[RENEWABLE ENERGIES]

[Study, analysis and simulation of a renewable energy in a mall Ecotesco]

[Alejandro González Gombao]

Final project – Erasmus program.

BMF- Budapest Műszaki Főiskola – Polytechnical institution-Obuda University

Project supervisor: Dr Kádár Peter (BMF)-PhD

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1. INTRODUCTION-SYNOPSIS.

The objective of the project is the study, analysis and simulation of complex renewable energy facility installed in a mall, of chain Tesco.

The complex Tesco called ***Ecotesco*** comprises several technologies, like electricity generation through photovoltaic (PV), solar thermal, heating and cooling with absorption systems, ground heating, and other less important.

All these technologies are studied and commented on the project, explaining its operation, and comment on specific machines and components used, with photos, graphics and more details.

The project is focus on the simulation and analysis in detail the installation of photovoltaic and solar thermal energy.

For the analysis, simulation and the gathering of the databases, It has been used several software's, that obtain a database of production as well as a detailed analysis of daily production, performance curves, economic analysis ... all for a vision of profitability and a viewpoint of advantages and disadvantages about renewable energies in this application.

2. PRESENTATION.

This project is performed by Alejandro González Gombao, student of Industrial Engineering from the Polytechnic University of Valencia (Spain).

In agreement with the BMF - Obuda University in the city of Budapest (Hungary) through the Erasmus program for a period of 5 months from September to February 2009/2010.

The project is directed and supervised by Dr. Kádár Péter (PhD), professor of Kanda Kálmán Faculty of Electrical Engineering (BMF - Obuda University).

Author of the project: Alejandro González Gombao

Director and project coordinator: Dr. Kádár Péter

Date: Budapest ………/…………/……….

3. OVERALL DESCRIPTION.

The project started when my tutor Dr Kádár Peter and me, Alejandro González Gombao We agreed to carry out a study of a renewable energy installation in supermarket chain Tesco, in the town of Dunakeszi, a few kilometres from Budapest.

The idea was to conduct a detailed description of all the technologies and by studying various simulation programs obtain a database of annual production. For calculations and simulations, the project is mainly focused on solar photovoltaic and thermal energy.

The realization of the project began doing a tour of the facilities. Mr Kádár Peter was responsible for all the show and explain all kinds of details, while I was taking note of detail like marks the solar panels, number of panels, investors, type of solar collectors, etc. ... and photographing them.

Once seen all the installation and Ecotesco elements I began the research, learning and description of the various systems of the project, such as photovoltaic systems, absorption pumps, solar therm, etc. The same way that proceeded to draft the description of the hypermarket, explaining the elements with photos and details.

At this point, I investigated the different simulation programs, making a description of each in the project. The research base for me, it was test the response of programs with small samples, such as small plants. Thus I did the selection of programs that would be suitable for the simulation of the project.

Thus far all work has been continuous and fluid. The complications began to emerge obtaining the outputs and results through the programs. The reason for this was due to the settings of the programs, because they must be as accurate as possible, such as brand of solar panels, position, etc, and they must be identical to those found in the supermarket. First of all I started with the simulation of the photovoltaic system through several programs, obtaining a very successful annual production.

Compared with other studies and similar facilities installed in Budapest, the results of production are very similar. I made 3 simulations to check different results and determine if the 3 results obtained have similar numbers. In fact, the results as seen in the project are very similar.

Next, I made the calculation of production hot water in solar thermal installation.

Once all this, with all the data, I drew a diagram showing summary production data and consumption of the hypermarket. Some data are estimated according to other facilities, such as consumption of hot water or power electricity. Others are calculated using simulations or calculation of heating required in the hypermarket.

Finally, I added my opinion and conclusion. I am proud of the work accomplished, study and solve some tasks, by myself as if it were real life. I have accumulated a wealth of knowledge and experience, so I thing I am one step close to being an engineer.

4. LITERATURE AND BIOGRAPHIES.

The realization and development of this project has been supported by several biographies, literature, documents of interest and information on websites on Internet.

All the information related to the investigation of the technologies described in the project been developed based on the following literatures:

- Wind and solar power systems-Design, Analysis, and Operation by Mukund R. Patel (Second edition)
- Photovoltaic Systems. Introduction to Design and Dimensioning of Solar Photovoltaic Energy Facilities. S.A.P.T. Technical, publications S.L. 2001.
- Solar Thermal Installation Manual (solar thermal energy for hot water production, heating and air conditioning housing of outdoor) by Lemvigh-Müller, Ricardo. S.A.P.T. Technical Publications.
- Photon Magazine.

Web sites:

- www.energias-renovables.com (Spanish forum)
- www.ec.europa.eu (Energy European commission)
- www.energy.gov (U.S Department of energy)
- www.retscreen.net (Natural Resources Canada)

5. TERMS AND SYMBOLS USED

The symbols and terms used in the project are:

- V Volts.
- A Amperes.
- W Watts.
- kW Kilo Watts.
- MW Mega Watts.
- Wp Watts peak.

Power.

- Pmax Maximum power.
- kWh Kilowatt hours.
- MWh Mega Watts hours.
- J Joules.
- kJ Kilo Joules.
- MJ Mega Joules.

Energy.

- Ah Amperes hour.
- kVA Kilovolt ampere.
- °C Celsius degrees.
- m_2 Square meters.
- Q Heat required in watts.
- U Heat transfer coefficient.
- A Area of the surface to calculate (m2).
- T Temperature.
- ΔT Temperature difference inside-outside.
- L Liters.
- € Euro.

- Power. When mentioned the term power, It refers to electrical terms and symbols.
- Energy When mentioned the term energy, it refers to terms and symbols of power consumed or produced by elements of the system in hours.

6. INVESTIGATION OF LITERATURES-RENEWABLE ENERGIES.

This section describes the various technologies used in mall with details, photos and diagrams.

6.1. PHOTOVOLTAIC SYSTEMS –ELECTRICAL GENERATION.[1]

6.1.1. Description.

A photovoltaic system is the set of devices whose function is to transform solar energy directly into electrical by several elements to produce energy and consumption.

These basic elements are:

- Solar cell modules.
- Voltage regulators.
- Batteries.
- Power inverter dc / ac or rectifier ac / dc.

6.1.2. Operating mode.

The process works like this: "sunlight striking the surface of the plate or photovoltaic panel, where it is transformed into direct current electricity by solar cells, this energy is collected and carried to a charge controller, which has the function to send all or part of this energy to the battery bank, where it is stored."

On photovoltaic systems exist various types of facilities, when we talk about energy production, We can produce in isolation for specific consumption, where the power generated is precalculated and where we store energy in batteries for later use. In these types of installations almost always the power generated is low. Some applications are: electrification of houses, pumping and irrigation systems, road lighting, television and radio repeaters, sewage treatment plants, etc…

And the other type of production is when we produce a large scale, for big power. In this type of installation the energy produced is not stored, is injected directly to the consumer network.

[1] http://energiasolar.galeon.com/

6.1.3. Description of the elements.[2]

"Solar panels are devices comprise a base which is mounted on the cells in series to obtain a proper voltage. These cells are manufactured from pure silicon (the main component of sand) with addition of impurities of certain chemical elements (boron and phosphorus) and are capable of generating a stream every 2 to 4 Amps at a voltage of 0.46 to 0.48 volts, using light radiation source. Part of the incident radiation is lost by reflection, and some transmitted (through the cell). The rest can do electrons jump from one layer to the other creating a current proportional to incident radiation. The non-reflective coating increases the efficiency of the cell".

There are 3 types of solar cells:[3]

- Single crystalline silicon:

Single-crystal silicon is the most widely available cell material. Its energy conversion efficiency ranges from 14 to 18%. In the most common method of producing it, the silicon raw material is first melted and purified in a crucible. A seed crystal is then placed in the liquid silicon and drawn at a slow constant rate. This results in a solid, single-crystal cylindrical ingot.

- Polycrystalline and semicrystalline silicon:

This is a relatively fast and low-cost process to manufacture crystalline cells. Instead of drawing single crystals using seeds, the molten silicon is cast into ingots. In the process, it forms multiple crystals. The conversion efficiency is lower, but the cost is much lower, giving a low cost per watt of power. Because the crystal structure is somewhat random (imperfect) to begin with, it cannot degrade further with imperfections in the manufacturing process or in operation.

- Thin film cell:

These are new types of PV entering the market. Copper indium diselenide ($CuInSe_2$ or CIS), cadmium telluride (CdTe), and gallium arsenide (GaAs) are all thin-film materials, typically a few micrometers or less in thickness, directly deposited on a glass, plastic, stainless steel, ceramic, or other compatible substrate material. In this manufacturing process, layers of different PV materials are applied sequentially to a substrate. This technology uses much less material per square area of the cell, and hence, is less expensive per watt of power generated.

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2 www.miliarium.com/monografias/Energia/E_Renovables/

3 Wind and solar Systems.(Mukund R.Patel).

Cadmium telluride appears to be a promising thin-film technology for low-cost-
per-watt capacity. The solar cell efficiency is 18% for a CIS cell.

- Regulator:

The regulator is the element responsible for regulating the intensity and tension of input and output to the batteries. Is an element that must be installed considering the number of solar panels and the power production.

- Batteries:

Batteries are responsible elements store energy produced. The batteries have several important characteristics as the depth of discharge and capacity Amps hours. The batteries are composed for cubes of 1 and 2 volts, and according to the voltage of the installation are configured.

- Power inverter dc / ac:

The inverter is the element responsible for transforming the direct current (dc) into alternating current (ac) to be consumed by the loads, or injected into the network. According to either type of installation, inverter is chosen.

6.1.4. Schemes:[4]

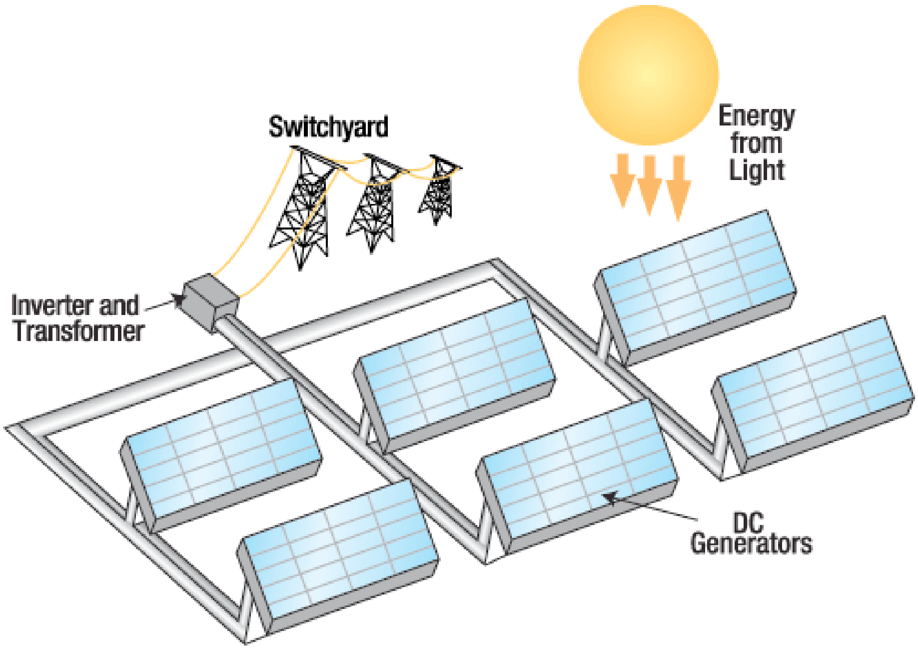

Fig. 6.1 System connected to network

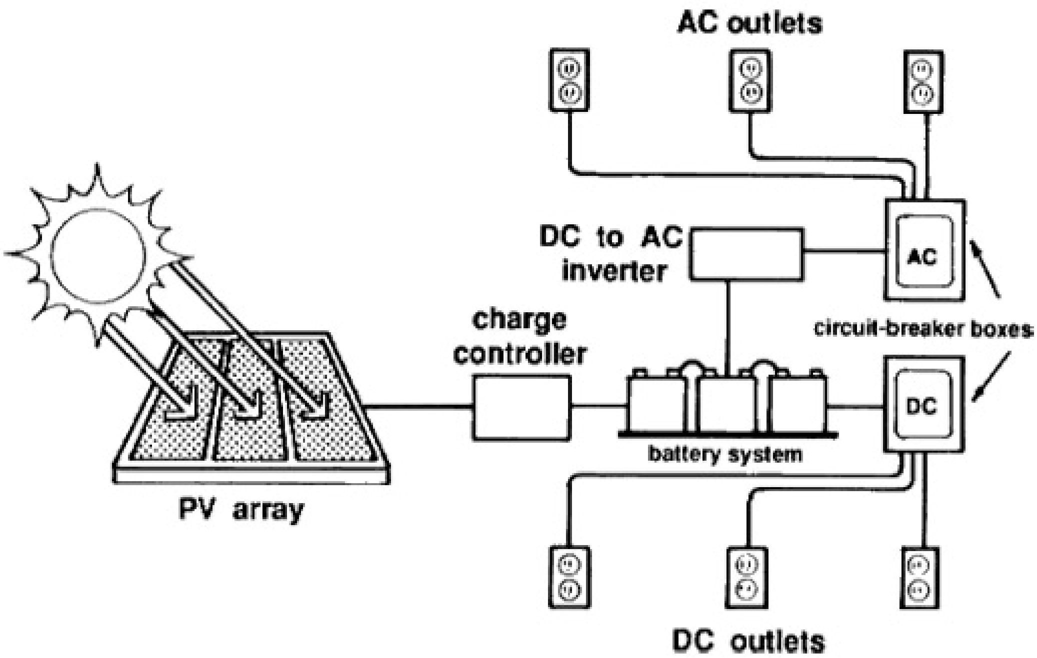

Fig. 6.2 Isolated system.

4 www.google.com- photovoltaic schemes

6.2. SOLAR SYSTEMS FOR HEATING [5]

6.2.1. Description.

Solar thermal energy is that which uses infrared radiation from the sun to generate heat that is intended mainly for the production of hot water and heating.

- System elements:
- Solar collectors.
- Accumulator.
- Temperature controller.
- Recirculation pump.

6.2.2. Operating mode.

The most widespread applications of solar thermal are sanitary water heating, underfloor heating and hot water for industrial processes.

The heating of sanitary water is for domestic use in homes and buildings, and there are 2 types, the open circuit and closed circuit. Open-circuit water is used directly from the collectors, with easier installation, and closed circuit the water is stored maintaining its temperature for posterior use.

The underfloor heating circuit are basically pipes installed on the ground that circulate the hot water that comes from solar panels.

In terms of industrial processes, water can be used to feed an absorption refrigeration machine that uses heat instead of electricity, to produce cold which may condition the air of industrial premises.

6.2.3. Description of the elements.[6]

- Solar collectors.

The solar panels are responsible for communicating to water heat energy from the sun through the greenhouse effect. They consist of a metal box with glass top. At the bottom of the box is placed a layer of insulating material, then another thin layer of dark metal, and above the latter circulates a serpentine-shaped tube through which flows water.

In the greenhouse effect, the sun's rays penetrate the metal box through the glass. The physical properties of these rays and their

[5] www1.eere.energy.gov/solar/sh_basics_water
www.emison.com/5152
[6] www.instalacionenergiasolar.com

interaction with the interior of the box make only a tiny fraction of these to come out to the outside, increasing the temperature.

With it also increases the temperature of the water passing through the tube, thus taking energy from the sun that has been trapped in the panel.

Not all energy reaching the panel is absorbed by water, heat losses are unavoidable cause the sensor performance is not 100%. Moreover, this performance depends on the temperature difference between outside and inside of the panel: How much higher is this temperature difference, there is more heat loss, and therefore lower the yield.

- Accumulator / Water tank.

Accumulator or water tank is the element responsible for storing the heated water for later use.

- Temperature controller.

Controls the water temperature in the accumulator tank and the collector. If the sensor temperature is higher than the battery, starts the pump, which circulates water through the collector accumulator, and returns the hottest again to accumulator. Otherwise (the battery temperature higher than the temperature in the collector) stops the circulation pump. Thus, it makes the most hours of solar heating and cooling water is avoided in time of low insolation.

- Circulation pump.

The circulation pump is the element responsible for the circulation of water through the installation.

6.2.4. Scheme: [7]

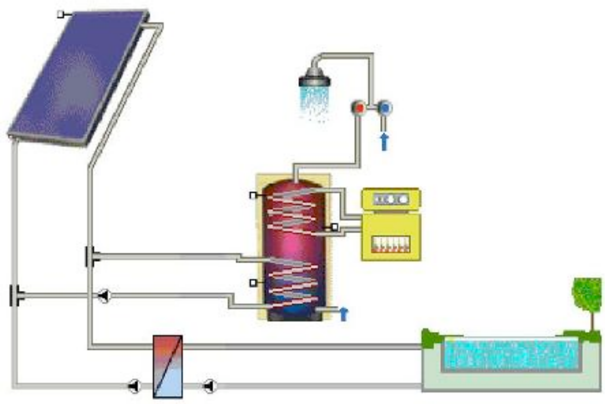

Fig. 6.3 Simple scheme of solar heating.

[7] www.inserteciberia.com/

6.3. HEAT PUMP SYSTEMS[8]

6.3.1. Description.

"For climates with moderate heating and cooling needs, heat pumps offer an energy-efficient alternative to furnaces and air conditioners. Like your refrigerator, heat pumps use electricity to move heat from a cool space into a warm. During the heating season, heat pumps move heat from the cool outdoors into your warm house; during the cooling season, heat pumps move heat from your cool house into the warm outdoors. Because they move heat rather than generate heat, heat pumps can provide up to 4 times the amount of energy they consume."

The most common type of heat pump is the air-source heat pump, which transfers heat between the outside air and the house.

"If you heat with electricity, a heat pump can trim the amount of electricity you use for heating by as much as 30%–40%".

High-efficiency heat pumps also dehumidify better than standard central air conditioners, resulting in less energy usage and more cooling comfort in summer months. However, the efficiency of most air-source heat pumps as a heat source drops dramatically at low temperatures, generally making them unsuitable for cold climates, although there are systems that can overcome that problem.

6.3.2. Operating mode.

A heat pump's refrigeration system consists of a "compressor and two coils made of copper tubing (one indoors and one outside), which are surrounded by aluminium fins to aid heat transfer".

In the heating mode, liquid refrigerant in the outside coils extracts heat from the air and evaporates into a gas. The indoor coils release heat from the refrigerant as it condenses back into a liquid. A reversing valve, near the compressor, can change the direction of the refrigerant flow for cooling as well as for defrosting the outdoor coils in winter.

In heating mode, an air-source heat pump evaporates a refrigerant in the outdoor coil; as the liquid evaporates it pulls heat from the outside air. After the gas is compressed, it passes into the indoor coil and condenses, releasing heat to the inside of the house. The pressure changes caused by the compressor and the expansion valve allow the gas to evaporate at a low temperature outside and condense at a higher temperature indoors.(Fig. 6.4 – 6.5)

[8] www1.eere.energy.gov/solar/
www.energysavers.gov/your_home/space_heating_cooling

6.3.3. Scheme:[9]

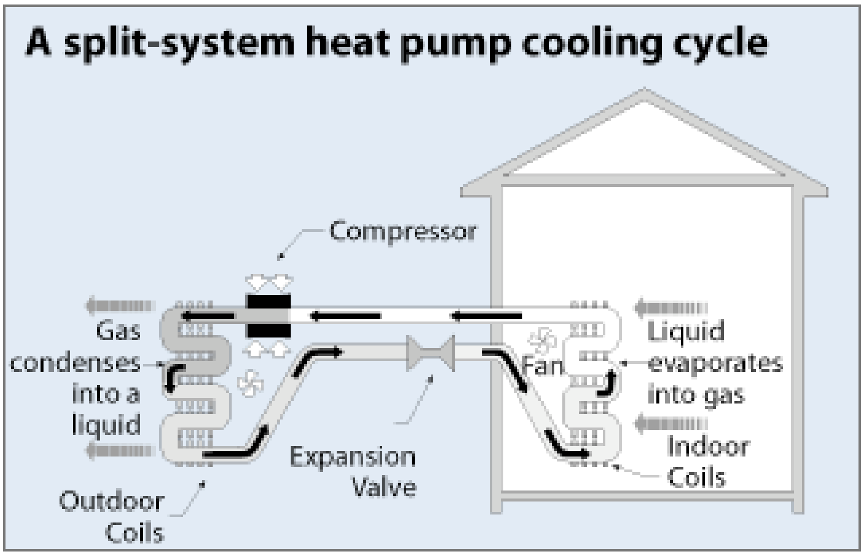

Fig. 6.4 . Heat pump cooling cycle..

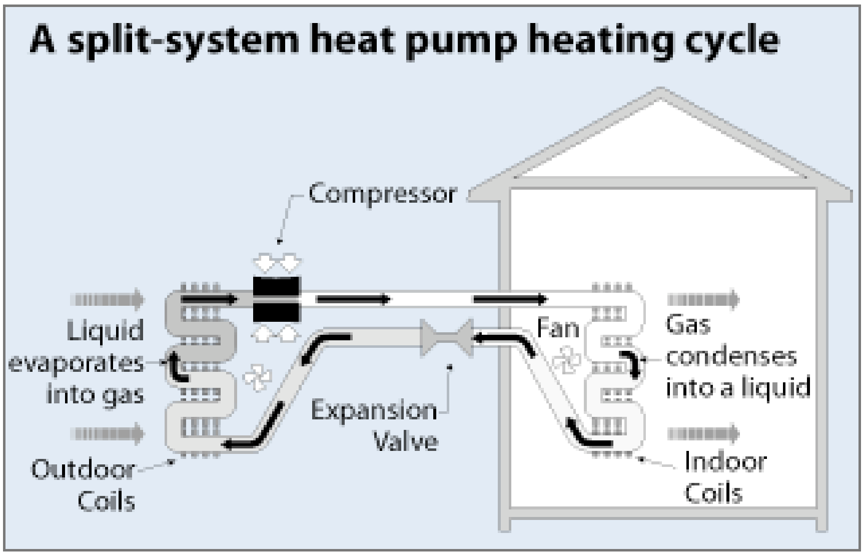

Fig. 6.5 Heat pump heating cycle.

[9] www1.eere.energy.gov/solar/solar_heating.html

6.4. ABSORPTION HEAT PUMPS -AIR-CONDITIONING [10]

6.4.1. Description.

Absorption heat pumps are essentially air-source heat pumps driven not by electricity, but by a heat source such as natural gas, propane, solar-heated water, or geothermal-heated water. Because natural gas is the most common heat source for absorption heat pumps, they are also referred to as gas-fired heat pumps. There are also absorption coolers available that work on the same principal, but are not reversible and cannot serve as a heat source. These are also called gas-fired coolers.

6.4.2. Operating mode.

In absorption systems, compression of the working fluid is achieved thermally in a solution circuit which consists of an absorber, a solution pump, a generator and an expansion valve as shown in Figure 3. Low-pressure vapour from the evaporator is absorbed in the absorbent. This process generates heat. The solution is pumped to high pressure and then enters the generator, where the working fluid is boiled off with an external heat supply at a high temperature. The working fluid (vapour) is condensed in the condenser while the absorbent is returned to the absorber via the expansion valve. (Fig 6.7)

Heat is extracted from the heat source in the evaporator. Useful heat is given off at medium temperature in the condenser and in the absorber. In the generator high-temperature heat is supplied to run the process. A small amount of electricity may be needed to operate the solution pump.

A key component in the units now on the market is generator absorber heat exchanger technology, or gas, which boosts the efficiency of the unit by recovering the heat that is released when the ammonia is absorbed into the water. Other innovations include high-efficiency vapour separation, variable ammonia flow rates, and low-emissions, variable-capacity combustion of the natural gas.

[10] www.heatpumpcentre.org

6.4.3. Description of the elements.

- Condenser[11]:

  Is a heat exchanger, in which it is intended that a fluid which runs through it, switch to liquid phase from the gaseous phase by heat exchange (transfer of heat to the outside) or by another means.

- Evaporator[12]:

  Evaporator is known for generating heat exchanger transfers heat energy contained in the environment to a low temperature refrigerant gas and evaporation process. This medium can be air or water

6.4.4. Scheme:[13]

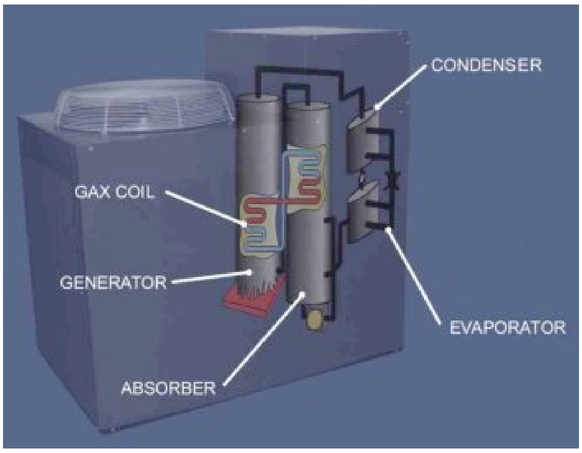

Fig. 6.6 Absorption machine

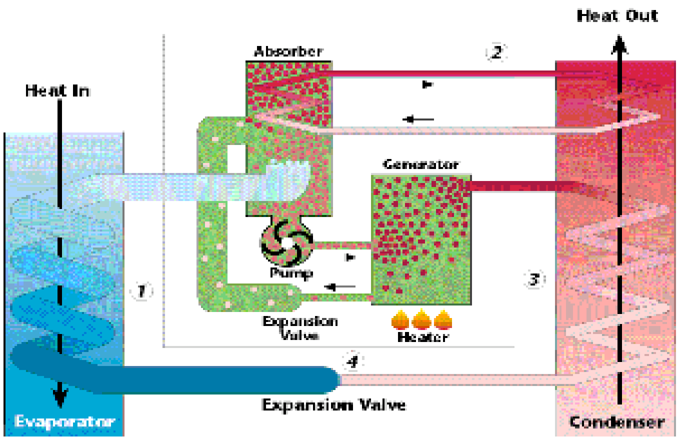

Fig. 6.7 Scheme absorption machine

11 www.wikipedia.com
12 www.wikipedia.com
13 www1.eere.energy.gov/solar/solar_heating.html

6.5. GEOTHERMAL HEAT PUMPS [14]

6.5.1. Description.

Geothermal heat pumps are similar to ordinary heat pumps, but use the ground instead of outside air to provide heating, air conditioning and, in most cases, hot water. Because they use the earth's natural heat, they are among the most efficient and comfortable heating and cooling technologies currently available.

6.5.2. Operating mode.

A geothermal heat pump doesn't create heat by burning fuel, like a furnace does. Instead, in winter it collects the Earth's natural heat through a series of pipes, in loops, installed below the surface of the ground. Fluid circulates through the loop and carries the heat to the house. There, an electrically driven compressor and a heat exchanger concentrate the Earth's energy and release it inside the home at a higher temperature. Ductwork distributes the heat to different rooms.

In summer, the process is reversed. The underground loop draws excess heat from the house and allows it to be absorbed by the Earth. The system cools your home in the same way that a refrigerator keeps your food cool - by drawing heat from the interior, not by blowing in cold air.

The geothermal loop that is buried underground is "typically made of high-density polyethylene, a tough plastic that is extraordinarily durable but which allows heat to pass through efficiently". When installers connect sections of pipe, they heat fuse the joints, making the connections stronger than the pipe itself. "The fluid in the loop is water or an environmentally safe antifreeze solution that circulates through the pipes in a closed system".

Another type of geothermal system uses a loop of copper piping placed underground. When refrigerant is pumped through the loop, heat is transferred directly through the copper to the earth.

6.5.3. Scheme: [15]

http://oee.nrcan.gc.ca/heatpump_fig7_e.gif

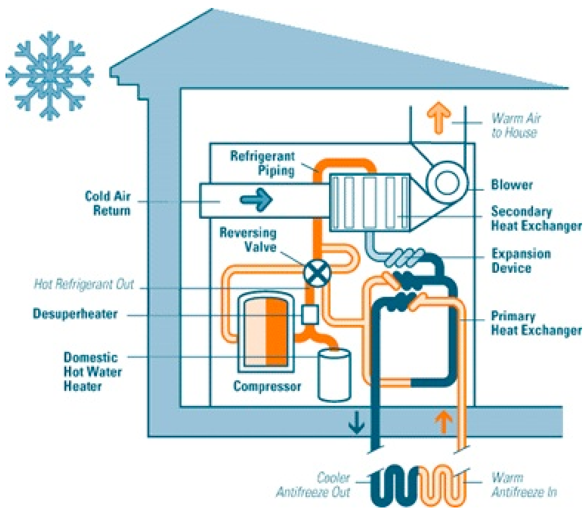

Fig. 6.8 Heating pump system.

[14] www.energystar.gov
[15] www.treehugger.com

6.6. DESCRIPTION AND OPERATION OF THE SOFTWARE.

This point is dedicated to the study of different software available for the nexts simulations and analysis. I tested each program and studied their different characteristics and application for a right choice at the time of the simulation. Tests have been simple examples of small facilities, behaviour of the sun at different locations, power generation with different characteristics, etc...

The programs have been obtained from various sources. One of the most important is through the collaboration of Dr Peter Kadar, through an exclusive CD with information, studies and programs dedicated to renewable energies.

The other source has been through the website: www.energy.gov (U.S. Department of Energy) in paragraph energy software tools, forums of energy and magazines of renewable energyes. Below are the various programs tested with a small description about the same

6.6.1. Choice of programs for the simulation.

-For photovoltaic.

- PVSIS

  It is a program dedicated only to the PV and has many details and aspects that lead to very successful results.

- PGIS

  Online Program for quick and efficient calculation of photovoltaic systems, perfect for the comparison of production with other simulation programs.

- RETScreen.

  It's simple, complete, in addition to calculate the production, you can perform a simple economic study to find an idea of the profitability of the project.

-For solar thermal energy.

- TSOL pro.

  Program dedicated solely to solar thermal systems, very detailed and specific, ideal for a good result for analysis.

- RETScreen.

  It's simple, complete, in addition to calculate the production, you can perform a simple economic study to find an idea of the profitability of the project.

6.6.2. Shadow analyzer[16]

Shadow Analyzer is a software tool very useful in solar applications. With this tool we can create all sorts of objects and 3D shapes such as buildings, industrial plants, etc ... but more importantly, we can observe the shadows that these figures produce. With this tool can analyze how they affect the leftovers of some objects to others and simulate the trajectory that makes the sun throughout the year, giving radiation and production data.(Fig. 6.9)

Another important point is that we can simulate the shadow of sun during a day in several seasons of the year on any geographical latitude.

Moreover we can analyze and calculate the losses caused for the shadows.

In the creation of objects, the program allows you to give texture to the surface, colour, and size all kinds of 3D shapes, as well as locations and position.

For all, the program has an easily interface with intuitive windows.

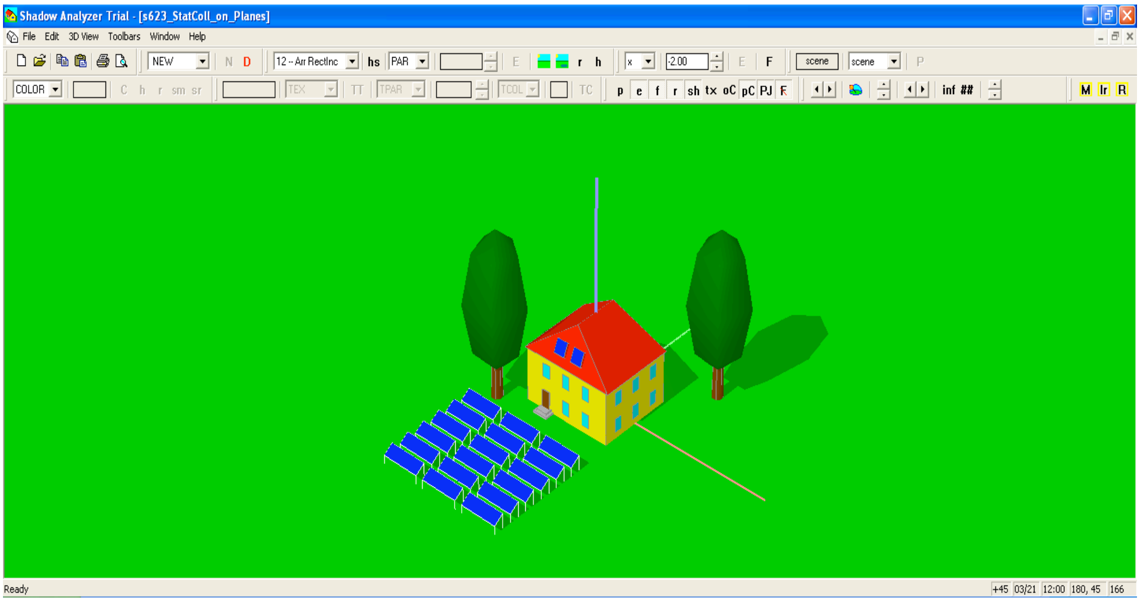

Fig. 6.9 Example of house with simple panels.

[16] www.drbaumresearch.com
Program help, and documents

Here an example of a house with an assembly of solar panels on the roof and floor of the house, with an inclination of 45 degrees.

This image represents the different analysis (like solar radiation with clear sky, or solar radiation without birds) that the program can make of the situation and components designed.(Fig 6.10)

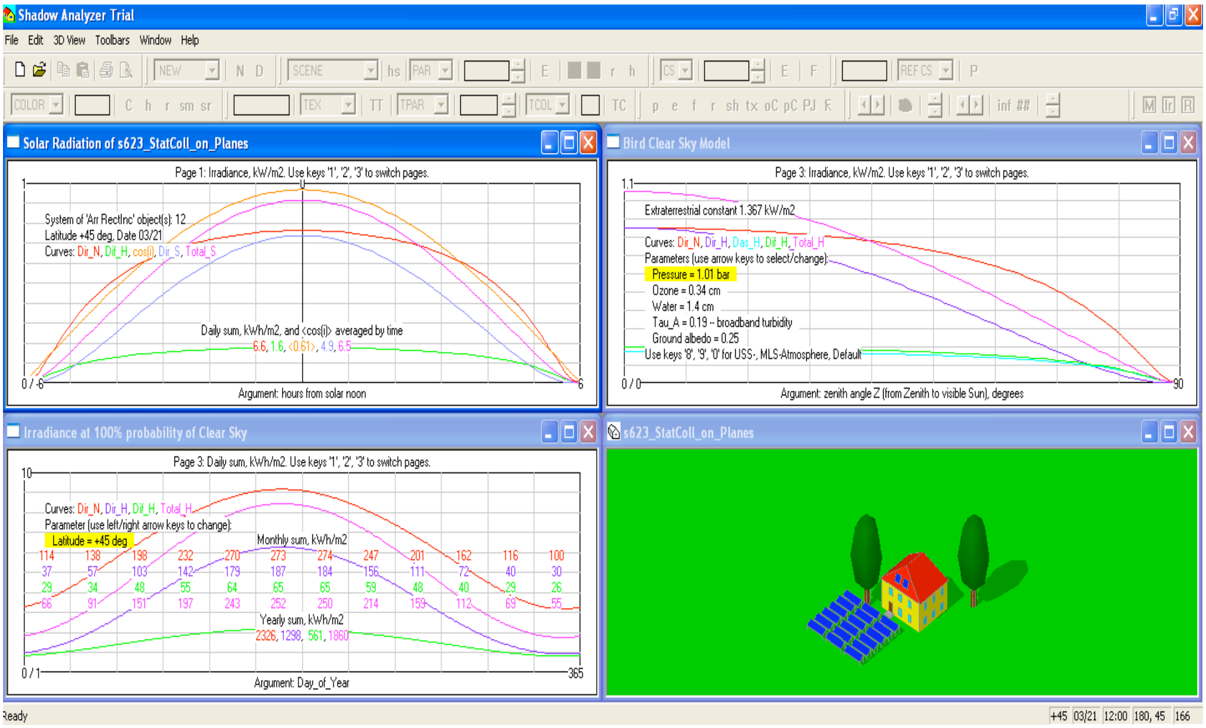

Fig. 6.10 Example of the analysis of the solar irradiation and shadows.

6.6.3. PV-F Chart[17]

PV-f chart is a program for analyzing PV systems are based on the study and performance of solar installations, as well as the profit and production that can be obtained according to what is studied.

For all this the program has different panels where you can enter data such as temperature, area available, cost per m^2, production period, electricity prices, etc ...

Once all this information is introduced, we can calculate the production in kWh, stored energy, energy produced, and economic benefits. These data can be displayed by year, month to month, or per day using tables.(Fig 6.11)

The program also has the option to represent all the image data, either separately or all data in a graph to compare.

Here an example of the program:

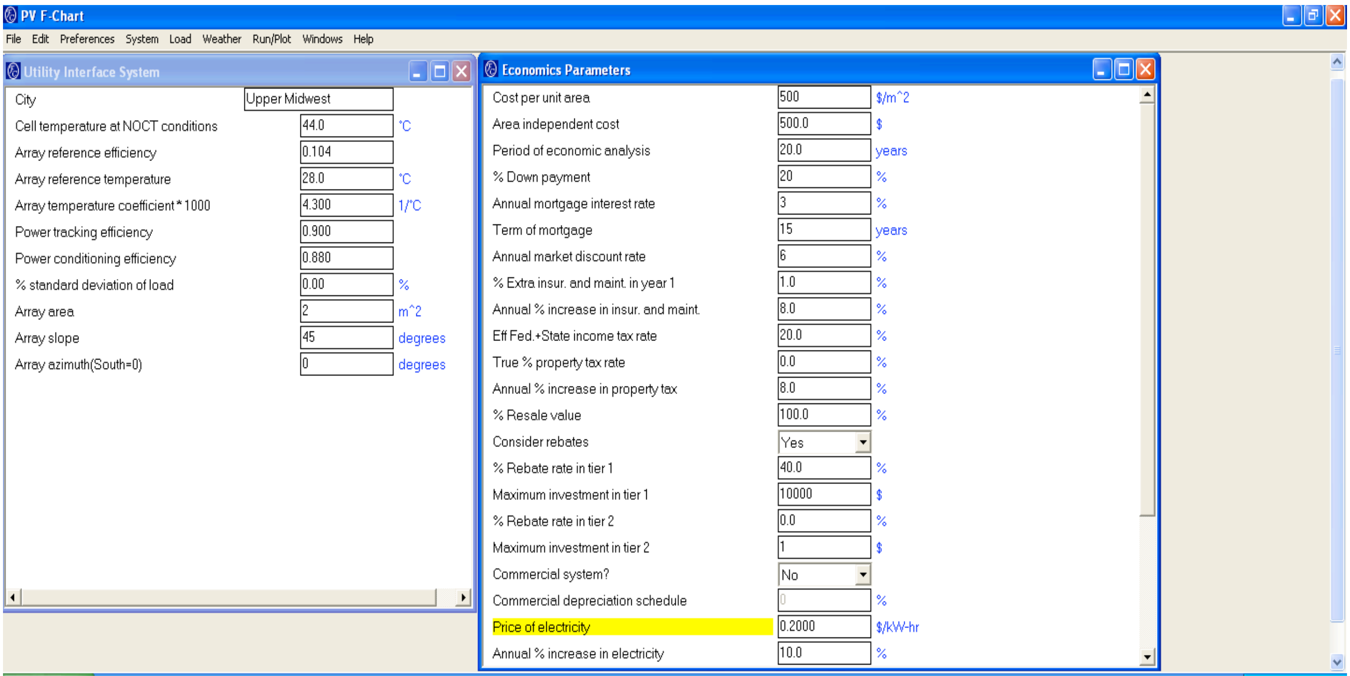

Fig. 6.11 Testing the PV-F chart software.

17 www.fchart.com
Program help, and documents

6.6.4. Ecotec [18]

Ecotect is a conceptual design tool for analysis and simulation of how environmental conditions affect buildings and facilities designed by the program. The program simulate lighting conditions such as solar, thermal, shading design, acoustics, all with different forms of construction.

Ecotec is able to draw all types of buildings, through 3D design and simulate the situations listed above with all kinds of details and lots of visual analysis.

For example, in terms of solar lighting options, we can graphically view and analyze the light daily, monthly or yearly, such as seeing and 3D graphically the sun trajectory makes for a day in one position and specific day. (Fig 6.12)

In terms of display options available, for example in the visualization of the shadows can play so that we can analyze in full detail how they affect the shadows between buildings or objects and also designed to simulate reflections on surfaces.

Regarding the analysis of the acoustics, acoustics can be analyzed in the form of dust or ray of emitting sources according to design.

Another important point is the ability to simulate artificial light that if is combined with the other options makes Ecotec is an ideal tool for the analysis of lighting on buildings and radiation.

And for finish all these options can make a balance of costs.

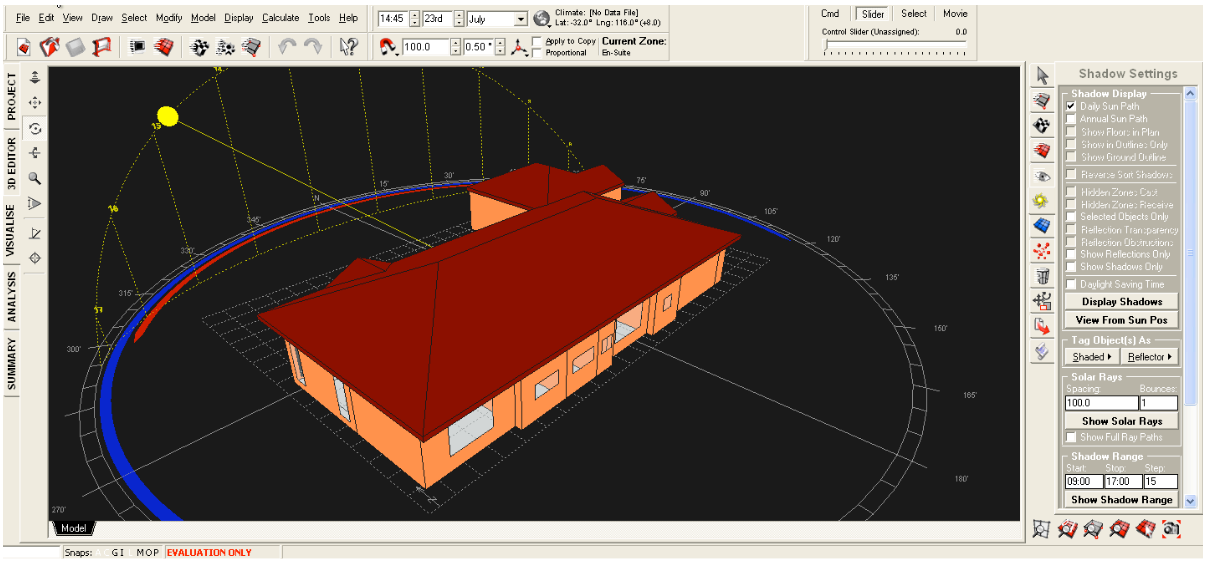

Fig. 6.12 Example of behaviour of the sun to a house with specific location.

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[18] www.ecotect.com/products/ecotect
Program help, and documents

6.6.5. eQUEST [19]

eQuest is a simulation tool for energy consumption. It can be designed all types of buildings, and set full details of existing consumption in these buildings. The program simulates the operation of fans, pumps, refrigerators, boilers and all other components of energy-consuming buildings as they respond to the environment and according to its construction.

Simulations can be performed per hour, or until one year periods. When tested, eQuest have the option of adding new elements and modifications like changing the design of any element, sizes, shapes, or add new consumption.

Equest has some very complex preferences detailing all kinds of details and the analysis can be represented graphically and summarized in order to analyze the results very quickly and effectively.

eQuest can be designed all types of buildings, and set full details of existing consumption in these buildings.

This is an image of menu of program design, where one can see the building like the mall Ecotesco, designed in 3D with colours and textures.(Fig 6.13)

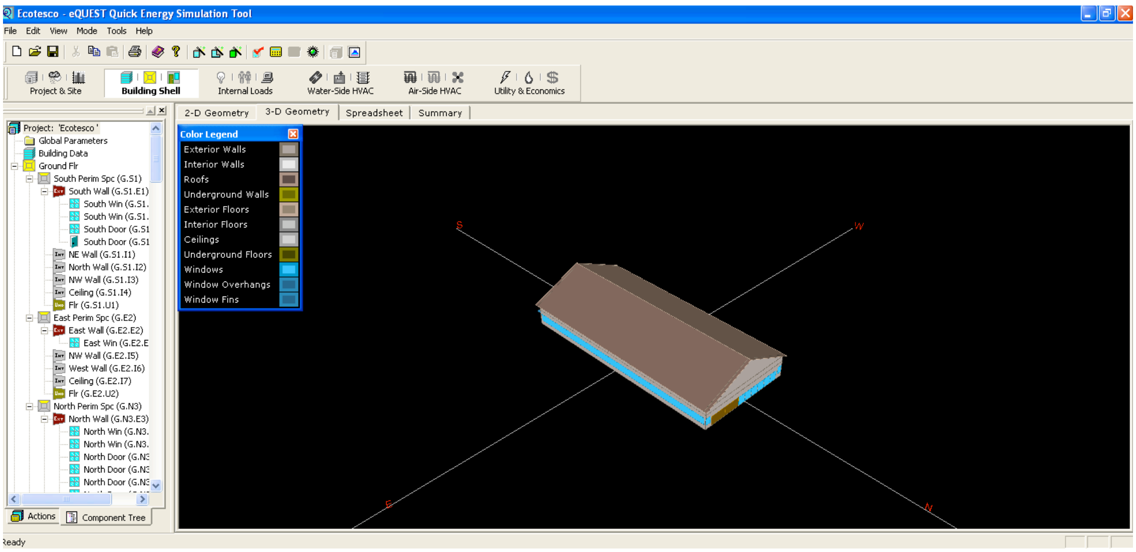

Fig. 6.13 Design of house

19 www.doe2.com/eQUEST/
Program help, and documents

This image corresponds to the menu of the loads, heating and cooling systems. On the right the program represents a diagram of the building contents, and on the left menu where you can change, configure and add all kinds of elements to the building:

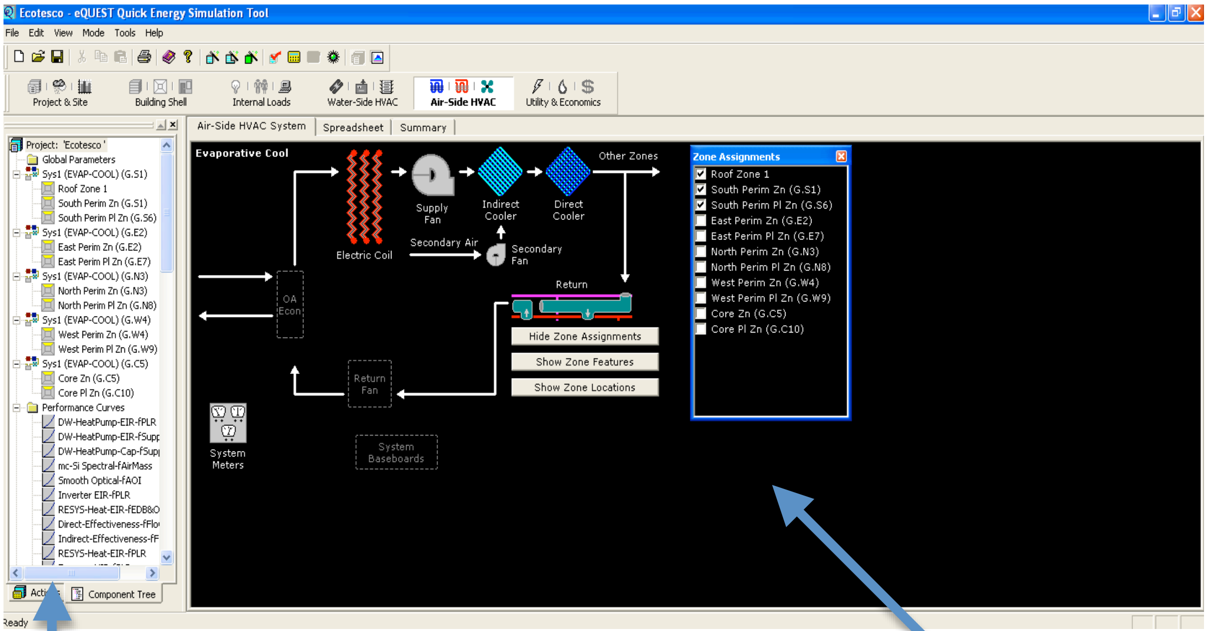

Fig. 6.14 Design loads, water heating and cooling.

Scheme
.

Options menu.

6.7. PVSYS 5.0.[20]

PVSYS is a program designed by the University of Geneva. It is designed specifically for the computation of solar photovoltaic installations. This program is very simple and effective as it can set all kinds of details of the installation, and type of collectors, investors, wires ... We also have the option of configuring shadow by images which can influence on the installation.

One of the interesting points of this program is how does the behaviour analysis of the solar collector selected, different radiations. This is of great interest as you can see how the board responds, this can serve to choosing a collector, and you can try different models and see their response.

Another important factor is the large database of PVSYS. This is something advantageous, since in some cases when simulations are not available elements, you have to create or choose a similar type.

In this image you can see some program windows, such as system configuration, and losses. This example is the calculation of energy production in Ecotesco.(Fig 6.15)

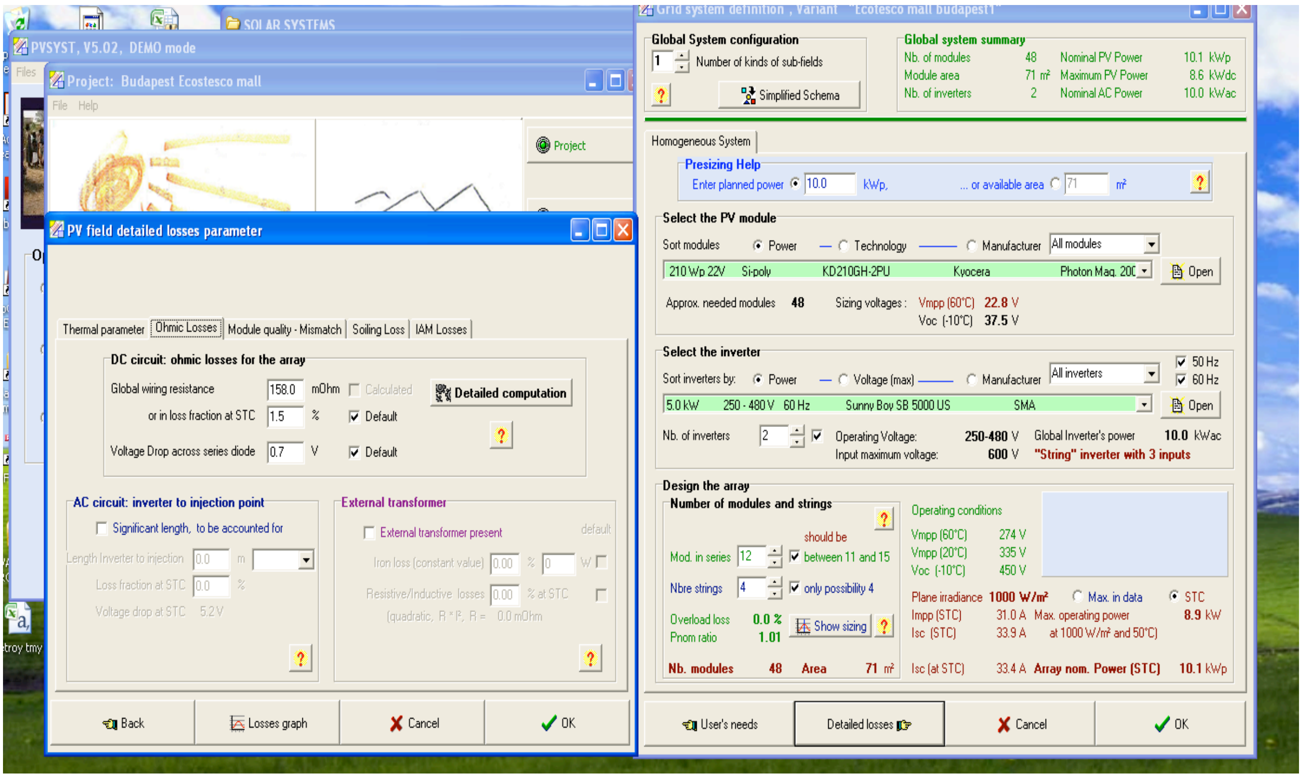

Fig. 6.15 Example

20 www.pvsyst.com

6.7.1. PVSim[21]

PVSIM is a program designed for calculating isolated photovoltaic installations.

It can calculate all the elements needed for installation including:

Calculation of solar panels, according to a base of radiation for months and a given consumption, the program calculates the number of panels needed and their production, how many panels are necessary and how many in parallel and serial, this is determined by the voltage of the installation.

Battery calculations, the program calculates the necessary batteries according to their output with the panels, and its configuration.

Cables, PVsim calculated the estimated losses in the wires, the resistivity of the same, voltage drops and maximum permissible intensity.

Another important point of the program is the calculation of the batteries for daily needs, as well as the cost of gas, electricity, and diesel calculated according to all specified in the preceding points and take stock of several years.

Finally, you can graph the results of production using 2 graphics: power-voltage and voltage-current.

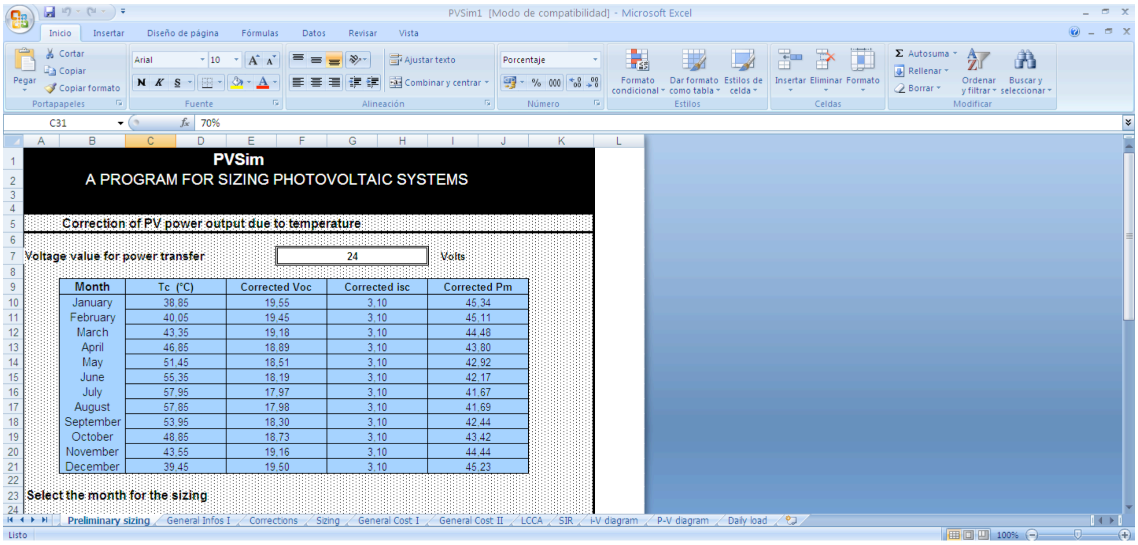

Fig. 6.16 Testing program

21 http://photovoltaics.sandia.gov/docs/
Program help, and documents

6.7.2. Sandia IVT racer

This program is used to observe the response of the solar panels changing various parameters of the program.

The program has a database with some models of solar panels, but there is the option to add more models. The parameters that we can change are inclination of the panel, sun position, wind speed, altitude, latitude and more... we can see how the curves of the graph will vary from what would be the ideal curve, the curves that can be observed are Amps-Watts-Volts.(Fig 6.17)

This is an example of testing solar panel of mark Kyocera.

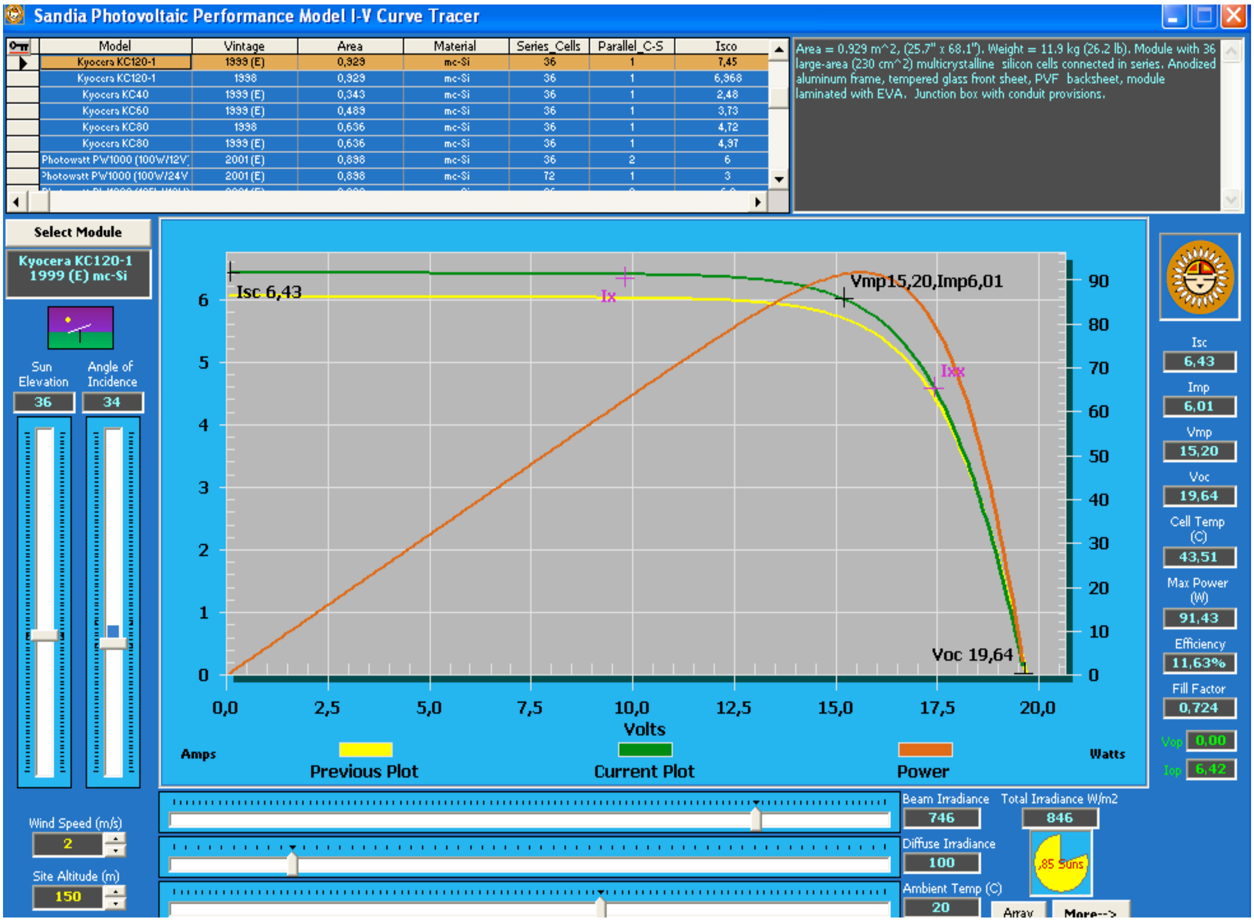

Fig. 6.17 Testing behaviour off some panels of Kyocera.

6.7.3. RETscreen[22]

RETScreen is a program focused on the analysis of projects through models. These models are related to all kinds of energy efficiency and renewable energy.

Such models are:

- Wind Energy Project Model
- Small Hydro Project Model
- Photovoltaic Project Model
- Biomass Heating Project Model
- Solar Air Heating Project Model
- Solar Water Heating Project Model
- Passive Solar Heating Project Model
- Ground-Source Heat Pump Project Model
- Combined Heat & Power (CHP) Project Mode

RETScreen analysis performed by the many databases, and using mathematical methods with calculation pages (Excel).

This program can perform planned projects and see results very reliable and accurate that can greatly help in making decisions before the execution.

It's a very interesting tool because it has a wide range of possibilities and data. (Fig 6.18)

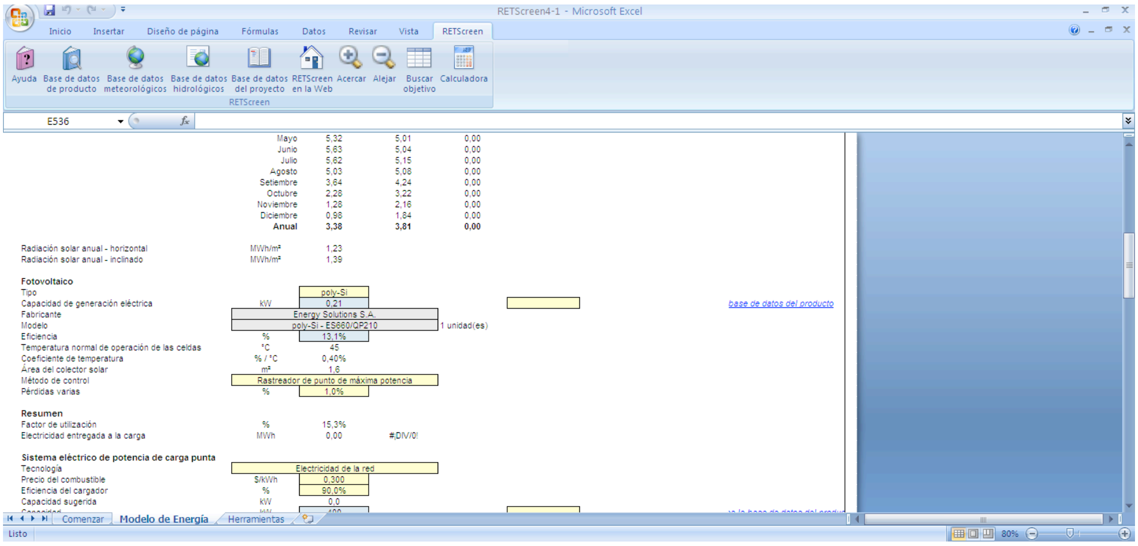

Fig. 6.18 Testing different types of simulation and methods

22 Notebook of Retscreen
www.retscreen.net

6.7.4. Sun Path.

Sun path is a bundle of several spreadsheets that are used to perform calculations related to solar radiation, position of the sun and all of things related with the trajectory and behaviour of the sun. All these data can be represented by graphs.

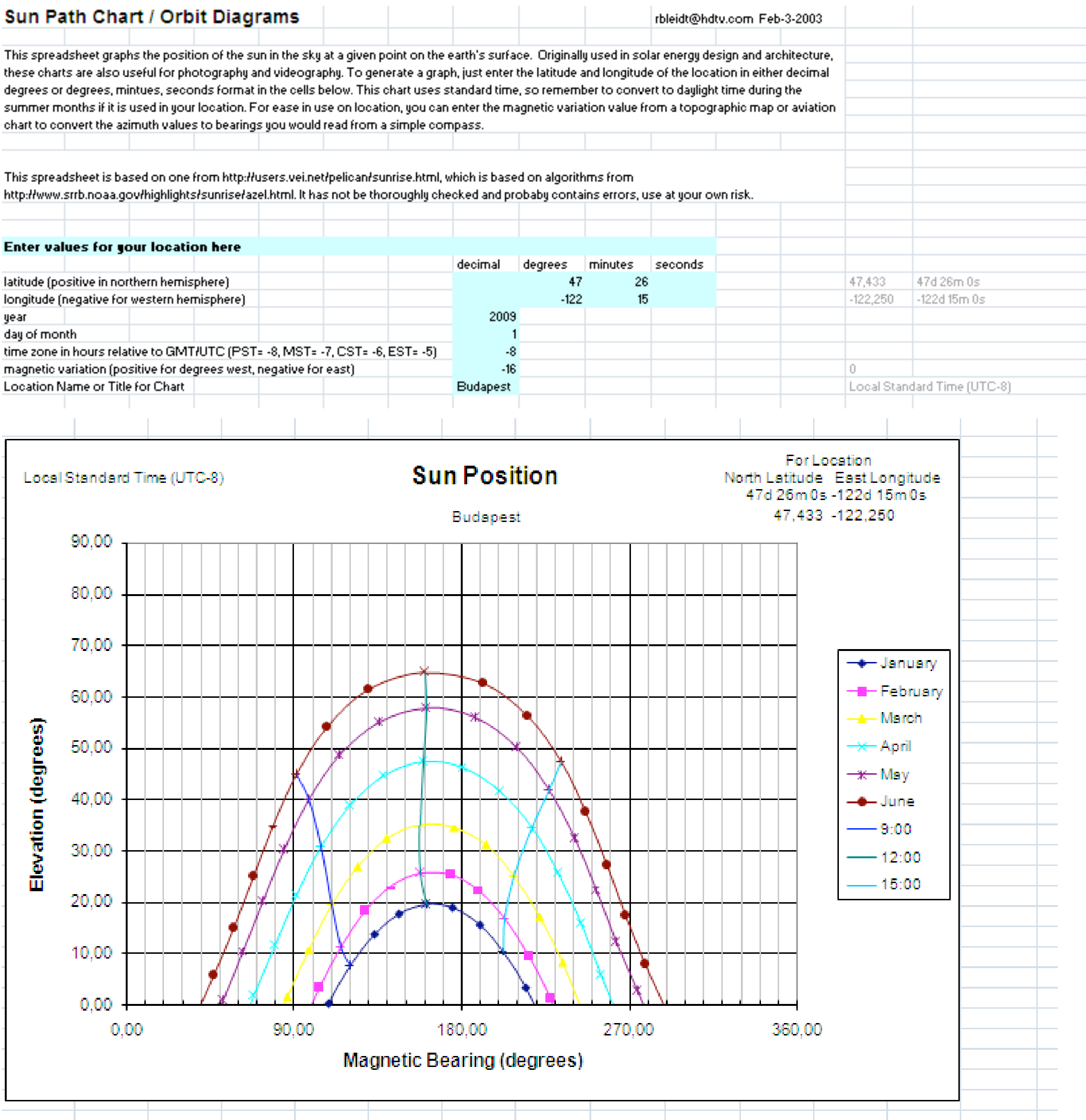

Fig. 6.19 Testing program with example of Budapest.

6.7.5. Solar Sizer.

Solar sizer is a program designed to simulate photovoltaic systems for domestic use. The program has the following configuration options:

Location of the installation, system voltage, load applications and housing, battery configuration, a configuration of solar panels, inverters, generators, type of mounting solar panels, batteries and regulators for cables. For all these options the program has a database with which we can make a custom configuration.

Once done, the program performs a series of reports based on the installation setup. The reports are energy, economics, and simulation accuracy. these reports can be seen the production in kWh per day and the energy stored, as well as the costs of installation. Maybe the program is limited for some applications it has a limited database and the program is basically for indoor installations and housing but is ideal to simulate basic isolated photovoltaic installations, since with an easy management can quickly get interesting data.

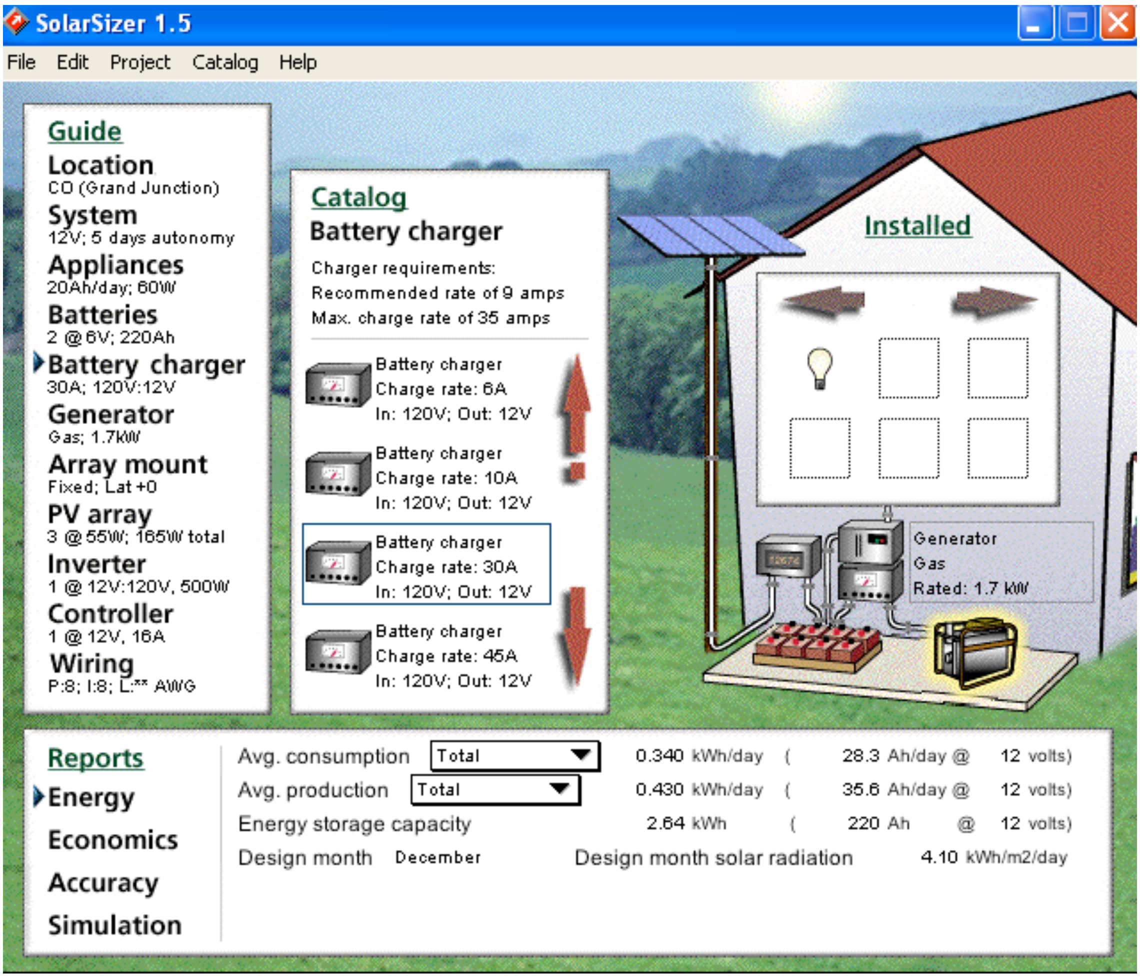

Fig. 6.20 Testing program

7. DESCRIPTION OF ECOTESCO .

7.1. WHAT IS IT?

Ecotesco is an initiative that has launched the Tesco supermarket chain in Hungary.

The initiative was taken to combat the effects of climate change and reduce emissions and energy consumption. In this project I will focus on energy consumption, detailing the technologies used, as described above (Cooling absortion systems for air condition and heat, heat ground systems, hot water, and photovoltaic energy production).

7.2. COOLING WITH ABSORPTION SYSTEMS.

Ecotesco has a great system of air conditioning and cooling. With this system refrigerated cold rooms and supermarket space.

The absorption refrigeration system is a means of producing cold that takes advantage of certain substances that absorb heat to change from liquid to gas. The cycle is based physically on the ability of certain substances, in water in a circuit at low pressure, evaporates in a heat exchanger called the evaporator, which cools a secondary fluid, which ventilated environments or chambers. Then the steam is absorbed by lithium bromide (absorbent) in the absorber, producing a concentrated solution. This solution is the heater, where the solvent and solute are separated by heat from an external source, the water returns to the evaporator and the absorber bromide to restart the cycle. [23]

Ecostesco used 2 systems of absorption:

- CO_2 for the refrigerated where the food is stored. The machine that produces a refrigerating system has an extra. This extra is a process that gets water evaporated to produce moisture, the humidity is used cool rooms in the supermarket.[24]
- Combination of lithium bromide to the air conditioning, no ammonia as a pollutant. which makes a very efficient and ecological system.[25]

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[23] www.wikipedia.com
[24] Detail in anexes.
[25] www.lennoxcommercial.com-www.wikipedia.com

7.2.1. CO2 Cooling system:

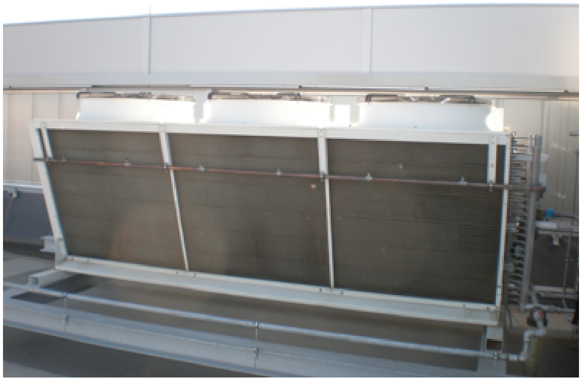

Fig. 7.2 CO_2 Cooling system

Fig. 7.1 Evaporated water pipes

Evaporated water

Fig. 7.3 Fans detail

Fig. 7.4 Plate of characteristics

This machine is responsible for the cooling system for freezers with CO_2 .

This machine consumes electricity in its operation.

In the diagrams of the control system, it refers to the number D.2, these schemes are available below.

7.2.2. Heat exchanger-Rooftop (Lennox):

Fig. 7.5 Rooftop

The Rooftop or hear exchanger, this is responsible for the heating and air conditioning of the mall, according to the season the machine generates heat or cold.

In summer season the machine absorbs heat to produce cold and in winter absorbs heat to produce cold.

Fig. 7.6 Plate of characteristics

In these photos you can see the engine room with compressors, lockers command elements and protection:

Fig. 7.8 Machines space

Fig. 7.7 Inside space

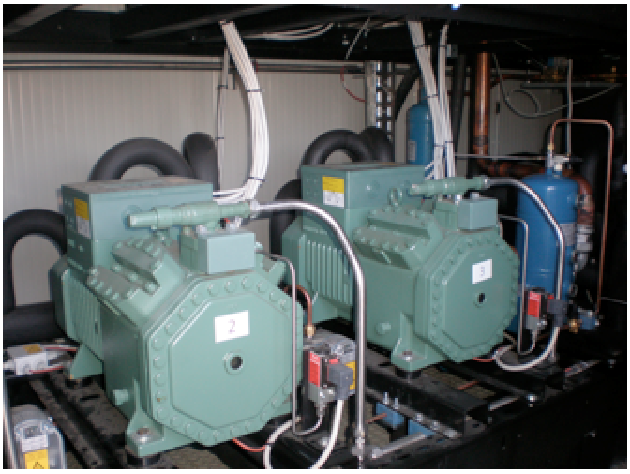

Fig. 7.9 Motors and compressors

Fig. 7.10 Exterior details

In control schemes can be seen these compressors, pumps and temperature sensors.

7.2.3. Refrigerator absorbed.

Exotics has a heat exchanger machine for the cooling and heating.

The refrigeration is produced by repetitions of concentration, refrigerant dilution, and heat exchange of an aqueous lithium bromide solution as an absorbing solution.(Fig. 7.11)

This absorption type refrigerator uses water as a refrigerant and an aqueous concentrated lithium bromide solution as an absorbing solution.

This machine does not use electricity for the production of heat or cold, just use the absorption with which makes the system very efficient and clean.

In this photo you can see the refrigerator absorbed:

Fig. 7.11 Heat exchanger

Fig. 7.12

- What is Lithium bromide.[26]

"Lithium Bromide (LiBr); white powder with a bitter taste; melts at 547°C, soluble in water, alcohol and glycol; used as an operating medium for air-conditioning and industrial drying system due to its very hygroscopic property. and as a sedative and hypnotic in medicine. It is also used in manufacturing pharmaceuticals and alkylation process. It is used as brazing and welding fluxes."

"Lithium chloride; white hygroscopic deliquescent granule or powder having high melting point at 614°C. Lithium chloride and bromide are the mostly prosodic materials used as an operating medium for air-conditioning and industrial drying system. It is used as brazing and welding fluxes. It is also used in as an intermediate for manufacturing other chemical compounds."

- The control.

All air conditioning and heating is controlled by sensors that measure the temperature of the space, which saves a great deal of energy.(Fig 7.13)

Fig. 7.13 Panel control

[26] http://chemicalland21.com/industrialchem/inorganic/

7.3. WATER HEATING WITH SOLAR COLLECTORS.

Ecotesco Hot water is produced by solar collectors that are responsible for heating the water.

Ecosteco has 55 panels installed on the roof. These are with tilted 45 degrees for better radiation. The heating system is active type, the panels collect the energy radiated by the sun and heat the water. Then the water is stored in a tank. This tank is responsible for maintaining the hot water and after is distributed by pumps.

"The panels are vacuum tube where the surface of apprehension is isolated from the outside by a double glass tube creates a vacuum chamber, heating the water inside" .This water is stored in a tank where it is kept warm for panel use. Each panel has 15 glass tubes. [27]

The panel's brand is soltec.[28]

Example:

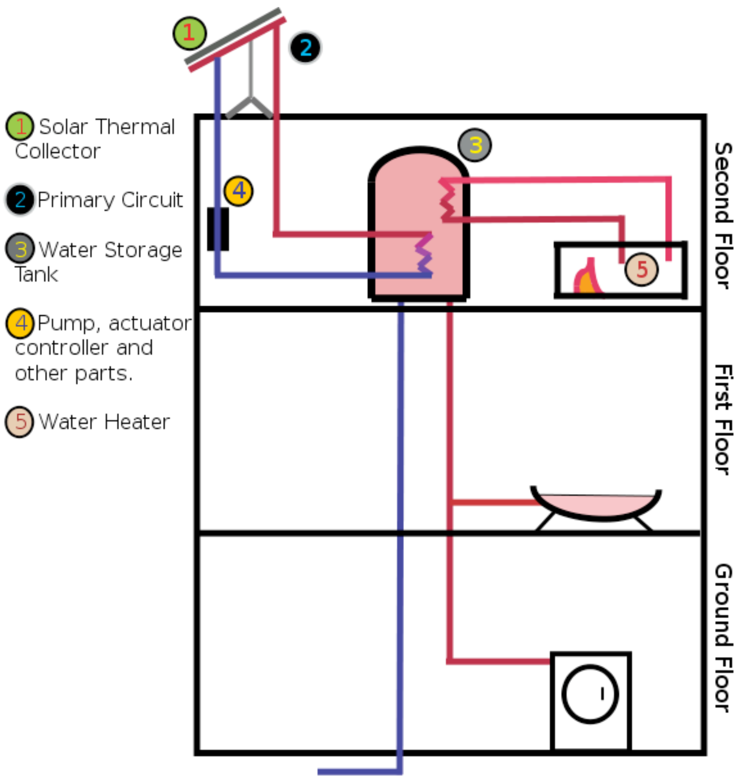

Fig. 7.14 Basic example of solar heating

http://upload.wikimedia.org/wikipedia/en/thumb/0/0c/Active_Solar_Water_Heater_Diagram.svg/573px-Active_Solar_Water_Heater_Diagram.svg.png

[27] www.wikipedia.com
[28] www.soltec-renovables.com

The panels:

Fig. 7.15 Set of panels

Fig. 7.16 One panel

This photo shows a solar panel, which consists of 15 evacuated tubes.

In control schemes, solar collectors refer to the number A.1

Fig. 7.17 Details of pipes

Evacuated tube collector:

Fig. 7.18 Vacuum pipe

Here It can see one of the tubes which are formed the solar collectors, with "Evacuated tube collector technology".

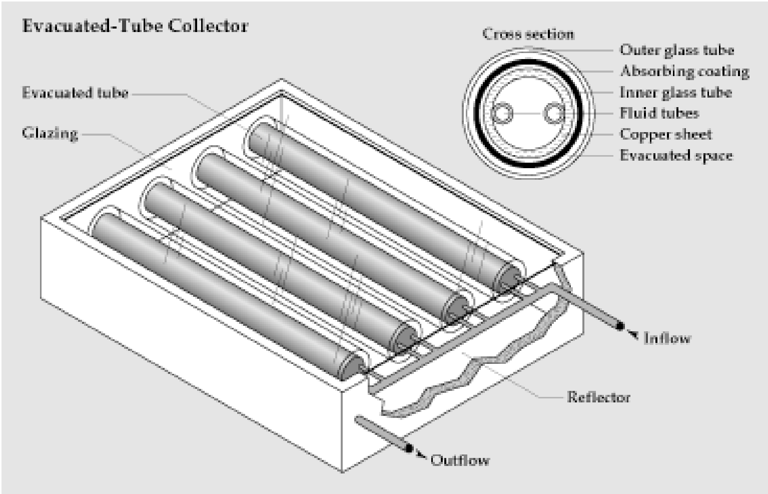

Fig. 7.19 Decomposition of the tube.

Hot water tank:

Fig. 7.21 Water tank

Fig. 7.20 Water pump

The photo on the right is the tank that stores hot water that comes from the solar collectors, also this hot water is used for the evaporation process, and the photo on the left is a water filter. The water tank is represented with the number A.2 in schemes.

7.4. ENERGY PRODUCTION BY PHOTOVOLTAIC SYSTEM.

Ecotesco has a photovoltaic system of producing electricity by solar radiation. This has 30 solar panels installed with an inclination of 45 ° and 18 mounted vertically on the front of the mall. The characteristics of the solar panels are in the annexes, where it can see a document with all the specifications about the solar module.[29]

Fig. 7.23 Set of solar panels 45°

Fig. 7.22 Panels 90°

All the energy produced is collected and distributed by 3 investors.

Investors used by Ecotesco are versatile because they can observe in daily production, monthly, production current value, voltage, represented in data graphs. (Fig 7.24)

Fig. 7.25 Inverters

Fig. 7.24 Current measure

[29] www.kyocera.com

"The investor sunny boy is more communicative, user-friendly and efficient than ever, the Sunny Boy is setting new standards in inverter technology. A modern graphic display, readout of daily values even after sunset, simplified installation concept and wireless communication via Bluetooth. With a peak efficiency of 97 %, the transformer less devices Sunny Boy provide an optimal solar yield, maximum flexibility in system planning and exceptional module compatibility. The characteristics of the solar panels are in the annexes, where it can see a document with all the specifications about the solar module." [30]

Ecotesco not produce energy for the same mall, but it produces energy to be injected and then sold to the energy company. In this way produce more than they consume, and thus get an economic benefit.

This is the scheme that follows: [31]

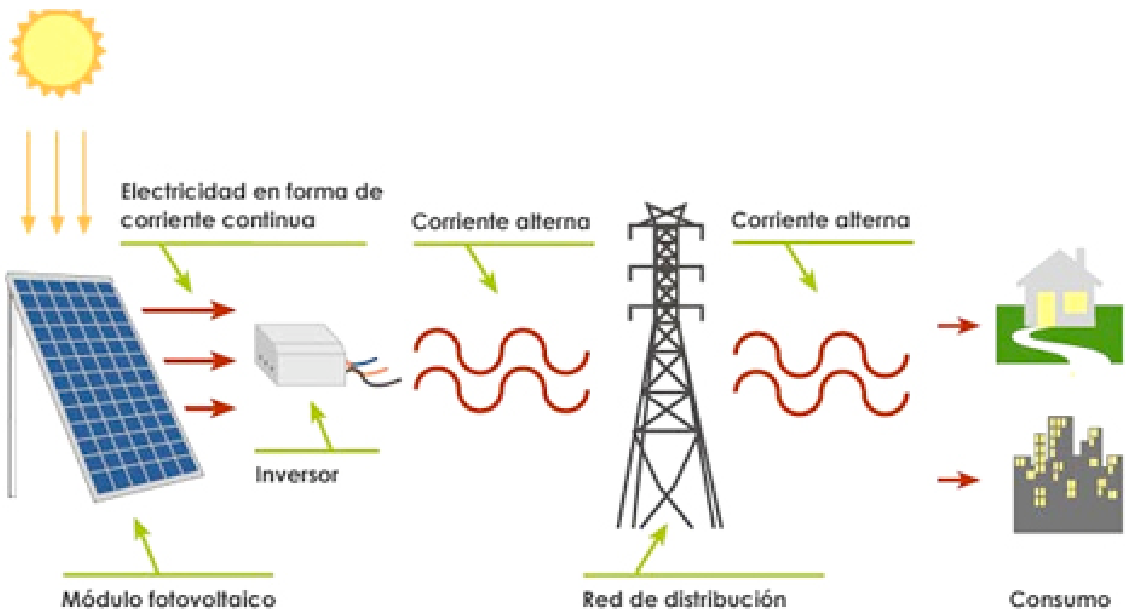

Fig. 7.26 Scheme of operation photovoltaic system in Ecotesco

[30] www.sma.de/en/products/solar-inverters
[31] http://www.construible.es

7.4.1. Actual measurements in other similar TESCO.

Currently exist similar facilities like this Tesco. This installations have been studied a few years ago, and exist several data base of the annuals productions. With this data, later It could compare the production of this Tesco. Below are the graphs of the 2 different Tesco.

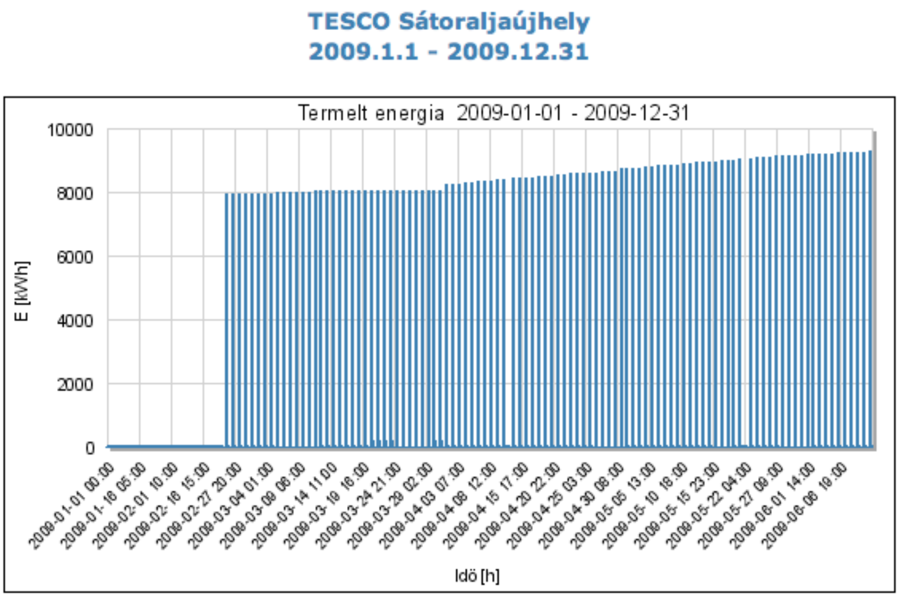

Fig. 7.27 Annual production of Tesco Sátoraljaújhely

Total energy production in 2009 was approximately ≈ **9000 kWh.**

This production is similar to Tesco studied, since as seen in the next simulations, similar yields are obtained.

TESCO - Gyál

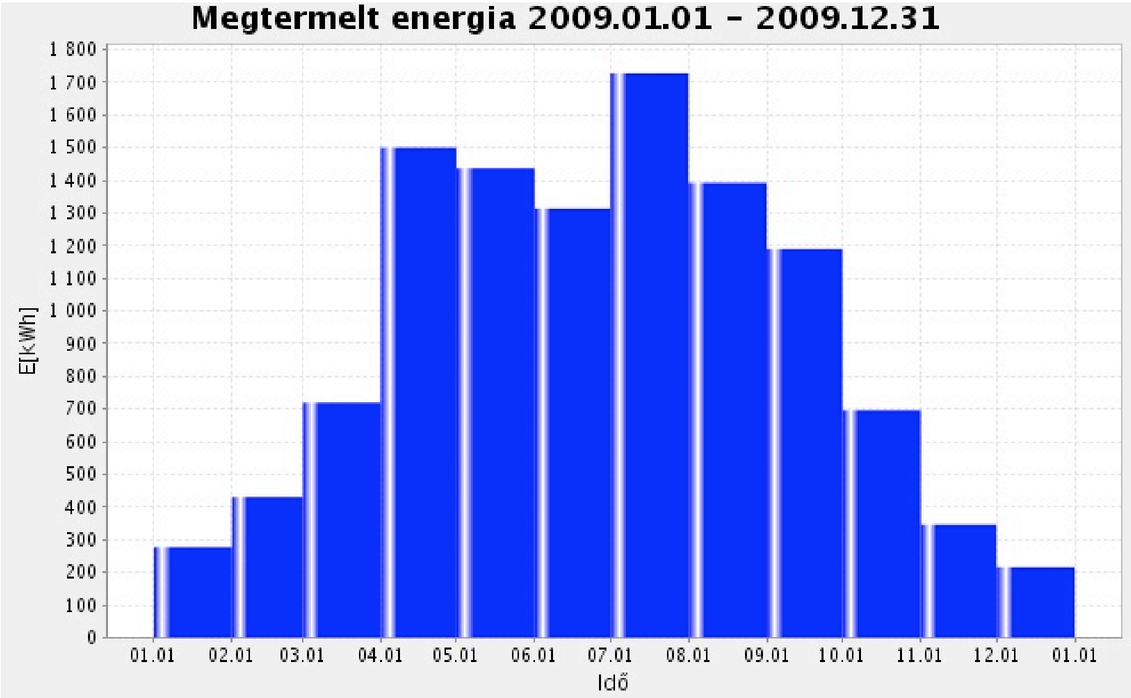

Fig. 7.28 Annual production of Tesco Gyál

Total energy production with Kyocera KC200 panels in this facility in 2009 was **11246 kWh.**

This production is similar to Tesco studied, since as seen in the next simulations, similar yields are obtained.

In paragraphs 8.1.5 , 8.2.5 and 8.3.5 shows the simulation results obtained for this case study of Tesco.

7.5. GROUND HEATING.

Ecotesco has a water heating system. The system is the typical ground heating described above. The explanation of the operation is that, in the ground can be found temperatures above the application temperature. However, even when the temperature is cool, the soil is warm, and can be removed with a geothermal heat pump. This is what makes the installation of Ecotesco, is based on the extraction of heat from the ground, this is done by these pumps used to force the transfer of heat from the ground to the application.

Photos of the complex installation of ground heating of Ecotesco:

Fig. 7.30 Pipe system

Fig. 7.29 Plate of characteristics

Fig. 7.32 Details of compressors

Circulating compressors in the system piping.

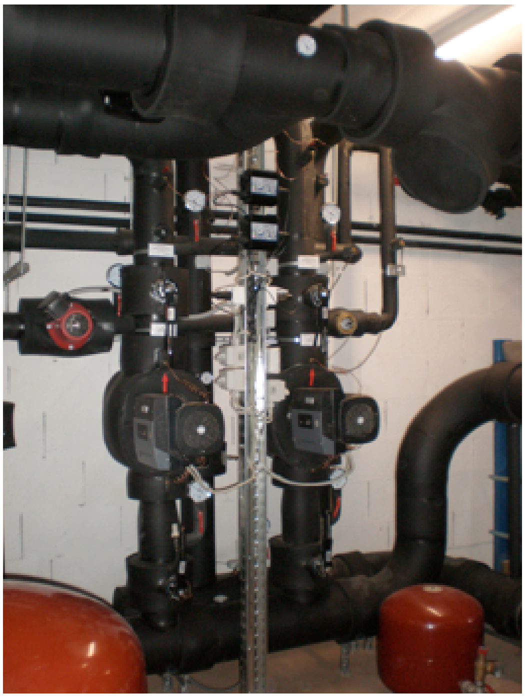

Fig. 7.31 Details of compressors 2

Fig. 7.33 Details of pipes system

The heat pumps and compressor can see in the control schemes, and refers to the number C.3

Fig. 7.34 Ground heating system

In the photo you can see the machine where you can manage the ground heating, in the machine exist a small display for control and manipulation options related to the ground heating system.(Fig 7.34)

Pipes to ground.

Fig. 7.35 Pipes system to groun

7.6. OTHER ECOLOGICAL AND EFFICIENT TECHNOLOGIES.

7.6.1. Heat recuperator.

Is composed of a machine that takes the heat generated by the furnace and other machines of the mall for reuse. This represents a major energy savings in some of the applications related to heating.

Here is a photo of the machine:

Fig. 7.36 Heat recuperator

Fig. 7.37 Details of heat recuperator

7.6.2. Lighting.

An important aspect to consider is that Ecotesco not use any type of incandescent lighting, but yes for low power, as it uses sensors to measure the amount of lumens and can regulate the lighting of all spaces. Not only with enlightenment of the spaces can save, in the freezers used Led's to produce less heat in them and not consume more than they should.

Fig. 7.39 Fluorescent lamp

Fig. 7.38 Leds in refrigerator cabins

Another point to consider are the holes of natural light on the roof. These holes are prepared to let the light but not heat, thus avoiding that in the days of summer air conditioning is not affected, and in turn saving energy.

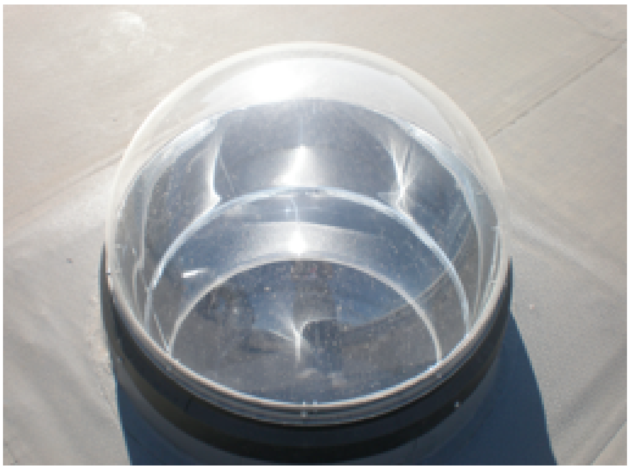

Fig. 7.40 Hole for natural light

7.7. EMERGENCY SYSTEMS.

Ecotesco has several extra security systems for the case of any electrical or heating failure on Ecotesco. It is a very important aspect to keep in mind, if there is a power failure, the freezers could not work, and thus the stored food could be lost, causing great economic losses.

In terms of heating, if heating systems fail on Ecotesco, It would suffer a very uncomfortable internal cold, because winter temperatures in Hungary are very low, therefore these systems are:

7.7.1. Heating.[32]

The heating system consists of 2 condensing boilers operated by Gas. They produce heat through combustion, these are brand-Ultragas Hoval, model 900D able to produce 900 kW.(Fig 7.41)

"The Hoval Ultragas can be operated on room-sealed Therefore systems and is very quiet. The combination of a variable speed fan and the sophisticated noise containment system Ensure minimal noise emissions, turning the powerhouse into a discrete whisperer."

Combination specialist. The integrated controller Hoval TopTronic T makes the Hoval Ultragas ideally suited for combined operation with a solar system. Equipped with the corresponding key functions, the controller is capable of registering the operating dynamics of the solar system in order to smoothly and continuously control the auxiliary operation of the gas boiler."

Fig. 7.42 Scheme of Ultragas

Fig. 7.41

[32] www.hoval.com

7.7.2. Diesel generator.

Ecotesco has a diesel generator for electrical network failures. The engine has a power generator of 350 kVA. In the following pictures you can observe the appearance and characteristics:

Fig. 7.44 Diesel engine

Fig. 7.43 Diesel engine 2

Characteristics of the generator.

Fig. 7.46 Details of diesel generator

Fig. 7.45 Electric details

7.8. SYSTEM CONTROL SCHEMES.

7.8.1. Scheme 1- Heating , hydrobank, work system.

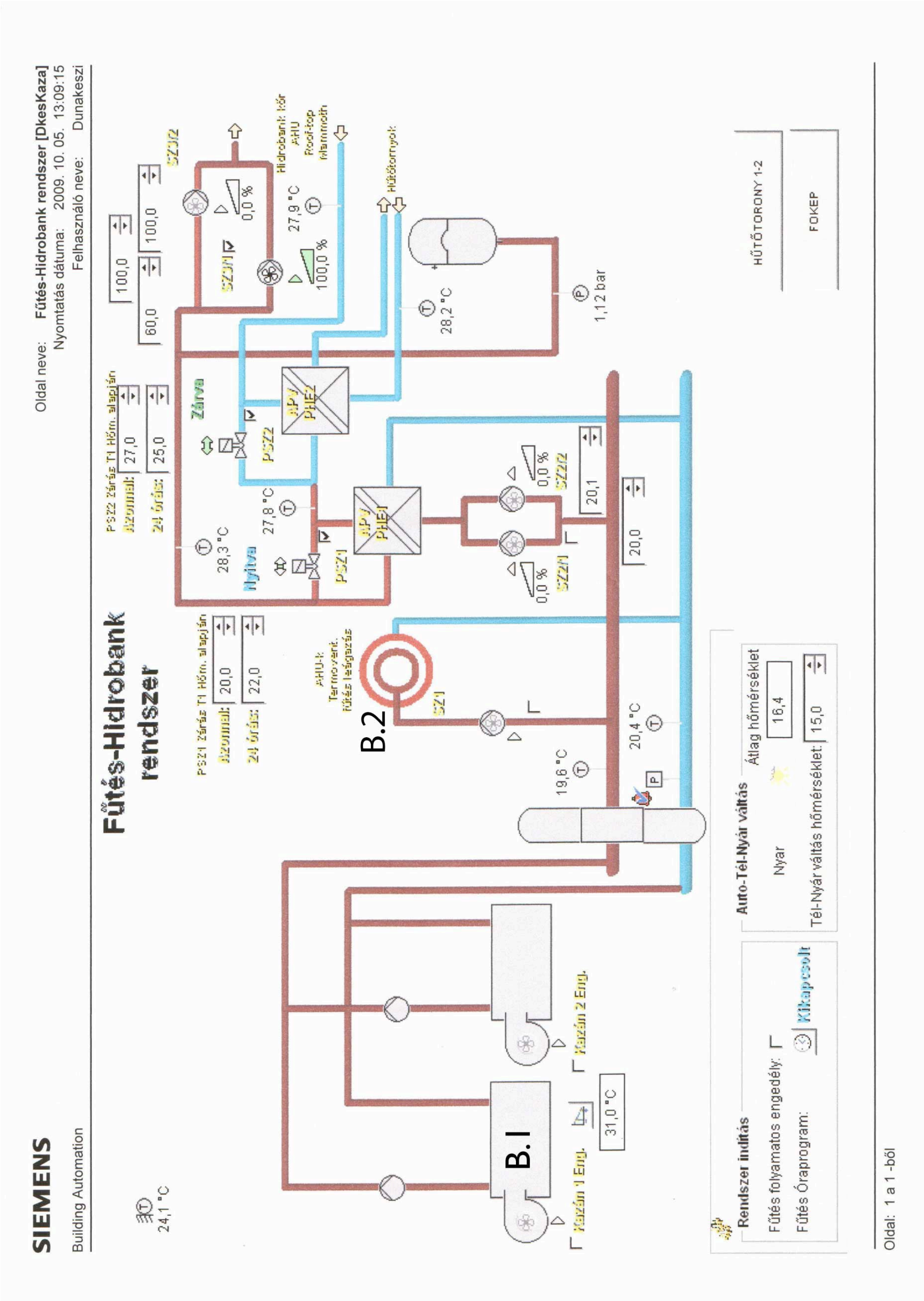

Fig. 7.47 Hidrobank work system

B.1- Gas heating. (Fig 7.41 – Fig. 7.42)

B.2- Extra heating ventilation.

7.8.2. Scheme 2- Solar water heating.

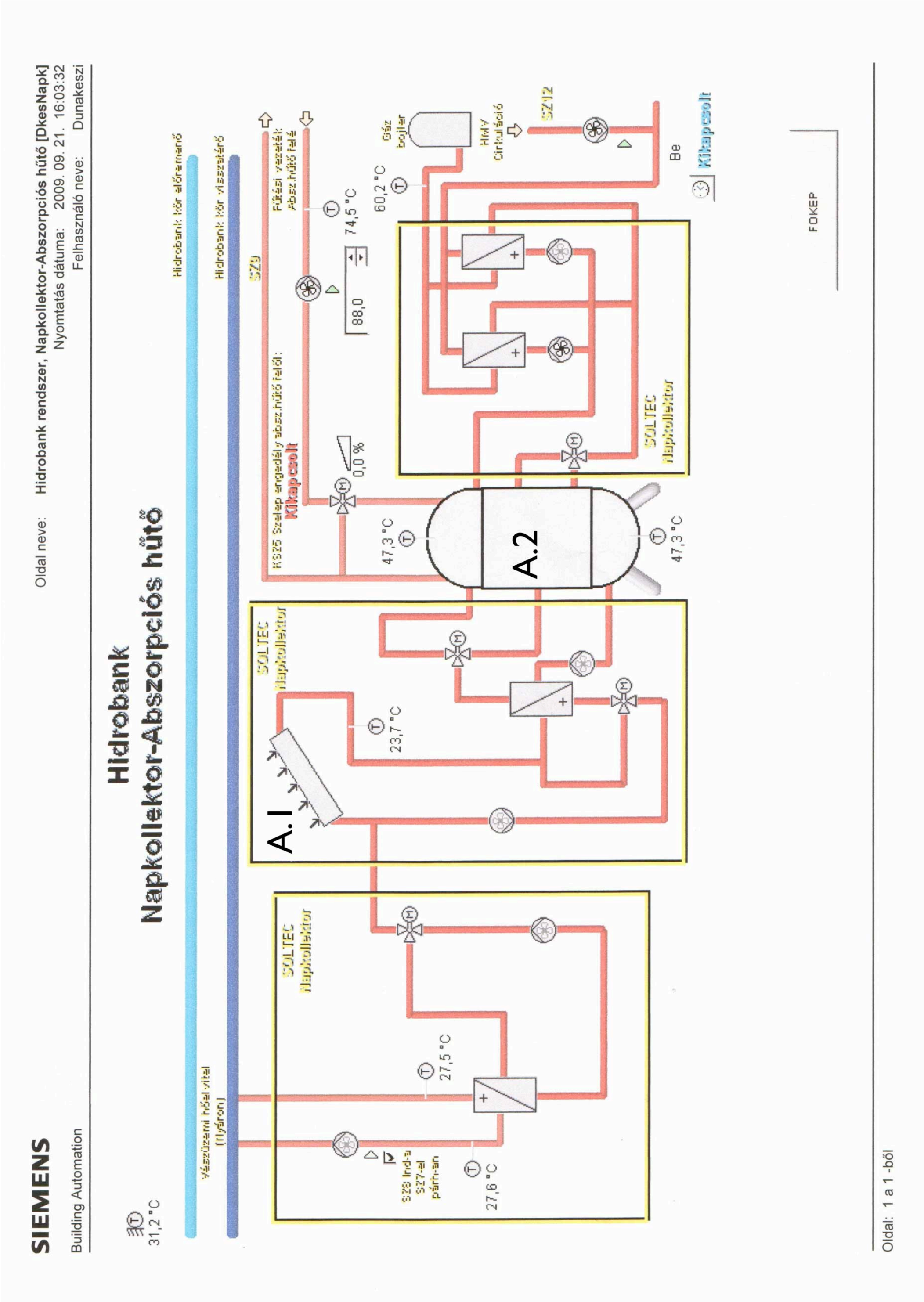

Fig. 7.48 Solar water heating

A.1-Solar collectors (Solartec).(Fig. 7.15 – Fig 7.18)

A.2-Storage tank hot water produced by solar collectors. (Fig 7.21)

7.8.3. Scheme 3- Cooling absorption system:

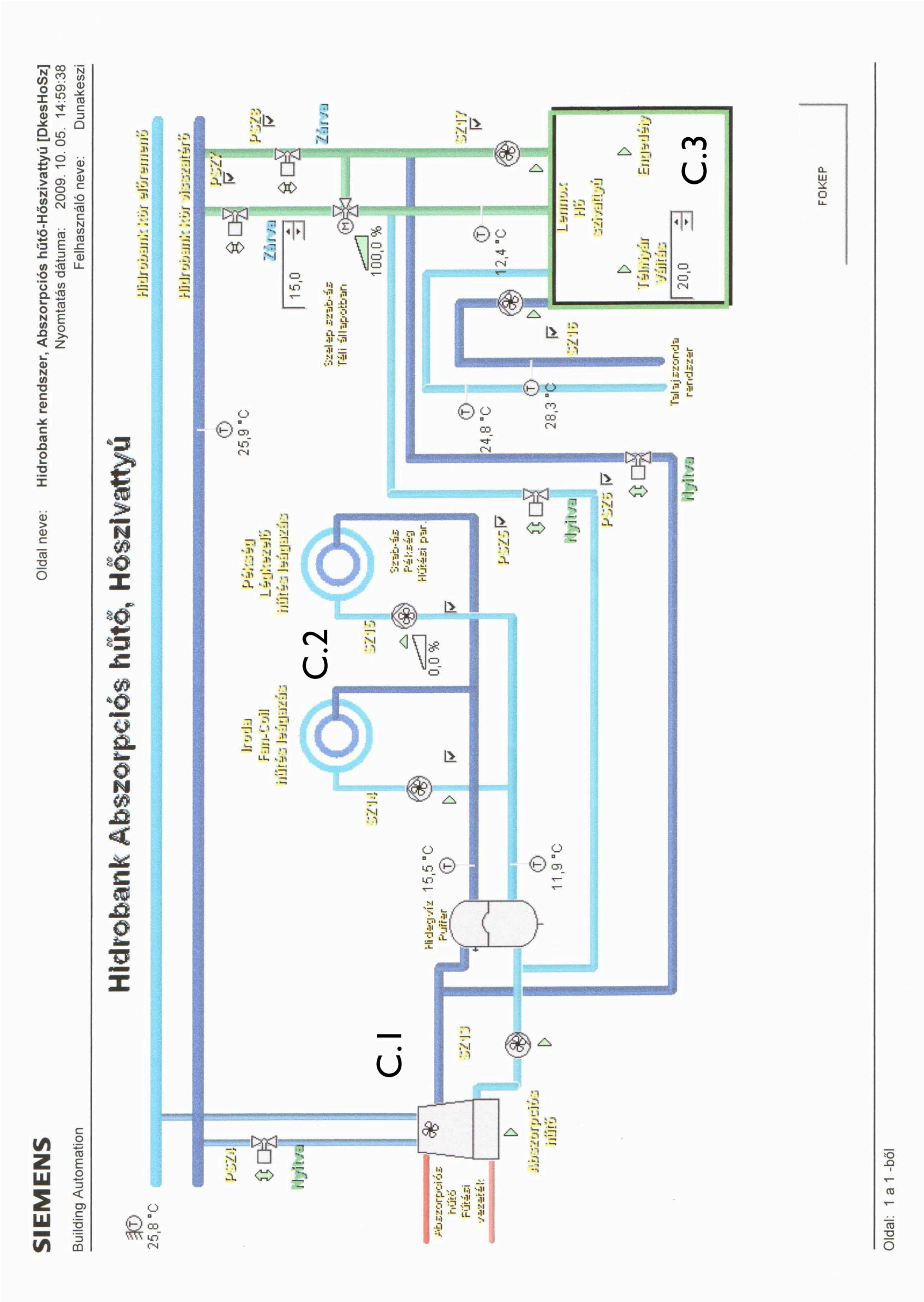

Fig. 7.49 Cooling absorption system

C.1- Refrigeration absorption system.

C.2- Roof top heating and cooling (Lennox). (Fig 7.5)

C.3- Heat pump. (Fig 7.20)

7.8.4. Scheme 4- Cooling absorption system 2:

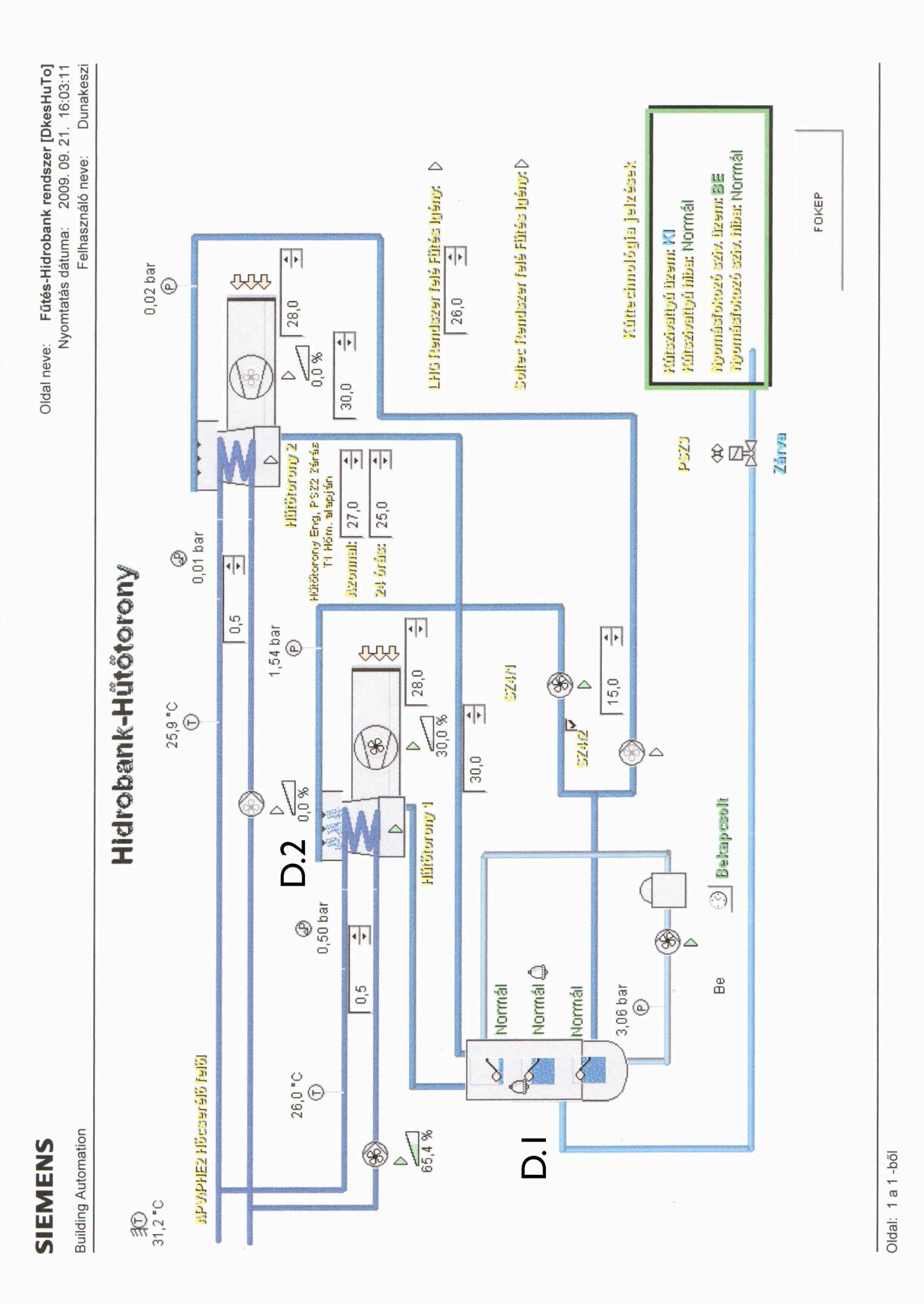

Fig. 7.50 Cooling absorption system 2

D.1- Piping system for heating by evaporation. (Fig 7.33)

D.2- CO_2 cooling evaporation system (LU-VE). (Fig. 7.1 – Fig 7.4)

8. SIMULATION AND DATABASE:

The studies described below correspond to the mall - Ecotesco, which is located in Dunakeszi a few kilometres from Budapest (Hungary). On the next map we can see the location.

All studies were performed with data for this location.

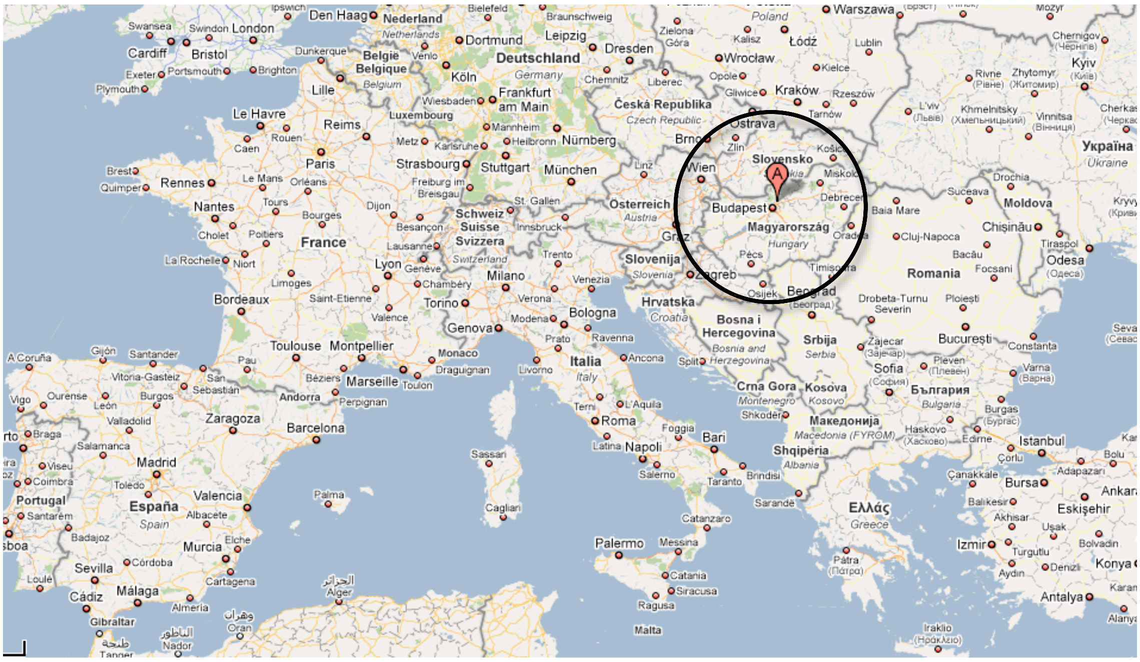

Fig. 8.1 Map location in Europe.

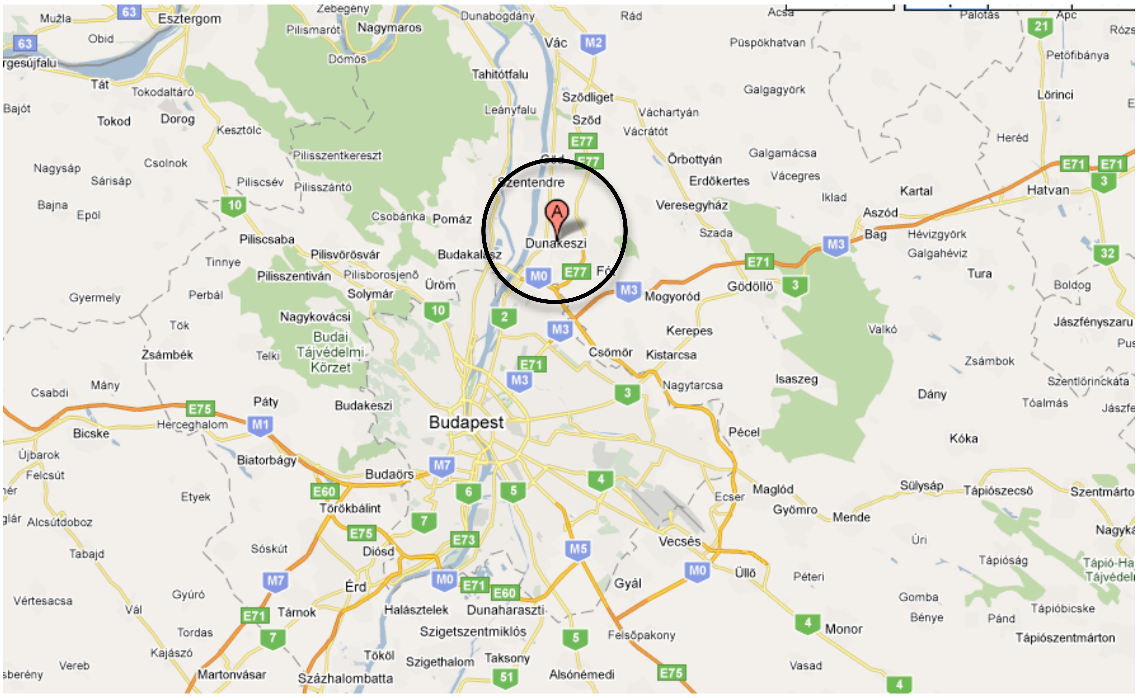

Fig. 8.2 Map location in Hungary.

8.1. PHOTOVOLTAIC ENERGY PRODUCTION-SIMULATION 1- PVSYS 5.0

8.1.1. Objective.

The objective is to simulate the photovoltaic energy production Ecotesco during one year with all of details, such as radiation, the behaviour of the plate and energy lost in the system.

8.1.2. Features.

The characteristics of the simulation are:

- 48 Solar collectors.
- Installed on the roof of Ecotesco.
- Inclination of 45 degrees south.
- Mark Kyocera.
- 3 Inverters (on simulation 2)
- Simulation by PVSYS 5.0 software.
- 3D design and Studio of shadows by Shadow analyzer software.

8.1.3. Model.

The installation of solar panels has 48 ud.30 of them are installed at 45 degrees and other 18 to 90 degrees to the vertical plane.

In the simulation has taken all panels at 45 degrees to get the total output power together, it is possible to make 2 separate calculations, one for 45 degrees and the other to 90 degrees. The result would be a bit lower than that obtained, the reason is because the radiation on the panels at 90 degrees is lower so in this case the simulation is done for all the panels in 45°.

So you can see and compare with previous data because the inverters are 3. For the case of the simulation inverters are oversized, so the program don't give the option to simulate if not choose another setting, thus who have chosen 2 inverters.

The results obtained are shown below.

8.1.4. Drawings/Diagrams.

All data and diagrams have been obtained automatically using the software PVSYS 5.0.

The study was conducted with the database program, selecting the same elements and features that Ecotesco solar photovoltaic installation.

- Energy incident at the receiver:

This graph represents the energy incident on the installation in months for a year in kWh/m2. (Fig 8.3)

As seen in the graphs the months with more solar radiation is obvious the summer months, so during those months is when Ecotesco will produce more energy.

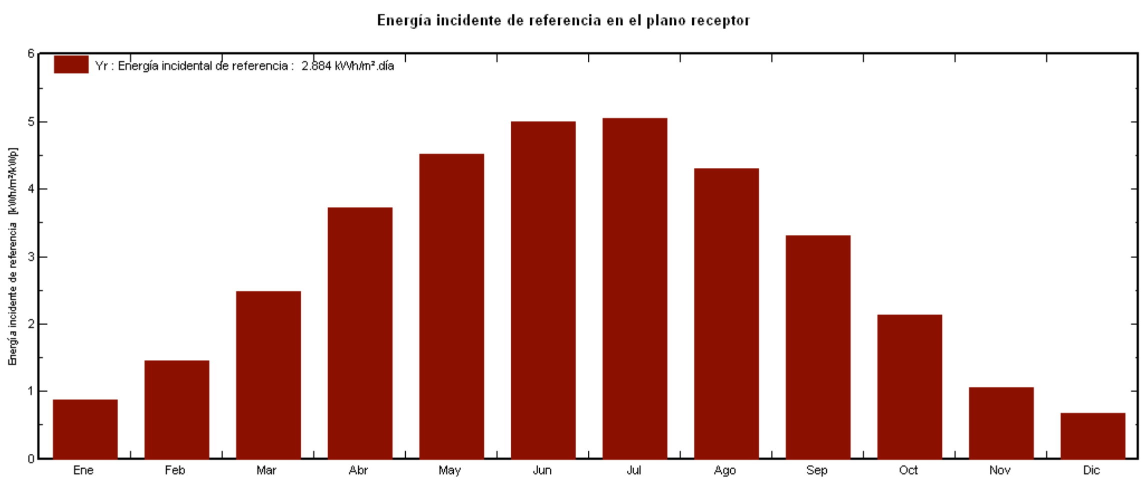

Fig. 8.3 Energy incidence on collectors by PVSYS 5.0

- Behaviour of the module V-I.[33]

In this graph can observe the behaviour of the solar collector KD210GH Kyoscera with different levels of radiation.(Fig 8.4)

X-axis represents the output voltage of the collector, and the Y-axis the intensity, and into the graph the curve obtained according to the test varying the load (Ohm) and incident radiation.

In all cases of Radiation is indicated the each point of maximum work, and the best conditions of the collector is when we have a radiation of 1000W/m^2 on the panel.

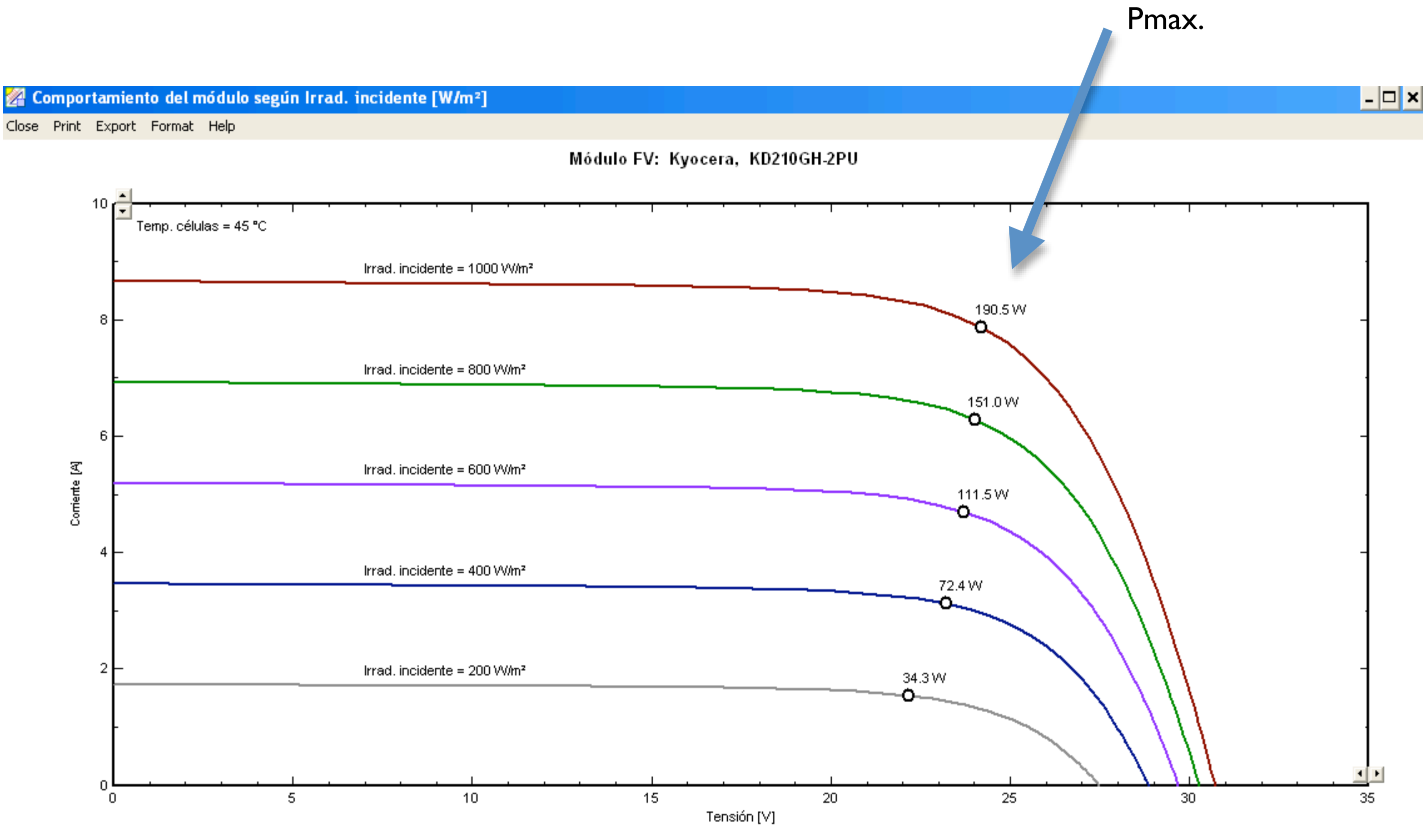

Fig. 8.4 Behaviour current-volts of module KD210GH-Kyocera by PVSYS 5.0

"The top left of the I-V curve at zero voltage is called the short-circuit current. This is the current We would measure with output terminals shorted (zero voltage). The bottom right of the curve at zero current is called the open-circuit voltage. This is the voltage we would measure with output terminals open (zero current)."[34]

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33 Wind and solar Systems.(Mukund R.Patel).

34 Wind and solar Systems.(Mukund R.Patel).

- Behaviour of the module P-V.[35]

In this graph the power is plotted against the voltage. The cell not produces at zero voltage or zero current, and produces the maximum power at the voltage corresponding to the point of maximum work on the I-V curve. "This is why the PV power circuit is always designed to operate close to the maximum work point with a slight slant on the left-hand side. The PV circuit is modelled approximately as a constant current source in the electrical analysis of the system."

The X-axis represents the output voltage of the collector in volts and in the Y-axis the power obtained by the collector. This graph is linked to the above, it is the same test, and as you can see the same points of maximum work for different radiations.

As seen in the graph, the best conditions for the panel production is when the irradiation is 1000 W/m2, where panel produces 190.5 W, at a voltage of 24 V approx. (Fig. 8.5)

Pmax.

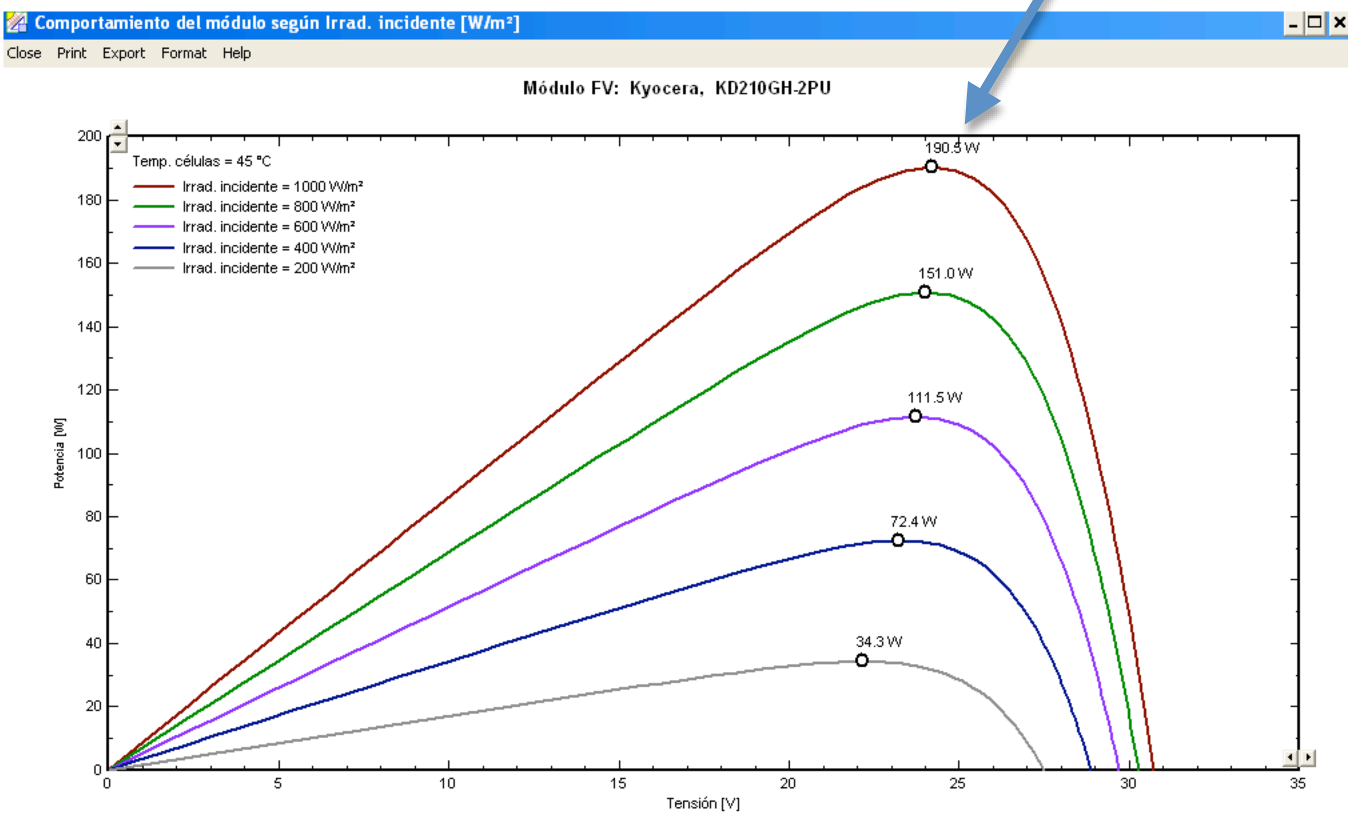

Fig. 8.5 Behaviour power-volts of module KD210GH-Kyocera by PVSYS 5.0

Short-circuit current

Zero voltage.

[35] Wind and solar Systems.(Mukund R.Patel).

-<u>Examples of production methods during the day.</u>

These charts present the production for one day of the PV system.

It has become an example of a day in the season of winter (January) and one day in summer (July).

- January (Winter). The production is 12,60 kWh day.

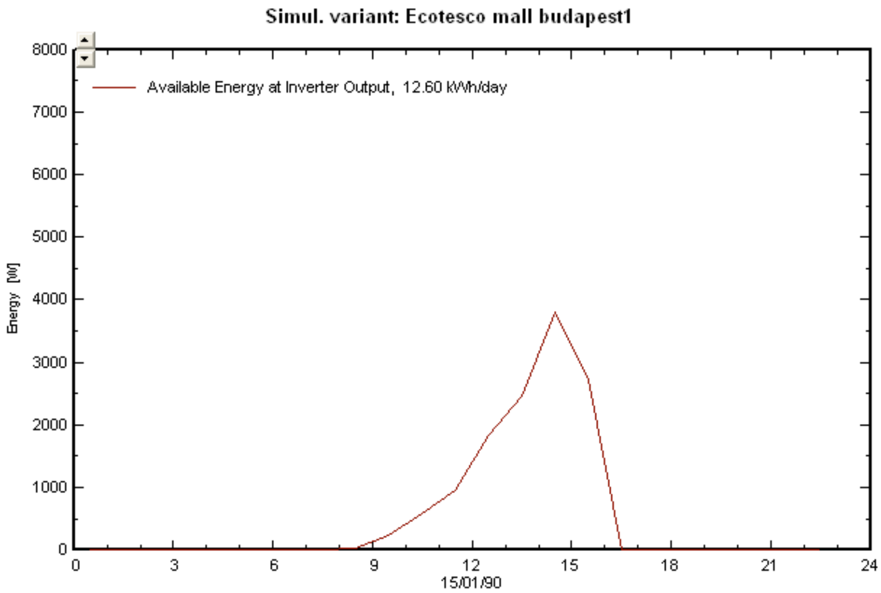

Fig. 8.6 Daily production on winter season (January) by PVSYS 5.0

- July (Summer). The production is 43,15 kWh day.

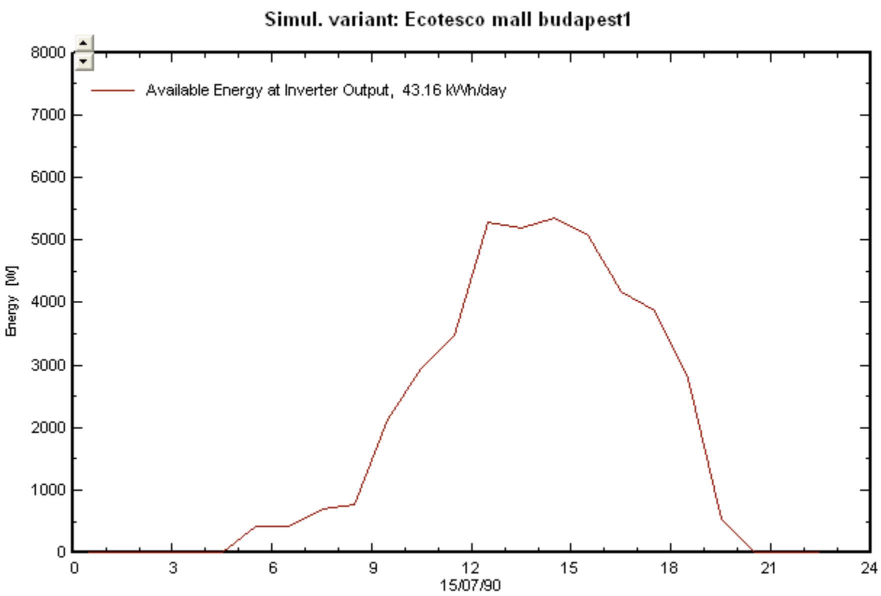

Fig. 8.7 Daily production on summer season (July) by PVSYS 5.0

The daily production can vary greatly because they can intervene clouds or other atmospheric phenomena throughout the day. These graphics are similar to a production/day that would generate an average over the month.

8.1.5. Results.

- First page. (Fig. 8.8)

On the first page shows a detailed report of brands and models of collectors and investor used to the simulation as well as location details of the project.
All elements are the same that are available in Ecotesco.

- Second page.(Fig 8.9)

On the second page can be seen graphically the balance of annual energy production and the losses of the system. The balance is made each month, to visualize in detail the production, and finally a table with a balance of data and results.

- Third page. (Fig 8.10)

The third page is the scheme of losses relating to the production system. As shown in the diagram below that represents the losses produced by each element of the system, from the time of radiation on the panel until the power output in the inverter.

The system according to the study suffered the greatest losses at the time of irradiation on the panel, and during the operation of the inverter.

According to the diagram and the data obtained in the simulation, the panels produced **10,276 kWh**, and at the end of the system taking into account all losses total production is **8312 kWh** per year. (Fig. 8.9 – Fig. 8.10)

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Grid-Connected System: Simulation parameters

Project :	**Budapest Ecostesco mall**			
Geographical Site	**Budapest**		**Country**	**Hungary**
Situation	Latitude	47.3°N	Longitude	19.1°E
Time defined as	Solar Time		Altitude	105 m
	Albedo	0.20		
Meteo data :	Budapest, Síntesis Datos por Hora			

Simulation variant :	**Ecotesco mall budapest1**			
	Simulation date	27/10/09 23h26		

Simulation parameters				
Collector Plane Orientation	Tilt	45°	Azimuth	90°
Horizon	Free Horizon			
Near Shadings	No Shadings			
PV Array Characteristics				
PV module Si-poly	Model	**KD210GH-2PU**		
	Manufacturer	Kyocera		
Number of PV modules	In series	12 modules	In parallel	4 strings
Total number of PV modules	Nb. modules	48	Unit Nom. Power	210 Wp
Array global power	Nominal (STC)	**10 kWp**	At operating cond.	8.9 kWp (50°C)
Array operating characteristics (50°C)	U mpp	289 V	I m pp	31 A
Total area	Module area	**71.3 m²**		
Inverter	Model	**Sunny Boy SB 5000 US**		
	Manufacturer	SMA		
Characteristics	Operating Voltage	250-480 V	Unit Nom. Power	5 kW AC
Inverter pack	Number of Inverter	2 units	Total Power	10 kW AC
PV Array loss factors				
Thermal Loss factor	Uc (const)	29.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
=> Nominal Oper. Coll. Temp. (G=800 W/m², Tamb=20°C, Wind velocity = 1m/s.)			NOCT	45 °C
Wiring Ohmic Loss	Global array res.	158 mOhm	Loss Fraction	1.5 % at STC
Serie Diode Loss	Voltage Drop	0.7 V	Loss Fraction	0.2 % at STC
Module Quality Loss			Loss Fraction	2.5 %
Module Mismatch Losses			Loss Fraction	2.0 % at MPP
Incidence effect, ASHRAE parametrization	IAM =	1 - bo (1/cos i - 1)	bo Parameter	0.05
User's needs :	Unlimited load (grid)			

Fig. 8.8 Detailed report of brands and models of collectors and inverters used. By PVSYS 5.0

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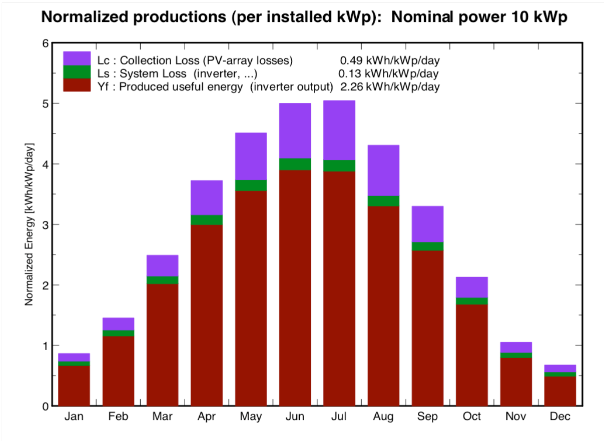
Grid-Connected System: Main results

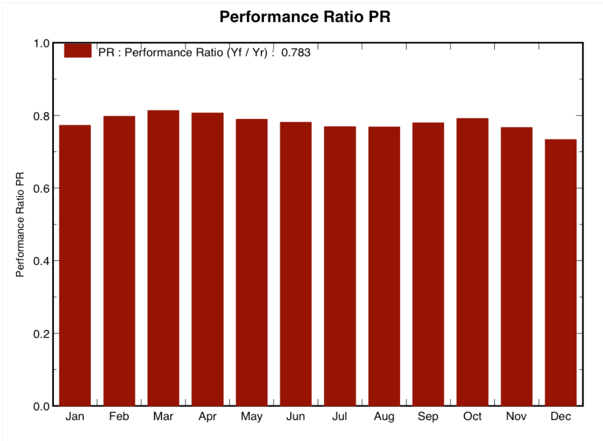
Project : **Budapest Ecostesco mall**

Simulation variant : **Ecotesco mall budapest1**

Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	45°	azimuth	90°
PV modules	Model	KD210GH-2PU	Pnom	210 Wp
PV Array	Nb. of modules	48	Pnom total	**10 kWp**
Inverter	Model	Sunny Boy SB 5000 US	Pnom	5.0 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**10 kW ac**
User's needs	Unlimited load (grid)			

Main simulation results				
System Production	**Produced Energy**	**8312 kWh/year**	Specific prod.	825 kWh/kWp/year
	Performance Ratio PR	78.3 %		





Ecotesco mall budapest1

Balances and main results

	GlobHor	T Amb	GlobInc	GlobEff	EArray	E_Grid	EffArrR	EffSysR
	kWh/m²	°C	kWh/m²	kWh/m²	kWh	kWh	%	%
January	30.0	-0.50	26.8	25.3	232	209	12.17	10.93
February	46.0	1.20	40.7	38.6	355	327	12.23	11.28
March	86.0	6.20	77.1	74.0	672	632	12.23	11.50
April	128.0	10.70	111.6	107.5	955	907	12.01	11.41
May	162.0	15.70	139.7	135.2	1169	1112	11.73	11.16
June	172.0	19.00	150.0	145.3	1239	1180	11.59	11.04
July	183.0	20.70	156.3	151.4	1272	1212	11.42	10.88
August	154.0	20.70	133.4	128.7	1086	1033	11.42	10.86
September	110.0	16.80	99.0	95.4	821	778	11.64	11.02
October	71.0	10.70	65.9	62.9	560	526	11.93	11.19
November	35.0	4.00	31.4	29.7	268	243	11.95	10.84
December	23.0	1.20	20.9	19.8	176	155	11.81	10.37
Year	1200.0	10.59	1052.8	1013.9	8805	8312	11.73	11.08

Legends:				
	GlobHor	Horizontal global irradiation	EArray	Effective energy at the output of the array
	T Amb	Ambient Temperature	E_Grid	Energy injected into grid
	GlobInc	Global incident in coll. plane	EffArrR	Effic. Eout array / rough area
	GlobEff	Effective Global, corr. for IAM and shadings	EffSysR	Effic. Eout system / rough area

Fig. 8.9 Balance of annual energy production and the losses of the system. By PVSYS 5.0

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Grid-Connected System: Loss diagram

Project : **Budapest Ecostesco mall**

Simulation variant : **Ecotesco mall budapest1**

Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	45°	azimuth	90°
PV modules	Model	KD210GH-2PU	Pnom	210 Wp
PV Array	Nb. of modules	48	Pnom total	**10 kWp**
Inverter	Model	Sunny Boy SB 5000 US	Pnom	5.0 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**10 kW ac**
User's needs	Unlimited load (grid)			

Loss diagram over the whole year

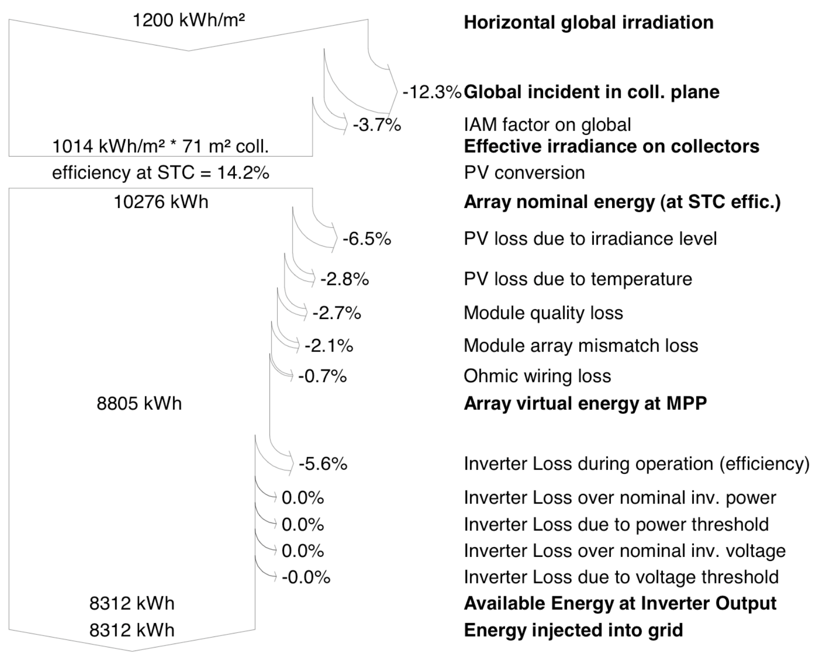


Fig. 8.10 Scheme of losses relating to the production system.

8.2. PHOTOVOLTAIC ENERGY PRODUCTION - SIMULATION 2- PVGYS-SOLAR.

8.2.1. Objective.

The objective is to simulate the photovoltaic energy production Ecotesco during one year with all of details, such as radiation, the behaviour of the plate and energy lost in the system.

8.2.2. Features.

The characteristics of the simulation are:

- 48 Solar collectors.
- Installed on the roof of Ecotesco.
- 30 solar collectors with inclination of 45 degrees south.
- 18 solar collectors with inclination of 90 degrees south.
- Mark Kyocera.
- 3 Inverters
- Simulation by PVGYS Solar.

8.2.3. Model.

The installation of solar panels has 48 ud. 30 of them are installed at 45 degrees and other 18 to 90 degrees to the vertical plane.

This simulation is done in two parts, according to the inclination of the panels. one for 30 panels in 45 degrees and the other to 18 panels in 90 degrees.

Also, on simulation has made the study of production of one isolated panel.

For the case of losses in this type of simulation can not get into detail as to models and features of investors, however you can detail some of the losses. So based on the results of the previous simulation is considered a total loss system of 22%.

The results obtained are shown below.

8.2.4. Tables/Diagrams.

All data and diagrams have been obtained automatically using the software PVGYS Solar (Fig. 8.16 – Fig. 8.16)

The study was conducted with the database program, selecting the same elements and features that Ecotesco solar photovoltaic installation.

These are some interesting graphics and tables obtained in the simulation.

- Incident global irradiation.

  Data:

  Location: 47°38'11" North, 19°8'34" East, Elevation: 128 m

Month	Irradiation at inclination: (Wh/m2/day) 40 deg.
Jan	1559
Feb	2464
Mar	3587
Apr	4724
May	5269
Jun	5472
Jul	5871
Aug	5347
Sep	4597
Oct	3371
Nov	1866
Dec	1186
Year	**3783**

Fig. 8.11 Irradiation

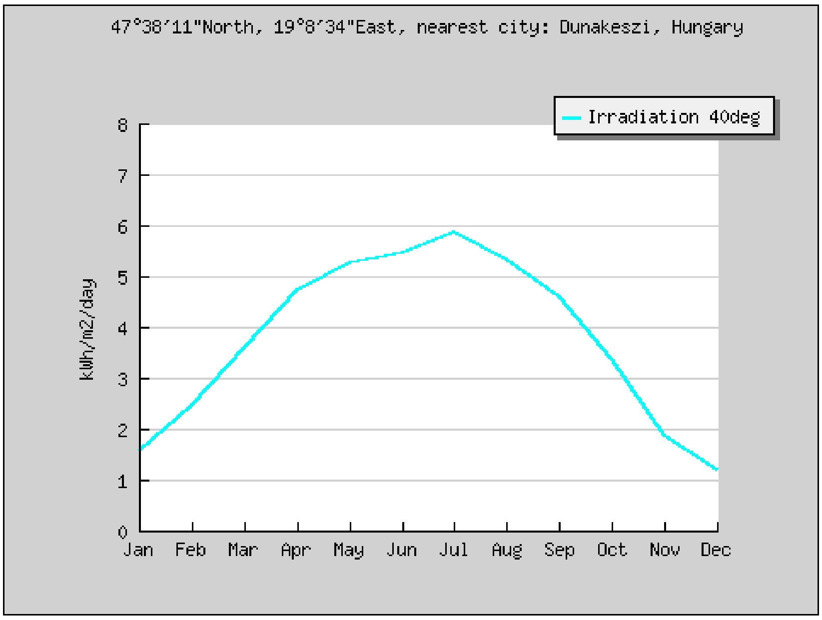


Fig. 8.12 Graph of irradiation

8.2.5. Results.

The results are shown in 2 parts, the production of the panels at 45 degrees and 90 degrees.

-Simulation data:

- Nominal power of the PV system: 3.8 kW (crystalline silicon)
- Inclination of modules: 90.0°
- Orientation (azimuth) of modules: 0.0°
- Estimated losses due to temperature: 6.2% (using local ambient temperature data)
- Estimated loss due to angular reflectance effects: 4.7%
- Other losses (cables, inverter etc.): 12.0%
- Combined PV system losses: 22.9%

  - First page.

The first page shows the analysis of the production of two models of inclination of the system, data is represented in kWh per month for one year.(Fig. 8.13 – Fig 8.14)

  - Second page:

On the second page, shows the balance tables with the results of the two production models. The software simulates the production of panels in two ways, one for fixed panels and one for tracking solar panels, according to the tables, we can analyze what would be the production of this system with solar tracking panels with the same conditions. (Fig. 8.15 – Fig 8.16)

Production graphs:

-Annual production of panels on 90° degrees:

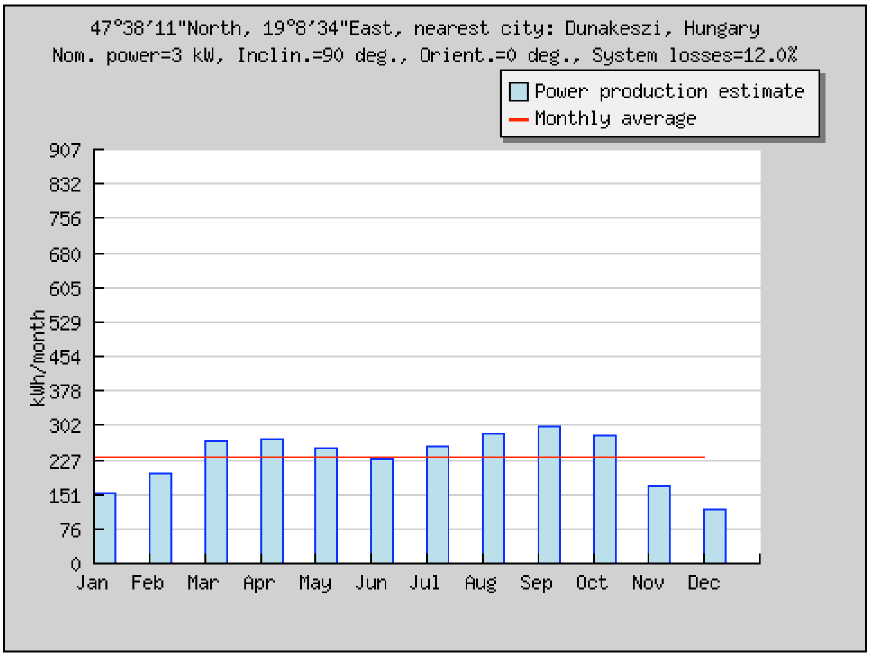


Fig. 8.13 Energy production of panels on 90°

-Annual production of panels on 45° degrees:

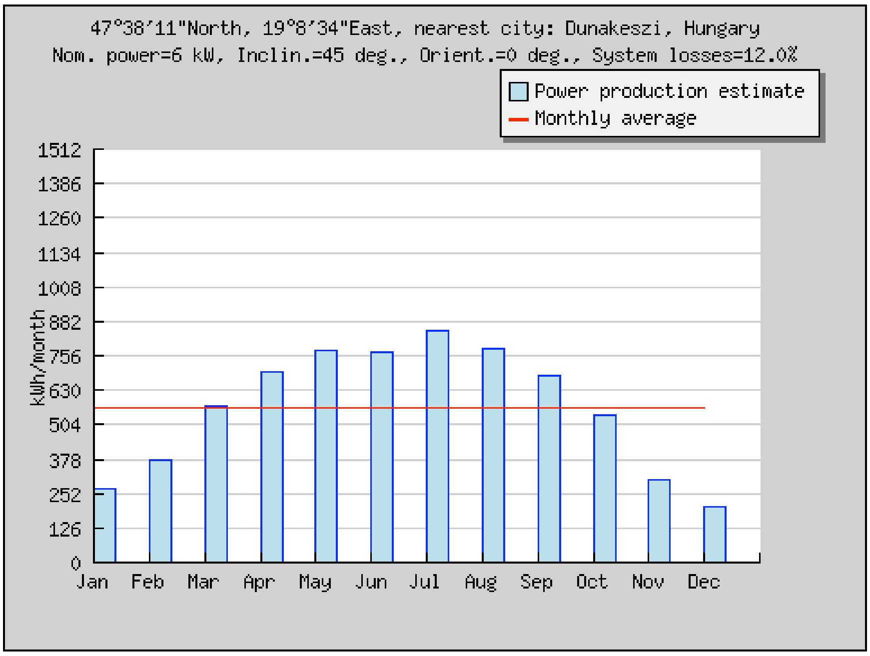


Fig. 8.14 Energy production of panels on 45°

- Balance and results:

-Annual production of 18 panels on 90° degrees:

PV electricity generation for: Nominal power=3.8 kW, System losses=12.0%				
	Inclin.=90 deg., Orient.=0 deg.		2-axis tracking system	
Month	Production per month (kWh)	Production per day (kWh)	Production per month (kWh)	Production per day (kWh)
Jan	152	4.9	181	5.9
Feb	198	7.1	258	9.2
Mar	267	8.6	419	13.5
Apr	271	9.0	550	18.3
May	251	8.1	657	21.2
Jun	227	7.6	669	22.3
Jul	256	8.2	747	24.1
Aug	282	9.1	637	20.5
Sep	300	10.0	515	17.2
Oct	279	9.0	387	12.5
Nov	169	5.6	207	6.9
Dec	116	3.8	135	4.4
Yearly average	**231**	**7.6**	**447**	**14.7**
Total yearly production (kWh)	**2770**		**5362**	

Fig. 8.15 Table of annual production of 18 panels at 90°

-Annual production of 30 panels on 45° degrees:

PV electricity generation for: Nominal power=6.3 kW, System losses=12.0%				
	Inclin.=45 deg., Orient.=0 deg.		2-axis tracking system	
Month	Production per month (kWh)	Production per day (kWh)	Production per month (kWh)	Production per day (kWh)
Jan	266	8.6	302	9.8
Feb	372	13.3	430	15.4
Mar	574	18.5	698	22.5
Apr	700	23.3	917	30.6
May	776	25.0	1094	35.3
Jun	766	25.5	1116	37.2
Jul	847	27.3	1244	40.1
Aug	785	25.3	1061	34.2
Sep	683	22.8	858	28.6
Oct	540	17.4	645	20.8
Nov	300	10.0	345	11.5
Dec	202	6.5	225	7.3
Yearly average	**568**	**18.7**	**745**	**24.5**
Total yearly production (kWh)	**6811**		**8936**	

Fig. 8.16 Table of annual production of 18 panels at 90

Tables with results of the annual production of 48 photovoltaic modules in Ecotesco, with different inclinations.

The total production of the system as the simulation performed with PVSYS 5.0 is 2770 + 6811 = **9581 kWh** in one year. (Fig. 8.15 – Fig. 8.16)

8.3. PHOTOVOLTAIC ENERGY PRODUCTION -SIMULATION 3- RETSCREEN

8.3.1. Objective.

The objective is to simulate the photovoltaic energy production Ecotesco during one year with all of details, such as radiation, the behaviour of the plate and energy lost in the system.

8.3.2. Features.

The characteristics of the simulation are:

- 48 Solar collectors.
- Installed on the roof of Ecotesco.
- 48 solar collectors with inclination of 45 degrees south.
- 18 solar collectors with inclination of 90 degrees south.
- Mark Kyocera.
- 3 Inverters
- Simulation by Retscreen.

8.3.3. Model.

The installation of solar panels has 48 ud. 30 of them are installed at 45 degrees and other 18 to 90 degrees to the vertical plane.

This simulation is done for all the panels with the same inclination, Retscreen do the simulation with the best inclination because the program doesn't have an option for selecting inclination..

For the case of losses in this type of simulation can not get into detail as to models and features of investors, however you can detail some of the general losses. So based on the results of the simulation 1 is considered a total loss system of 21%.

With the Retscreen program has made a study of energy production and an economic study for a lifetime of the installation of 30 years, assuming that calls for a 10-year bank loan with an interest rate 8%.

The results obtained are shown below.

8.3.4. Tables/Diagrams.

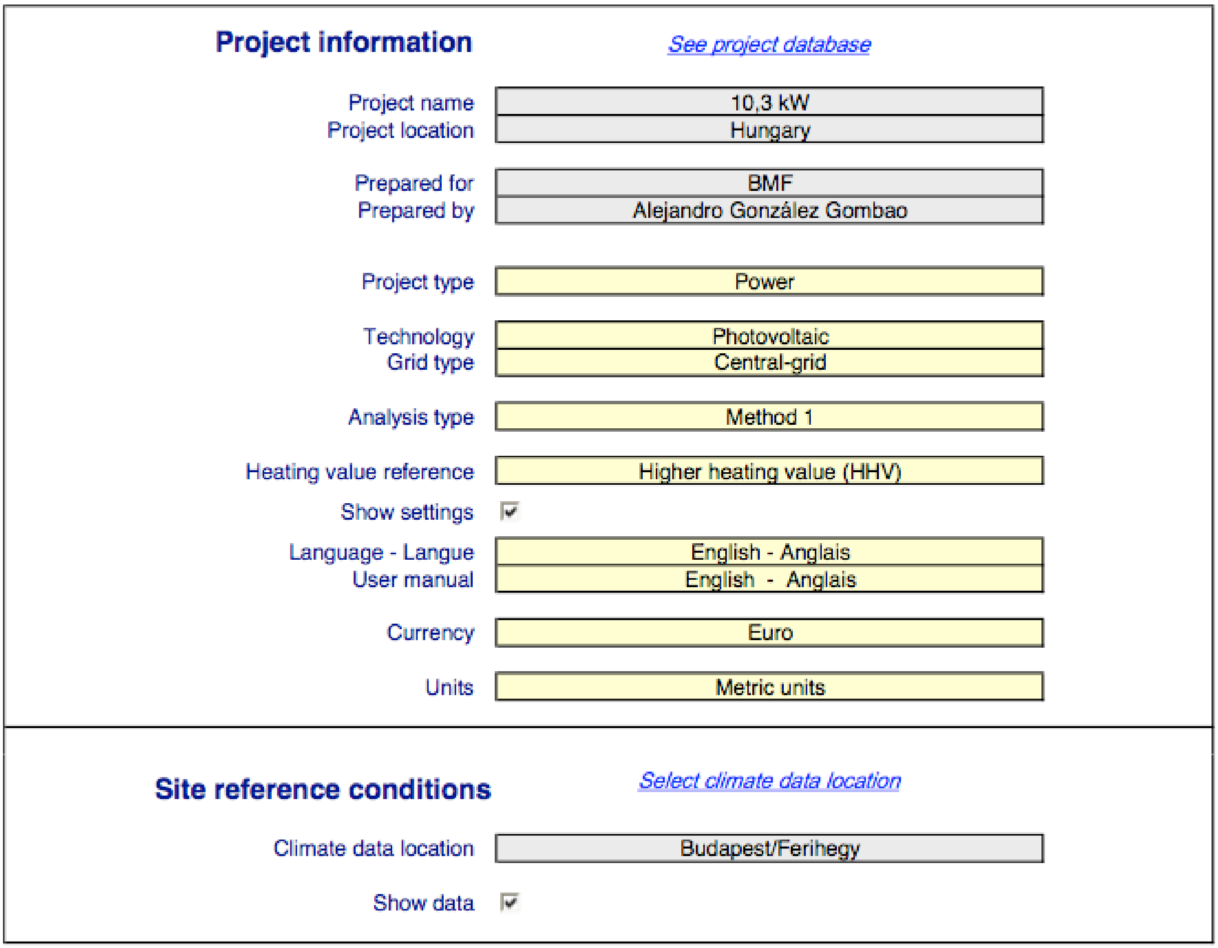
All data and diagrams have been obtained automatically using the software Retscreen

The study was conducted with the database program, selecting the same elements and features that Ecotesco solar photovoltaic installation.

Economic data have been obtained in reference to rules and data of Hungarian companies. As well as the life of the Project and Budget years have been supposed. The information may be modified and get a new economic study for new characteristics.

These are some interesting graphics and tables obtained in the simulation:

-Project information:



Project information	See project database
Project name	10,3 kW
Project location	Hungary
Prepared for	BMF
Prepared by	Alejandro González Gombao
Project type	Power
Technology	Photovoltaic
Grid type	Central-grid
Analysis type	Method 1
Heating value reference	Higher heating value (HHV)
Show settings	☑
Language - Langue	English - Anglais
User manual	English - Anglais
Currency	Euro
Units	Metric units

Site reference conditions	Select climate data location
Climate data location	Budapest/Ferihegy
Show data	☑

Fig. 8.17 Project information.

<u>-Climate data of Budapest:</u>

	Unit	Climate data location	Project location
Latitude	˚N	47,4	47,4
Longitude	˚E	19,3	19,3
Elevation	m	185	185
Heating design temperature	℃	-9,9	
Cooling design temperature	℃	30,2	
Earth temperature amplitude	℃	20,9	

Month		Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
		℃	%	kWh/m²/d	kPa	m/s	℃	℃-d	℃-d
January		-0,7	82,5%	1,23	99,6	2,9	-1,6	580	0
February		0,9	76,2%	2,14	99,4	3,4	-0,1	479	0
March		5,4	69,5%	3,10	99,2	3,9	5,3	391	0
April		11,0	65,3%	4,26	98,9	4,2	12,3	210	30
May		16,2	65,8%	5,32	99,0	3,7	18,7	56	192
June		19,0	65,8%	5,63	99,0	3,6	21,9	0	270
July		21,1	64,1%	5,62	99,0	3,6	24,6	0	344
August		20,9	64,5%	5,03	99,1	3,1	24,5	0	338
September		16,0	70,2%	3,64	99,2	3,3	19,1	60	180
October		10,5	75,6%	2,28	99,5	2,9	12,5	233	16
November		4,1	81,3%	1,28	99,4	3,0	4,7	417	0
December		0,2	83,9%	0,98	99,6	3,2	-0,3	552	0
Annual		10,4	72,0%	3,38	99,2	3,4	11,9	2.976	1.370
Measured at	m					10,0	0,0		

Fig. 8.18 Climate data of Budapest.

By this table Retscreen make by method of calculating ,the annual energy production according to the number of the panels and model configured.

8.3.5. Results.

The results obtained by Retscreen are base on the previous radiation database.(Fig. 8.18)

Retscreen calculated production by the configuration chosen, like number and models of the panels.

The following table is done automatically by Retscreen, and the graph above using Excel to display the results graphically. (Fig. 8.19–Fig 8.21)

-Production results by Retscreen:

RETScreen Energy Model - Power project

☐ Show alternative units

Proposed case power system | **Incremental initial costs**

Technology		Photovoltaic	
Analysis type	●	Method 1	
	○	Method 2	
Resource assessment			
Solar tracking mode		Fixed	
Slope	°	45,0	
Azimuth	°	0,0	

☑ Show data

Month	Daily solar radiation - horizontal kWh/m²/d	Daily solar radiation - tilted kWh/m²/d	Electricity export rate €/MWh	Electricity exported to grid MWh
January	1,23	2,35	200,0	0,597
February	2,14	3,50	200,0	0,789
March	3,10	3,94	200,0	0,967
April	4,26	4,52	200,0	1,049
May	5,32	5,01	200,0	1,176
June	5,63	5,02	200,0	1,129
July	5,62	5,13	200,0	1,180
August	5,03	5,10	200,0	1,168
September	3,64	4,32	200,0	0,980
October	2,28	3,34	200,0	0,806
November	1,28	2,26	200,0	0,546
December	0,98	1,93	200,0	0,491
Annual	**3,38**	**3,87**	**200,00**	**10,876**

Annual solar radiation - horizontal	MWh/m²	1,23		
Annual solar radiation - tilted	MWh/m²	1,41		
Photovoltaic				
Type		poly-Si		
Power capacity	kW	10,08	€ 38.000	See product database
Manufacturer		Energy Solutions S.A.		
Model		poly-Si - ES660/QP210	48 unit(s)	
Efficiency	%	13,1%		
Nominal operating cell temperature	°C	45		
Temperature coefficient	% / °C	0,40%		
Solar collector area	m²	77		
Miscellaneous losses	%	15,0%		
Inverter				
Efficiency	%	98,0%		
Capacity	kW	5,5		
Miscellaneous losses	%	6,0%		
Summary				
Capacity factor	%	12,3%		
Electricity exported to grid	MWh	10,876		

10,3 kW
Hungary

02/12/2009
RETScreen4-1

Fig. 8.19 Annual energy production by Retscreen

-Results represented graphically:

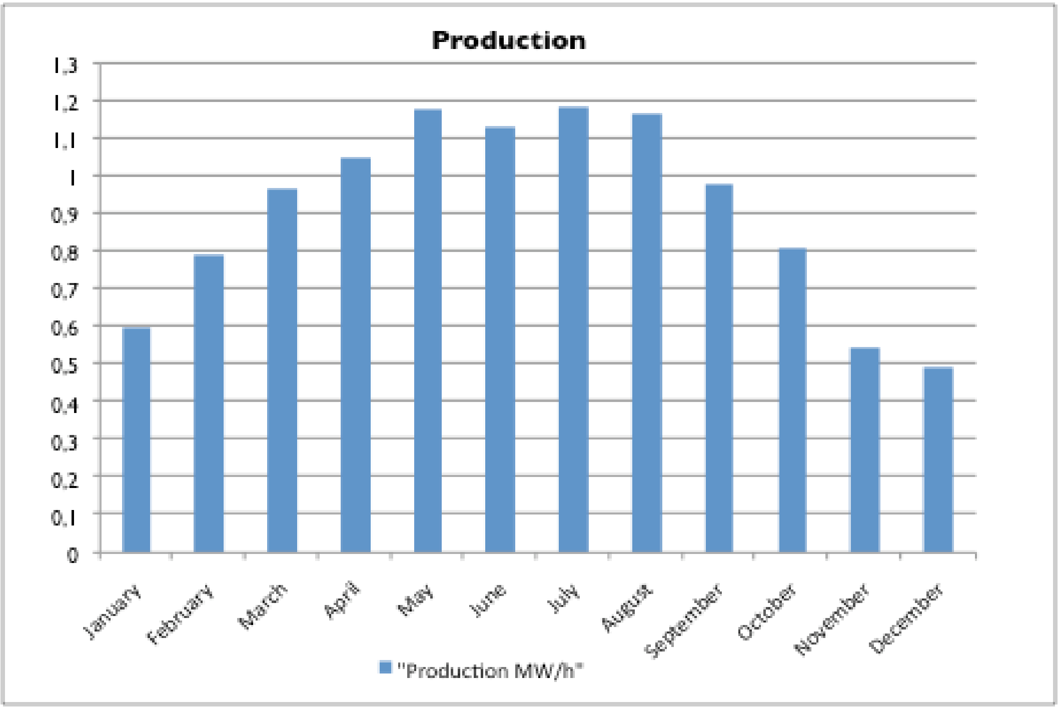


Fig. 8.20 Graphical annual energy production by Retscreen

As The results of the data, the annual production is: **10876 kWh.**

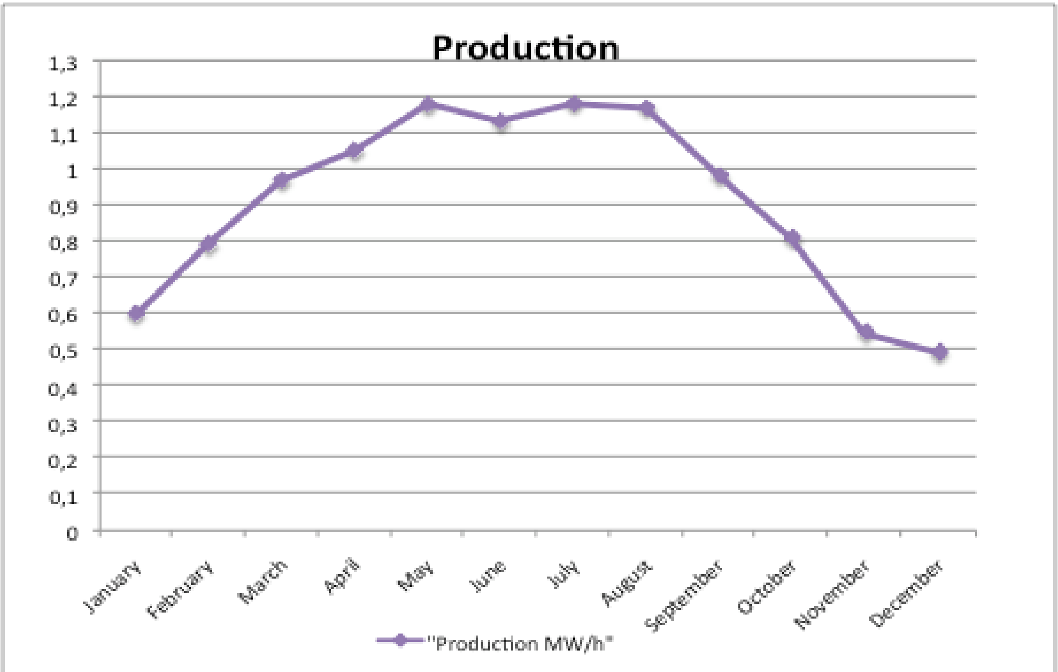


Fig. 8.21 Graphical annual energy production by Retscreen

As can be seen in the results, depending on configuration taken, the project stars to generate profits from the 24 year, when would recover the investment made.

-Economic study:

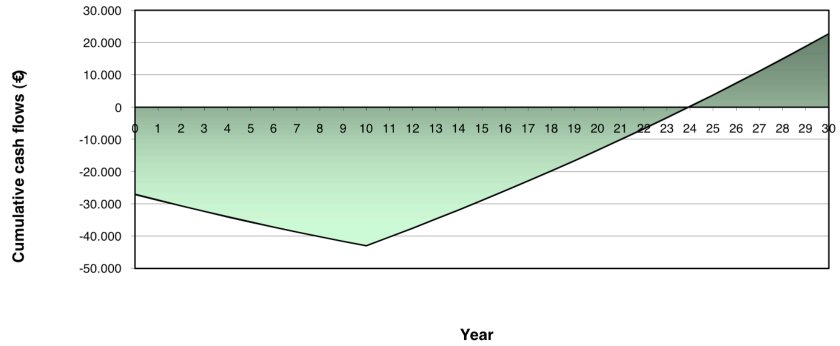
Emission Analysis

Base case electricity system (Baseline)		GHG emission factor (excl. T&D)	T&D losses	GHG emission factor	
Country - region	**Fuel type**	**tCO2/MWh**	**%**	**tCO2/MWh**	
Canada	All types	0,196	6,0%	0,209	
Electricity exported to grid	MWh	11	T&D losses	2,0%	
GHG emission					
Base case	tCO2	2,3			
Proposed case	tCO2	0,0			
Gross annual GHG emission reduction	tCO2	2,2			
GHG credits transaction fee	%	0,0%			
Net annual GHG emission reduction	tCO2	2,2	is equivalent to	0,5	Cars & light trucks not used
GHG reduction income					
GHG reduction credit rate	€/tCO2	0,00			

Financial Analysis

Financial parameters			
Inflation rate	%	2,0%	
Project life	yr	30	
Debt ratio	%	50%	
Debt interest rate	%	8,00%	
Debt term	yr	10	
Initial costs			
Power system	€	38.000	70,4%
Other	€	16.000	29,6%
Total initial costs	€	54.000	100,0%
Incentives and grants	€		0,0%
Annual costs and debt payments			
O&M (savings) costs	€	0	
Fuel cost - proposed case	€	0	
Debt payments - 10 yrs	€	4.024	
	€		
Total annual costs	€	4.024	
Annual savings and income			
Fuel cost - base case	€	0	
Electricity export income	€	2.175	
	€		
Total annual savings and income	€	2.175	
Financial viability			
Pre-tax IRR - equity	%	2,3%	
Pre-tax IRR - assets	%	-0,3%	
Simple payback	yr	24,8	
Equity payback	yr	23,9	

Cumulative cash flows graph



10,3 kW

02/12/2009

Fig. 8.22 Economic study.

8.4. EVALUATION/OPINION OF PHOTOVOLTAIC SIMULATIONS.

According to studies with the 3 different programs for the same project, the simulation gets different results.

This graph shows the differences results.

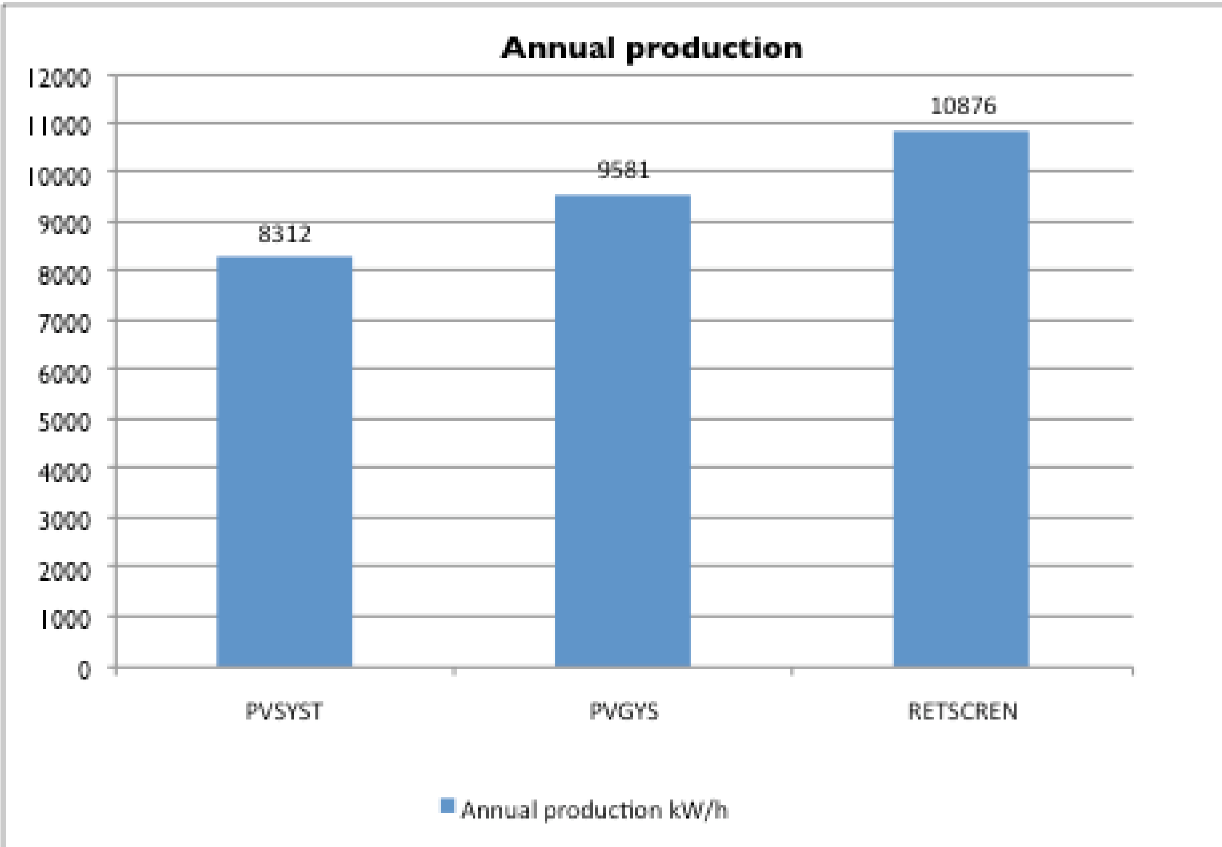


Fig. 8.23 Comparison of 3 different results.

Obviously was virtually impossible to get the same results in the 3 simulations. This due to each program that have a different database and they considered some aspects like losses in the system, inverter, or the losses of the solar panels. Other factor is the deferent's database of irradiation in the programs. (Fig 8.23)

If we analyze the graph and data of the simulations, we can see Retscreen. This program is that which says the facility generates more energy than the rest, in my view this is because Retscreen doesn't consider the inclination and the position of solar panels, with which adopts the best position for its production, making it more favourable. In change, We make separate PV-GIS calculation, which would be perfect to get a result because We can considered the different inclinations, but there is a inconvenience, this program not permitted to detail type of panels or inverters, only value of the power Wp of the panel, the location of the installation and losses but is not perfect to calculate the losses, It based on the value that your enter.

In my opinion I think the best production would be the right is PV-SIS, even as the lowest value, and simulated for a single tilt. This is due to done in mind that with accuracy characteristics of the modules and inverters, calculating production system and losses more accurately than previous programs.

As evaluation , suggests that this system could be enhanced with some aspects. Starting at the position of the modules to 90 °, in this position the panels are not able to capture solar radiation in many moments of the day, which makes the panels do not generate all that they could.

Another aspect to improve are inverters, for that installation of 10.3 kW is installed 3 inverters of 5 kW, being oversized the installation, and this produces irregularities in the work of the same, translated into lost in the system.

The economic side, by Retscreen studying can see that a montage brings benefits as such medium-long term, all depends on investment and production to be obtained with such installation.

In this case, we see that as profitable sale, we will be raising benefit form year 24 during 27 years.

-Summary of research results:

Simulation	Results of annual energy production
1 by PVSYS 5.0	8312 kWh
2 by PVGYG Solar	9581 kWh
3 by Retscreen	10876 kWh
Average	9590 kWh

Fig. 8.24 Summary of results

Comparison of average result with other Similar Tesco.

Simulation	Results of annual energy production
Average of simulations	9590 kWh
Tesco Sátoraljaújhely	≈9000 kWh
Tesco Gyál	11246 kWh

Fig. 8.25 Comparison with other facilities

In these tables,(Fig. 8.24) I can see that yields are very similar. So with these data I could say that the simulations have given results very approximate and reals.

8.5. SOLAR THERMAL HEAT PRODUCTION -SIMULATION 4- TSOL PRO 4.5

8.5.1. Objective.

The objective is to simulate the production of heat by solar thermal collectors, with full details for accuracy for the simulation.

8.5.2. Features.

The characteristics of the simulation are:

- 55 Solar thermal collectors.
- Installed on the roof of Ecotesco.
- Collectors are with inclination of 45 degrees south.
- Mark Soltec
- Simulation by TSOL PRO 4.5.

8.5.3. Model.

The installation consists of 55 solar thermal panels installed at 45 degrees on the roof of the mall in Budapest-Hungary. In the next simulation we obtain the heat produced by these panels heating water.

For this simulation has been used TSOL PRO program. This program is dedicated solely to the simulation of solar thermal installations, detailing all kinds of details of the installation, from collectors model and dimensions, to details of mounted pipes.

For this case, It has been assumed daily consumption of 3500L and a desired temperature water of 50 °, assuming that we have a water temperature of 8° in winter and 12° in summer.. On the taken for the system configuration, the collector is configured a different brand and model but with similar characteristics, a 1500L storage tank, a gas boiler with power of 900 kW, for additional heat input or in an emergency and a heat exchanger. It has chosen a standard configuration because they do not have all the necessary data. This can have a small and insignificant variation in the final outcome.

The results are determined by a mathematical model calculation with variable time stops of up to 6 minutes. Actual yields can deviate from these values due to fluctuations in climate, consumption and other factors. The system schematic diagram above does not represent and cannot replace a full technical drawing of the solar system or the complete installation.

The complete installation is more complicated, as seen in the point 2.8 of the project (Schemes control).

The configuration and results of the installation is displayed later in the results section.

8.5.4. Drawings/Diagrams.

All data and diagrams have been using the software automatically Obtained TSOL PRO.

The following is the schema representing a simple solar thermal. The scheme was obtained through the program TSOL, and shows some of the data of the installation.(Fig 8.27)

-Scheme:

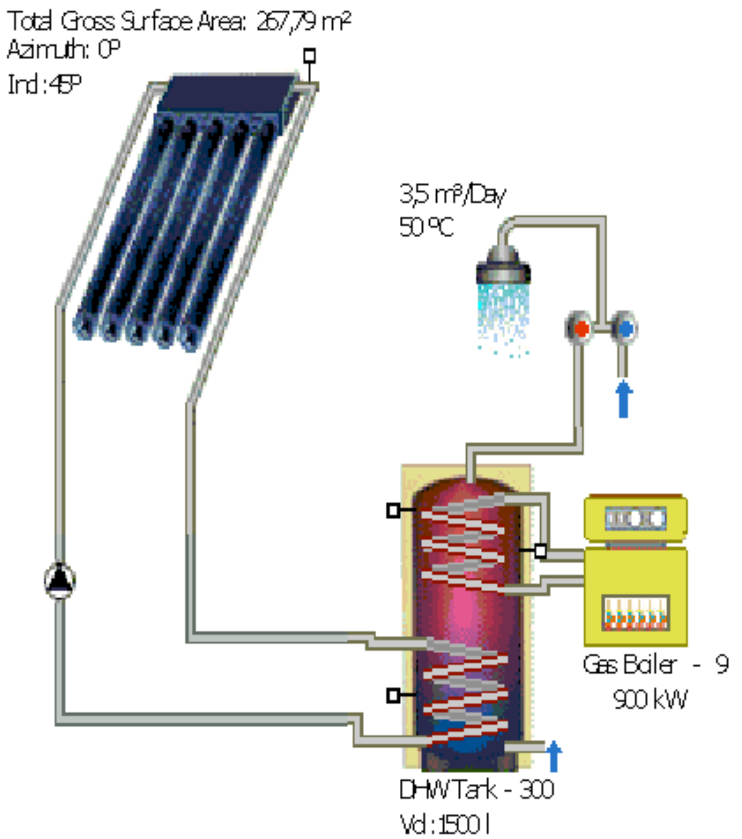


Fig. 8.26. Scheme of the system.

<u>-Daily maximum collector temperature.</u>

This graph represents the highest temperatures recorded throughout the annual production of the system. The temperature is displayed in degrees centigrade.(Fig. 8.29)

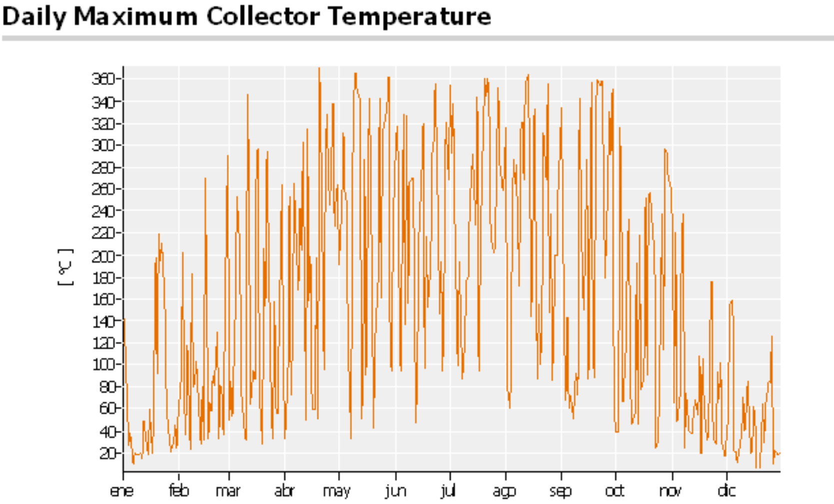


Fig. 8.27 Daily maximum collector temperature.

In the graph we can see that the highest temperatures are recorded throughout the summer months, where the temperature and radiation is higher in Budapest.

<u>-Solar energy consumption as percentage of total consumption.</u>

This chart represents an estimate of annual consumption of hot water as percentage of total production. The summer hot water demand is lower because the environmental temperature is higher, and Ecotesco require less hot water. As the graph represents the demand exceeds production, so gas boiler supplies the difference. In the results section is represented in more detail.

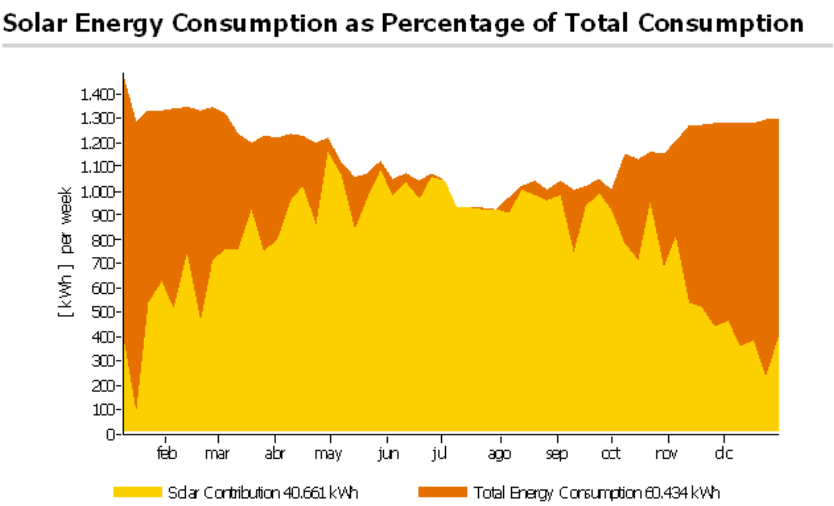


Fig. 8.28 Solar energy consumption as % of total consumption.

-Detail configuration, losses and production. (Fig. 8.30- Fig. 8.31)

Consumidores ACS

DHW Consumption:

Annual Energy Reqirement:	59,07 MWh
Operating Days:	365 Days
Not Operating:	-No Limitation-

Circulation:

-Circulation not available-

Bivalent (Twin Coil) DHW Tank

Manufacturer:	T*SOL Database
Type:	DHW Tank - 300
Volume:	1500 l
Height/Diameter:	2,50
Number of Tanks in Series:	1

Insulation:

Thickness of Insulation:	100 mm
Thermal Conductivity:	0,065 W/(m*K)

Connections:

	Height:	Losses:
Upper Tank Outlet:	100 %	0,25 W/K
Lower Tank Inlet:	0 %	0,25 W/K
Circulation Return:	-without-	

Heat Exchanger Collector Loop Connection

	Height:	Losses:
Return:	2 %	0,25 W/K
Flow:	40 %	0,25 W/K

Heat Exchanger Auxiliary Heating:

	Height:	Losses:
Return:	60 %	0,25 W/K
Flow:	95 %	0,25 W/K

Heat Exchanger:

kA Value: Collector Loop Connection:	1 W/K per Litre Tank Volume
kA Value: Auxiliary Heating:	1 W/K per Litre Tank Volume

Control:

Desired Tank Temperature:	50 °C	
Limited Load Times:	None	
	Height:	Switching Temp:

Fig. 8.29 Configuration and losses.

Bivalent (Twin Coil) DHW Tank

Control:

Heat Exchanger Auxiliary Heating:		
Collector Loop - Switch On/Off:	19 %	
Switch Off Collector Loop:	90 %	90 °C
Switch On Auxiliary Heating:	75 %	-3 C
Switch Off Auxiliary Heating:	75 %	3 C

Caldera de gas

Manufacturer:	T*SOL Database
Type:	Gas Boiler - 9
Nominal Output:	900 kW
Burner Type:	Modulating Boiler
Temperature Range:	5 C / 20 C / 30 C
Return Mixing Valve:	None
Fuel:	Natural Gas (H)
Efficiency:	95 %
with a Return Temperature of:	60 °C
Efficiency:	95 %
with a Return Temperature of:	30 °C
Domestic Hot Water Supply Efficiency:	80 %
Efficiency Related to Higher Heating Value:	86,68 %
with a Return Temperature of:	60 °C
Efficiency Related to Higher Heating Value:	86,68 %
with a Return Temperature of:	30 °C
Domestic Hot Water Supply Efficiency related to Higher Heating Value Hs (HHV):	72,99 %
Hi (LHV):	37512 kJ/m³
Not Operating:	-No Limitation-

Fig. 8.30 Configuration and losses.

8.5.5. Results.

The results obtained in the simulation are based on the database TSOL pro ,performing the calculation using a mathematical model.

Some elements are configured in the installation are not exactly the same as those installed in Ecotesco , They were chosen as close as possible to what the result is very close to the real.

-The first part of the results is a summary of production data, and system diagram of the installation with the energy and losses in each point of that. (Fig 3.32- Fig. 3.33)

-The second is the details of the production each month during a year.(Fig. 8.34)

-Lastly the graph, with the annual energy production.

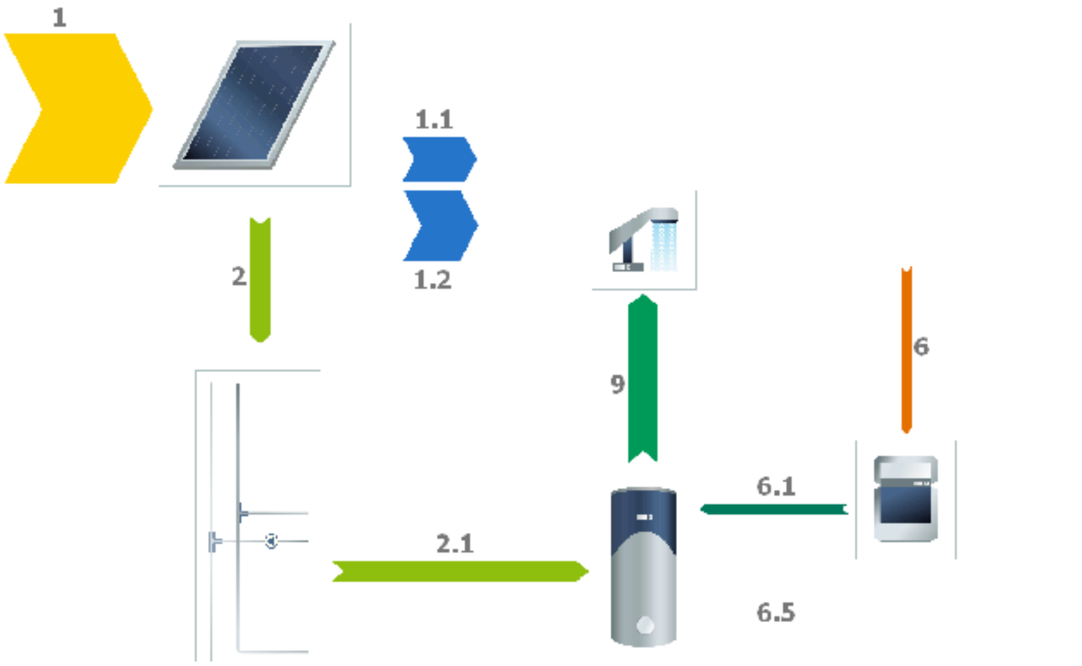
1) Diagram (by TSOL pro software.)

Glossary

1	Collector Surface Area Irradiation (Gross Surface) Energy Irradiated onto Tilted Collector Area (Total Solar Surface)
1.1	Optical Collector Losses Reflection and Other Losses
1.2	Thermal Collector Losses Heat Conduction and Other Losses
2	Energy from Collector Array Energy Output at Collector Array Outlet (i.e. Before the Piping)
2.1	Solar Energy to Storage Tank Energy from Collector Loop to Storage Tank (Minus Piping Losses)
2.5	Internal Piping Losses Internal Piping Losses
2.6	External Piping Losses External Piping Losses
3.1	Tank Losses Heat Losses via Surface Area
6	Final Energy Final Energy Current into System. This can flow in as natural gas, oil or electricity (not including solar energy) taking efficiency levels into account
6.1	Supplementary Energy to Tank Supplementary Energy (e.g. Boiler) to Tank
6.5	Heating Element Energy from Heating Element
9	DHW Energy from Tank Heat for DHW Appliances from Tank

Fig. 8.31 Glossary.

Energy Balance Schematic



Legend

1	Collector Surface Area Irradiation (Gross Surface)	308 MWh
1.1	Optical Collector Losses	89 MWh
1.2	Thermal Collector Losses	146 MWh
2	Energy from Collector Array	43 MWh
2.1	Solar Energy to Storage Tank	41 MWh
2.5	Internal Piping Losses	1.376 kWh
2.6	External Piping Losses	1.242 kWh
3.1	Tank Losses	1.515 kWh
6	Final Energy	21.072 kWh
6.1	Supplementary Energy to Tank	19.773 kWh
6.5	Heating Element	0 kWh
9	DHW Energy from Tank	59 MWh

Fig. 8.32 Diagram of the installation

2) Annual production. (by TSOL pro software).

Results of Annual Simulation

Installed Collector Power:	187,46 kW	
Installed Gross Solar Surface Area:	267,79 m²	
Collector Surface Area Irradiation (Active Surface):	278,37 MWh	1.149,26 kWh/m²
Energy Produced by Collectors:	43,28 MWh	178,67 kWh/m²
Energy Produced by Collector Loop:	40,66 MWh	167,87 kWh/m²
DHW Heating Energy Supply:	58,92 MWh	
Solar Contribution to DHW:	40,66 MWh	
Energy from Auxiliary Heating:	19,77 MWh	
Natural Gas (H) Savings:		**4.475,4 m³**
CO2 Emissions Avoided:		**9.463,92 kg**
DHW Solar Fraction:		**67,3 %**
Fractional Energy Saving (EN 12976):		**67,8 %**
System Efficiency:		**14,6 %**

Fig. 8.33 Results of annual simulation.

Results of Annual Simulation

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Solar Contribution to DHW in MWh												
41	2	3	4	4	4	4	4	4	4	4	2	1
Sol Loop to Tank in MWh												
41	2	3	4	4	4	4	4	4	4	4	2	1

Fig. 8.34 Summary of annual production.

3) Graphs.

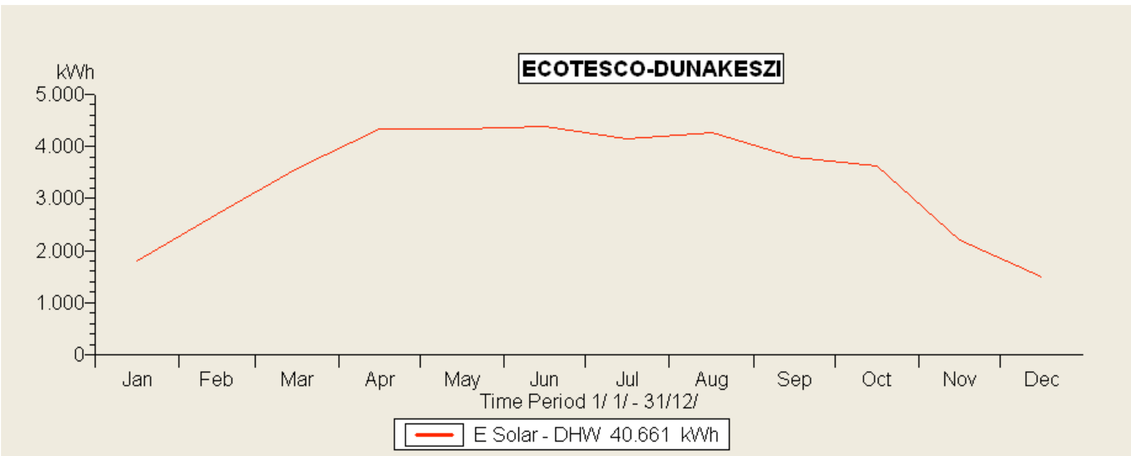


Fig. 8.35 Graph of annual energy production in kWh(By TSOL pro)

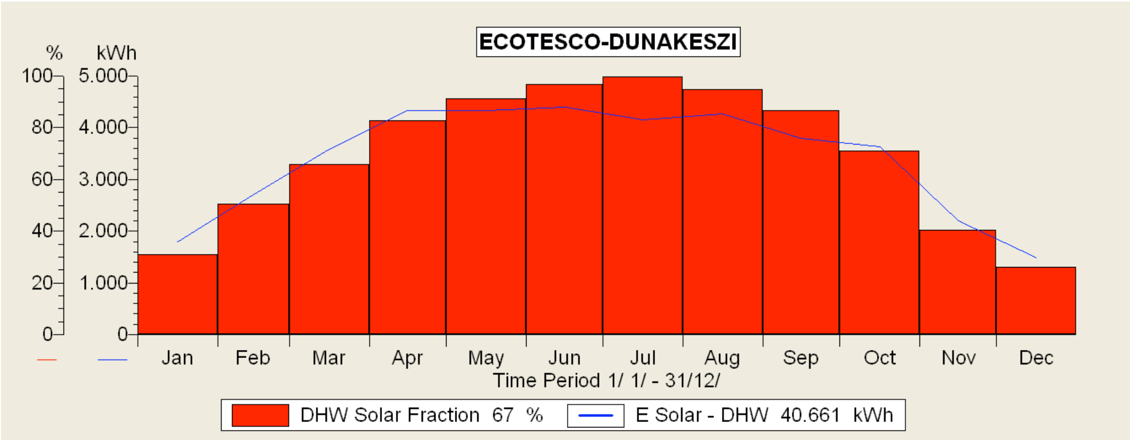


Fig. 8.36 Graph of annual energy production in kWH as % of solar fraction (By TSOL pro

In the graph can see the data of solar thermal production during a year. The months of highest production in summer, because the radiation is more higher than winter. The auxiliary heating of gas boild is not necessary, because the system produces enough to meet needs.

According to the simulation results, the solar thermal production of the system is **40661 kWh / year.** (Fig. 8.34)

8.6. SOLAR THERMAL HEAT PRODUCTION -SIMULATION 5- RETSCREEN.

8.6.1. Objective.

The objective is to simulate the production of heat by solar thermal collectors, with details for accuracy for the simulation and a simple economic cost-benefit study of the installation using the RETScreen program.

8.6.2. Features.

The characteristics of the simulation are:

- 55 Solar thermal collectors.
- Installed on the roof of Ecotesco.
- Collectors are with inclination of 45 degrees south.
- Mark Soltec
- Simulation by Retscreen with a model for Solar thermal heating.

8.6.3. Model.

The installation consists of 55 Solar thermal panels installed at 45 degrees on the roof of the mall in Budapest-Hungary. In the next simulation we obtain the heat produced by these panels heating water. For this simulation has been used Retscrenn program.

Retscreen make a rough calculation of the energy production of heat or hot water, depending on configuration and data entered. This calculation is done based on another project, it suppose that the installation was completely through gas boiler, and now the new one is realized by solar collectors, without changing the water temperature characteristics and pray. This is for energy saving ,in this project these characteristics are the same, because it is a new project.

For this case I have assumed a desired temperature of 50 degrees, with a daily consumption of 3500 L as the simulation of simulation 4

The selected panels are not exactly the same as the installation of Ecotesco available, but are of a similar performance. As shown below in the results section, RETScreen is not very sophisticated in defining the losses of the system, just leaves the option of entering a percentage of losses.

Retscreen performs a calculation less detailed than before with Tsol, because you do not specify the type of installation, piping details, deposit, etc ...

As for the heat exchanger has been an efficiency of 95% for the exchanger, and a 30 W/m2 power to the pump based on the area of the panels. The results reflected the final power demand of the pump.

Regarding the economic the configuration is similar to that of PV, with a study for a lifetime of the installation of 30 years, assuming that calls for a 10-year bank loan with an interest rate 8%.

The results are shown below.

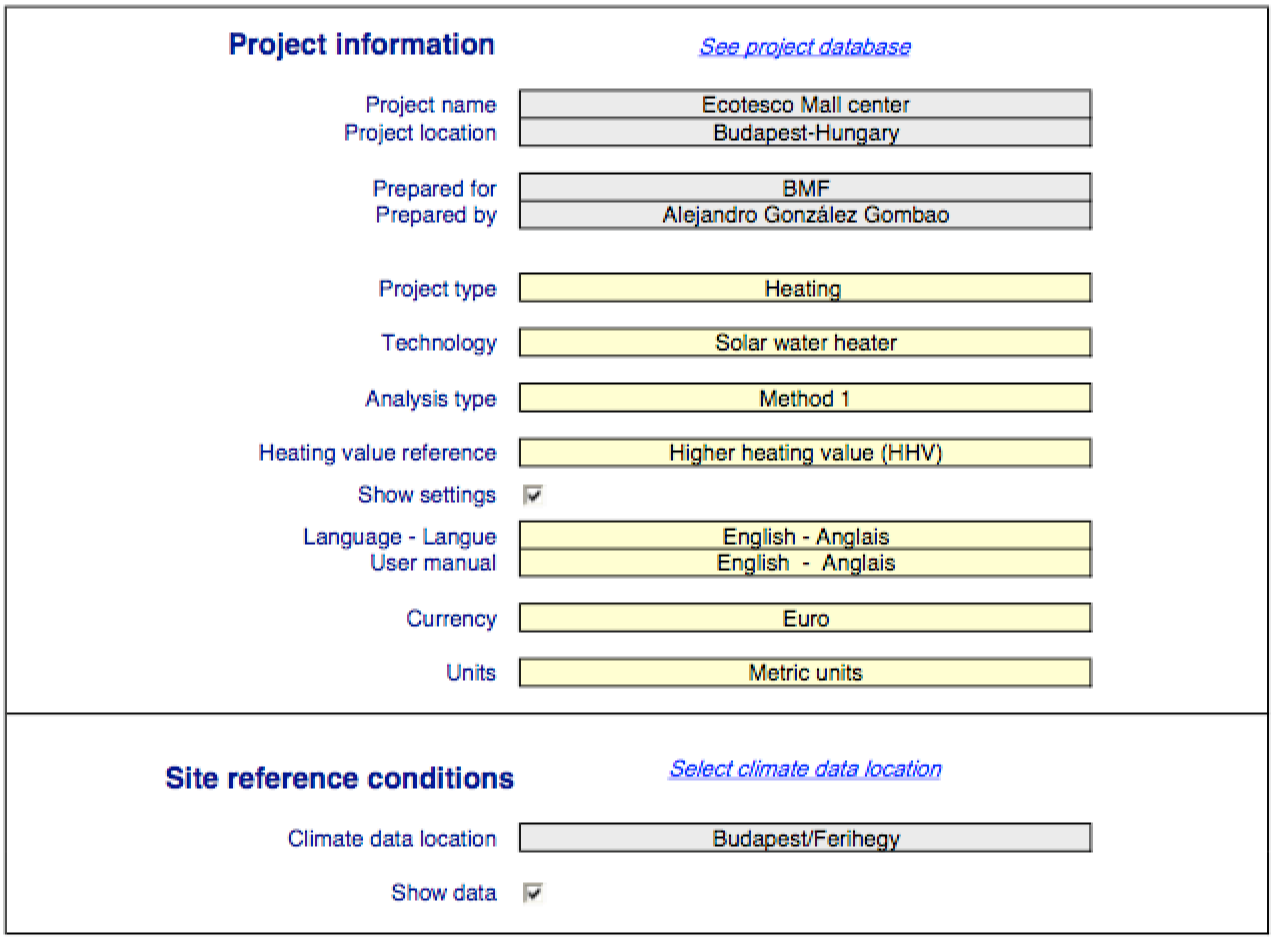
8.6.4. Drawings/Diagrams.

All data and diagrams have been obtained automatically using the software Retscreen

The study was conducted with the database program, selecting the same elements and features that Ecotesco solar photovoltaic installation.

These are some interesting graphics and tables obtained in the simulation:

-Project information: (Fig. 8.38)



Project information — See project database

Project name	Ecotesco Mall center
Project location	Budapest-Hungary
Prepared for	BMF
Prepared by	Alejandro González Gombao
Project type	Heating
Technology	Solar water heater
Analysis type	Method 1
Heating value reference	Higher heating value (HHV)
Show settings	☑
Language - Langue	English - Anglais
User manual	English - Anglais
Currency	Euro
Units	Metric units

Site reference conditions — Select climate data location

Climate data location	Budapest/Ferihegy
Show data	☑

Fig. 8.37 Project information.

-Climate data of Budapest: (Fig. 8.39)

	Unit	Climate data location	Project location
Latitude	˚N	47,4	47,4
Longitude	˚E	19,3	19,3
Elevation	m	185	185
Heating design temperature	℃	-9,9	
Cooling design temperature	℃	30,2	
Earth temperature amplitude	℃	20,9	

Month	Unit	Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
		℃	%	kWh/m²/d	kPa	m/s	℃	℃-d	℃-d
January		-0,7	82,5%	1,23	99,6	2,9	-1,6	580	0
February		0,9	76,2%	2,14	99,4	3,4	-0,1	479	0
March		5,4	69,5%	3,10	99,2	3,9	5,3	391	0
April		11,0	65,3%	4,26	98,9	4,2	12,3	210	30
May		16,2	65,8%	5,32	99,0	3,7	18,7	56	192
June		19,0	65,8%	5,63	99,0	3,6	21,9	0	270
July		21,1	64,1%	5,62	99,0	3,6	24,6	0	344
August		20,9	64,5%	5,03	99,1	3,1	24,5	0	338
September		16,0	70,2%	3,64	99,2	3,3	19,1	60	180
October		10,5	75,6%	2,28	99,5	2,9	12,5	233	16
November		4,1	81,3%	1,28	99,4	3,0	4,7	417	0
December		0,2	83,9%	0,98	99,6	3,2	-0,3	552	0
Annual		10,4	72,0%	3,38	99,2	3,4	11,9	2.976	1.370
Measured at	m					10,0	0,0		

Fig. 8.38 Climate data of Budapest.

By this table Retscreen make by method of calculating ,the annual energy production according to the daily radiation, number of the panels and model configured.

8.6.5. Results.

The following pages show the results of annual energy production and the economic study are obtained automatically by Retscreen. (Fig. 8.40)

RETScreen Energy Model - Heating project

Heating project

Technology		Solar water heater	
Load characteristics			
Application		Swimming pool	
		Hot water	

	Unit	Base case	Proposed case
Load type		Industrial	
Daily hot water use	L/d	3.500	3.500
Temperature	°C	60	50
Operating days per week	d	7	7

Percent of month used

Supply temperature method		Formula
Water temperature - minimum	°C	6,5
Water temperature - maximum	°C	14,2

	Unit	Base case	Proposed case	Energy saved	Incremental initial costs
Heating	MWh	73,9	59,0	20%	€ 1.000

Resource assessment

Solar tracking mode		Fixed
Slope	°	45,0
Azimuth	°	0,0

Show data

Month	Daily solar radiation - horizontal (kWh/m²/d)	Daily solar radiation - tilted (kWh/m²/d)
January	1,23	2,35
February	2,14	3,50
March	3,10	3,94
April	4,26	4,52
May	5,32	5,01
June	5,63	5,02
July	5,62	5,13
August	5,03	5,10
September	3,64	4,32
October	2,28	3,34
November	1,28	2,26
December	0,98	1,93
Annual	**3,38**	**3,87**

Annual solar radiation - horizontal	MWh/m²	1,23
Annual solar radiation - tilted	MWh/m²	1,41

Solar water heater

Type		Evacuated		€ 55.721
Manufacturer		Jiangsu Sunrain Solar Energy		
Model		TZ 58/1800-20R		
Gross area per solar collector	m²	3,38		
Aperture area per solar collector	m²	1,86		
Fr (tau alpha) coefficient		0,40		
Fr UL coefficient	(W/m²)/°C	1,46		
Temperature coefficient for Fr UL	(W/m²)/°C²	0,000		
Number of collectors		55	25	
Solar collector area	m²	185,74		
Capacity	kW	71,61		
Miscellaneous losses	%	5,0%		

See technical note
See product database

Balance of system & miscellaneous

Storage		Yes
Storage capacity / solar collector area	L/m²	6
Storage capacity	L	613,8
Heat exchanger	yes/no	Yes
Heat exchanger efficiency	%	95,0%
Miscellaneous losses	%	5,0%
Pump power / solar collector area	W/m²	30,00
Electricity rate	€/kWh	0,100

Summary

Electricity - pump	MWh	8,4
Heating delivered	MWh	41,1
Solar fraction	%	70%

Heating system

Project verification	Unit	Base case	Proposed case	
Heated floor area for building	m²	3.500	3.500	
Heating load for building	W/m²	40	36	
Domestic hot water heating base demand	%	50%	50%	
Total heating	MWh	520	464	11%

Heating system

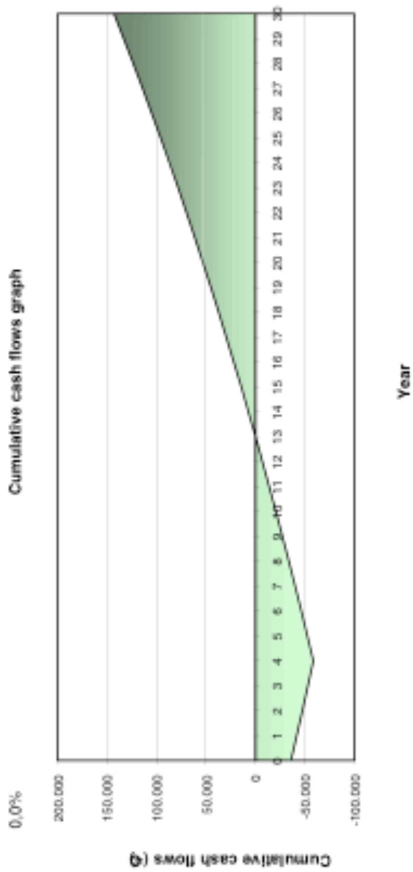
	Unit	Base case	Proposed case	
Fuel type		Natural gas - m³	Natural gas - m³	
Seasonal efficiency		70%	70%	
Fuel consumption - annual	m³	71.307,0	63.623,3	m³
Fuel rate	€/m³	0,400	0,350	€/m³
Fuel cost	€	28.523	22.268	

Fig. 8.39 Results of annual energy production.

-Economic study:

Financial Analysis

Financial parameters			
Inflation rate	%	2,0%	
Project life	yr	30	
Debt ratio	%	50%	
Debt interest rate	%	10,00%	
Debt term	yr	4	
Initial costs			
Heating system	€	56.721	79,1%
Other	€	15.000	20,9%
Total initial costs	€	71.721	100,0%
Incentives and grants	€		0,0%
Annual costs and debt payments			
O&M (savings) costs	€		
Fuel cost - proposed case	€	23.106	
Debt payments - 4 yrs	€	11.313	
Other	€		
Total annual costs	€	34.419	
Annual savings and income			
Fuel cost - base case	€	28.523	
Other	€	0	
Total annual savings and income	€	28.523	
Financial viability			
Pre-tax IRR - equity	%	8,3%	
Pre-tax IRR - assets	%	4,6%	
Simple payback	yr	13,2	
Equity payback	yr	13,0	



02/02/2010
RETScreen4-1

Fig. 8.40 Economic study.

8.7. PERSONAL EVALUATION AND OPINION OF SOLAR THERMAL SIMULATIONS.

According to the first study of pro TSOL, the annual production methods is **40661 kWh**, and the second study by RETScreen annual production of **41100 KWh.**

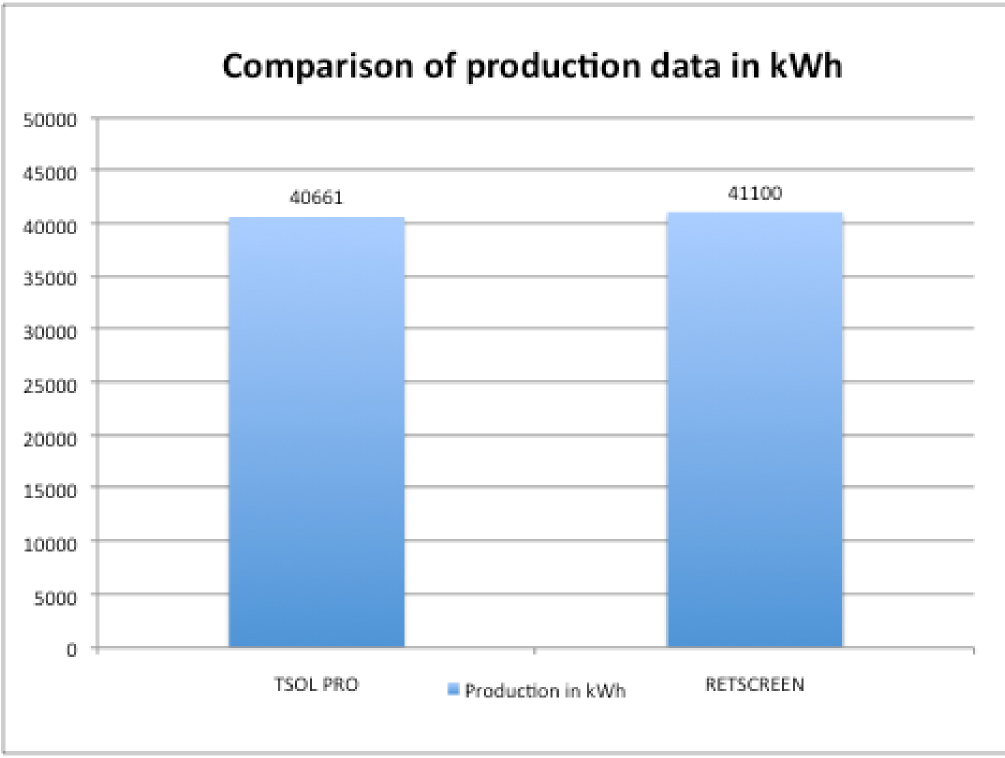


Fig. 8.41 Comparison of production data.

From my point of view this difference is because the first program takes into account all kinds of details at the time of calculation. These details relate to losses in pipes, storage tank or other system processes. Besides this, with TSOL analysis you can know that the system power supply at home phase, this is represented by the scheme added in the results section.

Moreover, I know the production every month, as well the results observed in production are higher in the summer months because the radiation is much greater. Note that in these months the hot water demand is lower, so the system does not need an extra supply of heat, with enough hot water supply due to production of solar panels.

Otherwise, the calculation of RETScreen is very similar to above but larger. In my opinion this is due to perform a calculation RETScreen more gross production, regardless of specific losses such as in the previous case. RETScreen considered lost according to the percentage system to be introduced into the program.

Note that have not used the same solar collectors are installed on Ecotesco, both programs have used panels with similar parameters.

From my point of view should be considered as better analysis of the solar thermal installation made with the pro TSOL, and that performs a calculation using RETScreen tighter and you can get an estimate of the profitability of the project.

Anyway, the data of the programs are very similar and very successful. One panel usually produce between 2 and 3 kWh / day ,thus doing a rough calculation of the solar system of Ecotesco ,the production would be: 55 panels * 2.5 kWh * 365 days = 50,187.5 kWh.

In summary, as I have said is a rough calculation, and also must be considered that the installation is in an area where in winter months levels of radiation are very low.

8.8. HEATING & COOLING CALCULATION.

This section is dedicated to the calculation of the heating necessary for the shopping center Ecotesco during a year.

For this case there was any type of software used to simulate the installation, but has been made using Excel with a simple equation for the difference temperature method.

Elements of calculation:

- Internal temperature = 20 °
- Heat transfer coefficient = 1.1
- Size of the mall = 70x50x10 m

The equation is:

- $Q = U * A * \Delta T$

Where:

- Q = Heat required in watts.
- U = Heat transfer coefficient.
- A = Area of the surface to calculate (m2).
- ΔT = Temperature difference inside-outside.

In the table can be observed temperature data for each month, and heating demand in kW. For a best estimate of demand for heating of the supermarket, is done through a demand curve for heating depending on the hour time.(Fig 8.29)

Negative results mean that the system functions like air conditioning, not heating, like heating, with thermal power demand and consumption.

On the next page you can see the table of all data.(Fig 8.30)

8.8.1. Summary table:

This is a graph of the estimated consumption of energy.

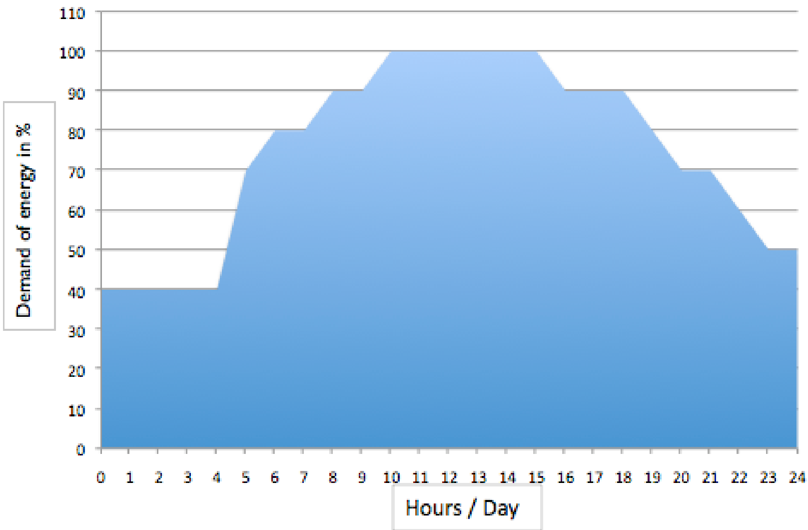


Fig. 8.42 Estimation demand curve for cooling and heating

-Heating calculation:

Month	Int. temp.(ºC)	Ext. tem.(ºC)	AT (ºC)	Coef.	kW	Average kWh/Day	Type
January	20	-0,7	20,7	1,1	79,70	1482,33	Heating
February	20	0,9	19,1	1,1	73,54	1367,75	Heating
March	20	5,4	14,6	1,1	56,21	1045,51	Heating
April	20	16	4	1,1	15,40	286,44	Heating
May	20	20	0	1,1	0,00	0,00	
June	20	27	-7	1,1	-26,95	-501,27	Cooling
July	20	30	-10	1,1	-38,50	-716,10	Cooling
August	25	30	-5	1,1	-19,25	-358,05	Cooling
September	20	22	-2	1,1	-7,70	-143,22	Cooling
October	20	10,5	9,5	1,1	36,58	680,30	Heating
November	20	4,1	15,9	1,1	61,22	1138,60	Heating
December	20	0,2	19,8	1,1	76,23	1417,88	Heating

Fig. 8.43 Table of heating calculation by Excell.

After the Heating and cooling calculation can take a balance of energy during any period of operation, because all the production and consumption data of Ecotesco are available.

The data of energy consumption and hot water are taken based on the installed total power and consumed by the equipment of the mall.

8.9. CALCULATION OF HOT WATER CONSUMPTION.

This section is dedicated to the calculation of energy consumption for hot water in Ecotesco. The calculation has been done without software, just with a simple equation.

Elements of calculation:

- Desired temperature for water is 40°
- Average water temperature in summer 20°
- Average water temperature in winter 20°
- 50 people / day in Ecotesco
- 70 liters / Person

I have assumed that at the mall half consume 70 litters per person, with a total of 50 people.

Equation:

$$\Delta E = N^\circ \text{ of persons / day} * \text{Litter / Person} * \Delta T * Cp$$

Where:

- Cp = Coeficient specific heat of water (4,2 kJ / kg K)
- ΔT = Temperature difference inside-outside.
- ΔE = Energy necessary in kJ

-Energy consumption calculation:

Winter season	ΔE = 50 * 70 *(40-10) * 4,2 = 441000 kJ / day	441000 kJ = **122,5 kWh / day**
Summer season:	ΔE = 50 * 70 *(40-20) * 4,2 = 294000 kJ / day	294000 kJ = **81,66 kWh / day**

Fig. 8.44 Hot water consumption

8.10. ENERGY BALANCES.

The function of this section is the visualization in summary of all the energy consumed by the hypermarket Ecotesco, to analyze and compare in detail the results obtained.

The schemes represent energy consumption in kWh during one the day, for summer and winter seasons.

As can be seen, the schemes represent all sources and energy consumption that is available in the facility. Some of the data have been estimated according to size and installed power in Ecotesco. Others of them have been calculated using calculation methods and software simulations, discussed above. (Fig. 8.45-8.46)

8.10.1. Energy balance- Winter season.

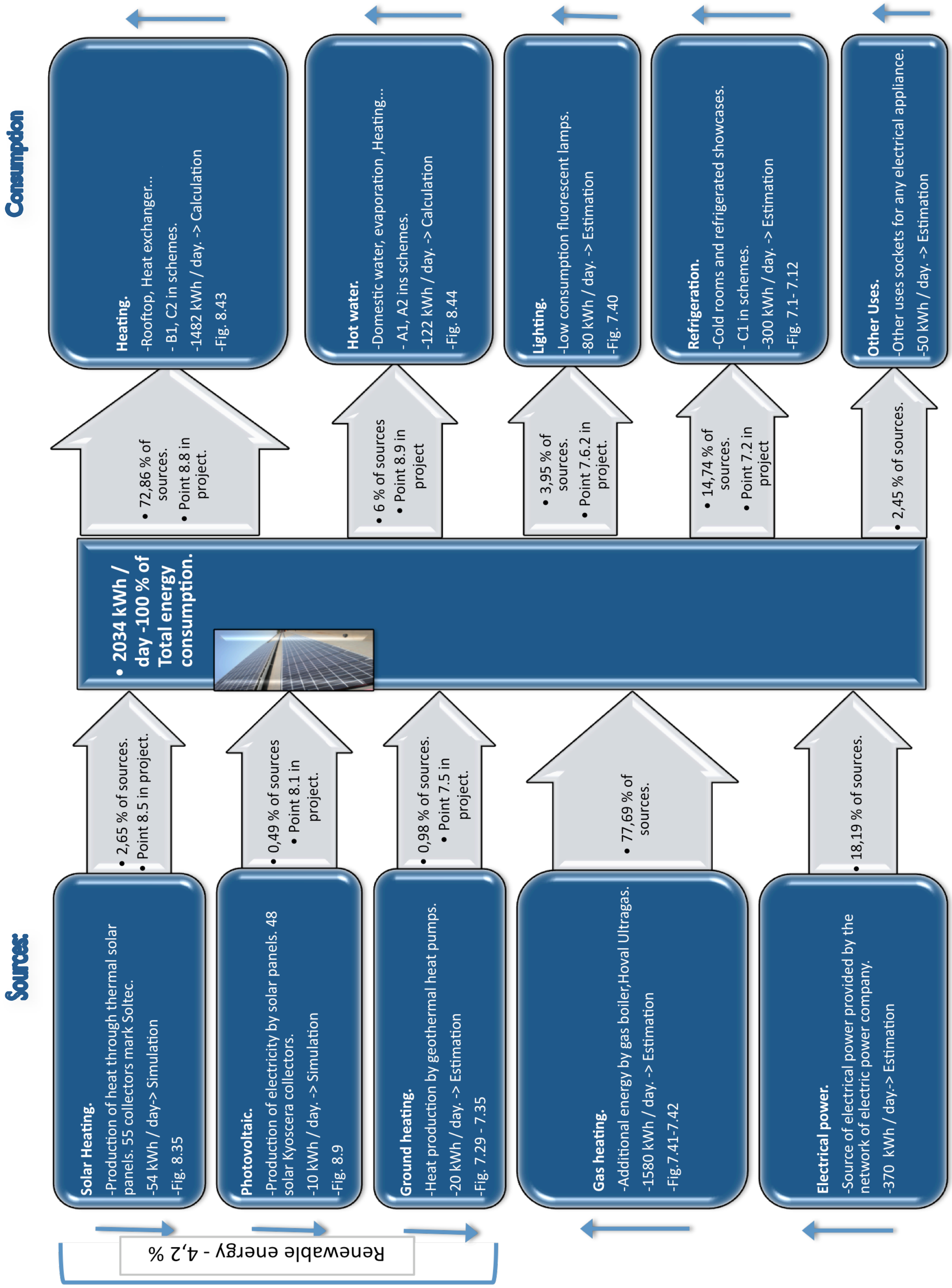


Fig. 8.45 Daily energy balance-Winter season.

8.10.2. Energy balance- Summer season.

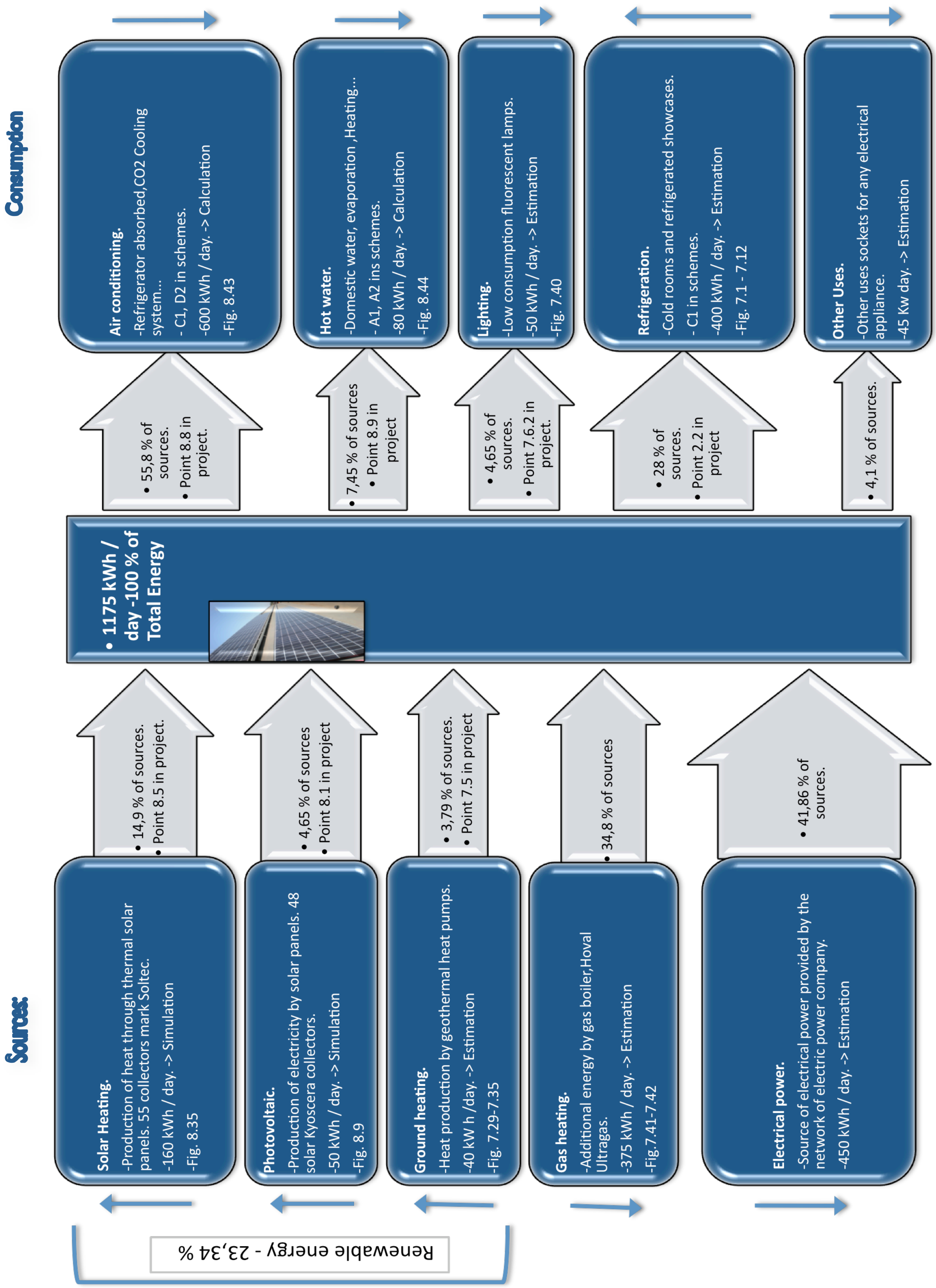


Fig. 8.46 Daily energy balance-Summer season.

8.11. CONCLUSIONS.

As a general conclusion of the project, from my point of view I can say that an installation likes available in Ecotesco means savings for the system.

As has been observed in the results obtained benefits to a short-medium term, means save money and CO2 emissions, because thanks to solar thermal energy get huge savings of gas and electricity.

Regarding the results in a photovoltaic electricity production is injected into the power grid of the power company, Ecotesco derive economic benefit because the energy produced by plants sold at a price higher than that purchased.

From my point of view, as seen in the following chart (Fig. 8.47) the installation of renewable energies Ecotesco is efficient and beneficial, as this will eventually save a large percentage of energy, and thus reductions emissions into the atmosphere and economic cost reductions.

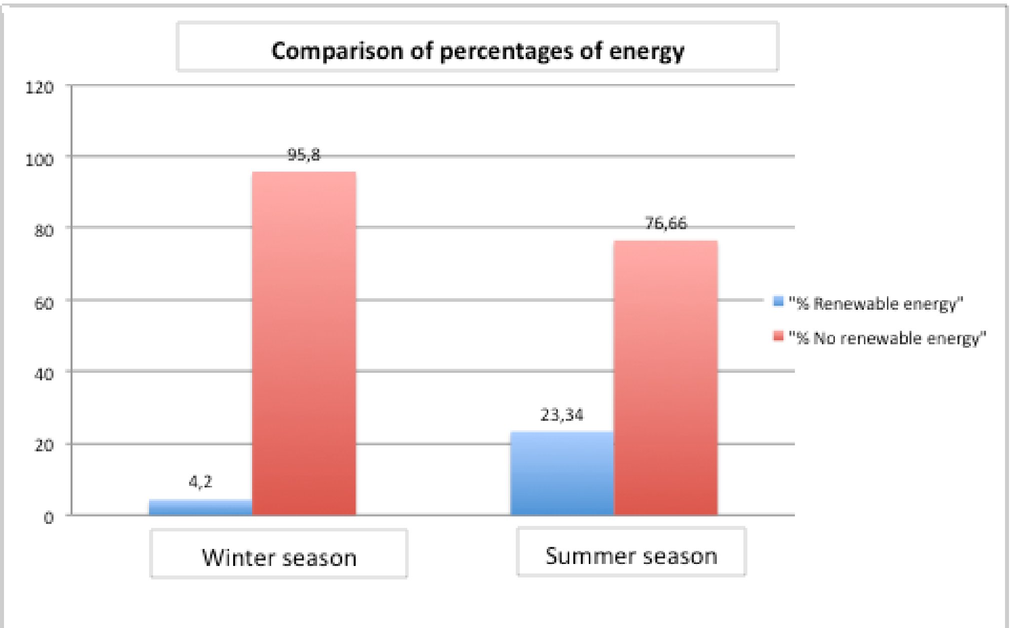


Fig. 8.47 Comparison of percentages of energy.

As shown in the graph (Fig. xx) in the season of winter the percentage of renewable energy is minimal, due to such low levels of radiation in the area. However the summer months, the percentage of renewable energies is quite high, so the supermarket works largely with clean energy, making Ecotesco a facility model in terms of renewable energies.

In summary, in present day, can say that should consider renewable energy as an essential factor for sources of energy, whether electricity or heat, obtaining therefore less pollution and saving money.

Project done by Alejandro González Gombao.

Signature:

9. DATASHEETS.

9.1. SUNNY BOY INVERTER.

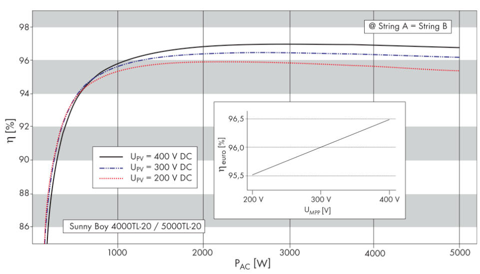
Technical Data
SUNNY BOY 4000TL / 5000TL

	SB 4000TL-20	SB 5000TL-20
Input (DC)		
Max. DC power	4200 W	5300 W
Max. DC voltage	550 V	550 V
PV voltage range, MPPT	125 V – 440 V	125 V – 440 V
Recommended range at nominal power	175 V – 440 V	175 V – 440 V
Max. input current	2 x 15 A	2 x 15 A
Number of MPP trackers	2	2
Max. number of strings (parallel)	2 x 2	2 x 2
Output (AC)		
Nominal AC output	4000 W	4600 W
Max. AC power	4000 W	5000 W
Max. output current	22 A	22 A
Nominal AC voltage / range	220 V – 240 V / 180 V – 280 V	220 V – 240 V / 180 V – 280 V
AC grid frequency / range	50 Hz, 60 Hz / ± 5 Hz	50 Hz, 60 Hz / ± 5 Hz
Power factor (cos φ)	1	1
AC Connection	single-phase	single-phase
Efficiency		
Max. efficiency	97.0 %	97.0 %
Euro ETA	96.4 %	96.5 %
Protective equipment		
DC reverse polarity protection	●	●
DC load disconnecting switch ESS	●	●
AC short circuit protection	●	●
Ground fault monitoring	●	●
Grid monitoring (SMA grid guard)	●	●
Integrated all pole sensitive residual current monitoring unit	●	●
General Data		
Dimensions (W / H / D) in mm	470 x 445 x 180	470 x 445 x 180
Weight	25 kg	25 kg
Operating temperature range	–25 °C ... +60 °C	–25 °C ... +60 °C
Noise emission (typical)	≤ 29 dB(A)	≤ 29 dB(A)
Consumption: operating (standby) / night	< 10 W / < 0.5 W	< 10 W / < 0.5 W
Topology	transformerless	transformerless
Cooling concept	OptiCool	OptiCool
Installation: Indoor / Outdoor (electronics IP 65 / connection compartment IP 54)	●/●	●/●
Features		
DC connection: MC3 / MC4 / Tyco	❍/●/❍	❍/●/❍
AC-connection: Terminals	●	●
Graphic display	●	●
Interfaces: Bluetooth / RS485	●/❍	●/❍
Warranty: 5 years / 10 years	●/❍	●/❍
Certificates and approvals	www.SMA.de	www.SMA.de

● Standard ❍ Optional

Values apply for nominal conditions – Version: February 2009

Efficiency curve



www.SMA.de
Freecall +800 SUNNYBOY
Freecall +800 78669269

SMA Solar Technology AG

Fig. 9.1 Characteristics sunny boy inverter of PV (Ecotesco)

9.2. SOLAR PANEL KYOCERA.

THE NEW VALUE FRONTIER
KYOCERA

KD210GH-2PU

High efficiency multicrystal photovoltaic module

EXAMPLES OF APPLICATION

- Grid-connected systems, for e.g.
  - Residential solar power systems
  - Public and industrial solar power systems
- Solar power stations

CUTTING-EDGE TECHNOLOGY

Exhaustive research work and continuous further development of production processes enable the integrated Kyocera high-performance solar cells with a standard size of 156 mm x 156 mm to achieve over 16 % efficiency, guaranteeing an extremely high annual yield of energy from the photovoltaic system.

To protect against the harshest weather conditions, the cells are embedded between a reinforced glass covering and EVA foil, and are sealed with a PET foil backing. The laminate is set in a sturdy aluminium frame which is easy to assemble. Our warranty covers a surface load of 2,400 N/m², but (in addition to that), the module even passed TÜV certification test IEC 61215 ed. 2 with the test condition of 5,400N/m².

The junction box on the module backside is equipped with bypass diodes that eliminate the risk of the individual solar cells overheating (hot spot effect). Many series-connected photovoltaic modules can be easily wired using pre-assembled solar cables and multi-contact plugs.

Kyocera manufactures all the components at its own production sites – without buying in semi-finished products – to ensure consistently high product quality.

TUVdotCOM Service: Internet platform for tested quality and service
TUVdotCom-ID: 0000023299
IEC 61215 ed. 2, IEC 61730 and Safety Class II
Kyocera is ISO 9001 and ISO 14001 certified and registered.

TÜV

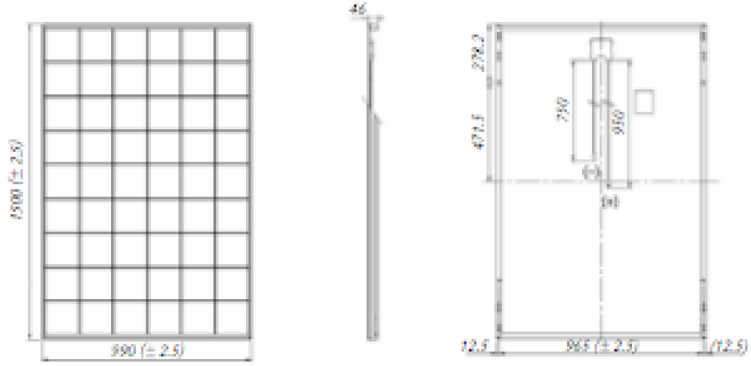
KYOCERA SOLAR

We care!

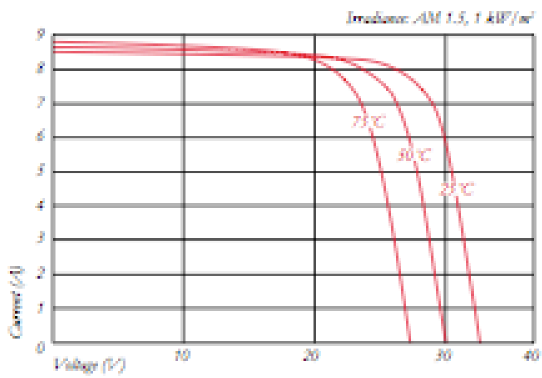
Fig. 9.2 Characteristics solar panel Kyocera of PV (Ecotesco)

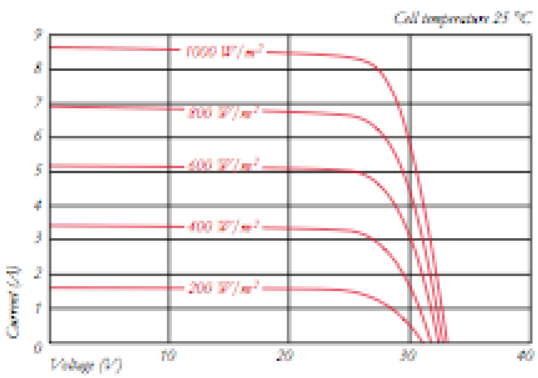
SPECIFICATIONS

in mm



ELECTRICAL CHARACTERISTICS





ELECTRICAL PERFORMANCE

PV Module Type		KD210GH-2PU
At 1000 W/m² (STC)*		
Maximum Power	[W]	210
Maximum System Voltage	[V]	1000
Maximum Power Voltage	[V]	26.6
Maximum Power Current	[A]	7.90
Open Circuit Voltage (V_{OC})	[V]	33.2
Short Circuit Current (I_{SC})	[A]	8.58
At 800 W/m² (NOCT)**		
Maximum Power	[W]	148
Maximum Power Voltage	[V]	23.5
Maximum Power Current	[A]	6.32
Open Circuit Voltage (V_{OC})	[V]	29.9
Short Circuit Current (I_{SC})	[A]	6.98
NOCT	[°C]	49
Power Tolerance	[%]	+5 / -5
Maximum Reverse Current I_R	[A]	15
Series Fuse Rating	[A]	15
Temperature Coefficient of V_{OC}	[V/°C]	-1.20×10^{-1}
Temperature Coefficient of I_{SC}	[A/°C]	5.01×10^{-3}
Temperature Coefficient of Max. Power	[W/°C]	-9.60×10^{-1}
Reduction of Efficiency (from 1000 W/m² to 200 W/m²)	[%]	6.0

DIMENSIONS

Length	[mm]	1500 (±2.5)
Width	[mm]	990 (±2.5)
Depth / incl. Junction Box	[mm]	46
Weight	[kg]	18
Cable	[mm]	(+)950 / (−)750
Connection Type		MC PV-KBT3 / MC PV-KST3
Junction Box	[mm]	100x108x15
IP Code		IP65

GENERAL INFORMATION

Performance Guarantee	10*** / 20 years****
Warranty	5 years

CELLS

Number per Module		54
Cell Technology		polycrystalline
Cell Shape (square)	[mm]	156x156
Cell Bonding		3 busbar

* *Electrical values under standard test conditions (STC): irradiation of 1000 W/m², airmass AM 1.5 and cell temperature of 25 °C*
** *Electrical values under normal operating cell temperature (NOCT): irradiation of 800 W/m², airmass AM 1.5, wind speed of 1 m/s and ambient temperature of 20 °C*
*** *10 years at 90 % of the minimally specified power P under standard test conditions (STC)*
**** *20 years at 80 % of the minimally specified power P under standard test conditions (STC)*

Fig. 9.3 Characteristics solar panel Kyocera of PV (Ecotesco)