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Título del proyecto:

Fabrication of solar panels on the surface of a solar car

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1. ABSTRACT

Glyndwr University will participate in South Africa Solar Challenge, a race that involves cars that run exclusively with energy solar.

This technology is a mix of electrical cars that are being developed today, with solar cells, getting the car to supply for itself, and besides, it is clean energy.

The manufacture and adaptation of cells in that car was one of our goals, getting the most output. The design of the car was made in Solid Works and energy was calculated with the help of the program PVSIST.

2. ACKNOWLEDGEMENTS

I would first like to thank the Erasmus programme for giving me this opportunity to study in a foreign country. Also I would like to thank my supervisor Graham Sparey Taylor for his encouragement and guidance during the completion of this project. He is a man who loves his work and that was very important as he motivated me.

I would also like to thank the Glyndwr University for their support of the project.

I also wish to mention the support received from the company Creative Solar, owned by Eneko Sola. One of its engineers, Jon Carricaburu, helped me in many parts of the project.

Finally, I want to dedicate this work to my parents, family and friends for their help and support.

Contents

4. INTRODUCTION

4.1. A necessary change

The global primary energy use is heavily based on the combustion of hydrocarbons. 88% of the energy used in world is generated by using solid resources, such as coal, liquids (petroleum and its derivatives) and natural gas. These resources have two fundamental problems:

1. They are highly polluting to the atmosphere because of the emission of toxic agents such as smoke, soot and other particles in suspension during the incomplete combustion of CO and CO_2, the main contributor to global warming. The current energy model contributes by 50% to global warming (greenhouse effect).

2. Primary energy is scarce and non-renewable

The level of global hydrocarbons:

Resource	World Consumption (%)	Possible Reserves (years)	Environmental problems	Observations
Oil	37%	45	Its combustion releases toxic agents into the atmosphere	Its consumption was reduced by increasing gas consumption
Carbon	28%	209		It is the most polluting
Gas	23%	52	Global warming	This is expanding. Less polluting than solid and liquid

Table 1: Level of global hydrocarbons

As mentioned earlier, emissions of CO_2 into the atmosphere produce global warming. Earth's atmosphere is composed of many gases. The most abundant are nitrogen and oxygen. The rest, less than 1%, are called greenhouse gases (CO_2, methane, nitrogen dioxide ...).

The latter, in small concentrations are vital to our survival. When sunlight hits the earth, some of that energy is reflected in the clouds and the rest passes through the atmosphere and hits the ground. Not all this energy is harnessed by the land, a portion is returned to space. As the earth is cooler than the sun, the energy can´t be returned in the form of light and heat and is returned in the form of infrared energy.

Greenhouse gases absorb this energy like a sponge and warm up the surface of the earth and the air that surrounds it. Without such energy, the planet would be about 30 degrees colder than it is today, and therefore, life could never have developed.

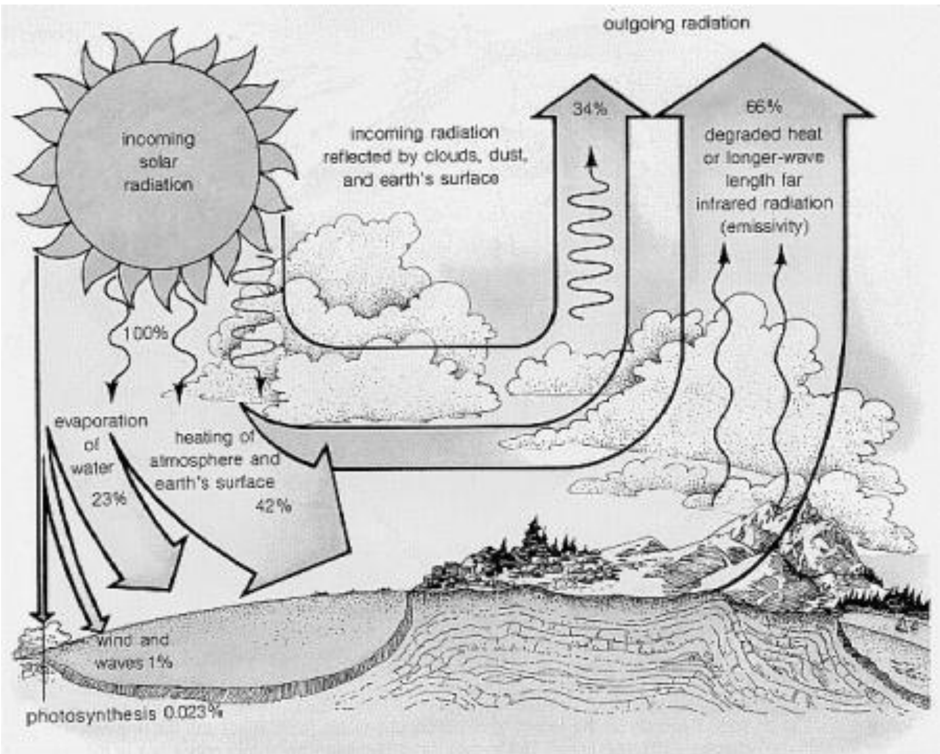


Figure 1: Light process. Miller, 1991

Since the beginning of the industrial revolution, the carbon dioxide content of the atmosphere has increased about 20% due to the widespread burning of fossil fuels like coal and gasoline and the destruction of tropical forest.

These actions have resulted in increased greenhouse effect, which in turn has produced global warming.

Moreover, in the coming years this will cause a sharp increase in energy consumption due to the increasing population, the ever-growing economic engine of the industrial countries and the increasing demand of developing countries, that seek the living standards of industrialized countries. (Pedro Gómez Vidal, 2006).

Because of the problems that these energies generate, the use of so-called alternative or renewable energies has been promoted in recent years. These energies may replace the current ones either for their lower polluting effect or primarily because they can be renewed.

The most important types of alternative energies are:

Solar Energy	Wave Power
Wind Energy	Blue Energy
Water Power	Geothermal
Tidal Energy	Biomass Energy

The development of this project will be focused on solar energy. This energy is produced by the sun, and is converted to useful energy by humans. It can be classified into two types:

- Solar thermal – Used to heat things.
- Solar photovoltaic - Used to generate electricity

In this case, it will be used the photovoltaic one. It consists in the direct conversion of sunlight into electricity (direct current), through an electronic device called solar cell. There are basically two types of applications of this energy:

- Network-connected systems
- Autonomous systems or isolated

In this project it will be implemented photovoltaics in a car. These electric vehicles are called solar cars, and are powered directly through photovoltaic cells located on their surface.

4.2. Design

At present, solar cars are in development. The best way to look at these vehicles is in the races that are organized every year in various locations around the world. In any case, these vehicles have little autonomy and depend on sunlight to move. In addition, the priority to optimizing its performance leads to minimization of the passenger compartment, usually with place for one or two people. Therefore, this type of car can´t become an alternative to the commercial vehicle, but will serve to very specific situations (e.g. golf cars).

However, solar technology could help to develop electric or hybrids cars (normally used electricity and gasoline when needed). In these cases, the solar panels would take up much less space and they will help to extend the battery life, always respecting the design and interior roominess of the vehicle.

The Recharging process of battery in electric vehicles could be done even by users at home, if they had photovoltaic panels and the technology to provide energy from the vehicle. This is definitely one way to enjoy the sun and allows consumers greater energy independence.

4.3. Aim of the project

The aim of the project has been to study and develop the manufacture of solar panels on the surface of a solar car. This project has had several objectives. The main goal has been to get the most output out of the car. To do this, we have studied how solar cells work by size.

Also, we have found the best distribution of cells in the car (taking into account profitability, losses, efficiency etc) and we have studied its best adaptation in the roof of the car.

4.4. Description

4.4.1. World Solar Challenge

World Solar Challenge is a competition that motivates research and development of solar energy to meet future transportation needs. In this race all participants naturally want to win, but the fact to participate is already a motivated because they are contributing to a search for an alternative means of transport for future generations.

This event is considered the most important electrical power race, and was created in 1987 by Hans Tholstrup, a Danish adventurer.

Figure 2: World Solar Challenge

This event is a challenge for the best engineers and scientists worldwide because they have to design a vehicle that is light and efficient. On the one hand, solar panels capable of generating a large amount of electrical energy must be developed, and, on the other, a vehicle that makes effective use of it.

But above all, is a challenge to build a vehicle that is fast and in turn, driven solely by energy from the sun. (World Solar Challenge)

4.4.2. North American Solar Challenge (NASC)

The American Solar Challenge (ASC2010) is a competition to design, build, and drive solar-powered cars in a cross-country time/distance rally event.

Originally called Sunrayce USA, the first race was organized and sponsored by General Motors in 1990 in an effort to promote automotive engineering and solar energy among college students. At the time, GM had just won the inaugural World Solar Challenge in Australia in 1987; rather than continue actively racing, it instead opted to sponsor collegiate events.

Subsequent races were held in 1993, 1995, 1997 and 1999 under the name Sunrayce [year] (e.g. Sunrayce 93). In 2001, the race was renamed American Solar Challenge and was sponsored by the United States Department of Energy and the National Renewable Energy Laboratory. Beginning in 2005, its name changed again to its present form to reflect the border crossing into Canada and the addition of co-sponsor Natural Resources Canada.

After the 2005 race, the U.S. Department of Energy discontinued its sponsorship, resulting in no scheduled race for 2007. The race is now sponsored by Toyota.

The 2008 NASC took place on July 13-22, 2008, on a route between Dallas, Texas and Calgary, Alberta. The University of Michigan's Continuum won the race with a total elapsed time of 51 hours, 41 minutes, and 53 seconds, marking that school's fifth victory. The Ra 7 from Principia College followed in second place.

As many of the top cars were bumping up against the 65 mph (105 km/h) race speed limit in the 2005 event, race rules were changed for 2008 in order to improve safety and limit performance. Open class cars are now only allowed 6 square meters of active cell area, and upright seating is required for both open and stock class cars. The same changes were made for the 2007 World Solar Challenge.

In the next American Solar Challenge, there will be:

- New route
- New site
- New combined event
- New rules

Teams compete in a 1100 mile drive from Tulsa to Chicago. The route has been chosen to combine pieces of old routes used in previous events, giving a bit of an historical tribute for the 20 years of organized events in North America.

Road Race – American Solar Challenge (ASC)

Sat, June 19: Travel day / Support Vehicle Inspections in Tulsa, OK
Sun, June 20: Start in Tulsa, OK; must reach Neosho, MO checkpoint
Mon, June 21: Finish in Topeka, KS
Tue, June 22: Start in Topeka, KS; must reach Jefferson City, MO checkpoint
Wed, June 23: Finish in Rolla, MO
Thu, June 24: Start in Rolla, MO; must reach Alton, IL checkpoint
Fri, June 25: Finish in Peoria, IL
Sat, June 26: Start in Peoria, IL; finish in Naperville, IL
Sun, June 27: Ceremonial run into Chicago, IL and awards ceremony

(American Solar Challenge, 2010).

4.4.3. South Africa Solar Challenge

The South African Solar Challenge 2010 is an epic, two-week race in solar-powered cars through the length and breadth of South Africa. Teams will have to build their own cars, design their own engineering systems and race those same machines through the most demanding terrain that solar cars have ever seen. The race is from the 26th September 2010 to the 6th October 2010; all teams need to be in South Africa before the 23rd September 2010.

The South African Solar Challenge (SASC) is a competition designed to drive and provide education in innovation and business. The event is managed by the Advanced Energy Foundation. The primary objective is to design, manage, build and race solar powered vehicles across South Africa. The challenge sees a collaboration between scholars, students, private individuals and various industry and government partners, to work together to have a safe, technology rich event. (web: South Africa Solar Challenge)

Figure 3: South Africa Solar Challenge

4.5. Objectives of the project

The objectives of this project are to learn and to improve the knowledge about the system shown above. In addition, it is expected to give any help to the teacher and other students involved in the development of the solar car. It is a way to contribute to the development of cleaner technology helping to reduce pollution in the world.

Objectives in relation to the project are:

a) To understand an electric circuit of a solar car and to improve the knowledge of vehicle mechanics.

b) To find and to learn how solar cells work in the car (its quality, performance, etc).

c) To know and to understand the operation of a solar car, by examining some of its components.

d) To learning about the layout of the car (including solar panels) by taking into account what to be achieved. To do this, it must be calculated power and energy generated, by taking into account losses, efficiencies and yields in the system.

e) To improve the understanding of program SolidWorks by doing the design on it.

f) To learn to look for solar radiation dates with PVGIS and NASA web

g) To carry out the calculation of energy generated in PVSYST

h) To perform a simulation of how the car works with the original cell size and reduced cells.

i) To learn how to find information, how to organize it and how to make outlines.

j) To learn to make references, as they had never done before and therefore to know where to find this information.

k) To learn how to distribute tasks and phases of the project in time.

5. BACKGROUND

In this section, it will be defined and studied the different elements that make up the solar car.

5.1. Review of literature

Hans Tholstrup and Larry Perkins opened up solar car racing when they went on an epic Solar Trek from Perth to Sydney (Australia) in 1983. The vehicle practically resembled a 16 foot open boat. But it did 4052 km in 20 days, at an average speed 23 km/hour. This vehicle was the world's first solar powered car. And its name fit the exploit - 'Quiet Achiever'. The Danish adventurer's exuberance helped. The solar car races soon started capturing eyeballs and helped to propagate solar energy as an alternative.

The success of his first venture across the Australian outback led Hans Tholstrup to start the World Solar Challenge in 1987. The leapfrog over the first effort showed in 1987 when GM's Sunraycer won the event with an average speed of 67 km/hour. Today, the event is a biannual jamboree and also a barometer for the developments in the field of solar cars. For instance, 2005 witnessed cars touching speeds in excess of 100 km/hour. This lead to some major regulation changes concerning safety.

The World Solar Challenge started it and soon others followed the lead. The North American Solar Challenge brings to the fore numerous University teams pitting their brains as well as their skills against each other. This year's one ran from Dallas, Texas to Calgary, Alberta. General Motors had followed up its success in the World Solar Challenge by starting this American/Canadian version. This was an inspirational effort to promote auto engineering and solar energy among college students. It may not have intruded into the popular firmament of Formula One, but with races around the world - the Suzuki Circuit (Japan), World Solar Rally (in Taiwan), Phaethon (Greece) amongst others, the enthusiast can expect action to flare up.

Solar cars are powered by the sun's energy. The main component of a solar car is its solar array, which collect the energy from the sun and converts it into usable electrical energy. The solar cells collect a portion of the sun’s energy and store it into the batteries of the solar car. Before that happens, power trackers converts the energy collected from the solar array to the proper system voltage, so that the batteries and the motor can use it. After the energy is stored in the batteries, it is available for use by the motor & motor controller to drive the car. The motor controller adjusts the amount of energy that flows to the motor to correspond to the throttle. The motor uses that energy to drive the wheels.

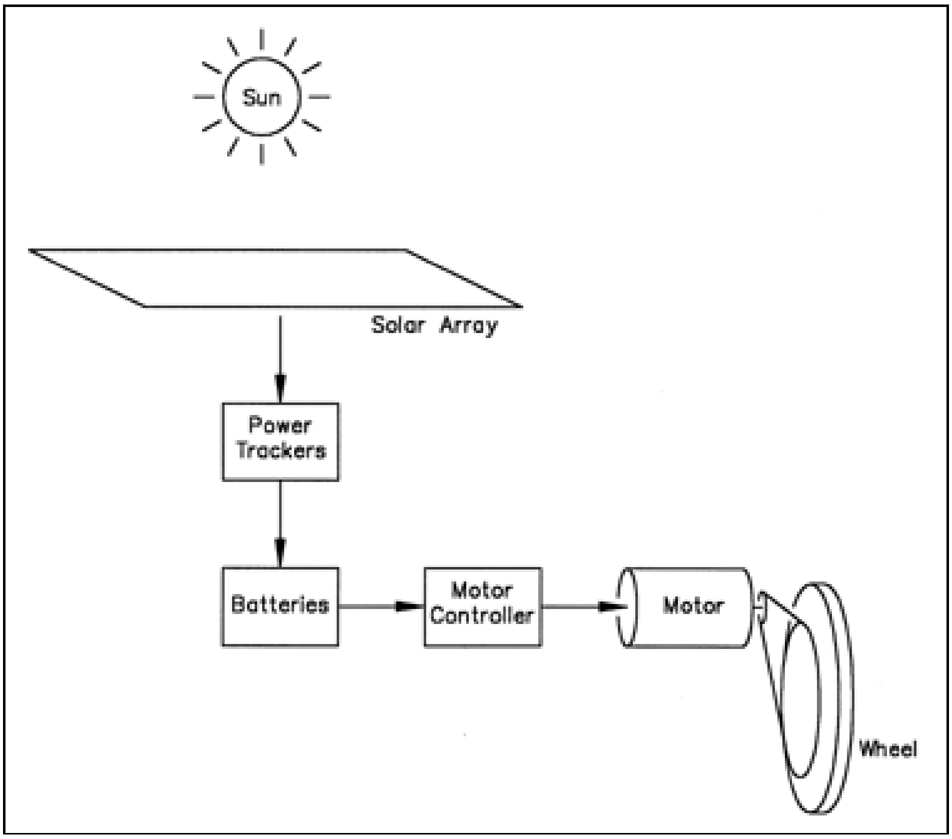


Figure 4: Solar Car Scheme

5.2. Electric motor

An electric motor is an electric machine that converts electrical energy into mechanical energy through electromagnetic interactions. Some electric motors are reversible, since they can transform mechanical energy into electrical energy to operate as generators.

In various circumstances, electrical engines have many advantages over combustion engines:

- With equal power, their size and weight are smaller.
- They may be constructed of any size.
- They have a high torque and, depending on engine type, almost constant.
- Their performance is very high (typically around 75%, increasing as it increases the power of the machine).
- Such engines do not emit pollutants, although the generation of electricity for most of the supply networks are emitted pollutants.

5.3. Battery

A battery is a container consisting of electrolytic cells in which two different metal electrical plates (cathode and anode) are separated by an ionic solution which is the medium capable of conducting electrons between the two plates.

These elements are contained in a metal or plastic container, with separators of the active elements such as paper or cardboard, construction aids such as lead or cadmium or mercury improve the stamping limiting corrosion, in addition to elements of presentation.

The battery, previously recharged by an external source (such as the outlet), sends electricity to the engine required to drive the car, also called acceleration. The acceleration of the car will make the wheels' generators spin and produce electricity, which is stored in the battery. This electricity, in turn, is re-sent to the engine to make it accelerate or push the car, thus repeating the cycle indefinite times.

5.4. Regulator or converter

This section will be focused on the converter that sits between the solar panel and motor. The solar panel is in charge of converting the energy from the sun into electrical energy in DC form, and the engine to convert the direct current into rotational motion.

The objective of the converter is to adapt the voltage and current levels provided by the panel with the voltage and current levels demanded by the motor activity. It must not be forgotten that the converter is a "middleman" of energy required, allowing the system to make proper use of it but as a "broker" must have the best possible performance since the objective is to use all the energy that gives us the panel in the engine.

5.5. Photovoltaic Generator

The energy from sunlight can be converted into other energy forms that allow easy transport and distribution: electrical energy. This uses some devices called photovoltaic cells that convert light energy, photons, into electric current, electrons.

Photovoltaic cells are a type of cell capable of producing an electrical phenomenon. A photovoltaic cell can be formed by a sheet of gold or silver, silicon and iron-nickel base.

The key operation of photovoltaic cells is its "sandwich" distribution of materials endowed with different shape, so that some of them have excess electrons and others, on the contrary, have deficit. Photons of sunlight carry on the energy that tear off the remaining electrons from a layer and makes them move toward the "gaps" of the other.

Figure 5: Solar car

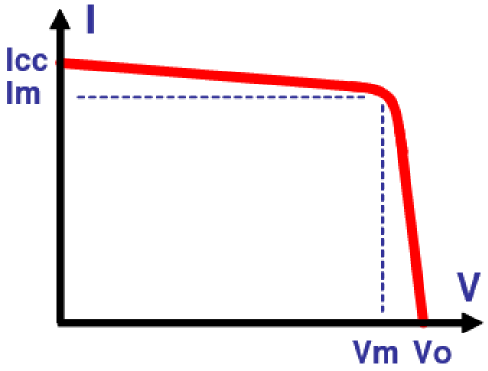
The result is the creation of electron flow, and therefore, an electrical voltage. This voltage is very small, but by connecting a large number of cells, they can reach the desired voltage.

Photovoltaic cells feed a battery, which, in turn, is responsible for electric motor drive the car.

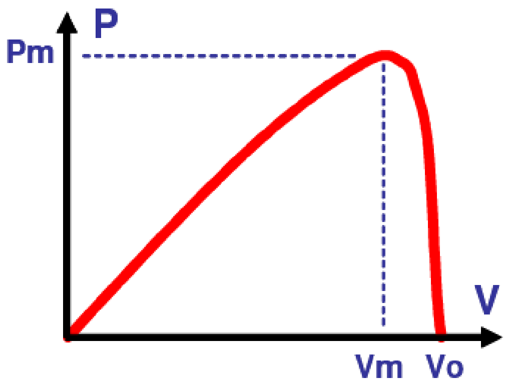
- Characteristic curve of a solar panel:

There are two curves, in relation, that represent the ratio between the current or power generated off the voltage across the panel. These curves can be seen below:

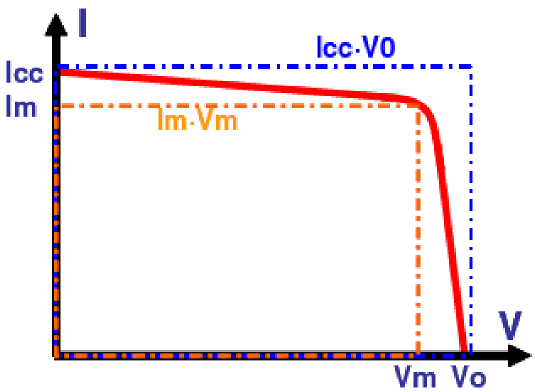
Voltage-current relationship



Voltage-power relationship



To calculate the quality of solar panel energy terms, there is a term called form factor, which relates the maximum power that is able to provide the panel with the maximum power that could really offer. The value of this factor is usually between 0.7 / 0.8, with 1 being the best value possible.

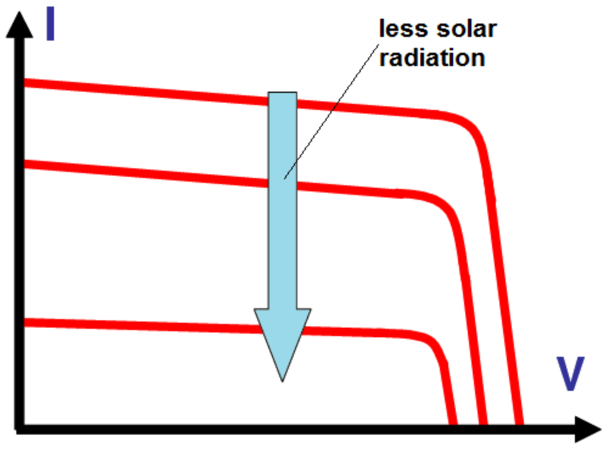


$$FF = \frac{Vm \cdot Im}{Vo \cdot Icc}$$

These curves may vary depending on the type and amount of radiation and temperature of the panel.

- Influence of light

The following graph, which relates the voltage and current curves, is the effect of solar radiation on the photovoltaic panel. The lower the light received, or the lower the radiation level, the lower is the power that can provide the panel broadly constant open circuit voltage.



- Influence of temperature

As seen before, the intensity is directly proportional to the radiation, keeping the voltage constant. In this sense the placement of the panels is very important, their orientation and inclination to the horizontal, as the radiation varies throughout the day.

However, the temperatures increase in the cells an increase in the flow, but also a much larger decrease proportionally to the tension. The overall effect is that the power of the panel decreases with increasing operating temperature of the same.

6. METHODOLOGY

6.1. Tasks

At first, my tasks were:

6.1.1. To find out the flexibility of solar cells look at options for/other use in making array.
6.1.2. What information have I gathered?
6.1.3. Look at the theories and formula needed to solve the task.
6.1.4. Design process
6.1.5. Construction process
6.1.6. Testing process

Compare the design with theory.

Look at all other Solar Car teams.

Run a basic CFD on a wing with proud cell and with embedded cells.

6.2. Work done

In the chosen part of the final project, the interest of working on renewable energies' field was important, because it is believed it will be the future. This type of energy produces clean energy; it can curb dependence on energy imports, limits the greenhouse effect and can solve many environmental problems.

The objective of this project (solar car), is to get the most output of the car by placing solar panels on the roof.

By starting the project, there has been a gathering of information, because of the necessity to improve knowledge in this field.

Search of information on renewable energy and concretely on solar energy, has been done, in order to understand the world´s situation.

Secondly, a search for information about cars has been done, (its parts, the functioning of its components, etc), by focusing on electric cars because these cars run on electricity.

The car designed during the project uses solar cells. When choosing the type of cell, it was considered that there are different types, qualities, efficiencies, costs, flexibility, etc. Final chice was to work with monocrystalline cells, as they have good relation in quality-price.

Later, I have been working in the design process. With the chosen cell type (monocrystalline), two distributions have been made on the roof of the car drawing the largest area possible, and trying to get the most output.

The car is 1.8 meters wide by 5 feet long. The surface is convex along the car. The car is made of carbon fibre.

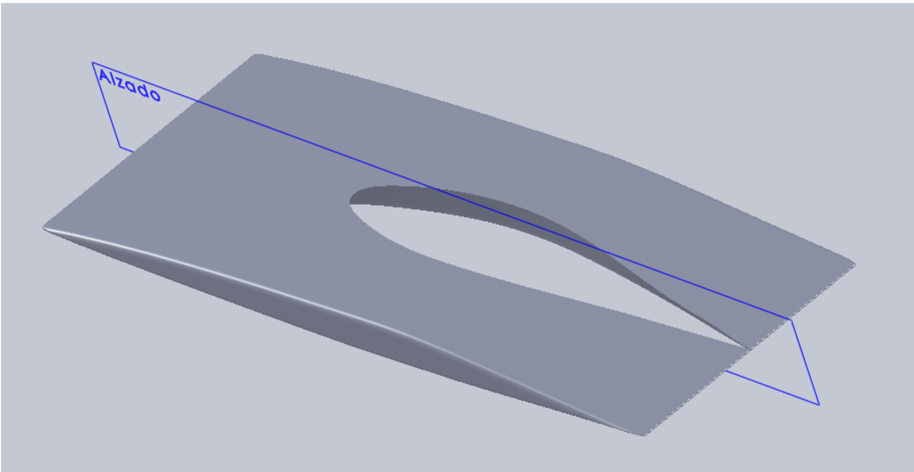


Figure 6: SolidWorks

To make the designs, we had in mind how many cells we had to put in serial/parallel to get the power that we needed. This power has been marked by the battery voltage. We have done all designs in Solidworks and later, all the calculations for each system, choosing the best of them.

Finally, we have chosen two designs, one with the original size of the cell and another one with reduced size. To do the designs, we had in mind as solar cells work depending on the size. We did different tests with cells that had different sizes, and finally we have decided to make these two designs. The case of cell depletion, this reduction of the cells has benefited us because, having smaller size, the efficiency is higher and it´s better to suit to the curvature of the car. In addition, this way could achieve benefits such as better performance of the system.

Later, knowing the race circuit, we have calculated the irradiance and, with the designs, we have calculated the energy generated as well. This is a simulation of the real race.

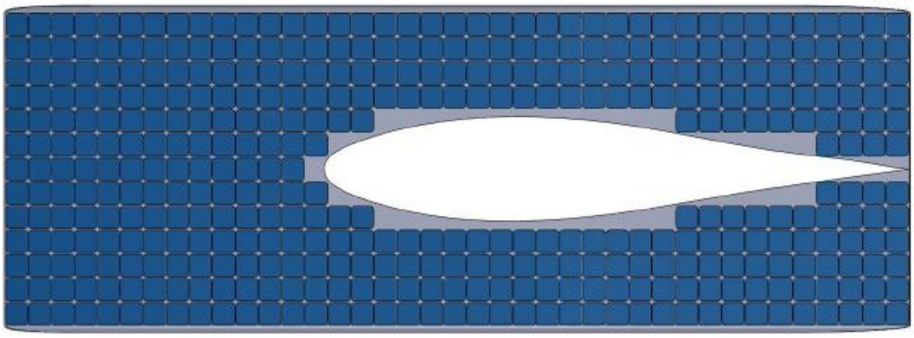
7. DEVELOPMENT

This project has several objectives. One is to get the most output of the car. Our starting point was a car with an area of 7.43 m ^ 2 in which solar panels had to be adapted.

The type of cell that has been used was monocrystalline cell, 12.5 cm x 12.5 cm in size, which has a voltage of 0.6 V, an intensity of 5.576 A, a 17.369% efficiency, a maximum power of 2.680 W and a form factor of 78.708%.

Figure 7: Solar Cell

First of all, we made a distribution in the car with the maximum possible capacity of cells (original size) to verify the maximum power that could be obtained. The number of cells that fit in the car was 413 cells. With this number of cells, knowing that each cell has 2.68 W, the car would produce a power of 1101 W.



Design 1: maximum possible capacity of cells

One approach to consider was the voltage that is used by the batteries, because this voltage limits distribution of the cells. This car will use four batteries in a series of 12 V each, so it will work with 48 V.

According to the theory we have studied with our generator power (solar panels), we have to generate a voltage between 12 and 48 V (voltage to the regulator works). The output and input control (P = V x I) had to be equal. The input voltage depends on temperature and input current is directly dependent on radiation. On the other hand, the output current will depend on the input power and the output voltage will be 48 V, which is required for battery charging.

$$P_1 \text{ (input power)} = V_1 \times I_1 = V_2 \text{ (48V)} \times I_2 = P_2 \text{ (output power)}$$

To produce a minimum voltage of 12 V at the regulator, we had to get into the generator at least 20% more voltage, therefore 14.4V.

Moreover, at the last moment, we have found more specific information that differentiated network systems connected to the isolated systems. The 14.4V listed above, would serve us if the system were networked. In our case, being an isolated system, at least 36 solar cells connected in series in the module to produce charging a 12V battery were needed. A particularly high temperatures (eg, in the tropics) must be employed at least 40 cells for each 12V battery voltage.

On the other hand, initially, this car was to be designed for the North American Solar Challenge event, but this year the rules have been changed and have reduced it by half rally, so finally, this car will participate in the event of the South Africa Solar Challenge.

In that event, we have another limitation, which is that we can only install cells in a maximum area of 6m ^ 2.

With this new constraint, we had two options, either leaving part of the car without cells, or reducing the size of car. We opted for the first, because with that surface we would have good aerodynamics.

With all the above, we made the first final sketch (original size cells), which was limited to 10 parallel strings of 39 cells in each chain. With this system, we have dealt with 6m ^ 2 of surface of the car. Thus, 390 cells have been used, it will produce 967W, losses included (1040 watts peak).

After completing the first sketch, we thought about the option of reducing the size of the cells. In this way, we could make better use of the car's surface, and, above all, make a better adaptation to it, since the car's roof is curved (convex). To arrive at this geometry, a study was made of aerodynamics, and then we had to install the plates in the best way possible.

We were looking for information about reduction of cells. The main advantage that is produced reducing its size is directly proportional to reduction in intensity, keeping a constant voltage. This is a good way because we should work with low intensity. Reducing its size, we also got more efficient cells. The problem of cutting cells is that solar panels are fragile, as it is a very fine and delicate material.

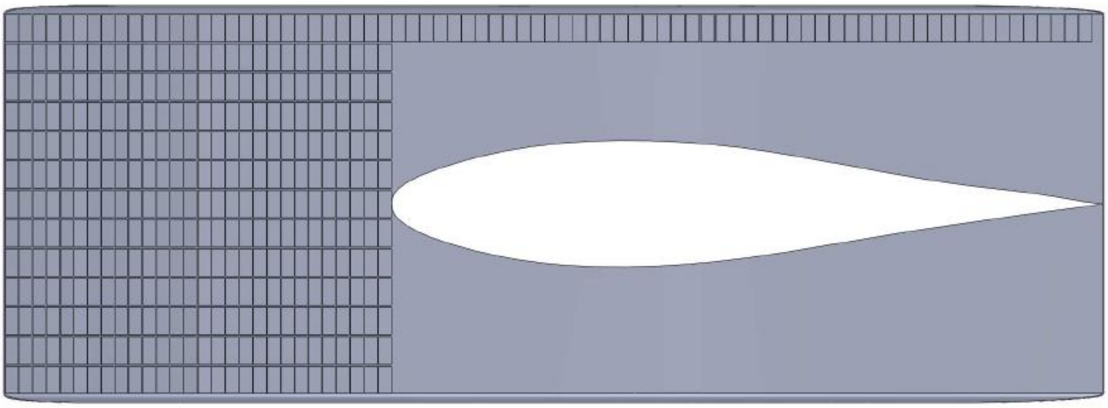
Very few companies have the necessary machinery to perform this operation. In addition, this machine only cuts one by one the cells, making it a very expensive process.

Another technique which is easier to use, is to manufacture solar cells directly on the size we want, without cutting. This reduction would be made before the crystallization process.

We decided to reduce the size of 125x125 to 61x125, being more or less divided in a half.

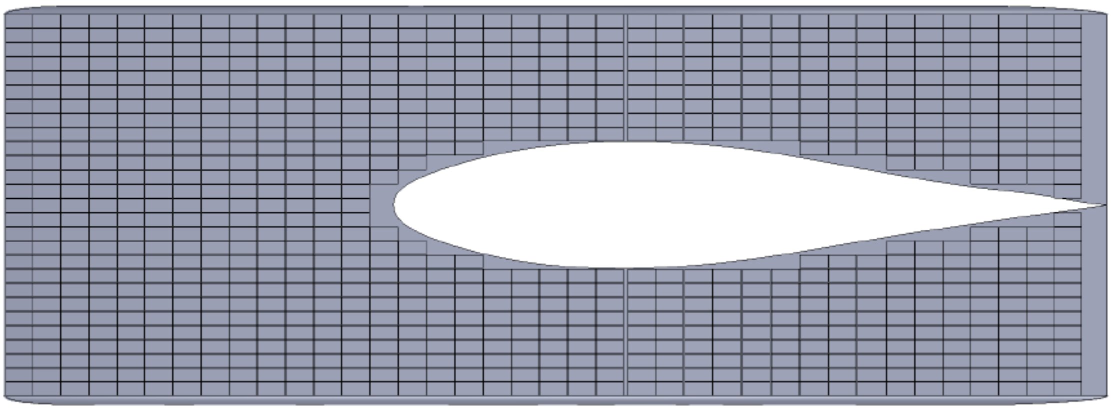
Taking into account all information that we used to make the draft with the original cell, we made two designs with small cells, one with the cell placed longitudinally in the car, and another one with the cell placed in the transverse direction.

Here below we can see the sketches we made:



Design 2: Cell placed in the longitudinal direction

In this design, we got 828 cells.



Design 3: Cell placed in the transverse direction

In this other design, we got 865 cells.

We have verified that it makes better use of the car by putting the cells longitudinally in the car, which is why this placement was chosen.

The designs that contain cells only in 6m^2 have 20 parallel strings of 39 cells in series on each chain. By reducing the solar cell size, power of each cell is reduced, so this new distribution generates 973W, losses included (1040 watts peak).

A small change that could have been done would of been to install a few cells in the cab behind the pilot, generating the energy required for the use of computer, GPS, etc.

Once the two designs had been obtained, one with original size cells and the other smaller cells, we studied the best possible adaptation of the cells in the car. The surface of the car, as we said before, is convex. The two options we have studied have been to put the cells resting on the surface (adapted as possible), or embedded.

We chose the first option, because to embed solar cells would have meant to work hard and punch the carbon fibre, a complex process. Another factor for which we have chosen the first option was that the cells are above the surface, cooling will be better and will greatly facilitate the connections between them.

Parallel to this work, we have looked for information about the event in South Africa Solar Challenge, we calculated its course and reference 12 cities (each city will be the beginning of a stage).

With the NASA and PVGIS programs, we got a lot of data for each city; horizontal solar radiation has been one of them. To have some more real dates, we have done the average of the two programs.

With this average, and with the help of the program PVSYST, we have obtained a report from each city with small cells and another one with cells of the original size. In these reports, we have obtained data as to how high the sun will be depending on the month and time of day. It can also be carried out by a simulation of movement of the sun around the car to see if at any time any cell is shaded. Note that the program has also generated a diagram with all the losses we have had during the process. The most important data we have obtained is the available solar energy.

$$\mathrm{Ep} = \frac{\mathrm{Gdm}(\alpha, \beta) * \mathrm{Pmp} * \mathrm{PR}}{\mathrm{GCEM}} \ \mathrm{KWh/day}$$

Besides all this, PVSYST has also made an excel file in which we obtained for each city, the energy available everyday of the year in each hour. This has been created to make the simulation as real as possible, and we can see that the partial sum of the data coincides with the energy available annually.

When we had finished the analytical part, we studied how to put the strings in the car. PVSYST gave us the opportunity to see the simulation of the sun around the car. With this application, we could see the shadow that produced the cab onto the surface of the car throughout the day, and therefore we have placed the highest number of modules longitudinally in the car.

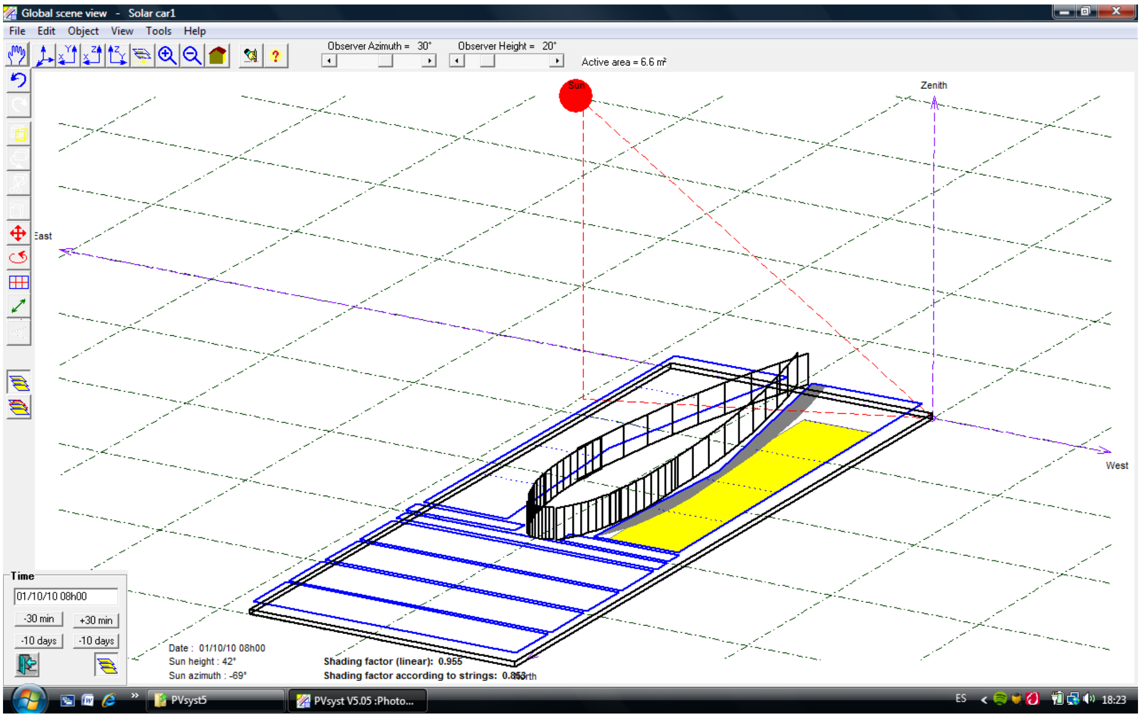


Figure 8: Unchosen direction (modules located in the transverse direction).

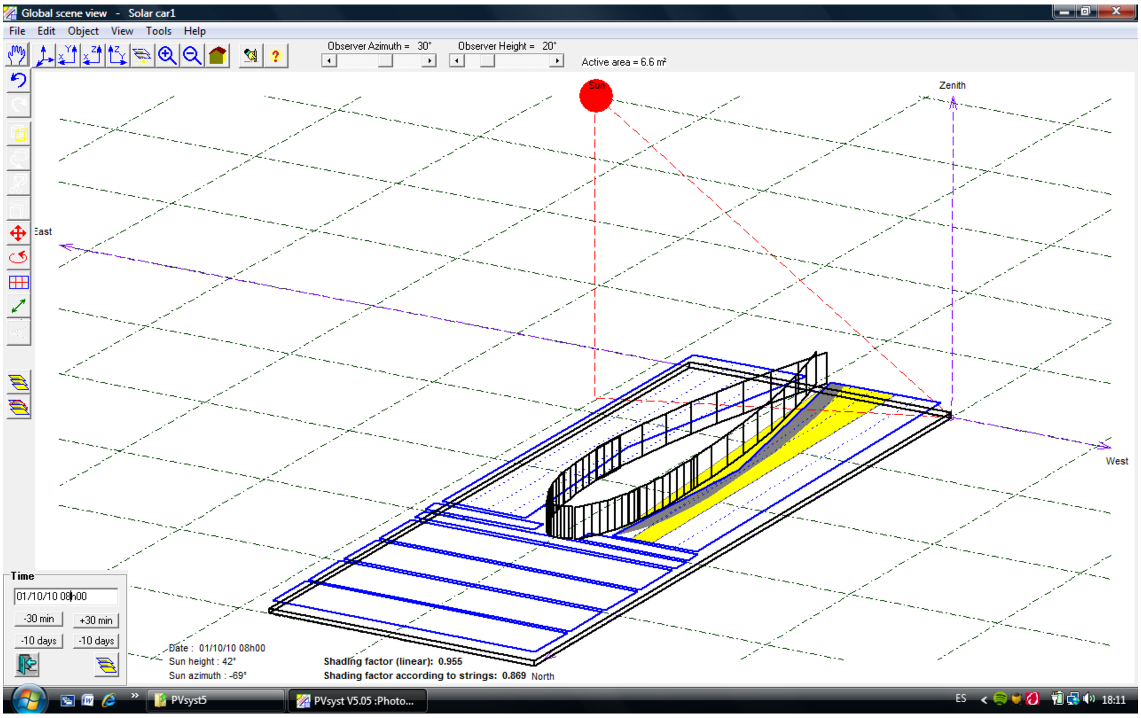
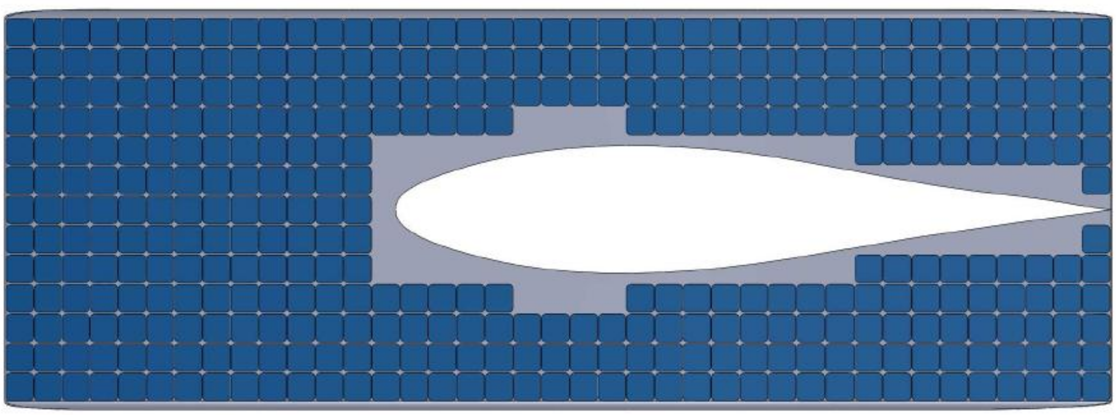


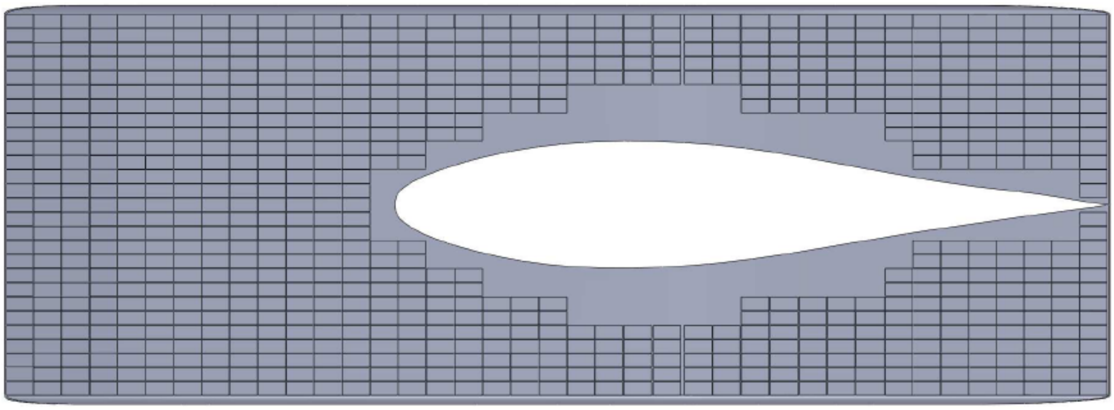
Figure 9: Chosen direction (modules located in the longitudinal direction).

Thus, it is more likely to be several cells of a few strings in the shade rather than being only a few cells, but the more strings in the shade, obtaining less energy, because if there is shade only in one cell, all the chain will stop working. To get the less shadow possible in the cells, we have installed the cells as far away as possible from the cockpit.

Finally, we have got the final designs in Solidworks, one of them with small cells and another one with cells to its original size:



Design 4: Final design with original size cells



Design 5: Final design with reduced cells

As we can see in the appendix 3 and appendix 4, there is a little problem with the final designs. We can see that the last string at the back of the car only has 38 cells (not 39). The 39th should go where the pilot's cabin ends, at the back side of the car, but in order to achieve that we should make the cabin slightly smaller, just 13cm (the size of one cell). I chose these designs because I wanted it to be symmetrical.

If we can´t change the design of the car, we will have to find another solution. I was thinking about this:

Solution 1: If the tip of the canopy is not very high, maybe it is possible to put the cell on it without changing the design of the canopy.

Solution 2: To try to find another distribution of the cells, this would be the last resort because this distribution is very good.

Solution 3: To try to put this last string inside the canopy, and if this is not possible because the string is too large, maybe we can combine some cells inside the canopy with some cell outside the canopy.

We only still had to make the installation process of the cells in the car. The first layer above the car will be made of glass. Then the cell will be placed between two layers of EVA (EVA encapsulation), and finally, cover all with another glass. Thus, the cells will be well covered and protected from external conditions.

8. RESULTS AND DISCUSSION

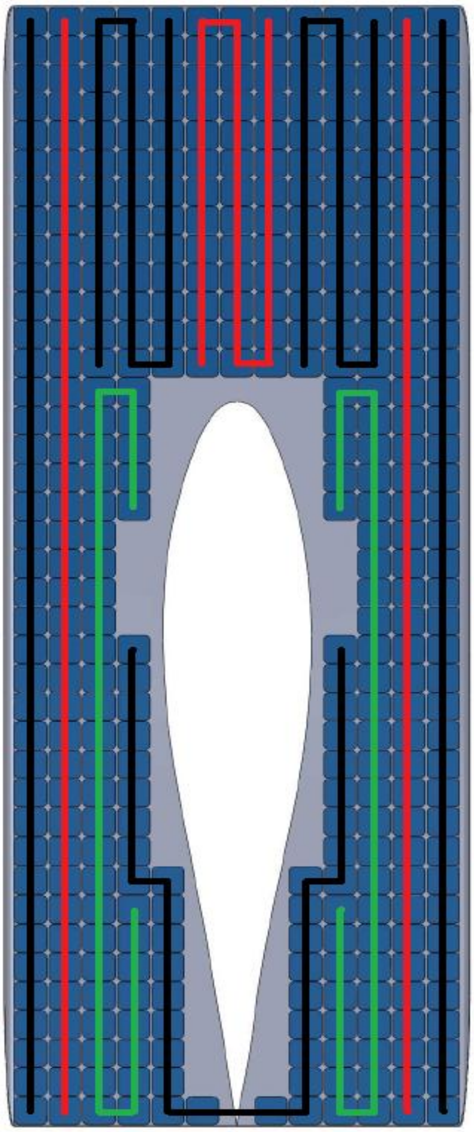
For each of the two designs, we have obtained a report from each of the twelve cities by passing the race. As these tests take up much space in this report we have only the analysis of the city of Johannesburg. Other analyses are included in the Notebook. In these analysis´s we can see dates like power nominal, power real, diagrams of the altitude of the sun according to the month, available energy diagrams and loss diagram over the whole year. At the end of each analysis we have included the final design with its explication and a simulation of the energy got per hour too.

On the other hand, before this analysis, we have also included two pages which show a large amount of useful data about Johannesburg for each month. Focusing on the months of September and October, we found that the air temperature is 18 º C, there will be a humidity of 45%, solar radiation horizontal of 6.02 KWh / m ^ 2 / d, an atmospheric pressure of 85.5 kPa, the velocity wind is 3.8 m / s and the temperature of the earth shall be 22 º C.

Johannesburg analysis obtained

Cells with original size

125 x 125 mm



Design 6: Final design with connections (original cell sizes)

This design has 10 parallel strings of 39 cells in each chain. Theoretically, each cell is 0.6 V and an intensity of 5.576A. Therefore, its power would be 3.3456W. In reality the voltage and current will be lower, so the power of each cell is 2.68W. Each chain will have around 20 Volts.

Thus, 390 cells have been used, it will produce 967W, losses included (1040 watts peak).

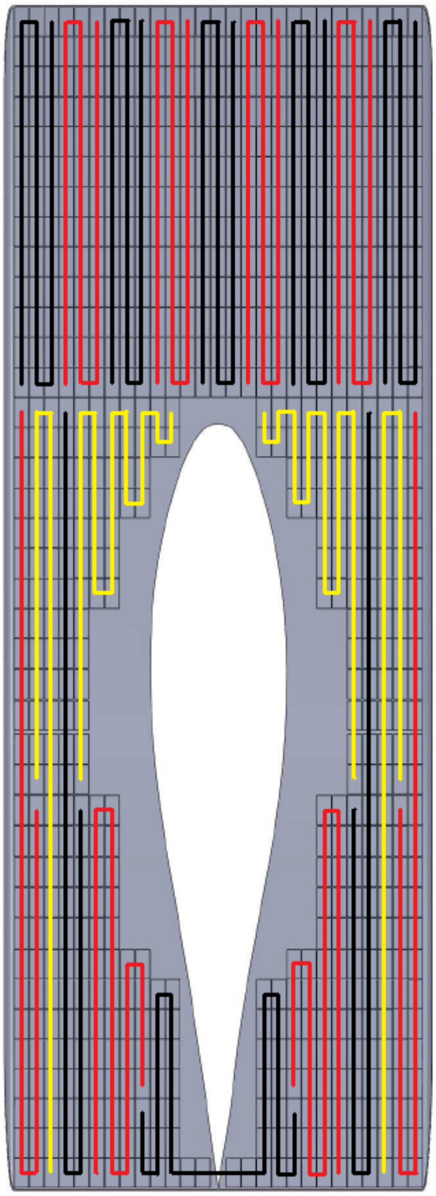
Getting real power – details in hours

PVSYST v5.05				
	File	File date	Description	
Project	Africa Solar.PRJ	20/04/10 12h56	SASC	
Geographical Site	Johannesburg.SIT	20/04/10 12h56	Johannesburg	South Africa
Meteo data	Johannesburg_SYN.MET	20/04/10 12h56	Synthetic Hourly data	
Simulation variant	Africa Solar.VCD	19/04/10 16h45	Johannesburg	
Simulation:	Hourly values	from 01/01/90	to 31/12/90	
Simulation run	20/04/2010 12:56			
date	GlobHor	T Amb	E Avail	E User
	W/m⁄	−C	W	W
26/09/1990 0:00	0	13.51	0	0
26/09/1990 1:00	0	13.08	0	0
26/09/1990 2:00	0	12.88	0	0
26/09/1990 3:00	0	12.79	0	0
26/09/1990 4:00	0	12.15	0	0
26/09/1990 5:00	101	11.54	12.05	0
26/09/1990 6:00	288	13.96	202	0
26/09/1990 7:00	521	15.56	393.1	0
26/09/1990 8:00	712	17.13	565.1	116.7
26/09/1990 9:00	839	19.52	1330	194
26/09/1990 10:00	906	22.19	750.9	205.1
26/09/1990 11:00	909	23.9	923	204.2
26/09/1990 12:00	838	25.34	959.5	202.8
26/09/1990 13:00	697	26.75	889.7	199.1
26/09/1990 14:00	506	26.23	506.3	203.8
26/09/1990 15:00	288	24.77	189.4	204.2
26/09/1990 16:00	116	22.52	0	205.2
26/09/1990 17:00	0	20.96	0	205.2
26/09/1990 18:00	0	18.33	0	205.2
26/09/1990 19:00	0	16.63	0	205.2
26/09/1990 20:00	0	15.78	0	205.3
26/09/1990 21:00	0	13.27	0	145.5
26/09/1990 22:00	0	12.47	0	0
26/09/1990 23:00	0	11.8	0	0

Johannesburg analysis obtained

Reduced size cells

61 x 125 mm



Design 7: Final design with connections (reduced cell sizes)

This design has 20 parallel strings of 39 cells in each chain. In this design we have used 780 cells. By reducing the solar cell size, power of each cell is reduced, so this new distribution generates 973W, losses included (1040 watts peak).

Getting real power (middle cell) – details in hours

PVSYST v5.05				
	File	File date	Description	
Project	Africa Solar.PRJ	20/04/10 13h12	SASC	
Geographical Site	Johannesburg.SIT	20/04/10 13h12	Johannesburg	South Africa
Meteo data	Johannesburg_SYN.MET	20/04/10 13h12	Synthetic Hourly data	
Simulation variant	Africa Solar.VCC	19/04/10 12h40	Johannesburg middle cell	
Simulation:	Hourly values	from 01/01/90	to 31/12/90	
Simulation run	20/04/2010 13:12			
date	GlobHor	T Amb	E Avail	E User
	W/m⁄	−C	W	W
26/09/1990 0:00	0	11.95	0	0
26/09/1990 1:00	0	11.85	0	0
26/09/1990 2:00	0	11.82	0	0
26/09/1990 3:00	0	11.3	0	0
26/09/1990 4:00	0	10.15	0	0
26/09/1990 5:00	114	9.01	10.12	0
26/09/1990 6:00	283	11.75	200.6	0
26/09/1990 7:00	492	13.19	377.8	0
26/09/1990 8:00	722	14.73	579.6	116.8
26/09/1990 9:00	853	17.54	1284	197.1
26/09/1990 10:00	924	19.69	776.7	205.1
26/09/1990 11:00	901	21.44	942.4	204.4
26/09/1990 12:00	858	22.99	1094	201
26/09/1990 13:00	710	24.05	678.3	204.1
26/09/1990 14:00	547	23.84	401.2	198.8
26/09/1990 15:00	347	22.83	218.3	203.3
26/09/1990 16:00	87.01	19.98	0	205.1
26/09/1990 17:00	0	18.52	0	205.2
26/09/1990 18:00	0	16.12	0	205.2
26/09/1990 19:00	0	14.57	0	205.2
26/09/1990 20:00	0	13.09	0	205.2
26/09/1990 21:00	0	11.04	0	205.5
26/09/1990 22:00	0	10.7	0	65.58
26/09/1990 23:00	0	9.62	0	0

9. CONCLUSION

This project is about the study and development of the manufacture of solar panels on the surface of a solar car. This project has had several objectives. The main goal has been to get the most output of the car.

At the beginning of the project, on the one hand, I was a little lost because I am mechanical engineering and this project combines mechanics with electricity, but, on the other hand, I found it very interesting because it is an important field in which I could learn a lot.

As the project progressed, I saw that I learned many things. Also, we have found the best distribution of cells in the car (taking into account profitability, losses, efficiency etc) and we have studied its best adaptation in the roof of the car.

With projects of this type, we help the development of this technology and also make people aware of the need for new types of energy production, since the current is extremely polluting and depleting.

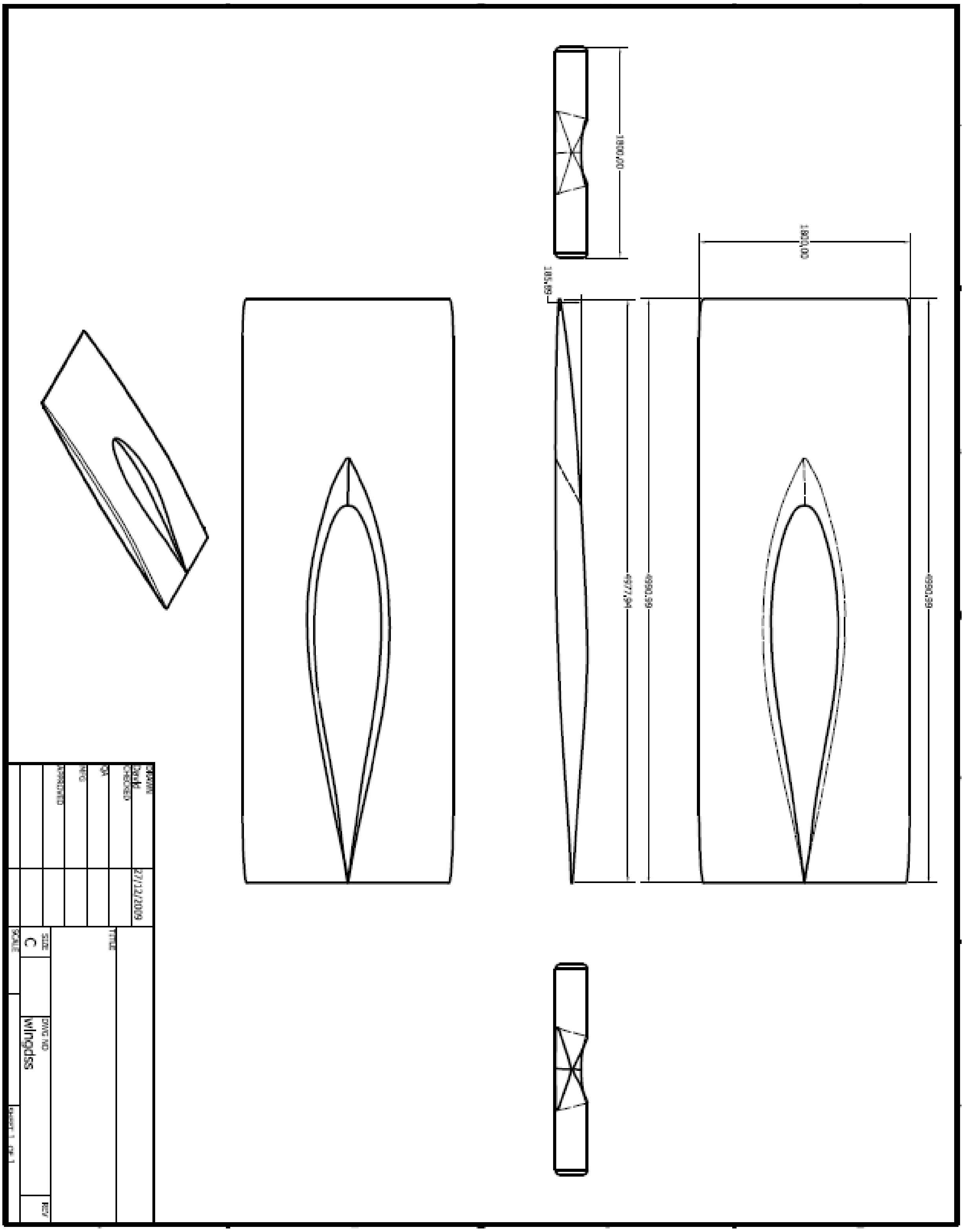
In developing the project, we have found several problems. One of them was how to adapt the cells to the car. Another was to know how to put the last string in the car (at the back) to do a symmetrical design. We also took a long time to find information about how many cells had to form each string. One of the most time-consuming processes was the making of the designs in SolidWorks.

A part from all this, I have carried out the objectives of the project, because I have learned how solar cells work and in addition, how well a car can operate using solar cells.

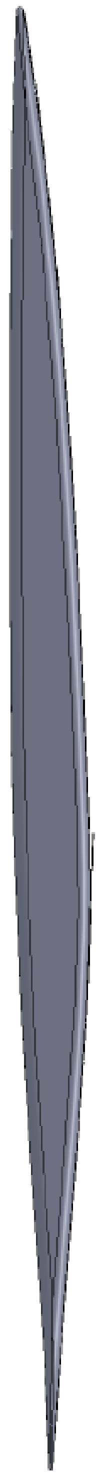
Regarding the project, I think that the two final designs are good, but I have chosen the one that uses reduced cells because they are more efficient, so we will get more energy.

Finally, most importantly, I've enjoyed doing the project because I have put into practice the knowledge that I have learnt in previous years.

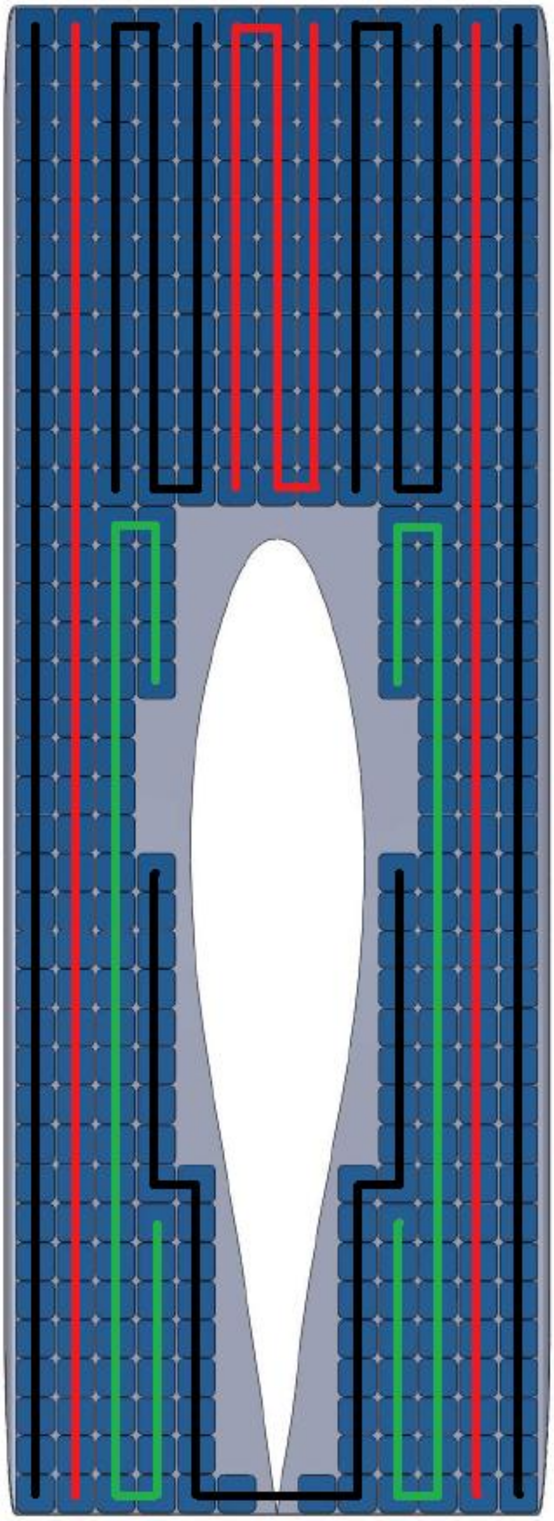
APPENDICES



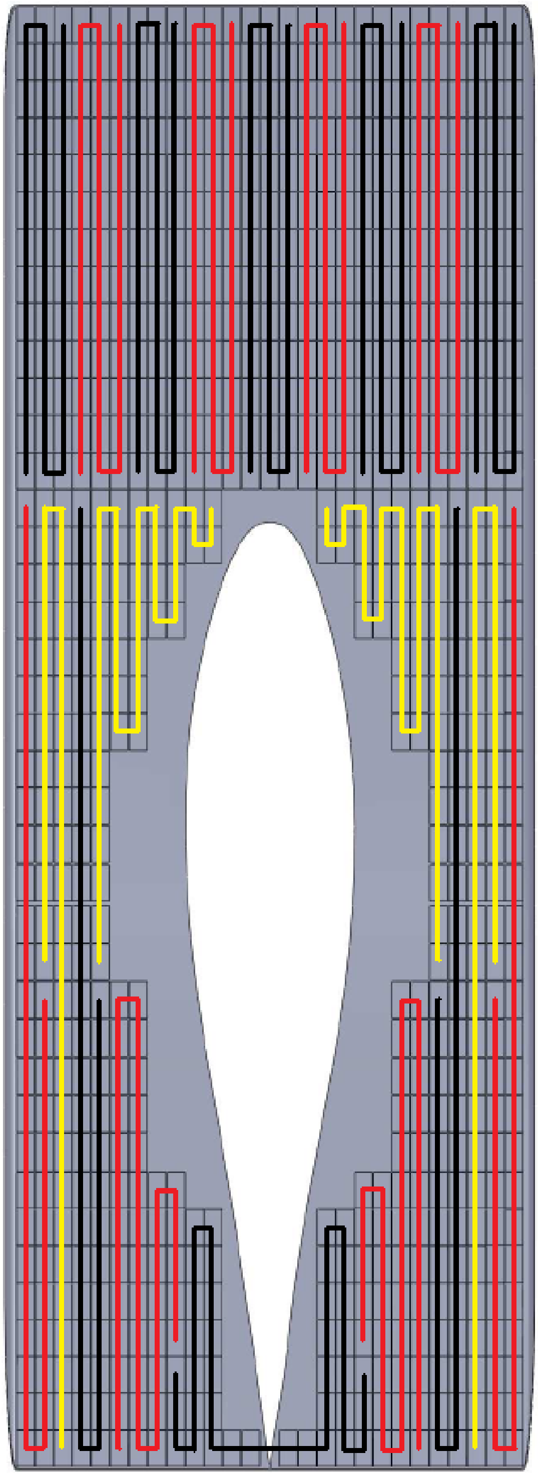
Appendix 1: AutoCad



Appendix 2: Solar Car Profile



Appendix 3: Final Design (original cells sizes)



Appendix 4: Final Design (reduced cells sizes)

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Available at:
http://motor.terra.es/ultimas-noticias-actualidad/articulo/coche-electrico-realidad-43303.htm

Fabrication of solar panels on the surfaces of a solar car

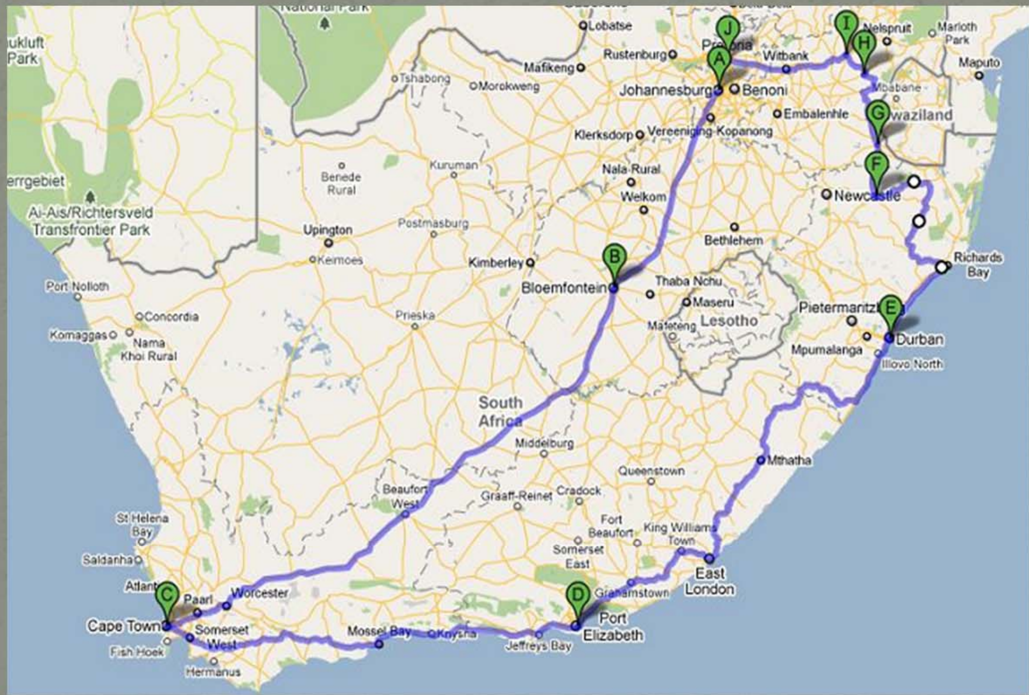
South African SOLAR Challenge

Fernando Bañales Izco

Contents

Background

South African Solar Challenge 2010

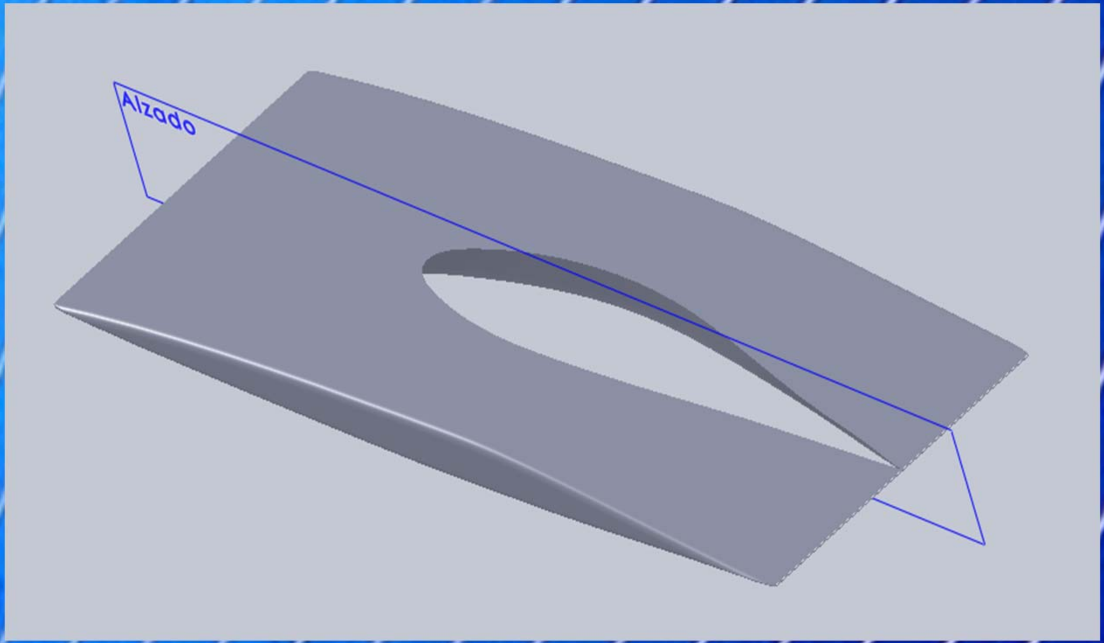


2500 miles = 4100 Km

Final Year Project

Project:

- **Fabrication of solar panels on convex surfaces:**
  The surfaces of solar power car (South African Solar Challenge).



Objectives


Lay Out
System Performance
Losses
Achieve maximum output
Cell Efficiency
Output Power

Final Year Project

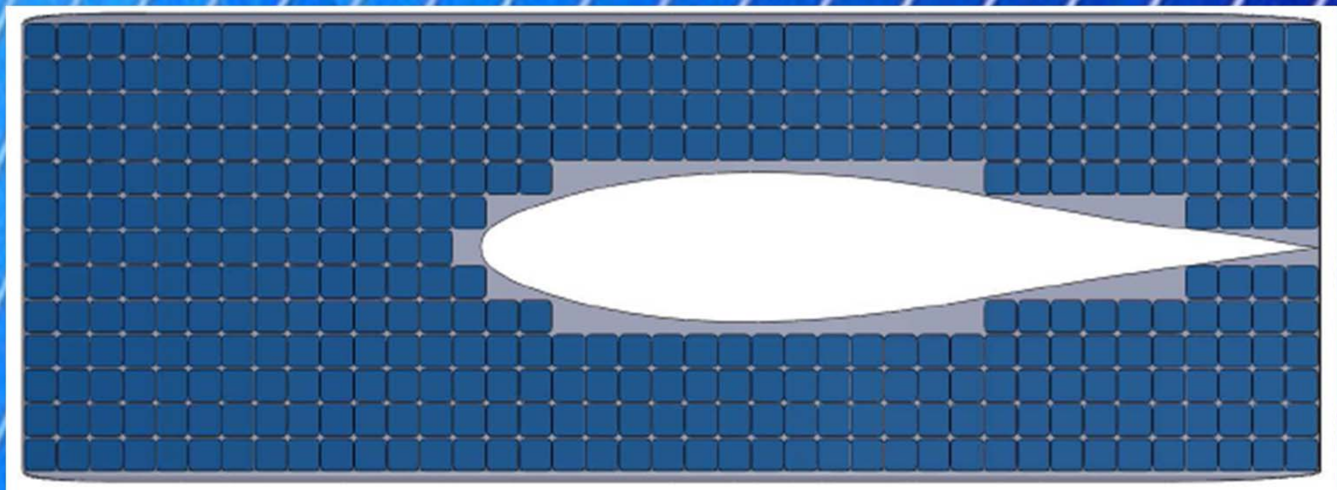
Work schedule:

1. Find out information about solar cells.
2. Propose my ideas.
3. Search theories and formulas necessary.
4. Design.
5. Make.
6. Test.

Design Process

Voltage : 0.6 V
Intensity : 5.576 A

Efficiency : 17.369%
Maximum Power : 2.68 W



413 cells * 2.68 W = 1101 W

Factors influencing the design

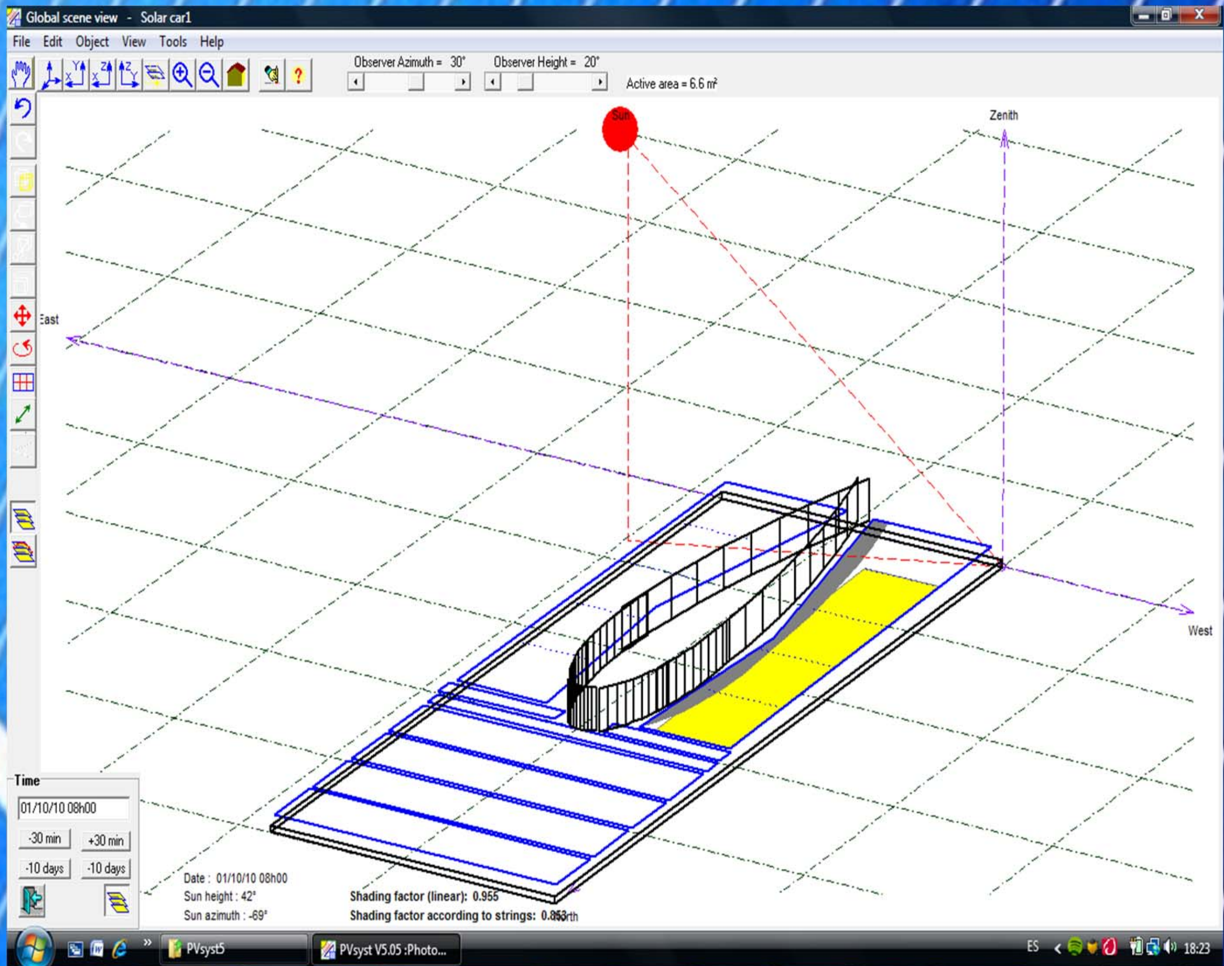
Battery
- Battery Voltage (12 V each battery)
- 4 batteries in series = 48 V

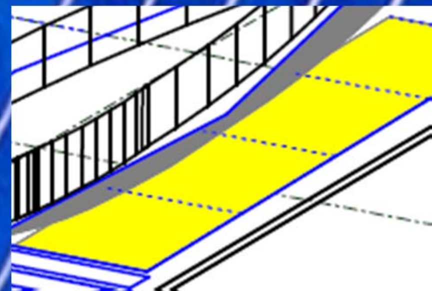
Regulator
- P1 (input power) = P2 (output power)
- V1 x I1 = V2 (48V) x I2

Isolated System
- More cells to get the same voltage

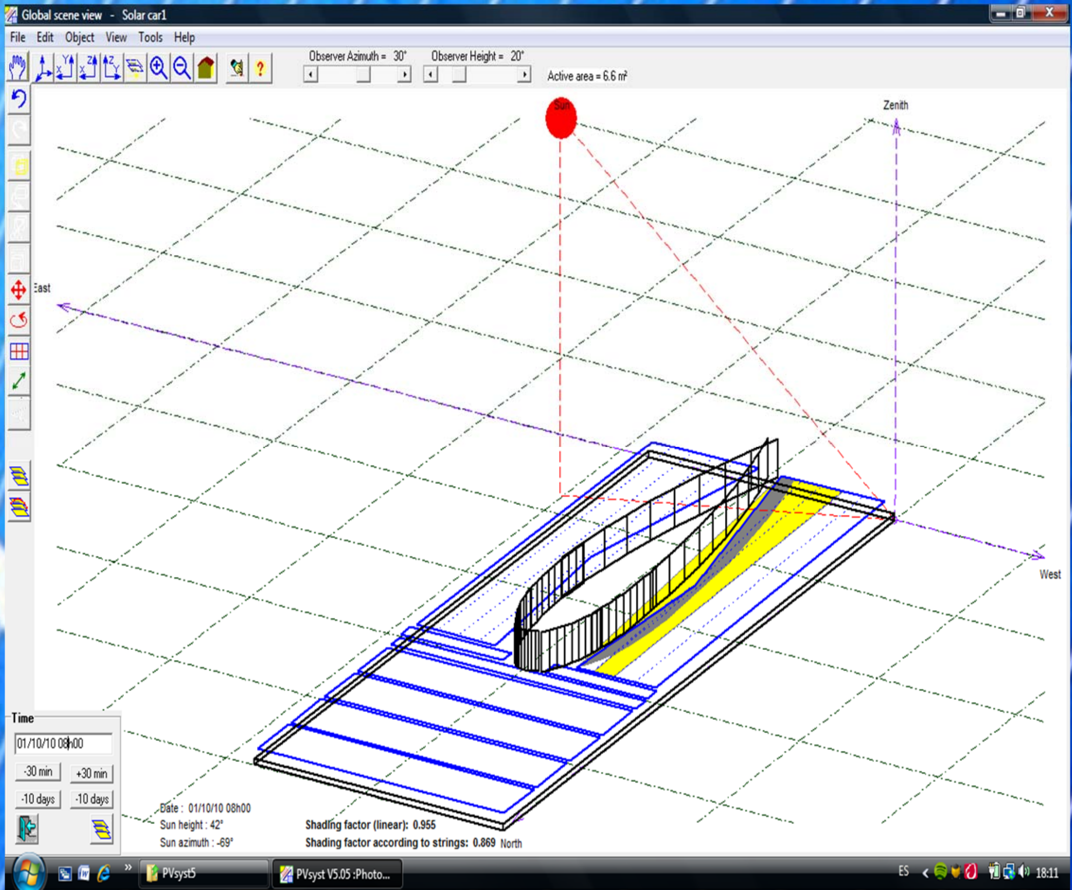
South Africa
- maximum area of 6m ^ 2

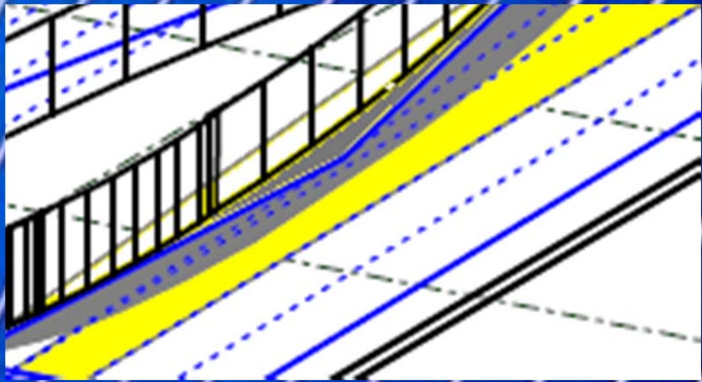
Shading
Modules located in transversal direction

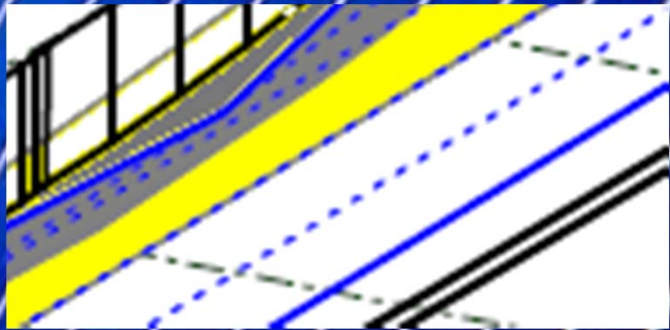




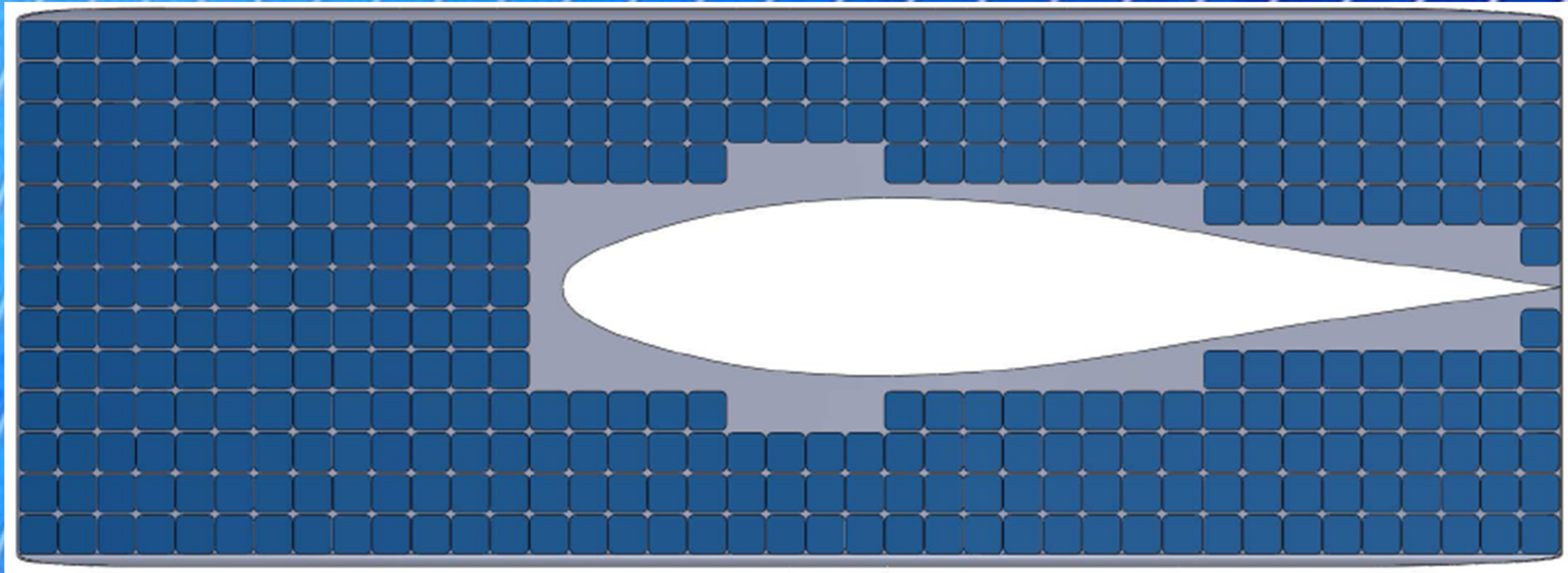
Shading
Modules located in longitudinal direction

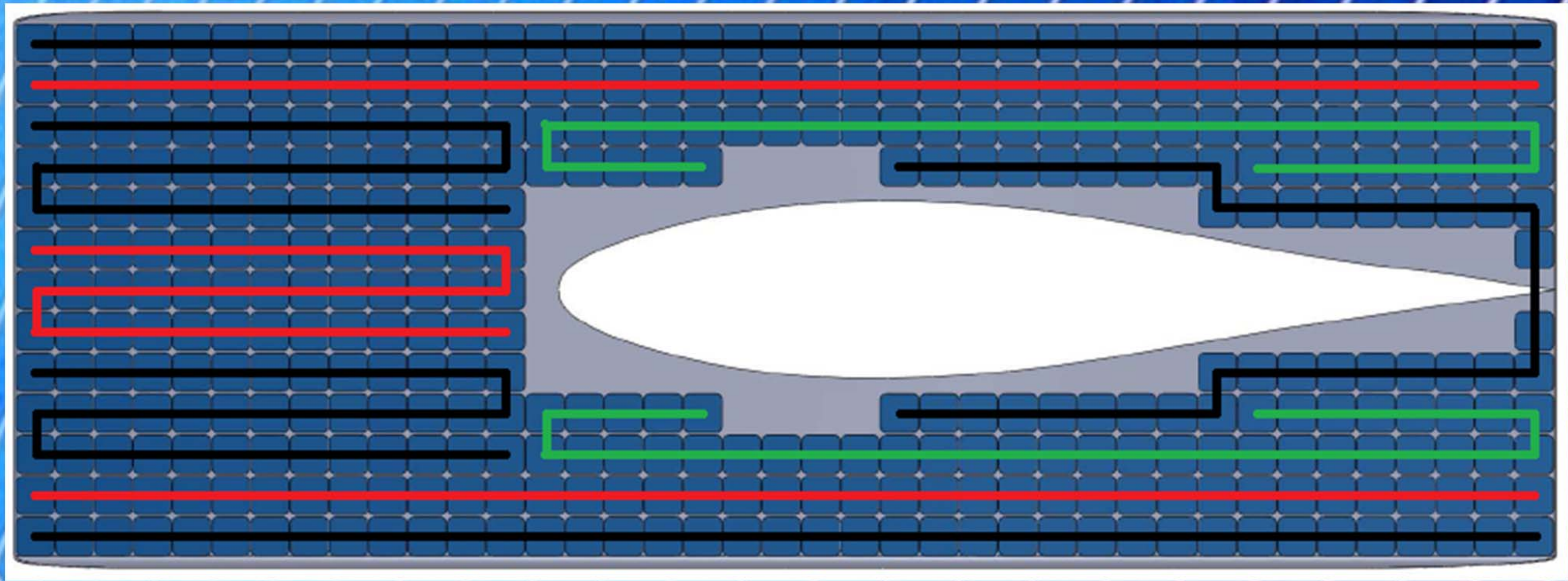




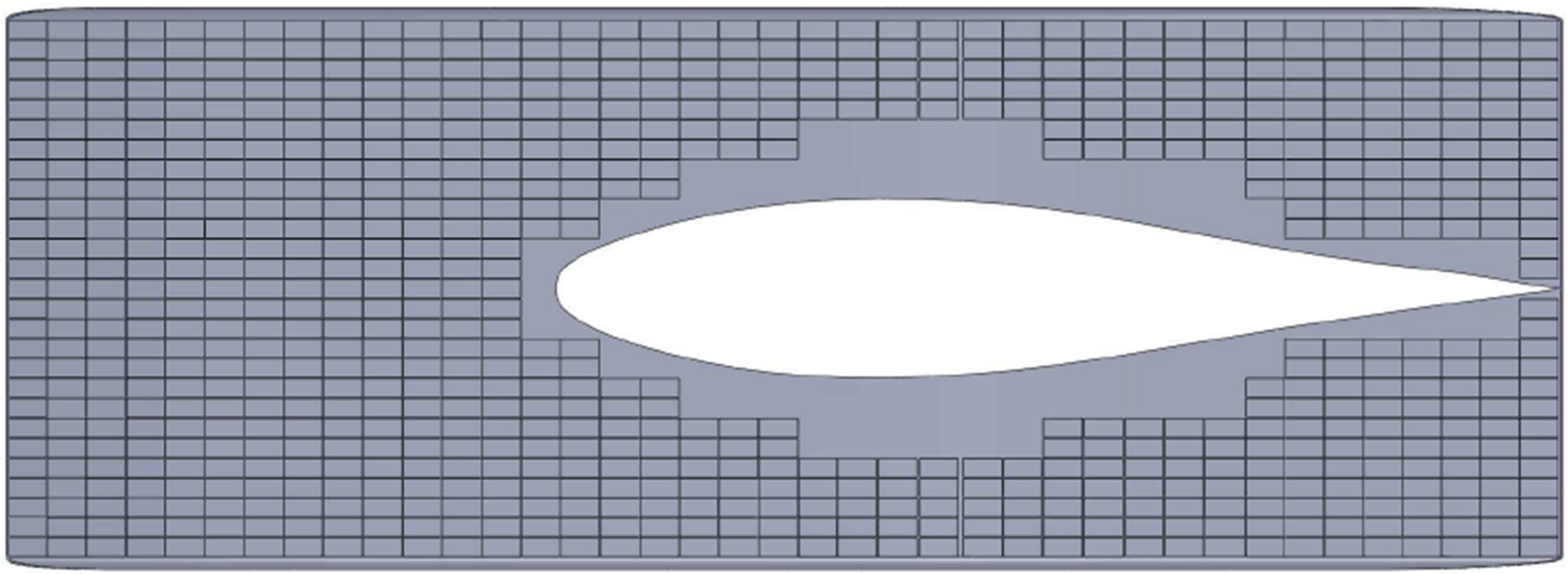


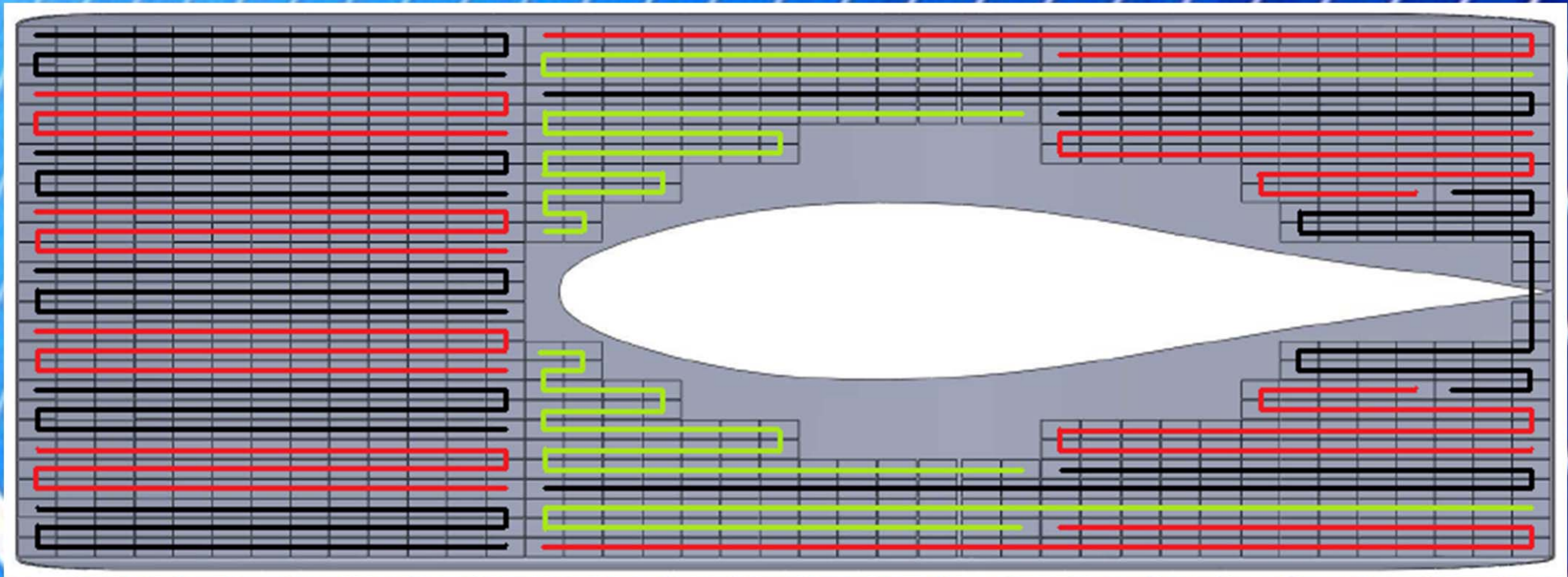
Final design (original size cell)





Final design (reduced size cell)





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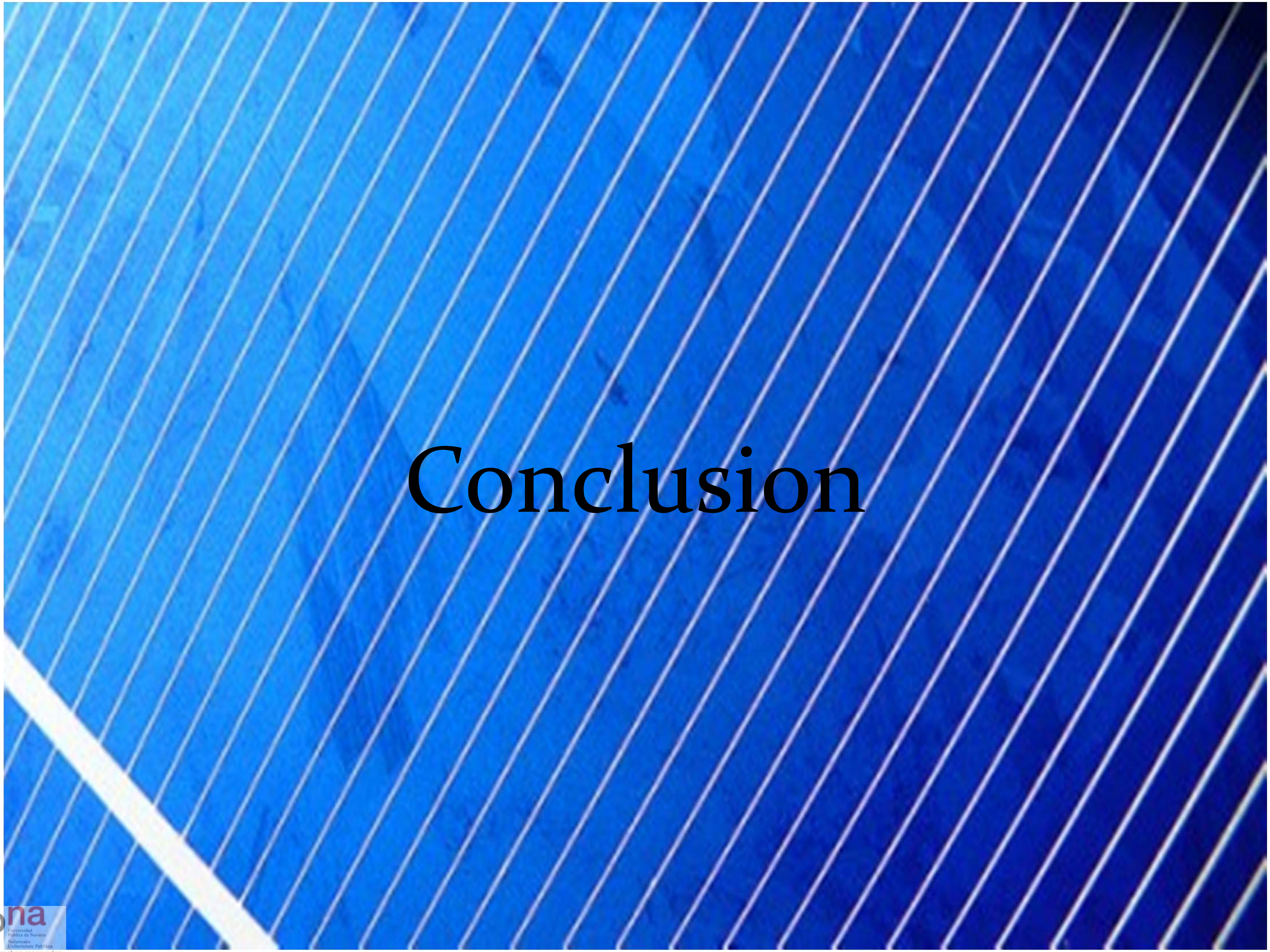

Conclusion

Thanks for your attention.