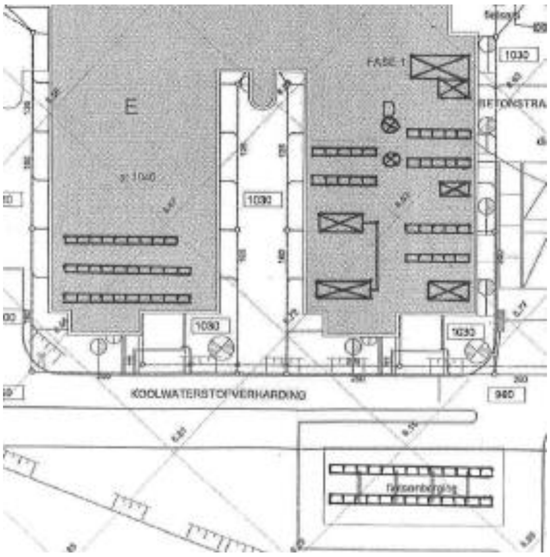


Figure 48: Final location of polycrystalline panels in bycicle parking + extra roof

The available surface in this area is 228.06 + 188 = 416.06 m^2. In this area, there can be placed up to 125 panels, taking into account their size and minimum distance between panels. For this panels, the configuration of the connection between them is going to be 13 strings with 10 modules each string.

For invert the energy produced, it will be used Fronius Symo 20.0-3-M (20000 Watt). The power will be 21258 Watt and the total PV power / max. DC power inverter will be 102%.

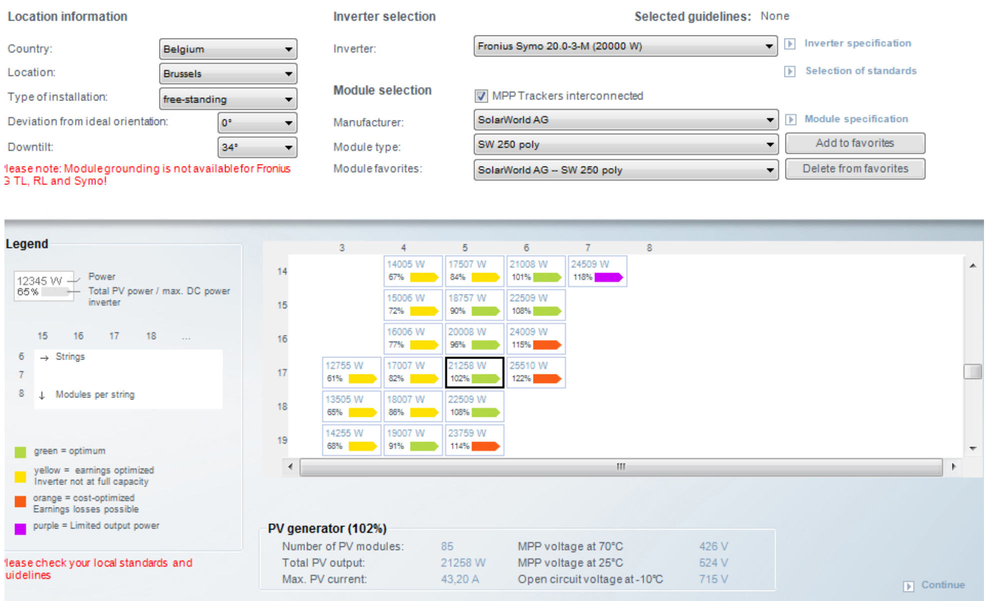


Figure 49: Configuration of the panels

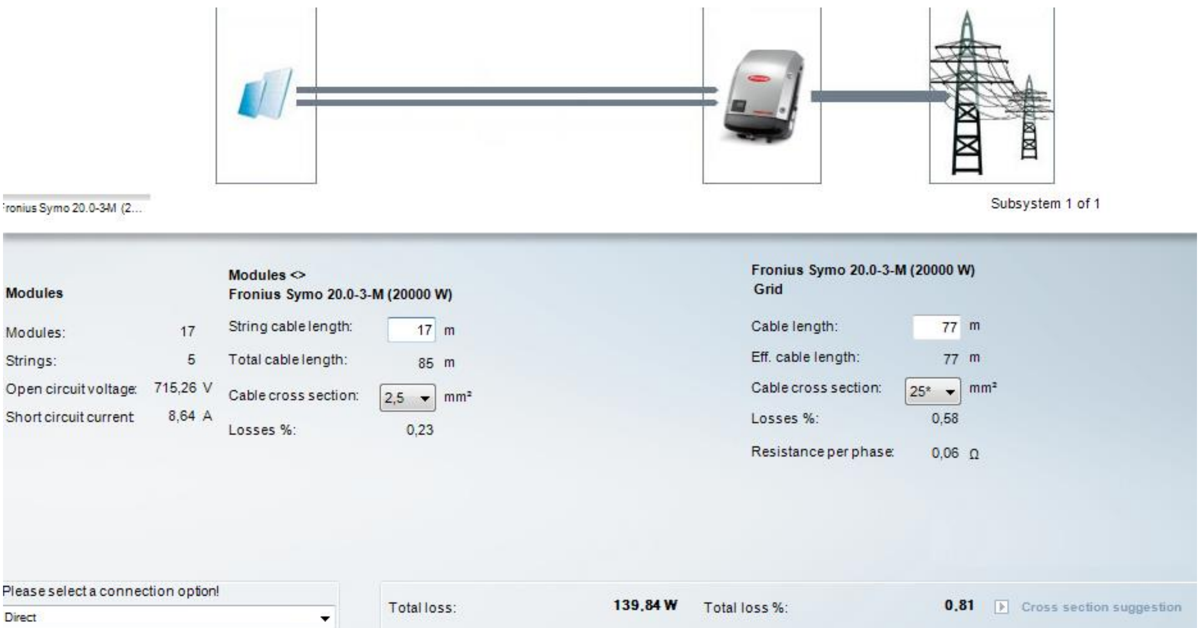


Figure 50: Configuration of the cables

- String cable length has been set to 17 meters: 10·length of panel (1.675 m) = 16.75 m ≈ 17 m.
- The cable length to the main electrical grid has been set to 77 meters, which is the distance to the point of the electric grid cable that is closest, in the northern façade.

With this configuration, the total loss will be 139.84 Watt, 0.81% of the total.

4. Atrium:

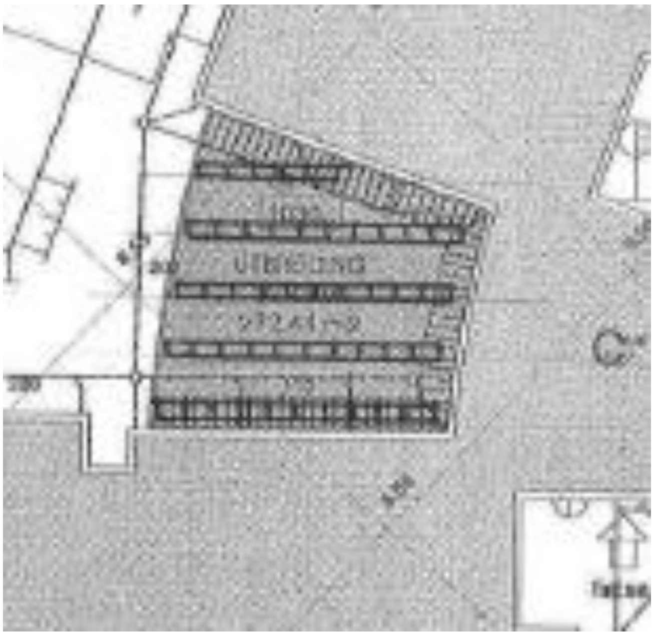


Figure 51: Final location of polycrystalline panels in atrium

In the atrium, there are 222 m^2 than can be used for placing solar panels. In this area, the amount of panels that can be placed, taking into account the size and minimum distance between each panel, will be 45 panels.

For this number of panels, the suitable configuration will be 4 strings with 12 modules each.

Therefore, the inverter that will be used for this will be the Fronius IG Plus 150 (12000 Watt).

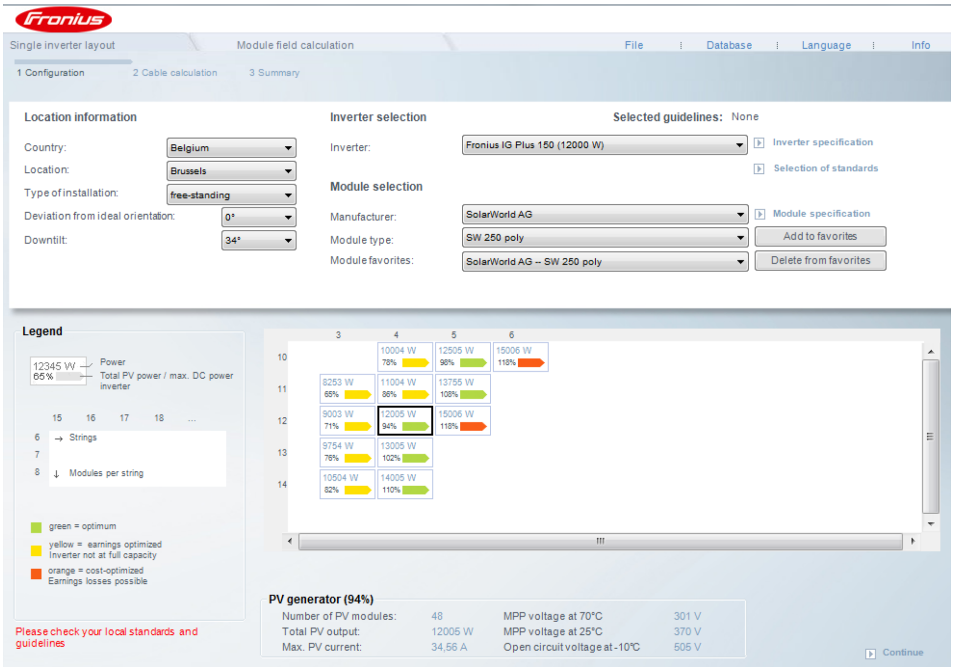


Figure 52: Configuration of the panels

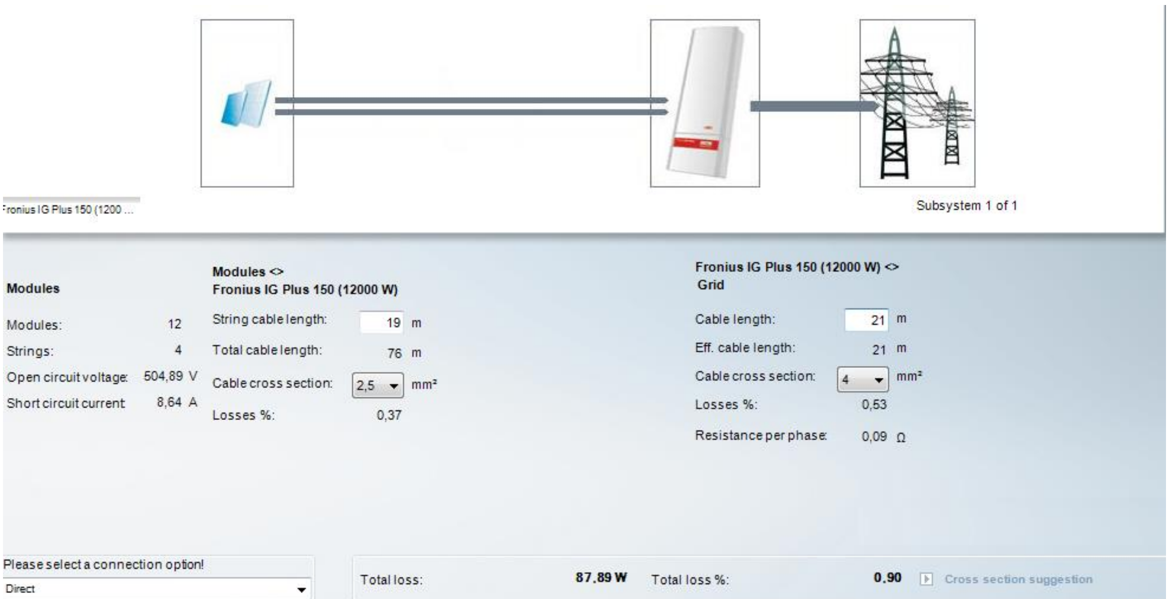


Figure 53: Configuration of the cables

- String cable length has been set to 19 meters:11·length of panel (1.58 m) = 18.43 m ≈ 19 m
- The cable length to the main electrical grid has been set to 21 meters, which is the distance to the point of the electric grid cable that is nearest.

A good place to place the inverter would be in "laagspaningsboard", close to the atrium.

With this configuration, the total loss will be 96.32 Watt, 0.86% of the total power.

5. <u>Building B and parking for visitors:</u>

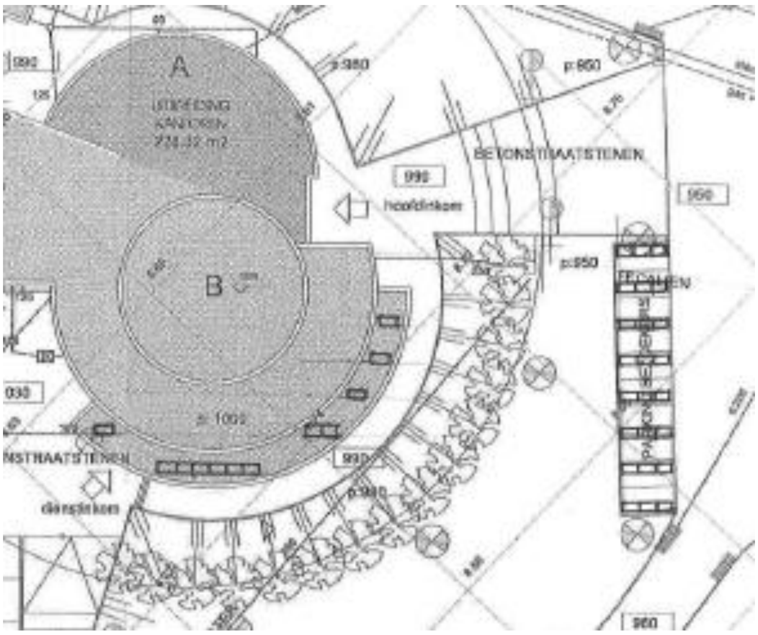


Figure 54: Final location of polycrystalline panels in visitors parking

Even if both areas are separated, are close enough for summing all together is one inverter. The available area here is 73 + 112 m^2 = 185 m^2. Here can be placed 36 panels.

The configuration for these panels will be 3 strings of 12 panels each. For this, the best inverter is Fronius IG Plus 100-3 (8000 Watt).

The power will be 9003 Watt and the total PV power / max. DC power inverter will be 107%.

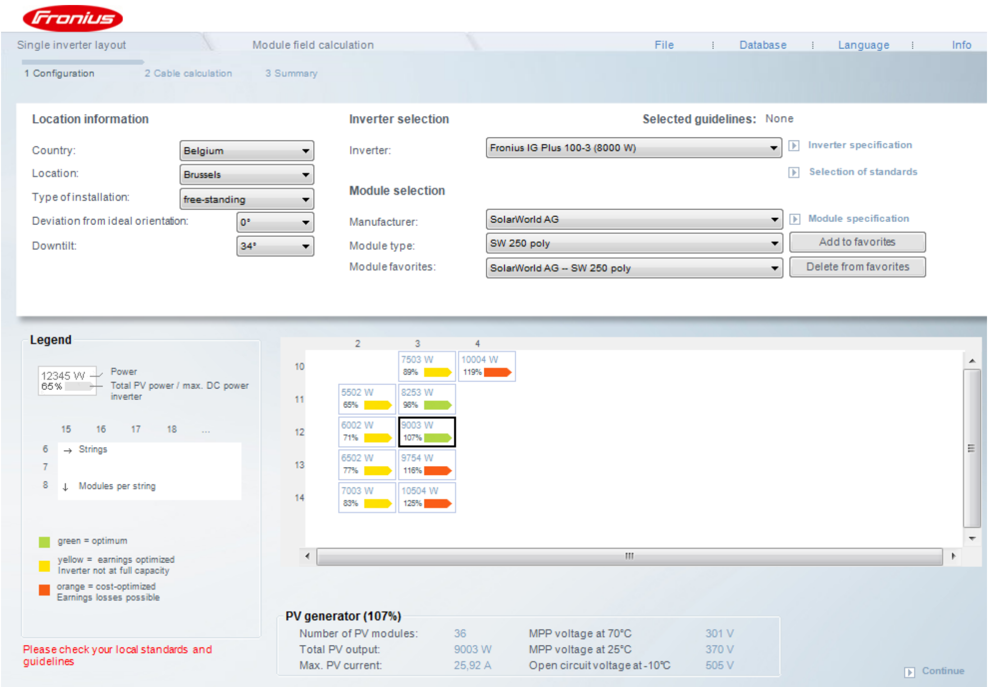


Figure 55: Configuration of the panels

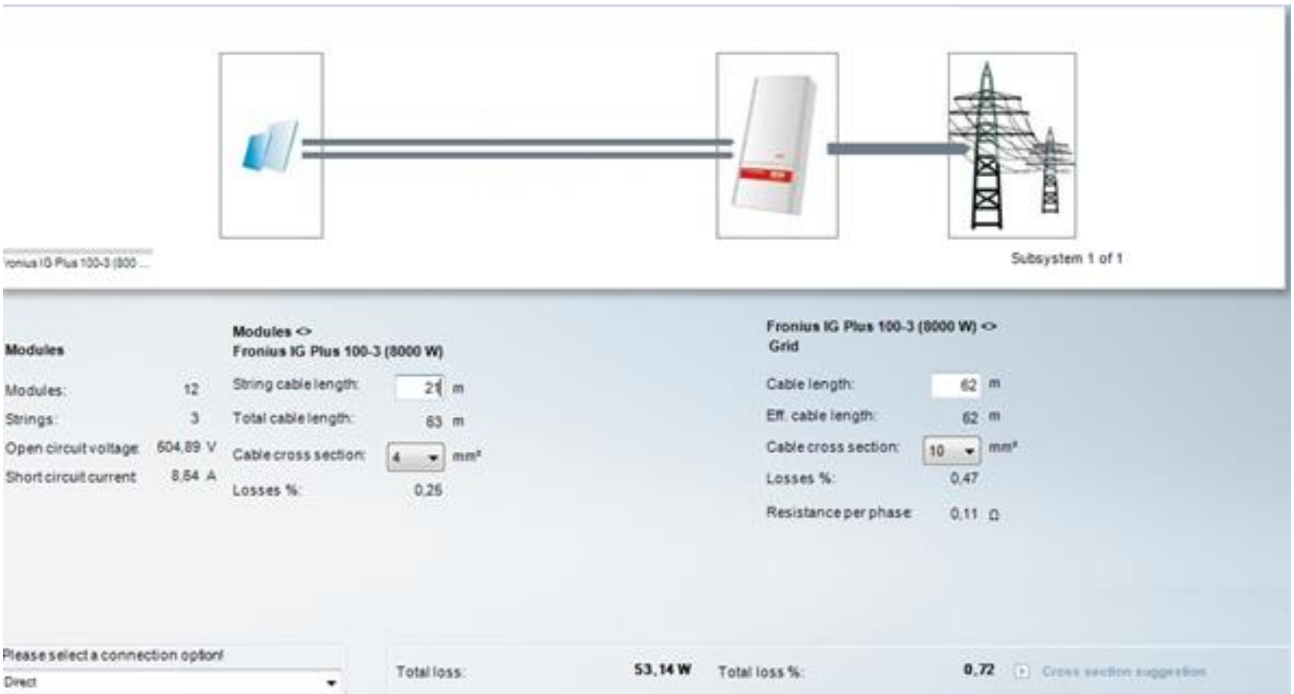


Figure 56: Configuration of the cables

- String cable length has been set to 21 meters: 12·length of panel (1.675 m) = 20.1 m ≈ 21 m.
- The cable length to the main electrical grid has been set to 62 meters, which is the distance to the point of the electric grid cable that is closest, in the northern façade.
- A good place to place the inverter would be in "traphal", close to the main entrance, with not much people transit, and the sound will not disturb.

6. <u>Big car park:</u>

Figure 57: Final location of polycrystalline panels in big parking

In the big parking, there are 1215 m^2 than can be used for placing solar panels. In this area, the amount of panels that can be placed, taking into account the size and minimum distance between each panel, will be 234 panels.

For this number of panels, the suitable configuration will be 17 strings with 14 modules each.

Therefore, the inverter that will be used for this will be the Fronius CL 60.0 (60000 Watt).

In this case, the inverter will be a bit over dimensioned because it will not work at its whole capacity. Nevertheless, it will work at 92 % of its capacity, which is not that bad.

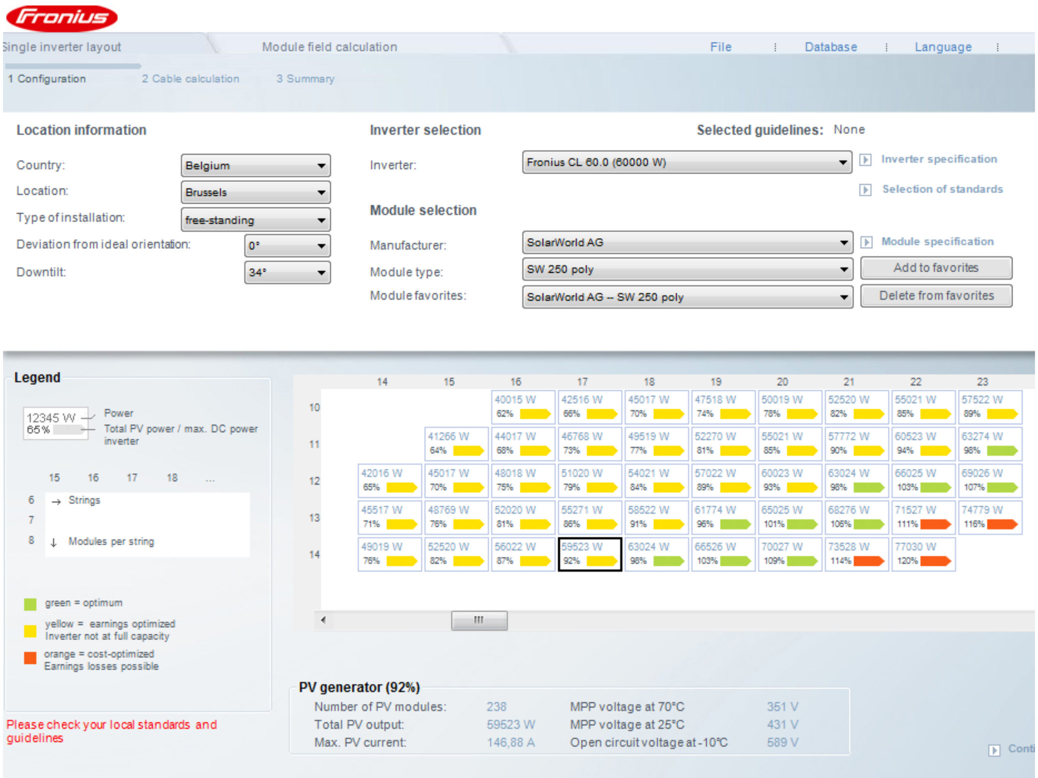


Figure 58: Configuration of the panels

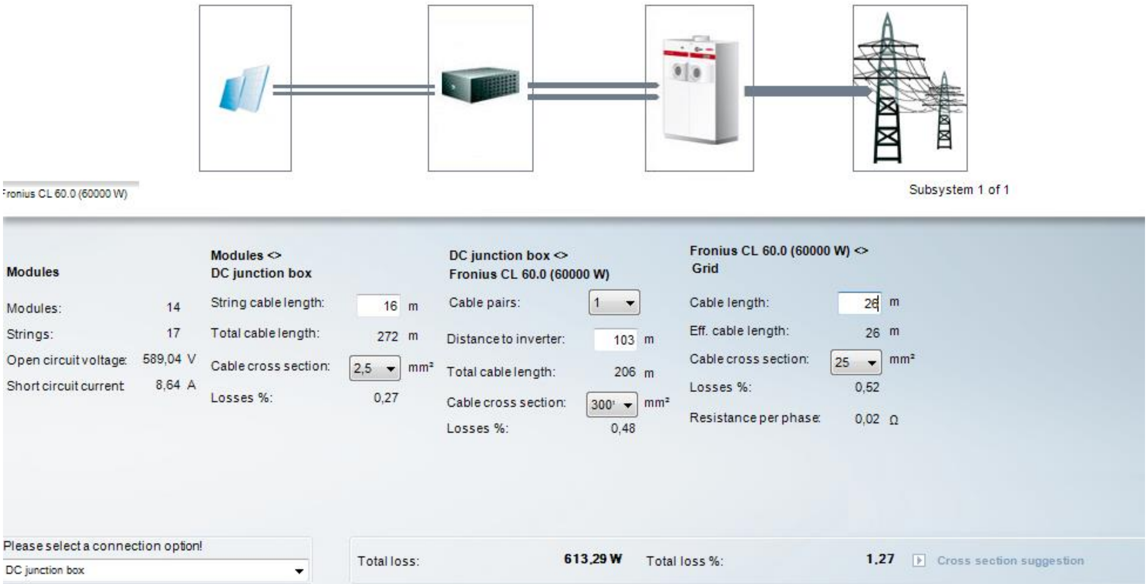


Figure 59: Configuration of the cables

- String cable length has been set to 16 meters:10·length of panel (1.58 m) = 15.8 m ≈ 16m
- The distance to the inverter has been set to 103 meters: A good place for placing the inverter might be the ”traphal”, close to the main entrance in the second floor. In this case.
- The cable length to the main electrical grid has been set to 26 meters, which is the distance from the atrium to the point of the cable that is nearest.

With this configuration and cable cross section, the total loss will be 613.29 Watt, 1.27% of total loss.

Professional Bachelor Electromechanics

PVSYST SOFTWARE

MONOCRYSTALLINE PANEL

1. <u>Southern façade:</u>

In the southern façade, the available area is 117 m^2 so there can be placed 92 panels. For these 92 panels, Mastervolt SunMaster QS 6400 Max-I inverter has been chosen. 4 of these inverters will be needed because of their power: In order not to over dimensionate or under dimensionate the inverters, 4 inverters of 5.2 kW each will be needed.

Regarding the connection between the panels, PVSYST software showed this as an optimal option:
23 strings, with 4 modules in serial each string. 92 solar panels in total, encompassing 116 m^2 of the whole available surface.

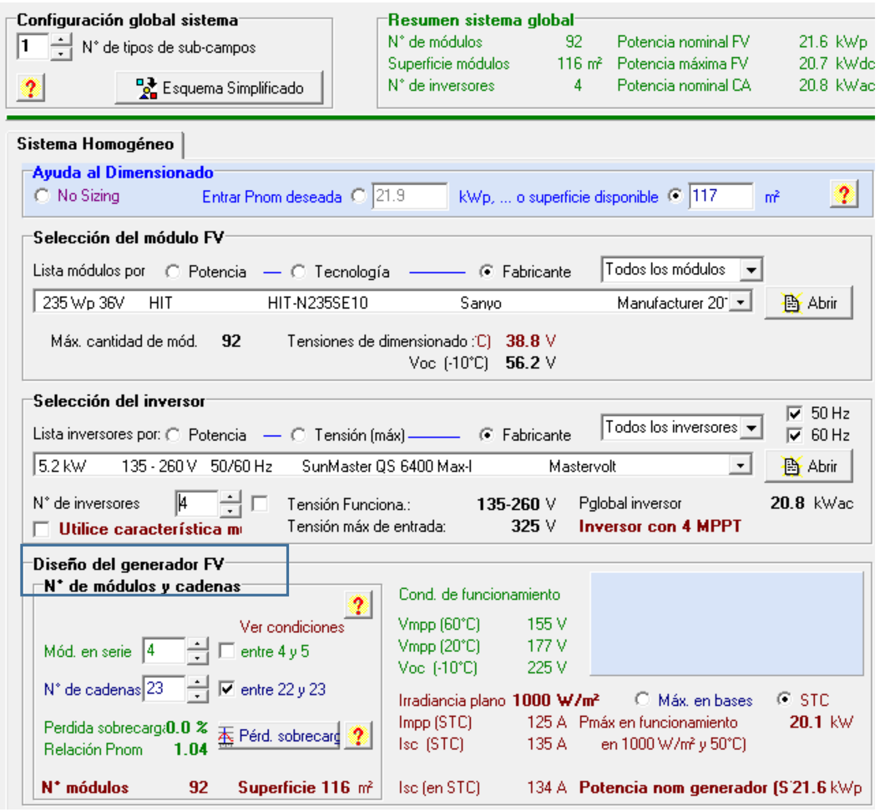


Figure 60: Configuration of panels and choice of inverter for monocrystalline panels with PVSYST software

Characteristics of inverter:

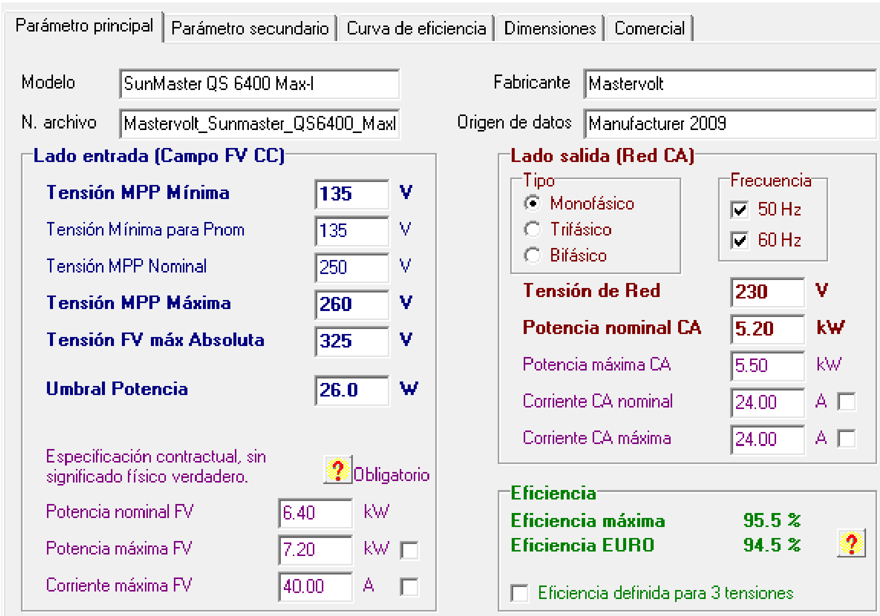


Figure 61: Characteristics of the chosen inverter

2. <u>Fields outside:</u>

In the fields outside, the available area is 3801.33 m^2 so there can be placed 548 panels.
For these 548 panels, Bonfigliogli RPS 450-120E has been chosen, of 108 kW of power. One inverter will be enough for these panels. In this case the configuration between panels will be 39 strings with 14 panels in serial per string.

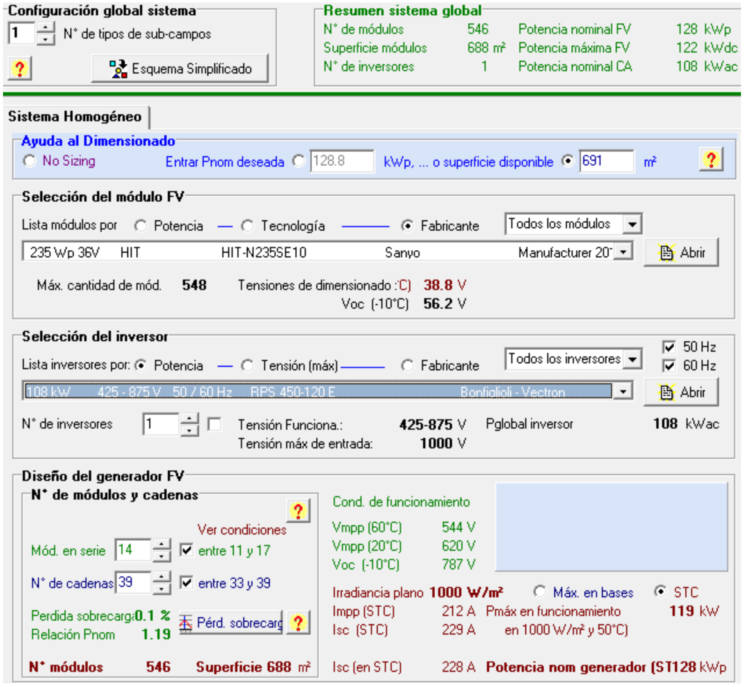


Figure 62: Configuration of panels and choice of inverter for monocrystalline panels with PVSYST software

Characteristics of inverter:

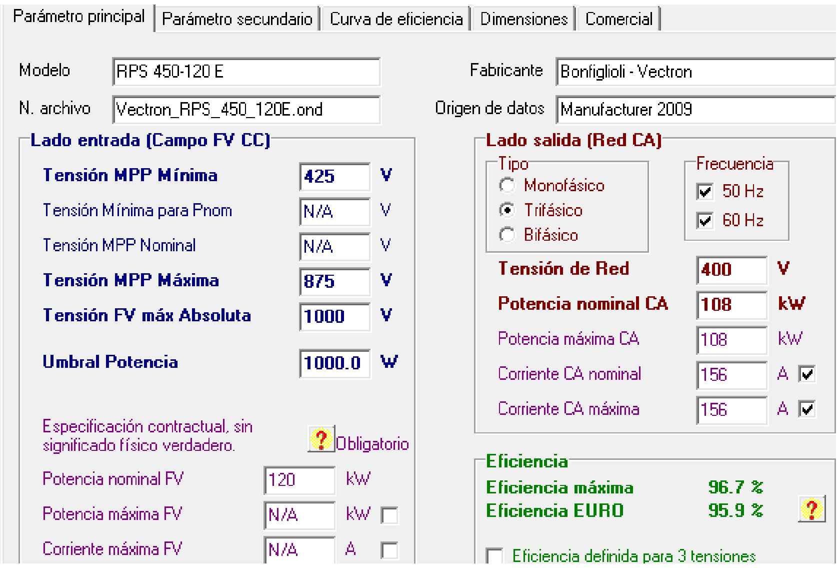


Figure 63: Characteristics of the chosen inverter

3. Extra roof + bike:

In the extra area of the roof and the bicycle parking, the available area is 416 m^2 so there can be placed 100 panels.

For these 100 panels, the inverter Layer GC-236 has been chosen, of 20 kW of power. One inverter will be enough for these panels.

This time the configuration between panels will be 10 strings with 10 panels per string, 100 modules in total, using a total surface of 126 m^2 out of 416 m^2.

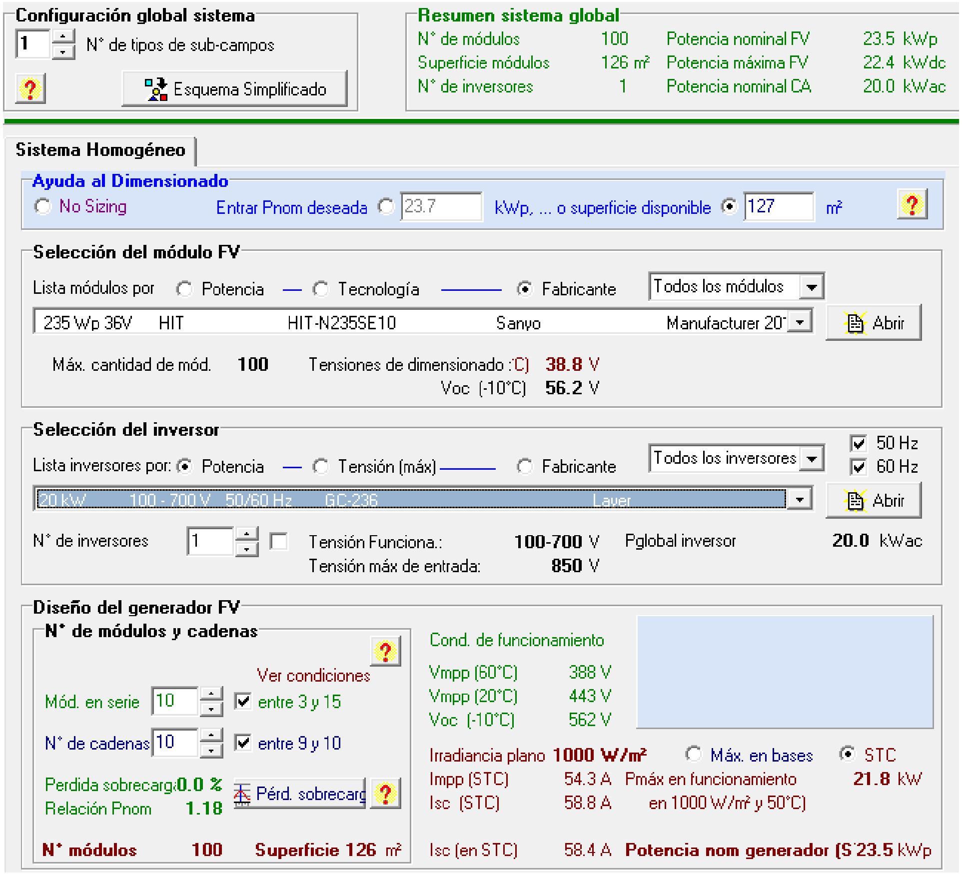


Figure 64: Configuration of panels and choice of inverter for monocrystalline panels with PVSYST software

Characteristics of inverter:

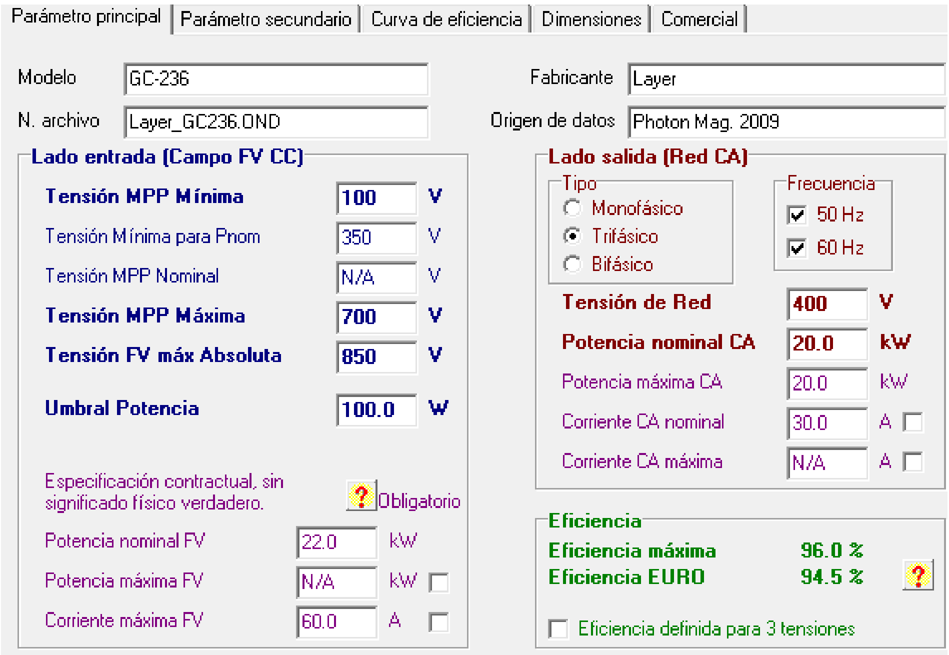


Figure 65: Characteristics of the chosen inverter

4. Atrium:

In the atrium, the available area is 222 m^2 so there can be placed 55 panels.
For these 55 panels, Mastervolt SunMaster QS 6400 Max-I has been chosen, of 5.2 kW of power. For one inverter will be enough for these panels.

Regarding the configuration, there will be 11 strings with 5 modules per string, 55 strings in total. For these panels, 69 m^2 of panels will be used, out of 222 m^2 available area.

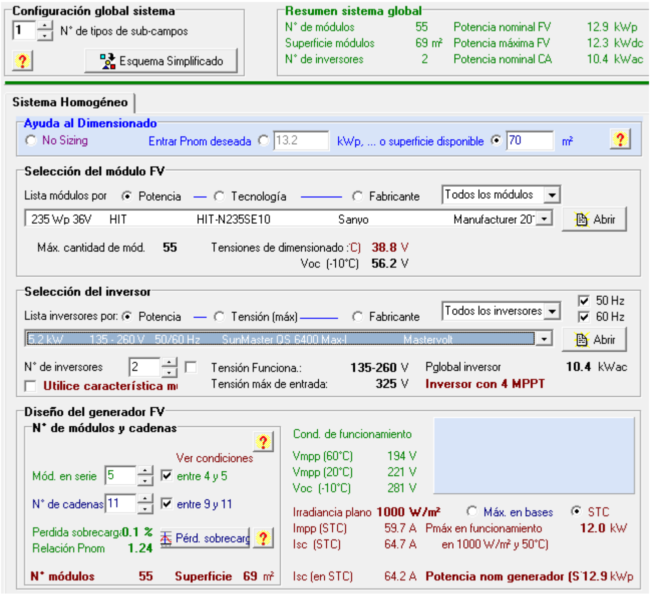


Figure 66: Configuration of panels and choice of inverter for monocrystalline panels with PVSYST software

<u>Characteristics of inverter:</u>

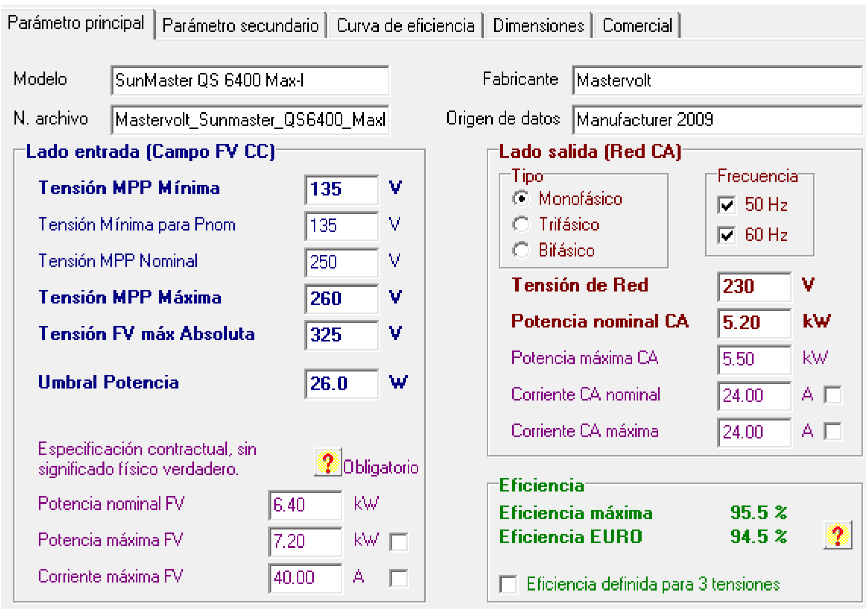


Figure 67: Characteristics of the chosen inverter

5. <u>Building B + visitors parking:</u>

In the B building and in the visitors' car park, the available area is 185 m^2 so there can be placed 45 panels.
For these 45 panels, SMA Sunny Boy 9000TL has been chosen, of 9.3 kW of power. For one inverter will be enough for these panels.

About the connection, there will be 5 strings with 9 solar panels each. The area that the panels will take will be 57 m^2.

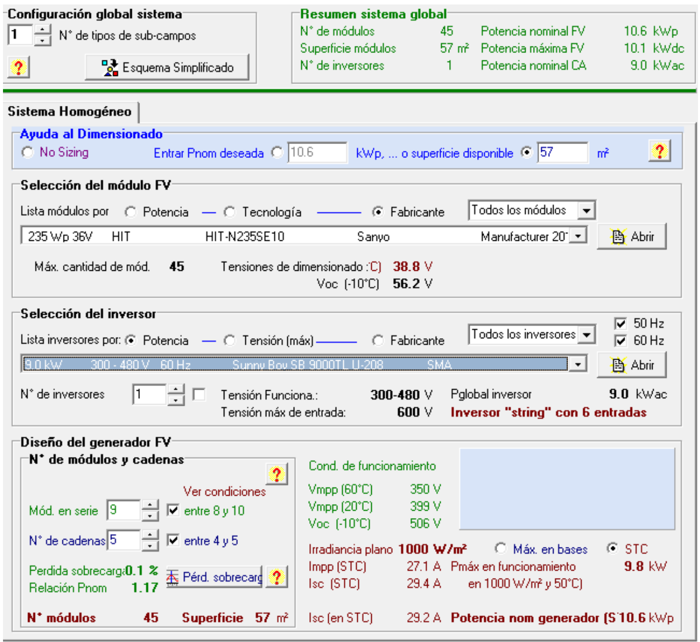


Figure 68: Configuration of panels and choice of inverter for monocrystalline panels with PVSYST software

Characteristics of inverter:

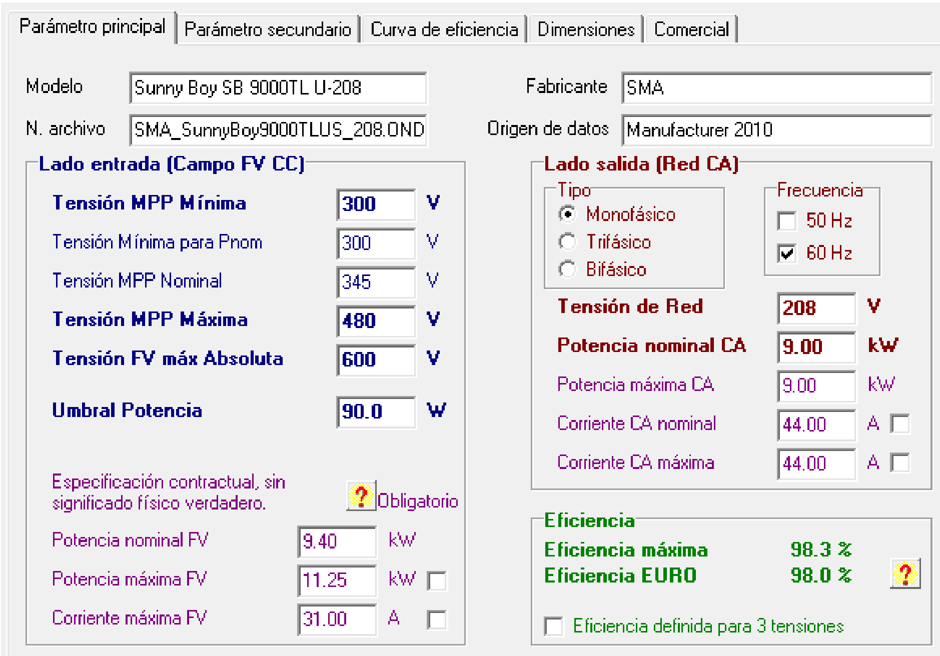


Figure 69: Characteristics of the chosen inverter

Big car park:

In the B building and in the visitors' car park, the available area is 1215 m^2 so there can be placed 288panels.
For these 288panels, Conergy IPG 60 K inverter has been chosen, of 54 kW of power.
One inverter will be enough for these panels.

Regarding the connection, there will be 18 strings with 16 panels per string. The panels will take 363 m^2 out of the 1215 m^2 that are already available.

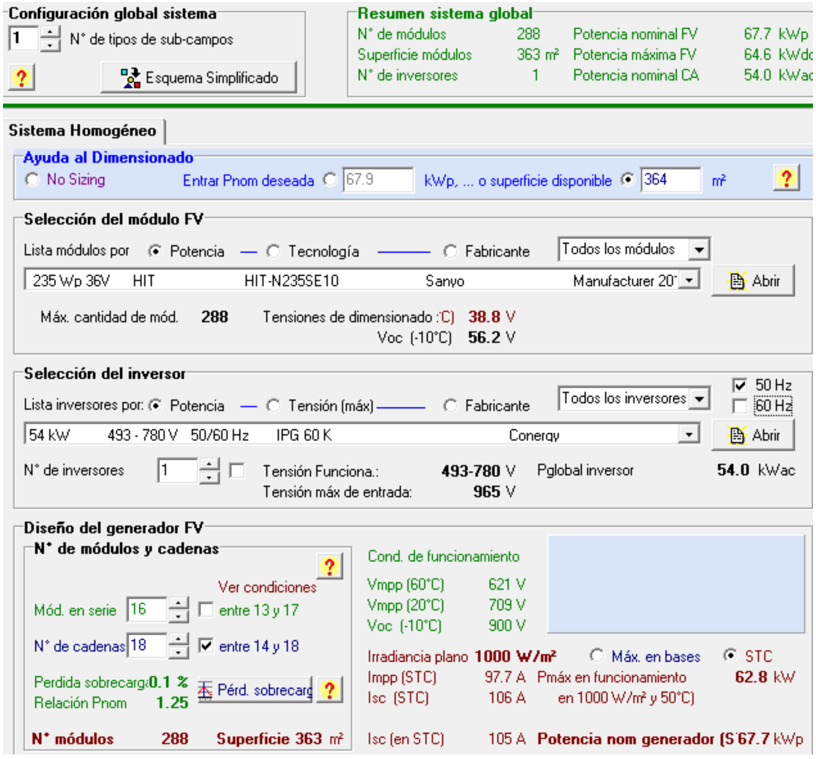


Figure 70: Configuration of panels and choice of inverter for monocrystalline panels with PVSYST software

<u>Characteristics of inverter:</u>

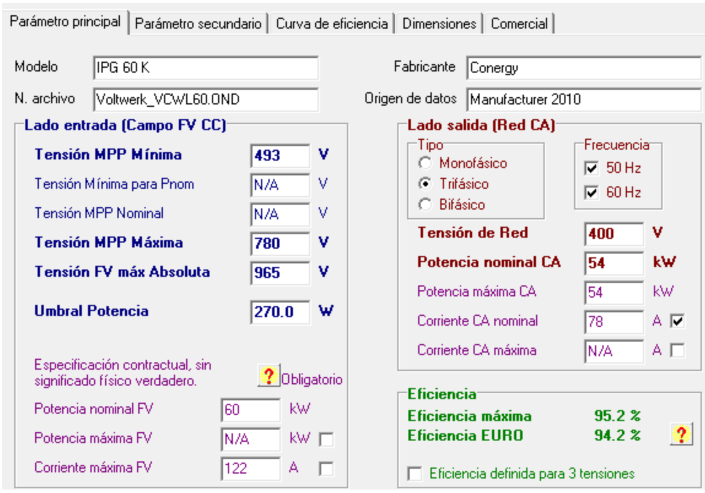


Figure 71: Characteristics of the chosen inverter

POLYCRYSTALLINE PANEL

1. Southern façade:

In the southern façade, the available area is 117 m^2 so there can be placed 69 panels. For these 69 panels, BYD BSG15 KTL-E inverter has been chosen, of 15 kW of power. One inverter will be enough for these panels.

Regarding the connection between the panels, PVSYST software showed this as an optimal option:
23 strings, with 3 modules in serial each string. 69 solar panels in total, encompassing 116 m^2 of the whole available surface.

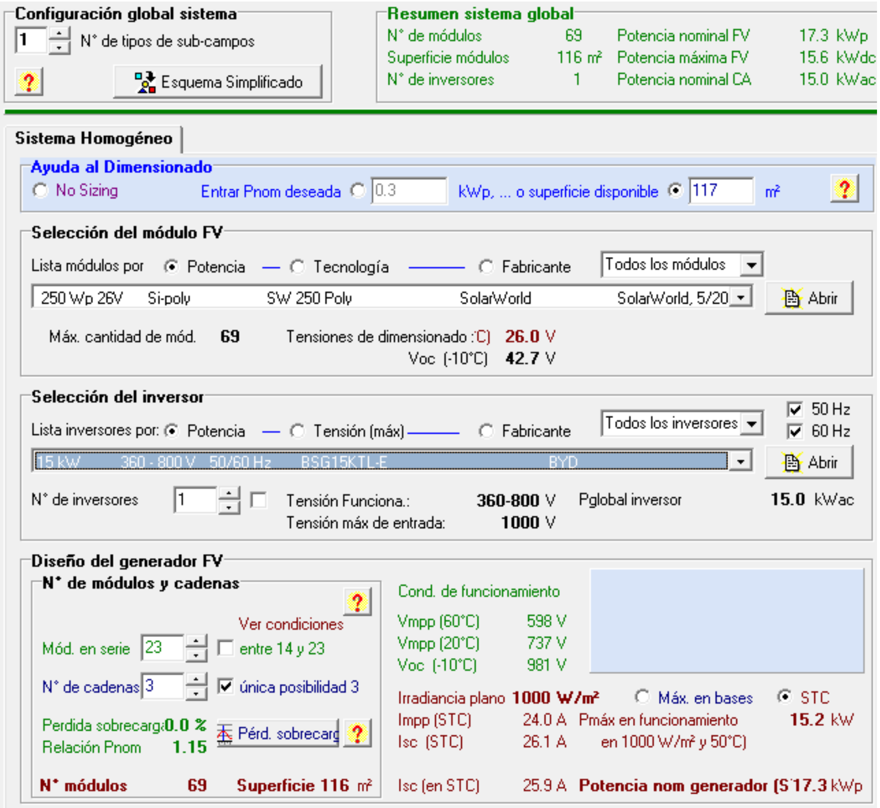


Figure 72: Configuration of panels and choice of inverter for polycrystalline panels with PVSYST software

Characteristics of the inverters:

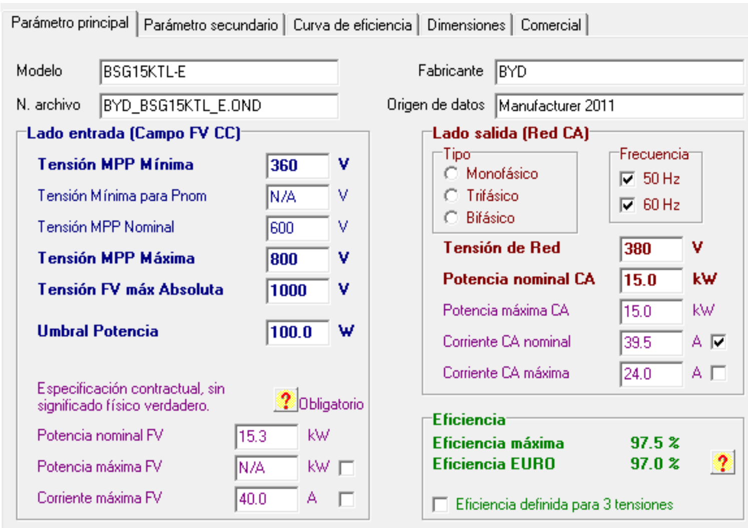


Figure 73: Characteristics of the chosen inverter

2. Field outside:

In the field outside, the available area is 3081.33 m^2 so there can be placed 294 panels. For these 294 panels, SMA Sunny Central 60 LV inverter has been chosen, of 60 kW of power. One inverter will be enough for these panels.

In this case the configuration between panels will be 21 strings with 14 panels in serial per string.

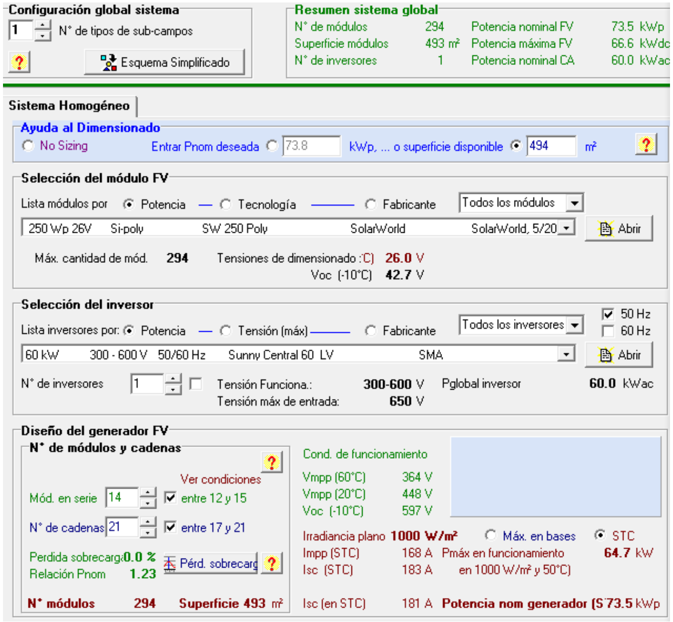


Figure 74: Configuration of panels and choice of inverter for polycrystalline panels with PVSYST software

Characteristics of inverter:

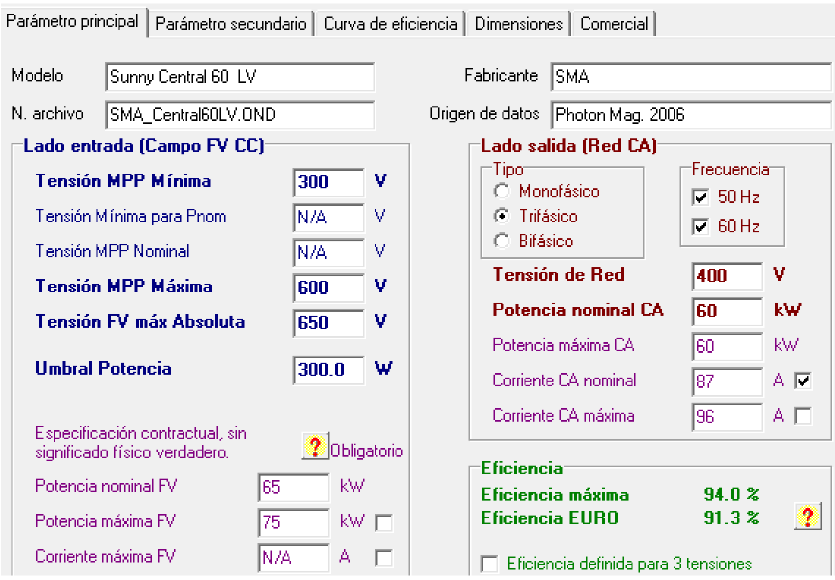


Figure 75: Characteristics of the chosen inverter

3. <u>Extra roof + bike:</u>

In the extra roof area and bicycle roof, the available area is 416.06 m^2 so there can be placed 125 panels.
For these 125 panels, we have chosen the Vacon NXV0030, of 30 kW of power. For one inverter will be enough for these panels.

This time the configuration between panels will be 7 strings with 18 panels per string, 126 modules in total, using a total surface of 211 m^2 out of 416 m^2.

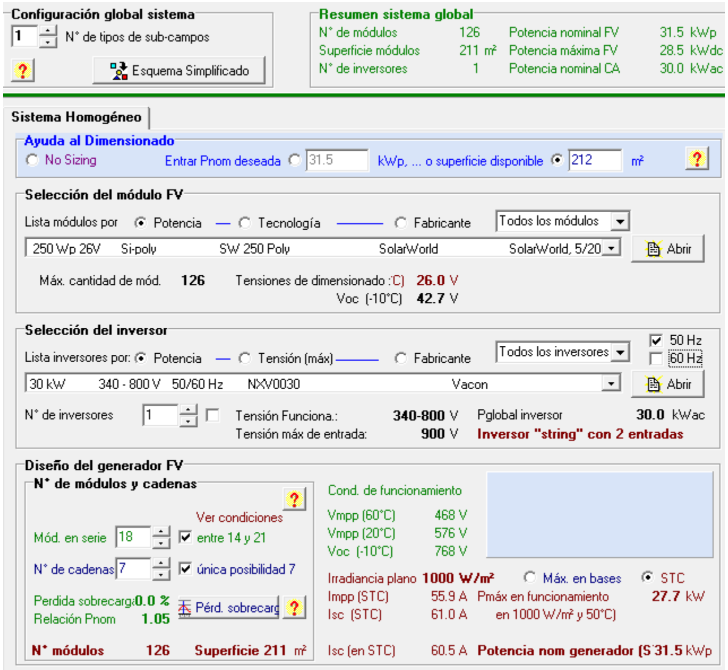


Figure 76: Configuration of panels and choice of inverter for polycrystalline panels with PVSYST software

<u>Characteristics of the inverter:</u>

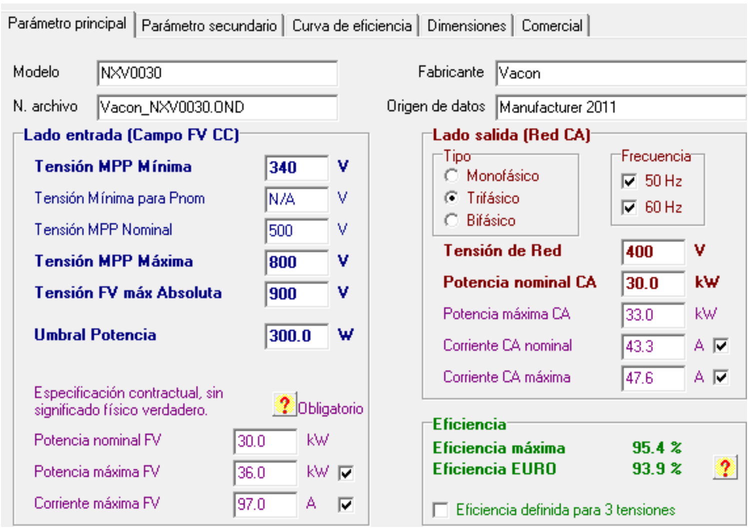


Figure 77: Characteristics of the chosen inverter

4. <u>Atrium:</u>

In the extra roof area and bicycle roof, the available area is 222 m^2 so there can be placed 45 panels.

For these 45 panels, Eltek Valere Theia 13000 TL has been chosen, of 11 kW of power. For one inverter will be enough for these panels.

Regarding the configuration, there will be 3 strings with 16 modules per string, 48 strings in total. For these panels, 80 m^2 of panels will be used, out of 222 m^2 available area.

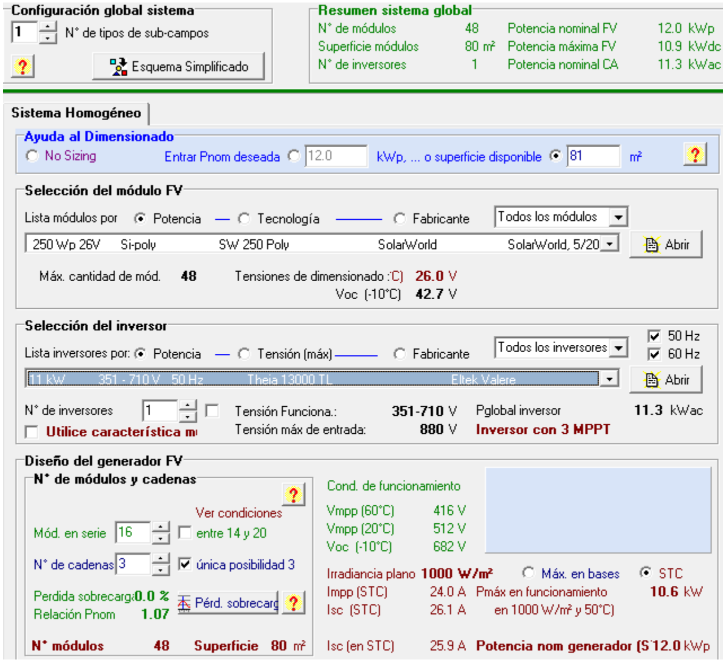


Figure 78: Configuration of panels and choice of inverter for polycrystalline panels with PVSYST software

Characteristics of inverter:

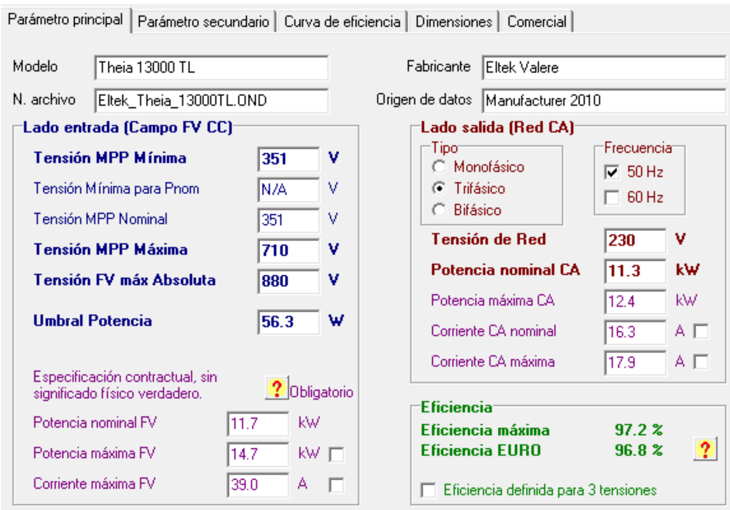


Figure 79: Characteristics of the chosen inverter

5. Building B + visitors parking:

In the B building's roof and in the visitors parking, the available area is 185 m^2 so there can be placed 36 panels.

For these 36 panels, Sunset Sun3Grid 8000 inverter has been chosen, of 8 kW of power. One inverter will be enough for these panels.

About the connection, there will be 2 strings with 18 solar panels each. The area that the panels will take will be 60 m^2 out of 185 m^2.

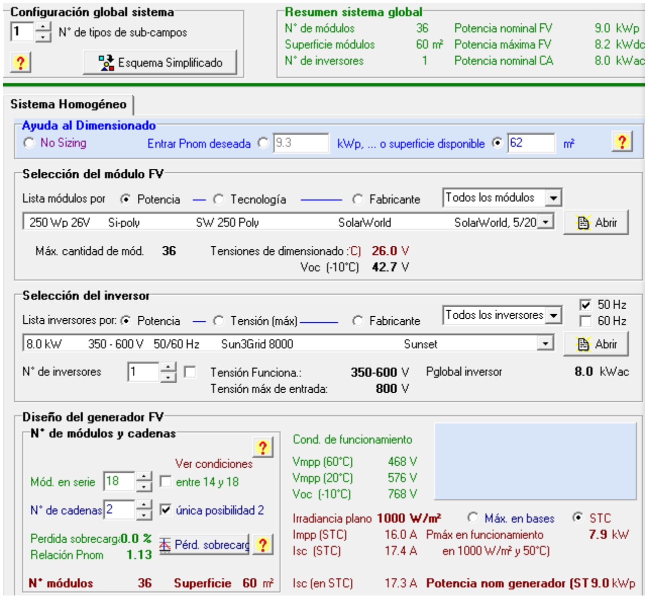


Figure 80: Configuration of panels and choice of inverter for polycrystalline panels with PVSYST software

Characteristics of inverter:

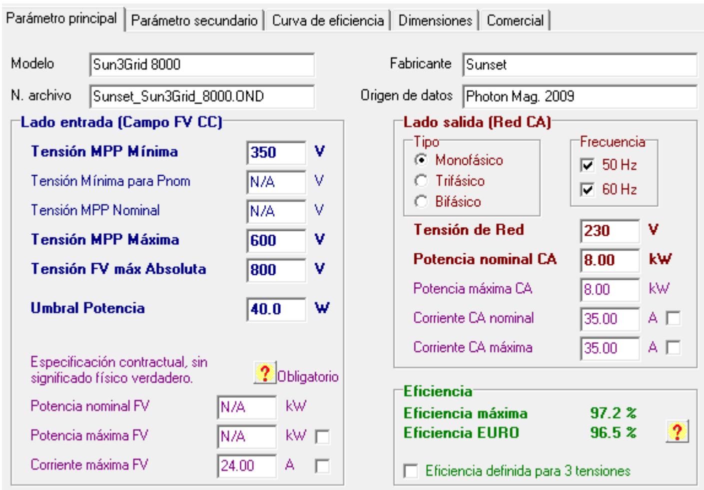


Figure 81: Characteristics of the chosen inverter

6. Big car park:

In the big car park, the available area is 1215 m^2 so there can be placed 234 panels.
For these 234 panels, Ingeteam IngeconSun 50 inverter has been chosen, of 50 kW of power. One inverter will be enough for these panels.

Regarding the connection, there will be 14 strings with 17 panels per string. The panels will take 399 m^2 out of the 1215 m^2 that are already available.

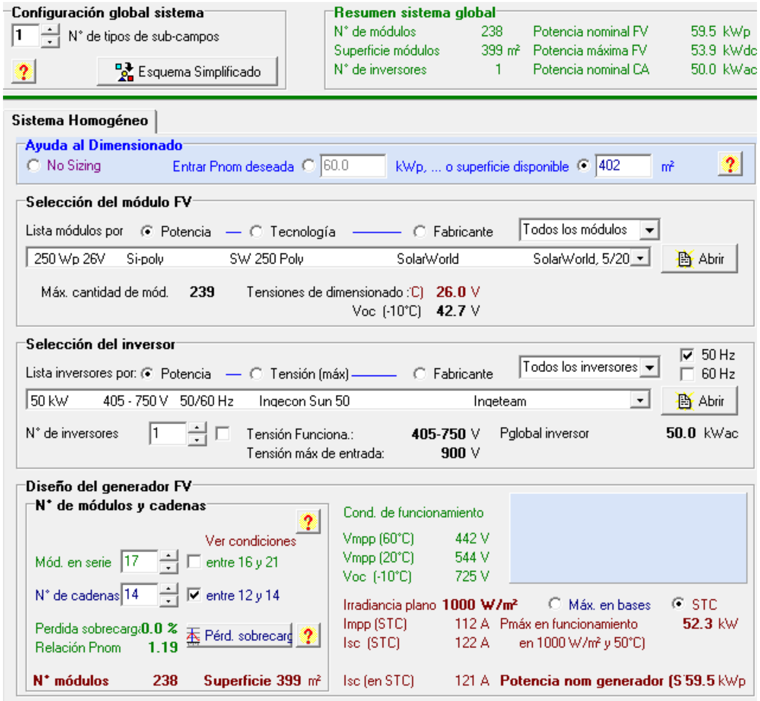


Figure 82: Configuration of panels and choice of inverter for polycrystalline panels with PVSYST software

<u>Characteristics of inverter:</u>

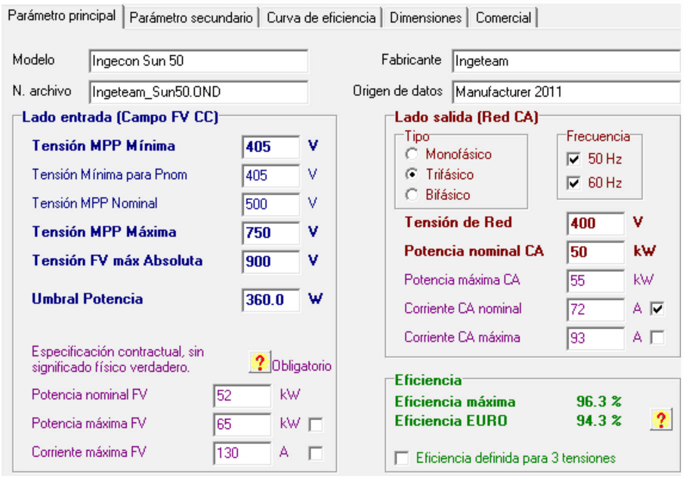


Figure 83: Characteristics of the chosen inverter

DESIGN OF THE INSTALLATION TO CARRY THE PRODUCED E TO THE MAIN ELECTRICAL POINT

The inverter power relay or reverse current relay which allows current to flow only in one direction makes that only power is consumed and not delivered to the grid. That is why the relay is connected upstream of photovoltaic power generation, in order to flow only in that way.

The following circuit shows how the installation will work. It is essential that the energy consumed in the school comes from the photovoltaic system and when this cannot supply the demand, will be consumed from the power supply and operate in parallel with less than five seconds time that should not be running in parallel longer.
The automation consists of: the relay detects when the solar farms are generating power and when it stops detecting it, it automatically sends the signal through RS-485 to disconnect the circuit breaker disconnecting generation.

Besides these devices, the box consist of a power control system that allow both display the power consumed in an average or instantaneous zero period and allows injection. So that energy can only flow to the consumer. Furthermore this unit is connected to other devices (CVM MINI) that are at the entrance of the photovoltaic generation and the generation of the electricity grid. The devices communicate via RS-485.

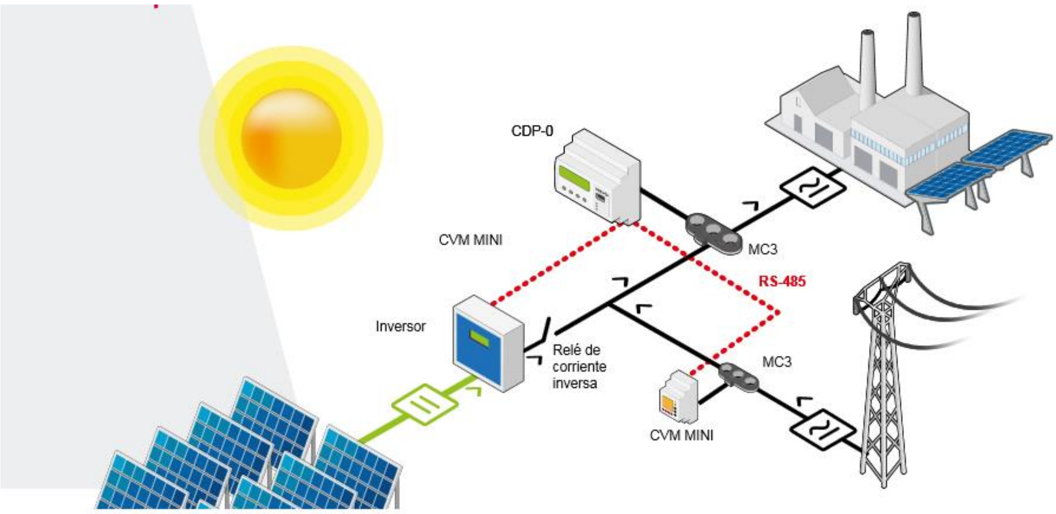


Figure 84: Sketch of the connection between grid, PV installation and building

For understanding better the installation, some previously set conditions have to be known. All this conditions have been set by the Spanish government, but following an European directives, so, it can be applied in whole Europe.

WIRING

- The connection cables must be sized for an intensity not less than 125% of the maximum intensity of the generator.
- The voltage drop between the generator and the point of interconnection to the public network or the indoor installation shall not exceed 1.5% of the rated current.

PIPES AND PIPELINES

- Tubes and pipes shall be in accordance with the provisions of the regulation according to the number of wires depending on the type and installation.

PROTECTIONS

Before the main low voltage

Minimum protections available are as follows:

- In about intensity: magneto thermal relays.
- Minimum instantaneous voltage: Connected between the three phases and neutral and act in a time less than 0.5 seconds from the voltage reaches the 85% assigned.
- Overvoltage: between phase and neutral. The action must occur in a time less than 0.5 seconds from the voltage reaches 110% of the value assigned
- Maximum and minimum frequency: between phases and acting, and whose actions should occur when less than 49 Hz and 51 Hz for more than five periods.

Investor tables near photovoltaic systems

GROUND

- MIE RAT 13
- They must have adequate technical conditions for which no transfers of defects to the public distribution network or private facilities.
- As power generating facility, the grounding scheme will be TT and the masses of the installation and receivers are connected to a separate ground of the neutral public distribution Network

The term "ground" includes all direct wire installation, no fuses or some protection, sufficient section, between certain elements or parts of an installation and an electrode or group of electrodes buried in the ground, in order to get on the set of facilities, buildings and near ground surface there are no dangerous potential differences while at the same time permit the passage of fault currents, or discharges of atmospheric origin.

Studies of the grounding should consider:
• The safety of people.
• The protection of installations.
• The protection of sensitive equipment.
• A reference potential.

To do this we need to know:
• The elements that make up the facility.
• The different power sources that request.
• The responses of the different elements of these different sources.
• The land, given its heterogeneity (rocks that form, layers, textures ...) and factors acting on it (humidity and temperature).

INSTALLATION

SOUTHERN FACADE
The installation from photovoltaic cells to the distribution panel will be in tube and on the facade. Being two power cables will still go rigid tube with 12 mm in diameter to the inverter which will be in the stairwell. From the stairwell to the low voltage panel, to be four conductors of 35 mm2 anger tube of 50 mm in diameter inside the building.
The voltage drop will be 0.68% in monocrystalline and polycrystalline 0.82%.

EXTRA AVAILABLE ROOF SURFACE+BICYCLE PARK ROOF
All elements as junction box are will be next to the inverter in the corresponding box, in this case will be on the stairs next to the inverter Southern facade.
From the bicycle park roof to the inverter will buried 0.9 meters under road and with a 36 mm diameter tube 36.
From the extra roof surface available to the inverter which is in the electrical box under the stairs will be in tube as in the façade as in the attic, and in the last case the tube is always around the corner to the beginning of the facade.
The voltage drop 1.08% in monocrystalline monocrystalline and polycrystalline 0.81%.

PART 2

The line goes on the catenary so it must have a minimum distance. The minimum height of the conductors on the cables or wires or conductors supporters nip is two meters.
If it crosses another line of low voltage, these must be separated a minimum of 0.10 meters if they are insulated conductors. As in this case are two low-voltage power lines in insulated

wire, there will be a minimum of 0.10 meters of separation between them.
If instead they are bare conductors, the minimum distance is one meter.
The parallel line the streets and roads must be six meters for bare conductors and four if they are isolated.

If there wooded area, drivers will be bundled.

The driver will be of type alloy aluminum-magnesium-silicon (Almelec) with section of 95 mm2 three phases and neutral 54.6 with a maximum intensity 230 A with a short-circuit current 16.1 kA to 0.3 seconds (page 45 of the regulation).
The conductors of the power line will be 0.6 / 1 kV XLPE
The voltage drop is 1.12% in monocrystalline and polycrystalline 1.1.

OTHER PROTECTIONS OF THE LINE.
The protections will have an overcurrent protection, overvoltage and short circuit protection.

PART 3

BUILDING B
The installation will be low front tube and the inverter will be next to the parking for visitors. So just the DC wires will go under tube. The tube will have a diameter of 12 mm.

INSTALLATION PARKING FOR VISITORS
Installation from the parking for visitors to the overall box of the school will be by cooper and it is going to have 16 mm2 per phase and 10 mm2 per neutral. The type of the cable will be 0.6 / 1 kV XLPE.
It will go in parallel to the general line maintaining a distance of 0.1 m with low voltage cables and 0.25 m with high voltage. It will have 0.2 meters apart from the gas line. Between the line joints and seals gas pipeline there will be a distance of one meter.
It will be buried at least 0.6 meters deep and 0.8 in road pavement. In our case it will be 0.9 meters deep under the road.
As it crosses a telecommunications line, the minimum separation between power lines and telecommunication will be 0.2 m. In case of joints in the two lines, the separation must be 1 m.

BIG CAR PARK
The inverter and its prospects boxes go in the box next to the Parking. The electrical installation will be in parallel to the general line maintaining a distance of 10 cm with low voltage cables and 25 cm with High voltage. It will have also 20 cm from the gas line.
As is buried it will have a minimum of 0.8 m in driveway. In this project it will be buried 0.9 m.

PART 4 (ATRIUM)
The inverter will be near the main low voltage box. The installation to the inverter (DC) is low tube on the front. The tube diameter is 12 cm.
The voltage drop is 1.02% in 0.79% monocrystalline and polycrystalline.

ANALYSIS OF THE HEATING SYSTEM OF PXL-TECH BUILDING

Placement of the radiators/heaters

When placing the radiators in inner-partitions, the heat loss through the external walls is avoided, and, furthermore, the inner walls are also warm enough in order to transfer this stored heat during the night, when the heating system must be shut down.

One of the main problems is the comfort. The radiators send out heat, whereas the windows dissipate it during the coldest months. So, a convective flow is created from the radiator to the window.

If the radiators are placed far from the windows, this convective flow will cross the whole room, producing thermal-disorders and unpleasant sensations (not comfortable atmosphere).

Otherwise, if the radiators are placed under the windows, these thermal-disorders are minimal. The warm air tends to flow up, and the cold air tends to flow down. So, a cyclic convection is created, which allows the spreading of the warm air faster and more homogeneously through the room.

The main objective is to heat the air of the house and avoid losing this heated air through weak points such as carpentry. That is why, the ideal placement for radiators is locating them under the windows: the cold air which is entering through the window is heated with the hot air the radiator is heating.

For the heat losses through the walls, there are very simple solutions that can be applied in the inner face of the wall:

- Placing a reduced thickness thermal insulator.
- Painting the surface behind the radiator with thermoreflector paint.
- Placing a reflector sheet which would reflect the radiation towards indoor.
- Changing the windows by hermetic carpentry windows with double glass and a reflecting system.

One way for developing the heating system and making it better, if the geothermal system is not suitable, may be the installation of two biomass boilers, which would replace the ones that are already working.

The biomass as an energetic source can be a possible solution to everyday life energetic problems, or at least for the hot water and heating system.

The use of biomass like energetic source has numerous advantages:

- The biomass is a never-ending source, which it also is neutral with the atmosphere.
- Decreases the dependence on fossil fuels.
- It allows the maintenance and cleaning of forests and mountains, so the waste here is reduced as well as the probability of having a fire.
- Biomass fuels are cheaper than conventional energetic fuels.
- There are different sort of fuels for the same biomass boiler such as pellets, olives' pit or almonds' peel.
- The availability of these biomass fuels is easier than fossil fuels.

But biomass also has disadvantages comparing to current fuels:

- Biomass boilers have generally a lower efficiency than the fossil fuelled boilers.
- Biomass fuels have less energetic density, which means that for the same energy amount than the current fuels, biomass fuels need more space for storage.
- The feeding system for the boilers and elimination of the ashes are more complex and need more maintenance work than current boilers.
- The distribution system of biomass fuels is not as developed as current fossil fuels.
- Some of the biomass fuels are highly humid, so these fuels, before using, would need a previous drying process.

The old boilers can be replaced by two cofferdam and water tubes mixed boilers, for solid fuels, with fixed grate. The old boilers have 1200 KWatt power each and the new biomass boilers will have 1395 KWatt each.

These new boilers are Ferroli's Wood Matic S. They need solid fuel, so an analysis of different fuels will be helpful when making the choice between gas-boilers or biomass boilers.

Cost of the gas per kW·h

CALDERA GN	
Coste gas natural T.U.R.2	0,0531 € / Kwh
Poder Calorífico GN	10000 Kcal / m3
Rendimiento caldera GN	90%
Coste anual de electr. Consumida	40 € / año
Coste anual de mantenimiento	80 € / año
Incremento anual del coste del GN	10 %
Coste (€ / Kwh)	0,059 € / Kwh

Table. Nº 9: Characteristics of a gas boiler and its costs

Cost of different solid fuels

	Pellet EN-Plus A1	Hueso de aceituna limpio y seco	Cáscara de almendra triturada	Astilla de pino G50
Poder calorífico inferior	4.200 kcal/kg	3.900 kcal/kg	3.700 kcal/kg	3.200 kcal/kg
Humedad	6%	12%	15%	20%-30%
Suministro sacos	0,230 €/kg	0,180 €/kg	0,170 €/kg	
Suministro big-bags	0,220 €/kg	0,165 €/kg	0,155 €/kg	
Suministro granel	0,230 €/kg	0,150 €/kg	0,140 €/kg	0,080 €/kg

Table. Nº 10: Costs of different solid fuels

Calculating the price in €/kW·h:

1. Pellet EN-PLUS:

   Minimum heat calorific value: 4200 kcal/kg
   1 kW·h= 859.845 kcal
   4200 kcal = 1 kg; 859.845 kcal = x kg → 1 kW·h = 0.2047kg
   Price: 0.2047 kg/kW·h · 0.23 €/kg = 0.047€/kW·h

2. Olives' pit (clean and dry):

   Minimum heat calorific value: 3900 kcal/kg
   1 kW·h= 859.845 kcal
   3900 kcal = 1 kg; 859.845 kcal = x kg → 1 kW·h = 0.2204 kg
   Price: 0.2204 kg/kW·h · 0.18 €/kg = 0.0396 €/kW·h

3. Almond's peel:

   Minimum heat calorific value: 3700 kcal/kg
   1kW·h= 859.845 kcal
   3700 kcal = 1 kg; 859.845 kcal = x kg → 1 kW·h = 0.2324 kg
   Price: 0.2324 kg/kW·h · 0.17 €/kg = 0.0395 €/kW·h

So as can be seen, the solid fuels are the cheapest choice, comparing to current gas.

Taking into account the gas consumption for 2013 and 2014 (the value for 2012 are not completed), the average fuel consumption for both years is 1117.376MW·h/ year

If the price for different fuels is calculated:

FUEL	PRICE	TOTAL
Gas	0.059 €/kW·h	65925.18 €/year
Pellet EN-PLUS	0.047 €/kW·h	52516.67 €/year
Olives' pit	0.0396 €/kW·h	44248.09 €/year
Almond's peel	0.0395 €/kW·h	44136.35 €/year

Table. Nº 10: Costs for different fuels

So, the savings are quite important per year if Olives' pit is used:

Savings: 65925.18 €/year (Gas) – 44248.06 €/year (Olives' pit) = 21677.12 €/year savings

Getting the prices of such big biomass boilers have been impossible, but making an estimation, the price can be around 100.000€. For this estimation, smaller boilers have been taken into account, the price of which is proportionally smaller.

So, if the cost of each boiler is 100.000€, as there is need for two, 200.000€ would be the total cost of the boilers.

200.000€ total / 21677.12 €/year = 9.22 years ≈ 10 years.

Then, make the approximation of 100.000€ per boiler, and with 21677.12€ savings per year, the breakeven point will be around 10 years, which is quite profitable.

VI. 4. Results

ECONOMIC ANALYSIS

For the economic analysis of the photovoltaic installation the prices of each component that will be used must be known.

Almost all prices have been obtained from official catalogues or from contacting with the supplier, so they are quite accurate.

For the case of the analysis made with PVSYST software, some prices could not be found, so the analysis cannot be as accurate as wanted, but the first analysis with FRONIUS software describes accurately the whole cost of the installation.

Later, an economic analysis of different solar trackers has been made, in order to see the different efficiencies.

In the graphics above the analysis has been done for different configurations and options:

Firstly, the first option is to choose the monocrystalline panels with inverters obtained from FRONIUS software. Secondly, polycrystalline panels with inverters obtained from PVSYST software.

Thirdly, monocrystalline panels with inverters obtained from FRONIUS software, and, finally, polycrystalline panels with inverters obtained from PVSYST software.

PRICE OF ELECTRICITY	0,15 €	
Total consumption of 2014	524336,6	**kW·h**
The objective is to reduce one third the consumption for the future	349557,73	**kW·h**
Aproximatedly	350000	**kW·h**
140000 kW·h changed to kWp	411,76	**kWp**
Limit which government will give subsidy	250	**kWp**
Amount that will be provided with photovoltaics	60,71	**%**

General economic analysis

	Panels	Nº of panels needed	Nº of panels can be placed	Cost (€/panel)	TOTAL COST OF PANELS (€)	TOTAL COST OF CABLES (€)	TOTAL COST OF INVERTERS		BUILING COST (MAKING A ROOF FOR PARKINGS)
							FRONIUS	PVSYST	
Monocrystalline	Sanyo HIT-N235SE10	1064	1128	342	363.888,00 €	109.154,52 €	47.485,00 €	11.649,20 €	265,4
Polycristaline	Solarworld SW 250	1000	763	225	171.675,00 €	76.150,72 €	47.711,00 €	128.963,00 €	265,4

	Investment	Installed nº of panels	Installed kWp	Provided by PV panels	Saved money (350000 kW·h ·provided %·15cent€ kW·h) (€/year)	Amortization (investment/saved money) (years)
Option A	520.792,92 €	1064	250,04	60,72	31.880,10 €	16
Option B	295.802,12 €	763	190,75	46,33	24.320,63 €	12
Option C	484.957,12 €	1064	250,04	60,72	31.880,10 €	15
Option D	377.054,12 €	763	190,75	46,33	24.320,63 €	16

Table. Nº 11: General economic analysis of the photovoltaic system

Economic analysis per zone for Monocrystalline panels

Monocrystalline	Nº of panels	Total cost of panels (€)	Total cost of inverters (€)		Cost of cable (€)	Building cost (€)	TOTAL COST (WITH FRONIUS INVERTERS)	TOTAL COST (WITH PVSYST INVERTERS)
			FRONIUS software	PVSYST software				
Southern façade	92	31.464,00 €	4.545,00 €	2.647,60 €	1.831,49 €	0,00 €	**37.840,49 €**	**35.943,09 €**
Fields outside	548	187.416,00 €	11.500,00 €	---	36.071,15 €	0,00 €	**234.987,15 €**	**223.487,15 €**
Available roof + Bycicle roof	100	34.200,00 €	14.256,00 €	---	5.995,98 €	0,00 €	**54.451,98 €**	**40.195,98 €**
Atrium	55	18.810,00 €	2.898,00 €	2.647,60 €	1.536,46 €	0,00 €	**23.244,46 €**	**22.994,06 €**
Building B + Visitors parking	45	15.390,00 €	2.786,00 €	1.754,00 €	512,69 €	22,40 €	**18.711,09 €**	**17.679,09 €**
Big car park	224	76.608,00 €	11.500,00 €	4.600,00 €	63.206,76 €	243,00 €	**151.557,76 €**	**144.657,76 €**
TOTAL	1064	363.888,00 €	47.485,00 €	11.649,20 €	109.154,52 €	265,40 €	520.792,92 €	484.957,12 €

Price of Sanyo HIT-235SE10	342,00 €

TOTAL COST (FRONIUS INVERTERS)	520.792,92 €
TOTAL COST (PVSYST INVERTERS)	484.957,12 €

Table. Nº 12: Economic analysis per zone for MONO panels

Economic analysis per zone for Polycrystalline panels

Polycrystalline	Nº of panels	Total cost of panels (€)	Total cost of inverters (€) FRONIUS software	Total cost of inverters (€) PVSYST software	Cost of cable (€)	Building cost (€)	TOTAL COST (WITH FRONIUS INVERTERS)	TOTAL COST (WITH PVSYST INVERTERS)
Southern façade	69	15.525,00 €	4.155,00 €		1.205,71 €	0,00 €	**20.885,71 €**	**16.730,71 €**
Fields outside	294	66.150,00 €	21.916,00 €	115.000,00 €	41.231,84 €	0,00 €	**129.297,84 €**	**222.381,84 €**
Available roof + Bycicle roof	85	19.125,00 €	4.545,00 €		1.165,75 €	0,00 €	**24.835,75 €**	**20.290,75 €**
Atrium	45	10.125,00 €	2.898,00 €		213,59 €	0,00 €	**13.236,59 €**	**10.338,59 €**
Building B + Visitors parking	36	8.100,00 €	2.697,00 €		547,92 €	22,40 €	**11.367,32 €**	**8.670,32 €**
Big car park	234	52.650,00 €	11.500,00 €	13.963,00 €	31.785,92 €	243,00 €	**96.178,92 €**	**98.641,92 €**
TOTAL	763	171.675,00 €	47.711,00 €	128.963,00 €	76.150,72 €	265,40 €	295.802,12 €	377.054,12 €

Price of Solarworld SW-250	225,00 €

TOTAL COST (FRONIUS INVERTERS)	295.802,12 €
TOTAL COST (PVSYST INVERTERS)	377.054,12 €

Table. Nº 13: Economic analysis per zone for POLY panels

Economic analysis of cables for Monocrystalline panels

	2,5 mm²	4 mm²	10 mm²	25 mm²	35 mm²	50 mm²	70 mm²	120 mm²	240 mm²	300 mm²
PRICE PER KM	1.998 €	2.940 €	5.850 €	12.934 €	17.974 €	25.858 €	36.384 €	58.280 €	115.112 €	150.030 €
PRICE PER M	2 €	3 €	6 €	13 €	18 €	26 €	36 €	58 €	115 €	150 €

COST OF CABLES PER ZONE

	2,5 mm²	4 mm²	10 mm²	25 mm²	35 mm²	50 mm²	70 mm²	120 mm²	240 mm²	300 mm²	Cost (€)
Southern façade	152 €				85 €						1.831 €
Fields outside	465 €						80 €		280 €		36.071 €
Available roof + Bycicle roof	169 €			77 €				80 €			5.996 €
Atrium	91 €	21 €				50 €					1.536 €
Building B + Visitors parking	78 €		61 €								513 €
Big car park	464 €				26 €					412 €	63.207 €
											109.155 €

Table. Nº 14: Economic analysis of cables for MONO panels

Economic analysis of cables for Polycrystalline panels

	2,5 mm^2	4 mm^2	10 mm^2	25 mm^2	35 mm^2	50 mm^2	70 mm^2	95 mm^2	120 mm^2	240 mm^2	300 mm^2	Cost (€)
Southern façade	105			77								1.205,71 €
Fields outside		504						80			240	41.231,84 €
Available roof + Bycicle roof	85			77								1.165,75 €
Atrium	76	21										213,59 €
Building B + Visitors parking		63	62									547,92 €
Big car park	272			26							206	31.785,92 €
												76.150,72 €

Table. Nº 15: Economic analysis of cables for MONO panels

Professional Bachelor Electromechanics

Economic analysis for solar panels with solar tracker in outer field

Single axis tracker	Solar Tracker 2-axis ST44M3V15P
Double axis tracker	Solar Motor Sun Tracer ST4TM3V17P-30S
Individual single axis tracker	SunTracer OG+

		Amount of trackers			**Total money**		
	Nº of panels in field	**Individual single axis tracker**	**Single axis tracker**	**Double axis tracker**	**Individual single axis tracker**	**Single axis tracker**	**Double axis tracker**
Monocrystalline	548	548	33	37	97.544,00 €	89.562,00 €	128.945,00 €
Polycrystalline	294	294	18	20	52.332,00 €	48.852,00 €	69.700,00 €

Panels per tracker			Price per tracker (€)		
Individual single axis tracker	Single axis tracker	Double axis tracker	Individual single axis tracker	Single axis tracker	Double axis tracker
1	17	15	178,00 €	2.714,00 €	3.485,00 €

	Nº of panels	Total cost of panels (€)	FRONIUS software	PVSYST software	Cost of cable (€)	Building cost (€)
Monocrystalline panels	548	187.416,00 €	11.500,00 €	---	36.071,15 €	0,00 €
Polycrystalline panels	294	66.150,00 €	21.916,00 €	---	41.231,84 €	0,00 €

TOTAL COST OF WHOLE INSTALLATION FOR THE FIELD

TOTAL COST (WITH FRONIUS INVERTERS)			TOTAL COST (WITH PVSYST INVERTERS)		
Individual single axis tracker	**Single axis tracker**	**Double axis tracker**	**Individual single axis tracker**	**Single axis tracker**	**Double axis tracker**
332.531,15 €	324.549,15 €	363.932,15 €	0,00 €	0,00 €	0,00 €
181.629,84 €	178.149,84 €	198.997,84 €	0,00 €	0,00 €	0,00 €

Table. Nº 16: Economic analysis for solar trackers in outer field

Professional Bachelor Electromechanics

Economic analysis for solar panels with solar tracker in both car parks and for B building roof

Single axis tracker	Solar Tracker 2-axis ST44M3V15P
Double axis tracker	Solar Motor Sun Tracer ST4TM3V17P-30S
Individual single axis tracker	SunTracer OG+

		Amount of trackers			Total money		
	Nº of panels in parkings	**Individual single axis tracker**	**Single axis tracker**	**Double axis tracker**	**Individual single axis tracker**	**Single axis tracker**	**Double axis tracker**
Monocrystalline	269	269	16	18	47.882,00 €	43.424,00 €	62.730,00 €
Polycrystalline	270	270	16	18	48.060,00 €	43.424,00 €	62.730,00 €

Panels per tracker			Price per tracker (€)		
Individual single axis tracker	Single axis tracker	Double axis tracker	Individual single axis tracker	Single axis tracker	Double axis tracker
1	17	15	178,00 €	2.714,00 €	3.485,00 €

	Nº of panels	Total cost of panels (€)	FRONIUS software	PVSYST software	Cost of cable (€)	Building cost (€)
Monocrystalline panels	548	91.998,00 €	14.286,00 €	---	63.719,45 €	265,40 €
Polycrystalline panels	294	60.750,00 €	14.197,00 €	---	32.333,84 €	265,40 €

TOTAL COST OF WHOLE INSTALLATION FOR THE CAR PARKS AND B BUILDING

TOTAL COST (WITH FRONIUS INVERTERS)			TOTAL COST (WITH PVSYST INVERTERS)		
Individual single axis tracker	Single axis tracker	Double axis tracker	Individual single axis tracker	Single axis tracker	Double axis tracker
218.150,85 €	213.692,85 €	232.998,85 €	0,00 €	0,00 €	0,00 €
155.606,24 €	150.970,24 €	170.276,24 €	0,00 €	0,00 €	0,00 €

Table. Nº 17: Economic analysis for solar trackers in both car parks and building part

I. 5. Conclusion

After doing the whole work a time to analysing the conclusion and reflection is needed.
The electric need has been analysed, and a photovoltaic system has been designed for these characteristics.

The photovoltaic system has been designed to fill up to approximatelly %60 percent of the electric need of the building.

So, after analysing the profitability of the different configurations and answering the research question made at the beginning, the installation will be profitable from the 12th or 16th year on, depending on the choice is taken.

Taking into account that new solar panels have a useful life cycle of 30 years approximatelly (old panels useful life cycle is approximatelly 20 years), at least 14 years of savings are guaranteed, which supposes lots of savings to PXL-Tech.

The saving for the consumption of the year 2014 were 47748,64 €, so, if we suppose 12 years of savings after the breakeven point and an approximation of 40000€ of saving per year (because the consumption of electricity is supposed that will go down) it will be a total approximated saving of 480000€.

So, as a personal opinion, the project should be done.

Regarding the project experience, it has been the best way of giving an ending to my university degree, in which I had the opportunity to apply a big part of what I had studied during the last four years.

Through this project I could get to know a different university, with different way of doing things, in short, a different culture. This helped me to grow as a student and as a person in the field of engineering.

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