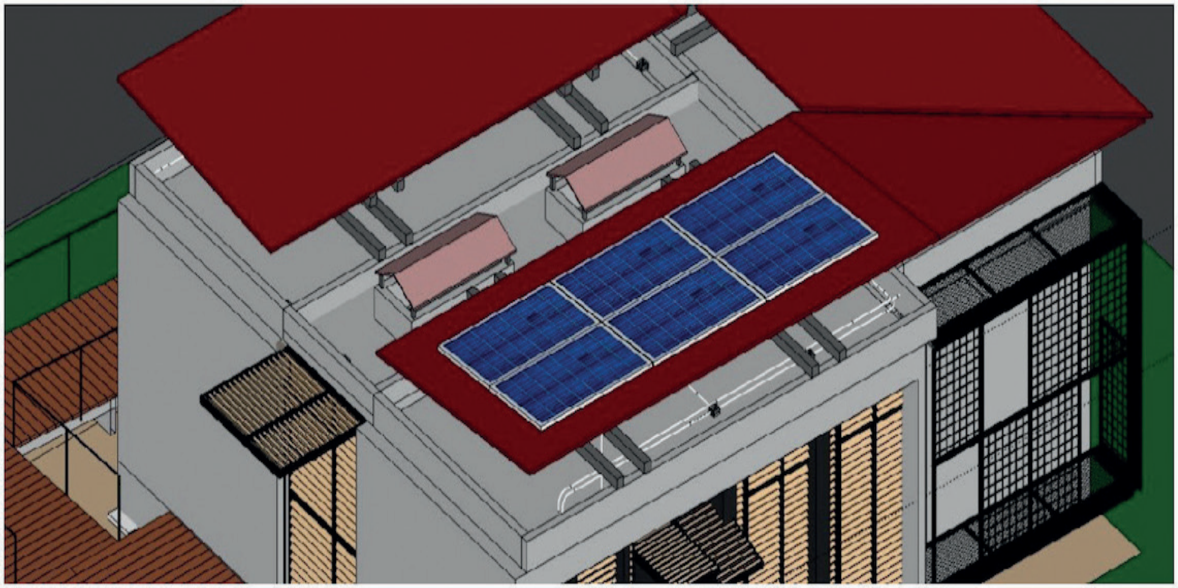
Chapter 3

Energy Management System



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Electrical System Design

A general description of the design criteria adopted for the electrical system of this project is going to be shown. To select the electric load (freezer, lighting system, laptop, washing machine, etc), studies made by utilities were used. In those publications, some reports explain the type of loads and electricity profiles in low income houses or what is called here social housing. Then, those studies were compared and the Mihouse electric load was defined. With the power and energy defined, the calculation of the photovoltaic system was carried out. The following table shows the energy consumed at Mihouse, which is simulated with a baseline similar to the papers studied, with an average of 1 000 W.

Table 3.1. One-year time series detailed analysis of Mihouse electrical load

#	Electric loads	AC voltage (V)	Power (W)	Daily hours	Total energy kWh/day
1	Led luminaire living	120	10	5	0,05
2	Led luminaire restrooms	120	10	2	0,04
1	Led luminaire kitchen	120	10	5	0,05
1	Led luminaire dinning	120	10	3	0,03
1	Led luminaire patio	120	10	2	0,018
1	Led luminaire bedroom 1	120	10	4	0,04
1	Led luminaire bedroom 2	120	10	4	0,04
1	Led luminaire bedroom 3	120	10	4	0,04
1	Blender	120	370	0,2	0,074

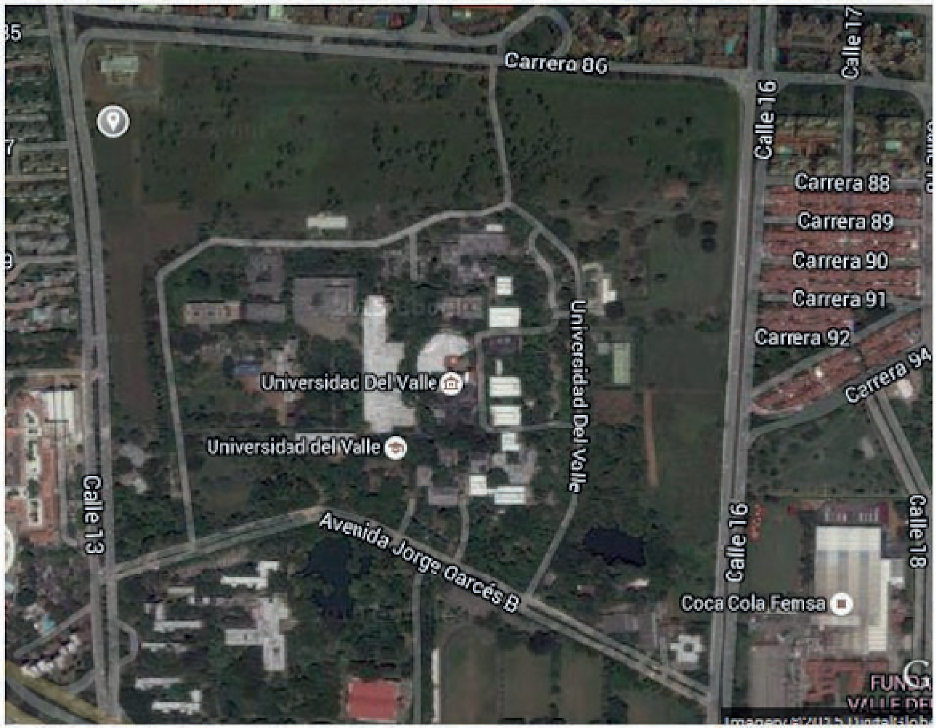
#	Electric loads	AC voltage (V)	Power (W)	Daily hours	Total energy kWh/day
1	Washing machine 31 pounds	120	125,6	1	0,1256
1	Refrigerator 222l	120	100	12	1,2
1	TV led flat 22’	120	30,4	3	0,0912
1	Phone charger	120	12	3	0,036
1	Laptop	120	65	6	0,39
1	Microwave	120	800	1	0,8
1	Oven	120	1000	1	1
	TOTAL		2583		

Source: The Authors.

Solar Energy Resource

After having the demand clear, the resource must be identified with the site latitude and longitude over The Solar Village location. Location can be found using Google Earth as a basic tool and latitude and longitude appears by default as shown on Figure 3.1.

Figure 3.1. The Solar Village location.



Source: Map of Valle del Cauca [online]. Google Earth [1 of december 2014]. Available on: http://www.google.com/intl/es/earth/download/ge/agree.html

Then, The Solar Village in Cali is located in Latitude: 3.379021 and longitude -76.537095. A most accurate solar resource can be obtained from weather stations, satellite data or statistics data registered. In this case a comparison between NASA meteorological data and the Universidad Autónoma de Occidente own weather station will be used.

First, the Surface meteorology and Solar Energy resource available at https://eosweb.larc.nasa.gov, which is a renewable energy resource web site (in its release 6.0), that has been sponsored by Nasa's Applied Science Program in the Science Mission Directorate and developed by Prediction of Worldwide Energy Resource Project (Power), will be used with an altitude of 990 m. Regarding solar radiation, it can be observed that the south of Cali has an average of 4560 Wh/m^2. On the other hand, the average temperature is approximately 23,5°C considering maximum of 33°C and minimum of 18°C, with sunny days almost all year.

Meteorological Study

Some data has been collected on a weather station located near to The Solar Village location. As presented here, temperature, solar radiation, humidity and rain will affect the contest and they must be considered by the team to reach interior values measurements

Data of Average Insolation on horizontal surface

The atmospheric Science data center that manages the Eos web application gives the following results:

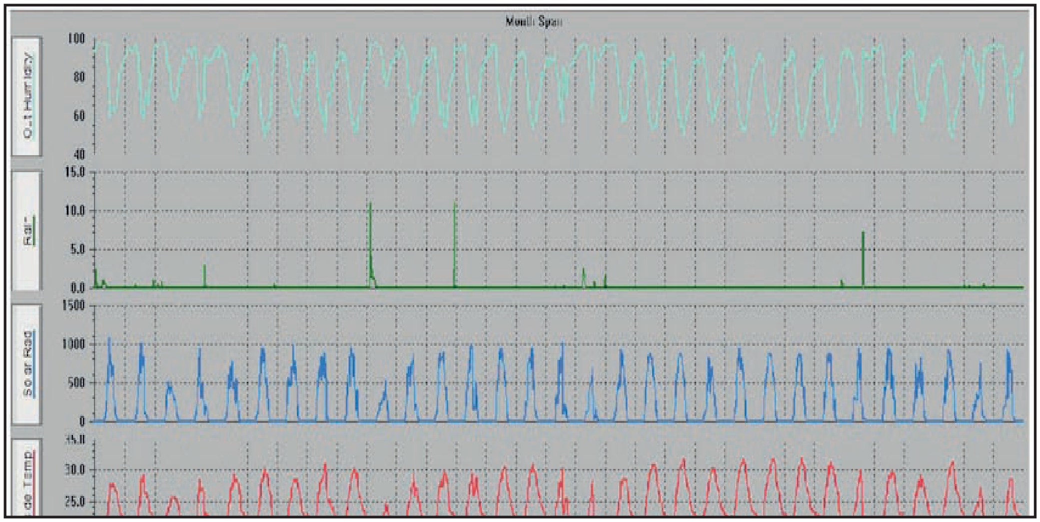
Table 3.2. Monthly Averaged Insolation Incident on a Horizontal Surface (kWh/m2/day)

Lat 3.37 Lon-76.5	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual average
22-year Average	4,05	4,28	4,37	4,21	4,09	4,05	4,34	4,30	4,26	3,99	3,89	3,82	4,13

Source: https://eosweb.larc.nasa.gov/. Responsible > Data: Paul W. Stackhouse, Jr., Ph.D. Officials > Archive: John M. Kusterer - Site Administration/Help: NASA Langley ASDC - Document generated on Fri Jun 12 08:52:20 EDT 2015.

To confirm the data prediction, some weather information from a meteorological station is presented here. In the first place, outside humidity, then level of rain which apparently is just a few mm, Solar radiation with one peak around the 10th of November and the last one is outside temperature, oscillating between 20°C - 30°C (Figure 3.2, Figure 3.3)

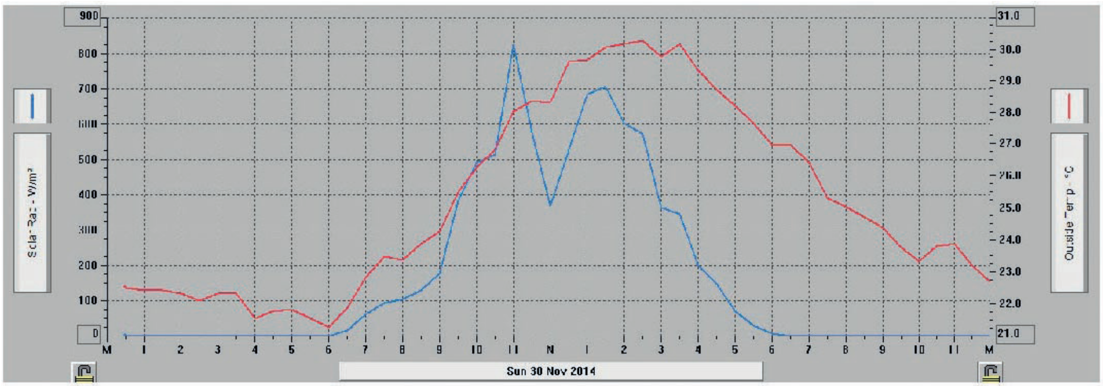
Figure 3.2. Meteorological span figures from 10th November until 10th of December 2014



Source: Obtained from the meteorological station at Universidad Autónoma de Occidente.

In this context, identifying solar radiation values would allow the Mihouse team to perform an accurate energy prediction. As an example, outside temperature and solar radiation of 30th of November 2014 is shown here.

Figure 3.3. Meteorological span figures from 10th November until 10th of December 2014



Source: Obtained from the meteorological station at Universidad Autónoma de Occidente.

Maximum values of 800W/m^2, could be presented in a regular day of November, with peaks of temperature of 30°C. As it is shown in blue line for radiation, when the sun rises, minimum values of solar radiation appear at 7 am with 100W/m^2 and in this case, radiation falls near noon when a solar radiation of 1000W/m^2 can be measured. Then it goes down near 6pm and the last value could be at 5pm with 100W/ m^2.

Photovoltaic System Design

In general terms and to accomplish with the Solar Decathlon requirements, a solar photovoltaic (PV) grid-tie system is considered to this project. Each dwelling will have its own electric load cover by that PV system which responds to the house needs and allows selling its surplus to the electrical grid. Furthermore, the methodology used to select and size this generation system will be presented.

That system consists of 12 solar PV panels for each house. They capture the solar radiation (photons), and convert it into electrical direct current (DC). That DC current flows to the synchronous grid-tie inverter that convert it to alternating current (AC).

PV modules general characteristics vary according to the technology. Nowadays, Solar PV High efficiency modules are being manufactured from Silicon such as:

- Multicrystalline silicon solar cells.
- Monocrystalline solar cells.
- Amorphous silicon.

There are some other new fewer commercial technologies:

- Hetero Intrinsic Junction HIT (Sanyo –Panasonic)
- THIN –FILMS (CdTe, CuIGaSe2, etc)
- Organic

Selecting the type of module to Mihouse depends not only on technology (high performance on tropical environments or adverse conditions), but costs, stocks, efficiencies, weight and area. Hence, PV modules and inverter equipment were selected using a multi-criteria selection system, based on these topics. Well recognized manufacturers must be taking into consideration for quality results. Moreover, code compliances are considered. After some time reviewing different solar PV manufacturer's rankings, it was decided to analyze and compare the following table:

Table 3.3. Top manufacturers

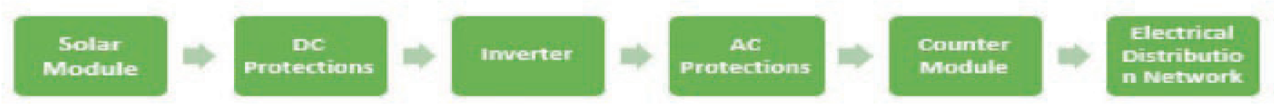
Top MANUFACTURERS
Canadian solar
Kyocera
Sunpreme
Solarworld
Yingli
Toshiba
Sanyo
Panasonic
First Solar

Source: The Authors.

To select the grid-tie inverter, first, the electrical power demanded by the dwelling must be considered. Then, voltage and AC current from the load side (house) and AC input range voltage which must match with the PV array output values.

Solar photovoltaic panels consist of many solar cells, being most of them made by silicon which are connected between them to produce an electrical direct current (DC) that goes to electronic devices such as inverter to convert direct current into alternating current for the amount of electricity required in a house for its electrical appliances. The full system is described by modules in the following scheme:

Figure 3.6. Components and energy flow on a solar PV grid connected system



Source: The Authors.

Basically, a solar PV grid connected system has the following components:

Solar PV grid connected system: Generally, a solar grid connected system consists of

- Inverter system.
- Protection System and health and safety elements.
- Electricity power meter.
- Transformer to grid (some cases).

Maintenance Plan

Solar energy has the advantage of minimum expenses for maintenance. However, as an electrical energy system, it requires preventive maintenance to avoid any failure during its regular operation and in case of a failure or damage; corrective actions must be carried out.

Preventive Maintenance. Cleaning: After installation, it is recommended to observe carefully how clean or dirty the modules are. This allows to identify or to determine the period of time for cleaning. This cleaning can be done with a small dry cloth during a day (producing electricity), or it can be done with a wet cloth on a disconnected system. Because a solar PV system does not have movement, there are minimal maintenance costs but even these diminish over time. This process should be done every three months to avoid particles allocated over the module.

Corrective Maintenance

- To change damaged or broken modules.
- To replace damaged wires or with some corrosive mark.
- To replace PV mounting structures physically damaged.

Produced Energy

After all the ideas, researches and decisions made during many meeting hours, the team designed an efficient project in terms of solar power generation and consumption. We believe that with the Mihouse prototype it can be demonstrated to the visitors of The Solar Village the state of art in photovoltaic solar technologies that can be integrated as architectural elements in low-income living residential condominiums.

For example, the total solar electric PV system consists of 544 Canadian 310 W panels for a total peak power of 168 kW placed on a roof system. This system is connected to the electronic subcomponents that will connect the solar power to the living house and additionally it will charge a 5 4400 Ah.

Available roof surfaces for setting solar panels

Since the buildings in the project proposed two clear areas in the roofs with a small declination of 15° (at the equator line), it was decided during the designing process that these would be the surfaces where it would be able to locate the solar panels. Then it was proceeded to calculate those available surfaces (See the following Table).

Table 3.4. Available surfaces

Roof area (m^2) in living unit type a	Roof area (m2) in living unit type b	Roofs per group of buildings	Roof area per group of buildings (m^2)
	53,83	4	215,32
54,24		2	108,48
		AREA IN 1 GROUP	323,8
		AREA IN 6 GROUPS	1942,8

Source: The Authors.

As seen in the previous table, each group of buildings has an available roof surface area of 323,8 m^2. Considering there are 6 groups of buildings that provided 1942,8 m^2 of available surface, it was affirmed that it is possible to easily install more than 1000 solar modules with an area of 1,9 m^2 each.

Then it was compared the estimated energy generated in the roof area to the calculated energy required for the proposal. This enabled us to know if there were enough panels on the roof and if it was needed more or less roof area for positioning more/less panels.

Estimated area versus required area for the solar PV system. Sizing the PV system allowed to decide the type, brand and size of solar module that complied with the available space on the roof. The number of living units, modules per-living unit and the total amount of solar modules for the project were considered to define the total required area. In the project, the area considered depended on the module area of 1,92 m^2. (See Table 3.5)

Table 3.5. Estimation of area per living unit module

Living units	148
Modules per living unit	4
Modules per building	24

Total modules/project	544
Area per module (m^2)	1,918828
Total area (m^2)	1043,84243

Source: The Authors.

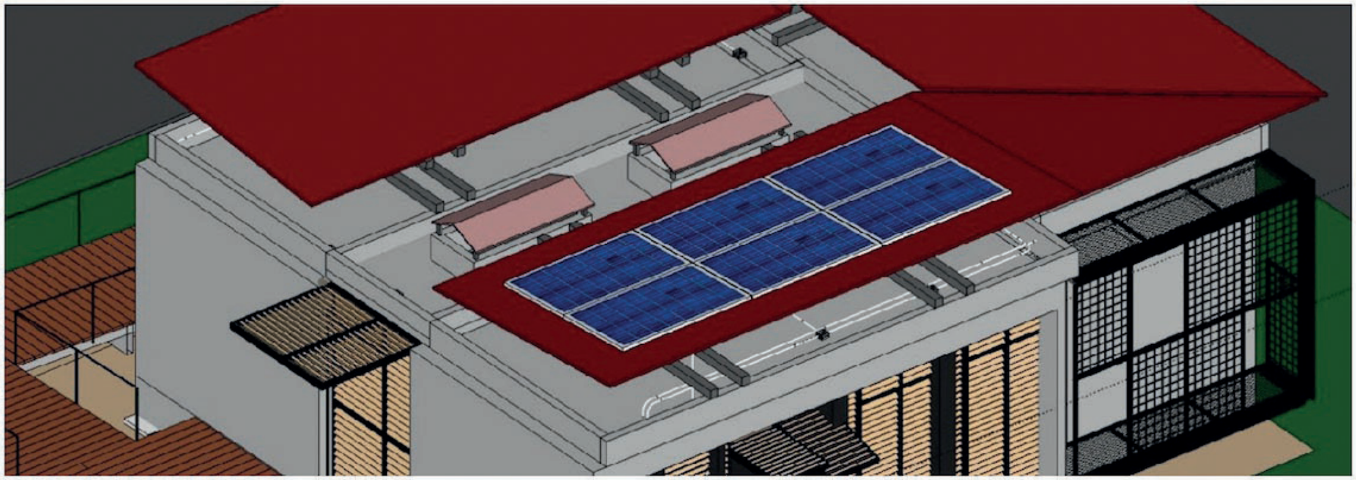
As seen on the table, these 148 living units have 4 (1,92 m^2) modules each, which means that for 544 solar modules it is required a global area of 1043,84 m^2. This represents more area available than what Mihouse requires.

Solar PV System

After identifying the total energy demand for this proposal, as presented on the last item "Electrical system design", the following step is to size the solar PV system i.e. panels, inverter, protection, wires, etc. that are detailed as follows.

The solar PV grid connected system must accomplish with the entire house demand, according to this, an energy generator should generate at least 2590 W during the maximum peak demand. Standardized, solar modules and inverters can be found in similar values to 3000 W. The solar PV system consists of 2 strings of 6 series connected modules. Multiple modules are wired in series to increase direct current (DC), voltage. The installed capacity for this rooftop system is 3000 W at Standard Test Conditions as it is presented in the following figure, using sketchup software (Figure 3.4)

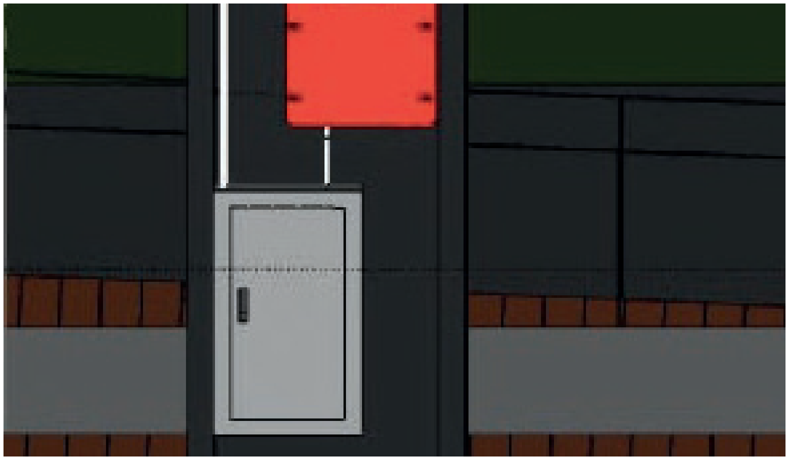
Figure 3.4. Rooftop with the solar PV system



Source: The Authors.

The DC voltage is converted by the inverter and connected to the house with the function of providing enough energy to cover living unit demand and send the energy excesses to the grid, in low demand periods. This fundamental electronic device will be located on the electrical feeder, as it is shown in the following figure.

Figure 3.5. Solar grid-connected inverter



Source: The Authors.

For the accessibility of the installation, Mihouse will have an electrical feeder cabinet that can be reached from outside the house for maintenance and repair tasks. There, the inverter, main switch, protections and the control systems are connected technically. Thus, any decathlete or reviewer or jury could check it anytime.

Electrical Load Study

Estimating solar and energy consumption in low income living houses is a hard task. However, some researches and publications show that a person in low-income neighborhoods in Colombia consumes an average of 35 kWh/month, which means that in Mihouse it is required approximately 175 kWh/month. On the other hand, an important Colombian utility showed in a study that a full family would consume 270,4 kWh/month (UPME, 2014). Taking into consideration those very serious reports and the team's professional considerations, Mihouse decided 134,07 kWh/month as design criteria (UPME 2014). This was also reviewed in June 2015 at: http://www.siel.gov.co/siel/documentos/documentacion/Demanda/Residencial/Consumo_Final_ Energia.swf

Table 3.6. Energy load requirements per living unit

Quan.	Load	Voltage (V)	Power (W)	Hour/day	Total energy (Kwh/day)	Monthly energy (Kwh/month)
1	LED living room	120	15	5	0,075	2,25
2	LED restroom	120	15	2	0,06	1,8
1	LED kitchen	120	15	5	0,075	2,25
1	LED dining room	120	15	3	0,045	1,35
1	LED yard	120	15	2	0,018	0,54
1	LED bedroom 1	120	15	4	0,06	1,8
1	LED bedroom 2	120	15	4	0,06	1,8
1	LED bedroom[3]	120	15	4	0,06	1,8
1	Blender	120	400	0,2	0,08	2,4
1	Washing machine 24 LBS	120	500	0,45	0,225	6,75

1	Freezer 200L	120	137,5	12	1,65	49,5
1	TV led 32’	120	60	3	0,18	5,4
1	Sound system	120	150	4	0,6	18
1	Mobile charger	120	12	3	0,036	1,08
1	Laptop charger	120	65	5	0,325	9,75
1	Microwave	120	770	1	0,77	23,1
1	Iron	120	750	0,2	0,15	4,5
TOTAL			2964,5		4.469	134.07

Source: UPME, 2014.

According to each possible living unit and recommended electrical appliances, the team researched regional and local academic and social publications that reported the way in which energy is used by people living in poverty. That energy assessment gave real data of how each electrical appliance works. After reading those reports, the design changed to be approached to that data. The electrical load for an average family is presented. A highly efficient lighting system that could be replaced by the inhabitants of the house in the future was considered. For instance, LED lighting with less power consumption could be used, but it is not a real commercial light found in a regular store or popular market. In the same way, the freezer, washing machine and the rest of the appliances considered all these important efficiency aspects by working 120V at 60Hz.

In this table, a total energy amount of 4469Wh per day is required per/living house (Table 36). Considering that these houses would be developed in Cali, Colombia, it is expected a monthly solar average radiation of 4,3 kWh/m^2 and an average of 4,3 Hours of Solar Power each day. So far, a load of 3000 Wp per house is considered, resulting on 12 kWp per building without considering lighting on common areas and other services (water pumps). It can be seen how the loads are distributed. This information was built with the help of software and constitutes an important input for simulating a load curve indicating the energy consumption of the living unit during a regular day (Table 3.7).

Table 3.7. Energy consumption during a regular day

	LED living room	LED bath	LED kitchen	LED dinning	LED patio	LED room 1	LED room 2	LED room 3	Blender	Washing ma chine 24 LES	Freezer 200L	TV led 32’	Sound	Charger cellphone	Charger laptop	microwave	Iron	Power/hour
0-1											0,137				0,065			0,202
1-2 AM															0,065			0,065
2-3 AM											0,137				0,065			0,202
3-4 A M															0,065			0,065
4- 5 AM											0,137				0,065			0,202
5- 6AM	0,015		0,015	0,015	0,015	0,015	0,015	0,015										0,105
6-7 AM											0,137		0,15					0,287
7-8 AM																		0
8-9 AM											0,137							0,137
9-10AM													0,15					0,15
10-11 AM									0,2	0,25	0,137						0,015	0,602
11-12:00																		0
12-13 H											0,137							0,137
13-14																		0
14-15											0,137							0,137
15-16																		0
16-17											0,137		0,15					0,287
17-18													0,15					0,15
18-19	0,015		0,015	0,015	0,015						0,137			0,012				0,209
19-20	0,015	0,015	0,015	0,015		0,015	0,015	0,015				0,06		0,012				0,177
20-21	0,015		0,015			0,015	0,015	0,015			0,137	0,06		0,012				0,284
21-22	0,015		0,015			0,015	0,015	0,015				0,06				0,77		0,135
22-23											0,37							0,137
23-24																		0

Source: The Authors.

Solar system design and simulation

Several computer tools to build models, run parametric studies, and analyze results were used. The following is a brief description of the programs used:

- Homer: is an optimizing tool for the design and simulation of renewable energy systems for isolated and grid-tie systems.
- SketchUp – OpenStudio: The OpenStudio plugin to Google SketchUp streamlines the task of defining 3D geometry for EnergyPlus analysis. OpenStudio also provides an interface for visualizing the output from EnergyPlus.
- Microsoft Excel: Results from EnergyPlus are downloaded to Excel spreadsheets. The energy analysis process makes extensive use of Excel's graphical analysis capabilities.

Mihouse supplies 100% clean electricity by photovoltaic panels with high efficiency and reputation in the market, there are 12 photovoltaic modules with an output of 310 W each with a serial connection type with the aim of achieving a greater power and performance. These modules correspond to the Canadian Solar brand Max Power CS6X-305. In addition, Mihouse controls and converts the energy produced from DC to AC every day. This is possible thanks to Inverter StecaGrid 3010, a referenced element highlighted in the market for its high coefficient of maximum performance (98,6 %), see Figure 3.7.

Figure 3.7. Panel and Inverter technical information

Source: Canadian Solar catalogue Available on: http://www.get-systems.com/productsfiles/solarcells/Canadian_Solar-Datasheet-MaxPower-CS6X-P-v5.51en.pdf

Electrical Energy Balance Simulation

Energy production and environmental benefits: Environmental benefits of Mihouse include tons of CO_2 saved due to its clean Energy production. Moreover, the functional architectural design allows natural lighting pass through wide windows allowing the fresh wind in the afternoon flow throughout the house, avoiding any air conditioning system and reaching comfortable temperatures.

P0'Because of the high values of solar radiation in Colombia and especially Santiago de Cali, this is an ideal scenery to take advantage of the solar resource. With the solar energy PV system, Mihouse is designed to generate 100 % of electric loads during the night time or during the day, becoming this proposal a sustainable living unit. These special weather features can be analyzed using computational tools as HelioScope. Folsom Labs develops HelioScope, an advanced PV system design tool that integrates system layout and performance modeling.

Electricity production using HelioScope

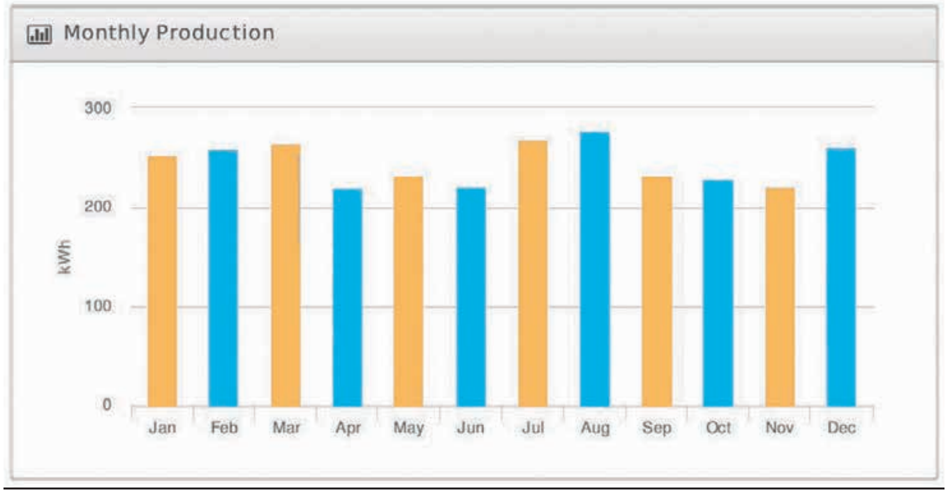
The helioscope software indicates power produced by the solar PV system, in this case 3,6 kW. Moreover, the annual power PV production.

Figure 3.8. System metrics

System Metrics	
Design	Design1_mihouse
Module DC Nameplate	3.66 kW
Inverter AC Nameplate	3.10 kW Load Ratio: 1.18
Annual Production	2.931 MWh
Performance Ratio	49.3%
kWh/kWp	800.7
Weather Dataset	TMY, BOGOTA, IWEC Data (epw)
Simulator Version	133 (032875edcc-6113e34bf3-2423c40650-a9ba78076c)

Source: The Authors with the software HelioScope.

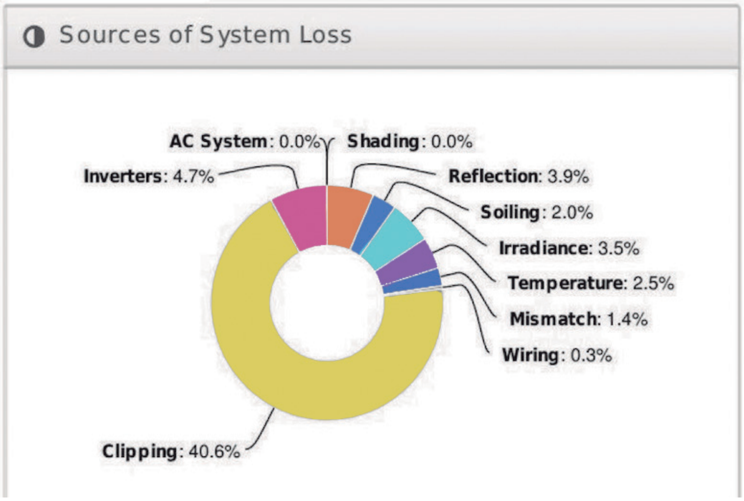
Figure 3.9. Monthly Production



Source: The Authors with the software HelioScope.

In the above Figure 3.8, main values of the Energy PV system are described. On the other hand, the following figure shows the monthly production on Mihouse considering all electric loads inside the house. As any electrical system, there are some losses, showed in the Figure 3.9.

Figure 3.10. Sources of loss



Source: The Authors with the software HelioScope.

Annual Production

Table 3.8. Annual Production

Annual Production		
	Description	**Output**
Irradiance (kWh/m²)	Annual Global Horizontal Irradiance	1,617.7
	POA Irradiance	1,624.7
	Shaded Irradiance	1,624.7
	Irradiance after Reflection	1,562.0
	Irradiance after Soiling	1,530.8
	Total Collector Irradiance	**1,530.8**
Energy (kWh)	Nameplate	5,607.2
	Output at Irradiance Levels	5,410.3
	Output at Cell Temperature Derate	5,272.6
	Output After Mismatch	5,196.1
	Optimal DC Output	5,182.1
	Constrained DC Output	3,076.2
	Inverter Output	2,931.0
	Energy to Grid	**2,930.7**
Temperature Metrics		
	Avg. Operating Ambient Temp	
	Avg. Operating Cell Temp	
Simulation Metrics		
		Operating Hours

Source: The Authors with the software HelioScope.

Condition Set

Figure 3.9. Condition Set

<table>
<tr><th colspan="2">Condition Set</th></tr>
<tr><td>Description</td><td>Condition Set 1</td></tr>
<tr><td>Weather Dataset</td><td>TMY, BOGOTA, IWEC Data (epw)</td></tr>
<tr><td>Solar Angle Location</td><td>Meteo Lat/Lng</td></tr>
<tr><td>Transposition Model</td><td>Perez Model</td></tr>
<tr><td>Temperature Model</td><td>Sandia Model</td></tr>
<tr><td>Temperature Model Parameters</td><td><table><tr><th>Rack Type</th><th>a</th><th>b</th><th>Temperature Delta</th></tr><tr><td>Fixed Tilt</td><td>-3.56</td><td>-0.075</td><td>3°C</td></tr><tr><td>Flush Mount</td><td>-2.81</td><td>-0.0455</td><td>0°C</td></tr></table></td></tr>
<tr><td>Soiling (%)</td><td><table><tr><th>J</th><th>F</th><th>M</th><th>A</th><th>M</th><th>J</th><th>J</th><th>A</th><th>S</th><th>O</th><th>N</th><th>D</th></tr><tr><td>2</td><td>2</td><td>2</td><td>2</td><td>2</td><td>2</td><td>2</td><td>2</td><td>2</td><td>2</td><td>2</td><td>2</td></tr></table></td></tr>
<tr><td>Irradiation Variance</td><td>5%</td></tr>
<tr><td>Cell Temperature Spread</td><td>4° C</td></tr>
<tr><td>Module Binning Range</td><td>-2.5% to 2.5%</td></tr>
<tr><td>AC System Derate</td><td>0.50%</td></tr>
<tr><td>Module Characterizations</td><td><table><tr><th>Module</th><th>Characterization</th></tr><tr><td>YL305P-35b (Yingli Solar)</td><td>Default Characterization, PAN</td></tr></table></td></tr>
<tr><td>Component Characterizations</td><td><table><tr><th>Device</th><th>Characterization</th></tr><tr><td>Fronius Galvo 3.1-1 (Fronius)</td><td>Default Characterization</td></tr></table></td></tr>
</table>

Source: The Authors with the software HelioScope.

Figure 3.10. Components

Component	Name	Count
Inverter	Fronius Galvo 3.1-1 (Fronius)	1 (3.10 kW)
AC Home Run	10 AWG (Copper)	1 (24.8 ft)
Strings	10 AWG (Copper)	3 (121.7 ft)
Module	YL305P-35b (Yingli Solar)	12

Source: The Authors with the software HelioScope.

Figure 3.11. Wring Zones and field segments

Wiring Zones

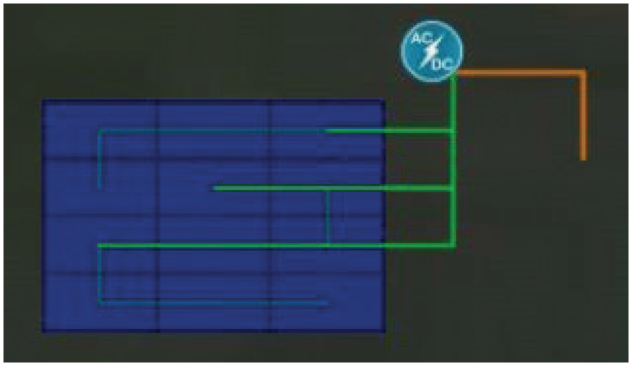
Description	Combiner Poles	String Size	Stringing Strategy
Wiring Zone	12	4	Along Racking

Field Segments

Description	Racking	Orientation	Tilt	Azimuth	Intrarow Spacing	Frame Size	Frames	Modules
Area util techo baños cocina	Fixed Tilt	Horizontal (Landscape)	3.37502°	180°	0.0 ft	4x3	1	12

Source: The Authors with the software HelioScope.

Figure 3.11. System Connection.



Source: The Authors with the software HelioScope.

Electrical estimated consumption

The methodology applied in Mihouse to estimate its energy production and the behavior of each of its elements allows virtual simulation of the operation and status of items like future projections of the house’s behavior. Mihouse has chosen for this work a software called Homer, or Hybrid Optimization of Mutiple Energy Resources, this program allows to enter the photovoltaic system with functional loads and the inverter chosen for subsequent computation and simulation of major managed system factors such as economic for the best and optimum configuration system.

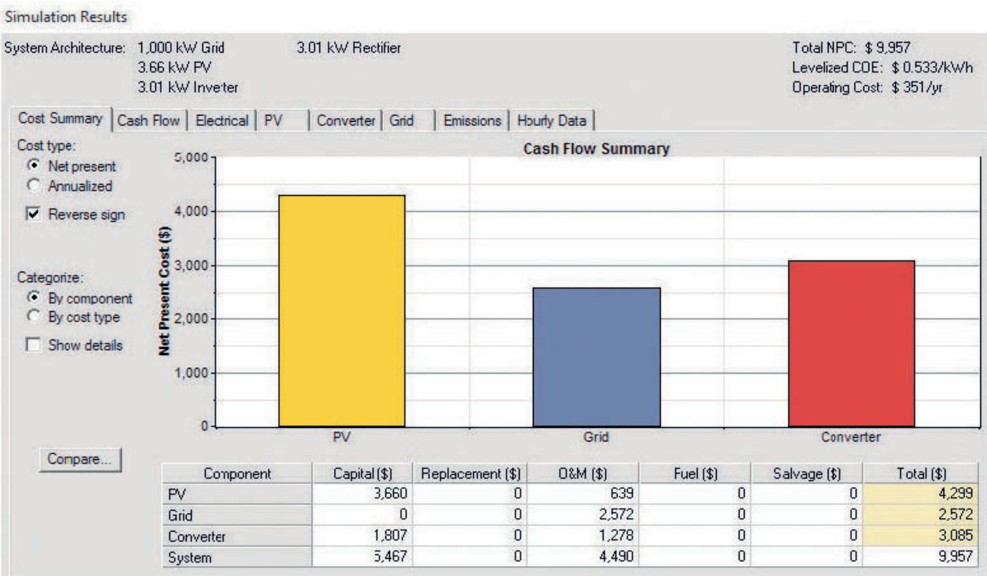
Description of the tools used for the simulations: Homer Energy LLC is a Boulder, Colorado based company incorporated in 2009 to commercialize the Homer® model, which was developed by the National Renewable Energy Lab, a division of the U.S. Department of Energy. Homer Energy’s primary focus is the continuing development, distribution, and support of Homer. The company also provides training, services, and community tools to professionals, researchers, and enthusiasts in the energy industry who desire to analyze and optimize distributed power systems and systems that incorporate high penetrations of renewable energy sources.

The Homer Energy principles have been working with economic and engineering optimization of microgrids for over two decades. Homer Energy’s team includes the economist and engineer who originally created the Homer software while at NREL, along with professional managers, analysts and other business professionals with experience in entrepreneurial ventures, power systems, and renewable energy. The project's collective vision is to empower people around the world with tools, services, and information in order to accelerate the adoption of renewable and distributed energy sources.

In addition to the Homer software, Homer Energy offers additional services such as web-based and in person training and assistance in the use of Homer. The project also customized the software for novel problems or types of equipment. In addition, it was provided a range of consulting services related to the policies, economics, and technologies of renewable and distributed power.

Since its release, the Homer software has been downloaded by over 100 000 people in 193 countries. This is a global community of pioneering practitioners in renewable and distributed power. In order to harness the collective wisdom of this group, Homer Energy has also created an online community with discussion forums where users can engage with each other. The following figures show the results of the simulation used with this program.

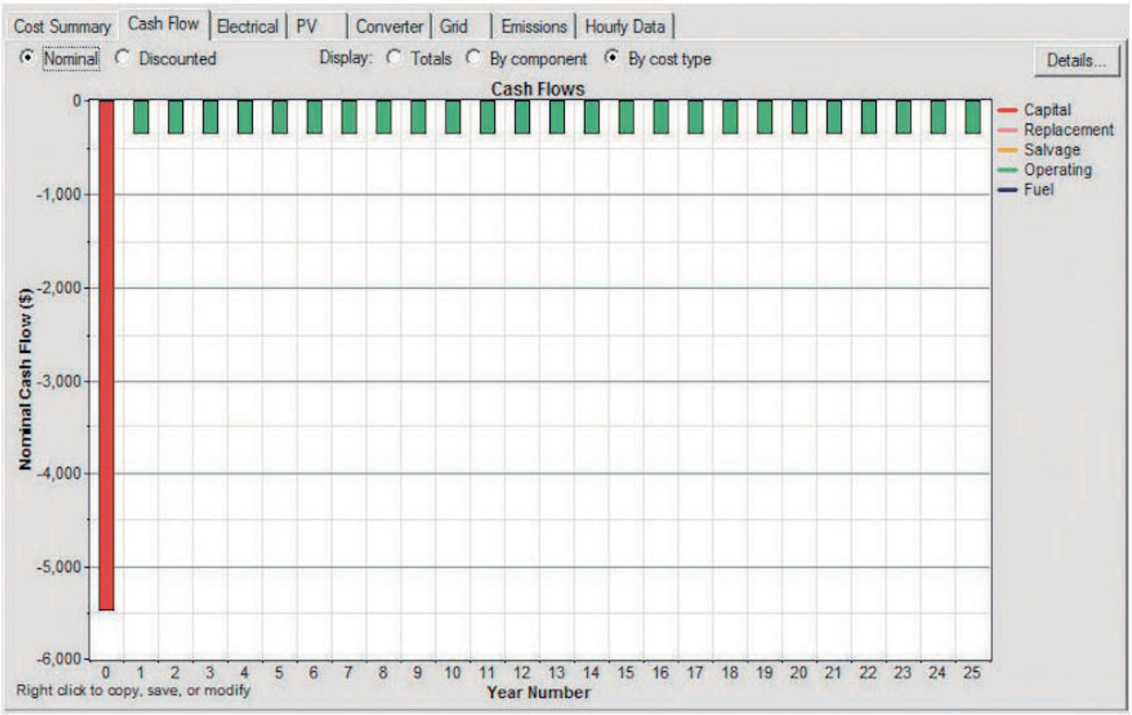
Figure 3.12. Simulation results, cash flow summary.



Source: The Authors with the software Homer.

In this figure, on COST SUMMARY window, a relation between different components is presented. It allows to identify how the individual cost of every single component impact the budget and it can be compared with the cash flow window. In this case, the main cost is due to the PV system, then the converter and finally grid connection. However, a comparison can be done with the values showed down the figure, where the capital costs, replacement, operation and maintenance, fuel (it is applied), and salvage are presented.

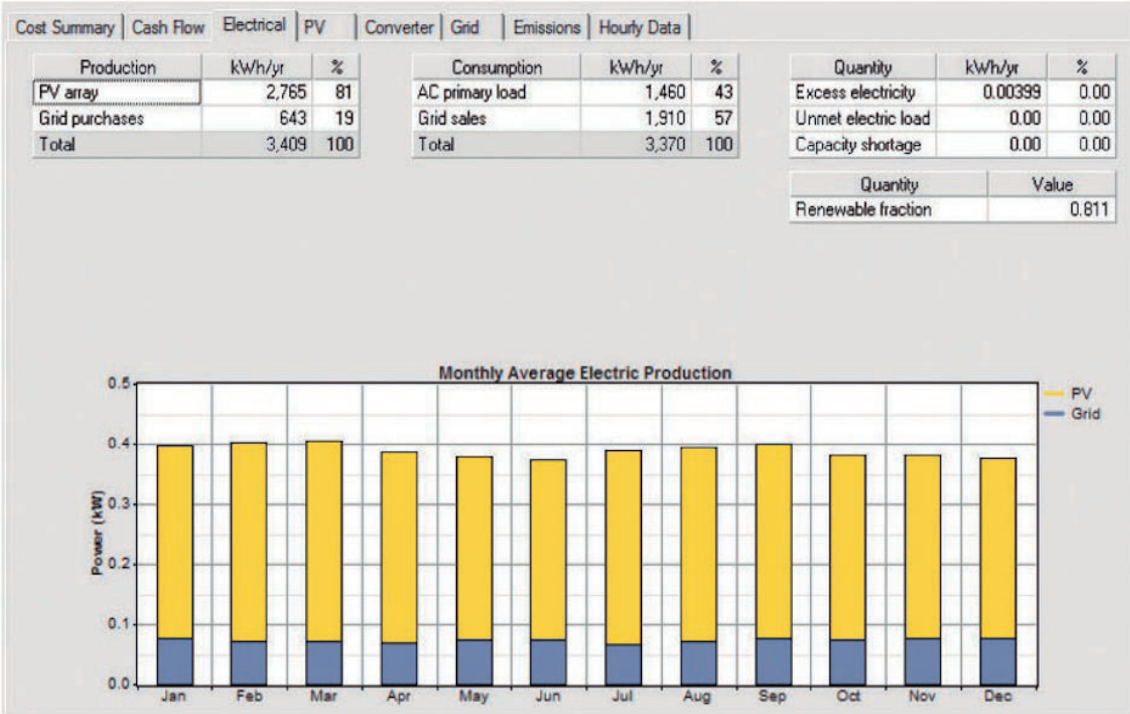
Figure 3.13. Simulation results, cash flow



Source: The Authors with the software HOMER.

In 3.13, the cash flow window shows how the first year, the initial capital is applied.

Figure 3.14. Monthly Average Electric Production



Source: The Authors with the software HOMER.

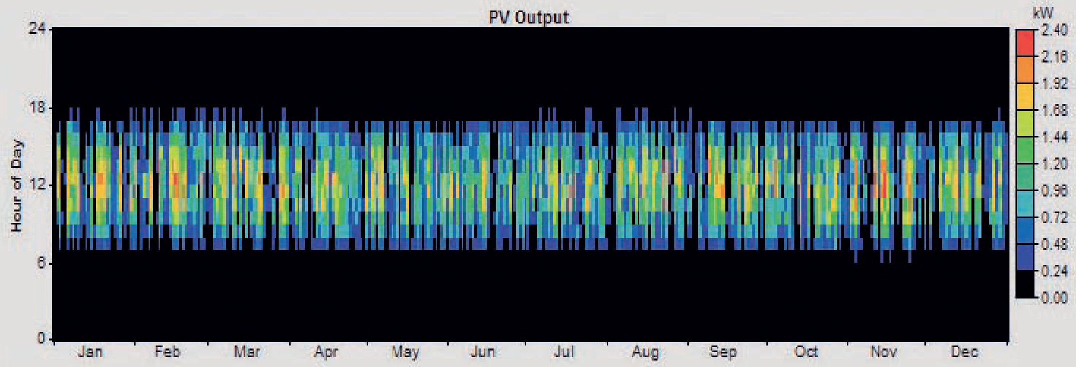
This figure indicates how the PV system and grid purchases met the demand.

Figure 3.15. PV Output.

Cost Summary | Cash Flow | Electrical | PV | Conveter | Grid | Emissions | Hourly Data

Quantity	Value	Units
Rated capacity	3.66	kW
Mean output	0.32	kW
Mean output	7.58	kWh/d
Capacity factor	8.63	%
Total production	2,765	kWh/yr

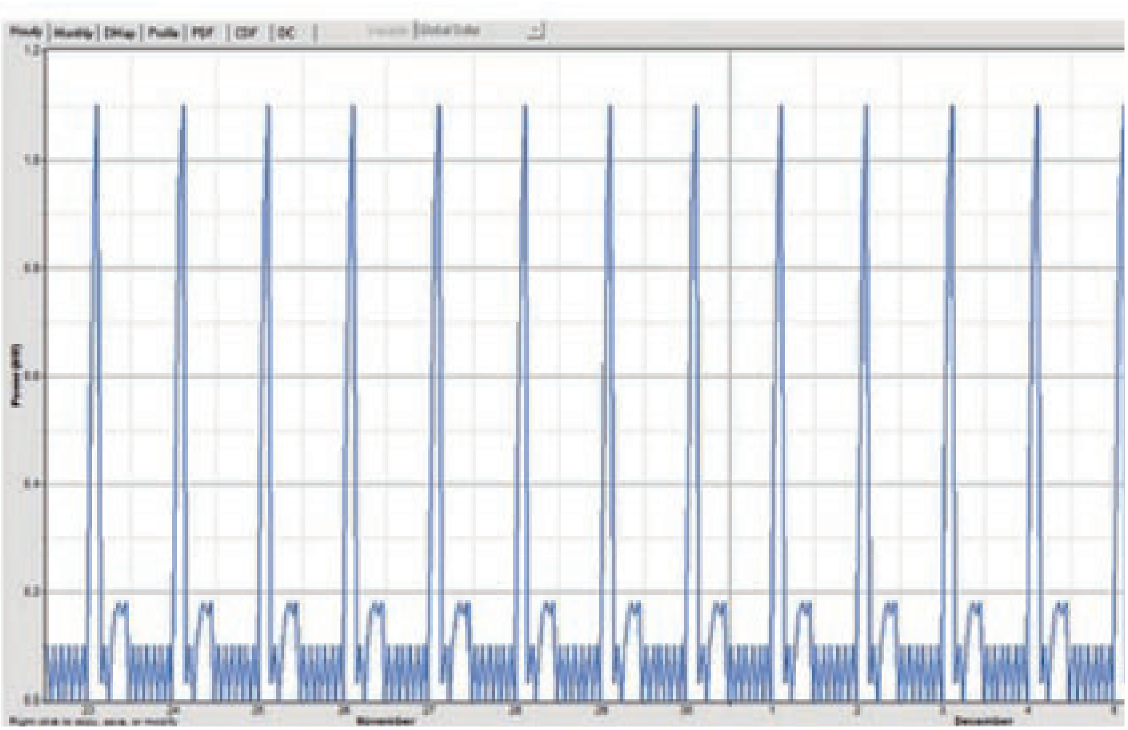
Quantity	Value	Units
Minimum output	0.00	kW
Maximum output	2.19	kW
PV penetration	189	%
Hours of operation	4,380	hr/yr
Levelized cost	0.122	$/kWh



Source: The Authors with the software HOMER.

As Is presented in figure 3.15, a PV window shows the day time when the PV array produces more electricity (DC), and the color intensity indicate the high values.

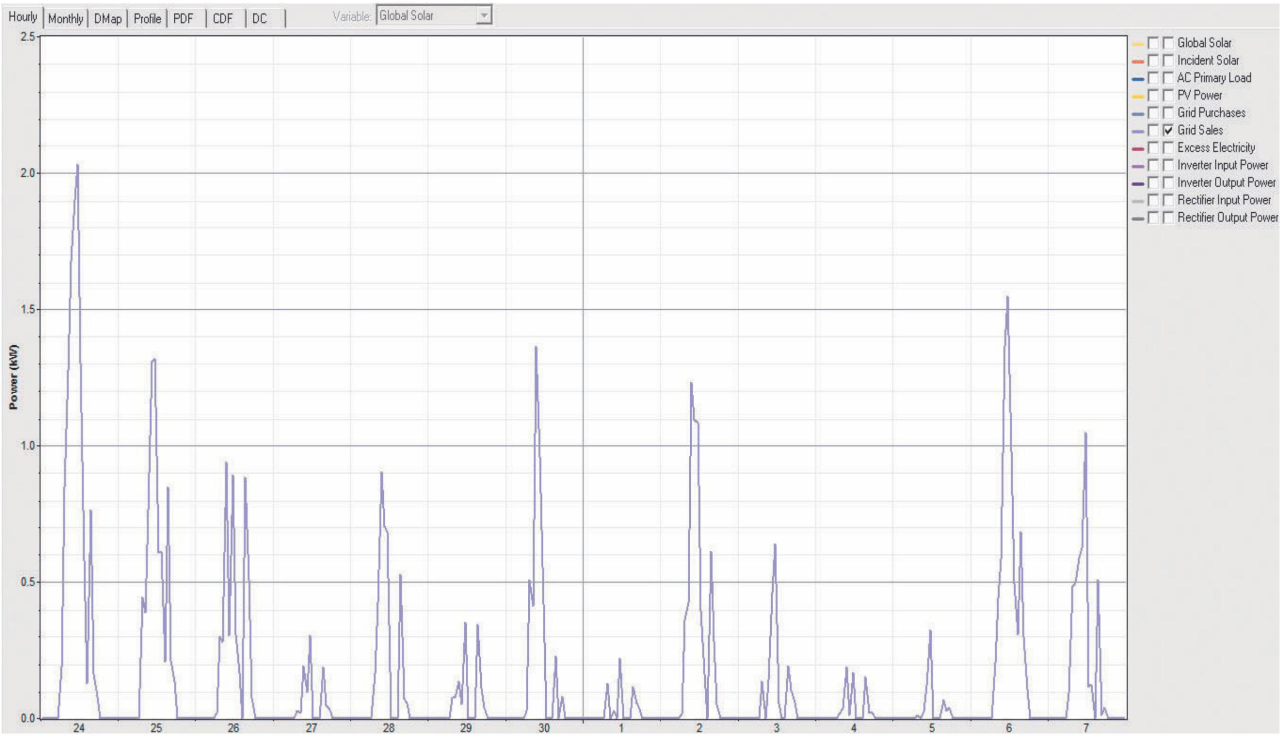
Figure 3.16. Primary Load



Source: The Authors with the software HOMER.

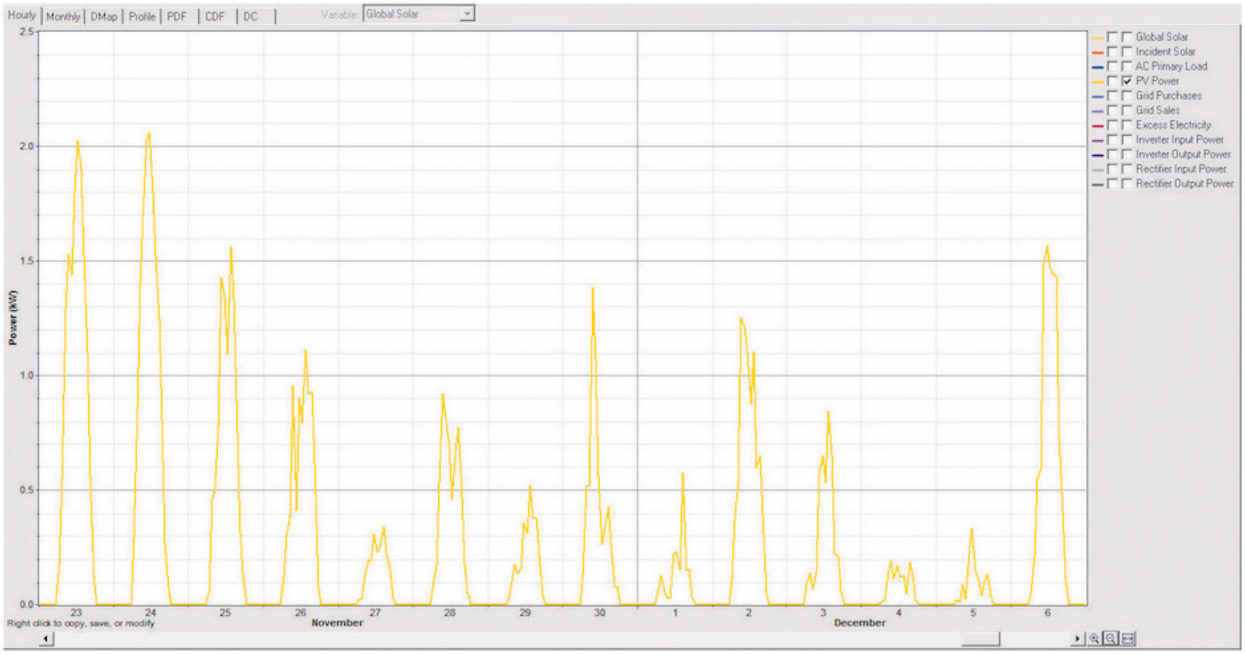
Finally, for a full energy analysis, a new wind allow to plot the AC primary hourly load. More hourly detailed results as presented in fig. 3.17 y 3.18 can be obtained.

Figure 3.17. *Grid sales*



Source: The Authors with the software HOMER.

Figure 3.18. PV power



Source: The Authors with the software HOMER.

Solar Thermal Design

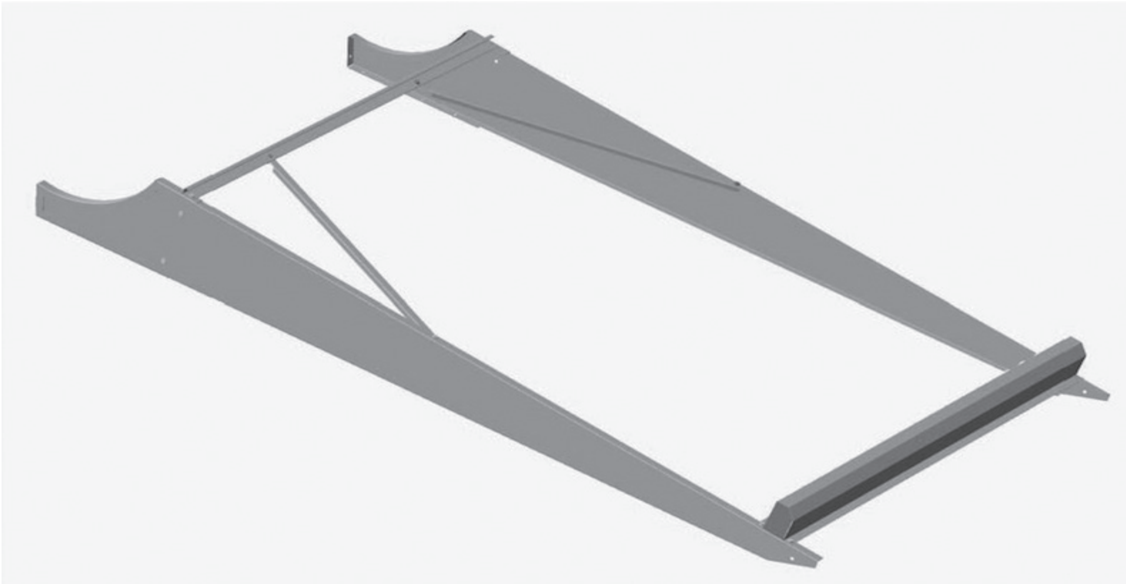
Mihouse decided to use a passive solar water heating system as the proposal to generate hot water in a cost-effective way. This hot water will be used in laundry and cooking as was requested by the solar decathlon SDLAC 2015 contest.

The solar water heater main function is to storage heat water produced by the solar vacuum tubes. This can be done between 1-4 days in small house systems. They are built in steel stainless, aluminum, glass fiber reinforced and plastics. The deposit size must be at least 50 liters per square meter of solar panels. In the Mihouse system, the tank size or volume considers 50 -75 l/m^2 for using hot water and heating. However, some manufacturers take into consideration 40 l per person and 50 l reserve in single family dwellings, thus Mihouse tank is almost 200-300 l for the entire family, as it is presented in the following calculation:

$$[\ 4 \text{ person} \times 40 \text{ L}\ ] + 50 \text{ L} = 210 \text{ L}$$

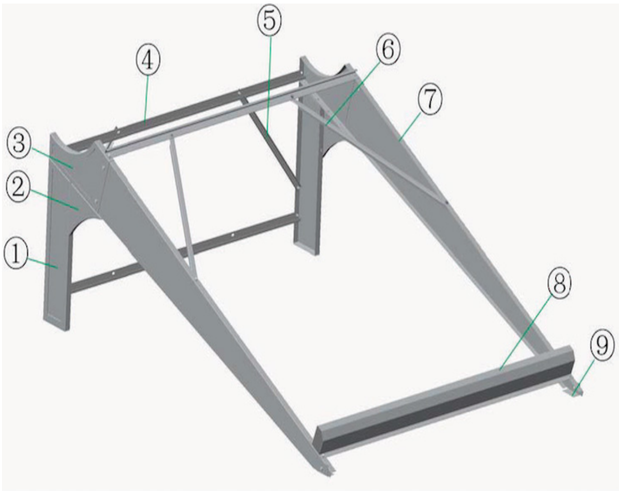
It must be said that this thermal system only serves hot water for laundry and showers. No heat air is provided in Mihouse due to location in Cali, Colombia, where the average temperature is 28°C, and a solar thermal system for heating will not be used. Supporting structure, a frame for a flat roof installation is presented in Figure 319, while the solar thermal components are shown in Figure 3.20.

Figure 3.19. Frame for a flat roof



Source: The Authors.

Figure 3.20. Heater components



1. rear pole
2. triangle plate
3. tank bracket
4. level bar
5. rear support bar
6. front support bar
7. front pole
8. back box
9. feet

Source: The Authors.

This configuration is for flat roofs, but Mihouse will not use rear poles or triangle plates.

- **Storage system:** Hot water produced by this solar system is delivered to a storage tank. This solar water heater uses a well-insulated storage tank connected to the collector. For low sun or shading, an electrical backup is with the system.
- **Accessibility for maintenance tasks:** Roof pathways with permanent anchor points are part of the Mihouse fall protection system. Roof simple anchor points are a vital part of a fall protection system. Fall protection anchor points are installed on the roof to connect lifelines.

Table 3.12. Electric and Photovoltaic – special chart

Operational conditions and external influence	Solar PV module: Voc: 44,8V Vmp:36,3V Solar string 6 modules series connected V-36.3V6-217.8V Solar Array: 12 modules in 2 strings. Inverter minimum input voltage 125V MPP voltage 270-500 V
PV system accesibility	The PV modules are installed on the roof, in plane with structural surfaces, although they are easy and safe accessible. The string panels, inverters and main distribution panels are installed in appropriate technical cabinets Accessible on the ground floor. The cabinet are suitably for ventilation, maintenance and accessibility to the equipment installed.
Wiring system design and implementation	Wire type: Centelsa Type PV, XLPE SR 600V 90°C Selection criteria of wiring systems in order to withstand the expected external Influences. Isolation, switching and control Means of isolating the PV inverter from the DC side and AC side. Isolation and switching.

Source: authors.

Energy Efficiency Design Narrative

Technical Project Manual

As a summary and taking into account additional information of the engineering and construction of the house, the technical project manual of the house is shown below.

Project Dimensions:

I. Gross area (m^2): 85,5 m^2

II. Gross volume (m^3): 205,2 m^3

III. Surface area (m^2): 81 m^2

IV. Net floor area (m^2): 67,5 m^2

V. Conditioned volume (m^3): 138,6 m

AC Systems

I. Heating system: does not apply

II. Cooling system: does not apply

III. Refrigerant: does not apply

IV. Heat recovery ventilation or energy recovery ventilation: does not apply

Domestic Hot Water

I. System (type, capacity): 150 L

II. Solar thermal collectors area (m^2): 1,53 m^2

III. Storage tanks (capacity): 150 L

Electrical Energy production

I. PV Modules: Photovoltaic solar panel

II. PV panels area (m^2): 17,46 (m^2)

III. Installed PV power (kWp): 3,6

IV. Estimated energy production (kWh/año): 1336

V. Other systems (type): Thermal solar panel

VI. Other systems installed power (kWp): does not apply

Energy Consumption

I. Estimated energy consumption (kWh/year): 1463,92

II. Estimated electrical consumption per conditioned (kWh/año per m^2): 1336

III. Energy use characterization (% of total energy consumption):

IV. Heating (%): 0 % does not apply

V. Cooling (%): 0 % does not apply

VI. Ventilation (%): 0 % does not apply

VII. Domestic hot water (%): 0 %

VIII. Lighting (%): 7 %

IX. Appliances and Devices (%): 93 %

Table 3.13. Characterization of total energy consumption in the competition's house

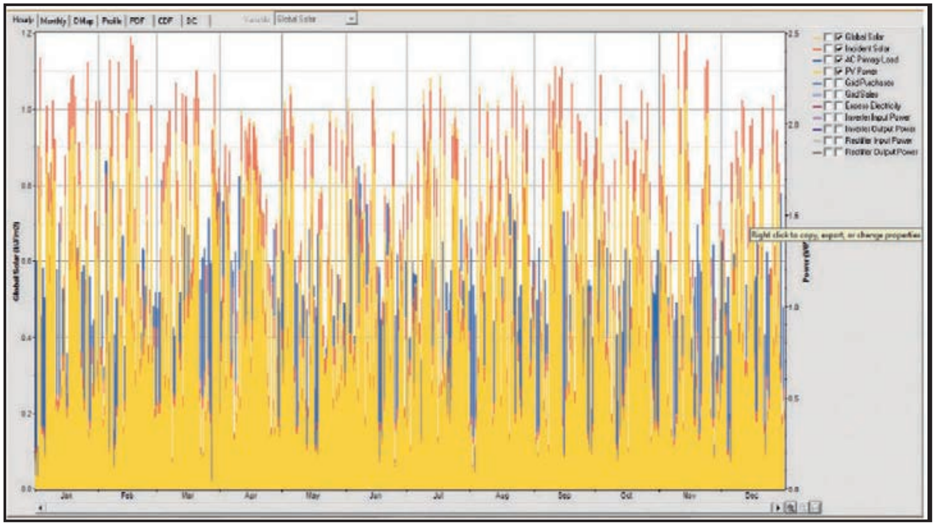
EQUIPMENT	POWER (W)	CHARACTERIZATION (%)
Blender	370	10
Washer 31 lbs	550	15
Tv led 22´	30,4	6
Phone charger	12	3
Computer all in one	65	4
Microwave oven	800	22
Stove	1000	30
DVD	10	3
Lighting	218	7
TOTAL	10	100

Source: The Authors.

Energy Balance

Estimated energy balance (kWh/año): 0

Figure 3.21. Energy Balance Simulation

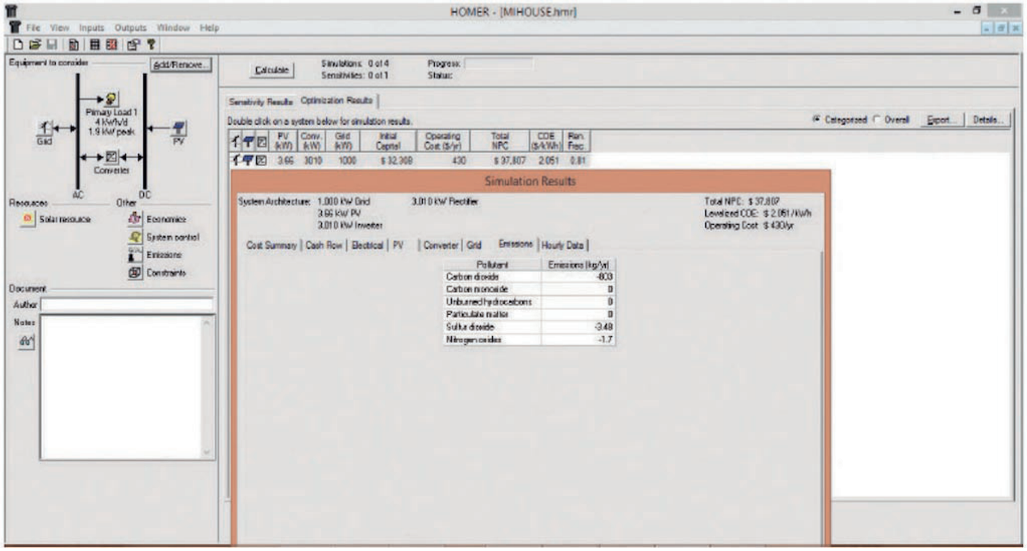


Source: The Authors with the software Homer.

In the Figure 3.21 it can be seen a simulation conducted, the annual energy balance will be zero, indicating that the consumption of housing will be supplied by solar photovoltaic renewable source.

Estimated CO_2 emissions (Tn/year): 0,803

Figure 3.22. CO_2 Emissions Simulation



Source: The Authors with the software HOMER.

The Figure 3.22 shows a software simulation with CO_2 emissions that are allowed to be emitted in the environment.

List of singular and innovative materials and systems

- Lighting system in kitchen with recycled materials and environmentally friendly.
- Using LED lighting in different areas of the house.
- Skylights for daylighting and ventilation inside the housing unit.
- Design of windows in living and dining room for the use of natural light.
- Intelligent power distribution network, the power grid is joined to a telecommunication network.