UNIVERSITY OF PADUA
FACULTY OF ENGINEERING
MASTER'S DEGREE IN ENERGY ENGINEERING

"ENERGY PRODUCTION USING PHOTOVOLTAIC SYSTEMS IN HUNGARY AND ITALY:

COMPARISON FOR A FAMILY HOUSE"

Supervisor: Prof. Michele De Carli

Co-Supervisor: Dr. Ákos Lakatos

Author: Torneri Davide

Mat. 1020434 IEN

1 Summary

1.1 List of figures and tables

2 Introduction

2.1 Solar Radiation

Solar radiation is the energy released from the sun into the space, produced by thermonuclear reactions originated from the nucleus of the sun.
As an electromagnetic wave the solar radiation reaches the earth atmosphere and it's accepted to define the "solar constant" as the flow of radiant energy that affects a unit area perpendicular to the rays outside the Earth's atmosphere.
The constant is equal to 1367 W/m2, but it is an average value because the Earth-Sun distance varies periodically during the year.

The effective value reached by the earth surface is influenced by many aspects, first of all there are few main components of the solar radiation which form the global radiation on the surface as we can see from the picture below :

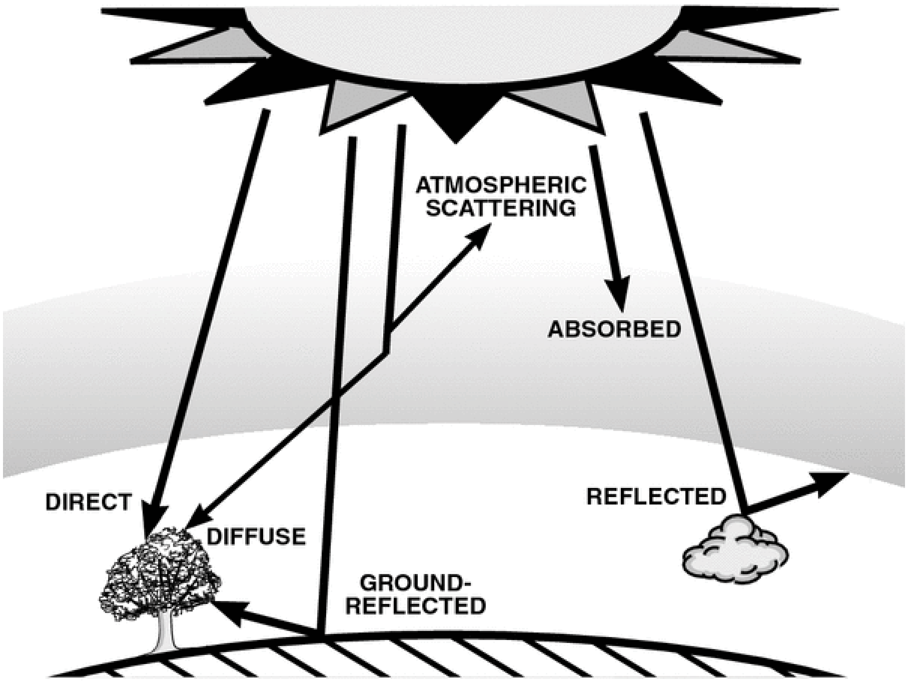


Figure 1 Global view of solar radiation on the surface

On a solar panel affects three components :

- Direct radiation
- Diffuse radiation
- Gruond-reflected radiation

The direct radiation affects on a surface with a definite and unique angle, instead the diffuse radiation doesn't have an unique angle of incidence but affects the surface from different directions and the ground reflected radiation derive from the reflection due to the surrounding environment.

2.2 Air mass concept

To describe the effect of the earth's atmosphere we introduce the concept of "Air Mass" which correspond at the length that the solar radiation has to cross to reach the atmosphere.
At international level are defined two operative conditions of the concept of the Air Mass:
the first one is called AM0, or rather air mass zero, represents the solar radiation measured outside the atmosphere , and the second one is AM1, which represent the spectral composition of the solar radiation measured at the sea level when the thickness of the atmosphere is crossed by perpendicular rays.
The picture below will explain graphically the concept of air mass:

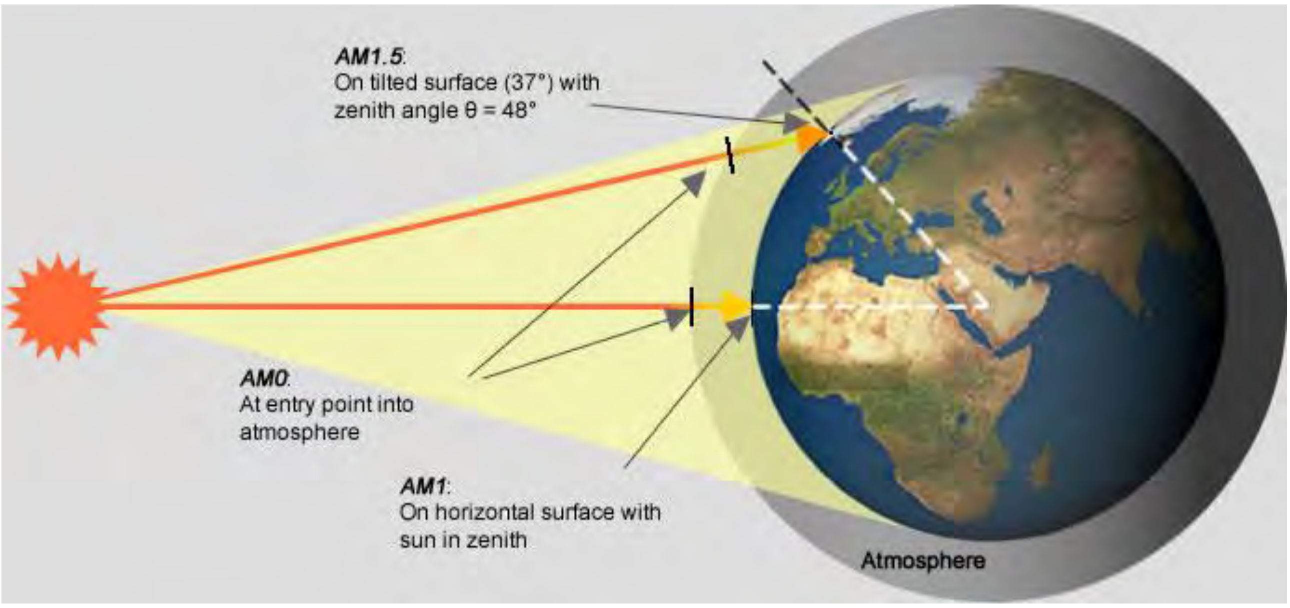


Figure 2 Air Mass concept

So the Air Mass quantifies the reduction in the power of light as it passes through the atmosphere and is absorbed by air and dust. The Air Mass is defined as:

$$AM = \frac{1}{\cos(\theta)}$$

where θ is the angle from the vertical (zenith angle).

3 Photovoltaic Overview

In this chapter we'll write down an introduction about the solar energy specifying which are the modern technologies whom are leading the market and some electrical characteristics .

3.1 How a solar cell works

The direct conversion of solar energy into electrical energy, made with the photovoltaic cell, it uses the physical phenomenon of light radiation with the valence electrons in semiconductor materials.
Up to now the most commonly used material in the construction of the photovoltaic cells was the crystalline silicon. The atoms of silicon, consisting of 14 electrons, 4 of those are valence electrons, available to bind paired with valence electrons of other atom.
Initially, the four valence electrons of an atom of crystalline silicon engage 4 others atoms around him and form a stable structure. When exposed to light, each valence electron is detached and passes to a higher energy level, called conduction band, where it is able to contribute to the electrical flow. In doing so, the electron leaves behind an unpaired electron, a so-called gap. If the gaps are so many in one area, for some sort of redistribution of these are occupied by electrons close, which in turn leaves another gap, and so on. This forms a stream of gaps that must be equal to the flow of electrons. The flow of electrons would be messy and unsuccessful if there were not an electric potential oriented in advance. The potential is obtained by overlaying two layers of silicon, in each of which introduces a particular chemical element (operation doping). Usually they are in contact with a thin layer doped with phosphorus and a thicker doped with boron.
Phosphorus has 5 valence. The presence of some extra electrons in the layer (in the ratio of 1 to 100) involves a charge weakly negative (n-layer, negative). The opposite happens in the layer doped with a few atoms of boron (p-layer), at a ratio of one atom for every million silicon atoms, which has valence 3: The bond gives rise to the gap.
The next picture shows a p-n junction:

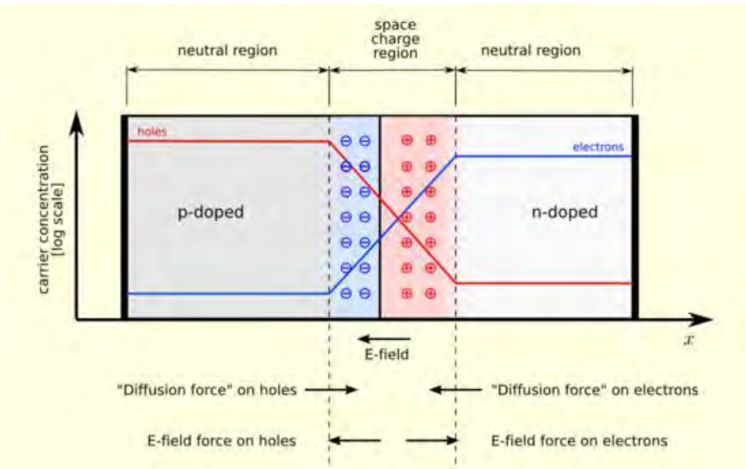


Figure 3 P-N junction

The photons of sunlight hit the photovoltaic cell from the side it may be reflected, absorbed or pass through the cell, by reason of the wavelength. Among the absorbed photons, some produce only heat and others push the electrons in the conduction band. The electron-hole pairs thus give rise to a unidirectional electronic flow. The contacts of the two layers are welded to two pn terminals in ribbon-conductive material.
If you connect the terminals, so closing the circuit from the outside, you get a flow of energy in the circuit (or electricity), in the form of continuous current.
The layout of the circuit in contact with the cell is a relevant aspect for our purposes. Generally the unexposed side (p) is completely connected while the side exposed to sunlight is good only partly covered. There are several reasons, but the most obvious is that the connection covers the cell, preventing the passage to the photons.

3.2 Photovoltaic characteristics

Photovoltaic systems are mainly grouped in two categories; Stand-alone system (also called off-grid) and grid connected system (also called on-grid). Stand alone systems can be integrated with another energy source such as Wind energy or a diesel generator which is known as hybrid system. The storage is the main difference between these categories, where the produced electrical energy is stored in batteries in off-grid system and the public grid utility is the storage tank for the excessive produced energy from on-grid systems.
On-grid systems are installed more often nowadays, some countries offer incentives to encourage people to invest in Photovoltaic and to reduce green house gas emissions. Feed-in-tariff was introduced in European countries such as Germany and Greece. “Net metering” mechanism was introduced in USA, and it is now under parliament discussion in Jordan.

Photovoltaic systems can provide electricity for home appliances, villages, water pumping, desalination and many other applications. The next picture explains briefly the different photovoltaic system applications:

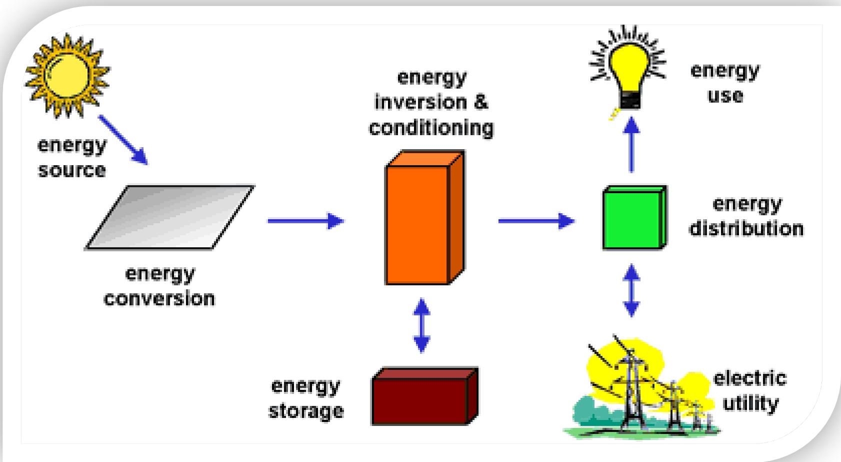


Figure 4 Photovoltaic system applications

3.3 Irradiation effect

Photovoltaic output power is affected by incident irradiation. PV module short circuit current (*Isc*) is linearly proportional to the irradiation, while open circuit voltage (*Voc*) increases exponentially to the maximum value with increasing the incident irradiation, and it varies slightly with the light intensity. Figure 5 describes the relation between Photovoltaic voltage and current with the incident irradiation.

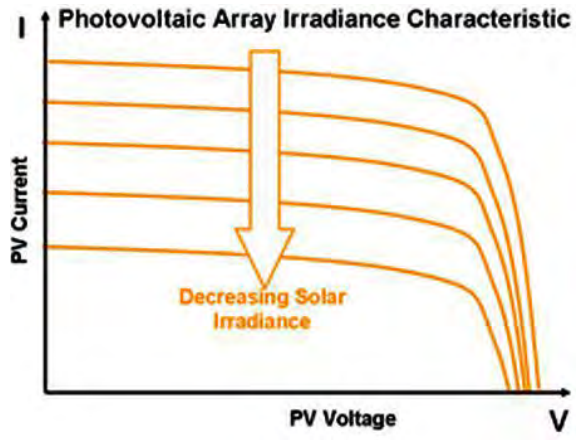


Figure 5 Effects of the incident irradiation on module voltage and current

3.4 Temperature effect

Module temperature is highly affected by ambient temperature. Short circuit current increases slightly when the PV module temperature increases more than the Standard Test Condition (STC) temperature, which is 25°C. However, open circuit voltage is enormously affected when the module temperature exceeds 25°C. In other words the increasing current is proportionally lower than the decreasing voltage. Therefore, the output power of the PV module is reduced. Figure 6 explains the relation between module temperature with voltage and current.

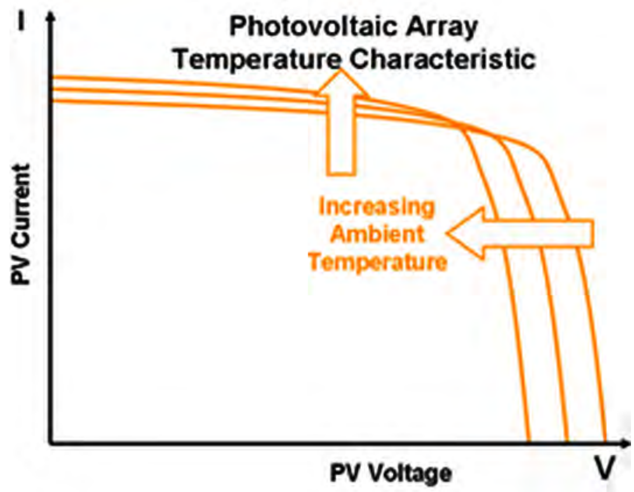


Figure 6 Effect of ambient temperature on module voltage and current

3.5 Maximum power point (PMPP)

Maximum electrical power of the PV module is equal to the current at maximum power point (IMP) multiplied by the voltage at maximum power point (VMP), which is the maximum possible power at Standard Test Condition (STC). Referring to Figure 7, the "knee" of the I-V curve represents the maximum power point (PMPP) of the PV module/system. At this point the maximum electrical power is generated at STC. The usable electrical output power depends on the PV module efficiency which is related to the module technology and manufacture.

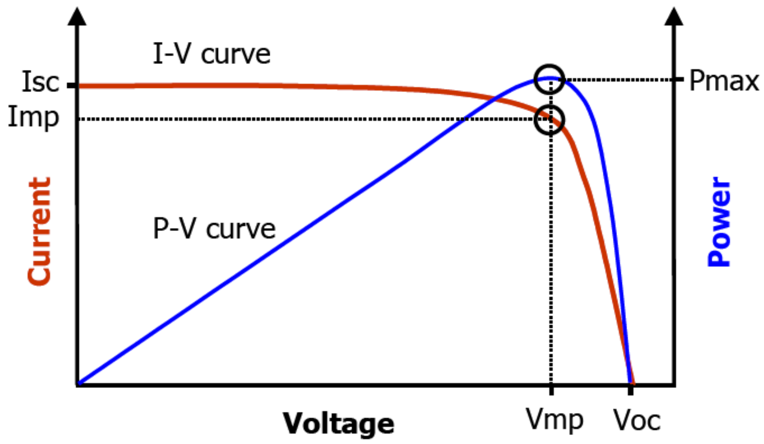


Figure 7 Maximum power point

3.6 Fill factor (FF)

The fill factor is an important parameter for PV cell/module; it represents the area of the largest rectangle, which fits in the I-V curve. The importance of FF is linked with the magnitude of the output power. The higher the FF the higher output power. Figure 8 illustrates the fill factor which is the ratio between the two rectangular areas and is given by the following formula. The ideal FF value is 1 which means that the two rectangles are identical.

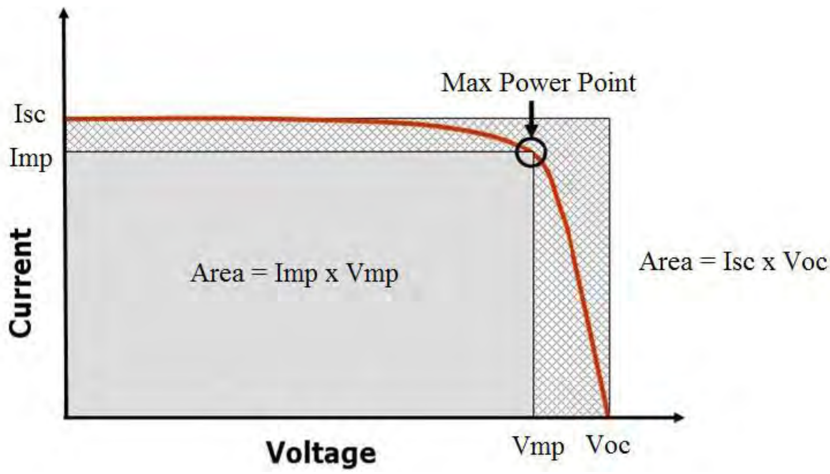


Figure 8 Fill Factor

3.7 Module efficiency (ηPV):

The PV cell/module efficiency is the ability to convert sunlight into electricity. The efficiency is necessary for space constraints such as a roof mounted system. Mathematically, it determines the output power of the module per unit area. The maximum efficiency of the PV module is given by:

$$\eta = \frac{Vmp * Imp}{G * A} * 100\%$$

Where G is global radiation and considered to be 1000 W/m^2 at (STC) and A is the Area of the PV module

4 Photovoltaic module technologies

The single junction technology is grouped into two main types; silicon crystalline and thin film technologies. Currently, multi-junction technology is under research and processing, to enhance the PV modules efficiency and to improve the response sensitivity of the sun light spectrum in order to cover the entire incident irradiation wavelength.

Front surface: mainly is a glass cover, and it must have a high transmission and low reflection capability for the concerned sun light wavelength. Low iron glass is commonly used because of its "low cost, strong, stable, highly transparent, and impermeable to water and gases and has good self-cleaning properties". **Encapsulate**: is used to provide a strong bond between the solar cells in the module, it should be stable at different operating temperatures and should be transparent with low thermal resistance. EVA (ethyl vinyl acetate) is commonly used with a very thin layer at the front and back surface of the assembled cells.

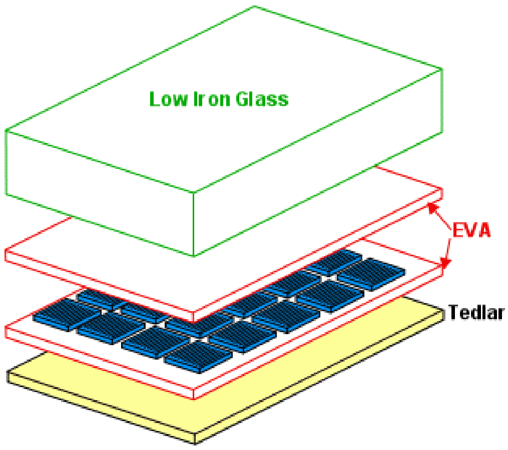


Figure 9 PV module layers

PV cells: is the part which is responsible for producing power. **Back surface**: is the back sheet for the PV module, it can be made from Tedlar (thin polymer sheet) material or glass for building facade. It must have low thermal resistance

4.1 Crystalline technology

Crystalline technology is the most efficient PV modules available in the market. In general, silicon based PV cells are more efficient and longer lasting than non-silicon based cells. On the other hand, the efficiency decreases at higher operating temperature.

4.1.1 Monocrystalline Technology

Monocrystalline is the oldest, most efficient PV cells technology which is made from silicon wafers after complex fabrication process.

Monocrystalline PV cells are designed in many shapes: round shapes, semi-round or square bars, with a thickness between 0.2mm to 0.3mm. Round cells are cheaper than semi-round or square cells since less material is wasted in the production. They are rarely used because they do not utilize the entire module space. However, on solar home systems where partial transparency is desired, round cells are a perfectly viable alternative. Next figure shows the monocrystalline PV module and cell layered structure.

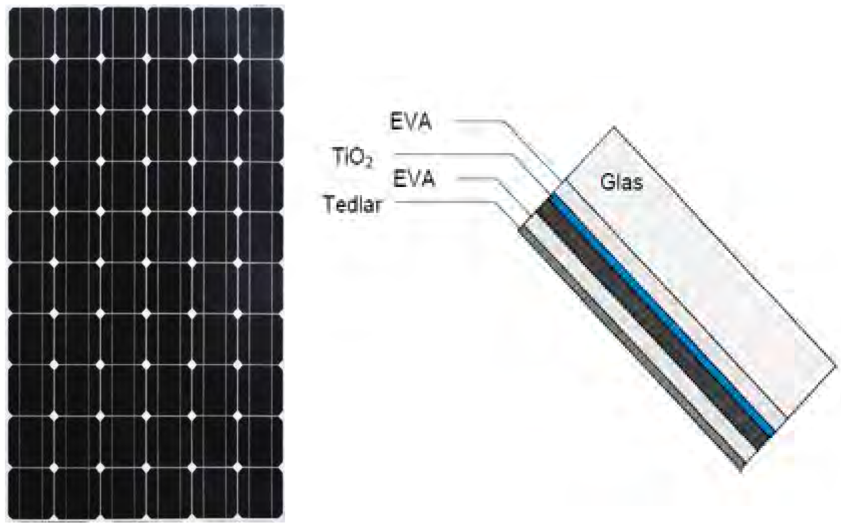


Figure 10 Monocrystalline PV module and cell layered structure

4.1.2 Polycrystalline

Polycrystalline PV modules are cheaper per unit area than monocrystalline; the module structure is similar to the monocrystalline . To increase the overall module efficiency, larger square cells should be used. By using larger cells the module cost will be lower, because less number of cells are used. Figure 11 shows a polycrystalline cell and module.

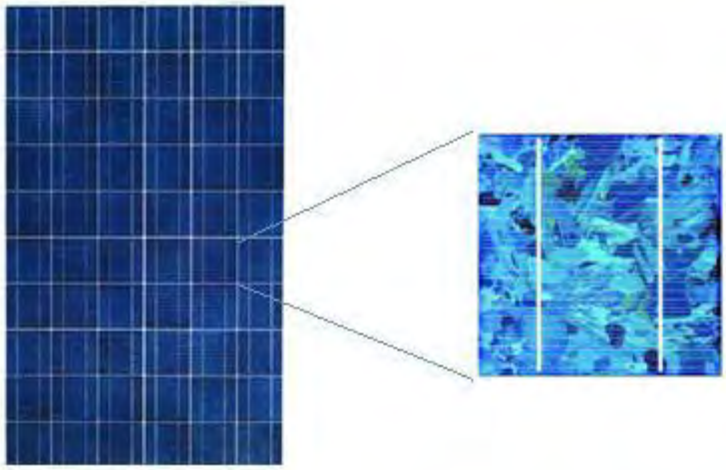


Figure 11 Polycrystalline cell and module

4.2 Thin film Technology

Thin film technology represents the second PV generation; due to less production materials and less energy consumption, it's cheaper than crystalline technology. Amorphous silicon, copper Indium Silinum (CIS) and Cadmium Telluride (CdTe) are used as semiconductor materials. Because of the high light absorption of these materials, layer thicknesses of less than 0.001mm are theoretically sufficient for converting incident irradiation.
Thin-film cells are not limited to standard wafer sizes, as in the case of crystalline cells. Theoretically, the substrate can be cut to any size and coated with semiconductor material. However, because only cells of the same size can be connected in series for internal wiring, for practical purposes only rectangular formats are common. "The raw module" is the term which is used for thin film technology.

Despite the relatively low efficiency per unit area, thin film technology has many advantages when compared to crystalline technology:

- Better utilization of diffuse and low light intensity.
- Less sensitive to higher operating temperature
- Less sensitive to shading because of long narrow strip design, while a shaded cell on crystalline module will affect the whole module.
- Energy yield at certain condition is higher than crystalline technology.

4.2.1 Amorphous Silicon technology (a-Si)

In this case, silicon is deposited in a very thin layer on to a backing substrate such as; metal, glass or even plastic. Figure 12 shows layered structure of an amorphous cell. This technology is not preferred to utilize for roof installation due to its low efficiency per unit area which leads to consume a larger area than utilizing crystalline silicon.

Another disadvantage of a-Si PV cells is light-induced degradation (known as the Staebler-Wronski effect), which reduces the module efficiency during the first 6-12 months of operation before levelling off at a stable value of the nominal output power.

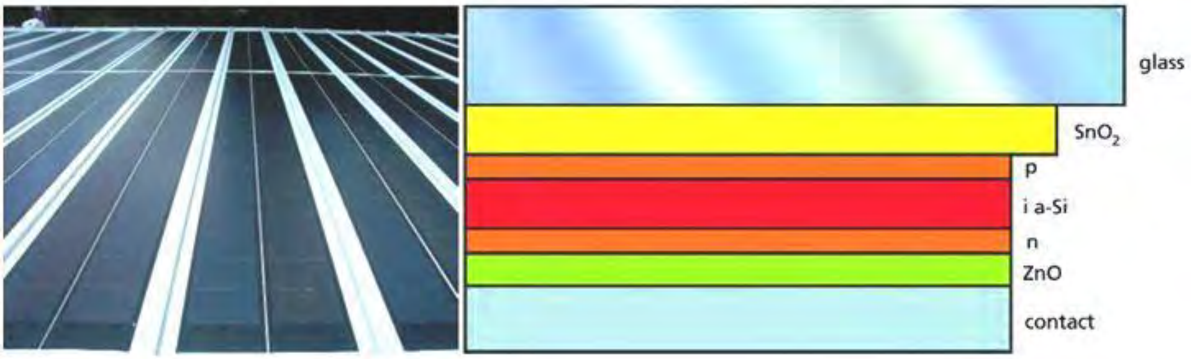


Figure 12 Flexible amorphous modules and layered structure of an amorphous cell

4.2.2 Copper indium Selenium technology (CIS)

Currently, Copper Indium Selenium or diselenide technology is the most efficient thin film technology. CIS compound is often also alloyed with gallium (CIGS) and/or sulphur, and it is not susceptible to light-induced degradation like amorphous silicon. Figure 13 shows the layered structure for CIS module. The other advantages of CIS are:

- Low cost processing method and using less than 1/200 active material vs. crystalline silicon.
- Has a wide spectrum response for the sun light.
- Has the highest module efficiency among thin film technology

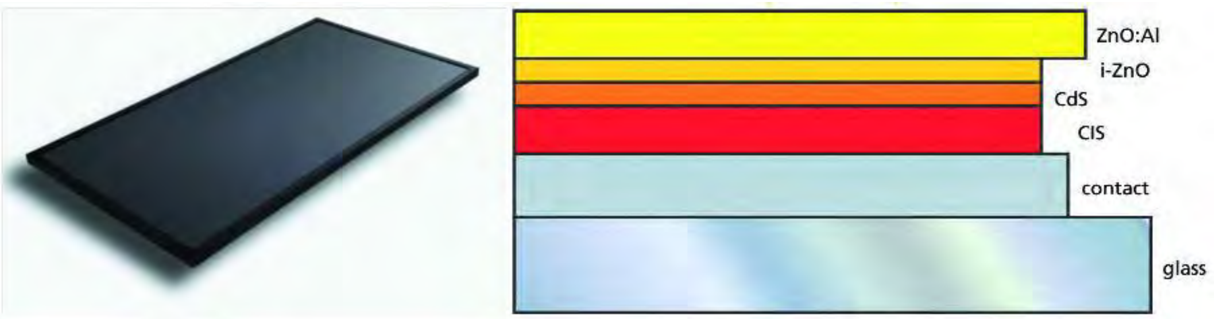


Figure 13 CIS modules based on copper indium disulphide and layered structure of a CIS cell

4.2.3 Cadmium Telluride technology CdTe

The main advantage of this technology is the lowest production cost among thin film technologies. The back contact is a weak point in CdTe cells since it is responsible for ageing. Modern high-grade

CdTe modules do not suffer any initial degradation such as Amorphous technology. Figure 14 shows the layered structure of CdTe PV module.

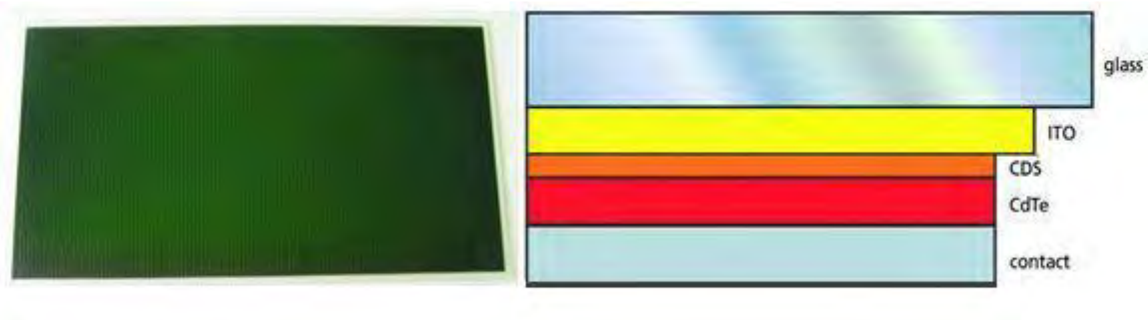


Figure 14 CdTe module and layered structure of a CdTe cell Source

5 Performance factors

Photovoltaic module is affected by many factors during conversion; these factors occurs mainly by climatic conditions, which affect the effective incident irradiation, and also from the fabrication and electrical specification of the PV modules. In this section a summary of the main factors, are introduced.

5.1 Optical loss

The effective irradiation is the total irradiation which reaches the PV cells. It is responsible on generating power. Incident irradiation faces obstructions before reaching the PV cells. It is reflected and absorbed from glass cover, EVA and ARC layers. This leads to decrease the expected output power. However, the main losses are caused by the interference between the air and the glass cover .

On the other hand, incident irradiation on the PV module falls in different angles and projections, and the optical losses become higher as the irradiation incident angle is higher; this depends on the season, location and mounting structure of the PV module.

5.2 Thermal effect

Thermal response of the PV module is the main factor which affects the electrical power output. The PV module receives the incident irradiation; a portion of it is converted to electricity in proportional with the module efficiency. The rest of the incident irradiation heats the PV module and increases its operating temperature in relation to the PV material heat capacity. PV module voltage is reduced extremely compared to the increasing of the current at higher operating temperature, so the generated power is reduced.

In the same time, a portion of the absorbed heat is dissipated into surrounding; this is occurred through conduction, convection and the radiation exchange heat transfer between the module and the surrounding.

5.3 Degradation

Degradation (or aging) of the PV module has a key role for decreasing the output power among its life time, and it differs from technology to another. It is important factor for the investors whom interested in Photovoltaic field.

Degradation generally is caused by UV absorption near the top of silicon surface for crystalline silicon based technology, many other factors such as lamination disintegration of backing material, bubbling at solder spots, and fissures in backing material, module delamination, solder-joint degradation, hot spots, encapsulate, discoloration, mechanical damage and cell degradation.

NREL (National Renewable Energy Laboratory) grouped the degradation into 5 categories:

1) Degradation of packaging materials.
2) Loss of adhesion.
3) Degradation of cell/module interconnects.
4) Degradation caused by moisture intrusion.
5) Degradation of the semiconductor device.

Regarding many studies of PV cells, it is concluded that the degradation differs from technology to another and from region to another depending on the climatic and weather conditions.
In general silicon crystalline modules have a linear degradation rate with around (0.3%-1% per year) during the module life time. On the other hand thin film technology degrades rapidly during the first 12-18 months of operation before levelling off at a stable value (the main effect known as the Staebler-wronski effect). In relation to thin film PV modules manufacture nowadays introduce the module specification after the first degradation in order to overcome the conflict between the nominal value for the first year and the next years.

6 Overview of the Italian and Hungarian energy production system

6.1 Introduction

In this chapter it's shown briefly an overview about energy production into the respective countries, starting with survey the data of the energy produced from different sources and open a bracket focusing the situation concerning the solar energy in each country.

6.2 Survey the Italian energy production system

6.2.1 General overview of the national energy situation

First of all it will be interesting to take a look about how electric energy is produced form different sources; the next simple chart shows the amount of energy in TWh produced:

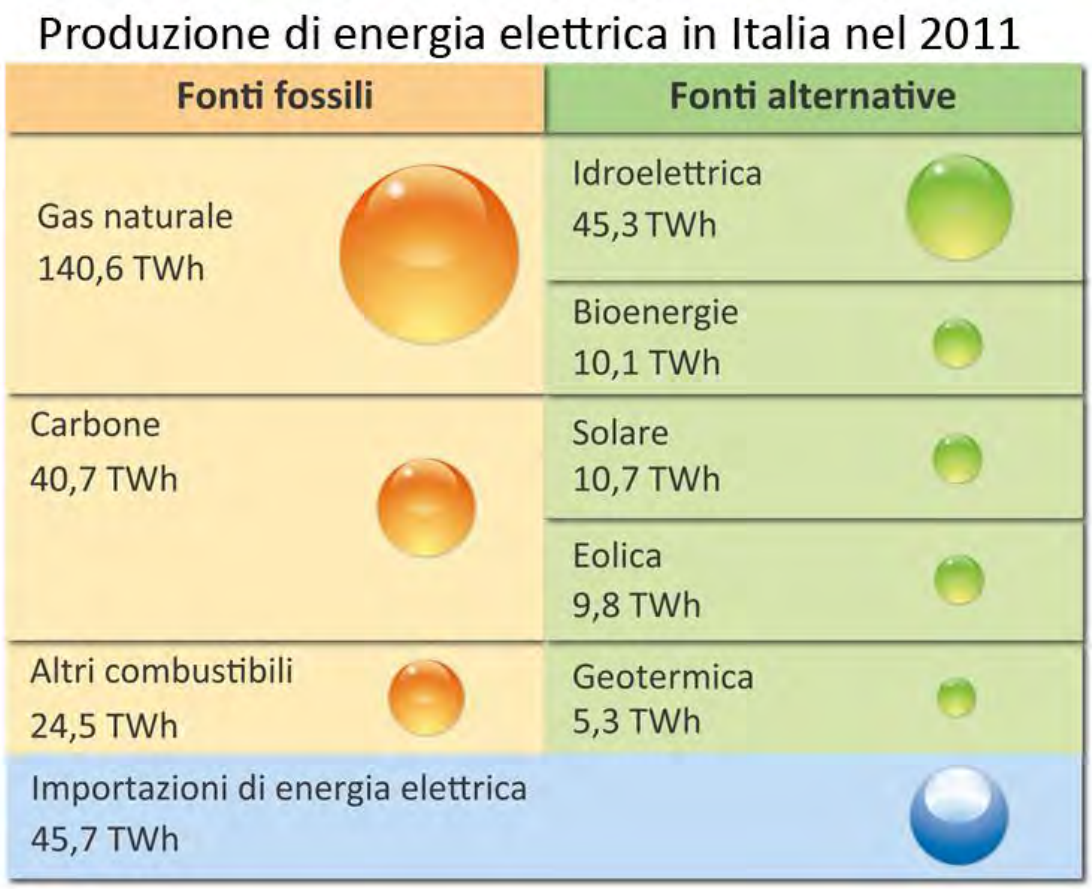


Figure 15 Italian's energy production 2011

If we want to make a simple description of the table, we see a distinction between traditional fossil fuels and alternative energy sources, in particular a huge amount of energy production is given by natural gas and coal.

The totality form fossil fuels is around 205 TWh in comparison with 81 TWh from alternative sources.
Here, we show a graph refers to 2012, concerning the growth trends of various energy sources, as we can see the trend follows an increase of solar and wind energy installed, slight increase of hydropower energy and a notable increase of thermo-electrical power plants.

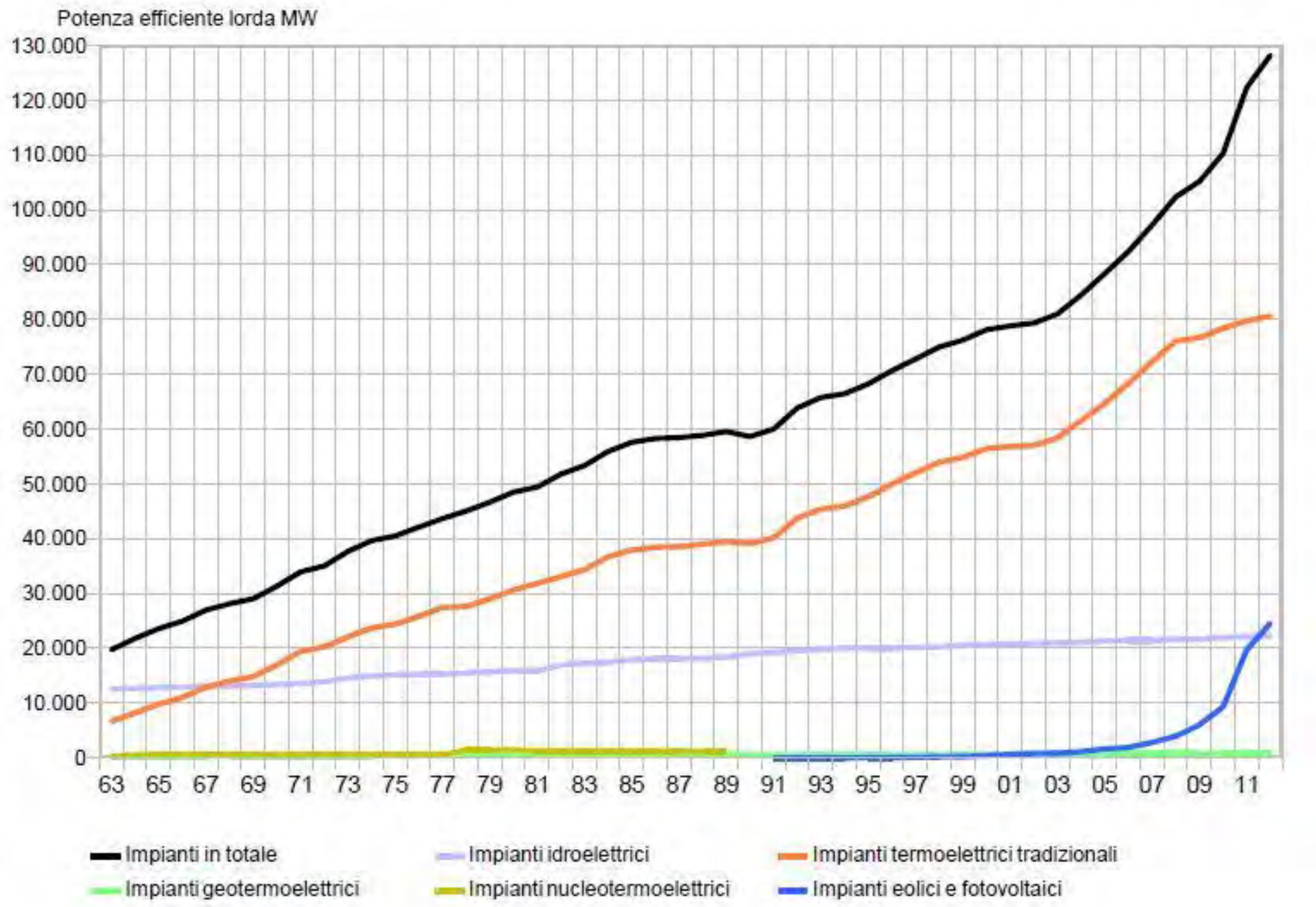


Figure 16 Italian's energy production trend

6.2.2 Focus on renewable energies in Italy

The year 2012 was a “green year” of electricity production in Italy, in the year just started ,electricity from renewable sources surpass the symbolic threshold of 100 billion kilowatt-hours. Renewable energies will be able to satisfy 31% of the Italian electricity needs (including imports), reaching 35% of national production.
Photovoltaic with 18.3 TWh has increased by 71.8% compared to 2011. To evaluate the speed of the development of solar energy in Italy, considering that in 2010 the production of photovoltaic had been just 1.9 TWh and 0.7 TWh in 2009. So in four years, the increase was 2600%. Wind energy , with 13.1 TWh produced in 2012 recorded an increase in production of 34.2% compared to 2011. Together the two sources, with 31.4 TWh ,covered 9.6% of the national electricity demand.

On the other hand it decreased hydroelectric and geothermal power, which with 43.3 TWh (-8.2% compared to 2011) and 5.2 TWh (-1.4%) have guaranteed 13.3% and the 1.7% of the demand. Overall, renewable sources in 2012 have covered 24.6% of the national electricity demand.

We can see in the graph below the growth of renewable energies in Italy from 2001 to 2011:

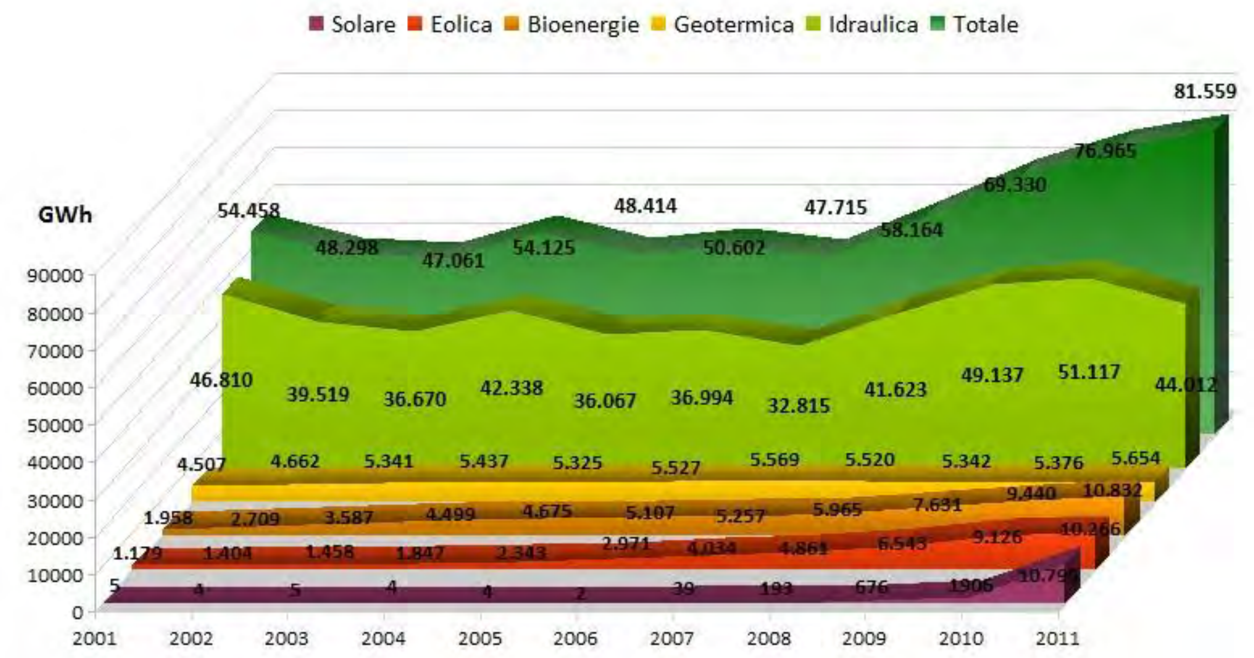


Figure 17 Production from renewable sources in Italy

6.3 Survey the Hungarian energy production system

6.3.1 General overview of the national energy situation

In this chapter we want to introduce and show the situation concerning Hungary's energy production and later on analyze energy production from solar power plants.

In Hungary, primary energy intensity, i.e. the primary energy demand of the total domestic output was approximately 2.4 times the average of the European Union in 2007. Converting it to purchasing power parity, however, the ratio is only 1.22. Electricity intensity, again converted to purchasing power parity, is even lower in Hungary (97 percent) than the EU average. It means that Hungary is simultaneously characterised by very low specific (per capita) energy consumption and a relatively high energy intensity.

As far as primary energy sources are concerned, with the degradation of the Hungarian deep coal mining, the fuel structure shifted toward increasing dependence on natural gas. As a result of the powerful increase of the volume of imported gas, the net import of fossil fuels increased at a considerable rate between 1990 and 2005, despite the fact that the level of energy consumption hardly changed during the period (Figure 18). The share of fossil fuels in the use of primary energy sources was 80% in 1990, as opposed to 75 percent in 2009 (Figure 19). 80% of the imported gas comes from Russia, essentially through a single transport route (the Brotherhood pipeline), which results in a vulnerable situation for Hungary in terms of the security of supply. In the map below are shown the main pipelines through East of Europe:

Figure 18 Eastern Europe pipelines system

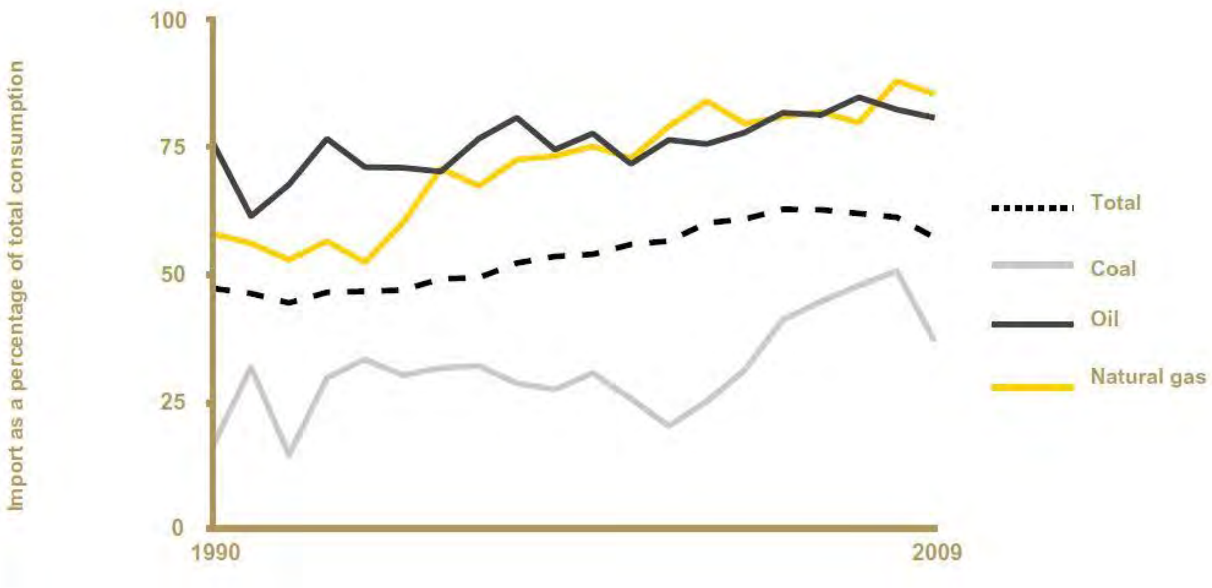


Figure 19 The energy import dependency of Hungary

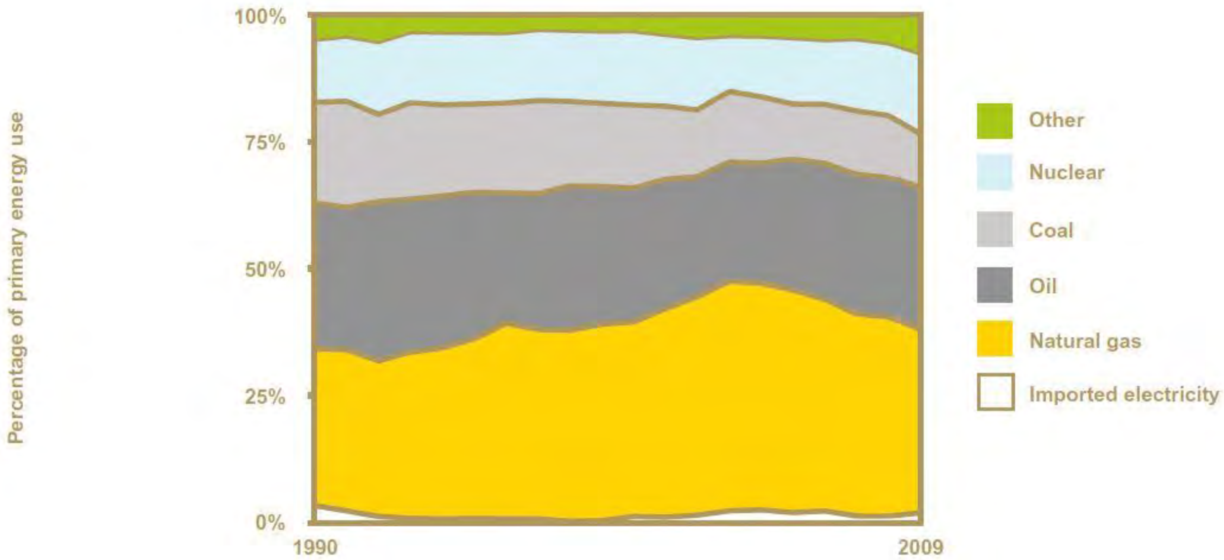


Figure 20 Hungary's primary energy use

While the Hungarian - Austria pipeline provides a link to the Austrian transit hub, its transport capacity is limited for the time being. Plans, however, have been drawn up for the doubling of its current capacity. Uniquely for Europe, the current Hungarian gas storage capacities exceed 50 percent of the annual natural gas consumption (approximately 5.8 billion m3). According to the requirements of the IEA and the EU, crude oil and oil products are stored at a quantity equivalent to at least 90 days of consumption.

The share of renewable energy in final energy consumption was 6.6% in 2008 (7.4% in 2010 is foreseen by the NREAP (national renewable energy action plan)), i.e. Hungary ranks in the lowest third among EU member states (2008 EU-27 average: 10.3 percent) lagging behind even the countries of a similar level of economic development (Bulgaria 9.4 percent, Czech Republic 7.2 percent, Poland 7.9 percent, Romania 20.4 percent and Slovakia 8.4 percent).

The difference is partly due to the more favourable and better exploited hydro energy potential and forestation indicators of the neighbouring countries as well as their more efficient regulatory systems. On the basis of Directive 2009/28/EC14, this indicator should reach 13 percent in Hungary by 2020. That Directive sets out an indicative trajectory, whose first stage will probably be met, as it provides that the share of renewable energy use should reach 6.04 percent on average during the two-year period between 2011 and 2012.

The targets set in Hungary's NREAP, adopted in December 2010, are more ambitious than those set out in the Directive: 7.4 percent for 2012 and 14.65 percent for 2020. Considering Hungary's geographical conditions, of the renewable energy sources, energy generation from biogenic sources (forestry and agricultural biomass, biogas and biofuels), geothermal energy and, on a long term, solar energy, are the most important.

In terms of the utilisation of renewable energy sources, Hungary has so far failed to make full use of the available domestic potential. According to the findings of a survey conducted in 2005 and 2006 by the Renewable Energy Subcommittee of the Hungarian Academy of Sciences, the theoretical annual renewable energy potential is around 720000 GWh, the full exploitation of which can never be achieved. The actually available level is characterised by the technically and economically feasible potentials. For the latter, however, no unequivocal estimates exist and this potential keeps growing with the development and gaining ground of new technologies. In their natural condition, the country's mineral raw materials are in the public ownership. These assets, registered by the National Office of Mining and Geology, constitute part of the country's natural resources and national wealth (Figure 21).

Energy carrier	Geological resources (2010)	Extractable reserves (2010)	Production (2008)	Production (2009)
	(million tons)			
Crude oil	209,4	18,4	0,81	0,80
Black coal	1625,1	1915,5	-	-
Brown coal	3198,0	2243,8	1,39	0,95
Lignite	5761,0	4356,3	8,04	8,03
Uranium	26,8	26,8	-	-
	billion m^3			
Natural gas	3563,0	2392,9	2,88	3,12

Figure 21 Hungary's fossil fuel resources

In the Hungarian energy supply, coal mining was of decisive importance up to the 1960's. Since that time, however, the volume of coal extracted has been declining. Increasing reliance on Hungarian coal is both necessary and can be supported, provided that environmental requirements are fulfilled. The size of the geological natural gas resource is 3563 billion m3. As far as the latter place of occurrence is concerned, however, no technological solution currently exists for the extraction. Taking only the operating mines into account, the size of the recoverable natural gas resource is, as at 1 January 2008, only 56.6 billion m3, ensuring (divided by annual production) supply for 21 years.

On the basis of our current technological knowledge, calculating with the drilling of fifty wells a year, app. 30 percent of that industrial asset can be extracted over the forthcoming 30 years. That would cover over one-third (34.2 percent) of domestic demand on the long term. In Hungary, uranium used to be mined near the village of Kôvágószôlôs, from which uranium oxide was produced locally, processed into fuel in the former Soviet Union. The mine was closed down for economic reasons in 1997, which put an end to Hungarian uranium mining and processing. Since 2006, however, the increase of market demand has spurred intensive search for uranium in Southwest Hungary (Mecsek, Bátaszék, Dinnyeberki and Máriakéménd).

6.3.2 Focus on renewable energies in Hungary

Renewable energy has been a supported idea by the mass media in Hungary since the mid 1990's. Increasing prices of oil and gas made renewable energies a promising alternative. Having good conditions for agricultural production, without deeper analyses, there was a general concordance that Hungary would benefit a lot from expanding renewable energy. Nevertheless, for long it was assumed that these sources of energy are quite expensive, and subsidies may make them competitive.

After joining the European Union (2003) renewable energy utilization started to grow intensively in Hungary. While before 2004 green electricity production amounted to only 0.5% of the total electricity production, by 2009 it reached 4.3%, and renewable around 5.1% in total primary energy supply. This growth represents a fivefold increase in electricity production compared to 2001. At present biomass represents almost 80% and geothermal 8.2% of renewable energy use. Hungary is rich in renewable energy sources. Pellets and other solid biomass are the most widely used resources in line with present renewable generation ratio.
The next charts show respectively the renewable energy potential in Hungary and the ratio of renewable energies sources:

Renewable energy pontential in Hungary

Maximum potential renewable energy in Hungary	Potential (PJ) (theoretical)
Solar photovoltaic (based on potentially installable solar modules)	1750
Biomass	300
Solar thermal	102.5
Geothermal	63.5
Water	14.4
Wind	532.8
Total	**2600–2700**

Figure 22 Renewable energy potential in Hungary

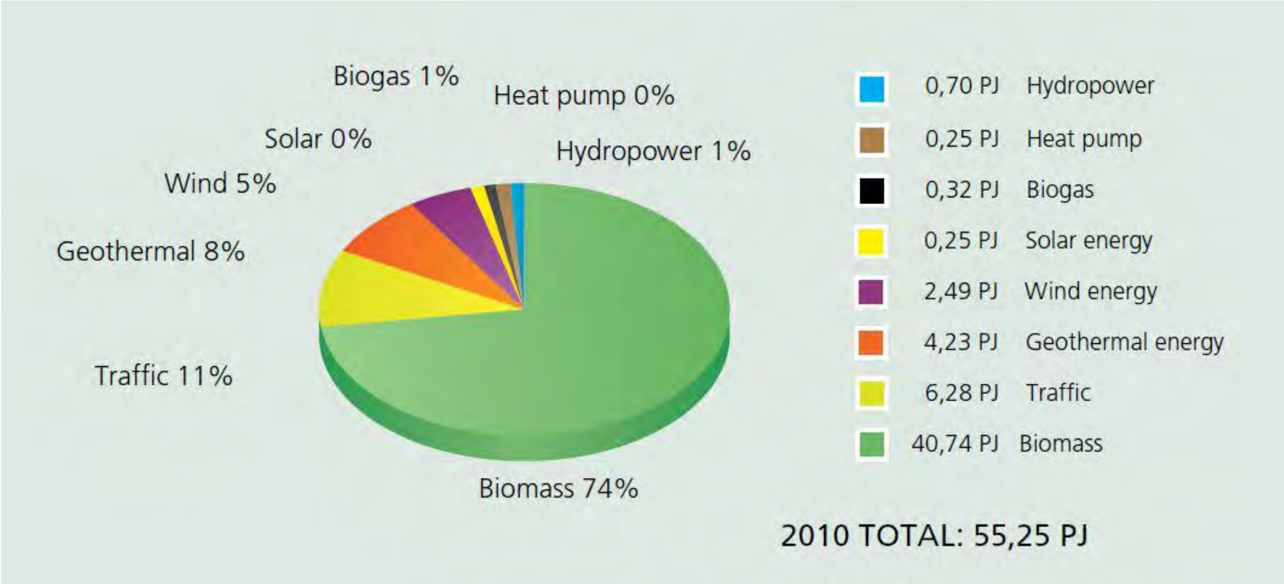


Figure 23 Ratio of renewable energies

The most important source after wood is geothermic energy, which provides nearly constant 3.6 PJ annually (capacities are little used in Hungary), which makes a sinking share in RE contribution. Liquid biofuels are the most dynamic RE since 2005/2006; however, its share is only a little higher than 2%. The slightly fluctuating hydro energy supply is stable but its share is falling. Wind energy is not much utilised in Hungary, and quite late was introduced. The solar energy is even less utilised, however in 2008 it has increased significantly.

The next table shows briefly the amount of production and share of renewable energy in total energy demand:

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Total energy demand	1047,6	1067,4	1085,6	1132,7	1111,9	1174,0	1163,2	1131,3	1116,2
Supply by RE	21,60	20,56	37,20	38,55	40,44	51,27	56,18	59,46	63,83
- biofuel. annual	0,01	0,03	0,03	0,05	0,10	0,21	0,46	1,20	6,10
- biofuel. wood	14,93	13,54	30,75	32,52	34,36	43,54	47,22	47,98	50,00
- wind	0,00	0,00	0,00	0,01	0,02	0,04	0,16	0,40	0,50
- solar	0,00	0,06	0,07	0,08	0,08	0,08	0,08	0,11	1,27
- hydroenergy	0,64	0,67	0,70	0,62	0,74	0,73	0,67	0,76	0,75
Share (%)	**2,06%**	**1,93%**	**3,43%**	**3,40%**	**3,64%**	**4,37%**	**4,83%**	**5,26%**	**5,72%**
- biofuel. annual	0,0%	0,1%	0,1%	0,1%	0,2%	0,4%	0,8%	2,0%	9,6%
- biofuel. wood	69,1%	65,9%	82,6%	84,4%	85,0%	84,9%	84,0%	80,7%	78,3%
- wind	0,0%	0,0%	0,0%	0,0%	0,1%	0,1%	0,3%	0,7%	0,8%
- solar	0,0%	0,3%	0,2%	0,2%	0,2%	0,2%	0,1%	0,2%	0,2%
- hydroenergy	3,0%	3,3%	1,9%	1,6%	1,8%	1,4%	1,2%	1,3%	1,2%

Figure 24 Production and share of renewable energy in total energy demand (PJ: Peta Joule)

6.3.3 Overall view of wind power energy in Hungary

In 2010 the share of electricity from the renewable energy sources reached 7,56%. The participation of large-scale wind turbines from Hungarian installed power plant capacity was approximately 5%.

Based on surveys conducted in the past years ,Hungary has a total wind energy potential of several thousand MWe.

The national target for 2020 is thus aligned, in respect to wind energy, to the limit of controllability of the electricity system, which is, to our present knowledge, capable of receiving wind energy up to an approximate total output of 740 MWe.

Currently Hungary uses a feed-in tariff system for wind energy, but this support scheme will change in the near future, after 2012.

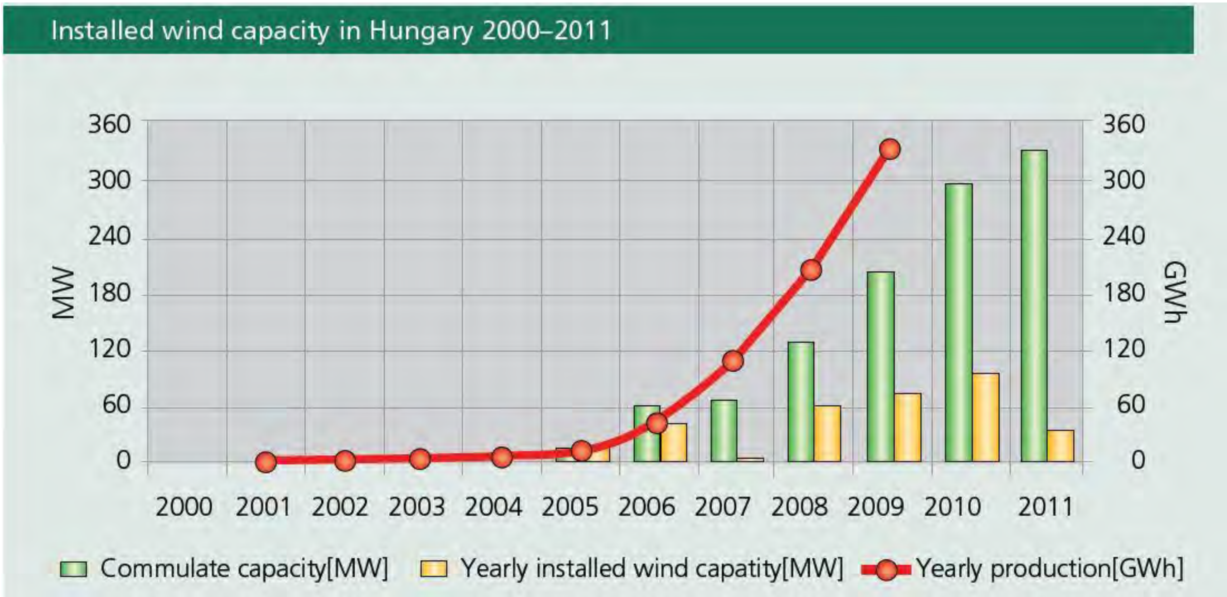


Figure 25 Cumulate and yearly installed wind capacity in Hungary between 2000 and 2011

Almost 43% of country's area is suitable for the economical utilization of wind power. In areas that are 75 m above sea level, the annual average wind speed is above 5,5 m/s. The opportunities are even more promising in higher altitudes.

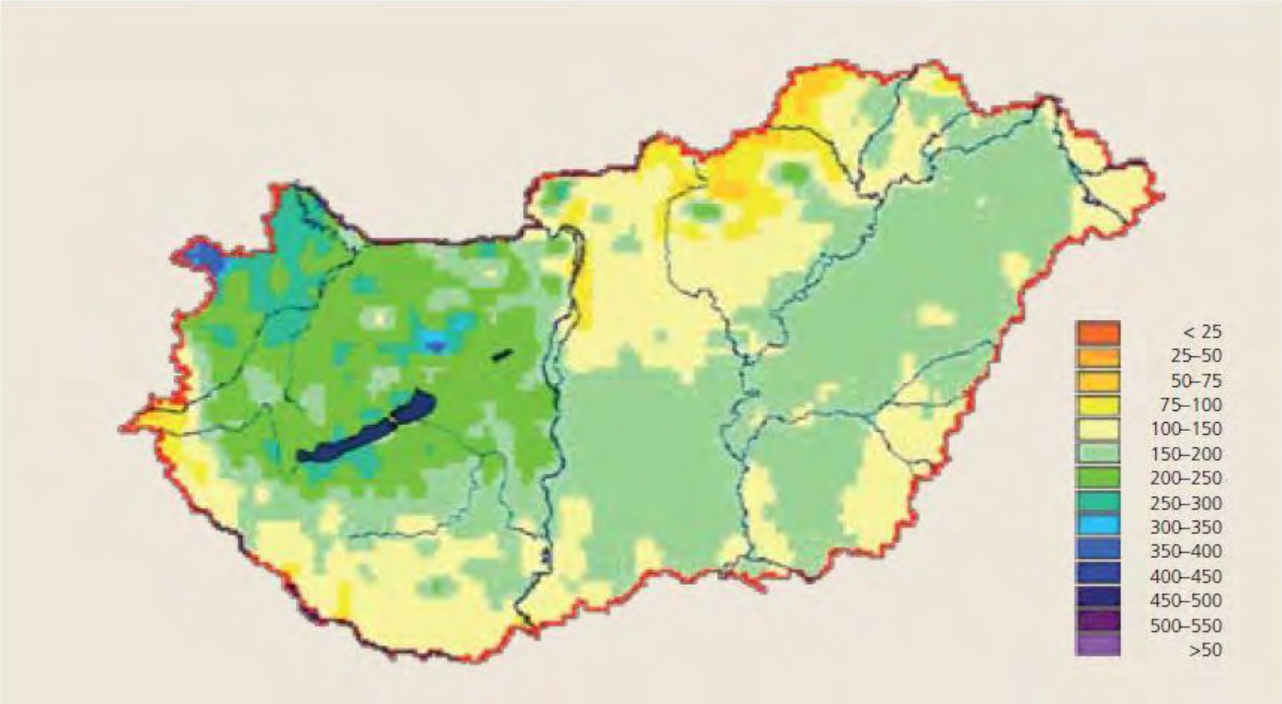


Figure 26 Specific wind performance (W/m2) on 75m above surface Country-side wind potential on 75m

In the following we can see which companies has more participation on wind market and manufactures in the country: as we can see first of all Gamessa , a Spanish brand, has a large market share, followed by Vestas, one of the most well known wind turbine maker.

Figure 27 Participation of manufactures of wind turbines in Hungarian wind energy market in spring 2011

The first Hungarian , in a public utility network integrated wind energy converter of 600 kW nominal capacity , was set into operation on May 23rd, 2001 in Kulcs, next there's a photo of the wind turbine.

Figure 28 First Hunrarian's wind energy converter

At the end we report a map concerning the graphical distribution of wind turbines: we can notice that most of them are placed in the north-west side of the country, according with the previous map, where there are the highest potential:

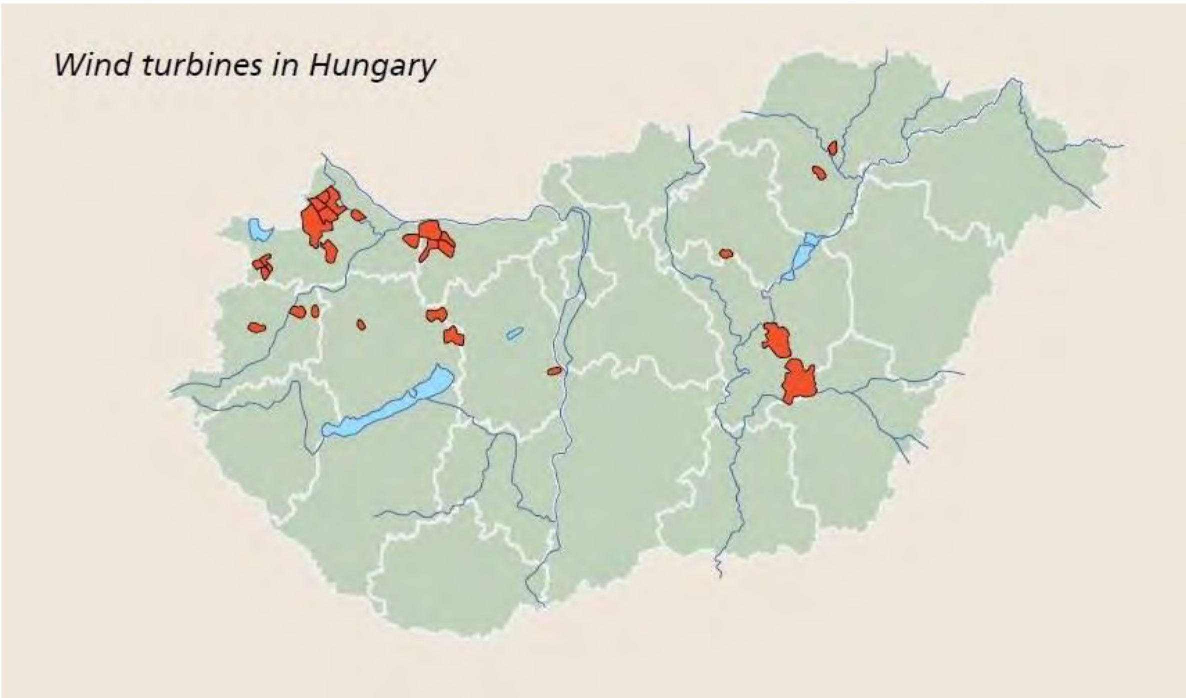


Figure 29 Graphical distribution of wind turbines in Hungary

6.3.4 Overall view of biomass, biogas and biofuels in Hungary

Hungary possesses excellent agro-ecological conditions for a competitive production of biomass. Hungarian agriculture is capable of sustainably producing biomass in excess of food and feed demands, and at the same time there is a significant biogas production potential. The theoretical potential of energy sources of biological origin (bioenergy) could exceed, by as much as 20% of the energy source demand estimated for 2020, and bioenergybased electricity production can be planned well in advance, and is also controllable. Therefore, the limitations of the production of bioenergy mainly lie in competitiveness. Bioenergy can primarily play a more important part in fulfilling local heating demands in the future, but there is also an intent to place emphasis on the spread of small and medium-capacity combined electricity and heat generating systems.

Biomass potential in Hungary:

- Total feasible resource potential: 145-188 PJ/year, 20 million tons
- Only a small part is used
- Most important resource: agriculture

Feasible biomass potential in Hungary:

	Volume, thousand tons/year	Energy, content in PJ/year
Solid biomass		145–188 PJ
Bio-ethanol	1330 kt/year	70 PJ
Biodiesel	250 kt/year	20 PJ
Biogas		25 PJ

Figure 30 Biomasses potential

The biogas market is set to grow:

- Only 10% of potential is currently being used
- Feasible potential is 24-48 PJ
- Share of total electricity production 2% ,
- The strategy supports the channelling of clean biogas to the natural gas pipeline network and the development of decentralized biogas plants
- Biogas production is expected to double by 2020

Biogas production

2010		2012		2015		2020	
MW	GWh	MW	GWh	MW	GWh	MW	GWh
14	85	21	125	43	262	100	636

Figure 31 Estimation of total contribution (installed capacity, gross electricity generation) expected

6.3.5 Overall view of hydropower in Hungary

Hungary is located in the heart of the Carpathian Basin which is a plain surface , therefore the hydropower potential is relatively small. Hydropower renewable energy means green electricity . The theoretical potential of electricity generation is around 7500 GWh/year.

In case it could reach this level ,it would be 2.3% of the total energy consumption of Hungary and 19% of the total electric energy.

By 2008 about 0.7 – 1 PJ/year is installed and the potential of around 5 PJ/year would be available by different investments.

Hydropower potential in Hungary is limited to 3 larger power plants, and several small power hydropower plants. The three main plants are:

- Kisköre
- Tiszalök
- Kesznyéten

Kisköre Power Plant

Was planned for 103.000 MWh capacity, during more 30years work the average capacity per year is 86.000 MWh as seen in figure 32. This is enough electricity for 30 thousand household.

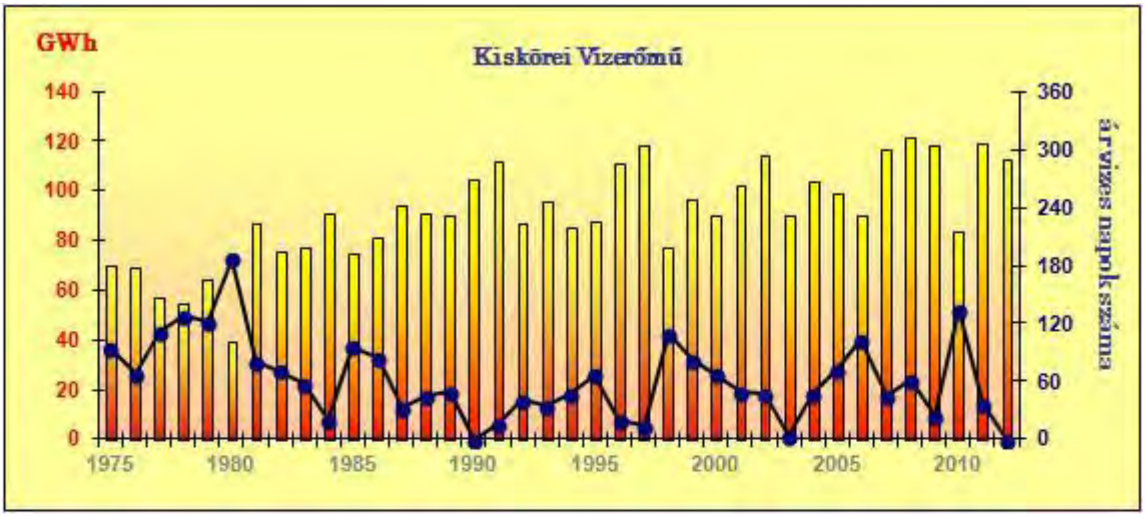


Figure 32 Kisköre hydropower annual electricity generation

Tiszalök Power Plant

Maximum production in Tiszalök was achieved in 1972 with electricity generation of 72938 MWh. The minimum was within 2 years: in 1974 only a average of 31704 MWh was generated. The yearly average is 48000 MWh (Figure 33).

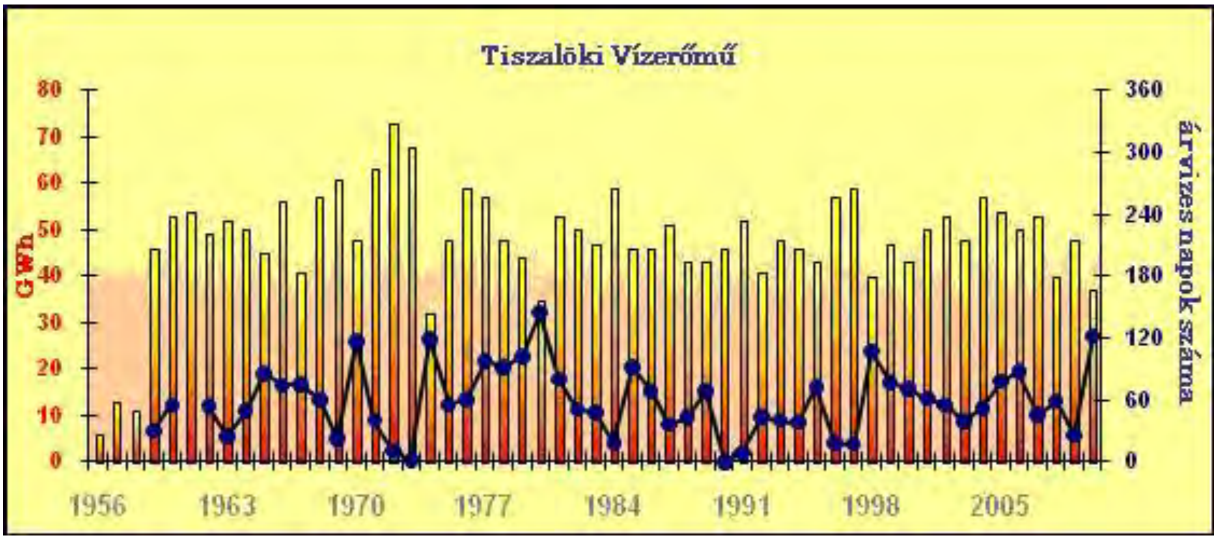


Figure 33 Tiszalök hydropower annual electricity generation

Kesznyéten Power Plant

Data of Kesznyéten is not available , due to privatisation uncertainties the ownership of the plant is unclear to public.

6.3.6 Overall view of geothermal energy in Hungary

Regarding geothermal energy, the geothermal gradient in Hungary significantly exceeds the global average, and represents one of the natural treasures of the country. In accordance with sustainable resource management, special attention must be paid to the preservation of this natural asset when establishing new capacities, which usually necessitates re-injection or recovery for the appropriate purposes.

There is significant potential in increasing the role of geothermal energy in the supply of heat, which at this time is already a widespread method of heating in certain sectors (e.g. in horticulture) in Hungary. In addition to the direct costs of the construction of wells and reinjection (which would not be necessary in all cases), the most important limiting factor in the case of geothermal energy is the provision of funding, which is due to the costs associated with the establishment of a heat supply and distribution systems.

The world average geothermal gradient is around 3°C/100m whereas in Hungary is 5-7 °C/100m. So far there is no electricity generation power plant in the country, however pilots projects were established by an Hungarian Oil company (MOL) in order to investigate the possibility to build a power plant on geothermal base.

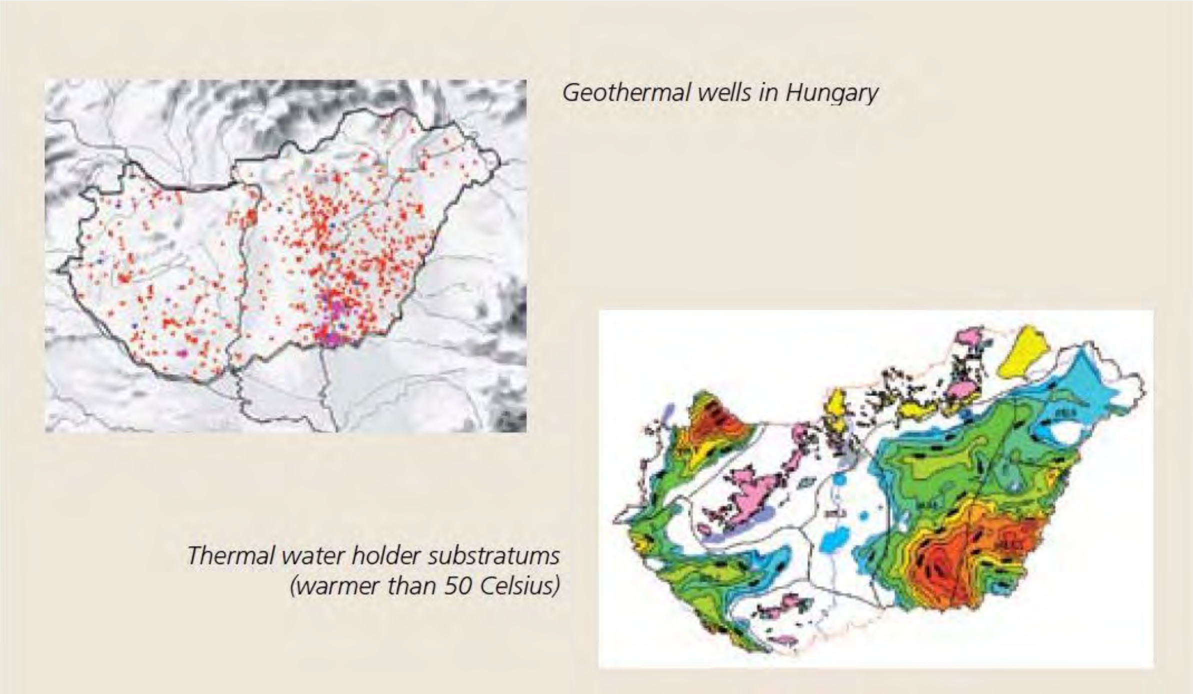


Figure 34 Hungarian geothermal map

Next map shows the wellhead temperature regions of Hungarian Upper Pannonian water wells:

Figure 35 Geothermal systems

7 Solar Energy: a comparison between Italy and Hungary

In this section we'd like to introduce and show the main differences between Italy and Hungary concerning the utilization of solar energy, starting to analyze the geography of the countries and then moving on talking about solar radiation , potential, installed capacity and so on.

7.1 Briefly geographic introduction

Figure 36 Political map of Italy

Italy is located in Southern Europe and comprises the boot-shaped Italian Peninsula and a number of islands including the two largest, Sicily and Sardinia. It lies between latitudes 35° and 47° N, and longitudes 6° and 19° E.

The country's total area is 301230 square km of which 294020 square km are land and 7210 is water.

Italy has 60,626,442 inhabitants according to 1 January 2011 municipal records. Its population density, at 201/km² is higher than that of most Western European countries. However the distribution of the population is widely uneven.

Figure 37 Political map of Hungary

With a land area of 93,033 square km, Hungary is a landlocked country in Central Europe. It measures about 250 km from north to south and 524 km from east to west. It has 2,258 km of boundaries, shared with Austria to the west, Serbia, Croatia and Slovenia to the south and southwest, Romania to the southeast, Ukraine to the northeast, and Slovakia to the north.

Most of the country has an elevation of fewer than 200 m. Although Hungary has several moderately high ranges of mountains, those reaching heights of 300 m or more cover less than 2% of the country. The highest point in the country is Kékes (1,014 m) in the Mátra Mountains northeast of Budapest.

It has a 9,937,628 inhabitants according the October 2011 census with a density of population at 107.2/km² .

7.2 Irradiation data

In this section we want to show and then discuss the data of the solar radiation in the two different countries, primarily using solar charts and maps.

7.2.1 The solar radiation in Italy

In 2012, the daily average irradiation time confirms the months of November and December as those with the less radiation. The months were instead mostly sunny July and June in particular the latter has reached the highest percentages (mean max 863 W/m^2).
As expected the maximum hours of light per day was recorded in June, the minimum value in the month of December.
Next graphic shows the values of the daily average solar irradiation each month:

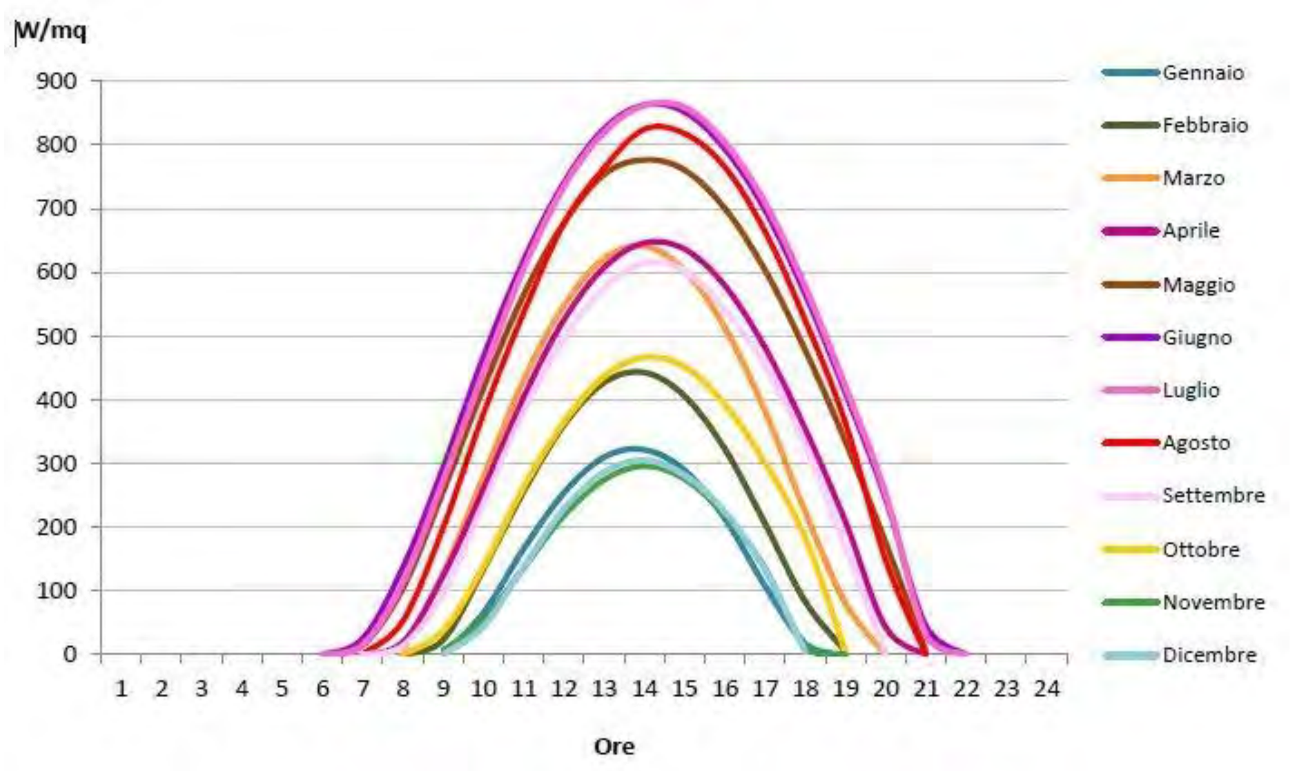


Figure 38 Daily average solar radiation in Italy 2012

7.2.2 The solar radiation in Hungary

The territory of Hungary is 93,000 km^2 with 457x103 PJ solar energy. So far the usage of solar energy in Hungary is very low, although the number of sunny hours is 1750-2050 per year.
As a result of the various effects of the atmosphere the intensity of rays reach 1400 W/m^2 , which is between 900-1000 w/m^2 in Hungary (in summer time with clear weather conditions). This means 1150 kWh/m^2 output of energy per year. This is what reaches the solar cells and could be utilizable

solar energy. The actually utilized energy is far less than this, because on one hand the angle of coming rays differs from 90° and on the other hand devices are unable to make use of all the incoming energy.

The utilizable energy depends not only on the geographical latitude but also on the climate. Based on Map 39 it can be stated that the highest value of utilizable solar energy, 2200 kWh/m^2 can be seen above the deserts and not around the Equatorial where climate is most commonly tropical. Although the value of AM is the highest around the Equatorial, here this is modified more by high level of humidity and rare cloudy weather than at the deserts.

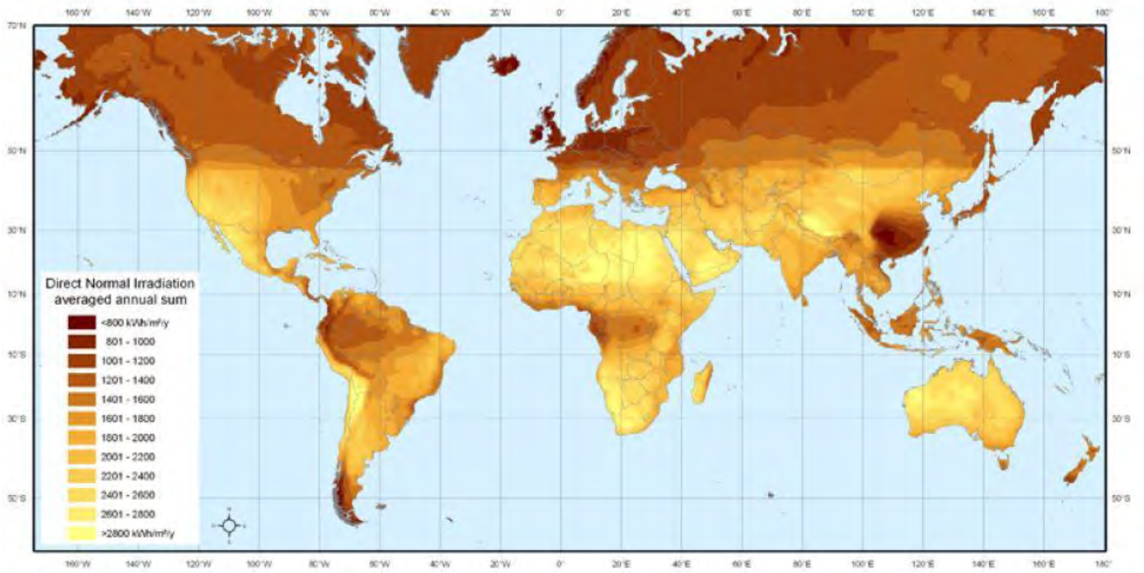


Figure 39 The effect of climate on the geographical distribution of solar energy coming to the ground

As you can see on Map 40 Hungary's situation is different. Most of the utilizable solar energy comes to the Great Plain and the least to the North-western and North-eastern regions. But you can also observe that the biggest difference is only 10%, therefore it is worth considering solar energy usage.

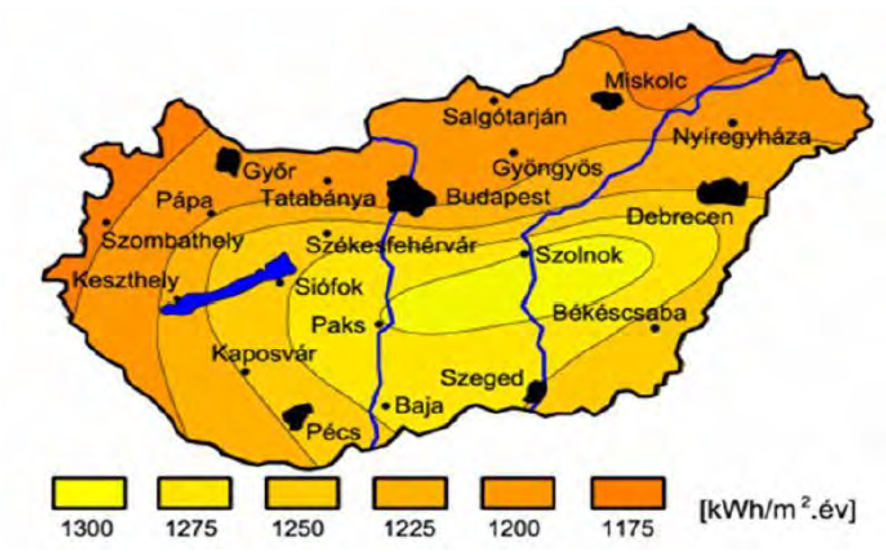


Figure 40 Geographical distribution of solar energy coming to the ground

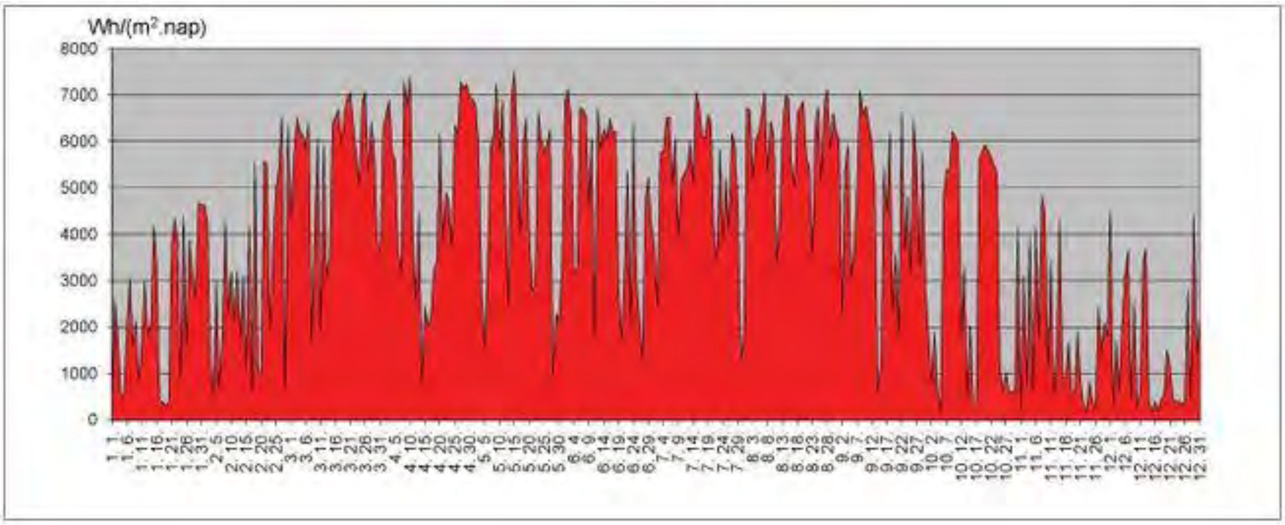


Figure 41 Annual solar radiation daily values

After the yearly amount of utilizable solar energy let's focus on its seasonal and daily distribution. As a result of Earth's orbit around the Sun the maximum angle of incidence of the rays in June is 66° and in December only 19°. It follows from this that the modification in winter is higher than in summer. In addition daytime is shorter in winter and there are fewer sunny/unclouded days. The latter can be seen on Diagram 41: in winter the peaks of sunny days are lower which is the result of the smaller angle of incidence and these days are rarer because of many cloudy days. As you can see on Diagram 43, on an average day in June the value of the coming energy is 4 times greater than in December. On Diagram 42 it is visible on the area under the curve that the monthly value of the coming energy in December period is approx. one quarter of the value in June.

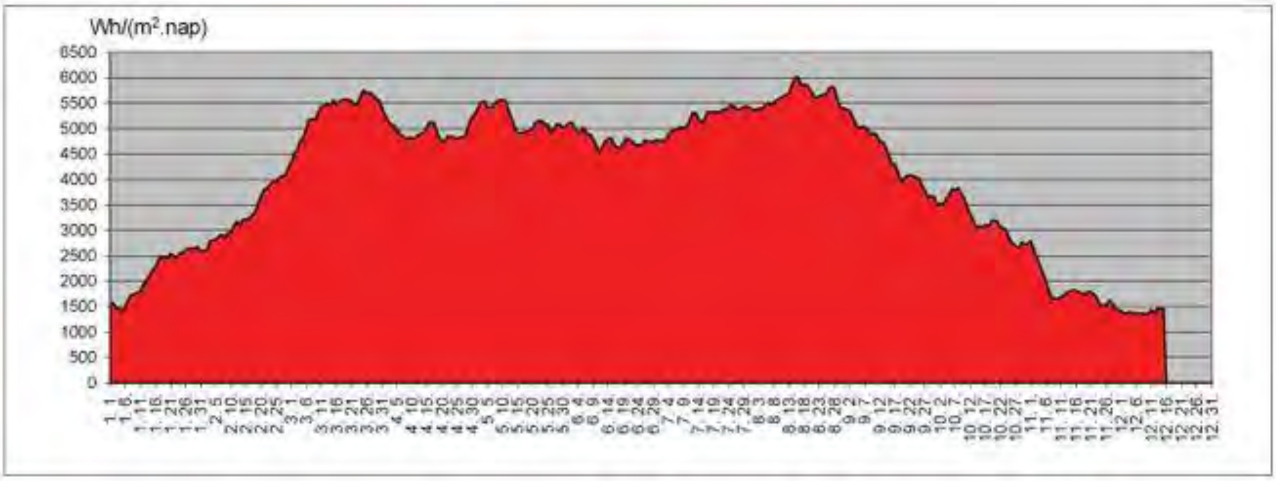


Figure 42 Data of daily sunshine with 30-day average values during a year in Hungary

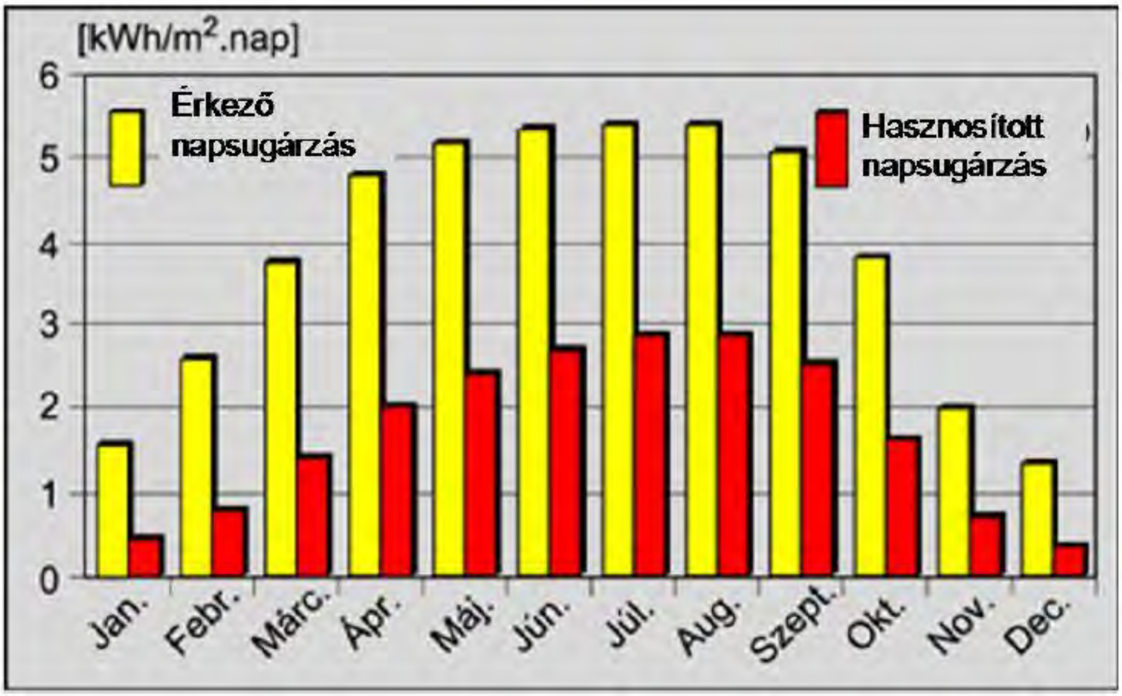


Figure 43 Values of daily coming solar energy (monthly averages) and monthly changes of the energy utilization with a flat-collector system [Yellow: Coming sunshine, Red: Utilized sunshine]

Some interesting data concerning Hungary in 2012 are the following:

- Annual radiation balance: 1453.2 kWh/m2
- Average Piece daily radiation: 3.971 Wh/m2
- Maximum daily radiation income on May 15th: 7492 Wh/m2
- The lowest daily radiation Income December 15th: 173 Wh/m2

The following graph shows the monthly average solar radiation data for the cities of Milan and Budapest:

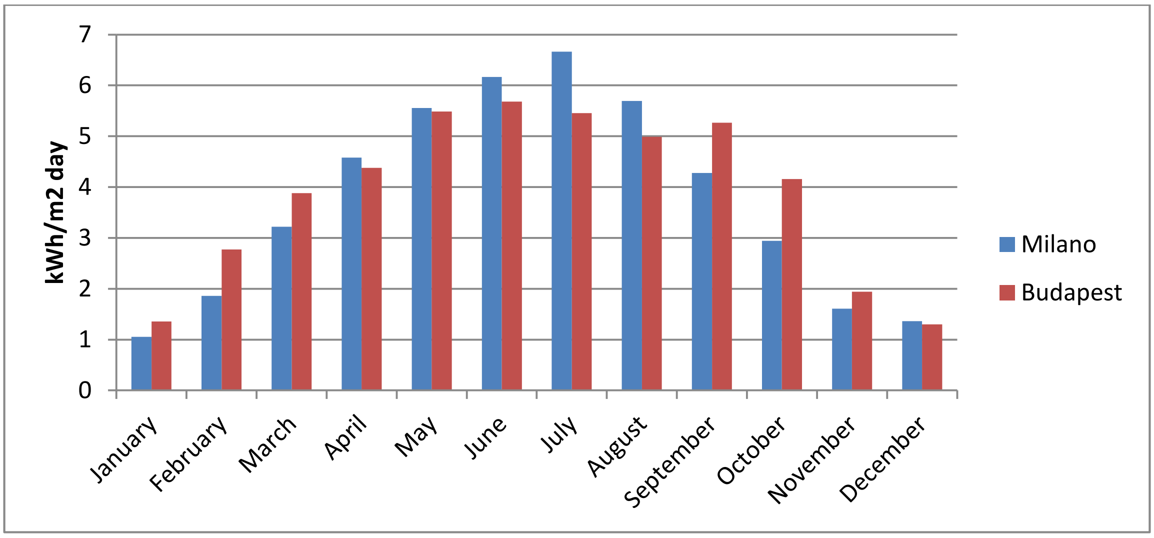


Figure 44 Monthly average solar radiation data

7.2.3 Solar radiation maps

In this chapter we show the solar maps for 2012 for Italy and Hungary

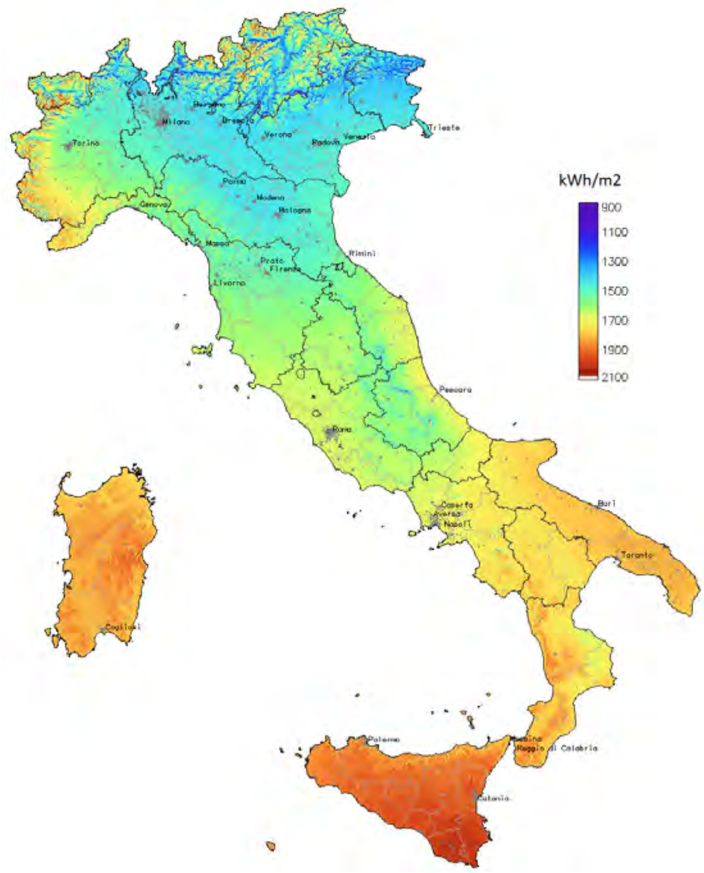


Figure 45 Solar radiation map of Italy

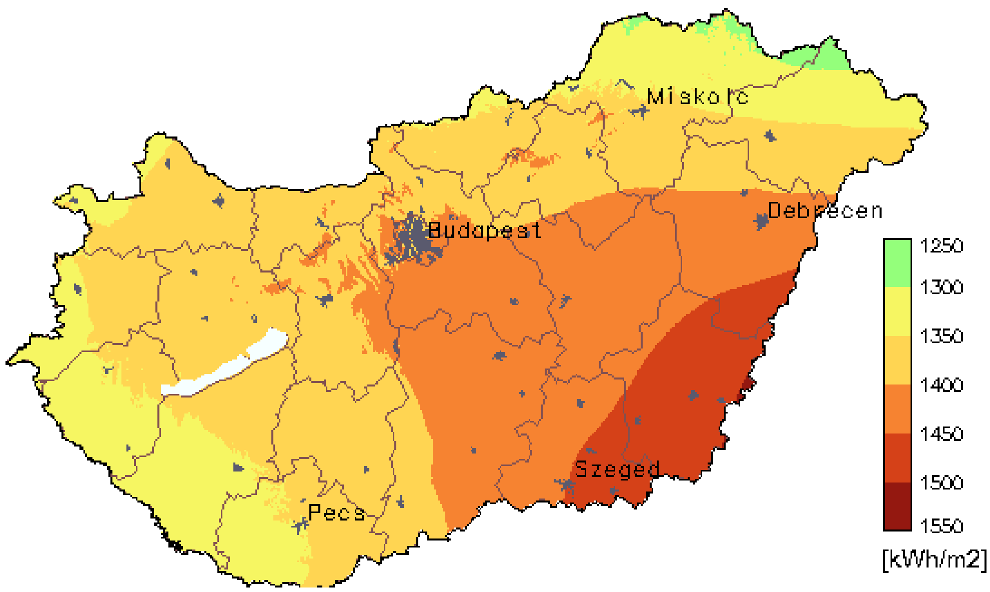


Figure 46 Solar radiation map of Hungary

7.2.4 Capacity and numbers of photovoltaic plants in Italy and Hungary

7.2.5 Growth of the solar technology in Italy

At the end of 2012 photovoltaic systems installed in Italy were 478331 with a gross maximum capacity equal to 16420 MW.

The park of photovoltaic systems consists mainly of plants incentivized through the Energy Bill and other installations , installed before the advent of this incentive , which in most cases have Green Certificates or other incentives.

In 2012, with continued growth of the systems installed, the consistency is increased to 148135 units , making a +45 % compared to existing installations in late 2011 and tripling the number of plants present in the end of 2010 on the national territory .

The installed capacity has reached 16420 MW. The greatest increase is noted , in percentage terms, for plants between 3 and 20 kW (+47 %) .

The average size of the plants has decreased from 38.7 kW to 34.3 kW of 2011 of 2012. The phenomenon is linked to the reduction in the installation of large systems determined by the Legislative Decree 1/2012 which placed restrictions regarding ground plants.

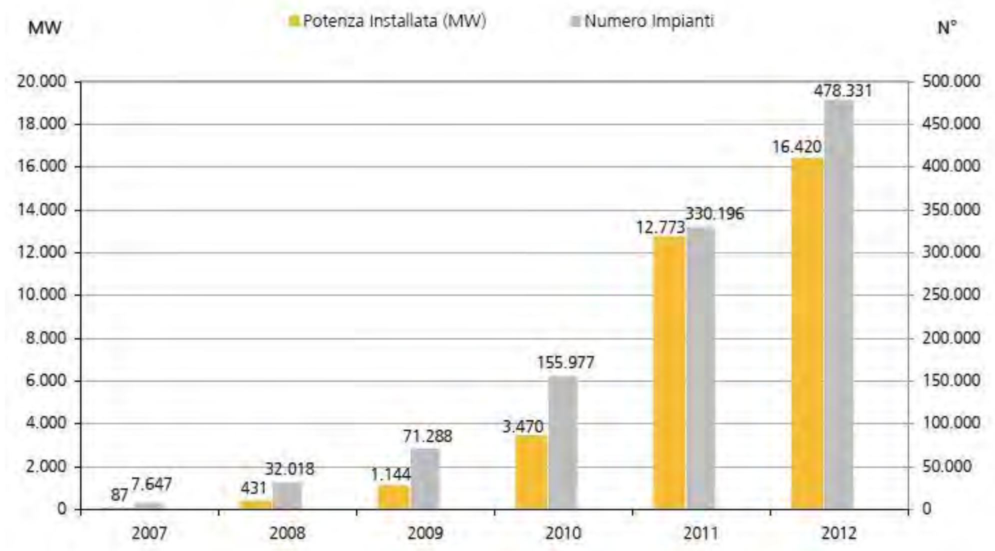


Figure 47 Evolution of power and number of photovoltaic plants in Italy

In the last few years the growth of the installed power and numbers of pv plants have followed a rapid increase. From 2008 to 2011, the number of photovoltaic systems has gone more than doubling from year to year. The growth in 2012 was rather less substantial percentage, the plants are 45% more than the previous year.

With regard to power, from 87 MW in 2007 has come down 16420 MW in 2012, 29% more compared to 2011.

The power has increased more than proportionally to the number, as it came into operation plants with larger capacity, this phenomenon is particularly evident until 2011, the year in which the size average grows to 38.7 kW.

In 2012 this trend has decreased and the average power was accumulated amounted to 34.3 kW; the plant began operating in 2012 have an average power equal to 24.6 kW, lower than plant began operating in both 2011, both in 2010.

7.2.6 Growth of the solar technology in Hungary

The use of solar energy in Hungary doesn't reach 1 percent in the total usage of renewable energy. Additionally, most of this is through solar collectors. Compared to other countries the Hungarian 1 MW of installed pv-systems is insignificant.

Most of the pv-panels and collectors are bought by private individuals, not by the public institutions or establishments. EU competition laws, KEOP (Environment and Energy Operative Program) tenders and other incentives are trying to change this tendency. State and Union-level support plays a central role in the spread of solar energy systems.

With the following graphs we want to show the growth of the solar power plants installed, showing it from few years ago since nowadays.

For the situation in Hungary regarding the growth of the solar energy we can show of the technology has developed during the years , through the following graphics:

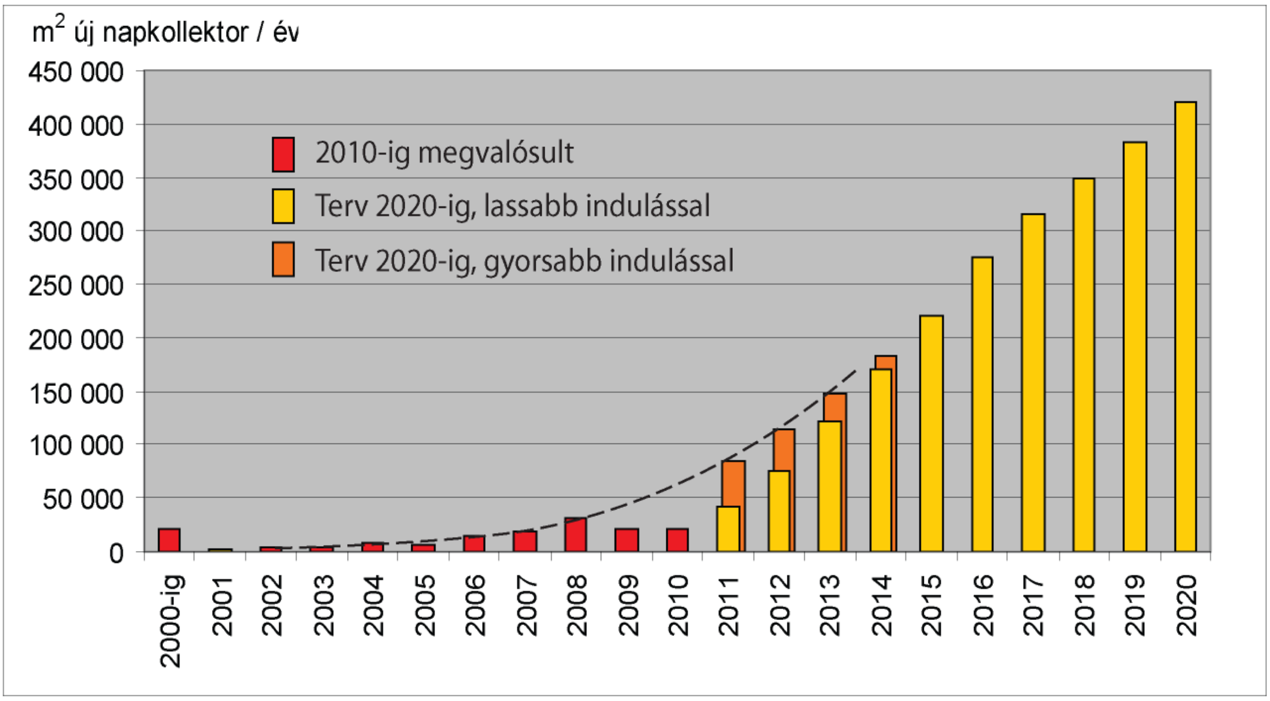


Figure 48 Amount of new solar systems implemented annually (m2 of new solar collector per year)

The following graph shows the growth plan to achieve in the year 2020:

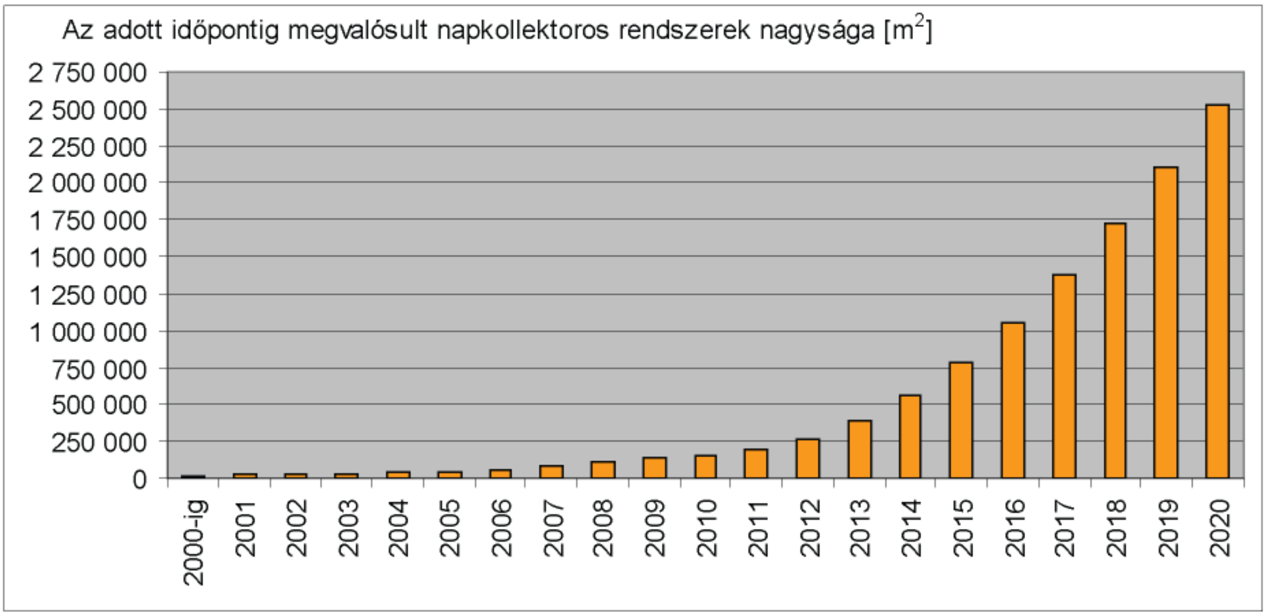


Figure 49 The size of the solar system implemented in 2020

The next one is about the production to be achieved for solar thermal energy systems in 2020:

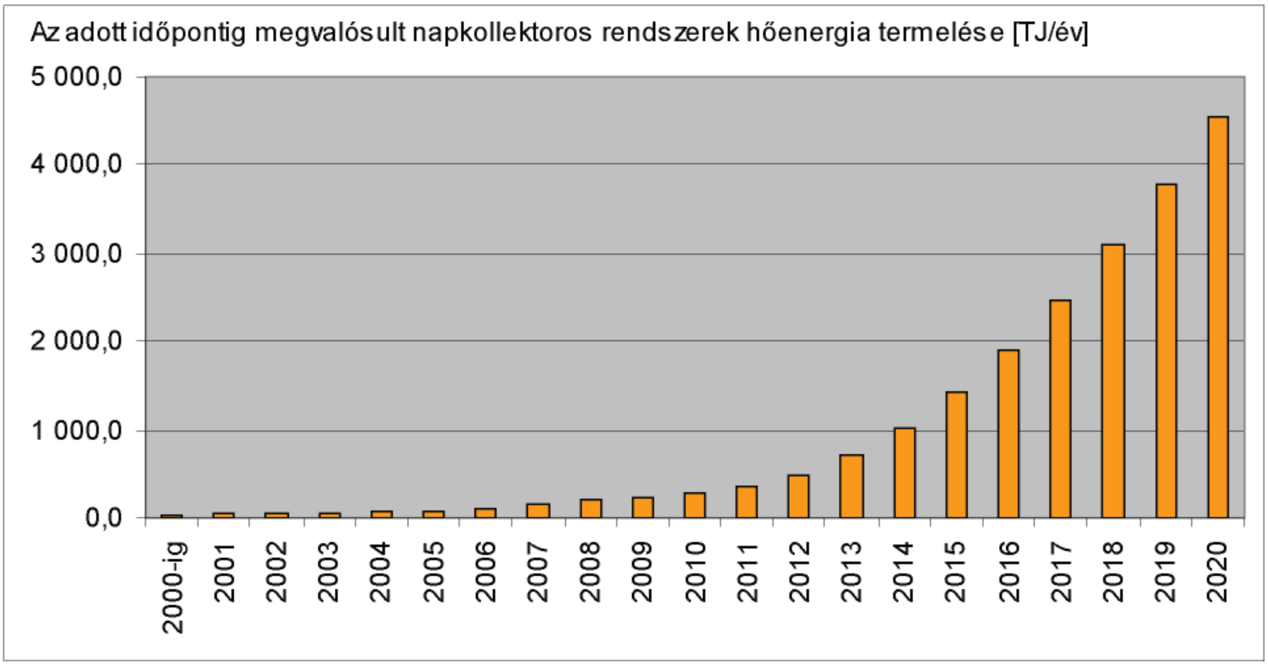


Figure 50 Amount of heat produced by the solar systems

8 Feed in tariff systems supporting renewable energies

8.1 European overview

The map shows the main incentive mechanisms for photovoltaic in Europe in 2012.
In the 27 European Union countries, the tariffs (feed-in tariff / feed-in premium) are implemented 22 countries including Italy. Poland, Romania, Sweden and Belgium encourage the production with the Green Certificates, while in Finland using other incentives.

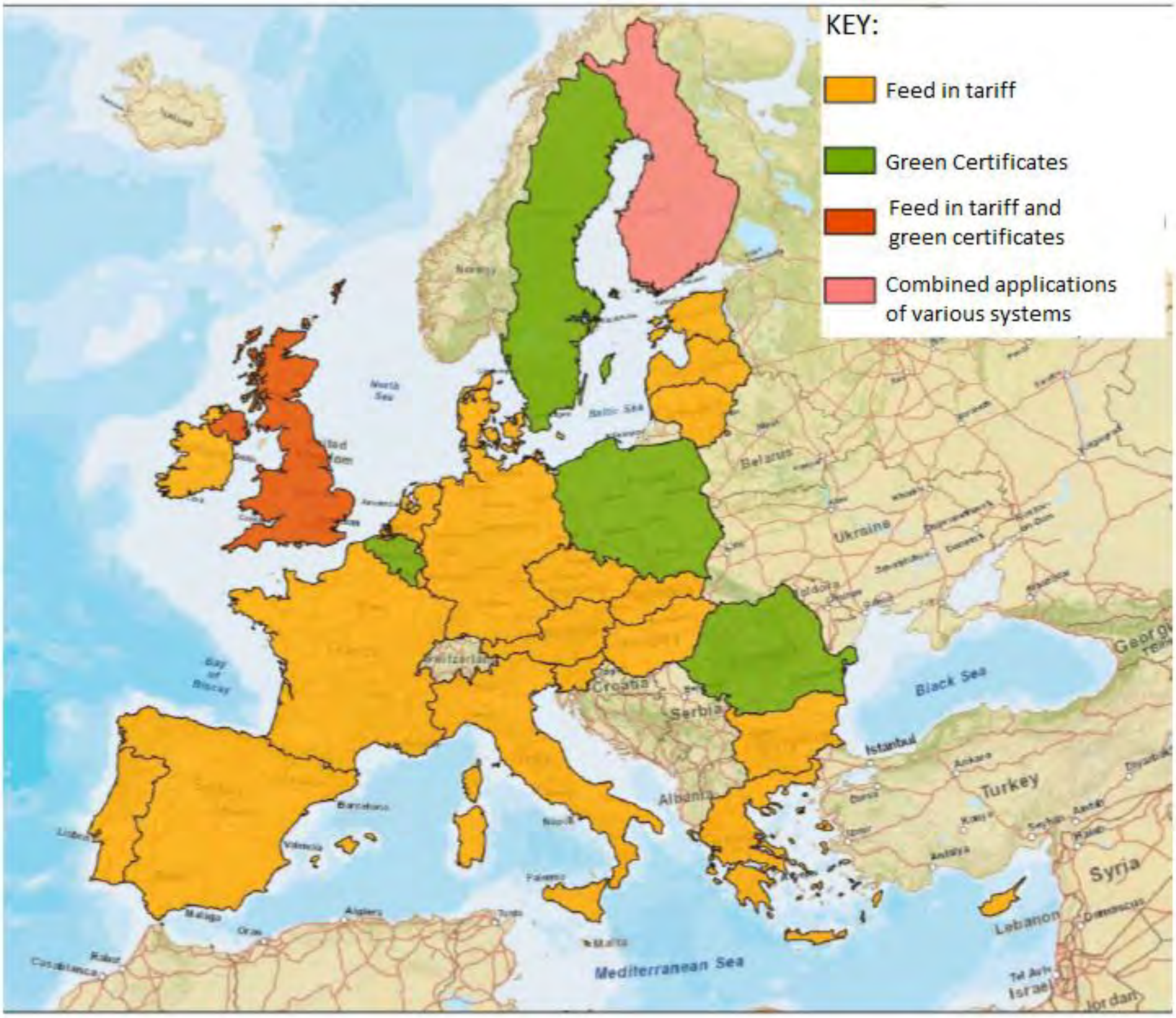


Figure 51 Subsidization system of EU member states

8.2 Italian's subsidization system: incentive and services for pv power plants

The GSE (Electric Market Manager) recognizes the incentives for the production of electricity from renewable sources and provides for the withdrawal of the energy fed into the grid and exchanged. Holders of solar photovoltaic systems can use the following incentives and / or services :

The feed in tariff is the incentive mechanism of production from solar energy introduced in 2005 and is currently regulated by the Ministerial Decree of 05 July, 2012 (Fifth feed in tariff).
The incentive is documented for the production of electricity from the date of entry into operation of the plant for a period of twenty years.
The rate is varied depending on the power and type of system and is constant throughout the incentive period .
The tariffs provided by the feed in tariff are different with respect to the exchange systems in place, dedicated withdrawal and sale of electricity to the market (for alone power plants up to 1 MW) .
Green certificates , introduced by Legislative Decree 79/99 , are issued by the GSE by the request of the producer, holder of IAFR plants came into operation on 1 April 1999, and by 31 December 2012, pursuant to the provisions of the Legislative Decree no. 28/2011 .
Dedicated withdrawal is a service that offers the GSE from 2008 to operators who request it . It is a simplified method for placing on the market electrical energy produced and fed into the grid through the intermediary of the GSE.
The photovoltaic plants incentivize with the first four feed in tariff can access at the dedicated withdrawal by entering into an agreement with the GSE for the withdrawal of all the energy fed into the grid .
The GSE authority recognizes at the producer the hourly price of electricity market in the area in which the plant is connected or rather the guaranteed minimum prices set by the Authority for Electricity and Gas for power plants with nominal power less than 1 MW and upon specific request by the party responsible at the time of signing of the agreement .
The power plants subsidize through the Fifth feed in tariff cannot access the withdrawal dedicated.
The exchange of electrical power on-site is a mechanism managed by GSE since 2009 for systems powered by renewable sources with power up to 200 kW (20 kW for those entering service until 31 December 2007).
The exchange on-site allows to enhance the energy fed into the grid according to a criterion of economic compensation with the value energy drawn from the grid.

8.3 Hungarian feed in tariff system

Hungary supports the fulfilment of energy and climate policy goals with numerous instruments. The support system consists of investment and operational support.
One form of operational support instruments – which is also applied in the country – is the feed-in tariff system ("KÁT"). This system supports renewable electricity production and waste-to-energy. The main goal is to eliminate the competitive disadvantage of these forms of electricity production in comparison to the other, mainly fossil based generation technologies. In the feed-in tariff system, eligible electricity producers get pre-defined feed-in tariffs by law for the generated electricity sold in the feed-in tariff system. These tariffs are higher than the electricity market price (except for large hydro power installations above 5 MW installed capacity). On the other hand the responsible party for the so called KÁT balance group has to buy this electricity at the pre-defined

feed-in tariffs. This subsidy form means that the supported producers are segregated and protected from the free electricity market. Eligible producers do not have to compete neither within the KÁT balance group nor with the other market players from outside the group.

The Act LXXXVI. 2007 on Electricity (hereafter Electricity Act) contains the framework conditions of the KÁT system, while more detailed rules of operation can be found in Government Decree No 389/2007 (XII. 23.) (hereafter KÁT Decree), and the Decree of the Minister for Economy and Transport No 109/2007 (XII. 23.) (hereafter Distribution Decree).

Based on the Electricity Act, the Hungarian Energy and Public Utility Regulatory Authority (hereafter Authority) determines in its decision the feed-in quantity and feed-in period for each eligible electricity producer. (Fossil fuel based cogeneration is not eligible for KÁT since the 1st of July 2011). The producers can sell in the KÁT system until the feed-in period expires or until the feed-in quantity is used up. The determination of the KÁT period and quantity is to ensure that the producer only gets support until his investment is returned. (In the case of biomass and biogas plants the benchmark feed-in period is 15 years, for landfill gas 5 years. If there is any other kind of support than these periods are shortened proportionally. For other technologies the feed-in period is determined individually.)

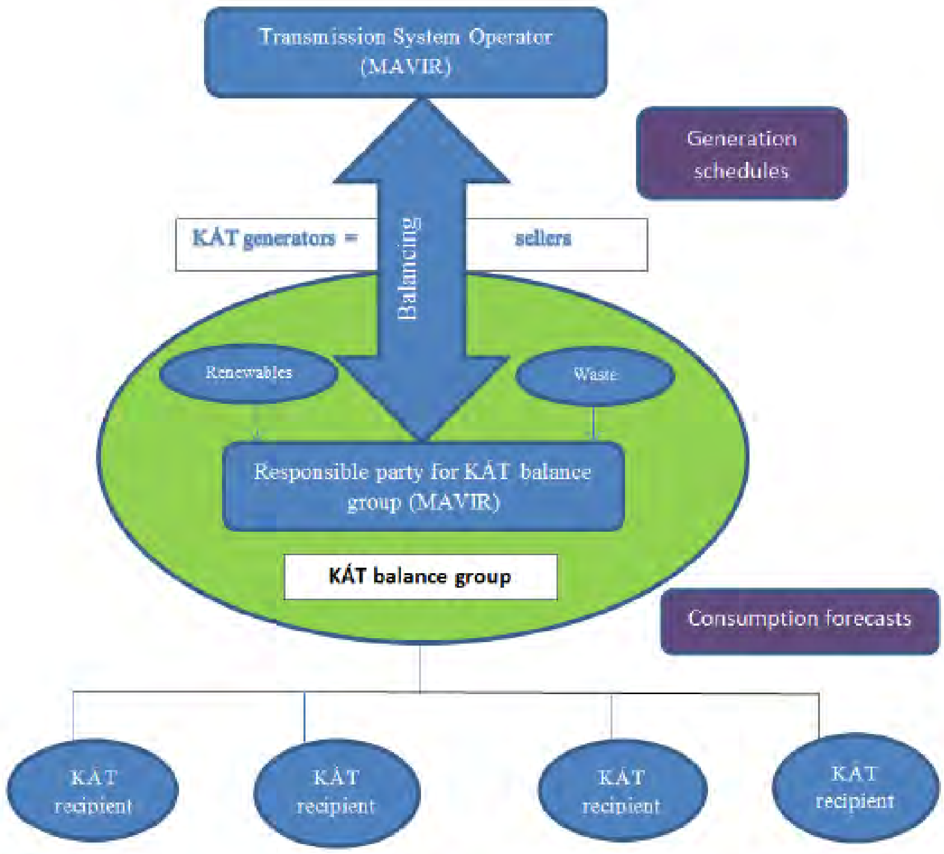
Feed-in tariffs are different for renewable electricity and waste-to-energy, furthermore tariffs are differentiated by size (nominal capacity), time of commissioning (before or after the 1st of January 2008), time zone (peak, valley and deep-valley period), as well as by technology (solar and wind energy get slightly different tariffs). The feed-in tariff is adjusted with the rate of Hungarian Consumer Price Index of the previous year for those renewable generators who were commissioned before the 1st January 2008. For waste-to-energy producers and those renewable producers who were commissioned after the 1st of January 2008, the price contains also an efficiency factor, so the adjustment factor is equal to the value of the consumer price index of the previous year reduced with one percentage point.

8.3.1 The operation of the KAT balance group

The so called KÁT balance group is the basis of the operation of the KÁT system, which works in its present form since January 2008. Apart from the Electricity Act, the KÁT Decree and the Distribution Decree regulate the operation of the balance group. According to the Electricity Act, the power plants which produce electricity eligible for KÁT support form a separate balance group, whose responsible party is the transmission system operator (MAVIR Ltd).

The tasks of MAVIR are to operate the KÁT balance group, to balance the deviations from the schedule, to buy the electricity eligible for KÁT support and to distribute (resell) it to KÁT recipients.

The following picture illustrates the operation of the system:



Electricity producers eligible for KÁT support are entitled to join the KÁT balance group after contracting with the responsible party (MAVIR). The MAVIR pays the feed-in tariff to the producer for the electricity sold into the balance group then distributes this electricity and its cost among obligated electricity suppliers in the proportion of their customers' forecasted consumption (except for universal service providers with regulated electricity prices who do not have to receive this electricity from the 1st of January 2013). The obligated suppliers take this additional costs into account when they price their products, so finally their consumers pay for the KÁT support.

9 Software SMA: Sunny Design 3

9.1 Introduction

Sunny Design is a software for planning and designing PV plants. Sunny Design offers recommendations on possible designs for your PV plant. Sunny Design also suggests a combination of PV array(s) and inverter(s) that are the closest to your requirements for your planned PV plant, especially in regard to performance class and energy yield.
You can also let the program estimate your potential self-consumption of the energy generated by the PV plant and show it in a chart.

9.2 Purpose of this project

The objective of this work is to implement with the help of the SMA software, a case of study comparing two different situations, here follows the main features:

Location	Verona	Debrecen
Azimuth Angle	0°	0°
Tilt Angle	30°- 40°- 45°	30°- 40°- 45°
Type of load profile	Private Household 4 people	Private Household 4 people
Type of installation	Roof	Roof

9.3 Overview of the software

In this section we'll explain briefly how the software works, showing the main characteristics and functionalities.
The most important Sunny Design functions are:

- Plan projects in compliance with all legal and industrial requirements. Try different layouts and choose from all SMA inverters.
  - Simple PV plants, e.g. with one or multiple PV arrays that are arranged in the same way
  - Complex PV plants, e.g. with multiple PV arrays that are arranged differently
  - PV plants with three-phase feed-in and a user-defined unbalanced load limit
  - PV plants taking country-specific requirements into account, e.g. inverter types or line voltage
- Create project documentation with standard values for projects
- Detect potential self-consumption of PV energy and show it in a chart

- Create own site with help from meteorological data from the Sunny Design database or imported meteorological data
- Create own PV modules
- Automatically check operation data of the planned PV plant
- Cable dimensioning

1. First section:

In the first section of the software is possible to set the general parameters about the project, for example the name of the project, location and grid voltage.

It’s interesting to pay some attention ,in this part, focus on the temperature settings; the software , after having chosen the location, gives automatically the values of minimum and maximum temperature of the place set (Milan: min -5°, max +26° ; Budapest min -14°, max +22°).

The user has the possibility to change this values, according to the climate data of the place; the effect of the modifications of the previous values are the following:

- decreasing the minimum temperature causes an increasing of the maximum voltage value of the pv modules
- increasing the parameter called “annual extreme high temperature” causes a decrease of the minimum voltage value of the power plant

this aspect has to be taken in consideration when we have to choose the inverter and take notice of the MPPT.

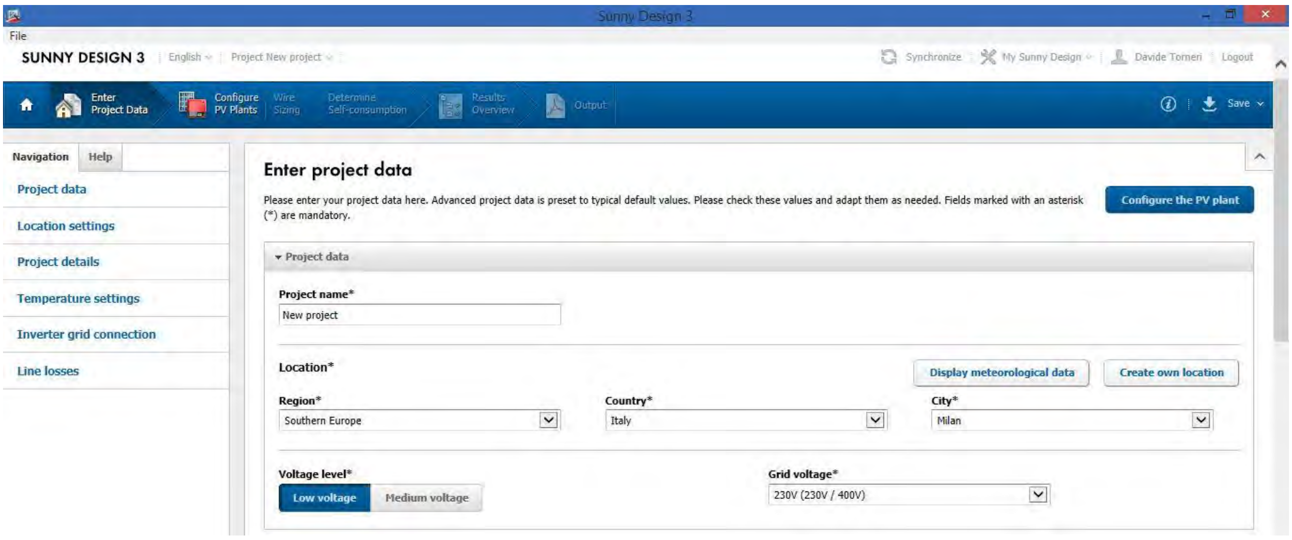


Figure 52 Enter project data section

2. Second section

Here the user can configure the pv power plant; the software allows to select the pv modules from a database with different brands or even is possible to create our own pv module.

Going on we have to select the number of pv modules, orientation and mounting type.

After there is the inverter design section, always possible to choose from a database with hundreds of different types , but usually is recommended to make a choice of the suggested and automatic design, and the software gives all the details of the Inverter selected from nominal ratio performance to voltage parameters.

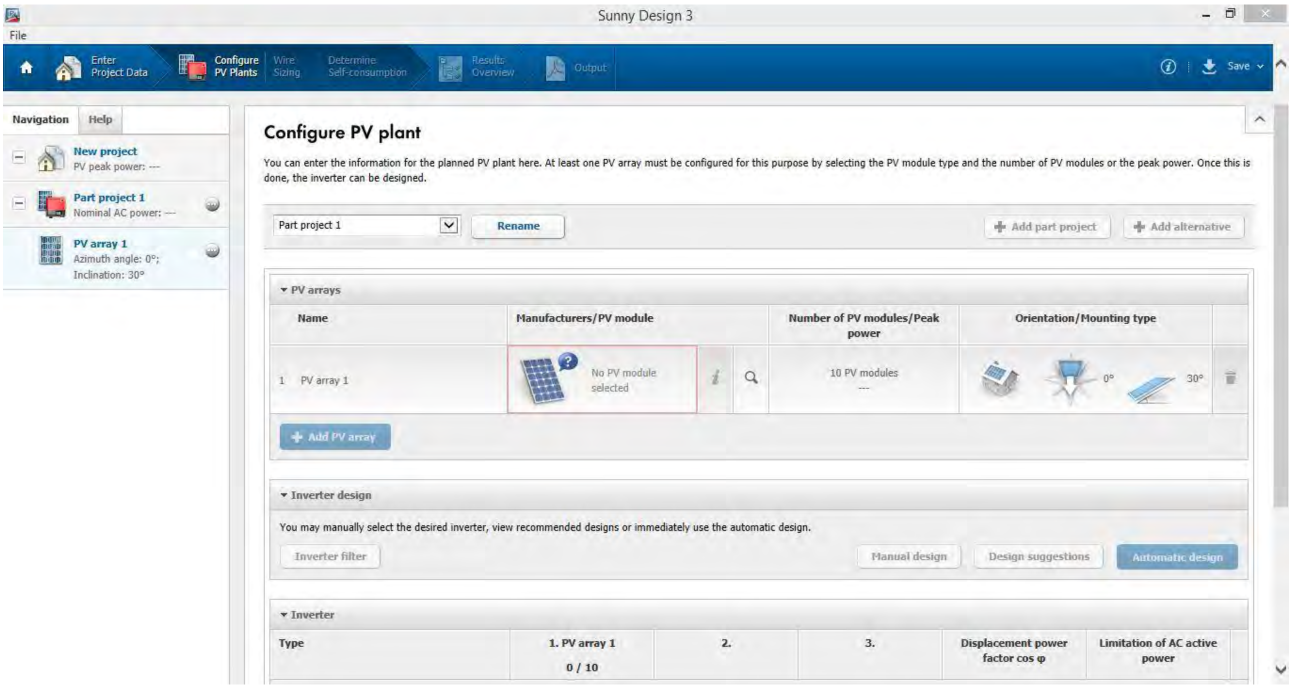
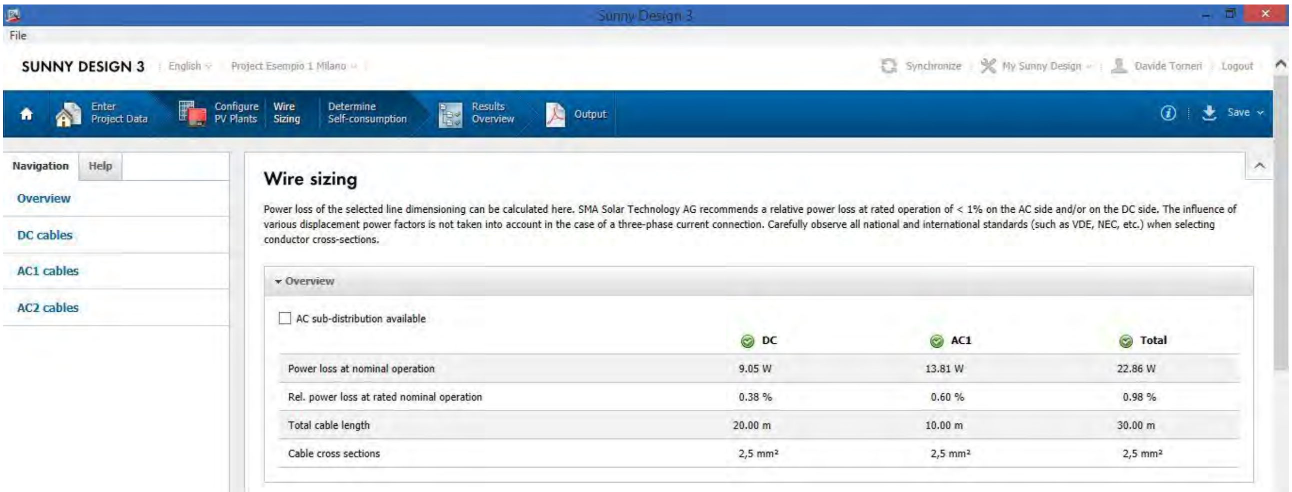


Figure 53 Configure PV plants section

3. Third section

Here is possible to configure the wire material, length and section and the software calculate the power loss of the selected line.



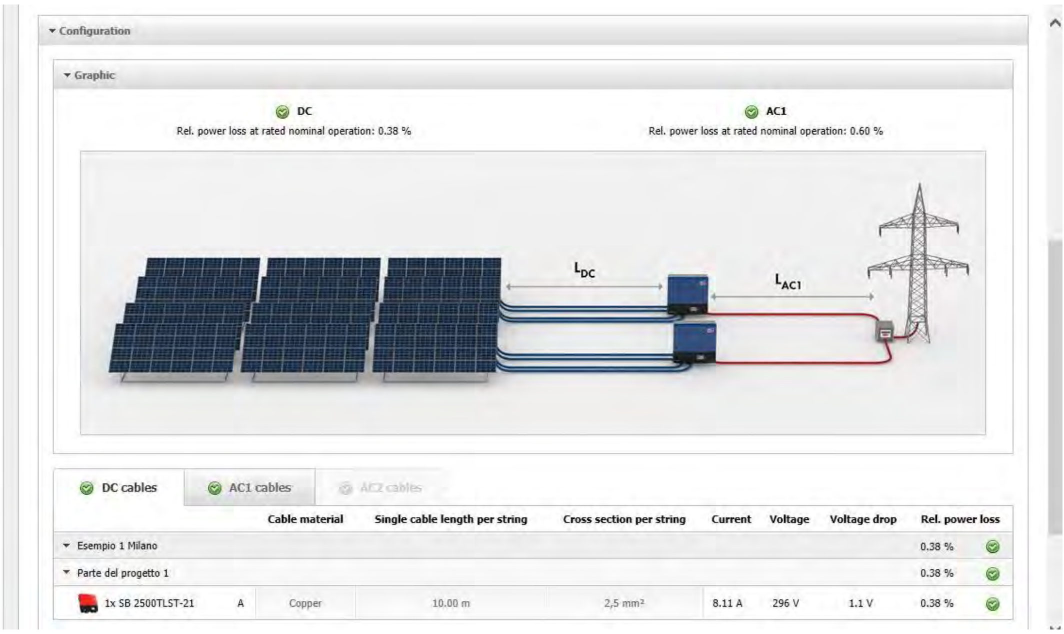


Figure 54 Wire sizing section

4. Fourth section

Here you can determine your possible self-consumption of the produced PV energy here entering the yearly energy demand.

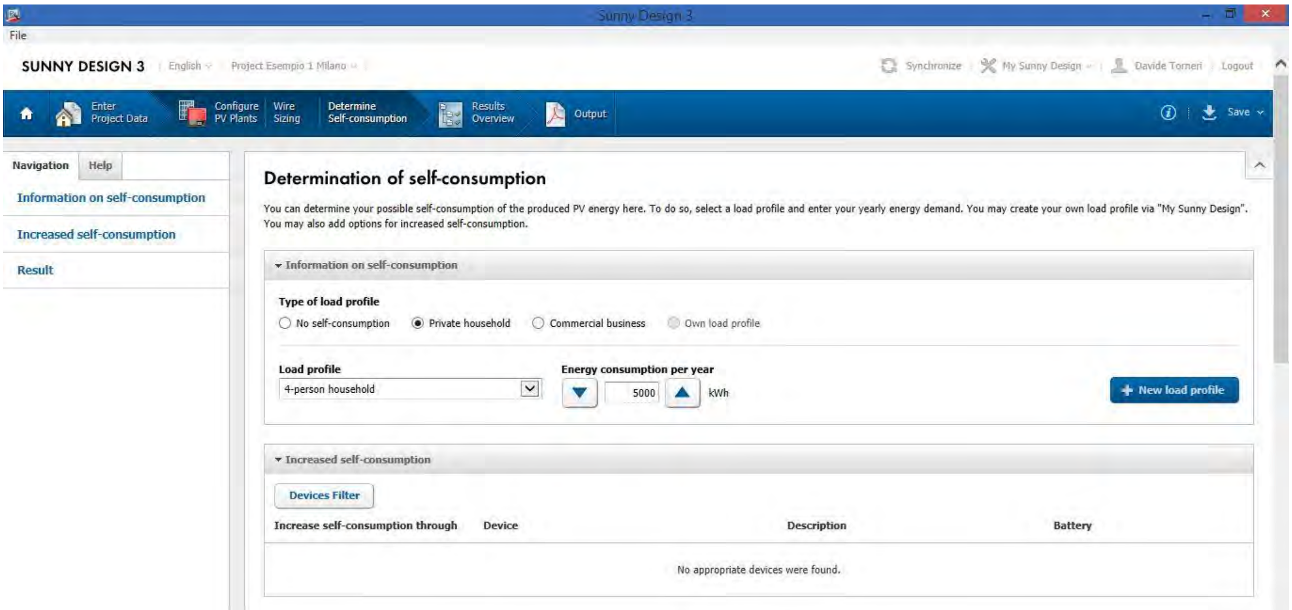


Figure 55 Self-consumption section

5. Fifth section

The final section shows the entries, results and current information on the design of the PV plant.

10 Details of the two houses in object of study

10.1 Verona

The flat in study is located nearby Verona precisely in the hill's side of the city; the main geographical characteristics are:

- Coordinates: 45°39'11" N – 11°07'21"E
- Altitude: 509m

10.1.1 Architectural characteristics

In this paragraph we'll show the characteristics of the flat, from the construction materials and the related thickness to a simple 3D model just to make the ideas clear about the object in study.
Basically is about a flat on one floor with two bedrooms, two little bathrooms, one kitchen shared with the living room and one little studio room.
The following table shows all the details.

WALL-1	Thickness [m]	Density [kg/m3]	Conductivity [W/mK]	Specific Heat [kJ/kg K]	Thermal resistance
Plaster	0,01	1400	0,7	0,84	0,01
Masonry	0,4	2000	1,17	0,84	0,34
Styrofoam	0,05	30	0,04		1,25
Plaster	0,01	1800	0,9	0,84	0,01
TOTAL	0,47				1,62

WALL-2	Thickness [m]	Density [kg/m3]	Conductivity [W/mK]	Specific Heat [kJ/kg K]	Thermal resistance
Plaster	0,01	1400	0,7	0,84	0,01
Masonry	0,4	2000	1,17	0,84	0,34
Styrofoam	0,05	30	0,04		1,25
Plaster	0,01	1800	0,9	0,84	0,01
TOTAL	0,47				1,62

WALL-3	Thickness [m]	Density [kg/m3]	Conductivity [W/mK]	Specific Heat [kJ/kg K]	Thermal resistance
Plaster	0,01	1400	0,7	0,84	0,01
Masonry	0,4	2000	1,17	0,84	0,34
Plaster	0,01	1400	0,9	0,84	0,01
TOTAL	0,42				0,37

WALL-4	Thickness [m]	Density [kg/m3]	Conductivity [W/mK]	Specific Heat [kJ/kg K]	Thermal resistance
Plaster	0,01	1400	0,7	0,84	0,01
Masonry	0,6	2000	1,17	0,84	0,34
Plaster	0,01	1400	0,7	0,84	0,01
TOTAL	0,62				0,54

FLOOR	Thickness [m]	Density [kg/m3]	Conductivity [W/mK]	Specific Heat [kJ/kg K]	Thermal resistance
Ceramic Tile	0,01	2300	1		0,01
Basement cement + sand	0,04	1900	1,2		0,03
Soundproof	0,01	1600	0,17		0,06
Piling	0,05	400	0,15		0,33
Concrete Base	0,2	1220	0,606		0,33
Plaster	0,01	1400	0,7		0,01
TOTAL	0,32				0,78

FALSE CEILING	Thickness [m]	Density [kg/m3]	Conductivity [W/mK]	Specific Heat [kJ/kg K]	Thermal resistance
Spruce Wood	0,025	450	0,12		0,21
polystyrene	0,05	35	0,035		1,43
TOTAL	0,08				1,64

Afterwards we have a simple 3D model showing the main characteristics including specially the thick of the walls:

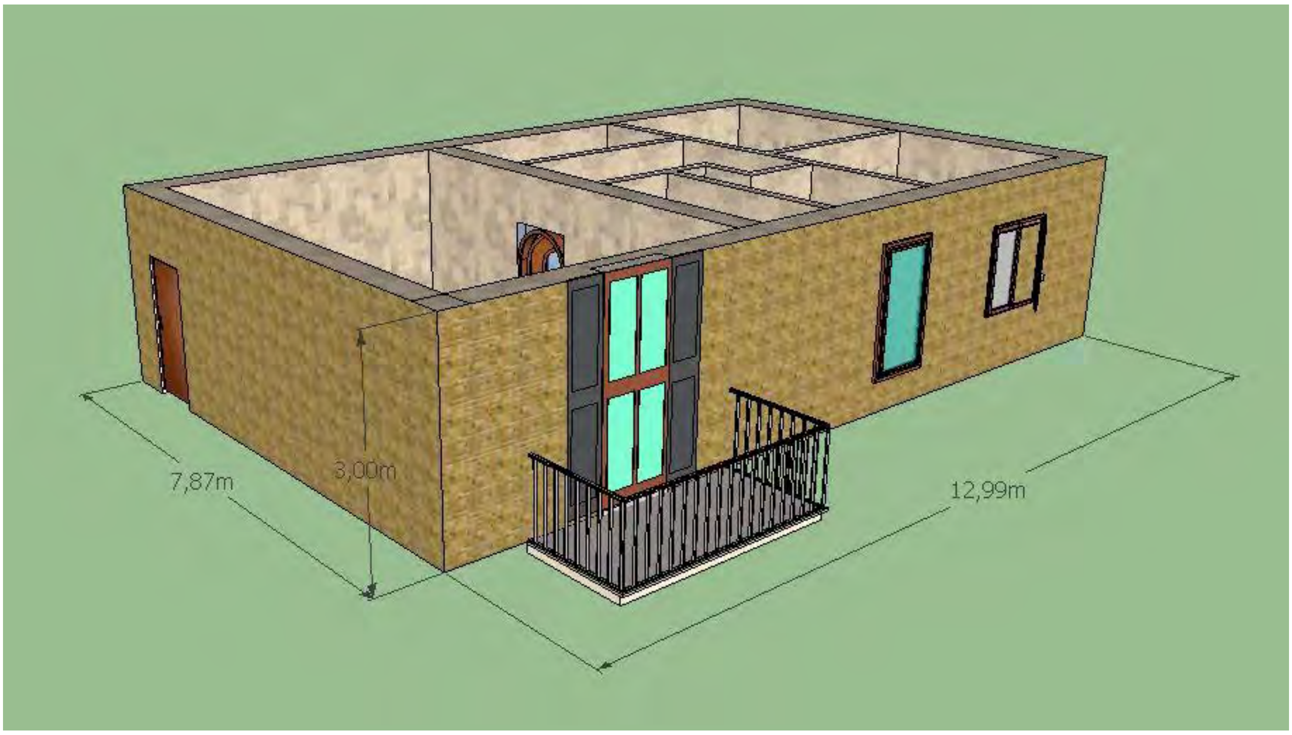


Figure 56 Perspective of the flat

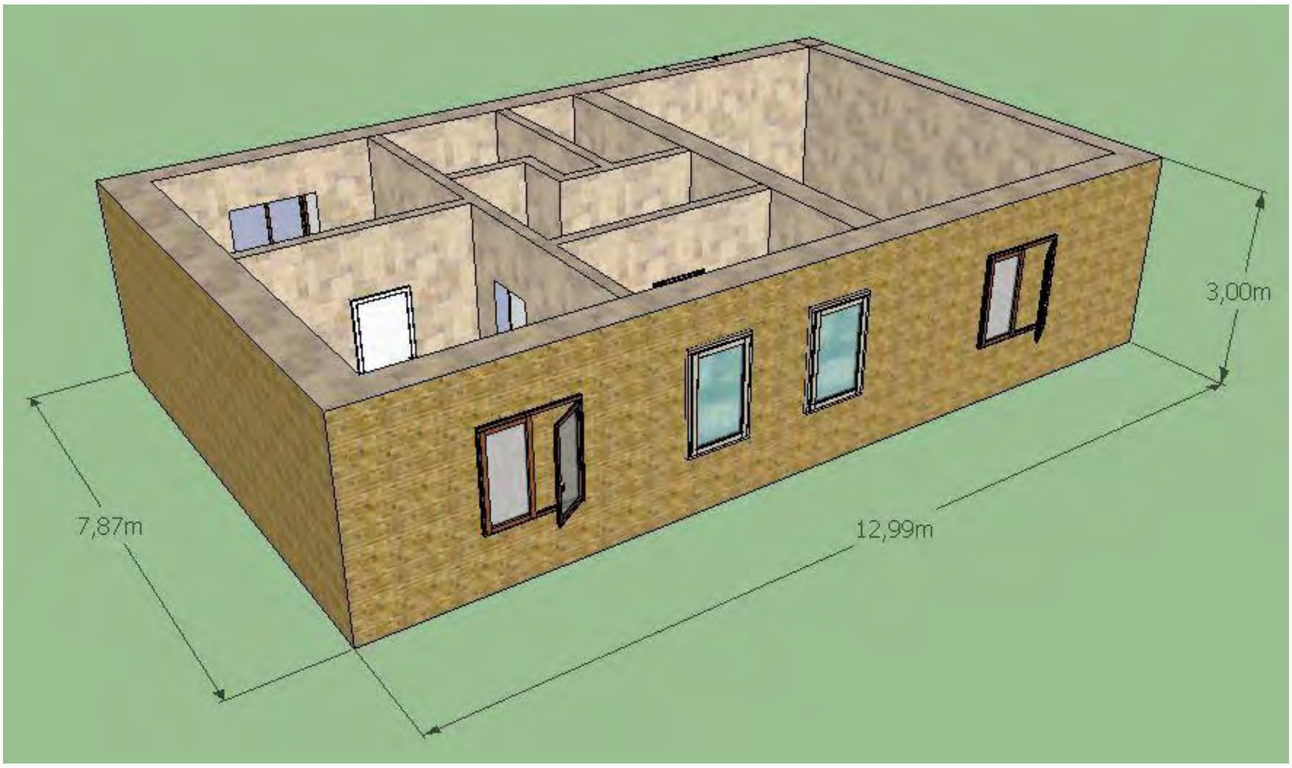


Figure 57 Perspective of the flat n°2

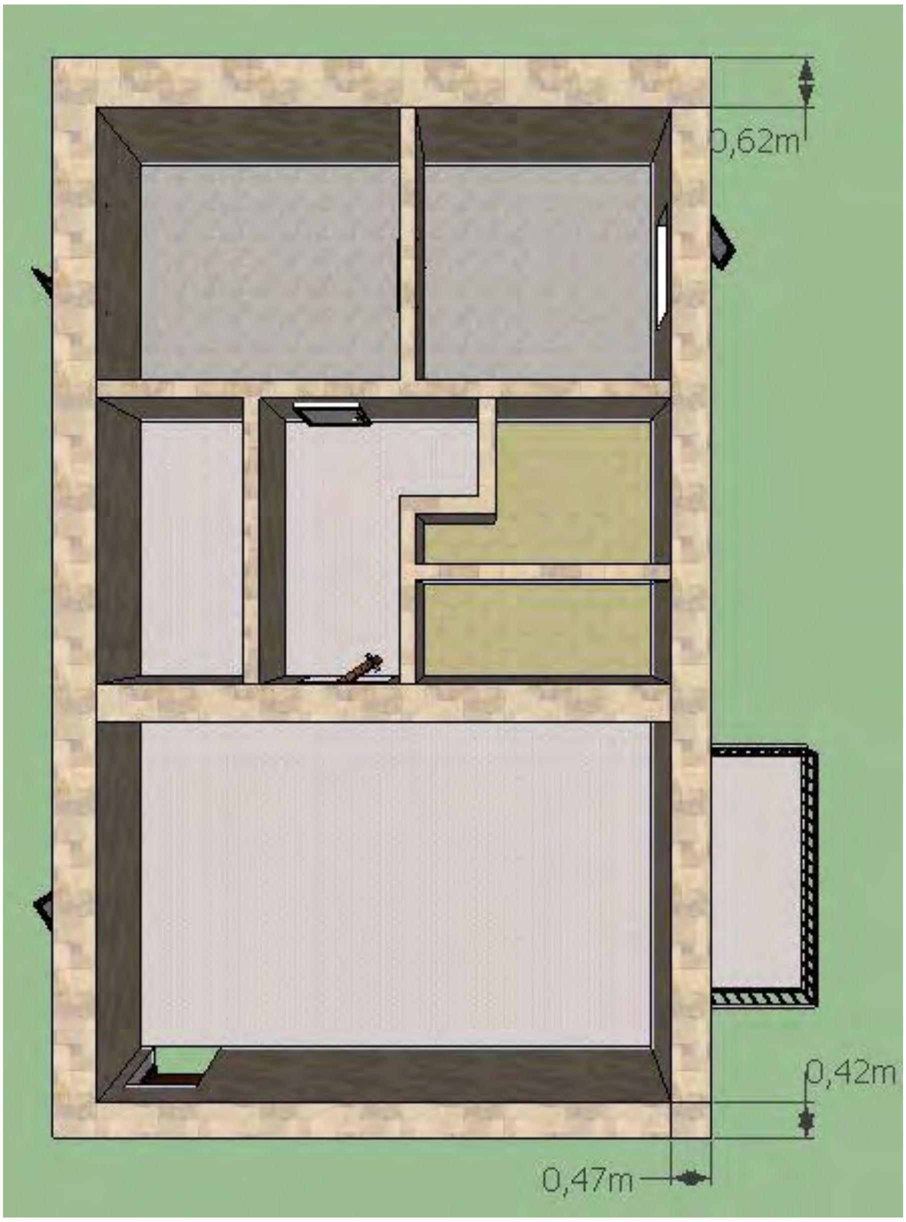


Figure 58 View from the top

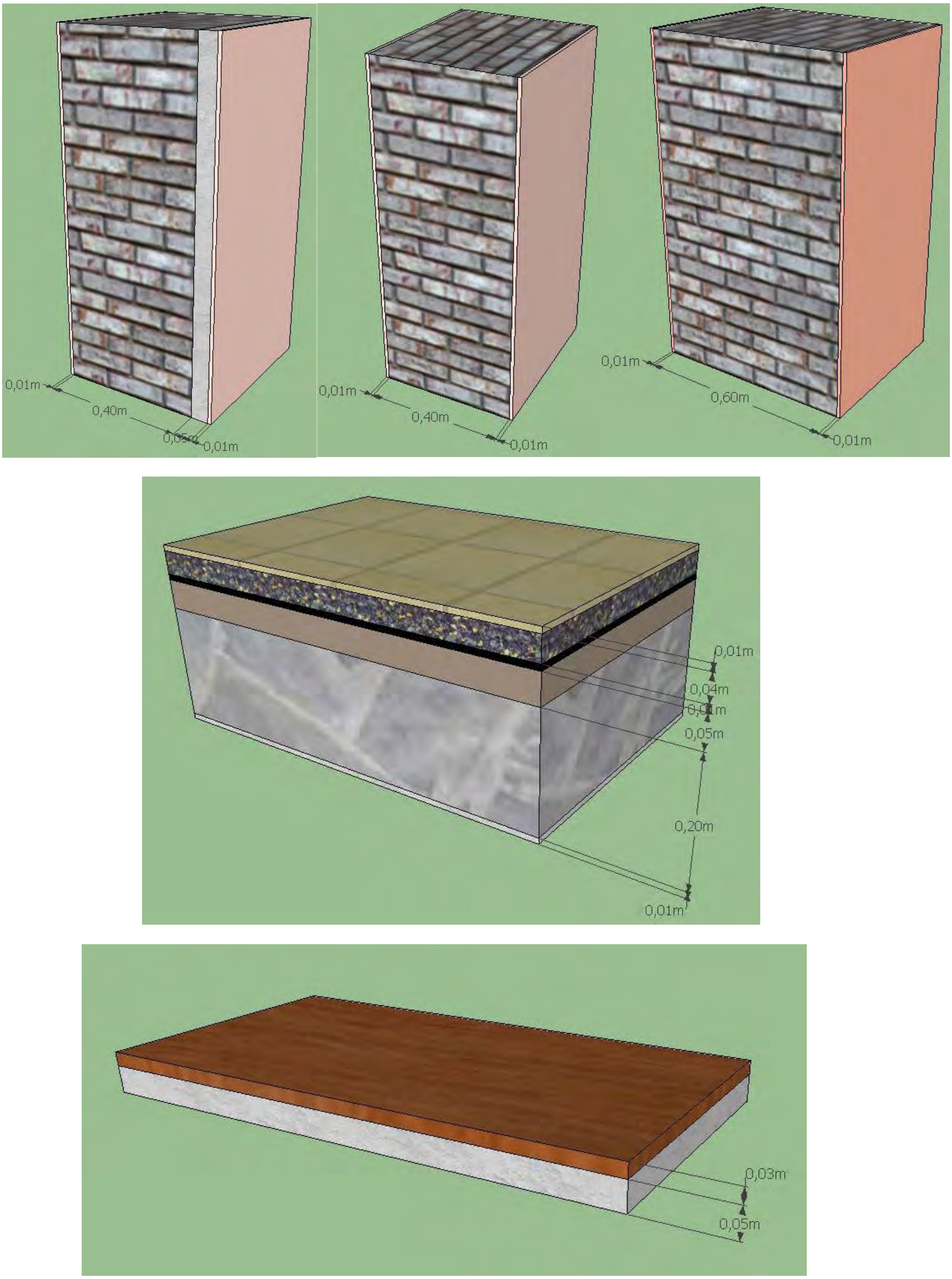


Figure 59 Details of the walls , floor and false ceiling

10.2 Debrecen

Here the house is located nearby the centre of the city of Debrecen and the main geographical characteristics are:

- Coordinates: 47°31’48”N - 21°38’21”E
- Altitude: 108 m

10.2.1 Architectural characteristics

In this case the house was built recently , so far it is quite new. Due to the different and more rigid winter season , the structure of the walls are basically more massive with a larger thickness of insulation material.
Precisely this house has 10cm of insulation material , which is polystyrene.
The area covered by the basement is 170m2 and all the walls have the same shape.

Furthermore the house has integrated a solar power plant, or rather one PV power plant and one for the domestic hot water.
The details of the PV power plant are given in the following table:

Manufacturing	**Haunghe Solar**
Model	**HH 190(36)M**
Maximum Power	190 Wp
Voltage at maximun power	36,5 V
Current at maximum power	5,21 A
Open curcuit voltage	44,5 V
Short circuit voltage	5,52 A
Panel efficency	14,90%
Power tollerance	3%
Cell type	Monocrystalline
Cell size	125X125mm
Cell number	72
Glass type&thickness	Tempered 3,2mm
Frame type	Anodized Aluminium Alloy
Junction box protection class	IP65

Table 1 Details of the PV module

Number of modules	20
Total installed power	3.8 kWp
Number of inverters	1
Orientation	45° WEST

Table 2 Details of the power plant

Here we have some photos of the house, in particular is shown the solar plant:

Figure 60 Photo of the house in Debrecen

The structure of the walls are all the same, here it's shown a 3D model of the wall:

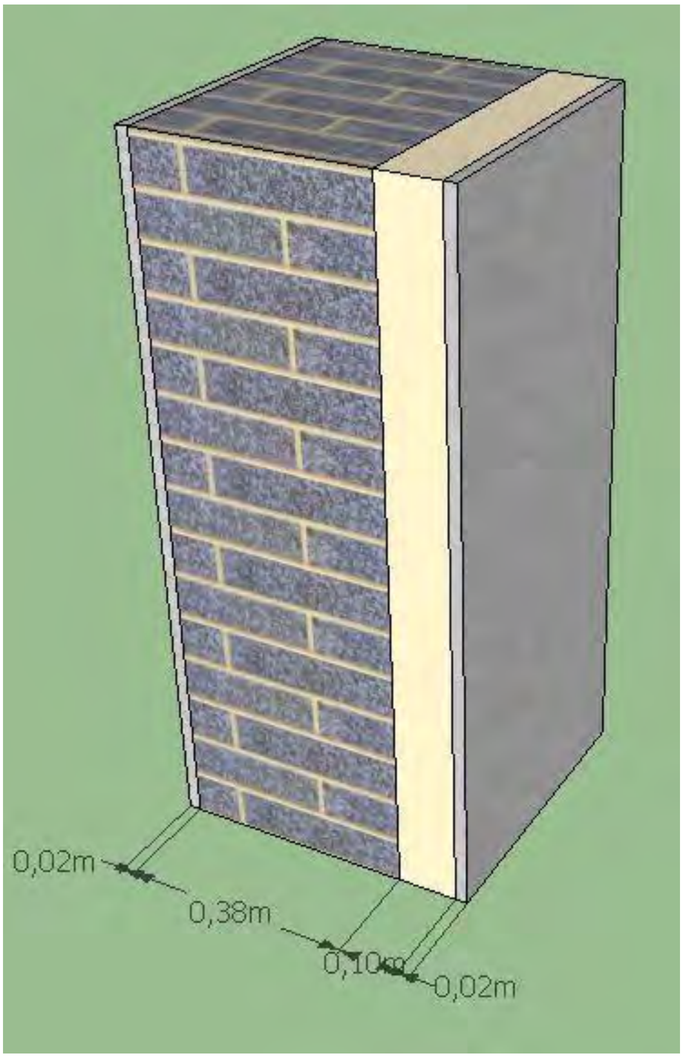


Figure 61 Structure of the wall

Wall					
Material type	Thickness [m]	Density [kg/m3]	Conductivity [W/mK]	Specific Heat [kJ/kgK]	Thermal resistence
Plaster	0,02	1400	0,7	0,84	0,03
Masonry	0,38	2000	1,17	0,84	0,32
Insulation	0,1	30	0,04		2,5
Plaster	0,02	1800	0,9	0,84	0,02
TOT	0,52				2,88
U value	0,328 [W/m2K]				

Table 3 Construction material characteristics

10.3 Project data

In this first section we're going to set the general project data, from the name to the meteorological data of the location.
In particular is possible to configure our own location through importing external meteorological data from an .epw file. In this case are available the data for the two selected location.

10.3.1 First configuration: Verona - Debrecen 30°

The first step is to create our own location, opening the configuration setting the main points to set are:

- Setpoint for the orientation of the PV array
  - Setpoint tilt angle: 30°
  - Setpoint Azimut: 0°
- Nominal power ratio:
  - Is defined as Maximum input power of the inverter / Nominal power of the PV array in standard conditions. Nominal power ratio for Southern Europe (optimally aligned) is approximately 90%.
- Inverter grid connection:
  - Low voltage with a line voltage of 230V 50Hz
  - Single phase feed in forasmuch as the pick power is 3.8 kW.

Here are shown the meteorological data of Verona and Debrecen, in particular we have the global radiation in kWh/m2y and the ambient temperature:

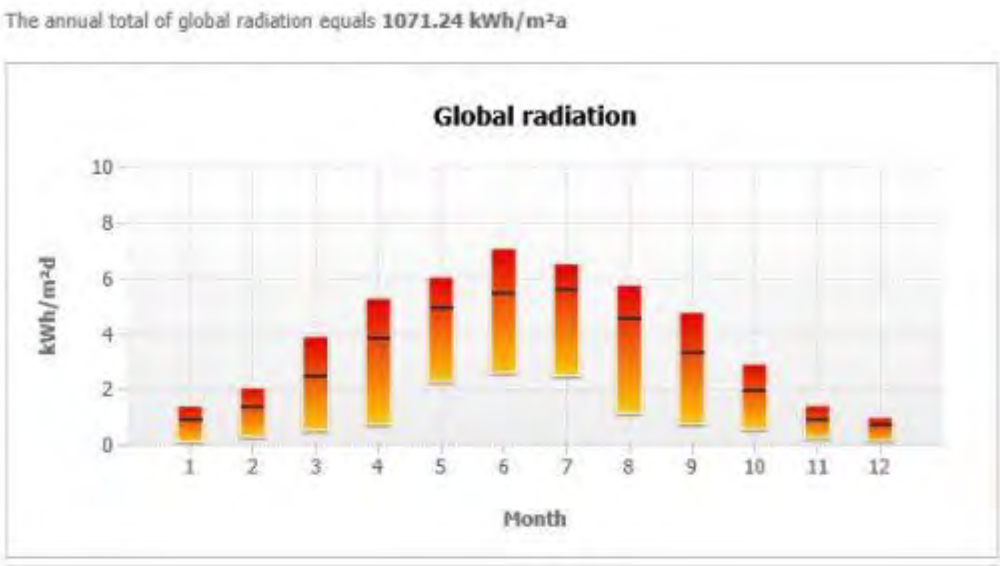


Figure 62 Global radiation of Verona

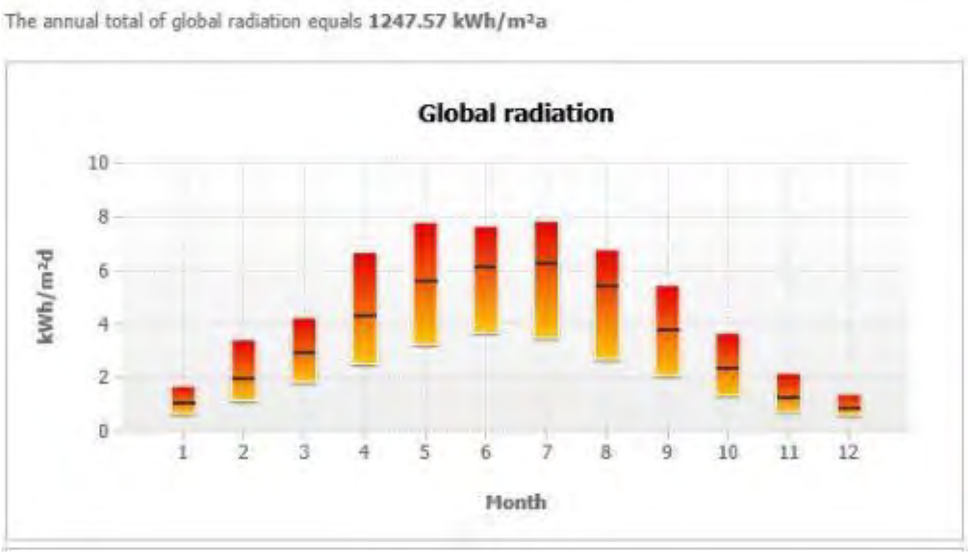


Figure 63 Global radiation of Debrecen

As we can see Debrecen has around 200 kWh/m2y more than Verona, not a big difference but it could be an interesting fact to take into account.

Moreover, always with the data given from the epw file, we can show in a similar chart the temperature of the ambient:

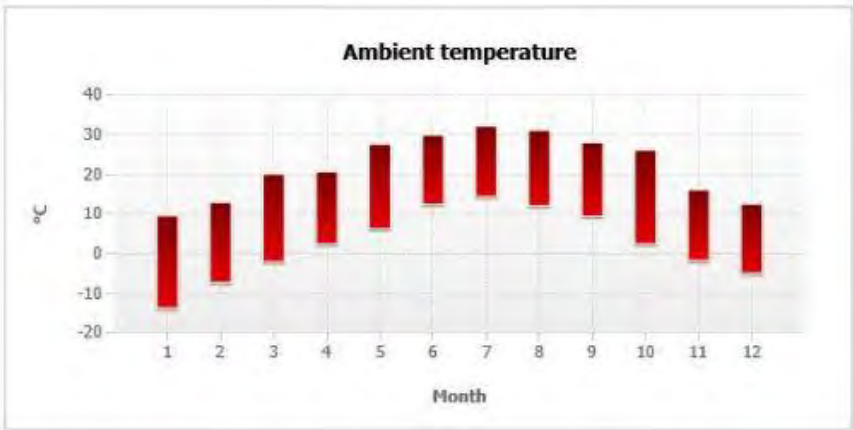


Figure 64 Verona's ambient temperature

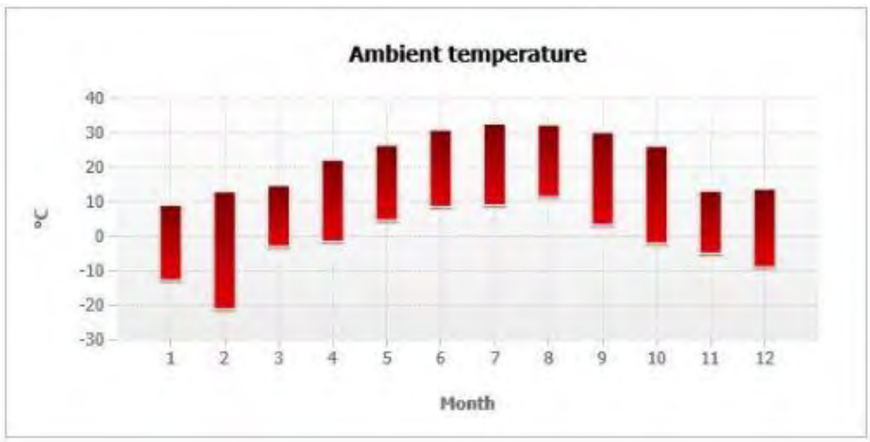


Figure 65 Debrecen's ambient temperature

Regarding the temperature we have a significant difference between the two locations, in particular the lowest value shown in this charts is around -20° C for Debrecen and more or less -10°C for Verona, so ten degree of difference.

10.3.2 Define load profile

We have now to set the load profile , or rather the annual energy demand. We need this value to calculate and estimate how much of the total energy produced from the power plant goes into the national grid and the rest is used to supply the demand of the household.
It's acceptable to estimate the electric requiring energy through take into account the main electric appliances hold in the house.
So in the next table we had guesstimate the energy demanded from the principal appliances:

Type of electrical equipment	Nominal Power (kW)	Average or estimated usage	Energy consumption kWh/year
Fridge	0,15	-	295
Electric Oven	1,875	0,5hours/day	342
Television	0,12	6hours/day	263
Washing Machine	2,3	4 washing per week at 60°	300
Dishwasher	2	4 washing per week	330
Illumination	0,3	4 hours/day	438
Total energy consumption per year = 1968 kWh/y			

Table 4 Energy demand

As a precautionary value we chose as the annual energy demand 2000 kWh/y.

10.3.3 Configuration of the PV plant

The purpose of this project is to highlight the main differences between the capacity of the same power plant mounted in two different localities. Due to this reason we have decided to chose the following configuration of the plant:

- 20 PV modules each have a nominal power of 190 W
- The manufacturer is Huanghe Solar

Later on one the strong points of this software is that it can do an automatic design or it can suggest the optimal configuration of the Inverter.
The choice of the project is not a stand-alone power plant but we have a self consumption and the rest of the energy produced is transmitted to the grid.
So choosing an automatic design of the inverter the software gives us this option; Inverter SB 3000TLST-21.
In the two following tables we have all the details and characteristics about the pv module and the inverter.

Information on PV modules

The data from the manufacturer's datasheet has been applied. No responsibility is assumed for the correctness of this information.

Manufacturer	Huanghe
PV module	W-HH 170-200(36)M
Electric properties	
Nominal power	190.00 Wp
Performance tolerance	---
MPP-voltage	36.50 V
MPP-current	5.21 A
Open-circuit voltage	44.50 V
Short-circuit current	5.52 A
Permissible system voltage	1000 V
PV module efficiency (STC)	14.88 %
Grounding recommendation	No grounding
Mechanical properties	
Number of cells in the PV module	72
Width	808 mm
Length	1580 mm
Weight	15.50 kg

Cell technology		monocrystalline Si
Temperature coefficients		
MPP-voltage	---	---
Open-circuit voltage	-0.3480 %/°C	-154.9 mV/°C
Short-circuit current	---	---
Degradation due to aging		
Open-circuit voltage tolerance		---
MPP-voltage tolerance		---
MPP-current tolerance		---
Short-circuit current tolerance		---
Additional information		
Current PV module		No
Favorite		No
Own PV module		Yes
Comment		

Table 5 PV module characteristics

Information on the inverter

Inverter	**SB 3000TLST-21**
General data	
Protection Type	IP65
Width	490 mm
Height	519 mm
Depth	185 mm
Weight	26.0 kg
Efficiency	
Max. efficiency	97 %
European efficiency	96.1 %

Input data	
Max. DC power	3.20 kW
Max. DC voltage	750 V
DC nominal voltage	400 V
PV voltage range, MPPT	125 - 500 V
Start voltage	150 V
Max. input current	15.0 A
Output data	
Max. AC power	3.00 kVA
Nominal AC power	3.00 kW
Min. displacement power factor (value)	0.8
Grid voltage	180 - 280 V
Grid frequency	45 - 65 Hz

Table 6 Inverter characteristics

10.3.4 Wire sizing

Power loss of the selected line dimensioning can be calculated here. Basically we have chosen the following parameters of the wires , including length and material

DC cables

		Cable material	Single cable length per string	Cross section per string	Current	Voltage	Voltage drop	Rel. power loss
Verona - Debrecen 30°								0.38 %
Parte del progetto 1								0.38 %
1 x SB 2500TLST-21	A	Copper	10.00 m	2,5 mm²	8.11 A	296 V	1.1 V	0.38 %

Table 7 DC wire sizing

AC1 cables

	Cable material	Single length	Cross section	Current	Voltage	Voltage drop	Rel. power loss
Verona - Debrecen 30°							0.60 %
Parte del progetto 1							0.60 %
1 x SB 2500TLST-21	Copper	10.00 m	2,5 mm²	10.02 A	1~230 V	1.4 V	0.60 %

Table 8 AC wire sizing

10.3.5 Results overview

Once all the parts are filled correctly without any kind of mistake, the software gives us an interesting result overview, displaying the main values and data regarding the entire project.
We're going to show and discuss these result, giving attention mostly on the major differences between the two projects.
In the following tables , in which we have previously highlighted the main parameters, are shown the results of the project; first starting with Verona.

System overview

20 x Huanghe W-HH 170-200(36)M (Generatore FV 1)
Azimuth angle: 0°, Inclination: 30°, Mounting type: Roof, PV peak power: 3.80 kWp

1 x SB 3000TLST-21

Technical data

Total number of PV modules:	20	Performance ratio (approx.)*:	83.7 %
PV peak power:	3.80 kWp	Spec. energy yield (approx.)*:	952 kWh/kWp
Number of inverters:	1	Line losses (in % of PV energy):	0.49 %
Nominal AC power:	3.00 kW	Unbalanced load:	3.00 kVA
AC active power:	3.00 kW	Self-consumption:	866.52 kWh
Active power ratio:	78.9 %	Self-consumption quota:	23.9 %
Annual energy yield (approx.)*:	3,619.20 kWh	Self-sufficiency quota (energy consumption in %):	43.3 %
Energy usability factor:	99.9 %	Annual battery cycles:	0

Table 9 System overview (Verona)

Evaluation of design

Parte del progetto 1

Location: Italy / Verona
Ambient temperature:
Annual extreme low temperature: -15 °C
Average high Temperature: 24 °C
Annual extreme high temperature: 33 °C

1 x SB 3000TLST-21

PV peak power:	3.80 kWp	
Total number of PV modules:	20	
Number of inverters:	1	
Max. DC power (cos φ = 1):	3.20 kW	
Max. AC active power (cos φ = 1)	3.00 kW	
Grid voltage:	230 V	
Nominal power ratio:	84 %	✓
Displacement power factor cos φ:	1	

SB 3000TLST-21

Technical data

Input A: Generatore FV 1
20 x Huanghe W-HH 170-200(36)M, Azimuth angle: 0°, Inclination: 30°, Mounting type: Roof

	Input A:	
Number of strings:	2	
PV modules per string:	10	
Peak power (input):	3.80 kWp	
Typical PV voltage:	329 V	✓
Min. PV voltage:	306 V	
Min. DC voltage (Grid voltage 230 V):	125 V	
Max. PV voltage:	507 V	✓
Max. DC voltage:	750 V	
Max. current of PV array:	10.4 A	✓
Max. DC current:	15.0 A	

Table 10 Evaluation of Design (Verona)

Self-consumption

Location: Italy / Verona

Information on self-consumption

Load profile:	**4-person household**
Energy consumption per year:	**2000 kWh**

Result

Without increased self-consumption

Self-sufficiency quota

43.3 %

Self-consumption quota

23.9 %

Distribution of PV energy

Energy yield **3619 kWh**

Grid feed-in **2753 kWh**

Self-consumption **867 kWh**

Consumption **1133 kWh**

Details

Energy yield of the PV plant	**3619 kWh**
Grid feed-in	**2753 kWh**
Consumption	**1133 kWh**
Self-consumption	**867 kWh**
Self-consumption quota (in % of PV energy)	**23.9 %**
Self-sufficiency quota (energy consumption in %)	**43.3 %**

Table 11 Self Consumption (Verona)

Down here are shown the results utilizing the data for Debrecen, substantially changes only the meteorological data , such as the annual total of global radiation and the environment temperature.

System overview

20 x Huanghe W-HH 170-200(36)M (PV array 1)
Azimuth angle: 0°, Inclination: 30°, Mounting type: Roof, PV peak power: 3.80 kWp

1 x SB 3000TLST-21

Technical data

Total number of PV modules:	20	Performance ratio (approx.)*:	85 %
PV peak power:	3.80 kWp	Spec. energy yield (approx.)*:	1171 kWh/kWp
Number of inverters:	1	Line losses (in % of PV energy):	0.56 %
Nominal AC power:	3.00 kW	Unbalanced load:	3.00 kVA
AC active power:	3.00 kW	Self-consumption:	915.18 kWh
Active power ratio:	78.9 %	Self-consumption quota:	20.6 %
Annual energy yield (approx.)*:	4,448.00 kWh	Self-sufficiency quota (energy consumption in %):	45.8 %
Energy usability factor:	99.6 %	Annual battery cycles:	0

Table 12 System Overview (Debrecen)

Evaluation of design

Project name: debrecen 30°
Project number:

Part project 1

Location: Hungary / Debrecen
Ambient temperature:
Annual extreme low temperature: -22 °C
Average high Temperature: 20 °C
Annual extreme high temperature: 33 °C

1 x SB 3000TLST-21

PV peak power:	3.80 kWp
Total number of PV modules:	20
Number of inverters:	1
Max. DC power (cos φ = 1):	3.20 kW
Max. AC active power (cos φ = 1)	3.00 kW
Grid voltage:	230 V
Nominal power ratio:	84 %
Displacement power factor cos φ:	1

SB 3000TLST-21

Technical data

Input A: PV array 1
20 x Huanghe W-HH 170-200(36)M, Azimuth angle: 0°, Inclination: 30°, Mounting type: Roof

	Input A:
Number of strings:	2
PV modules per string:	10
Peak power (input):	3.80 kWp
Typical PV voltage:	336 V
Min. PV voltage:	306 V
Min. DC voltage (Grid voltage 230 V):	125 V
Max. PV voltage:	518 V
Max. DC voltage:	750 V
Max. current of PV array:	10.4 A
Max. DC current:	15.0 A

Table 13 Evaluation of design (Debrecen)

Self-consumption

Project name: debrecen 30° **Location: Hungary / Debrecen**
Project number:

Information on self-consumption

Load profile:	**4-person household**
Energy consumption per year:	**2000 kWh**

Result

Without increased self-consumption

Self-sufficiency quota

45.8 %

Self-consumption quota

20.6 %

Distribution of PV energy

Energy yield **4448 kWh**

Grid feed-in **3533 kWh**

Self-consumption **915 kWh**

Consumption **1085 kWh**

Details

Energy yield of the PV plant	**4448 kWh**
Grid feed-in	**3533 kWh**
Consumption	**1085 kWh**
Self-consumption	**915 kWh**
Self-consumption quota (in % of PV energy)	**20.6 %**
Self-sufficiency quota (energy consumption in %)	**45.8 %**

Table 14 Self consumption (Debrecen)

10.3.6 Discussion and comparison of the principal results

As first we can notice a substantial difference regarding the “Annual energy yield” , this difference is coming principally from the different annual global radiation , because the other parameters don’t present big dissimilarity between each other.
How the annual energy yield is calculated; the global formula to estimate the electricity generated in output of a photovoltaic system is the following one:

$$E = A * r * H * PR$$

Where:

- E is the annual energy yield (kWh)
- A is the total solar panel area (m^2)
- r is the yield of the solar panel given by the ratio : electrical power (in kWp) of one solar panel divided by the area of one panel, given is STC
- H annual average solar radiation on tilted panels
- PR “performance ratio” is a very important value to evaluate the quality of a photovoltaic installation because it gives the performance of the installation independently of the orientation, inclination of the panel. It includes all losses.

We briefly show which are the main losses in a photovoltaic system:

Pre-Module Losses	Tolerance of rated power	Consider that the module does not deliver the power as stated in the data sheet. Manufacturers provide a tolerance, often up to 5%.
	Shadows	Shadows may be caused by trees, chimneys etc. Depending on the stringing of the cells, partial shading may have a significant effect.
	Dirt	Losses due to dirt up to 4% in temperate regions with some frequent rain. Up to 25% in arid regions with only seasonal rain and dust.
	Snow	Dependant on location and maintenance effort.
	Reflection	Reflection losses increase with the angle of incidence. Also, this effect is less pronounced in locations with a large proportion of diffuse light, i.e. clouds.
Module Losses	Conversion	The nominal efficiency is given by the manufacturer for standard conditions.
	Thermal losses	With increasing temperatures, conversion losses increase. These losses depend on irradiance (i.e. location), mounting method (glass, thermal properties of materials), and wind speeds.
System Losses	Wiring	Any cables have some resistance and therefore more losses.
	MPP	Ability of the MPP tracker to consistently find the maximum power point.
	Inverter	Inverter efficiency
	Mis-sized inverter	If the inverter is undersized, power is clipped for high intensity light. If it is oversized, the inverter's efficiency will be too low for low intensity light.
	Transformer	Transformer losses in case electricity has to be connected to a high-voltage grid.
Operation & Maintenance	Downtime	Downtime for maintenance is usually very low for photovoltaic systems.

Table 15 Main losses factors in a pv-plant

The difference concerning the annual energy yield is approximately about 1kWh, so far it's a significant value to take into account.

Furthermore there are some nearly differences in these following parameters:

- Grid feed in: 780 kWh of difference
- Self consumption : almost 20 kWh

Now we are going to report the main results coming from the others attempt; in particular now it changes the inclination (tilt angle) of the modules , while the other parameters remain all the same.

10.3.7 Results comparison between different tilt angle inclination

Here we're going to show how the performance of the power plant changes modifying the tilt angle, doing this because we are evaluating different mounting solutions.
First attempt is studying the case with an inclination of 40° and the second one is with 45° degrees, meanwhile the orientation remain always perfectly 0° azimuth , so in south direction.
The software gives us the following results:

System overview

20 x Huanghe W-HH 170-200(36)M (PV array 1)
Azimuth angle: 0°, Inclination: 40°, Mounting type: Roof, PV peak power: 3.80 kWp

1 x SB 3000TLST-21

Technical data

Total number of PV modules:	20	Performance ratio (approx.)*:	83.7 %
PV peak power:	3.80 kWp	Spec. energy yield (approx.)*:	928 kWh/kWp
Number of inverters:	1	Line losses (in % of PV energy):	0.48 %
Nominal AC power:	3.00 kW	Unbalanced load:	3.00 kVA
AC active power:	3.00 kW	Self-consumption:	865.19 kWh
Active power ratio:	78.9 %	Self-consumption quota:	24.5 %
Annual energy yield (approx.)*:	3,526.30 kWh	Self-sufficiency quota (energy consumption in %):	43.3 %
Energy usability factor:	100 %	Annual battery cycles:	0

Table 16 System overview (Verona 40°)

Information on self-consumption

Load profile:	**4-person household**
Energy consumption per year:	**2000 kWh**

Result

Without increased self-consumption

Self-sufficiency quota: 43.3 %

Self-consumption quota: 24.5 %

Distribution of PV energy:

- Energy yield: **3526 kWh**
- Grid feed-in: **2661 kWh**
- Self-consumption: **865 kWh**
- Consumption: **1135 kWh**

Details

Energy yield of the PV plant	**3526 kWh**
Grid feed-in	**2661 kWh**
Consumption	**1135 kWh**
Self-consumption	**865 kWh**
Self-consumption quota (in % of PV energy)	**24.5 %**
Self-sufficiency quota (energy consumption in %)	**43.3 %**

Table 17 Information on self-consumption (Verona 40°)

System overview

20 x Huanghe W-HH 170-200(36)M (PV array 1)
Azimuth angle: 0°, Inclination: 40°, Mounting type: Roof, PV peak power: 3.80 kWp

1 x SB 3000TLST-21

Technical data

Total number of PV modules:	20	Performance ratio (approx.)*:	85 %
PV peak power:	3.80 kWp	Spec. energy yield (approx.)*:	1153 kWh/kWp
Number of inverters:	1	Line losses (in % of PV energy):	0.56 %
Nominal AC power:	3.00 kW	Unbalanced load:	3.00 kVA
AC active power:	3.00 kW	Self-consumption:	913.68 kWh
Active power ratio:	78.9 %	Self-consumption quota:	20.9 %
Annual energy yield (approx.)*:	4,380.40 kWh	Self-sufficiency quota (energy consumption in %):	45.7 %
Energy usability factor:	99.7 %	Annual battery cycles:	0

Table 18 System overview (Debrecen 40°)

Information on self-consumption

Load profile: **4-person household**

Energy consumption per year: **2000 kWh**

Result

Without increased self-consumption

Self-sufficiency quota

45.7 %

Self-consumption quota

20.9 %

Distribution of PV energy

Details

Energy yield of the PV plant	**4380 kWh**
Grid feed-in	**3467 kWh**
Consumption	**1086 kWh**
Self-consumption	**914 kWh**
Self-consumption quota (in % of PV energy)	**20.9 %**
Self-sufficiency quota (energy consumption in %)	**45.7 %**

Table 19 Information on self-consumption (Debrecen 40°)

System overview

20 x Huanghe W-HH 170-200(36)M (PV array 1)
Azimuth angle: 0°, Inclination: 45°, Mounting type: Roof, PV peak power: 3.80 kWp

1 x SB 3000TLST-21

Technical data

Total number of PV modules:	20	Performance ratio (approx.)*:	83.7 %
PV peak power:	3.80 kWp	Spec. energy yield (approx.)*:	908 kWh/kWp
Number of inverters:	1	Line losses (in % of PV energy):	0.46 %
Nominal AC power:	3.00 kW	Unbalanced load:	3.00 kVA
AC active power:	3.00 kW	Self-consumption:	862.46 kWh
Active power ratio:	78.9 %	Self-consumption quota:	25 %
Annual energy yield (approx.)*:	3,451.40 kWh	Self-sufficiency quota (energy consumption in %):	43.1 %
Energy usability factor:	100 %	Annual battery cycles:	0

Table 20 System overview (Verona 45°)

Information on self-consumption

Load profile:	**4-person household**
Energy consumption per year:	**2000 kWh**

Result

Without increased self-consumption

Self-sufficiency quota

43.1 %

Self-consumption quota

25 %

Distribution of PV energy

Details

Energy yield of the PV plant	**3451 kWh**
Grid feed-in	**2589 kWh**
Consumption	**1138 kWh**
Self-consumption	**862 kWh**
Self-consumption quota (in % of PV energy)	**25 %**
Self-sufficiency quota (energy consumption in %)	**43.1 %**

Table 21 Information on self-consumption (Verona 45°)

System overview

20 x Huanghe W-HH 170-200(36)M (PV array 1)
Azimuth angle: 0°, Inclination: 45°, Mounting type: Roof, PV peak power: 3.80 kWp

1 x SB 3000TLST-21

Technical data

Total number of PV modules:	20	Performance ratio (approx.)*:	85 %
PV peak power:	3.80 kWp	Spec. energy yield (approx.)*:	1134 kWh/kWp
Number of inverters:	1	Line losses (in % of PV energy):	0.55 %
Nominal AC power:	3.00 kW	Unbalanced load:	3.00 kVA
AC active power:	3.00 kW	Self-consumption:	911.03 kWh
Active power ratio:	78.9 %	Self-consumption quota:	21.1 %
Annual energy yield (approx.)*:	4,310.00 kWh	Self-sufficiency quota (energy consumption in %):	45.6 %
Energy usability factor:	99.7 %	Annual battery cycles:	0

Table 22 System overview (Debrecen 45°)

Information on self-consumption

Load profile: **4-person household**

Energy consumption per year: **2000 kWh**

Result

Without increased self-consumption

Self-sufficiency quota

45.6 %

Self-consumption quota

21.1 %

Distribution of PV energy

Energy yield **4310 kWh**

Grid feed-in **3399 kWh**

Self-consumption **911 kWh**

Consumption **1089 kWh**

Details

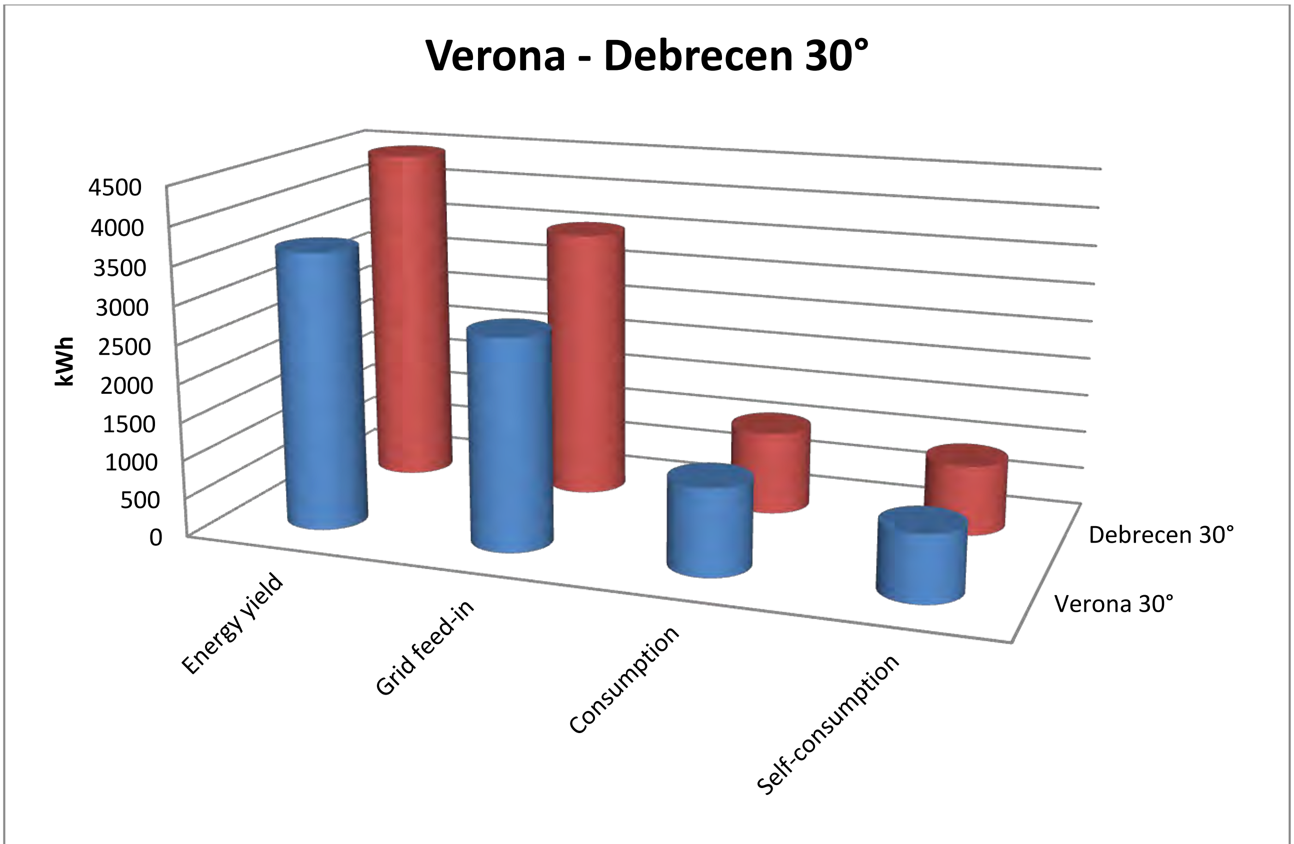
Energy yield of the PV plant	**4310 kWh**
Grid feed-in	**3399 kWh**
Consumption	**1089 kWh**
Self-consumption	**911 kWh**
Self-consumption quota (in % of PV energy)	**21.1 %**
Self-sufficiency quota (energy consumption in %)	**45.6 %**

Table 23 Information on self-consumption (Debrecen 45°)

10.3.8 Graphical comparison

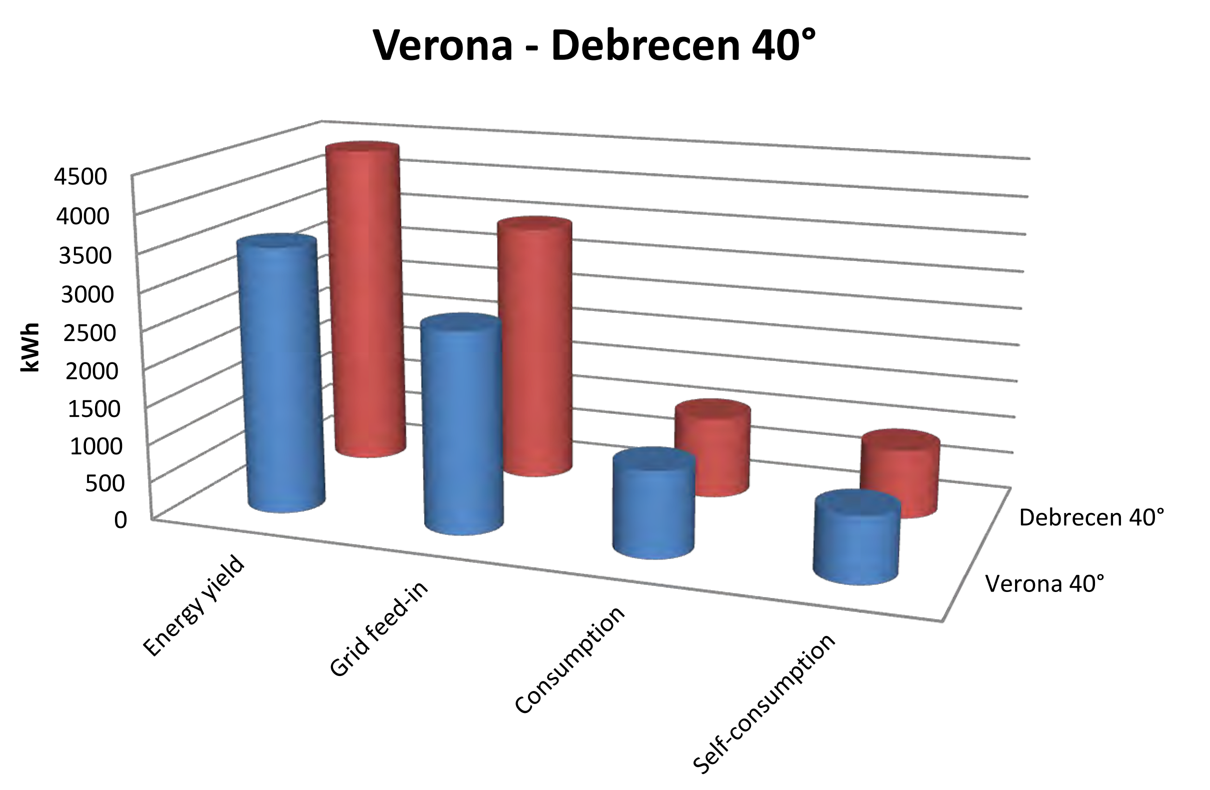
In this short chapter we are going to briefly show with three graphics how the results seems like , putting in evidence the four main parameters, which are

- Energy yield
- Grid feed in
- Consumption
- Self – Consumption



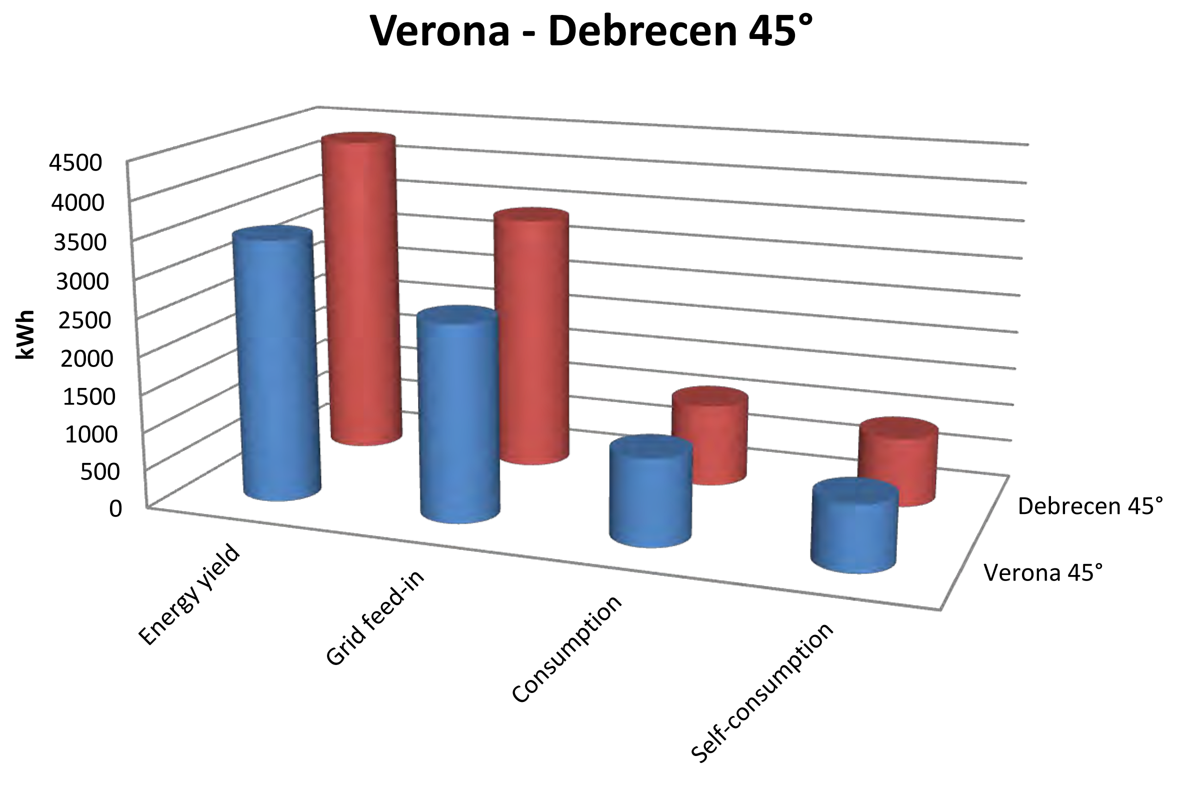
	Energy yield	Grid feed-in	Consumption	Self-consumption
Verona 30°	3619	2753	1133	867
Debrecen 30°	4448	3533	1085	915

Figure 66 Verona-Debrecen 30°



	Energy yield	Grid feed-in	Consumption	Self-consumption
Verona 40°	3526	2661	1135	865
Debrecen 40°	4380	3467	1086	914

Figure 67 Verona-Debrecen 40°



	Energy yield	Grid feed-in	Consumption	Self-consumption
Verona 45°	3451	2589	1138	862
Debrecen 45°	4310	3399	1089	911

Figure 68 Verona-Debrecen 45°

11 Heating - cooling demand and temperature behaviour

In this chapter we are going to study the energy demand for heating and cooling of the two buildings located respectively in Debrecen and Verona and as well the temperature behaviour using the software casaNOVA.

11.1 casaNOVA software

The software casaNOVA is based on the norm UNI EN 832 which gives a calculation method founded on a steady conditions to estimate the energy demand, taking in consideration the variation of the internal and external temperature and, with an utilization factor, it also considerate the dynamic solar gains.
Specifically this method can be used for the following situations:

- Estimation of the respect of the regulation in function of the energy demand
- Optimization of the energy performance of a building
- Calculation the conventional level of the energy performance of existing buildings
- Possible estimation of energy saving ways for existing buildings
- Estimates the energy resources needed at national or international level, by calculating the energy requirements of different buildings of the building stock

Moreover the calculation method for the heating and cooling demand include this following features:

- Thermal losses of the building when it is heated with a fixed temperature
- Thermal annual energy demand required to maintain the internal temperature in a settled value
- Annual energy demand required from the heating system

11.2 Explanation of the UNI EN 832

This European normative provide a simply method to calculate and estimate the energy needed for heating and cooling a residential building or a part of it.
The calculation procedure might be divided in the following steps:

- Define the geometry of the heated space, if necessary separate heated zones from non heated zones
- Calculate the heating losses coefficient "H" belonged to the heated space (heat loss through the building envelope and ventilation)
- Define the set point temperature
- For the seasonal calculation must previously define the length of the season and provide the climate data

Moreover:

- Calculate heat loss via transmission and ventilation Q_L
- Calculate internal gains (heat sources coming from lights, electrical appliances, lodger etc..) Q_i
- Calculate solar heat gains Q_s
- Calculate the utilization factor η_u for the total free gains ($Q_g = Q_i + Q_s$), which takes in consideration the increasing of the heat loss due to the environmental overheating
- Calculate the heating energy demand for the heated space $Q_h = Q_L - \eta_u * Q_g$
- Calculate the energy demand Q, including:
  - Heat dispersions Q_L
  - Domestic hot water Q_W
  - Heat recovered from auxiliary systems Q_R
  - Heating efficiency system η_G

$$Q = (Q_H + Q_W)/\eta_G - Q_R$$

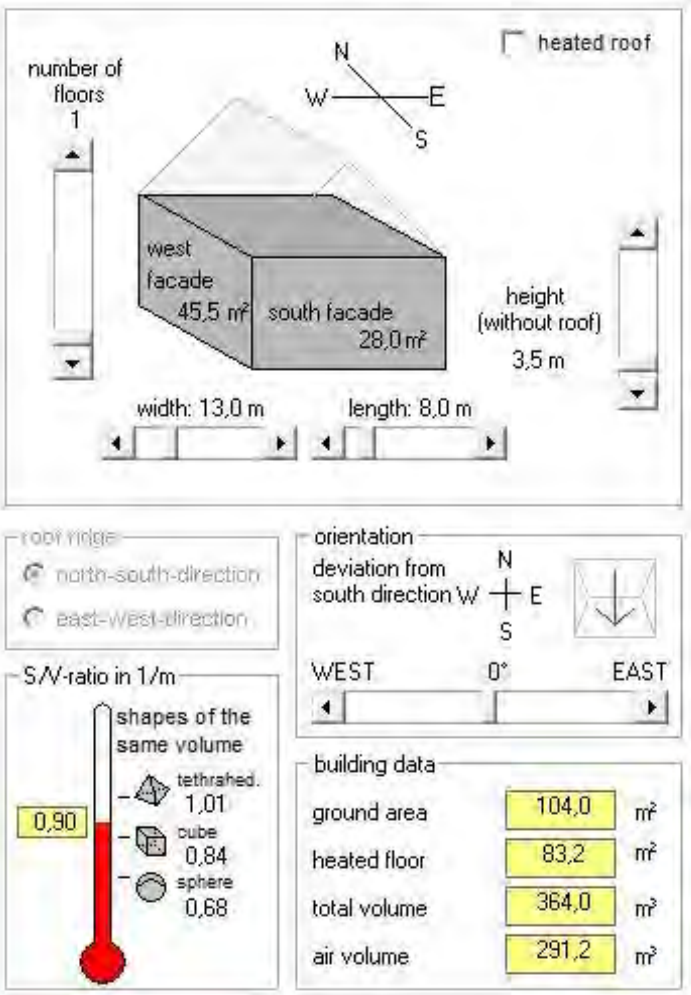
With this briefly introduction we've explained how the normative works, the software adopt this calculation method.

11.3 Setting and configuration of the software

In this chapter we show step by step the procedure to fill correctly every part of the software.

11.3.1 Building geometry

Here we have to define the geometry and orientation of the building.
Very simply the software asks the number of the floors, width, length and height, calculating automatically the area of the single surface. Moreover is possible to set the orientation , precisely defining the deviation from the south direction.
As first results it gives some structural data, which is possible to see them in the yellow slots.



11.3.2 Windows proprieties

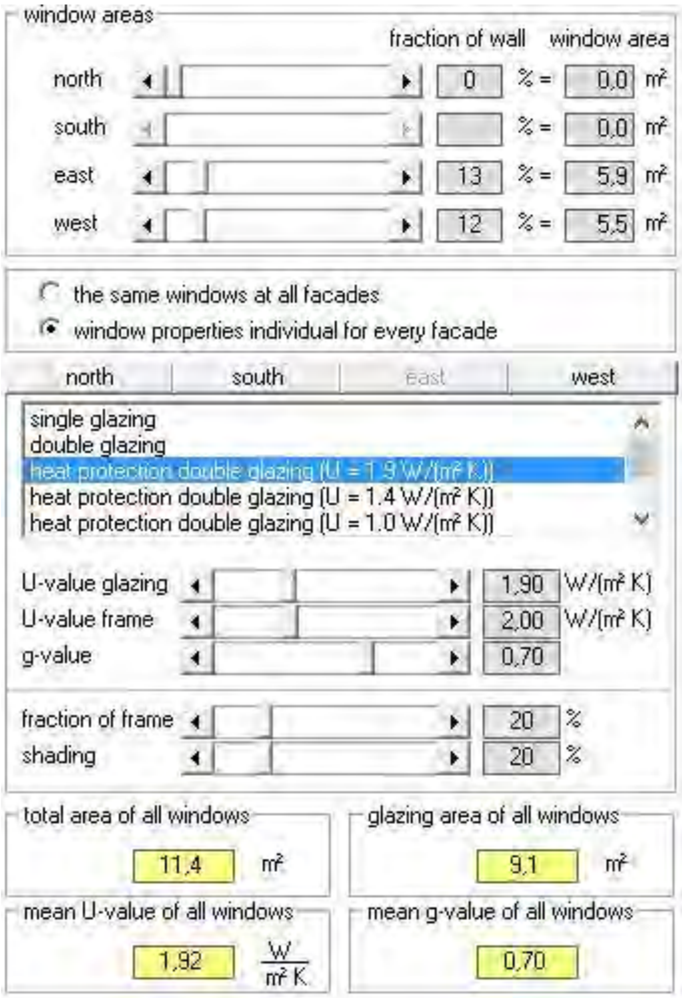
In the second part we have to set and define the proprieties of the windows belonging to the building.

As we can see first we have to set the area, just by clicking the adjusting buttons until we reach our value.

Then is possible to select the window transmittance, by choosing from the list of setting our own value.

The same is possible for the frame and at the end the fraction of the frame and shading.

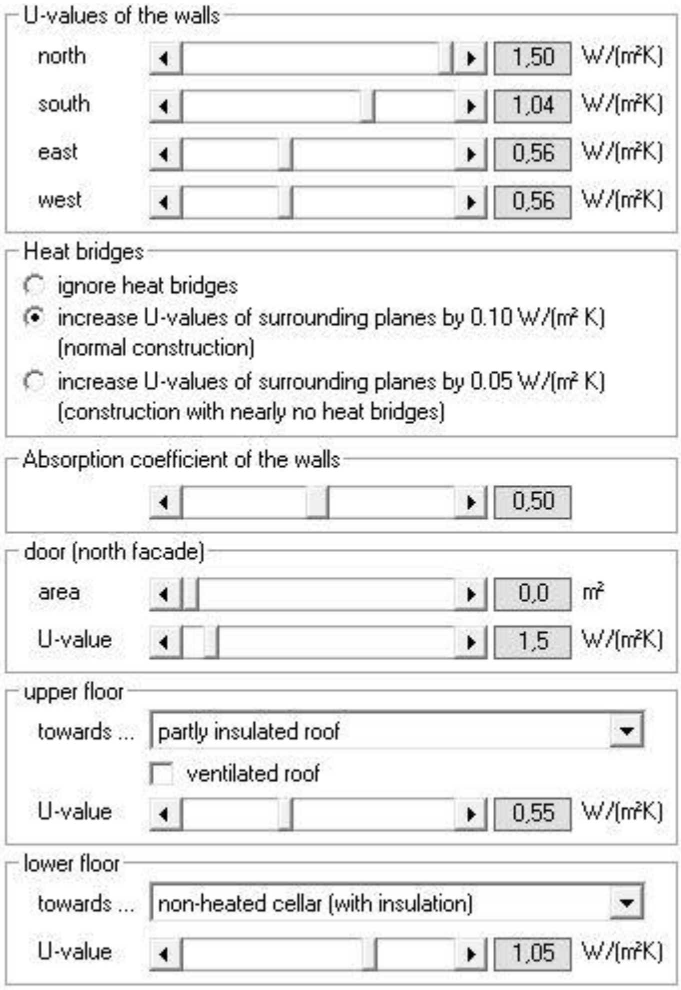
As a result of this section automatically we have some parameters show in the yellow slots.



11.3.3 Insulation

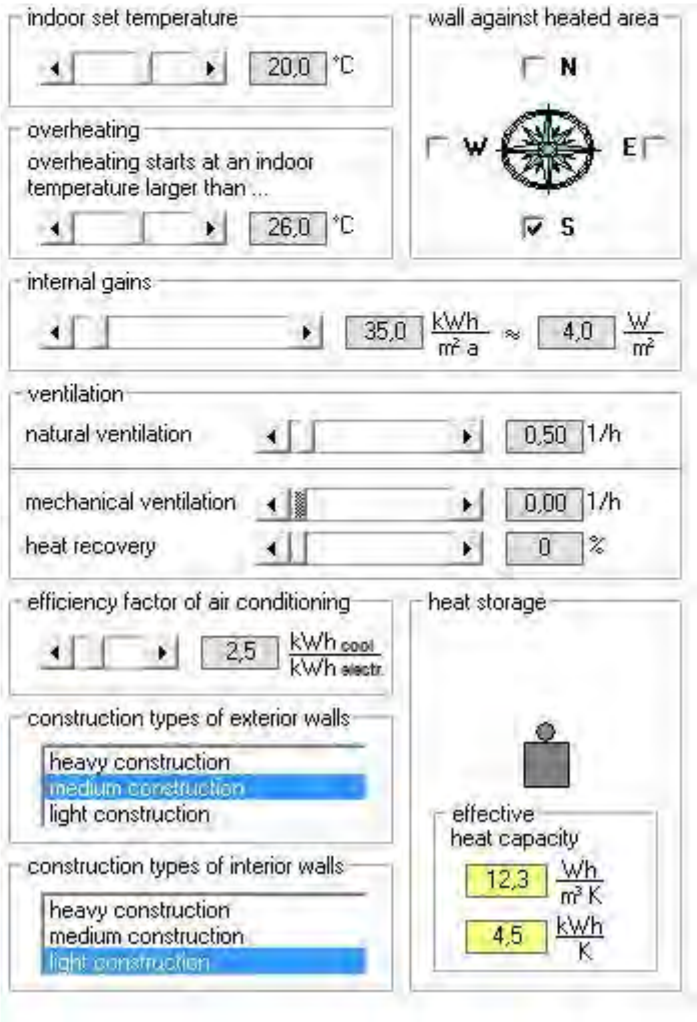
Here we define the transmittance of the walls depending on the construction materials and thickness.

Afterwards we can add some details as the heat bridges and with what the house confines from the top to the bottom.



11.3.4 Building

In the building section we have to set some important values like the indoor set temperature, overheating, internal gains, ventilation and so on.
As well as the constructions types of the external and internal walls.



11.3.5 Climate

The last section permit to define the climate if the city/area in study by chose from the list given or import data from an external file.
casaNOVA needs a complete yearly set of hourly data, i.e. 8760 values for:

- the outdoor air temperature,
- the total or direct radiation on a horizontal plane as well as
- the diffuse radiation on a horizontal plane.

Once filled all the parts of the software is ready to give the results, specifically they are the following:

- Heat and cooling energy demand:
    - Two diagrams show the specific heat energy and cooling demand of the building. The unit is kWh/(m² month) resp. kWh/(m² a), i.e. the demand per square meter of heated floor area.

- Heating hours, zero energy hours, cooling hours:
    - This monthly and yearly diagram presents the number of hours in a month / a year during which the course of room air temperature (without heating or cooling) is lower than the indoor set temperature (heating hours) or higher then the limit of overheating (cooling hours). Zero energy hours are those ones, during which the room air temperature is in the comfortable range (i.e. between the indoor set temperature and the limit of overheating).
- Course of temperatures
    - This diagram visualises then hourly course of the outdoor and the room air temperature.

11.4 Method of calculation

In this chapter we'll show briefly how the software does the calculation of the various parameters explaining the formulas for each one.

11.4.1 Transmission losses

$$Vt = \sum_{walls} U_w A_w (T_s - T_a)\Delta t + \sum_{windows} U_f A_f (T_s - T_a)\Delta t + k_b U_b A_b (T_s - T_a)\Delta t + k_d U_d A_d (T_s - T_a)\Delta t$$

where:

- Vt = transmission losses
- Uw,Uf = heat transfer coefficients of walls and windows
- Ub = heat transfer coefficient of ground floor (against unheated cellar or ground)
- Ud = heat transfer coefficient of roof resp. uppermost ceiling
- Aw,Af = surface area of walls and windows
- Ab = surface area of ground floor
- Ad = surface area of uppermost ceiling
- Ts = indoor air temperature
- Ta = ambient temperature
- Kb = Correction of U-value of the ground floor
- Kd = Correction of U-value of the roof
- Δt = calculation period

11.4.2 Ventilation losses

$$V_L = n * V * C_{air} * \rho_{air} * (T_s - T_a) * \Delta t$$

where:

- VL = ventilation losses
- n = air change rate in l/h
- V = exchangeable volume of indoor air
- ρair, Cair = volumetric thermal capacity of air (= 0.34 Wh/(m3K))
- Ts = indoor air set temperature
- Ta = ambient temperature
- Δt: calculation period

11.4.3 Internal gains

$$G_i = A_{floor} * Q_{int}$$

with:

- Gi = internal gains
- A_{floor} = heated floor area
- Q_{int} = specific internal gains

11.4.4 Solar gains

$$G_s = \sum_{windows} g_f(1 - r_f) * A_f * H_f$$

where:

- Gs = solar gains
- gf = g-value of glazing
- rf =frame ratio window
- Af = surface area window
- Hf = solar radiation of window surface

The solar gains effected by the radiation on the outside walls result from:

$$G_{w,s} = \sum_{walls} \frac{U_w}{\alpha_a} A_w H_{w,s}$$

- $G_{w,s}$ = solar gains through the walls in kWh
- $H_{w,s}$ = solar radiation through the walls surface in kWh/m2

- A_W = outside wall area in m2
- α_a = exterior surface heat transfer coefficient (20 W/m2K)
- U_W = U value of the wall in W/m2K

11.4.5 One-zone model

In the one-zone model it is made use of the conception that the room air and the confining walls of the rooms possess a joint temperature T(t). Temperature changes obey the differential equation:

$$C * \frac{dT}{dt} = \dot{Q}$$

where "$\dot{Q}$" is the temporal change of the difference Q of heat gains and heat losses:

Q = heat gains – heat losses

For determining the number of heating, cooling and zero-energy hours, the course of room air temperature is calculated on hourly base for the whole year. The calculation is done iterative with the following formula:

$$T_{room}(t) = T_{room}(t - \Delta t) * e^{-\frac{\Delta t}{t}} + \frac{\dot{Q}}{C} * \tau * \left(1 - e^{-\frac{\Delta t}{t}}\right)$$

where:

- $T_{room}(t)$ = indoor air temperature at the time t
- $T_{room}(t - \Delta t)$ = indoor air temperature at the time $(t - \Delta t)$
- Δt = time interval factor for calculation (1 hour)
- Q = mean gains during the period
- Ta = ambient temperature

And the parameters C and τ:

- C = effective capacity of heat storage

$$C = C_{a,w} * A_{a,w} * C_{r,w} * A_{r,w}$$

  - $A_{a,w}$ = area of exterior walls
  - $A_{r,w}$ = area of internal walls
  - $C_{a,w}$ $C_{r,w}$ = specific thermal heat storage of exterior / interior walls (per m² wall area)

For the interior and exterior walls CASAnova distinguishes between three types of construction:

Construction type	$C_{a,w}$ / $C_{r,w}$
Lightweight	25 kJ/m2k
Medium	35 kJ/m2k
Heavy	105 kJ/m2k

- τ = thermal constant due to the thermal inertia

$$\tau = \frac{C}{U * A + n * Cair * \rho air * V}$$

- mC = effective capacity of a building to store heat
- UA = sum of products of U-values times areas of walls / windows
- n = air change rate in 1/h
- V = exchangeable volume of indoor air

For the determination of the cooling demand as well as the maximum heating and cooling loads of the building, again the course of temperature is calculated with the help of the formula above. But this time, if the room air temperature increases the limit of overheating, the demand of cooling energy is determined, which would be needed to cool down the rooms to the limit temperature. Before the next time-step, then, the room air temperature is set to the limit of overheating. Analogous the heating energy demand is calculated, if the room air temperature decreases the set temperature and for the next time-step the room temperature is set to the indoor set temperature.

11.4.6 Effective heating days

The number of effective heating days is the number of those days, during which the mean outdoor air temperature is lower than the limit of outdoor temperature for heating.
The lowest acceptable outdoor temperature below which heating must start results from the thermal energy balance of the building:

$$Qh = Vt + Vl - \eta * (Gs + Gi)$$

with Qh = 0. Thereby, because of its small and fluctuating nature, solar gains are neglected (Gs = 0). This yields:

$$T_{lim} = Ts - \frac{\eta * C}{U * A + n * Cair * \rho air * V}$$

- Tlim = limit of outdoor temperature for heating
- TS = indoor air temperature
- η = utilisation factor
- Gi = internal gains
- UA = sum of products of U-values times areas of walls / windows in W/K
- n = air change rate in l/h
- (ρair · cair) = volumetric thermal capacity of air (= 0.34 Wh/(m3 K))
- V = exchangeable heated indoor air volume

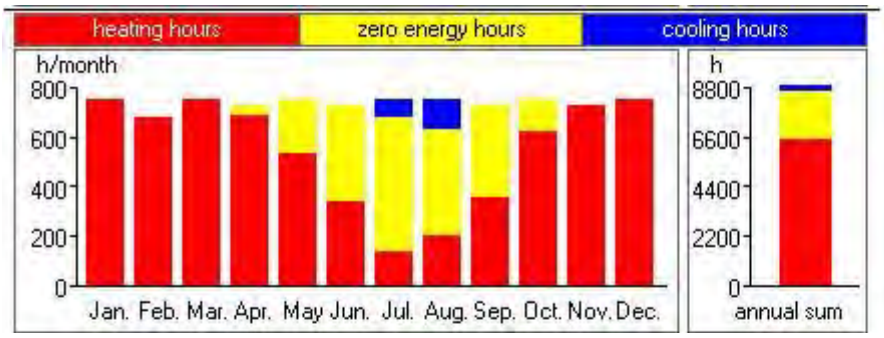
11.5 Results Verona

Once filled correctly all the parameters required by the software, it shows mainly in a graphical and tabular way the results. We'll show and explain them one by one and later on compare and discuss the results between the two different cities.

11.5.1 Preview

The first section gives us a general preview of the main parameters, in particular the first two diagrams show the specific heat energy and cooling demand of the building. The unit is kWh/(m² month) and kWh/(m² a), i.e. the demand per square meter of heated floor area.

The second monthly and yearly diagram presents the number of hours in a month and year during which the course of room air temperature (without heating or cooling) is lower than the indoor set temperature (heating hours) or higher than the limit of overheating (cooling hours). Zero energy hours are those ones, during which the room air temperature is in the comfortable range (i.e. between the indoor set temperature and the limit of overheating).



11.5.2 Climate – Building

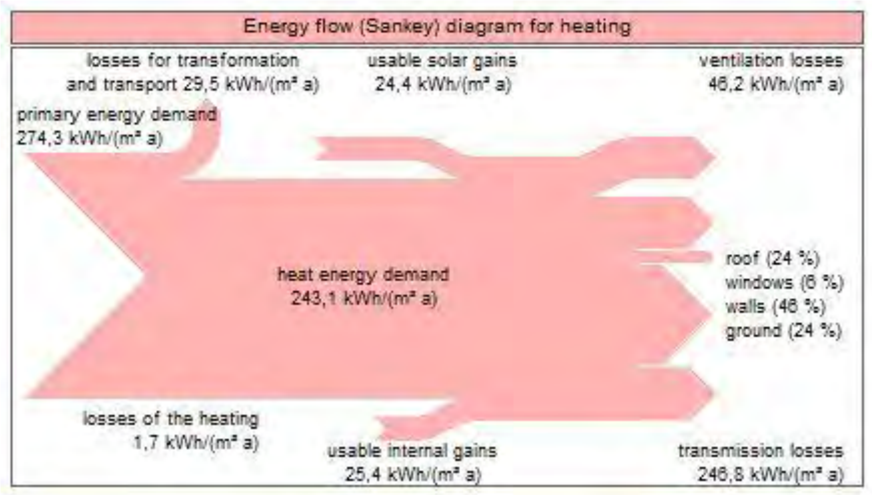
This output screen contains Information about the selected climatic region and gives an overview on same important building properties, we'll report the table gave in output:

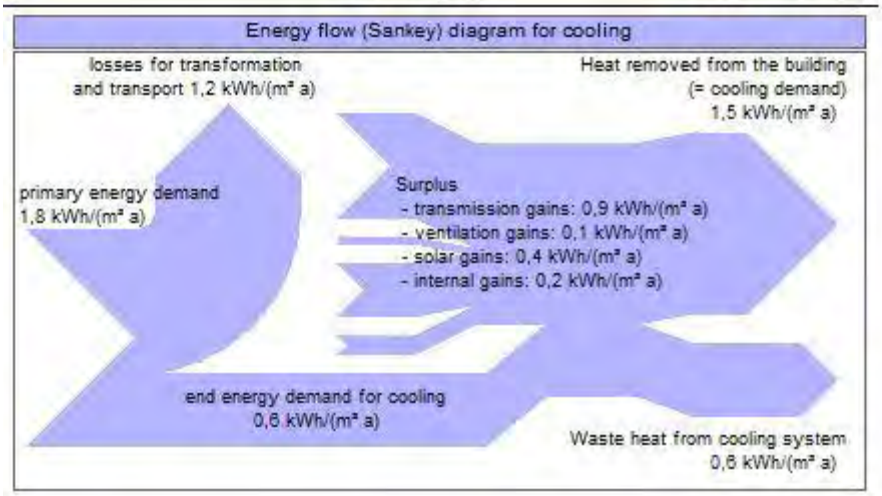
Climate		
Verona (Italy)		
Maximum temperature of the year	31,3	°C
Maximum monthly mean value	21,7	°C
Month with maximum mean temperature	July	
Mean temperature of the year	11,8	°C
Minimum monthly mean value	2,8	°C
Month with minimum mean temperature	January	
Minimum temperature of the year	-14	°C

Building		
Mean U value	0,94	W/m2K
Specific transmission losses	332,6	W/K
Specific ventilation losses	52,2	W/K
Specific losses	384,8	W/K
Thermal inertia	21,8	hours
Maximum heating load	11,7	kW
Maximum specific heating load	140,9	W/m2
Maximum cooling load	3,1	kW
Maximum specific cooling load	36,7	W/m2
Limt temperature for heating	19	°C
Effective heating days	260	days

11.5.3 Energy flows

The energy-flow diagram (Sankey-diagram) for heating illustrates graphically the yearly demand of primary energy, energy for heating and heat energy, internal and solar gains as well as transmission and ventilation losses. The width of the bars is proportional to the corresponding amounts of energy. Numbers given in the diagram are specific, i.e. they give the energy demand, gains and losses for one year per square meter of heated floor area.
The energy-flow diagram for cooling presents the different amounts of energy for those periods of time, during which the room air temperature exceeds the given limit of overheating. Shown are the surplus internal and solar gains as well as the supply of heat by transmission and ventilation, when there is overheating. The end cooling energy demand is that amount of energy which a cooling system (air-conditioning) would need to take out the surplus heat from the building. Finally, this energy is also given to the surrounding as waste heat. As source of energy for the cooling system, electricity with a primary energy factor of three is supposed.



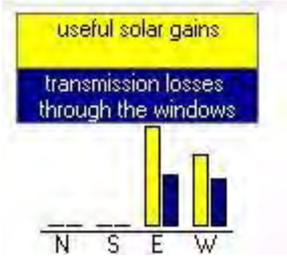


11.5.4 Heating review

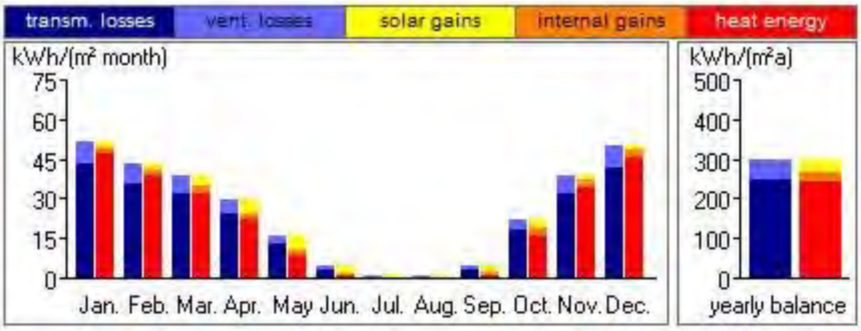
Yearly balance: in this table, gains and losses of energy are summed up for one year. The difference between losses and gains is the heat energy demand for this year. All results are given as absolute values, i.e. they refer to the whole building (unit: kWh/a) and as specific values, i.e. per square meter of heated floor area (unit: kWh/(m² a)).

yearly balance:	absolute in kWh/a	specific in kWh/(m² a)
transmission losses:	20530	246,8
ventilation losses:	3842	46,2
usable solar gains:	2033	24,4
usable internal gains:	2112	25,4
heat energy demand:	20227	243,1

Balance of windows: this diagram compares yearly useable solar gains with transmission losses through the windows. Results are displayed separately, for each orientation of the facades.



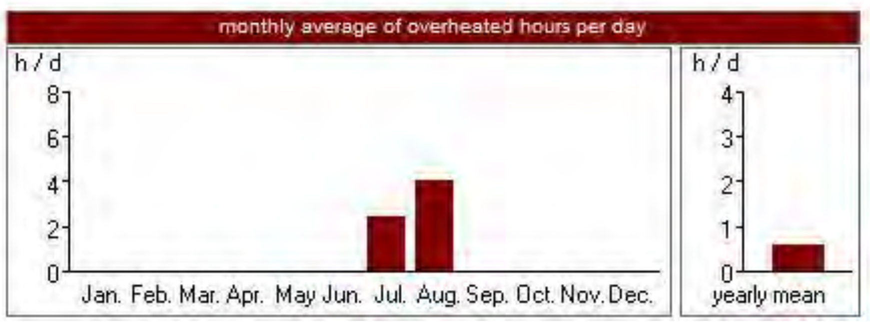
Monthly-yearly heat balance: these diagrams show ventilation and transmission losses, useable internal and solar gains, as well as heat energy demand with monthly resolution as well as the yearly sums. If there is a difference between the gains and the losses, heat demand is necessary.



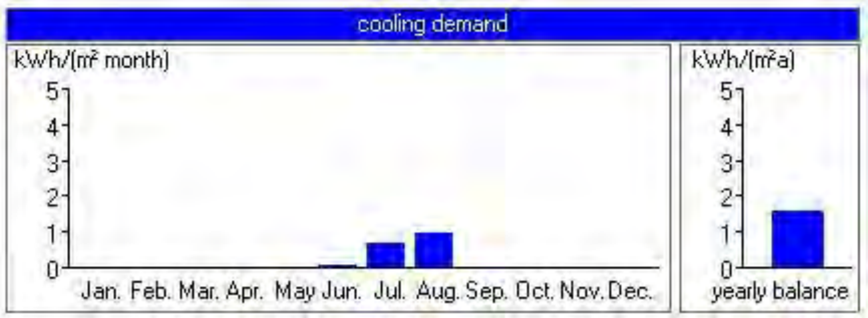
Usable-non-useable solar and internal gains: In these two diagrams (monthly / yearly), the total internal and solar gains are compared to the part of them which are needed during the heating season. All further gains led to an increasing of room air temperature higher than the set of temperature. Thereby, the usability factor for internal and solar gains are assumed as being equal.

11.5.5 Cooling review

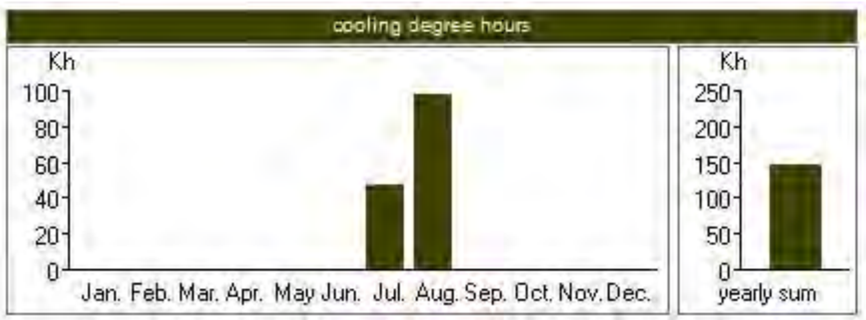
Monthly average of overheated hours per day: these two diagrams display the monthly averages of daily overheating hours as well as their annual mean for the case, that the building has no cooling system or air-conditioning.



Cooling demand: the graphics visualise the cooling demand inside the building per month resp. per year. The values are specific, i.e. it is the mean cooling demand per m² of heated floor area.



Cooling degree hours: cooling degree hours are the result of the multiplication of the number of hours, during which the comfortable temperature range is exceeded with the temperature difference between the limit of overheating and the room air temperature. The unit of the cooling degree hours is Kh (Kelvin-hours).



11.6 Energy review chart

For the heat supply inside the building, a heating system is necessary. This usually consists of a boiler, pipes for the distribution of the heat and the systems to transfer the heat to the rooms (radiators or under floor heating).
During the generation as well as during the distribution and the transfer to the rooms, heat losses occur which had to be taken into account when determining the end energy. Additionally, electrical (auxiliary) energy is needed e.g. for the operation of the boiler or for the pumps for the heat distribution.

The heating systems of CASAnova are taken form a German regulation (DIN 4701-10), whereby only a limited number of systems have been taken into account. For simplification, in CASAnova the boiler and the distribution are always situated in the heated zone.

The following heating systems are at the users disposal:

- low temperature boiler and radiators at the outside walls or underfloor heating;
- condensing burner and radiators at the outside walls or underfloor heating;
- high efficiency condensing burner and radiators at the outside walls or underfloor heating;
- biomass heating with direct and / or indirect thermal output as well as radiators at the outside walls or underfloor heating;
- district heat from thermal power station or combined heat and power system with radiators at the outside walls or underfloor heating;
- soil heat pump with buffer storage and radiators at the outside walls or underfloor heating;
- electric direct heating;
- electric storage heating.

11.6.1 Primary energy factor

Before the energy carrier is consumed by the heating system, already energy is lost (e.g. for distribution, refinery etc.). The primary energy factor describes how many kWh of primary energy are needed to get one kWh of energy for heating (end energy). Thereby, renewable energies (e.g. wood) can have a primary energy factor less than one.
The primary factors, used in CASAnova are also taken from the German regulation DIN 4701-10.
The following primary energy factors are used in CASAnova:

- natural gas: 1,1
- fuel oil: 1,1
- wood: 0,2
- district heat from combined heat and power system, fossil fuel: 1.1
- district heat from combined heat and power system, renewable energy: 0.0
- district heat from thermal power station, fossil fuel: 0.7

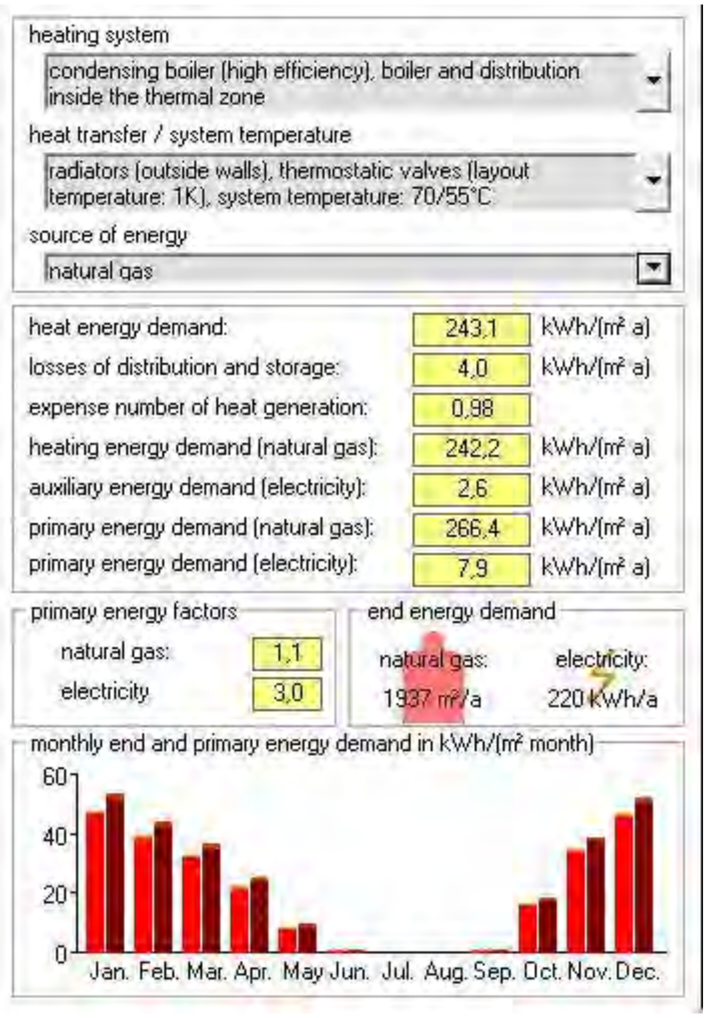
- district heat from thermal power station, renewable energy: 0.1
- electricity: 3,0

11.6.2 Losses and needs

This table contains the specific yearly losses for heat distribution, storage, transfer, the auxiliary energy for generation and distribution, the expense number of heat generation as well as the corresponding end and primary energy demand for the main source of energy (natural gas, fuel oil, district heat, electricity) and the auxiliary energy (electricity). The expense number of heat generation describes the ratio of the operating expense to the requested profit (demand) in an energy system. This number varies for biomass heat generators (pellet furnace) between 1.36 and 1.49 and is therefore larger than for condensing boilers having values between 0.93 and 1.08. For the heating value of wood or biomass an average value of 4.6 kWh/kg is used.

11.6.3 Monthly end and primary energy demand

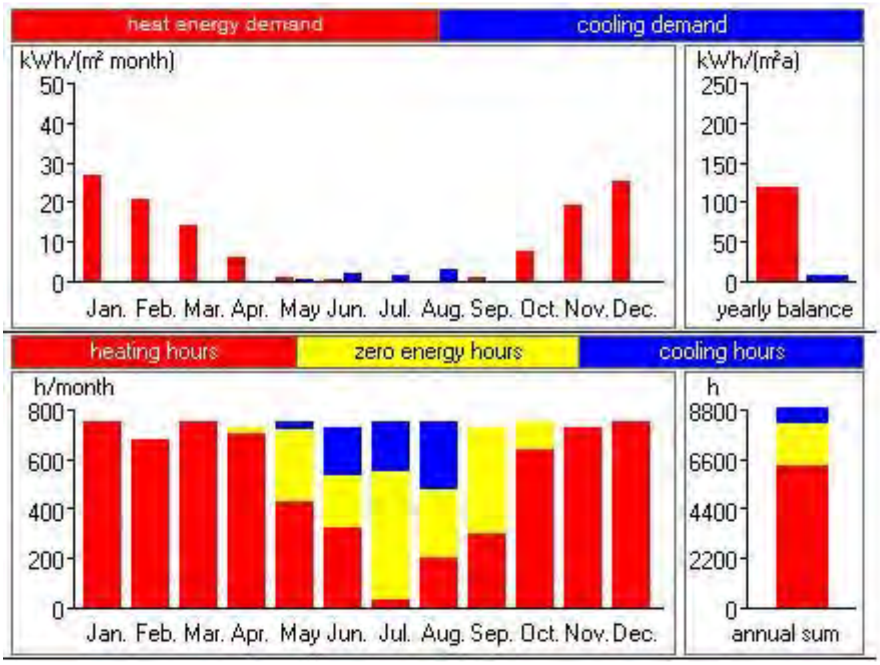
This graphic presents the end and primary energy demand. Apart from heating systems which "only" need electrical energy, the monthly demands are split in the main source of energy (natural gas, fuel oil, wood, district heat) and auxiliary energy, i.e. electricity.



11.7 Results Debrecen

In this section we are reporting the principal results from the simulation done with the house located in Debrecen. We'll just report the main graphs and tables, the description of these are explained in the previous chapter.

11.7.1 Preview

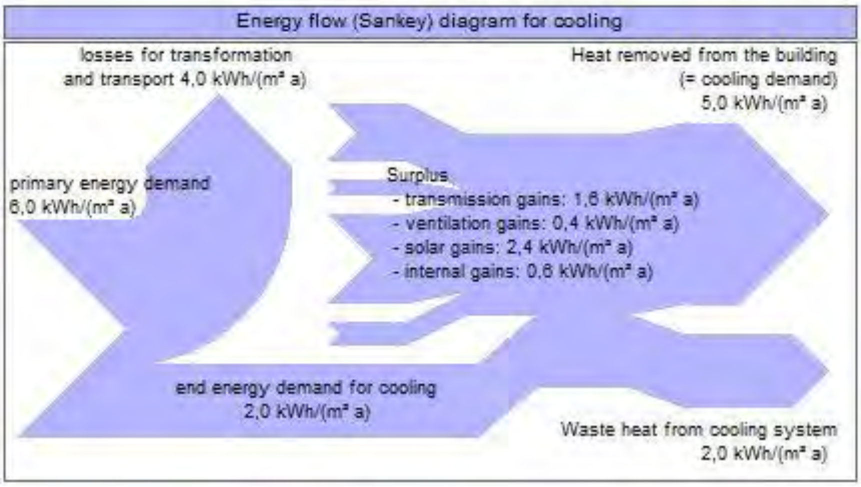


11.7.2 Climate – Building

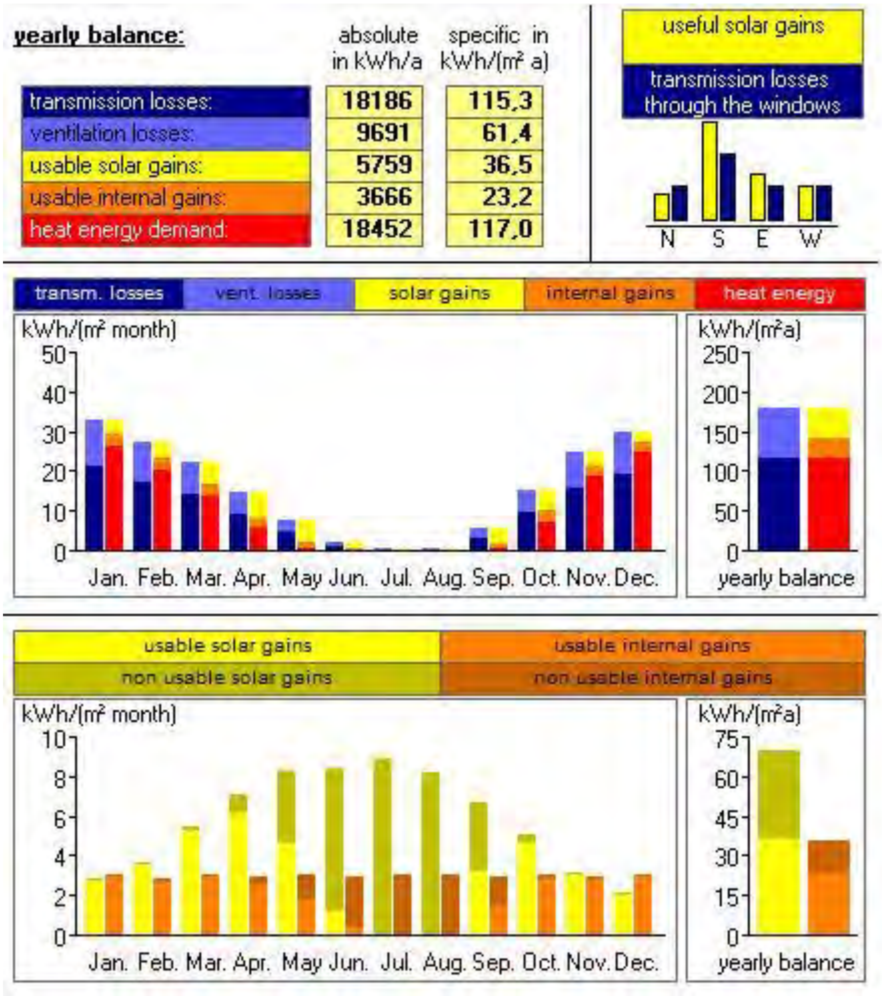
Climate		
Debrecen (Hungary)		
Maximum temperature of the year	34,3	°C
Maximum monthly mean value	20,6	°C
Month with maximum mean temperature	July	
Mean temperature of the year	10,4	°C
Minimum monthly mean value	-0,6	°C
Monthwith minimum mean temperature	January	
Minimum temperature of the year	-16,2	°C

Building		
Mean U value	0,49	W /m2K
Specific trasmission losses	279,3	W / K
Specific ventilation losses	1151	W / K
Specific losses	384,6	W / K
Thermal inertia	38,2	hours
Maximum heating load	12,3	kW
Maximum specific heating load	77,7	W / m2
Maximum cooling load	6,6	kW
Maximum specific cooling load	41,8	W / m2K
Limit temperature for heating	18	°C
Effective heating days	281	days

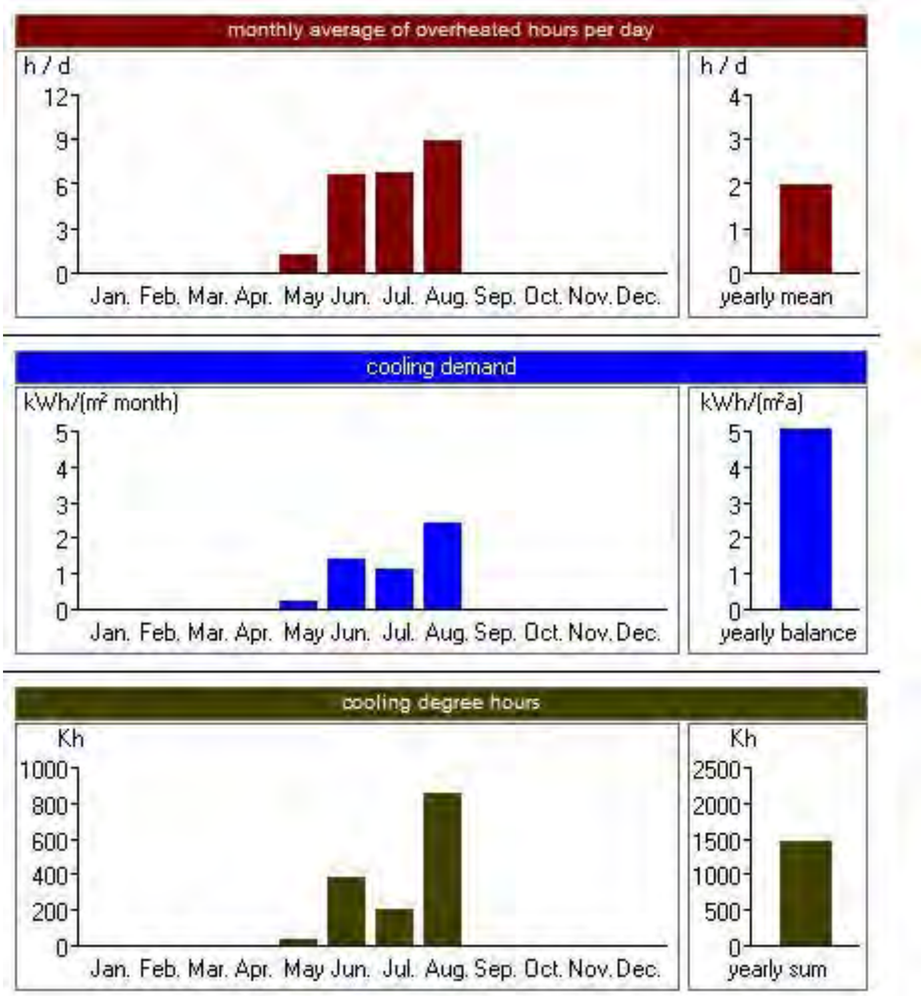
11.7.3 Energy flows



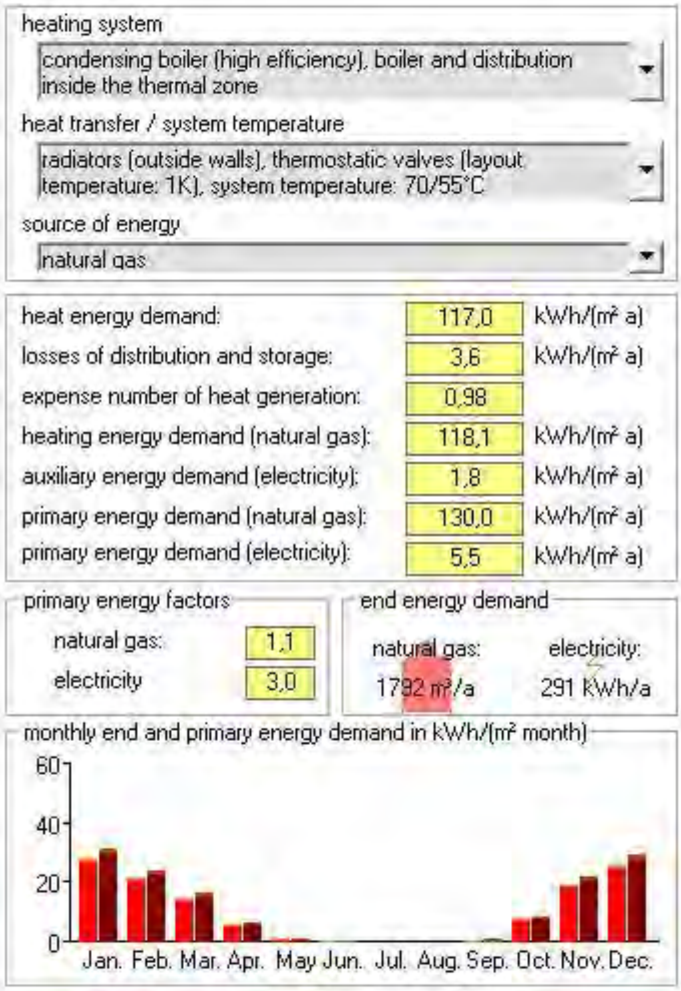
11.7.4 Heating



11.7.5 Cooling



11.7.6 Monthly end and primary energy demand



11.8 Comparison of the principal results

11.8.1 Economical analysis

Here on going I would like to analyse some differences coming from an economical analysis, or rather ,taking the prices of electric energy and natural gas in each country, according to the results for the energy needed coming from the simulations, it will be shown a review and a chart of the main differences.

11.8.2 Electric energy and natural gas: a cost comparison

First of all it is necessary to set a price for both electric energy and natural gas in the two countries.
Starting from Hungary, according with the following table (taken from the Hungarian energy office website), even though there are four main service providers , precisely

- EDF DÉMÁSZ
- E.ON Energiaszolgáltató
- ELMŰ Nyrt
- ÉMÁSZ Nyrt

the overall price could be settled around 40 ft/kWh.
Considering an exchange rate of approximately 1 € ~ 300 ft, the final price will be 0.132 €/kWh.
Please note the price includes VAT tax defined as "a form of consumption tax. From the perspective of the buyer, it is a tax on the purchase price. From that of the seller, it is a tax only on the value added to a product, material, or service, from an accounting point of view, by this stage of its manufacture or distribution. The manufacturer remits to the government the difference between these two amounts, and retains the rest for themselves to offset the taxes they had previously paid on the inputs."
We now report the table of the prices taken from Edf Demasz which is one of the major player on the Hungarian electricity market.

Electricity charges for universal service customers of EDF DÉMÁSZ Zrt. from 1/1/2013				
Price components	General all day tariff ("A1")			
	Residential customers until 1320 kWh p. a. (1)	Residential customers above 1320 kWh p. a.	Residential customer with approx. average (2400 kWh/year "A1" tariff) consumption	Non-residential customers
Standing charges and capacity charges				
Distribution standing charge (5), HUF/year				
without VAT	1.536			
with VAT	1.951			
Distribution capacity charge (5), HUF/kW/year				
without VAT				
with VAT				
Energy related charges (HUF/kWh)				
Universal service price (6)	16,35	17,28	*16,77*	21,77
Energy related system use charges (5)	14,07	14,07	*14,07*	14,07
For separate funds (7)	0,00	0,00	*0,00*	2,08
Total (8) (9)				
without VAT	30,42	31,35	*30,84*	37,92
with VAT	38,63	39,81	*39,16*	47,59
			Average charge[10] (HUF/kWh)	
without VAT			*31,48*	
with VAT			*39,97*	

Table 24 Electric Energy prices in Hungary

Secondly regarding Italian's electric energy prices in order determined by the data available from April 2014 taken from "l'Autorità per l'energia elettrica ed il gas", the price in €/kWh for a household family with less than 3kW power installed, including all the taxes, is more or less 0.25€/kWh.

We now report the table whom shows the details of the prices.

	Servizi di vendita			Servizi di rete	Oneri generali	TOTALE		
	Monorario	Biorario				Monorario	Biorario	
Quota energia (€/kWh)	fascia unica	fascia F1	fascia F23			fascia unica	fascia F1	fascia F23
kWh/anno: da 0 a 1800	0,08601	0,09156	0,08325	0,00484	0,037562	0,128412	0,133962	0,125652
da 1801 a 2640	0,08972	0,09527	0,08696	0,04181	0,054492	0,186022	0,191572	0,183262
da 2641 a 4440	0,09371	0,09926	0,09095	0,08163	0,077282	0,252622	0,258172	0,249862
oltre 4440	0,09799	0,10354	0,09523	0,12430		0,299572	0,305122	0,296812
Quota fissa (€/anno)	17,4186			6,1200		23,5386		
Quota potenza (€/kW/anno)				5,7228	0,2342	5,9570		

Table 25 Electric energy prices in Italy

Briefly now we'll report a table and a chart which summarize the situation:

SUMMARY	Price		Amount of costs	
Italy	0,25	€/kWh	492	€/year
Hungary	0,13	€/kWh	260	€/year
Energy Consumption 1968 kWh/year				

Table 26 Summary of energy prices

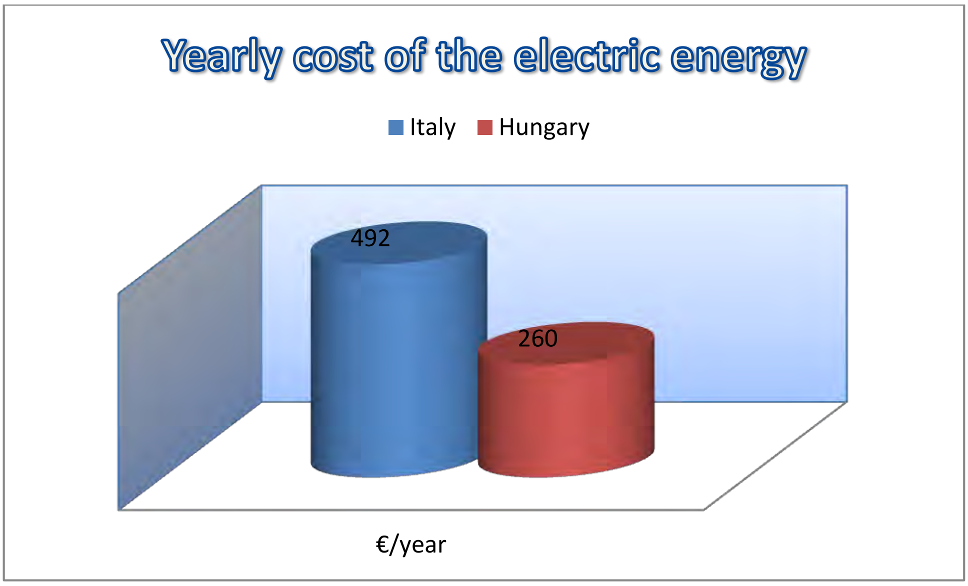


Figure 69 Yearly costs differences

Regarding the natural gas prices in each country, we could choose the two following mean values which are respectively:

	Natural Gas Price
Italy	0,9 €/m3
Hungary	140 ft/m3 -> 0,462€/m3

Then according within the results taken from casaNova simulations, we have summarized here the comparison between Verona and Debrecen about the yearly costs:

	Natural gas demand [m3/y]	Cost [€/m3]	Yearly cost [€/y]
Italy	1937	0,9	1743
Hungary	1792	0,46	824

Even if the gas demand is more or less similar the final cost is notable different , principally due to the diversified currencies.

12 Conclusions

Despite Hungary could has a great potential regarding renewable energy sources, as what it has come out from this thesis, this potential it is not very utilized. Many reasons and aspects have put some barriers even if in the recent years it is notable a significant improvement. Perhaps wrong policies and bad subsidisation system could be the firsts tasks to work on it.

The re-elected prime minister Viktor Orban , who has won the elections in February 2014, with an enormous consensus by the citizens, in accordance with the Russian prime minister Vladimir Putin is now planning to build the Southstream pipeline which aim is to directly connect Russia with Europe, excluding all the mid countries.

Within this it will be increased the European dependence from Russian gas, besides this strategy was hardly contested by the European Commission which has also opened an inquiry against Gazprom, the major Russian gas owner.

Moreover Orban has given the agreement to build two more nuclear reactors in the site of Paks , which already has four reactors. This will be supported with huge financials coming from Russian government, therefore a lot of people think and are concerned because this will enlarge Hungarian's energy dependence form Russia, mostly because nuclear fuel is taken from the Soviet Union.

However one of the main tasks of Orban's policy is to say no to foreigners multinationals and thinking about a renationalisation of energy companies, due to this there will be substantial decrease of energy bills, which were already settled with previous government's laws which have constricted these multinationals to reduce at least 10% of the price on the bills.

Overall researcher's opinion is that renewable energies are not competitive yet, in Hungary. The share will be increased in the coming decades, primarily from biomass and wind energy. Generally a huge amount of primary energy will be still based on natural gas though the efficiency of gas power plants is sharply increasing making possible a substantial saving of gas. What is more, apart from biomass and wind energy, geothermal usage is possible but with enormous costs likewise solar energy which it is still expensive.

In terms of EU's goal in this area is that by 2020 the total energy consumption be within 20 percent share of "green" sources. Hungary has 13 percent, but still only 5 per cent hold.

Peter Kaderják, director of the regional centre for energy policy research, says that reaching this target it is not an unrealistic idea with a very systematic ad resolute policy.

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