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EUROPEAN UNION

DECENTRALIZED ENERGY PRODUCTION OF ROOFTOP SOLAR SYSTEMS

A-Z INVESTMENT GUIDE FOR HOUSEHOLDS AND PRIVATE USERS

EnerGAIN

PROMOTION OF DECENTRALIZED ENERGY PRODUCTION FROM RENEWABLE ENERGY SOURCES

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Guide for Investment in households

FOREWORD

Photovoltaic systems stand as the fastest developing technology for production of electrical energy. The price of photovoltaic modules in the last 10 years is decreased for 10 times and the price of other components for more than 3 times. Thus, the production price of electrical energy from these systems is already competitive to the price of electrical energy offered to households. This dramatic fall of prices is mainly due to mass production which is result of preferential tariffs.

But this is not enough…We use electrical energy in households mainly in the evening hours and production of electrical energy from photovoltaic systems is in the daily hours. This means that these systems cannot be used for coverage of own needs with electrical energy. In order to adjust the production and consumption devices are needed for accumulation of the surplus energy. These devices will have high prices in a longer period. Because of this the role of an energy buffer should belong to the electro-distribution grid which transfers the surplus energy to the consumers, who at that moment have a need of electrical energy.

It is evident that there is great interest and enthusiasm for investment in photovoltaic systems. But there are also barriers for their wider application. Part are objective technical limits such as the limited capacity of the electro distribution grid and electro energetic system as a whole. However, many of the barriers are of subjective character such as: inertness of bureaucracy, lack of knowledge for the new trends in technology, opportunism towards changes, etc. As a result of this, the regulation is changing very slowly in favor of decentralized production units and photovoltaic systems.

Enabling the exchange of electrical energy is a benefit for everybody. Households – investors in photovoltaic systems get worthwhile investment, electrical energy suppliers – profit due to the balance of undertaken and sold energy in expensive and cheap tariff, the state achieves the set targets for installed capacities with renewable energy sources with financial burdening, citizens – new employments, etc.

This guide has several goals. The main is, as simple as possible, to introduce the citizens with the technology of photovoltaic systems, giving ideas of possible potential places for installation, calculation of their cost-effectiveness. Of particular importance is the use of experiences from the Republic of Bulgaria and Republic of Macedonia for improvement of regulations as well as application of good practices from both countries.

This guide is prepared within the project Promotion of Decentralized Energy Production from Renewable Energy Sources , Ref. no. SV006.1.11.023, a project implemented and co-financed by the European Union via INTERREG – IPA program for cross-border cooperation between Bulgaria – Macedonia. The goal of the project is to improve awareness and capacity building and knowledge for decentralized production of electrical energy and introduction of innovative solutions for energy efficiency on all levels (households, public and business sector).

The project is being implemented by: Foundation for local development and IT development – Gevgelija (FLORIT) and Association of eco energy producers – BG from Blagoevgrad (SPEE-BG), Republic of Bulgaria.

The preparation of the “Guide for investment in households” is made by the Center for Climate Changes – Gevgelija and the authors PhD Dimitar DImitrov and PhD Atanas Iliev. The Center for Climate Changes is a civil organization which main goal is protection and improvement of natural environment and alleviation of climate changes in Macedonia and the region.

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DECENTRALIZED PRODUCTION OF PHOTOVOLTAIC SYSTEMS

Guide for Investment in Households

Contents

1. Introduction

1.1. Renewable energy sources

Our life without energy is unimaginable. We use energy for electrical devices, lightning, heating up of premises, transport, etc. For all this, it is essential for energy to be available in suitable forms. One of those forms is electrical energy, which is most commonly produced by burning the fossil fuels. Electrical energy is considered as one of the noblest type of energy because it can be transformed in any type of useful energy. On the other hand, fossil fuels pollute the natural environment and contribute in the global warming of the Earth. Also, their reserves are limited and after a certain period of exploitation they will be exhausted. Beside the fossil fuels there are certain energy sources that almost do not have negative impact on the environment and are inexhaustible and renewable – so called renewable energy sources.

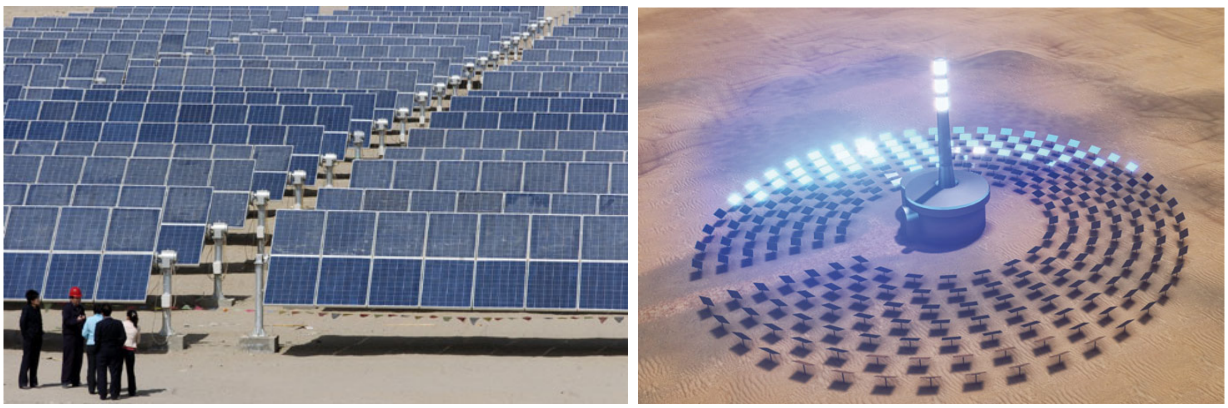
The use of renewable sources for production of electrical energy is in constant growth. According to the data of the IEA – International Energy Agency, in 2012, 13 % of the overall spent energy in the world is produced by renewable energy sources (including the big hydroelectric power plants). The expectations are that this percentage will rise up to 26 % by 2020. Some expectations point that by 2040 the share of the renewable energy sources compared to 2012 will be tripled.

Thus, renewable energy sources are sources that can be renewed or cannot be exhausted. Typical renewable sources are: solar energy, wind energy, hydro energy, biomass energy, geothermal energy and other. Perhaps these facts are clear to everyone but it is of essential importance how much energy can these sources generate, whether the produced energy can be used at once and whether its use is cost-effective.

Pic. 1.1: Renewable energy sources

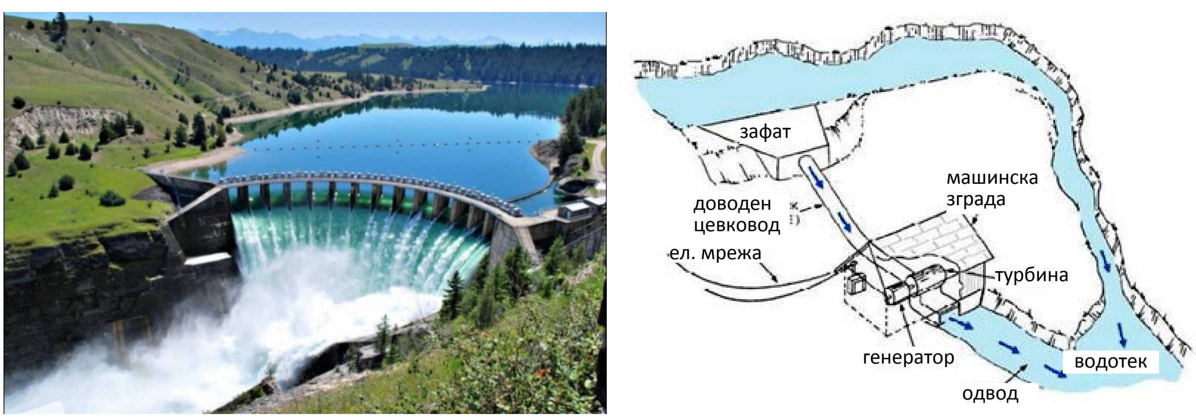
Beside the role in the protection of the natural environment, a great contribution in the use of renewable energy sources is the application of domestic resources and decrease of the import need, which at the same time means increase in the number of employments. On the other hand, the use of renewable energy sources is accompanied by high investments and usually the production price of the received energy is higher than the other sources. As a result of this, there are big investments in the improvement of technologies and efficiency, increase of the scope of their use in order to decrease the investments and achieve competitiveness with other (classical) sources of electrical energy.

The Solar Energy is result of the thermic reactions that happen in the Sun. On one hand, it is clear that this source will exhaust one day its fuel but on the other this will happen after several billions of years, which, from today's aspect is a very long period, so the solar energy is considered inexhaustible. It is most frequently used for acquisition of heat (hot water, steam) and electrical energy. The conversion of solar energy into electrical is exerted with photovoltaic systems, as well as with solar thermal plants with concentrators.



Pic. 1.2: Solar energy systems

Hydro electrical power plants use the energy of water movement. Generally hydro electrical plants are seeping and are placed by water flows (rivers, waterfalls, etc.) or accumulations beside ponds. Beside with the hydro electrical plants it is also possible to apply the water energy from oceans and seas through use of wave energy and water movement in the process of flux and reflux.

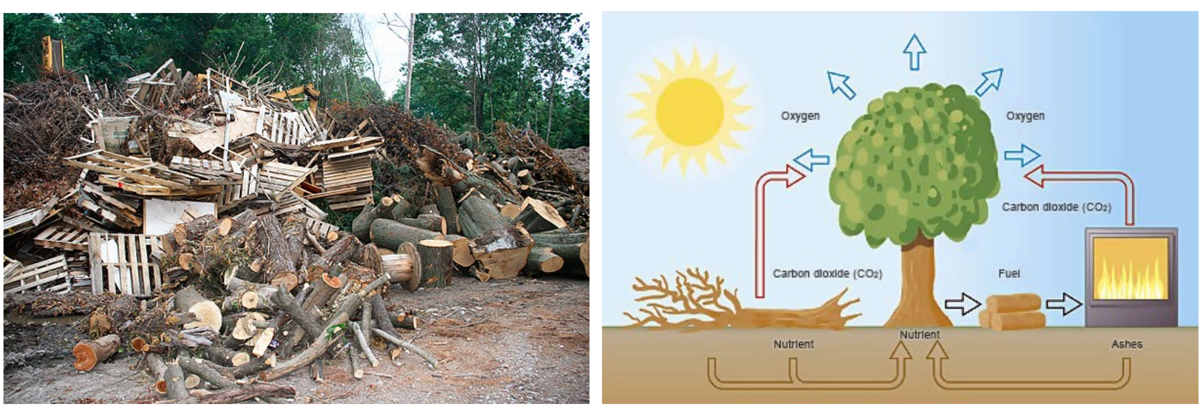


Pic. 1.3: Hydroelectric power plants

The energy of the movement of air masses – ***wind*** can be used for acquisition of electrical energy by use of wind generators. They can be set up on the land or out of land, on some water area (ocean or sea)

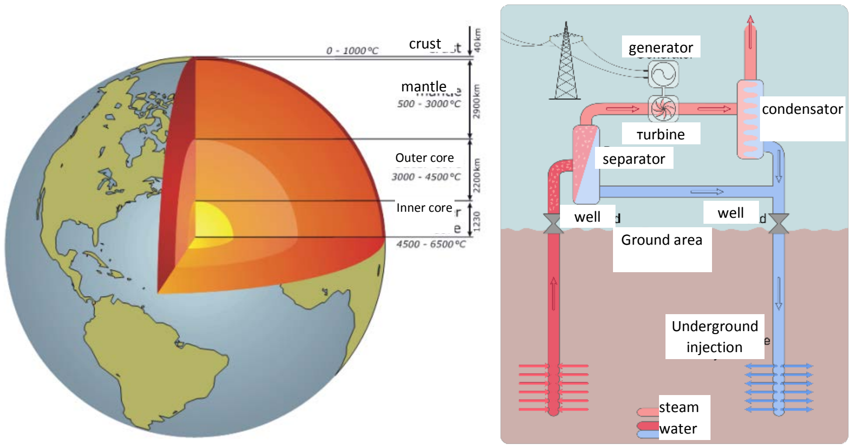
Pic. 1.4: Wind power plants

Biomass is an energy source contained in the biologically decomposing organic matters of plant and animal origin (forestry and agriculture residues, wooden and non-wooden plants purposely planted, farm waste, communal and industrial waste). There are several ways of biomass procession where we get solid, liquid or gas fuels. Then they burn in internal combustion engines, which move generators for production of electrical energy. Although in the process of biomass use there is combustion of fuel accompanied by gas emission that have negative impact on the environment, biomass (at plants for instance) previously absorbed more carbon dioxide. As a result it is considered that the overall impact on the environment is positive. Biomass is considered as a renewable energy source only if there is a balance between the consumption and planting.



Pic. 1.5: Utilization of biomass

Geothermal energy is heat energy from the interior of the Earth. This heat, in a type of steam or hot water at certain places spurts up on the very surface of the ground (geothermal springs, volcanic windows, gazers). With the use of steam-turbine plants this heat is transformed into electrical energy.

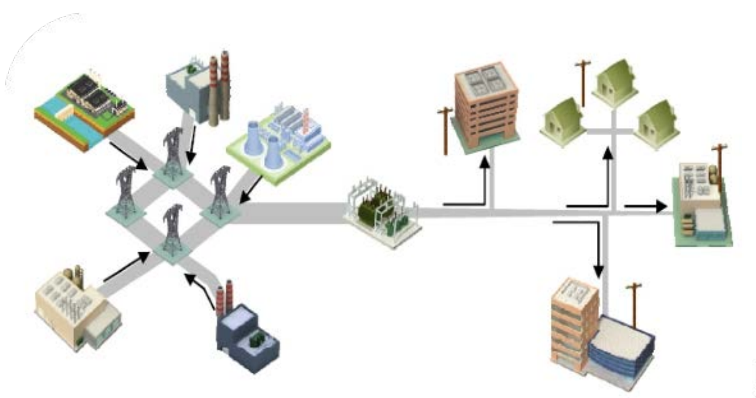


Pic. 1.6: Geothermal energy and plants for its exploitation

Beside the geothermal energy, accumulated energy in uranium and partially the energy received from the tide, all other types of energy in nature emerge from the solar energy.

1.2. Decentralized production of electrical energy

In the current electro energetic systems electrical energy is mainly generated in big electrical power stations, such as thermo electrical, nuclear, hydro electrical, plants on natural gas and other. Through the transmission and distributive network, electrical energy is transferred to customers.



Pic. 1.7: Centralized production of electrical energy

High confidence is achieved with the management of electrical networks during the transmission and distribution of electrical energy, with relatively acceptable price. However, the need for increased energy efficiency, continuity in the electrical energy supply and decrease of the negative impact on the environment, as well as deregulation of the market in this sector leads to change in the mentioned concept of the electro energetic system with big electrical power stations and big consumption centers. Thus, there are more small production units in the electro energetic system placed near the consumers, i.e., there is an ongoing process of decentralization of the production of electrical energy.

Decentralized production differs in many aspects from the traditional centralized concept of the electro energetic system. In addition, big numbers of production units are connected to the system with lower power, which are right next to the electrical energy consumers. They produce heat at the same time very often, which local consumers use for heating and even cooling of premises. Systems that use renewable energy sources are compatible with this concept. They usually have lower power and are connected to the distributive network on middle or low voltage. In this case, electrical energy is produced to the very consumers, which decrease the loss during transmission and distribution of electrical energy. This way of production is called decentralized, dispersed or distributive production. In some cases, decentralized units, beside production can encompass also plants for energy accumulation and to adjust their power according to the current demand of the system. In this way the ultimate beneficiaries, beside the role of producers actively participate in the balancing of the network.

The application of the decentralized production has many advantages. The most obvious result is set up of decentralized production units in the vicinity of consumers. At the same time, the amount of energy that is transferred through the network is decreased which results in double profit. One is that it can significantly lower the loss during transfer of electrical energy. Also, in case of bigger number of consumers, due to the weak exhaustion, can help in avoiding the need for additional investments in the so called “bottlenecks” of the network. In the following chart are given the plants that are applied as decentralized plants.

		ФОСИЛНИ ИЛИ ОБНОВЛИВИ							ОБНОВЛИВИ					
		Парно-турб. постројки со мала моќност	Гасни турбини	Микро-турбини	Мотори со внатрешно согорување	Стирлинг машини	Горивни ќелии - со висока температура	Горивни ќелии - со ниска температура	ФВ системи	Мали ХЕЦ	Ветрогене-ратори на копно	Ветрогене-ратори на море	Геотермални	Соларни термални
ОСНОВИ	Типна гориво / извор на енергија	гас, јаглен, дрвен јаглен биомаса	гас	гас	дизел, нафта, биогориво, гас	гас, соларна енергија	гас, водород	гас, водород	соларна енергија	енергија на вода	ветерна енергија	ветерна енергија	топлина од Земјата	соларна енергија
	Моќност [MWe]	0.5 - 10+	0.5 - 10+	0.03 - 0.5	0.05 - 10+	<0.01 - 1+	1 - 10+	<0.1 - 3+	<0.001 - 5	0.05 - 1	0.5 - 6+	5 - 10+	0.5 - 3+	<0.001 - 2
	Статус на технологија	Комерцијално достапна	Комерц. достапна	Во развој / комерц достапна	Комерцијално достапна	во развој/ демо/ комерц.	Во развој / комерц достапна	Во развој / комерц достапна	Во развој / комерц достапна	Комерц. достапна	Комерц. достапна	Во развој / комерц достапна	во развој/ демо/ комерц.	во развој/ демо/ комерц.
	Трошоци	€	€	€€	€	€€/€€€	€€€	€€€	€€€	€€€	€€€	€€€	€€	€€€
	Влијание врз околината	☼/☼☼	☼/☼☼	☼☼	☼/☼☼☼	☼☼	☼☼/☼☼☼	☼☼/☼☼☼	☼☼☼	☼☼☼	☼☼☼	☼☼☼	☼☼☼	☼☼☼
	Социјална прифатливост	•	••	••	•	••/•••	•••	•••	•••	•••	•••	•••	••	•••
	Степен на развој	Висок	Висок	Мал, во пораст	Висок	Мал	Мал	Мал, во пораст	Мал, во брз пораст	Среден	Среден	Мал, во брз пораст	Мал	Мал
ПРИМЕНА	Во индустрија	***	***	*	***	*	***	**	*	**	**	-	-	-
	Во комерцијални објекти	*	**	**	***	***	*	***	**	*	*	-	-	-
	Во домаќинства	-	-	***	**	**/***	-	***	***	-	-	-	-	-
	Можност за когенерација	Да	Да	Да	Да	Да	Да	Да	Не	Не	Не	Не	Да	Да
Трошоци	Инвестиција [€/kW]	550-1250	500-1100	1000-2000	350-1000	1500-8000	3500-10000	2000-8000	4000-8000	1400-5000	800-2000	1200-3000	800-4000	1500-2000
	Инсталирање [€/kW]	100-200	65-150	50-200	60-120	40-200	500-850	500-850	40-150	100-200	100-200	600-800	200-400	100-200
	Производна цена на ЕЕ [€ct/kWh]	3-7	3-5	8-15	4-7	9-15	15-35	10-25	20-40	6-14	6-10	8-15	NA	NA
	Работен век	20	20	20	20	15	10	10	20	60	20	20	20	20

Table 1.1 – Characteristics of technologies for production of electrical energy

1.3. Innovative examples of use of decentralized production in other countries

1.3.1. Plant for decentralized production of electrical energy and heat in METRO market Dusseldorf, Germany

One of the measures for energy efficiency in METRO GROUP, minimizing the expenses and reduction of CO2 emissions, in one of the facility of METRO Market in Dusseldorf, Germany is installed plant for decentralized combined production of electrical energy and heat.

The plan in the future is to adjust the production with the distributed hybrid energy system set up on the facility, for which at moment receives preferential price.

DATA ABOUT THE PROJECT

■ Investor: Metro Cash & Carry Deutschland GmbH
■ Partner: E.ON Connecting Energies GmbH
■ Location: Düsseldorf
■ Type of plant: 2G Agenitor 306
■ Power: 250 kWe, 265 kWth
■ Start of operation: 7/2013
■ Fuel: natural gas
■ Production of EE: about 1 GWh/year
■ Production of heat: околу 1,16 GWh/year
■ Reduction of CO2 emissions: 280 t/year
■ Investment: 475,000 EUR

1.3.2. Plant in adapted mill in Wegberg, Germany

The plant is purposed for cogenerated production of heat and electrical energy in a restored facility – mill, adapted and conversed into a hotel with restaurant

DATA ABOUT THE PROJECT

■ Investor: GC Wärmedienste GmbH
■ Fuel supplier: PRIMAGAS Energie GmbH & Co. KG
■ Fuel: liquid gas
■ Location: Wegberg
■ Power of the cogenerated plant: 5.5 kWe, 12.5 kWth
■ Power of the condensing boiler: 60 kWth
■ Start of operation: 2013
■ Consumption of EE: околу 100 000 kWh/year
■ Reduction of CO2 emissions: 30 t/year
■ Investment: approx. 50,000 euros

1.3.3. Burning cell in family building in Bottrop

Burning cell has been installed for a longer period in a family building in Bottrop which at the same time produces electrical energy (continuous power of 1,5 kW) and heat (600 W). 79 % of the electrical energy is directly used for own purposes, the surplus is sold on the network.

DATA ABOUT THE PROJECT
■ Type of facility: family house
■ Floor area: 400 m²
■ Year of construction: 1987
■ Number of tenants: 6 persons
■ Age of the heating system: 11 years
■ Consumption of oil: approx. 4,500 l /year
■ Type of plant: CFCL BlueGen inc. with additional heater
■ Production: Smit GmbH
■ Date of installation: 15.08.2014
■ Production of EE: 3 783 kWh
■ Use for own needs: 79 %
■ Reduction of CO2 emissions: 1.2 t/year

1.3.4. Sterling machine for production of electrical energy and heat in a family house

A boiler which uses gas as a fuel is replaced by a Sterling machine and integrated condensation boiler for coverage of ultimate burdening and big water tank for heating and sanitary hot water.

DATA ABOUT THE PROJECT
■ Type of facility: family house
■ Useful area: 120 m²
■ year of construction: 1956
■ No. of tenants: 3 persons
■ Age of heating system: 20 years
■ Energy consumption: about 32 000 kWh Natural gas per year
■ Plant: Brötje EcoGen WGS 20.1
■ Construction: Uwe Pyschny GmbH
■ Date of installation: 12.12.2013
■ Production of EE: 2 650 kWh
■ Use for own needs: 62 %
■ Reduction of CO_2 emission : 1,9 t/год

1.3.5. Replacement of coal boiler with co-generative plant in a family house

Family house built in 191, with useful area of 160 m^2 for heating of space used coal boiler. The boiler is replaced with co-generative plant with Sterling machine, which uses natural gas as a fuel.

DATA ABOUT THE PROJECT
■ Type of facility: family house
■ Useful area: 160 m²
■ Year of construction: 1919
■ No. of tenants: 2 persons
■ Age of heating system: 24 years
■ Coal consumption: 5-6 t/year
■ Plant: Viessmann Vitotwin 300 W
■ Performance: Smit GmbH
■ Date of installation: 07.03.2014
■ Production of EE: 1 695 kWh

■ Use for own needs: 34 %
■ Reduction of CO_2 emission: 2,1 t/year

1.3.6. Replacement of oil fueled boiler with co-generative plant in a family house

A family house built in 1981 with useful area of 133 m^2 used oil fueled boiler for heating of the space. The boiler is replaced with co-generative plant in internal combustion which as a fuel use natural gas. The electrical power is 1 kW. The system uses water tank which serves as a heating source for decrease of highest power and hot water tank for continuous heating of the space. 34 % of the produced electrical energy on annual basis is used for own needs in the facility and the remaining part of the energy is transferred to the grid.

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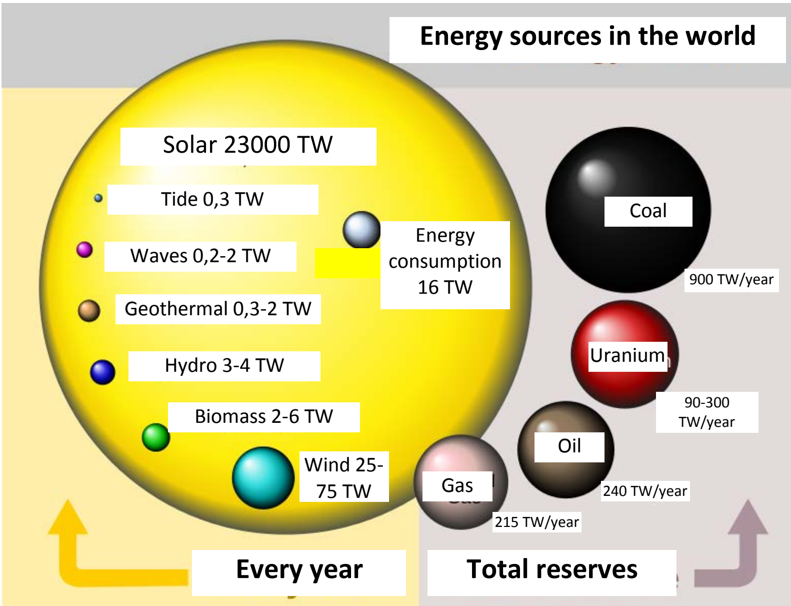
DATA ABOUT THE PROJECT
■ Type of facility: family house
■ Useful area: 133 m^2
■ Year of construction: 1981
■ No. of tenants: 2 persons
■ Age of heating system: 25 years
■ Oil consumption: 3000 l/year
■ Plant: Vaillant EcoPower 1.0
■ Performance: Huxel GmbH
■ Date of installation: 07.02.2014
■ Production of EE: 4 210 kWh
■ Use for own needs: 34 %
■ Reduction of CO_2 emission: 2,5 t/year

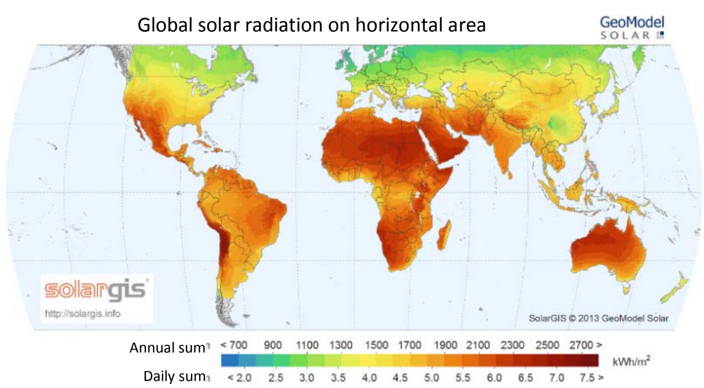
1.4. Energy from the solar radiation

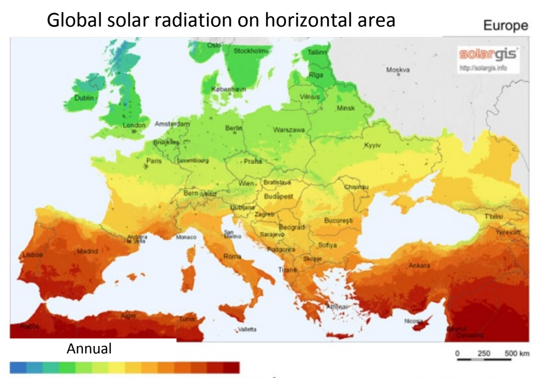
The energy from the solar radiation is the biggest energy source on Earth. The energy that annually comes to the surface 10000 times bigger of the annual energy needs in the world or the energy which in one hour comes to the Earth is slightly smaller of the energy that the world uses during one year.

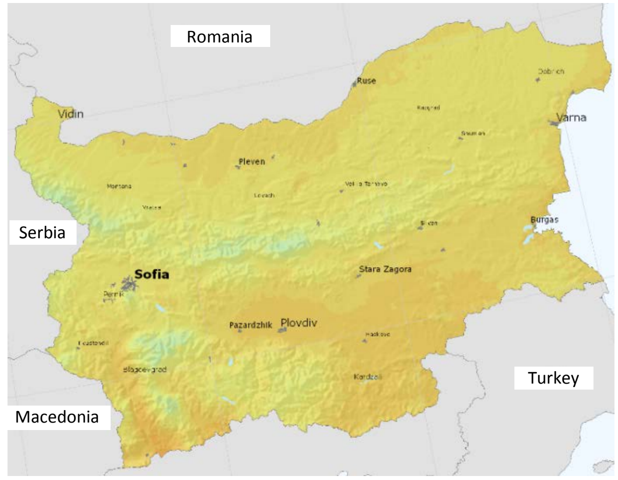


Pic 1.8: Amount of different types of energy in the world

The potential of the solar radiation on the Earth ground is biggest around the areas of Equator and lowest at the north and south pole. Beside this, solar radiation also depends on the altitude, micro location conditions, etc. In the Republic of Macedonia and Republic of Bulgaria, depending on the latitude and longitude, the energy of the global solar radiation which on annual basis falls on the horizontal area is about 1300 to 1550 kWh/m^2. This is about 30 % more from the solar radiation in the Central-European countries, Germany for instance.







Pic. 1.9: Energy of the solar radiation in the world, Europa, R. Macedonia and R. Bulgaria

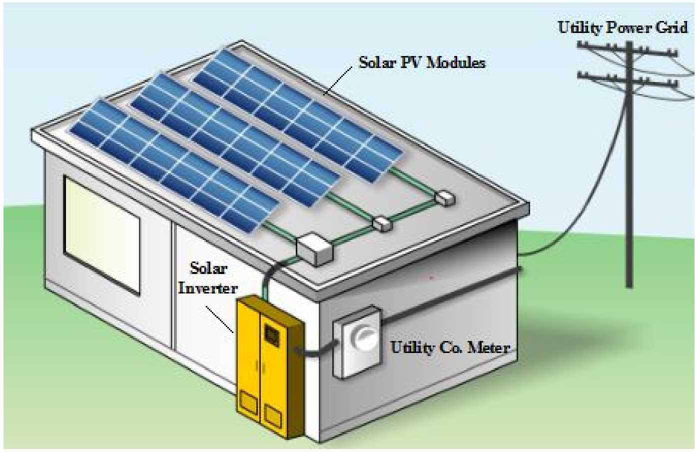
2. Photovoltaic systems and components

Photovoltaic (PV) systems are plants that make direct conversion of the solar radiation into electrical energy and adjust it for further application. In the following chart are given the advantages and disadvantages of the PV systems.

ADVANTAGES	DISADVANTAGES
• Ecologically accepted source of electrical energy • Available technology • Low maintenance expenses • Modularity • Lower price	• Variability (day-night, winter-summer) • Incertitude (changing weather conditions) • Inability to sell the produced EE on a liberalized market according to satisfying prices

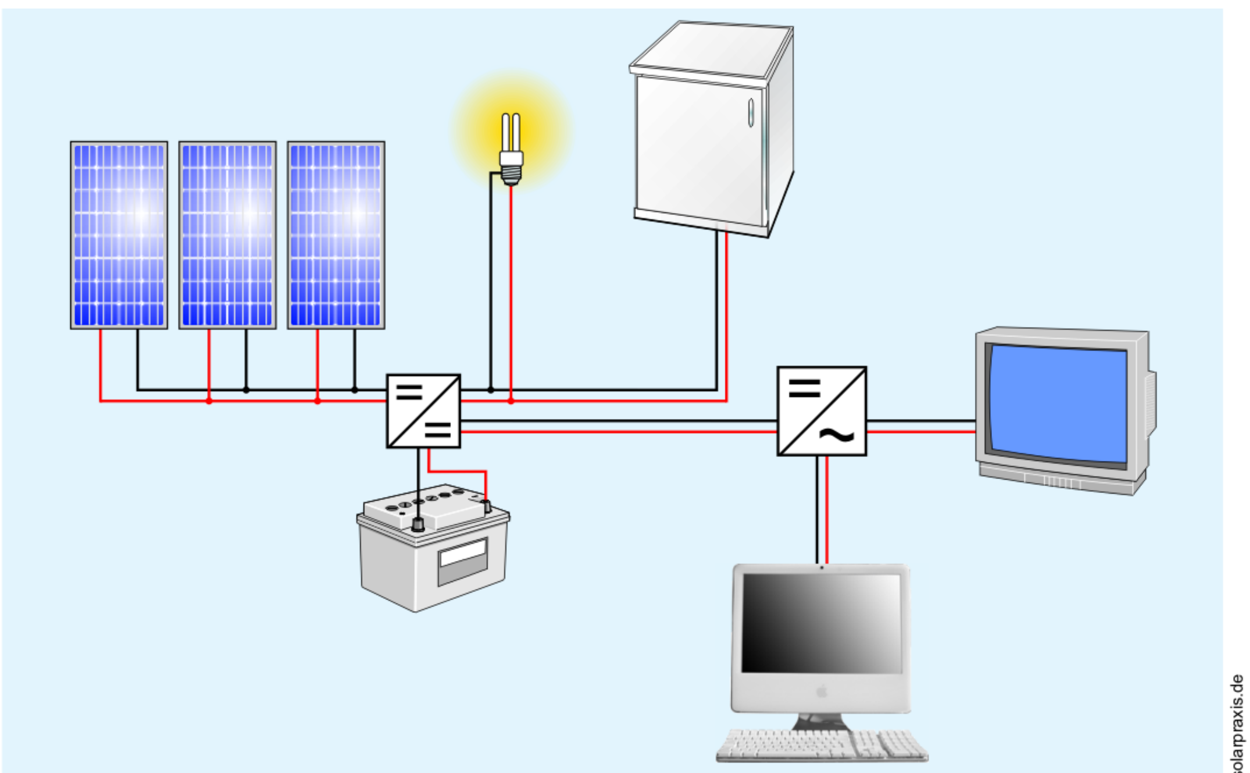
They are divided according to the type of ultimate beneficiaries, where we have: systems connected on networks and autonomous systems. The biggest number of installed PV systems are connected to the electro distributive network, as is case here and abroad.

In case where PV systems are connected to the network, we have big photovoltaic plants (power of several tens of Kws to several hundreds of MW) that installed in a field and smaller PV systems (up to 10 kW), which are frequently integrated in facilities.



Pic 2.1: Photovoltaic system connected on the grid

The autonomous PV systems are purposed for electrical energy supply for consumers who are far from the network. Usually they are with lower power (up to several tens of kW) and in order to provide continuous supply of electrical energy the systems uses accumulator batteries.



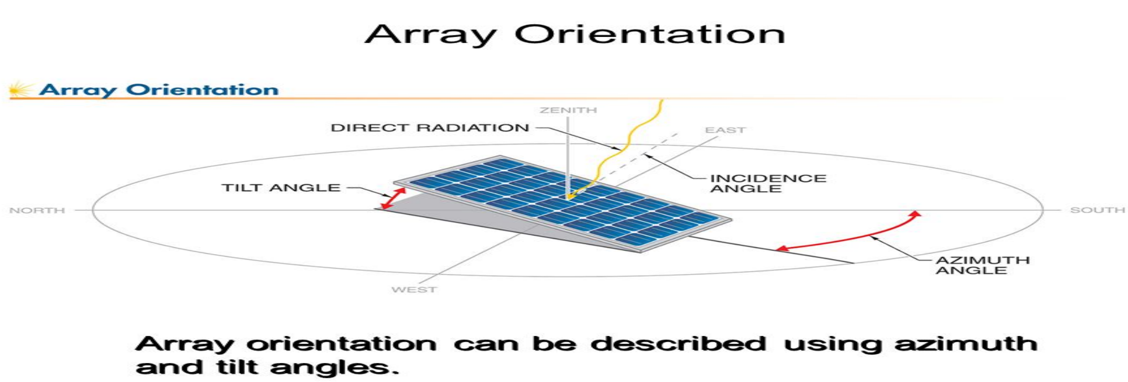
Pic.2.2: Autonomous photovoltaic system

2.1.1. Location and orientation of the photovoltaic panels

The production of electrical energy by the PV systems depends on the potential of the solar radiation on the location where they are set up. In order to increase the dropping solar radiation, PV modules are set up at a certain plane tilts, which for the locations of Macedonia and Bulgaria is best to be around 30°, with south Pane Azimuth.

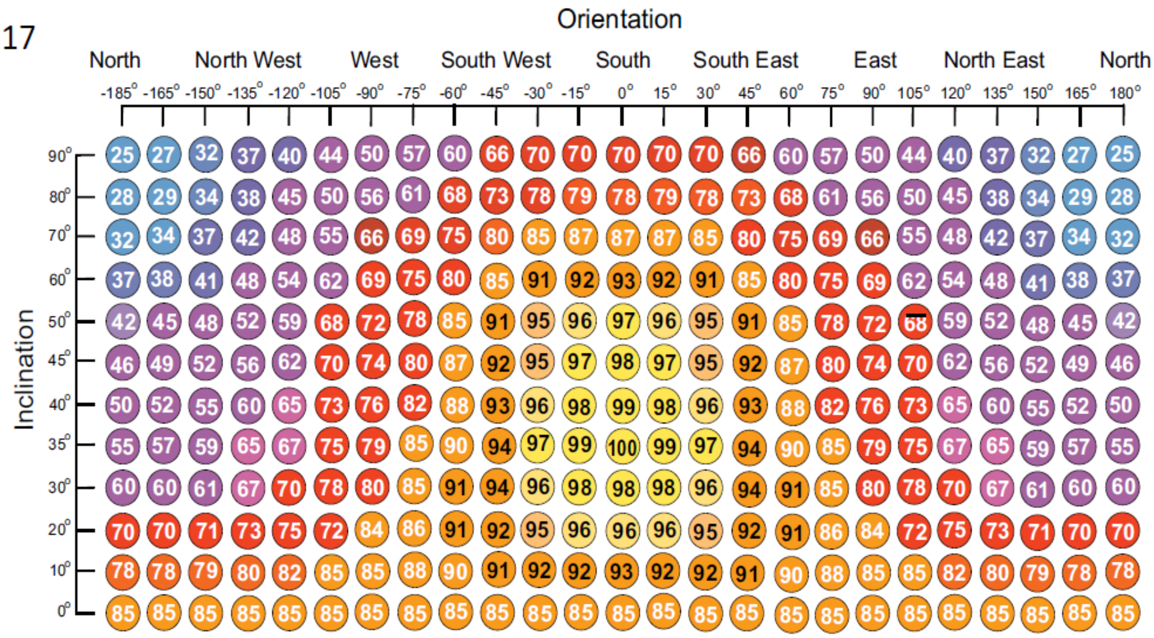
Large number of PV systems are placed on facilities where plane tilts and Pane Azimuth are dictated by the very facilities. In the pictures we can see the results of the analyses of solar radiation for different Pane Azimuth and plane tilts.

Pic 2.3: PV panels placed on roof with different pane azimuth and plane tilt



Pic. 2.4: Azimuth (orientation) and tilt angle

Fig 17

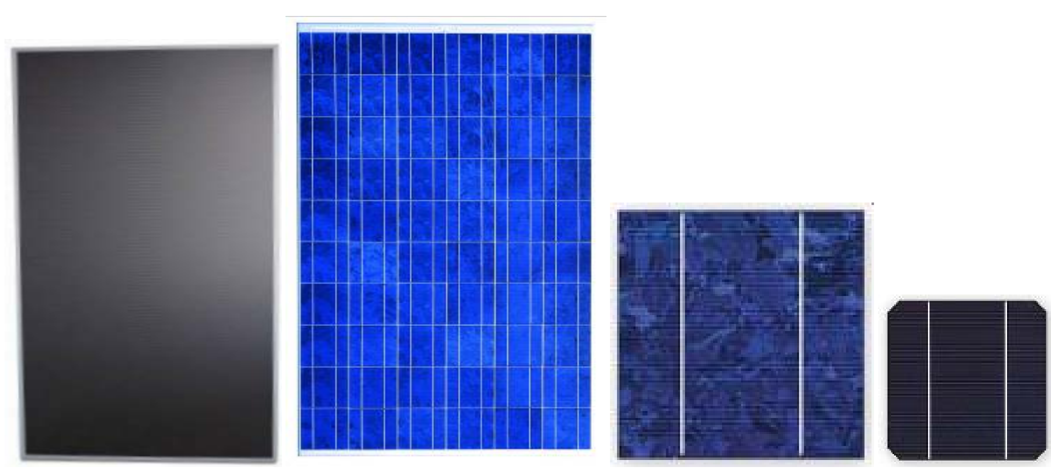


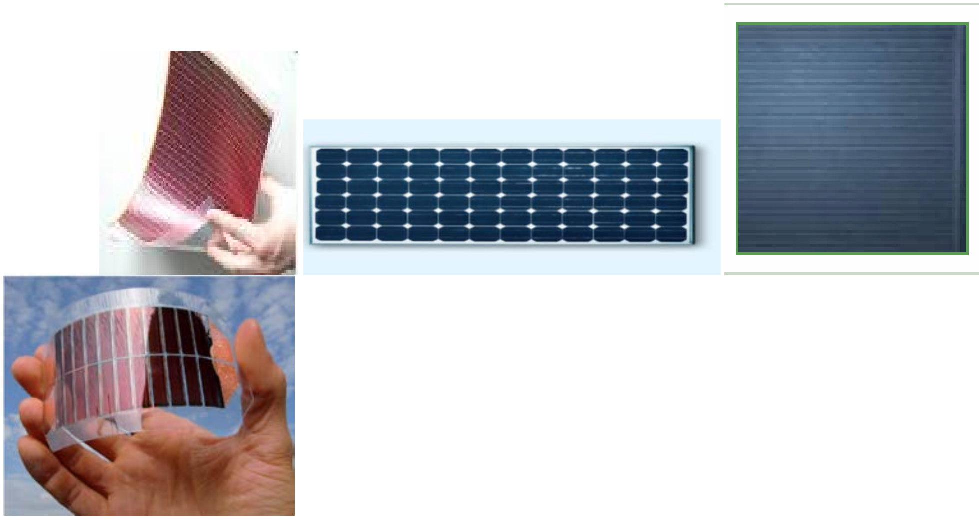
Pic. 2.5: Percentage of dropping energy in relation to energy at optimal set-up (on annual level)

2.2. Photovoltaic generator

2.2.1. Types of solar cells

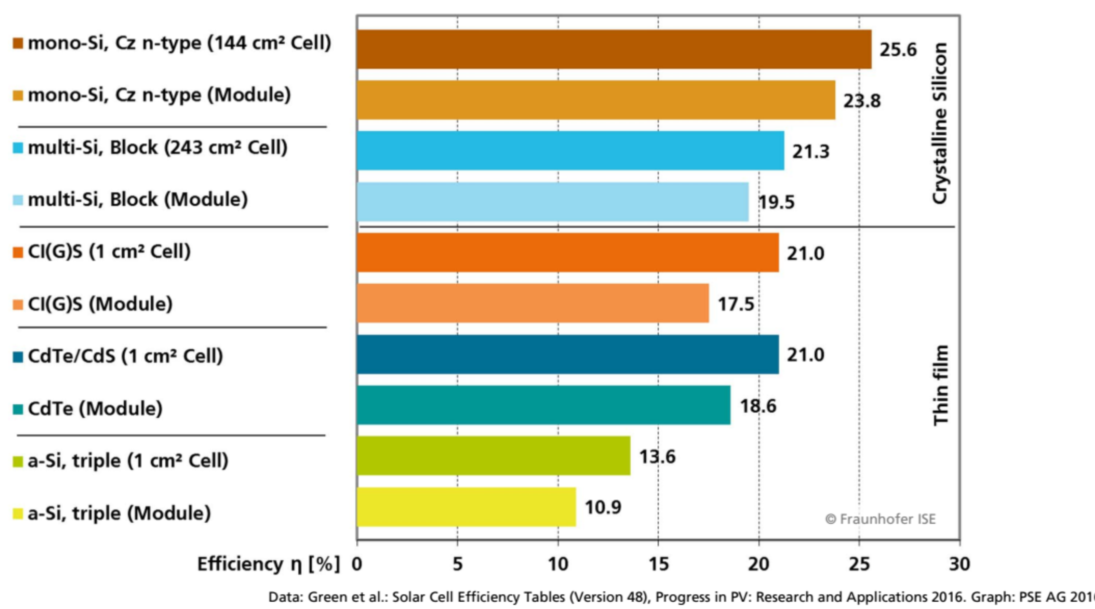
The solar cells are the core of the PV systems. They directly transform the solar radiation into electrical energy. The transformation is made without rotating parts, through complex quantum-dynamic processes. The cells are made of semiconducting material: monocrystaline and polycristaline silicon, amorphous silicon, gallium arsenide, cadmium telluride, copper indium diselenide, etc. Over 90 % of the PV cells on the market are monocrystalline and polycrystalline silicon.





Pic. 2.6: Outlook of PV modules with different cells technology

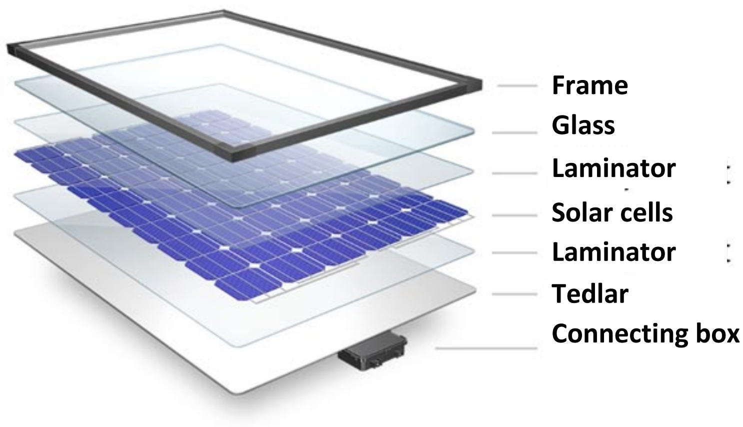
Cells of single crystal silicon have the highest efficiency, but their price is the highest. Cells of polycrystalline silicon had somewhat lower efficiency, lower cost and show better performance at higher temperatures relative to single crystals. Cells of amorphous silicon (from thin film) have the lowest price, but also lower efficiency. They have better performance during partial shading and cloudy time compared to others, their service life is lower and their performance is rapidly getting worse. The picture shows the achieved efficiency of commercially available photovoltaic cells.



Pic. 2.7: Efficiency of photovoltaic cells and modules made with different technologies and materials

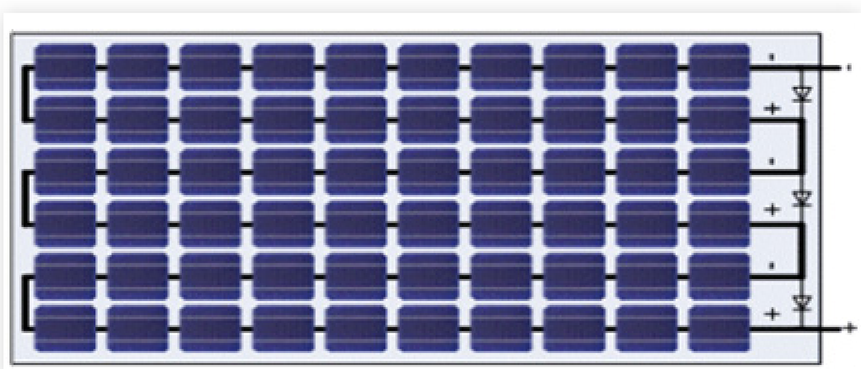
2.2.2. Characteristics of photovoltaic cells, modules and generators

The electrical power of a photovoltaic cell depends on the technology used and its area and totals 1-4 W. To get more power several cells are connected in a row. The cells are slim and are made of fragile material. As a result of this, for regular functioning they are placed on a base of special material (tedlar), protected by glass in advance and the whole construction is strengthened with aluminum profile. Thus, a photovoltaic module is formed.

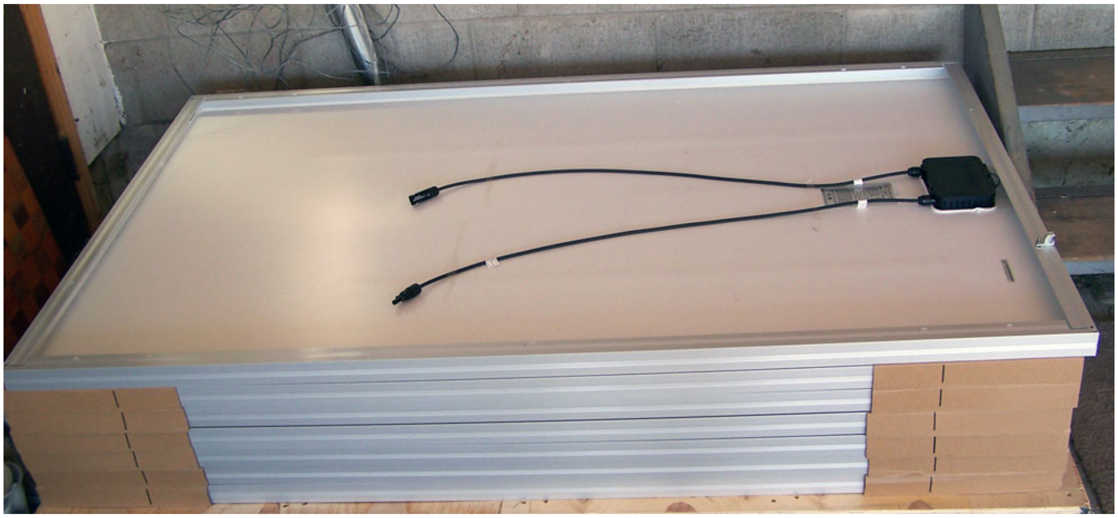


Pic. 2.8: Consisting components of photovoltaic module

All cells of the module are most frequently connected in a row. In parallel of every 15-20 cells a diode is placed which protects the module of extreme heating, which is result of shading and malfunctions in some of the cells. Electrical connection of the cells goes to distribution box placed on the back side of the modules. Two wires come out of the box at which ends there are connectors. Most frequently used connectors are of type MC-4, rarely Tuso.

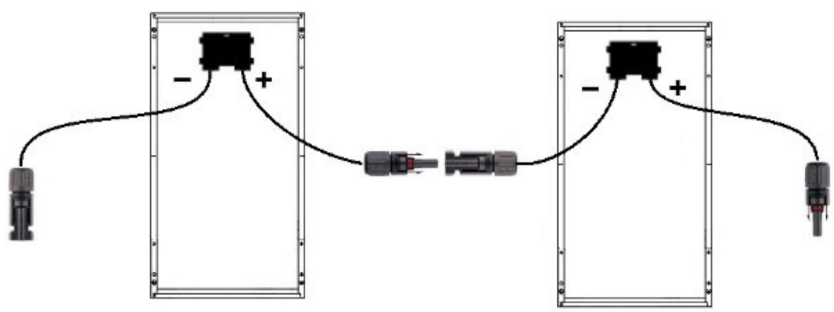


Pic. 2.9: Connection of cells in a photovoltaic module



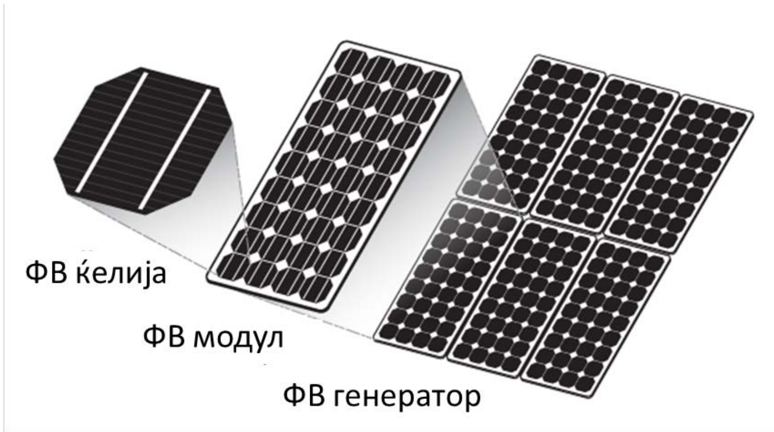
Pic. 2.10: Outlook of back side of a photovoltaic module

Bigger power can be achieved with a serial connection of the photovoltaic modules, made with suitable alignment of the connectors. In this way we have consecutive connected modules in a row – so called *string.* The number of serially connected modules in a one string is determined with special calculations and depends on the minimal and maximum value of the input voltage of the inverter and characteristics of modules.



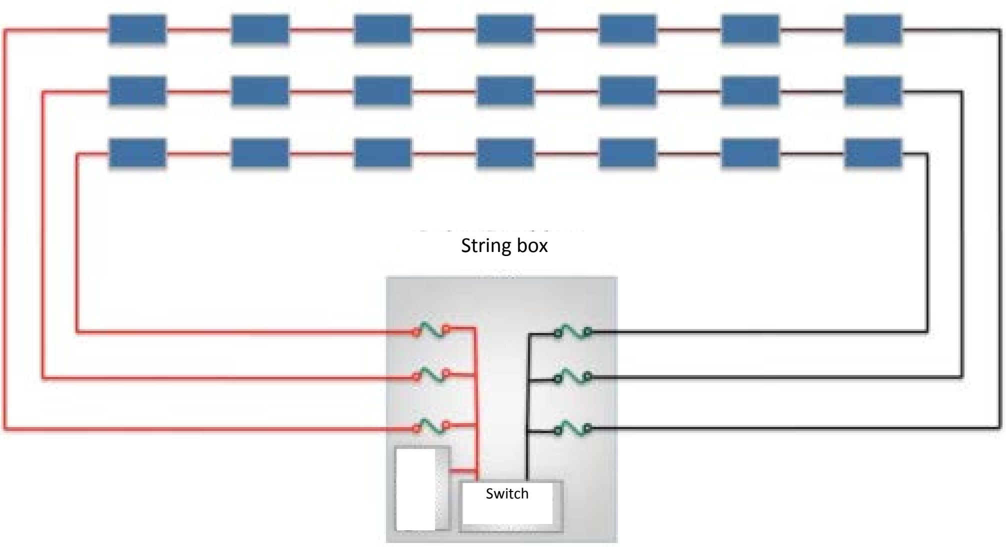
Pic. 2.11: Connection of photovoltaic modules

The strings can be connected in parallel and this is most often performed in the so called string boxes. Beside the connections, in the string boxes are placed elements for over-electrical and over-voltage protection and in certain cases a clutch for switching off of the circuit. A PV system is created in this way.

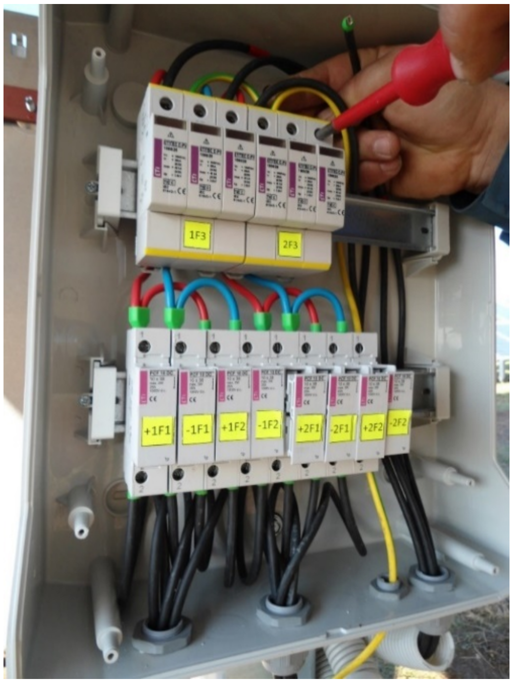


Pic. 2.12: Names of consisting components of photovoltaic generator

Pic. 2.13: Photovoltaic panels



Pic. 2.14: Connection of photovoltaic generator

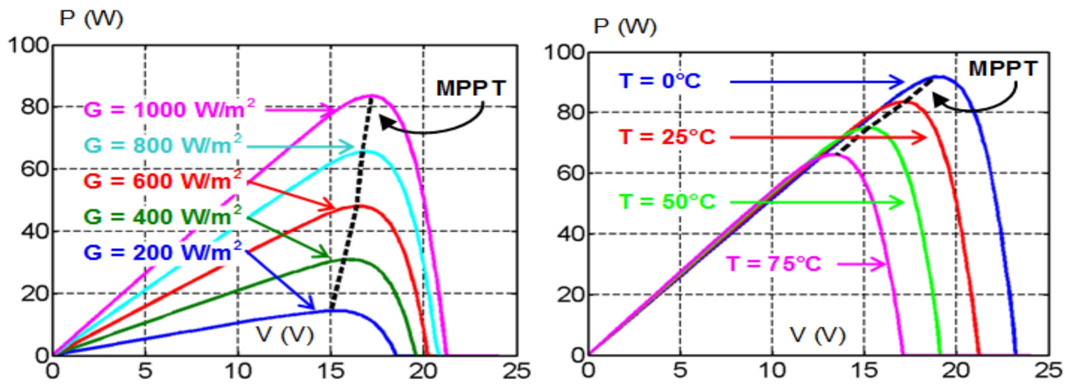


Pic. 2.15: String box

It is very important at a PV generator all modules to be from the same producer, same type and to have the same characteristics. Also, the number of modules in a string should be the same. Otherwise, the generator will not work efficiently and there is a possibility of damaging of modules.

The outlet of the PV generator depends on the intensity of the solar radiation that falls on the area of the modules and temperature od cells. If these two parameters do not change, the power of PV generator depending on the voltage and the reaction of the consumer connected to its ends, the power changes from zero to some maximum value P_{mp}, where the generator works most efficiently. For adjusting the generators to work in that point there are devices for looking the maximum power point tracking (MPP tracker), which are most frequently integrated in the inverters.

With the decrease of the solar radiation is decreased the maximum power that the PV generator can give. Opposite of this is the impact of the cells temperature. With the lower temperature rises the power and vice versa. In addition, for every °C of higher temperature of the cells, the power of the PV system falls from 0,35 – 0,5 %. On the picture is shown a model which power falls from 92 W at 0 °C to 65 W at 75 °C. Suitably, the decrease of power totals (92 – 65) x 100 / (92 x 75) = 0,391 %/°C



Pic. 2.16: Characteristics of power of photovoltaic module during application of solar radiation and change of cells temperature

Regarding the dependence of the power the PV generator from the intensity of the solar radiation and cells temperature, modules are tested at exact determined conditions, called Standard Test Conditions (STC). The characteristic parameters that are received at these conditions are seen in catalogues for modules given by the producers.

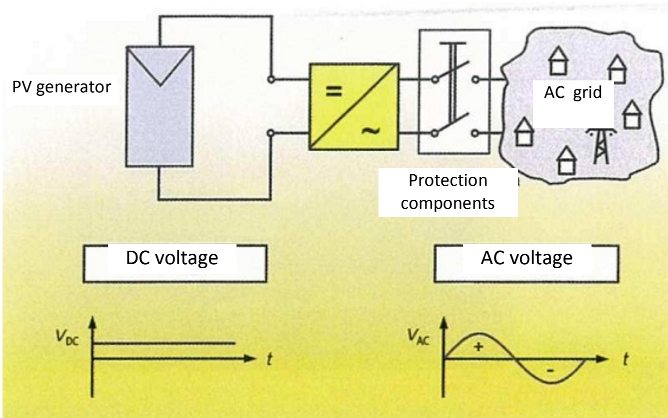
The cells temperature depends on the air temperature and intensity of solar radiation. Unlike the air temperature, the temperature of the cells can hardly be measured and therefore it should be calculated. In order to enable the calculation, modules are tested also at other conditions that can be really expected. They are called *normal working operation conditions*, where their temperature of the cells is measured (NOCT – Normal Operation Cell Temperature). Normally the NOCT is 45 – 50 °C.

Standard Test Conditions – STC (Стандардни тест услови)	
Сончево зрачење	1000 W/m²
Температура на ќелиите	25 °C
Спектар на сончево зрачење	AM1.5

Normal operation cell temperature - NOCT Температура при нормални работни услови	
Сончево зрачење	800 W/m²
Температура на воздухот	20 °C
Брзина на ветер	1 m/s

2.3. Inverters as components of PV systems

PV generators make conversion of solar radiation into electrical energy. The generated energy is with one-way parameters (voltage and electricity). (230 V, 50 Hz). The electro distribution grid and the biggest number of consumers work on alternating voltage. For conversion of one-way voltages and currents into alternating (with suitable values of the voltage) inverters are used.



Pic. 2.17: Purpose of inverter in a photovoltaic system

Modern inverters beside conversion of one-way voltages and currents into alternating integrate many other functions such as: adjustment to the working point of the PV generator to work in a regime of maximum power point tracking (MPPT), control of reactive energy, protection, monitoring, etc.

At autonomous PV systems the inverter has the role to maintain the constant frequency and effective value of the consumers' voltage. In contrast to this, at the systems connected to the grid, the inverter adapts to the frequency and voltage of the grid.

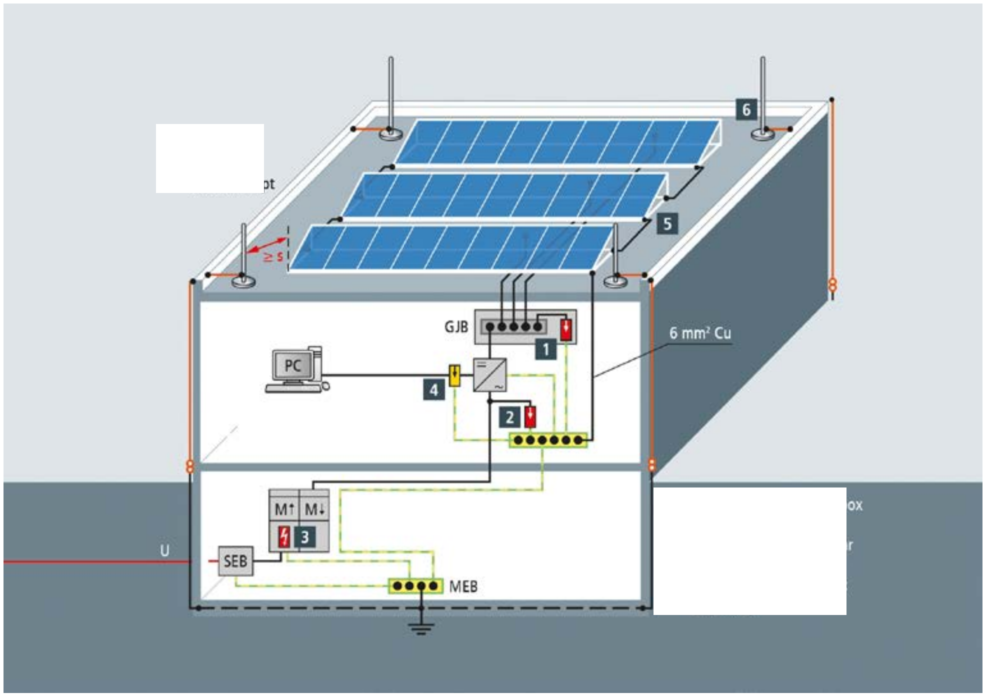
Inverters can have transformers and in that case there is a process of galvanic separation of the grid from the generator, which enabled the overvoltage of the grid to be transferred towards the generator but their efficiency is lower. Inverters without transformers have high efficiency (over 98 %).

At dimensioning of PV systems what is important is the range of the voltage of one-way side of inverter. It depends on it the number of PV modules in one string.

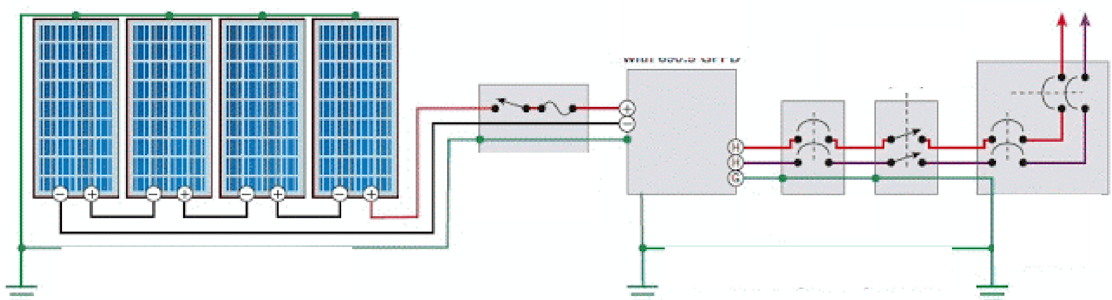
2.4. Other components of PV systems

For regular functioning of PV systems, beside PV modules and inverters, other components can be found in PV system such as wiring, components for over-current and overvoltage protection, lightning protection, grounding, monitoring devices, etc.

The wiring is consisted of electrical cables that connect the components. The section of the wiring cables is chosen so that not in a single point the loss of voltage is not bigger than several percent.



Pic. 2.18: Lightning protection in a photovoltaic system placed in a facility



Pic. 2.19: Diagram with over-current protection of a photovoltaic system (fuse)

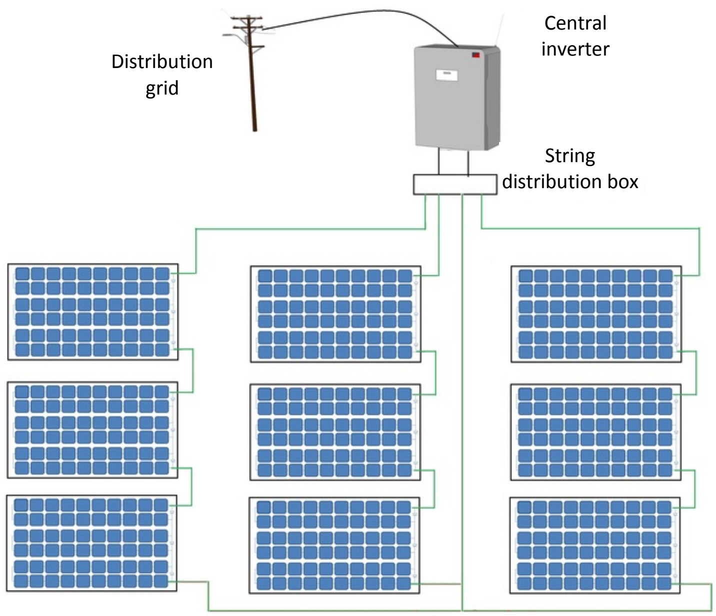
2.5. Configurations of PV

2.5.1. Connection of PV generators and inverters

In practice there are several ways of connecting (topologies, configurations) of PV generator with the inverter. There are configurations with:

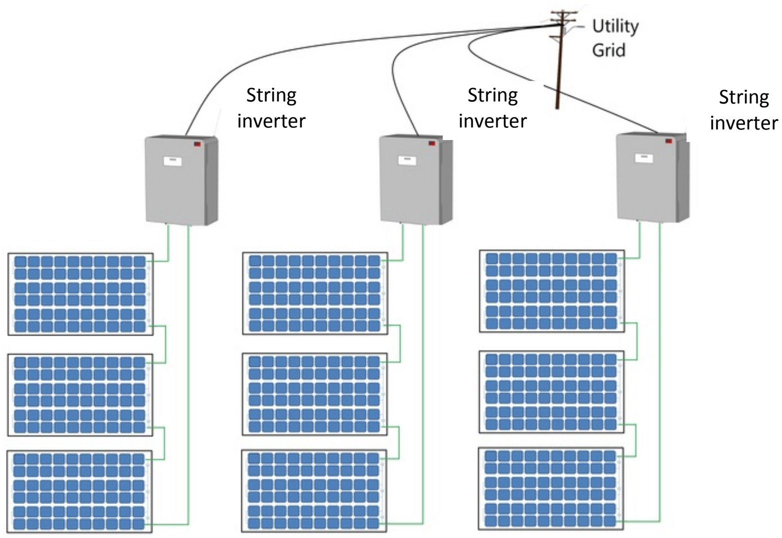
- Central inverter (with power of several ten of kilowatts up to 100 megawatts)
- String inverters (with power of several hundred watts up to several ten of kilowatts)
- Multi-string inverters (with power of several hundred up to several ten of kilowatts)
- Micro-inverters (with power of 50 W to 500 W)

In the configuration with central inverter the system is consisted of one inverter, which means that its power can be very big. This configuration is with the lowest price for the same power, it is simple for projecting and performance. What is deficient about this is that the whole plant is connected to one MPPT device and the system at partial shading has significant smaller power. They have smaller confidentiality because during malfunctions the whole plant is out of function. In smaller countries it is difficult to provide authorized servicing of the inverter in a short period.



Pic. 2.20: Configuration of photovoltaic system with central inverter

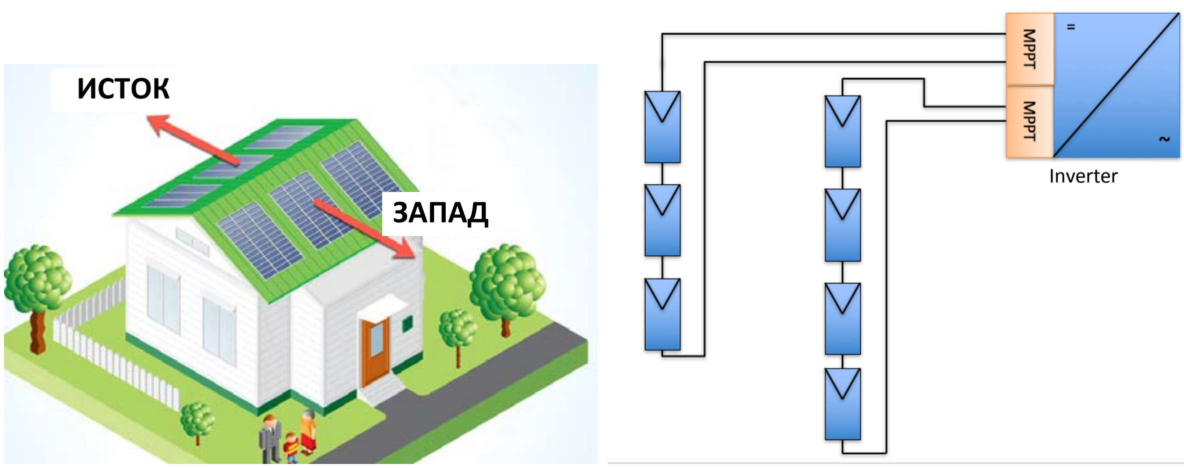
In the configuration with string inverters, every inverter is connected to one or more alongside connected strings in the one-way side of the inverters. At the systems with bigger power, more string inverters are connected in parallel. In case of more connected strings, the configuration is similar as in the case with the central inverter, but the power here is much smaller.



Pic. 2.21: Configuration of photovoltaic system with string inverters

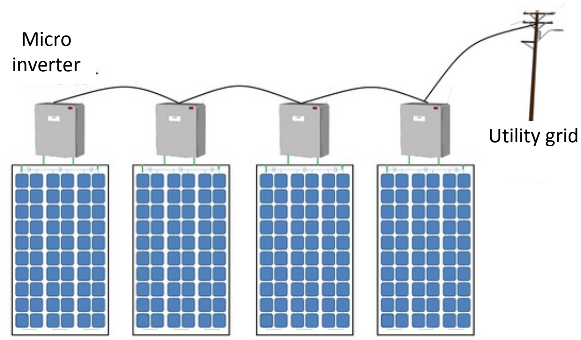
The advantages of string inverters are: smaller dimensions in regard to the central inverters, separate MPPT for smaller parts of PV generator, possibility to make a monitoring on every string, bigger confidentiality, possibility for keeping spare inverters. Disadvantage is the higher price and same power with the central inverters.

Special type of string inverters are the so called multi-string inverters. They contain (most frequently) two or three MPPT devices. In the two devices the number of strings can be differentiated, even the number of modules per string. These inverters are used in case when parts of the PV generator are under different conditions, for example, different shading, roof areas with different orientation and azimuth.



Pic. 2.22: Application of multi-string inverter at PV generator placed on a house roof on both sides

Micro inverters are very often called module inverters because for every PV module there is a separate inverter. Micro inverters are connected with other inverters on the alternating side.



Pic. 2.23: Configuration of photovoltaic system with micro inverters

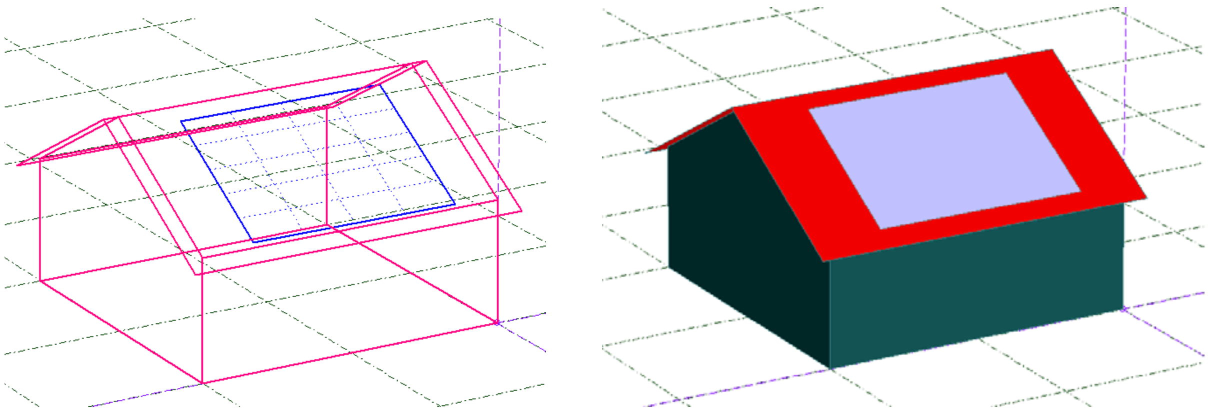
The advantage of configurations with micro-inverters is better behavior at partial shading of PV generator because the existence of MPPT device for every inverter optimizes the output of every PV module separately. With a monitoring system the behavior of every PV module can be followed. Disadvantage is the highest price for same power, high maintenance expenses, difficult approach for maintenance of PV generators set on the roof.

Pic. 2.24: Shading impact at conventional and micro inverter

2.5.2. Dimensioning of components of PV systems

Before starting with planning of PV system it is necessary to know the location of the of the system set up, its purpose and financial resources that can be spent for provision and installation of the equipment for PV system. Also it is essential to determine the closer and more distant facilities that can shade the PV modules, volume, shape, plane tilts and pane azimouth of the roof or other area where the modules should be placed and possibilities for their attachment.

The data about the solar radiation are necessary for determination of the energy that should be received from the PV system for a period of one year. Nowadays, for dimensioning of PV systems are used specialized software tools (PVSYST, PV*SOL, SAM, PV Designer). These tools offer possibilities for detailed creation of the scene (near and far objects, height of the horizon), exact location, plane tilt and pane azimouth of the modules, etc. They integrate large number of databases with components that are regularly updating and databases about solar radiation.



Pic. 2.25: CAD design of PV system placed on a roof house (simulation with software too PVSYST)

TABLE 2.1 – Performance of PV system connected to the grid with power of 5 kWp – energy balance

	GlobHor kWh/ml	T Amb °C	GlobInc kWh/ml	GlobEff kWh/ml	EArray MWh	E_Grid MWh	EffArrR %	EffSysR %
January	58.6	-1.30	89.5	86.7	0.428	0.415	14.64	14.20
February	76.2	0.30	103.3	100.2	0.485	0.471	14.36	13.96
March	116.9	4.80	139.4	135.4	0.640	0.623	14.06	13.68
April	136.5	10.40	143.3	138.8	0.636	0.618	13.58	13.19
May	170.8	16.10	167.5	161.8	0.719	0.700	13.14	12.78
June	195.9	20.40	185.1	178.8	0.778	0.755	12.86	12.49
July	207.1	22.90	199.1	192.8	0.824	0.802	12.66	12.33
August	184.1	22.70	191.6	185.7	0.800	0.780	12.78	12.45
September	137.4	18.10	159.9	155.2	0.683	0.665	13.06	12.73
October	89.9	11.90	116.3	112.8	0.521	0.506	13.71	13.33
November	57.0	5.00	78.3	75.9	0.362	0.350	14.16	13.70
December	46.5	-0.30	69.9	67.6	0.334	0.322	14.63	14.10
Year	1476.8	10.98	1643.4	1591.6	7.210	7.008	13.43	13.05

Also, the inverter producers offer software tools for simulation, which usually have limited possibilities but can be used for determination of the number of PV modules in strings as well as the number of parallel connected strings.

2.5.3. Set-up of photovoltaic modules on a roof

The way of setting up PV modules is of great significance for the investment, maintenance and performance of PV systems. In practice, at family houses, PV modules are placed on ground or curved roofs (see picture).

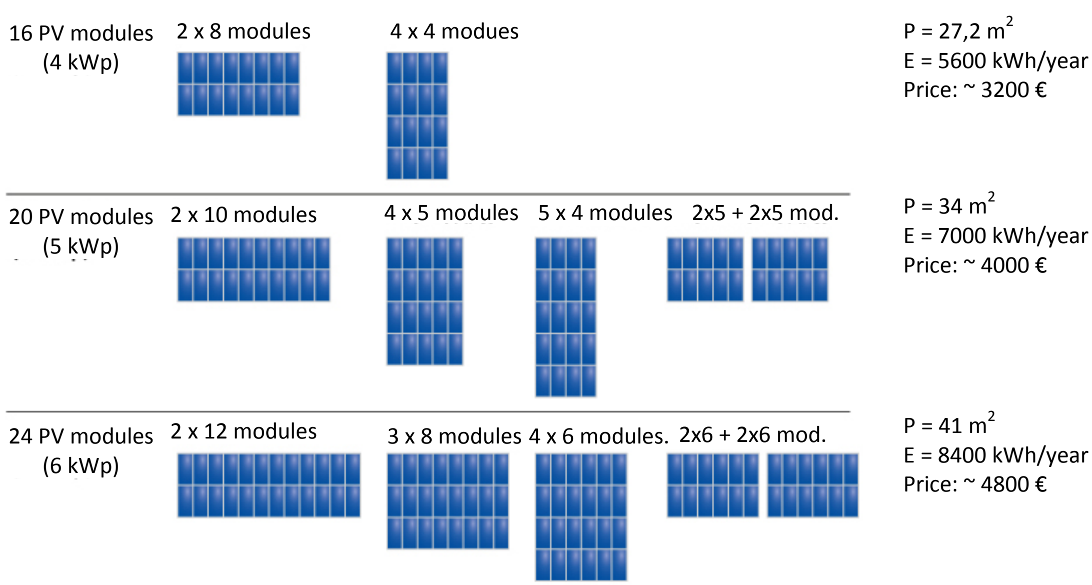
Pic. 2.26: Set up of PV modules on roof and ground

Pic. 2.27: Set up of PV modules on roof with special holders

The advantages during set up on the ground are: simpler mounting, possibilities for regular cleaning of the modules, lower temperature of the cells due to better conditions for heat transmission, multi-functionality (ex. parking shading) etc. The main obstacles are the higher price and the need to obtain a construction permit, which is a complex and expensive procedure.

For setting up PV modules on curved roofs there are special holders that are attached on the roof construction, which is an advantage due to the low price of the overall bearing construction. This is most frequently the crucial factor where the place the modules, where at family houses additional construction is rarely used for adaptation of the tilt angle and orientation of modules. During set up of modules on the roof only permission from the municipality is necessary for the mounting of the equipment, which is relatively easy to achieve. What can be a drawback is the more difficult mounting to the inaccessibility of the roof, lack of regular cleaning of the modules and weak ventilation of the back part of the modules, which leads to higher temperatures of the cells and weaker performances.

In the following diagrams are presented the possible ways of set up of modules on roof areas, together with the suitable installed power, estimated production of electrical energy се прикажани можните начини на поставување and expected price.



Pic. 2.28: Number of modules, necessary area, power, annual production, price and way of set up of PV modules on a roof (dimension of one PV module 1 m x 1,7 m with power of 250 Wp)

2.6. Accumulation of energy

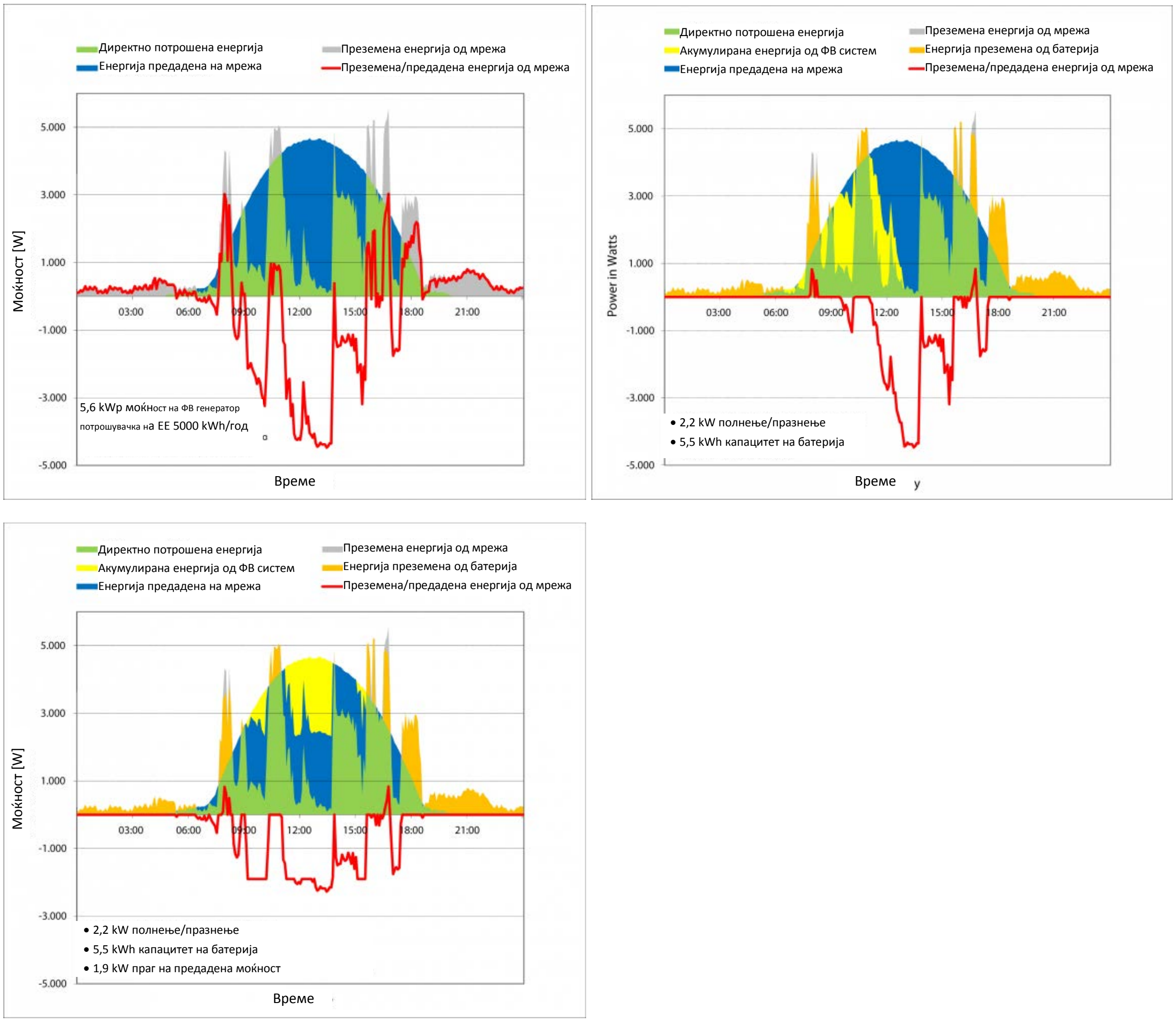
The solar radiation is present only during the day and with variable intensity per hours and additionally its intensity depends on the cloudiness. As a result of this, it is usually said about the production from the photovoltaic systems that It is of variable character. It is similar with some other systems that use renewable energy sources. In cases where the production units with variable character are connected to the electrical network, the deficit or surplus of energy of the produced energy should be balanced in the overall electro energetic system and distributive networks as well. This can be achieved with devices for temporary accumulation of the energy and management of consumption and production.

Decentralized production is the best solution for balancing. For instance, in Germany more than 70 % of the energy from the PV systems is produced with systems that are smaller and are connected to the low-voltage network, as well the biggest number of consumers. Decentralized balancing is the best way to implement this due to the vicinity of the production units, consumers and devices for accumulation of energy which decrease the loss during transmission and distribution of energy.

The batteries for accumulation of electrical energy have high specific price which is not lower for biggest capacities. From technical aspect, decentralized accumulation of energy offers more possibilities an advantages. In addition to this, with certain mechanisms for support big number of house owners and private investors can be stimulated to install batteries on electrical energy. This will increase the confidence in the network as well as the maximum capacity of PV systems that can be accepted in the distributive network.

The application of the batteries at PV systems aimed at covering own consumption decreases the energy that is transferred to the network, which is important from financial aspect, for the transferred energy we have lower price and is more cost-effective to accumulate that energy and use it later. Also, the burden on the network is alleviated, which leaves space for connection of more production units. To illustrate this, an analysis is presented for the consumption of one four member family which set up a photovoltaic system in their house with 5,6 kWp power. Three cases have been analyzed: with and without battery with accumulation capacity of 5,5 kWp without limit of transferred power and with limited transfer of power of 1,9 kW.

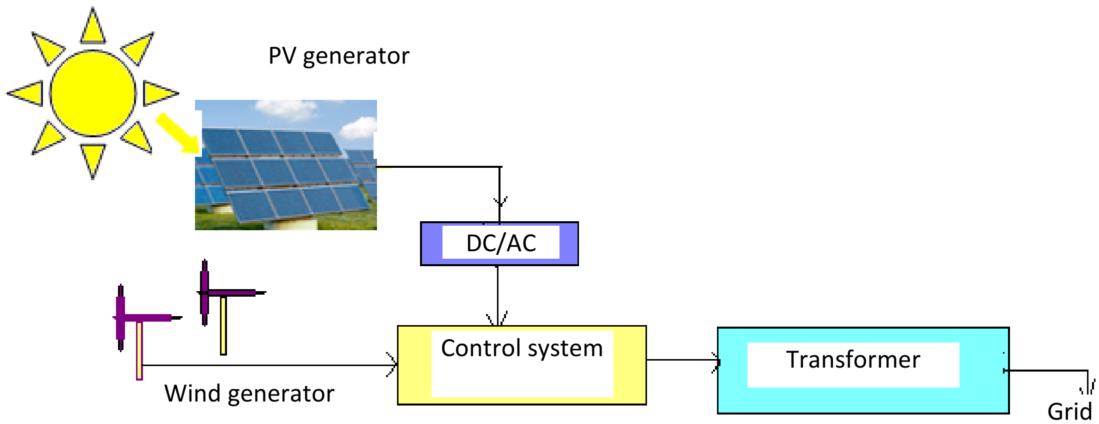
Between 9 and 10 o'clock the power of the PV system is about 3 kW, of which the consumers use 0,7 kW (own consumption). 1,9 kW of power is transferred to the network and the remaining part is accumulated in the battery. After 10 o'clock the consumption is bigger than the power of PV system. In addition, the shortage of power is received from the battery. Between 11.30 and 14.00 the transferred power is surpassed towards the network of 1,9 kW, because the power of the battery charging is limited to 2,2. After 14.00 o'clock the consumption grows so the transferred power on the network is not bigger than 1,9 kW even if there is no accumulation battery. Around 8.00 and 17.00 the consumption overpassed the production from the PV system and the power that the battery can received, so the shortage is restituted from the network.



Pic. 2.29: Diagrams of consumption of a household and production from PV system a) without battery b) with battery capacity of accumulation 5,5 kWh without limit of transferred power c) with battery capacity of accumulation 5,5 kWh with limit of transferred power of 1,9 kW

2.7. Distributed hybrid energy systems

The hybrid energy systems are systems that produce energy from two or more sources. For example, a hybrid photovoltaic system integrates in itself a wind generator or small hydro electrical plant and/or electrical plant on biogas or gas, etc.



Pic. 2.30: Configuration of hybrid photovoltaic system connected on the grid

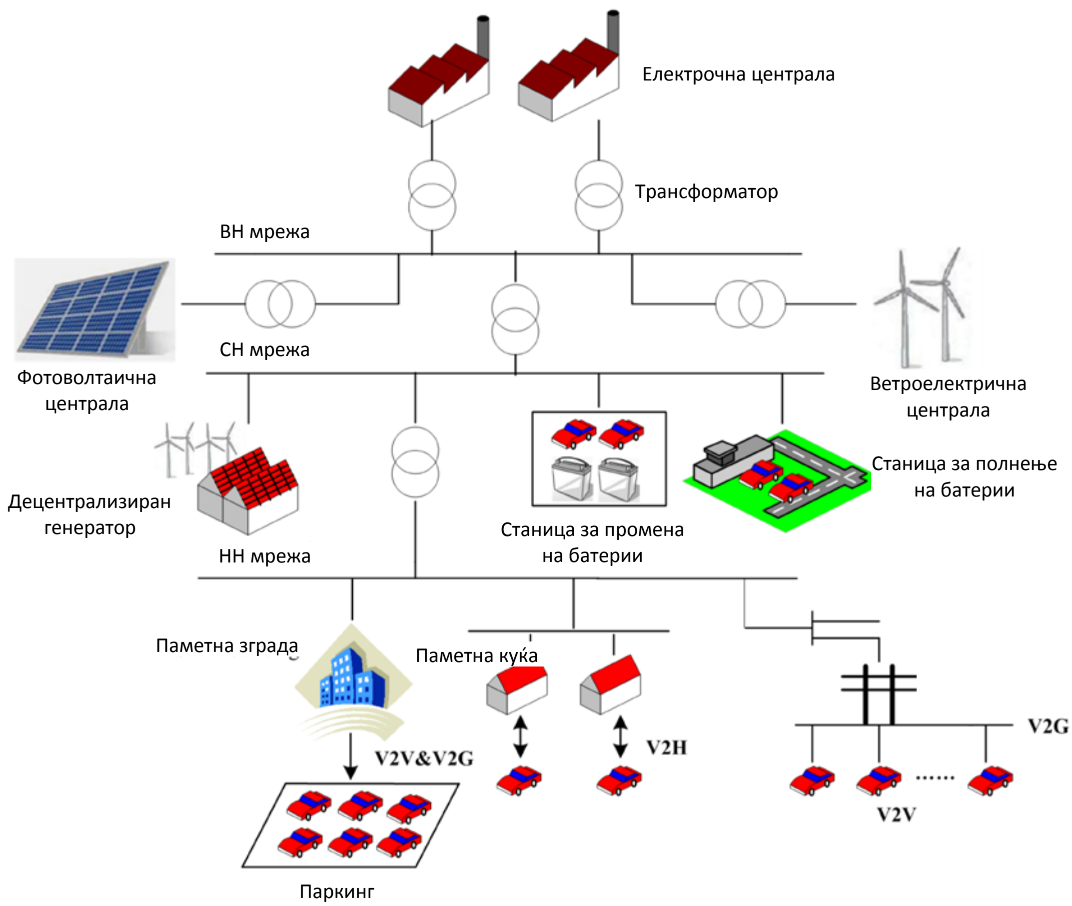
They integrate very often accumulator batteries. Hybrid energy systems find application in systems for autonomous supply with electrical energy where the production price of the electrical energy is lowered, the confidence is increased and there is smaller pollution. On the other hand, the hybrid systems can appear as connected to the electro energetic network most commonly as decentralized production units.

The basic reason for "hybridization" of the production unit connected to the electro energetic network is continuity in the production. Photovoltaic systems, as well as some other systems that use renewable energy systems (wind generators, small hydro electrical plants) have a variable character of production, which is a consequence of the variability of the energy received from the basic source of energy (sun, wind, water flow), which is characterized with regular and accidental changes. These energetic plants are characterized with high investment and very low expenses for regular work. This means that it is cost-effective if they work maximum use of the energy from the prime source.

On the other hand, the generators that use natural gas, biogas, oil or diesel fuel have lower investment, fuel and maintenance expenses are high. However, these production unit can be put into and out of function faster, or change their power without causing any additional expenses. These plants can be managed or dispatched.

In the hybrid photovoltaic systems the variable production or lack of production from the photovoltaic system can be restituted with production from dispatchable source. In this case the production can be adjusted to the needs of local consumers which is of great importance to the distributive network and from the aspect of decreased loss and improved voltage conditions and connecting new consumers to the network and new generators without need of additional investments.

The hybrid systems will be of particular importance in the near future when the expansion of electrical vehicles is expected. The vehicles will recharge their batteries with energy from the network. It is also predicted that there will be frequent occasions in certain period when they will return the accumulated energy in the network, so called regime “vehicle to grid” (v2g).



Pic. 2.31: Distribution grid with decentralized generating and connection of electrical vehicles

2.8. Good practices of application of photovoltaic systems in households

2.8.1. PV system on a house roof in New Jersey, USA, 12 kW HIT cells

Location: New Jersey, USA

Start of work: 7/2017
Installed power of the PV generator: 12,21 kWp
Type of modules: 37 Panasonic Hit (VBHN330SA16) 330 Wp
Production: 16000 kWh
Inverter: 37 SolarEdge P400 optimizers, and a 11.4kW SolarEdge Inverter
Monitoring webpage : https://monitoringpublic.solaredge.com/solaredge-web/p/site/public?name=12kWPanasonicHit#/dashboard

Due to the limited area of the roof, high-efficient modules with HIT-technology are used (Heterojunction with Intrinsic Thin layer).

2.8.2. PV system on a barracks roof in Great Britain 7,7 kWp + 4 m^2 hot-water collectors

Location: Great Britain
Start of work: 9/2013
Installed power of the PV generator: 7,7 kWp
Production: 6050 kWh
Period with feed-in tariff: 20 години

In order to satisfy their own consumption with electrical and heat energy, the tenants installed PV system with power of 7,7 kWp and solar collector on an area of 4m^2 .Beside the standard consumption, the system enabled heating and cooling of the facility and recharging of batteries from the electrical vehicle of the owner. The surplus of electrical energy is transferred to the grid, with secured feed-in tariff for the first 20 years.

2.8.3. PV system on a garage roof in Bad Mergentheim (Germany) 8,4 kWp

Location: Bad Mergentheim, Germany
Coordinates: 49.28° N, 9.50° E

Annual global solar radiation on the horizontal area: 1,055 kWh/m^2
Average temperature: 10.8 °C
Precipitations (per year): 640 mm/m^2
Start of work: 10/2011
Installed power of the PV generator: 8,3 kWp
Type of modules: SF150-L (150 W)
Number of modules: 56
Pane tilt and orientation: 4°, -165° N
Production: 7795 kWh
Inverter: Kostal Piko 8.3
Financing: Volksbank Vorbach-Tauber

PV system is located on atypical location due to the orientation of the garage roof towards north with pane tilt of 4°. PV generator is made with modules that contain CIS (Copper indium gallium selenide) cells produced by Solar Frontier. These modules act better than modules made of crystal silicon at low values of solar radiation and have bigger tolerance at partial shading made by the surrounding facilities. It is projected this system on annual basis to produce about 6000 kWh of electrical energy. This value was overpassed and 7795 kWh were produced.

2.8.4. PV system on a house roof in R. Bulgaria 1,83 kWp

Location: R. Bulgaria
Type of modules: Innotech Solar EcoPlus 230 Wp
Number of modules: 8
Type of inverter: Kaco Powador 2002
Bearing of modules: SolarFix

2.8.5. PV system on a house roof in R. Bulgaria 1,83 kWp

Location: Р. Бугарија
Type of modules: Luxor 250 Wp
Number of modules: 40
Type of inverter: Fronius Symo 20.0-3-M co Datamanager 2
Bearing of modules: SolarFix

3. Regulations and administrative procedures

3.1. Review of laws and regulations

- Law on energy (Official Gazette of RM no. 16/2011)
- Law on construction
- Law on ambient air quality (Official Gazette of RM no. 67/04 and 92/07)
- Law on protection of environmental noise (Official Gazette of RM no. 79/07)
- Decree on the limit values of the levels and types of polluting substances in the ambient air and alertthresholds, deadlines for limit values achievement, margins of tolerance for the limit values, targetvalues and long-term targets (Official Gazette of the. Republic of Macedonia No. 50/2005);
- Law on protection of cultural heritage (Official Gazette of RM no. 20/04 and 115/07)
- Decree determining the projectsand the criteria on the basis that will establish the need to implement the procedure for assessment ofenvironmental impact
- Regulation for preferential producers of electrical energy from renewable energy sources
- Regulation for licenses for performing energy activities (Official Gazette pf RM no. 143 from 15.10.2011)
- Rules of procedure of the Energy Regulatory Commission

3.2. Grid rules and decentralized production

The operator of the distributive grid is obliged to provide secure, quality and confident supply to all consumers in the system. The way this is realized is prescribed in the by-law act *Grid rules for distribution of electrical energy.* Decentralized generators are connected to the distributive grid according to grid rules, for which it is necessary to submit special request (BSP-2). Beside the general rules, during connection of electrical energy generators, the requests in the grid rules should be followed, which particularly refer to the dispersed generators.

During connection of generators in a given distribution grid it is essential to have a state analysis of the distribution grid during different regimes of work. So, for the grid is analyzed the connection of the generator. Special emphasis is put on the analyzes of the following typical states during:

- Minimal load of the grid and minimal production of electrical energy
- Minimal load and maximum production of electrical energy
- Maximum load and minimal production
- Maximum load and maximum production

In all typical states it is necessary the voltage in all knots of the grid not to overpass the allowed limits of deviation which are given in the grid rules. The maintenances of the voltage not only in the place where the generator is connected but throughout the whole grid can present a problem for the distribution operator. Depending on the type of plant that connects (directly connected generator or via inverter) estimations are made of the impact on the network from the aspect of appearing:

- flickers;
- higher harmonics;
- imbalance of phases;
- injection of reactive power.

If the given conditions are fulfilled, operator of the distribution system gives the producer consent where the standards for the installed equipment are designated.

3.3. Procedures for obtaining construction permit

3.3.1. Procedure in the Republic of Macedonia

The first step in getting license for production of electrical energy from systems that use renewable energy sources is obtaining a construction permit. For that purpose it is necessary to engage a company for preparation of urbanistic documentation. Pursuant to Law on amending and supplementing the Law on construction (Official Gazette no. 31 from 22.02.2016) for photovoltaic systems placed on a roof with power of 1 MW there is no need for construction permit but the municipality issues an approval for set up of the equipment. A special request is submitted for this, pursuant to Law on construction.

From the operator of the distribution system (EVN – distribution) request and approval for connection in the distribution system.

The construction permit and approval for set up of the equipment are necessary documents for the following procedures:

- Execution of the PV system
- Obtaining permit use
- License for production of electrical energy
- Registration of the facility in the Register of facilities that use renewable energy sources
- Granting a status of preferential producer
- Purchase contract for electrical energy with the operator on the electrical energy market

For obtaining a production license for electrical energy from renewable energy sources, there is a wider procedure in the Republic of Macedonia that included the following steps:

• The investor can start the procedure for obtaining a license right after the approved construction permit.

• The procedure for issuing a licence starts at the Energy Regulatory commission of the Republic of Macedonia from the day of the admission of the request for issuance of license and necessary documentation (article 14 of the Regulation for conditions, way and procedures for issuing, change and revocation of license for performing energy activities).

• The Energy regulatory commission of the Republic of Macedonia is obliged within eight working days after receipt of the request to note the defaults. If the Energy Regulatory Commission of the Republic of Macedonia finds that the request has formal defaults, it will submit minutes that will determine a deadline for removal of the defaults, which cannot be longer than 15 days.

• If the Energy regulatory commission of the Republic of Macedonia finds that the request has no formal defaults, it makes conclusion that obligates the requestor to prepare a notice for the public media within three days.

• The Energy regulatory commission of the Republic of Macedonia makes the decision for issuing a license within a deadline that cannot be longer than 20 days of the day of completion of the preparatory session.

• The request for issuing an approval for use of construction is submitted to the Ministry of transport and communication or the municipality (art. 72, 73, 74, 75, 76 and 77 – from the Law on construction „(Official Gazette of the Republic of Macedonia ", no. 130/09).

• The construction permit ceases to be valid if the investor does not start with the construction within six months of the day when the construction permit became legally effective.

• The authorized organ of article 58 of the Law on construction ("Official Gazette", no. 130/09) will issue the permit for use of construction within 15 days of the day of the conducted technical examination, if the commission that conducted the technical examination in the minutes concluded that the construction cam be put into function.

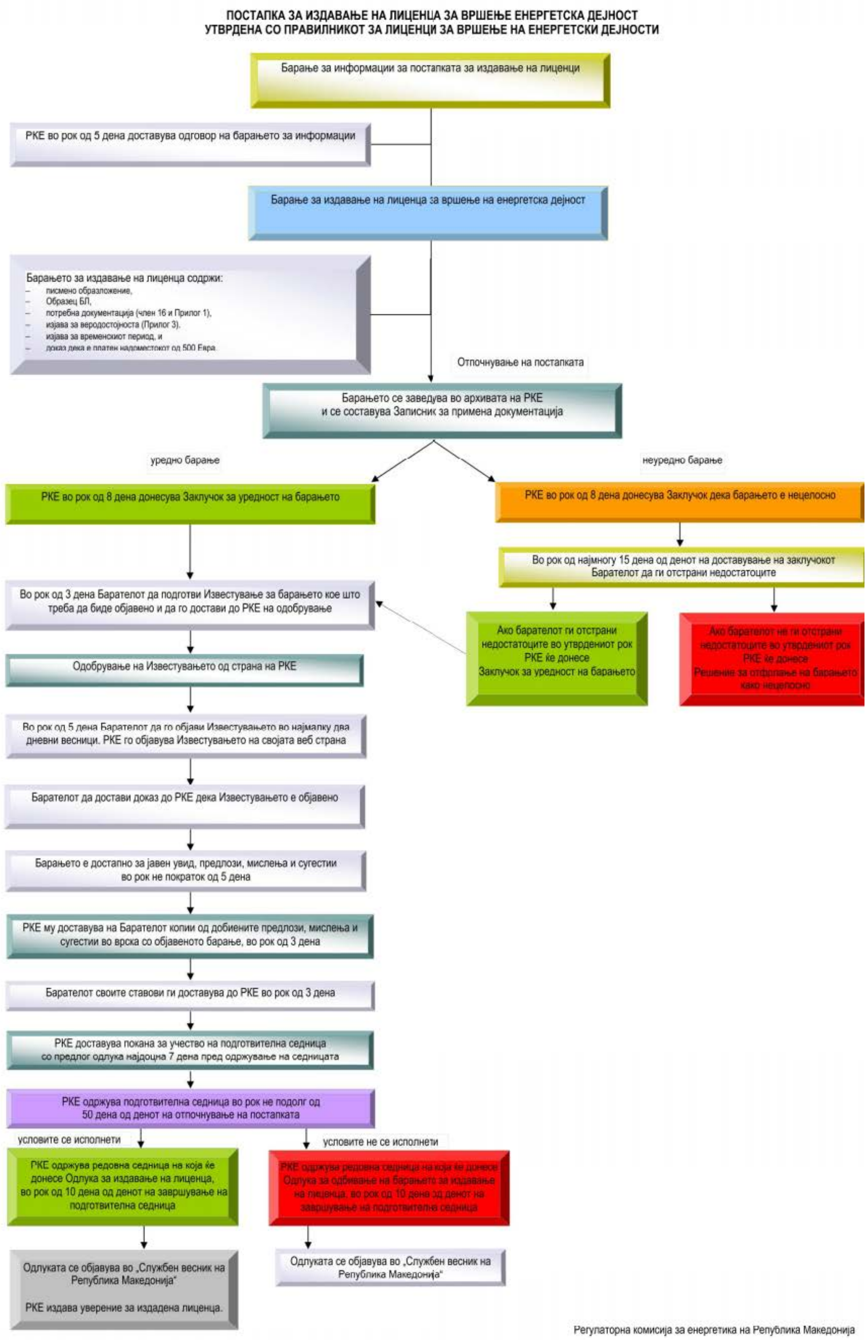
• The facilities that are constructed from renewable energy sources belong to the second and third category pursuant to article 57 of the Law on construction.

• The Energy regulatory commission of the Republic of Macedonia is obliged to issue the license if all conditions are fulfilled not later than 90 days of the day when the request was submitted, pursuant to article 40 of the Law on energy (“Official Gazette of the Republic of Macedonia”, no. 63/06, 36/07 and 106/08 and article 14 of the Regulation for conditions, way and procedures for issuing, change and revocation of license for performing energy activities (“Official Gazette of the Republic of Macedonia”, no. 31/09).

• Energy Agency of the Republic of Macedonia issues a certificate at the request of the investor for obtaining a temporary status of an authorized producer of electrical energy from renewable energy sources.

• After obtaining a permanent license from the energy regulatory commission of the Republic of Macedonia, the investor submits a request for a code from the Register of plants for renewable energy sources in the Energy agency of the Republic of Macedonia (art. 12, 13, 14, 15, 16, 17, 18 and 19 from the Regulations for use of renewable energy sources for production of electrical energy, (“Official Gazette of the Republic of Macedonia”, no. 127/08).

These procedures are presented in the following block diagram:


ПОСТАПКА ЗА ИЗДАВАЊЕ НА ЛИЦЕНЦА ЗА ВРШЕЊЕ ЕНЕРГЕТСКА ДЕЈНОСТ
УТВРДЕНА СО ПРАВИЛНИКОТ ЗА ЛИЦЕНЦИ ЗА ВРШЕЊЕ НА ЕНЕРГЕТСКИ ДЕЈНОСТИ
Барање за информации за постапката за издавање на лиценци
РКЕ во рок од 5 дена доставува одговор на барањето за информации
Барање за издавање на лиценца за вршење на енергетска дејност
Барањето за издавање на лиценца содржи:
– писмено образложение,
– Образец БЛ,
– потребна документација (член 16 и Прилог 1),
– изјава за веродостојноста (Прилог 3),
– изјава за временскиот период, и
– доказ дека е платен надоместокот од 500 Евра.
Отпочнување на постапката
Барањето се заведува во архивата на РКЕ
и се составува Записник за примена документација
уредно барање
неуредно барање
РКЕ во рок од 8 дена донесува Заклучок за уредност на барањето
РКЕ во рок од 8 дена донесува Заклучок дека барањето е нецелосно
Во рок од најмногу 15 дена од денот на доставување на заклучокот Барателот да ги отстрани недостатоците
Ако барателот ги отстрани недостатоците во утврдениот рок РКЕ ќе донесе Заклучок за уредност на барањето
Ако барателот не ги отстрани недостатоците во утврдениот рок РКЕ ќе донесе Решение за отфрлање на барањето како нецелосно
Во рок од 3 дена Барателот да подготви Известување за барањето кое што треба да биде објавено и да го достави до РКЕ на одобрување
Одобрување на Известувањето од страна на РКЕ
Во рок од 5 дена Барателот да го објави Известувањето во најмалку два дневни весници. РКЕ го објавува Известувањето на својата веб страна
Барателот да достави доказ до РКЕ дека Известувањето е објавено
Барањето е достапно за јавен увид, предлози, мислења и сугестии во рок не пократок од 5 дена
РКЕ му доставува на Барателот копии од добиените предлози, мислења и сугестии во врска со објавеното барање, во рок од 3 дена
Барателот своите ставови ги доставува до РКЕ во рок од 3 дена
РКЕ доставува покана за учество на подготвителна седница со предлог одлука најдоцна 7 дена пред одржување на седницата
РКЕ одржува подготвителна седница во рок не подолг од 50 дена од денот на отпочнување на постапката
условите се исполнети
условите не се исполнети
РКЕ одржува редовна седница на која ќе донесе Одлука за издавање на лиценца, во рок од 10 дена од денот на завршување на подготвителна седница
РКЕ одржува редовна седница на која ќе донесе Одлука за одбивање на барањето за издавање на лиценца, во рок од 10 дена од денот на завршување на подготвителна седница
Одлуката се објавува во „Службен весник на Република Македонија“
РКЕ издава уверение за издадена лиценца.
Одлуката се објавува во „Службен весник на Република Македонија“
Регулаторна комисија за енергетика на Република Македонија

3.3.2. Procedures in the Republic of Bulgaria

Before starting any administrative activity, the investor should:

- Consult experts.
- Estimate the consumption of electrical energy
- Determine the installed power of the system
- Estimate the cost-effectiveness of the project

In order to obtain a construction permit for photovoltaic system it is necessary to engage a company for preparation of the urbanistic documentation. Pursuant to Law on amending and supplementing the Law on construction (Official Gazette no. 31 from 22.02.2016) for photovoltaic systems placed on a roof with power of 1 MW there is no need for construction permit but the municipality issues an approval for set up of the equipment. A special request is submitted for this, pursuant to Law on construction.

Request from the distribution system operator (EVN – distribution) and approval for connection in the distribution system.

The construction permit and approval for set up of the equipment are necessary documents for the following procedures:

- Execution of the PV system
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- Purchase contract for electrical energy with the operator on the electrical energy market

In the Republic of Bulgaria the connection of photovoltaic systems to the electro distribution grid is prescribed by the Law on renewable energy sources. Renewable electrical energy (REE), including the photovoltaic systems, is promoted through:

• Securing guaranteed access to the electrical energy produced by the photovoltaic systems to transmission and distribution grids in accordance with the security criteria defined in the regulations of article 83, par. 1, item 4 and 5 of the Law on energy.

• Guarantees buying of electrical energy produced in the photovoltaic systems, for a fixed period (20 years), with a preferential price for the whole period.

Pursuant to article 24 (1) and (2) of the Law on renewable energy sources, photovoltaic systems up to 30 kW can be installed or built on roofs and façade constructions and connected to the electrical grid. What is essential for these photovoltaic systems for energy generation is that they can be connected with lower voltage – up to 0,4 kV.

In the plants with this capacity, as well as for own needs, their planning from KEBR is not necessary. They can be installed and connected in any time until the photovoltaic fulfill the protection requests of the grid. This means that the inverter which converts the voltage and electricity has all necessary protection.

Also, there are no barriers for construction of grid photovoltaic systems for own needs through sale of the surplus energy (art. 25) and there are no preferential purchase price (art. 31 and 32 of the Law on electrical energy). The surplus of the produced energy is bought on the free market at a very low price, which is an obstacle for the development of these type of systems, at least until now. With liberalization of the market of electrical energy we hope that installation of these systems will increase enormously. These are the legal frameworks of ZEVI, which give possibility for investment in photovoltaic systems.

For selection of grid system we will systematically present below the chronology of activities which the investor have to do so the system can work, as well as contacts of the investor with institutions which are responsible for issuing and obtaining all approvals, permits and final documents and contracts.

a) Delivery of documents for issuance of blueprints with visa projection by the local authorities by natural way or contract for property ownership, actual blueprints of the property /time – deadline 14 to 30 days/ the document is issued by the main city architect of the municipality/ price of the document is 16 levs.

б) Submission of projects – electrical and constructive minutes pursuant to art. 147, par. 1, item 14 of the Law on territorial arrangement, together with the visa projection by the municipality for coordination of projects and issuance an “Authorization for installation of FtSPT”.

Deadline: 30 + 14 days/price 250 levs

c) At the same time are submitted document to the local electro company for distribution – document for ownership, blueprints with visa projection and electrical project for issuance of an Opinion for the item connection of photovoltaic systems to the electrical grid. Deadline up to 30 days/price 38 levs.

d) After getting the opinion and Certificate for installation by the municipality, the documents are submitted to the electrical company for concluding contract for access and connection of photovoltaic systems to the electrical grid/deadline 30 days, at the local electro company/price – 380 levs.

e) After the signing of the contract and completed mounting of photo-voltage system, a request is submitted to the local electro company for 72 hourly samples/30 days/no taxes for this.

f) Signing of protocol for completion and connection of photovoltaic system with electro company/72 samples, also no taxes.

g) Signing of long-term contract for sale of electrical energy (20 years at preferential prices with local electro company) within a period of 30 day.

Strengths of this type of systems are:

Preferential price for buying the energy, the long-term contract (20 years) for buying of this energy. Until today, the complete payoff of the investment for installation of photovoltaic system is not more than 8 years.

Weaknesses of this type of systems are:

For all of these items there is a possibility the employees in the municipality and electrical company to slow down the implementation of this investment through requests for additional documents and prolongation of the deadline for implementation. It is essential ZEVI to know this or the company for installation to be familiar with the overall process in details.

Example: condition by municipality is the impact of the photovoltaic systems by RIOSV, as well as considering the investment in photo-voltage system by the public council of the municipality. This is essential due to the fact that investment permits in these systems are obtained pursuant to art. 147, par. 1, item 14 of the Law on territorial arrangement.

Forcing the employees at EDF to write a period of sale – six months, under condition the whole investment to be implemented within 3 months with all permits.

All these steps for investment in grid photovoltaic system for production of electrical energy are taken from practices of the municipality of Smoljan and ERP Smoljan to EVN Bulgaria (ELEK distribution group, EVN group).

For establishment of photovoltaic system on roofs of multi-family buildings there are no obstacles as long as the roof satisfies the need of the owners. However, all owners must agree in written form, which is a weakness. The owners can authorize someone to represent them and make contacts with institutions and contractor.

For autonomous photo-voltage systems (own use) installed on the roof of one family and multifamily buildings, especially for small systems (up to 5 kWp), basically there are no needs for permits or other documents.

Example: the investor builds a new house and does not want to connect to the electrical grid. For this purpose will be installed autonomous photovoltaic systems with power of 6 kWp. Unfortunately, in the Law on territorial arrangement it is stated that if you want to obtain a construction permit for new house, it is necessary to obtain preliminary contracts with water supply company and electrical company. The investor does not have relations with ERP and accordingly can state at the municipality that the produced energy from the photo-voltage system will be used for own needs, providing a project design of PV. This is the main obstacle for the development of autonomous PV in construction of new houses.

Strengths: Provision of autonomous power of the owner and independence from the companies for distribution of electrical energy. Possibility for getting electrical energy in places where it is not available. The autonomous system can be mobile and can be used on any location.

Weaknesses: The lasting of the battery is short and they are still very expensive. Also, there is a need for suitable premise for keeping of batteries that emit sour (harmful) gases. With inaccurate and insufficient dimensioning of the autonomous system there are possible periods without voltage of electrical energy, especially in bad days. When the consumption is bigger than the possibilities of the set up system, it is recommended to place bigger accumulators or enlargement of the photovoltaic system or there is a possibility of supplementing of energy with an additional generator (on diesel fuel, gas, wind turbine, etc.)

4. Financing

4.1. Mechanisms for investment support in photovoltaic systems

4.1.1. Preferential tariffs

In order to stimulate construction of systems that use renewable energy sources, Republic of Macedonia has provided preferential tariffs for several types of systems and electrical plants.

The preferential tariff for photovoltaic systems, for the first time adopted in 2008 has been three times modified since then.

TABLE 4.1 – Preferntial prices of electrical energy produced from PV systems in the Republic of Macedonia

Year	Power of PV system 50 kW [€cents/kWh]	Power of PV system 51-1000 kW [€cents/kWh]	Preferential period in years
2008	46	41	20
2011	38	34	15
2011	30	26	15
2013	16	12	15

For photovoltaic systems, by the decision of the government of the R. Macedonia is determined maximum installed power (intake). The intake totals 18 MW, of which 4 MW are for systems up to 50 kW, 14 MW – for systems up to 51 – 1000 kW. This intake in Macedonia is almost fulfilled, so there is need for other means of support.

For the Republic of Bulgaria the preferential purchase prices were introduced by the State regulation commission for energy and water (КЕВР http://www.dker.bg). In the following tables are presented the preferential tariffs for the electrical energy produced by photovoltaic systems for the previous period and now.

TABLE 4.2 **Tariffs for PV systems mounted on roofs and facades [lv./MWh]**

Beginning of preferential tariff	**Installed power to 5 kWp [lv./MWh]**	**Installed power to 5 kWp [€cents/kWh]**	**Installed power from 5 kWp to 30 kWp [lv./MWh]**	**Installed power to 5 kWp до 30 kWp [€cents/kWh]**

29.12.2006	782,00	40,0	718,00	36,7
01.04.2009	823,00	42,1	725,00	37,1
31.03.2010	792,89	40,5	728,29	37,2
30.03.2011	760,48	38,9	699,11	35,7
30.06.2015	228,00	11,7	211,71	10,8
30.06.2016	255,39	13,1	213,92	10,9
01.07.2017	271,67	13,9	231,20	11,8

Prices are without VAT included -20%.

TABLE 4.3 **Preferential tariff [lv./MWh]**

Total installed power of PV modules	**01.7.2011**	**01.7.2012**	**01.9.2012**	**01.7.2013**	**01.7.2014**
Up to 5 kWp, mounted on roofs and facades	605,23	400,7	381,18	353,97	211,81
From 5 kWp to 30 kWp, mounted on roofs and facades	605,23	400,7	289,96	284,18	203,97
From 30 kWp to 200 kWp, mounted on roofs and facades of production premises	596,5	369,08	226,87	211,4	169,12
From 200 kWp to 1000 kWp, mounted on roofs and facades of production premises	583,77	316,11	206,34	196,58	144,68
Up to 30 kWp	576,5	268,68	193,42	195,44	152,19
From 30 kWp to 200 kWp	567,41	260,77	188,1	191,13	143,35
From 200 kWp to 10 000 kWp	485,6	237,05	171,37	176,29	134,03
Over 10 000 kWp	485,6	236,26	169,85	160,2	131,36

Prices are without VAT included -20%.

With the decisions of KEBP during the course of years, the prices of the tariffs for photovoltaic systems are constantly decreased, with small fluctuations. Also, in the recent years, the decisions were made only for PV systems to 30 kW, mounted on roofs and facades on existing facilities and neighboring terrains in urban environment, which is an indicator that the emphasis in future will be put on roof installations.

According the Bulgarian photovoltaic association (vei-bg.org from 06.09.2017) the overall installed capacity of the photovoltaic electro plants connected to the distribution grid in the Republic of Bulgaria is for systems: up to 30 kWp - 3 690,56 kW, up to 5 MWp – 682 719,53 kW and bigger from 5 MWp - 133 331,32 kW. With this, the overall capacity of the Re public of Bulgaria, including beginning of September 2017 totals about 820 MW.

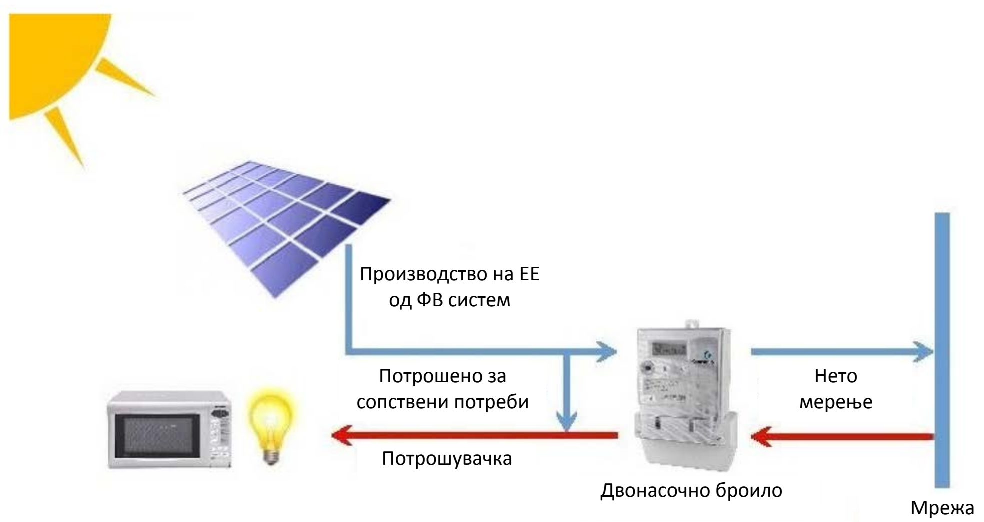
4.1.2. Own consumption and exchange of electrical energy

PV system can be mounted on roof, walls or in the vicinity of some facility (house, building). The produced electrical energy can be used by the consumers who are located in the facility and in that case it is said that PV system is purposed for covering the own consumption. At the same time the PV system is connected to the grid. It is normally not to expect the produced and consumed energy in every moment to be equal. The surplus of produced energy is transferred to the grid and the shortage is undertaken from it. In addition, the price of electrical energy.

Mainly there are three ways of using the PV systems for coverage of own consumption, which differ according to the dealing and payment of surplus energy. The first way is by limiting the power of PV system, where with special device (limiter) is limited the power of PV system and in not a single moment is bigger than the consumption. In this way, it is not allowed for the energy to be transferred in the grid. This way is used in case when it is not possible to have contract for transfer of the electrical energy with the supplier or operator of the distribution system. The second way enables for the energy to be transferred to the grid but there is no compensation for that. With the application of the third way it is enabled for the energy to be transferred to the grid, where the supplier grants a minimum compensation, in amount of the regulated price of electrical energy, which in the Republic of Macedonia totals 4 €cents/kWh.

Special way of using the PV systems for own consumption is the so called net metering. This is the way to stimulate the use of PV systems in households. In addition, the household pays only the balance between the undertaken and transferred energy for a certain period of time (monthly, quarterly, seasonally, half-annual or annual). In this case, most frequently the transferred energy is valued the same as undertaken.

In accordance to this, during dimensioning of PV system it essential that the produced energy is equal or smaller than the consumed one. The billing is made with the supplier, where his benefit is in the balance between the day and night tariff. Special type of billing is net billing. There is billing of electrical energy through financial compensation.



Pic. 4.1: Application of PV system for own consumption

Main factors that have an impact on cost-effectiveness of application of PV systems for covering own consumption are: overall consumption and overall production of electrical energy, as well as the shape of the daily diagram of consumption. For commercial consumers the daily diagram of consumption changes from case to case and is not possible without special analysis to be estimated whether the use of PV system is favorable to be used for covering of own consumption.

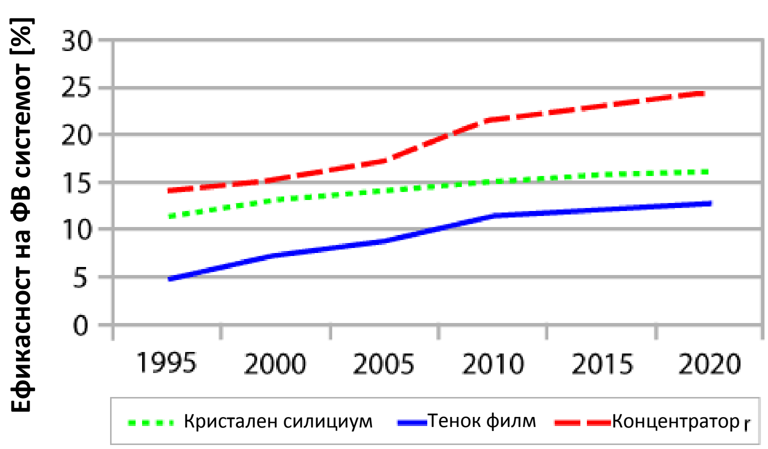
It is very important to be determine the ratio of the produced and consumed energy because this limits the level of use of own energy. If there is a balance between the consumed and produced energy, also important is the degree of congruence of the diagram of consumption with the diagram of production. From this depends what portion of the generated energy directly will be consumed and what portion of the energy will be transferred to the grid.

5. Techno economic analysis

The technical efficiency of the use of renewable energy sources is connected with the coefficient of the useful action of the process. It presents a quotient between the received useful energy and overall invested energy. When we talk about photovoltaic systems, the input energy is the energy of the solar radiation and the goal of the engineers is to find such system which in the most efficient way will transform the solar energy into electrical energy. The technical efficiency is determined on the basis of physics and it is always smaller than one.

$$\eta_{technical} = \frac{\text{Добиена енергија од системот}}{\text{Вложена енергија}} < 1$$

Nowadays the challenge of the engineers is to construct photovoltaic panels with as bigger efficiency as possible, which for a give input amount of solar radiation will produce as much as bigger amount of electrical energy as possible. Nowadays, with the development of technology, the efficiency of photovoltaic continues to grow and depending on the technology achieves about 15-20 %.



Pic.5.1 Efficiency of photovoltaic systems depending on technology

It is important to emphasize that the research is going on and that in laboratory conditions has been achieved degrees of efficiency bigger than 40 %, but they are still not available on the market due to the high prices which are unacceptable for the potential buyers.

So, if one project which is feasible from technical aspect to be acceptable and implemented it must be also acceptable for the investor from commercial aspect. Hence, there is a need for analysis of the economic efficiency of the home photovoltaic systems which is connected with the determination of the expected expenses and benefit during the lifecycle of the technical system.

The economic efficiency of a technical system can be defined as a quotient of the expected benefit since the undertaking of the project (B – Benefit) and overall expenses during the exploitation period:

$$\eta_{economy} = \frac{\text{Добивка од проектот}}{\text{Трошоци за реализација на проектот}} > 1$$

In contrast to the technical efficiency which is always smaller than 1, expectations of the investor in one home photovoltaic system are that with undertaking of the project he will achieve the wished benefit or personal satisfaction, that will justify the invested financial resources. Most commonly, the benefit from the project is expressed in monetary units (for example, benefit made as a result of electrical energy sale). But not all benefits from the undertaking of the project are directly financially measurable. So, for instance, projects for production of electrical energy from solar energy through domestic photovoltaic systems provide pure energy which is located right next to the consumers. This decreases the harmful emission of greenhouse gases in the atmosphere and contributes in clean natural environment and additional benefits are the decrease of energy losses which appear during the transmission of energy from big classical electrical plants to the final beneficiaries. So, for complete evaluation of these projects for production of electrical energy from the photovoltaic systems a conversion is necessary of all benefits with suitable monetary equivalent.

We can conclude that the decision whether we will launch a certain project for construction of a home photovoltaic system is a technical and economic problem where also the technical aspects and economic benefits of the project should be taken into consideration. Although in many cases the economic efficiency has advantage over the technical, there is a connection between them because the development of technology and engineering makes the technical systems cheaper and cost-effective from economic aspect. We should take into account the wish of the investor to invest in projects that are healthy for the natural environment, the wish with his investment to contribute in the preservation of the environment and his additional expectations from the implementation of the project.

In a detailed analysis which overpass the volume of this Guide, also should be considered the accompanying risks (that offer opportunities and threats) during entering into these projects. We should mention here the risk of provision of quality photovoltaic panels, the risk connected with the price of the electrical energy (which is expected to rise), about the maintenance of the home photovoltaic systems.

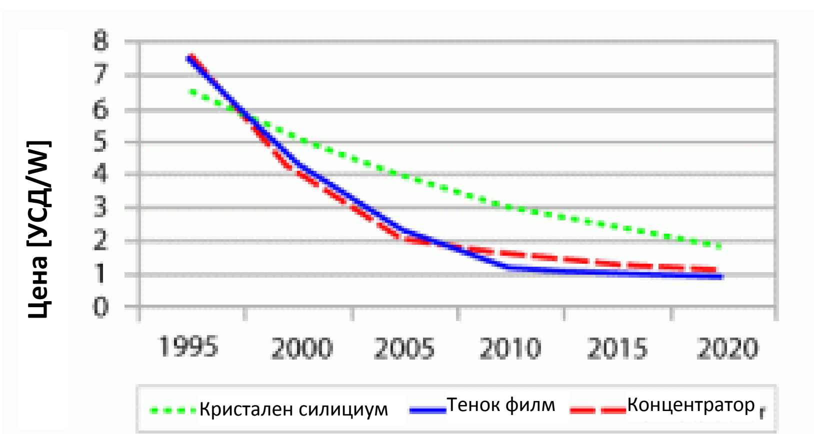
It is presupposed that the photovoltaic systems will work with availability of 99 %. It is predicted that 1 % of the projected electrical energy will not be produced because of unavailability of photovoltaic systems, when there is no solar radiation and no possibility for production of electrical energy.

5.1. Analysis of the structure of expenses and profit – Cash Flow of the project for construction of photovoltaic system

The expenses that emerge during construction and exploitation of a home photovoltaic system are consisted of initial investment construction expenses and operational and maintenance expenses.

Projects that are undertaken for construction of photovoltaic systems for production of electrical energy, regardless whether they are home photovoltaic systems, systems implemented within industrial capacities or photovoltaic electrical plant are characterized with big initial investment. Positive side is that the capital expenses, with development of technology are in regular decline, so in the near future, in particular if we take into account the limited amount of fossil fuels, it is expected that the electrical energy from photovoltaic systems to be the cheapest.

In pic. 5.2 is presented the movement of capital costs (expressed in $/W) for three different technologies that are used during construction of photovoltaic system (crystal silicon, thin film and concentrator) for the period 1995-200. There is an obvious tendency in the price fall, which together with the continuous growth of the efficiency of photovoltaic panels makes the PV systems more competent source of electrical energy. Therefore, the expectations for the incoming years are that they will expand and home photovoltaic systems will be a cost-effective way of satisfying own needs of electrical energy in households.



Сл. 5.2 Movement of capital costs for construction of photovoltaic systems

The initial investment necessary for installation of photovoltaic systems, in general is consisted of:

- expenses for provision of modules and inverters,
- metal construction,
- project design,
- mounting, etc.

When we talk about home photovoltaic systems they are most frequently placed on the roof of the facility and there are no additional expenses here for purchasing or renting land where the photovoltaic systems will be placed. Also, If the installation of the photovoltaic systems is performed in a construction or reconstruction phase of the roof, it can contribute in additional savings of the investor because he will have to invest resources for construction/reconstruction of the roof.

Home photovoltaic systems are mainly constructed with installed power of several kWp. The prices of the photovoltaic panels depends of the producer of the equipment and its quality, which everyone should be cautious during the supply. Generally speaking, the specific costs are decreasing with the rise of the capacity of the photovoltaic plant.

The indicative specific prices of solar panels depending on the producer of the solar panel and watt peak capacity of the solar panel (Wp). As we can see there is a significant difference depending on the producer of the equipment. Of course, during provision of equipment beside the price, should be taken into account the following important features of the photovoltaic panel such as:

- Quotient of the useful effect of photovoltaic panel
- Annual percentage decrease of quotient of useful effect of the photovoltaic panel in the course of time
- Age of exploitation of the photovoltaic panel
- Guaranty by the producer
- Availability of service.

On the other hand the photovoltaic systems require relatively small maintenance and operation expenses during the period of exploitation. Here we understand the servicing expenses for the system, additional expenses for repairs, cleaning of the panels, insurance, etc. Depending on the type of installed parts in the photovoltaic plant and its installation, the annual operating expenses are estimated between 20-50 EUR/kW.

The benefits that are achieved with implementation of the photovoltaic system are realized through production of electrical energy. The main goal in undertaking this projects that are implemented with limited budget at home and industrial photovoltaic systems is to satisfy partially or completely own production of electrical energy, whereas the surplus of energy that will not be consumed is planned to be handed to the distribution grid. This will the expanses in buying electrical energy from the distribution system and in cases when there is surplus of production, it should be sold or replaced with suitable amount of electrical energy in the period when the production of electrical energy from photovoltaic system is insufficient to satisfy the own needs of the household.

5.1.1. Estimation of annual production of electrical energy from home photovoltaic system

One of the basic questions that every investor in home photovoltaic systems considers is what would be the annual production of electrical energy and what would be the distribution of that production per months. We can say that the production of electrical energy from home photovoltaic systems can be relatively good estimated for a give geographic location where the system is installed. What is typical for that production are the small oscillations on an overall expected production during one calendar year but also big oscillations during the different seasons which is reasonable due to the different solar insulation in the course of different months of the year. So, for example, there are big differences in the monthly production of electrical energy from the home photovoltaic systems in January and July, which is explainable due the different amount of solar radiation.

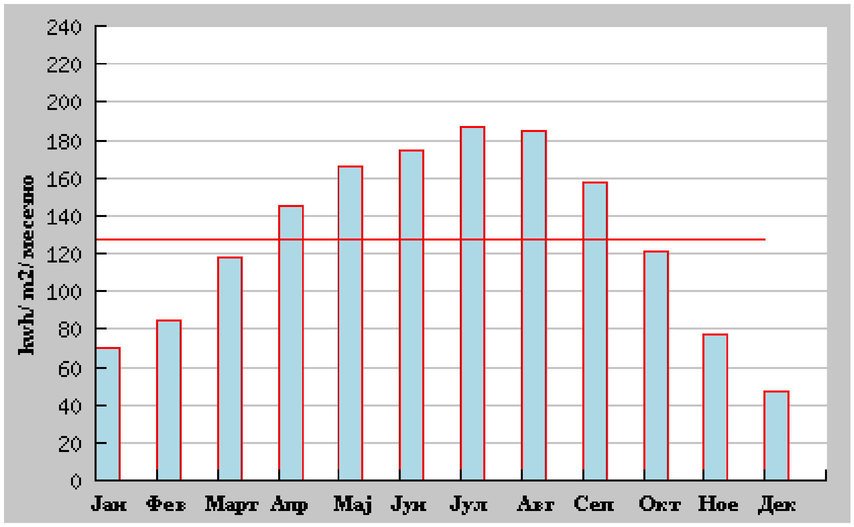
In the following table there is a comparison of the annual solar radiation in Macedonia with the leading countries in the use of solar energy in Europe.

Tab.5.1. Solar irradiation over Macedonia and solar irradiation over countries leaders in use of solar energy

Annual global irradiation (kWh/m^2)				
	Germany	Czech Republic	Spain	Macedonia
Minimum	1.074	1.115	1.365	1.482
Average	1.147	1.169	1.812	1.623
Maximum	1.445	1.267	2.028	1.722

Taking into consideration the location of Macedonia which is very attractive for use of solar energy, it is believed that in future there will be a space for bigger use of solar energy, whether for production of electrical energy through the photovoltaic plants or for production of hot water.

In pic. 5.5 we can see the solar irradiation per months for a given specific location in Macedonia. For the analyzed area the average solar radiation totals **128 kWh/m^2, total annually 1537 kWh/m^2.**



Pic.5.5 Distribution of solar radiation per months for the location Shtip in Macedonia

It is characteristic that the ratio between the solar irradiation for July and December totals more than 4, which means that the production of electrical energy from the photovoltaic system in July was four times bigger than in December. This shows that the production of electrical energy from hope photovoltaic plant depends in great measure from the season. The winter period is critical in particular when the solar insulation is decreased. From calculating aspect, an important feature value is the sum of the squares of deviation of the monthly solar radiation from the middle-year value. This statistical indicator named as standard deviation is a measure for overbalance of radiation. In this case the standard deviation is **49,53 kWh/m^2**

5.2. Means of financing projects for photovoltaic systems

Providing financial resources is one of the basic tasks for implementation of projects. The necessary resources for implementation of photovoltaic systems depends on the planned installation of the system. Home photovoltaic systems are with small installed power and scope of investment is within acceptable frames for households. But it must be mentioned that the specific investment per installed kWp decreases with the increase of installed power. Thus, for implementation of home photovoltaic system installed on a house roof it necessary to provide 1200-1400 €/kWp, while for photovoltaic plants with bigger power the specific investment, on today’s level of technology development (2017) totals about 1100 €/kWp.

For financing home photovoltaic system there are several ways:

- Own resources
- Resources provided through crediting
- Combined way of financing

- Resources provided through subsidies, donations, sponsorship or suitable development programs

Use of own resources. When we talk about smaller investments, like in the case of construction of home photovoltaic system, this way of financing can be one of the most favorable and most applied. In that case the expected benefits from the investment should be compared with the realized benefit from the interest when the same resources would be invested in a bank. At the same time, we must point out that the interest for the savings deposit at the commercial banks and savings banks in the Republic of Macedonia are very low, which present a stimulation more for the potential investors to invest their free saved deposits in construction of photovoltaic systems.

Resources provided by crediting. This way is essential when there are no own financial resources and when it is expected the project through its realized benefit (in this case, produced electrical energy) to enable return of the credit and provision of additional profit.

Combined way of financing: the investment is partially covered by own resources and partially by bank credit. This way of financing is a good compromise of the good sides of the first two ways of financing (not to enter into bigger debt and engage more own resources).

Resources provided through subsidies, donations, sponsorship or suitable development programs:

This way of financing decreases the share of participation by the investor and common good is achieved (decrease of harmful greenhouse gases, healthy environment, fulfillment of goals for in the representation of renewable energy sources of energy in the overall production). For instances, during a construction of home photovoltaic plant the state can give up on the tax or to subsidy a certain percentage in covering the initial expenses of the investors. Allocated funds can be provided through suitable development programs or project which have as an objective promotion of production of electrical energy from renewable energy sources.

5.2.1. Characteristics of credits

When a financial analysis is being prepared, it is necessary to define the key features of the credits that finance the project: amount of credit, rate interest, deadlines of credit, grace period and additional expenses that are connected with administrative procedures.

The interest rate is determined by the banks or agencies. The interest rate defines the interest or compensation which the borrower of the loan gives to the lender for the service: giving money. Usually, interest rates on short-term and long-term credits are different. Interest rates is connected with the investment risk, so it is expected more risky project to be financed with credits that have bigger interest rates. Also, short-term credits due to their certainty as a rule have smaller interest rates. As far as the financing of projects connected with construction of home photovoltaic systems, essential are credits with low interest rates or so called “green” credits that would stimulate the investors to continue investing in such projects.

Maturity of the credit is the time agreed with the bank (lender) for service of the loan. Ideal loan is the one that lasts the same period as the project that is financed with its assistance. But in practice it often impossible to be like that. Therefore, it is necessary to define a period that covers the main part of the investments, in particular those that are with highest percentage in the overall costs. If the loan is of shorter period than the project implemented by its assistance, the project will have to generate greater income so the investment is paid off as soon as possible. On the other hand, if the loan lasts longer than the project financed by its assistance, the project will be put in a situation to have a need for additional credit for replacement of amortized elements and the initial credit for the same project will still not be serviced. The time for service of the credit depends on the type of the project and ability to generate profit that will service the credit.

Also, the time for payment is longer for bigger loans. So it is expected that if you take a bank credit for implementation of photovoltaic system (around 5000 €) the loan maturation would be 3-5 years and if you take a credit for financing of a loan for photovoltaic electrical plant, the period for repayment would be from 10 to 15 years.

The grace period is the time in which the borrower still has not started to repay the loan. But the commercial banks usually offer this possibility when the loan is bigger and long-term but not at the short-term loans. The reason why this mechanism exists is to overcome the period where the project has not generated profit yet.

There are two types of grace periods. The first type is more common and refers only to the capital fund. During the grace period, the interest is paid to the lender but not the capital fund of the loan. In this way, after the expiration of the grace period the borrower owes the same amount of the capital fund as in the beginning.

The second type of grace period refers to the interest. In this case, the interest is not repaid but is added to the capital fund and in this way the overall amount that should be repaid is regularly increasing during the grace period. What is not usual and characteristic for this type of grace period is that the period is shorter.

Also, during making arrangements for the financing loans for photovoltaic systems it should be taken into account for the so called hidden expenses that appear during application for the loan at the commercial banks and additional expenses that might arise during the closing of the credit. As one of the significant factors for crediting in the agreements are the penalty interests rates, which the bank has the right to pay from the borrower (investor) if he does not service his obligations regularly towards the lender (bank).

Pic. 5.2 Installments for credit payment for implementation of home photovoltaic system

Amount of the loan:	5.000,00 €		Home photovoltaic system			
Type of payment:	Monthly					
Years of payment	Interest (%)						
	0,5	1	2	3	4	5	6
3	139,96	141,04	143,21	145,41	147,62	149,85	152,11
4	105,23	106,31	108,48	110,67	112,90	115,15	117,43
5	84,40	85,47	87,64	89,84	92,08	94,36	96,66
6	70,51	71,58	73,75	75,97	78,23	80,52	82,86

7	60,58	61,66	63,84	66,07	68,34	70,67	73,04
8	53,14	54,22	56,40	58,65	60,95	63,30	65,71
9	47,36	48,43	50,63	52,88	55,20	57,59	60,03
10	42,73	43,80	46,01	48,28	50,62	53,03	55,51

In tab.5.2 are presented the monthly installments that should be paid to the Bank of there is a loan of 5000 € for implementation of a home photovoltaic system. We can see in the table how the monthly installment depends on the interest rate (%) and of the years of repayment of the loan. If the credit which serves as an investment for the project has another value than 5.000,00 €, the value of the monthly installment presented in the table should be multiplied with the amount of the taken loan and to divide with 5.000,00. Thus, for example, if for the implementation of home photovoltaic system is taken a loan from the bank in amount of 7000 €, with interest rate of 4 % and repayment period of 5 years, from the table 5.1 we read for interest rate of 4 % and repayment period of the loan a value 92,08 €. To calculate the monthly installment for the loan which totals 7.000 €, that value is multiplied by 7.000 and divide with 5.000, receiving the monthly installment for the loan in a value of 128,91 €.

5.3. Time dimension of the money and Cash Flow of the project

The economic valorization of the technical projects, in particular projects connected with production of electrical energy from renewable energy sources is a complex task which should primarily give an answer to the question whether future expected benefits, with acceptable risk, can justify the investment and whether the proposed model of investment is the best way to achieve the requested goal.

The financial evaluation of the investments in photovoltaic systems, which primary goal is production of "clean" electrical energy can be divided into the following steps:

- Estimation of the ash Flow
- Adopting criteria for evaluation and calculation of cost-effectiveness indicators of the investment and
- Analysis of the results, comparison with the adopted criteria for acceptability with decision making whether to accept or refuse the project as an investment

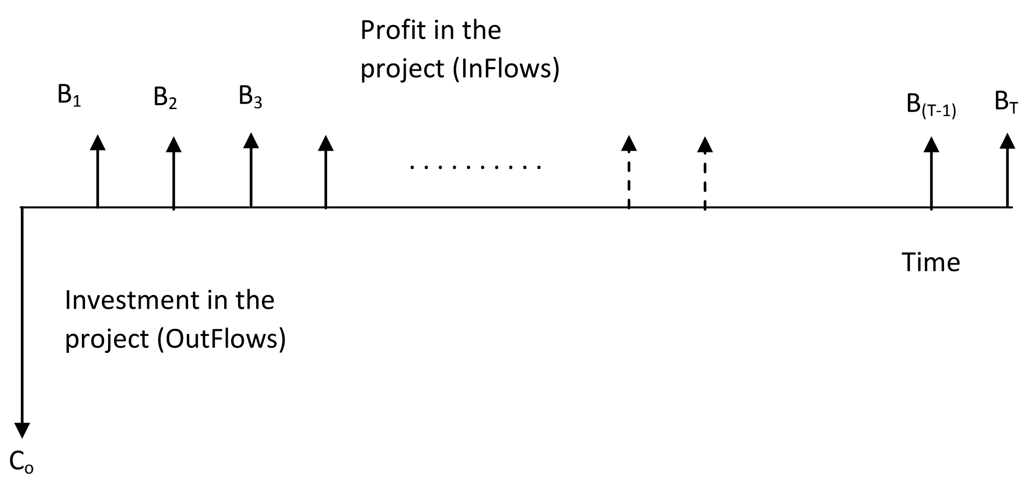
During economic valorization of the projects a generally accepted fact that today's value of one dollar is bigger than the value of that same numerously same one dollar in the future (''A nearby penny is worth a distant dollar!''). This finding for the variable value of money has more reasons. One is that in every society, more or less inflation is present, which devaluates the purchasing power of future money in comparison with the same amount of current money. Besides, it must be admitted that of several reasons there is a real risk for money return which increases with the period of waiting. So, every investor primarily is interested to return the invested resources as soon as possible and to realize bigger profit.

In today's market oriented environment, full of uncertainties, the wish to get the money fast is always present. So, the promise to get 1000 € after 5 days is far worthier than the promise the same amount of money will be get in 5 years. The logic for this is simple: the first event is much more obvious and certain in comparison to the second one. Intuitively: you can invest the money in bank and receive a particular interest which in five years will increase the initial value of the deposit.

Third reason for introducing the time dimension of the money value is the possibility for their reinvestment. One dollar today is worth more than a dollar received after one year because it can be productively invested during that current year. Waiting a year to pass to get the money, in fact we make a loss (expense) due to the missed opportunity, which is equal to the expected profit from the missed investment.

Because the money value has time dimension, during economic analyses of projects, practically it is impossible simple compilation of cash-flows that happen in different time periods. So, in order to reduce all cash-flows on one reference point, the method of actualization is used with which all cash-flows are actualized with the help of actualization rate (discount rate) of the first year of the project start.

(Cash Flow) presents the balance between all future Cash In Flows and Cash Out Flows in nominal amount connected with certain period and given investment project. Cash flows are presented on a time axis, where the negative part of the axis with an arrow pointed down are inserted the expected profits from the undertaking of the project. In pic. 5.6 is presented the typical cash-flow of a home photovoltaic system, where the investments are in the beginning (zero) year (C_0), while for the other period of exploitation of the project are predicted positive inflows as result of the produced electrical energy from a home photovoltaic system.



Pic.5.6 Typical Cash Flow diagram for project for home photovoltaic system

5.4. Methods for economic analysis for projects from renewable energy sources

The methods that are used for estimation of the economic cost-effectiveness of the investment projects for production of electrical energy from renewable energy sources is a complex process that need technical and economical knowledge. Project managers must well and essentially know the methods of economic analysis because their regular application is important for objective estimation of efficiency of the investment, as well as selection and ranking of investment projects.

Project managers, also, must differentiate the investment criteria from the methods for calculation of economic effectiveness of investments. The investment criteria tends towards achieving a certain effect (maximization of profit, minimization of loss, maximization of overall production), while the methods for estimation of economic effectiveness of the investment enable on the basis of already determined criteria to make a selection between several possible investment projects.

Furthermore, in this Guide, we will explain the most acceptable and most elaborated methods for estimation of economic effectiveness of investment projects in the engineering practice in retrospection of their application on different types of projects connected with the analysis of economic efficiency of investment in photovoltaic systems for production of electrical energy.

In the process of evaluation and decision making there is a tendency to eliminate the time dimension of the money value. That is why the methods that are used for valorization of projects make balancing of all income and revenues from the project at the same reference time.

The current value of money is evaluated after certain rate of actualization (discount rate). The rate of actualization (discount rate or capitalization rate) is an interest rate that is used so that the cash-flows that are taking place in future are converted in current values. The current value of money is calculate according to the following formula:

$$PV = \frac{FV_n}{(1+k)^n} = \frac{FV_n}{(1+s_a)^n}$$

Where:

PV - current value of the cash flow;

FV_n - value of the cash flow taking place in year n;

k - interest rate for conversion of future current flow into present;

s_a - degree of actualization (discount rate);

In general, economic and financial analyses are made with rates of actualization that are with some percentage point bigger of the current interest at the commercial banks. Rate of actualization makes devaluation of the cash flows that happen in distant future. It includes risk of losing the value, where in more risky projects or calculation with a current that has a greater risk of loss of its value, a calculation that is performed is with bigger actualization rate. As economic methods that can be used to perform the financial analysis of the investment in a project for home photovoltaic plants in this Guide we will explain:

- Method based on calculation of necessary Pay Back Period;
- Method of net present value and

- Method of cost-benefit ratio.

5.4.1. Method – Pay Back Period

With the method of payback period (PBP) is calculated the time necessary for the return of the amount of long-term invested resources. The shortest time is calculated T, for which the summarized net cash flow of present time covers the initial investment. For a project in a photovoltaic system where the initial investment happen in the first year, the payback period of the investment is the shortest time for which the condition is fulfilled.

$$NPV = -I_0 + \sum_{i=1}^{T} \frac{B_{ni}}{(1+s_a)^i} > 0$$

It is important to emphasize that the time (number of years) for pay back of the money should not be the same as the economic age of the investment project, which is, as a rule, longer. The selection of the deadline for pay back of the money is mainly based on the technological advancement. In fact, industrial companies are facing with shorter cycles of technologies and the growing competition and therefore is essential for t to be shorter because the fast pay back of the investment means bigger security and liquidity of the investment of the company that makes the investment. In other words, the projects with shorter payback period deadlines for the invested resources lowers the risk of the investment. It is believed that the risk degree grows proportionally with the duration of the deadline of payback period of investment.

Strong side of this method is simplicity and that is why this is one of the factors of its popularity in engineering sense. It can be used for comparison of several alternative projects, where effective is the one which has shorter deadline of payback period of return of invested resources, i.e., it has smaller t and vice versa, the project that has bigger t will be rejected.

This method is very popular among investors who would like to know long they can expect to return their invested resources. The method can give good indications for the cost-effectiveness of the investment in a home photovoltaic system. But if we talk about a complete and thorough economic analysis of the cost-effectiveness of investment in more complex and more expensive projects, more respected and used method is the method of net-present value, method of cost-benefit ratio and internal rate of profitability.

5.4.2. Method of Net Present Value

The calculation of Net Present Value is reduced to calculation of two equivalent cash flows, that are happening at a zero time, i.e., at the moment of the making of the analysis.

Net Present Value – NPV is the balance between the present value of all cash inflows or benefits and present value between all cash outflows of the project or costs (C) and cab be calculate according to the following formula:

If we suppose that the duration of the project is $T = n$ years , and annual cash flows are happening at the end of every year, the equation for calculating the net present value (NET) can be written in the next following form:

$$NPV = \sum_{i=0}^{n} \frac{B_i - C_i}{(1+s_a)^i} = \sum_{i=0}^{n} \frac{B_i}{(1+s_a)^i} - \sum_{i=0}^{n} \frac{C_i}{(1+s_a)^i} = \sum_{i=0}^{n} \frac{CF_i}{(1+s_a)^i}$$

where:

B_i - profit (benefits) that are made in the year *i*;

C_i costs that are made in the year *i*;

s_a - rate of actualization (discount rate);

The method of net present value is applicable to any type of projects. This method is theoretically supported and quantitative and enables comparison of cash flows at the same time points. Strength of the method is that it respects the overall age of the project.

It can be concluded that the net present value is an indicator of how big are the expected benefits reduced to present time, that will be received by undertaking the analyzed project. As such it can help the investor in projects for photovoltaic systems for production of electrical energy to estimate the expected profits during the whole economic duration of the project and to decide whether they are sufficient enough so that the project to be accepted as an investment.

From economic pint of view the project is acceptable for investment if the calculated net present value is positive. If the net present value is negative, then it is rejected as unacceptable investment. The criteria for acceptability of the project investments are presented in tab. 5.3

Tab.5.3. Criteria of acceptability of project according to the method of net present value

If...	So...	Then
NPV > 0	Investment will increase the income of the household	Project can be accepted
NPV < 0	Investment will decrease the income of the household	Project should be rejected
NPV = 0	Investment will not either increase nor decrease the income of the household	Decision cannot be reached based on this factor. Other factors should be taken into account and additional analyses performed.

This method can be used for comparison of projects which investment is approximately the same. The application of this method can help the investor correctly to point its investments in the right course and to realize a maximum profit.

When we talk about home photovoltaic systems, investments are not big and research shows that positive outcomes can be expected during longer term of exploitation.

In literature are given several weak sides of the method of net present value, where we can mention:

1. Subjectivity of the estimation of actualization rate (discount rate) – too high or too low rate of actualization changes the essence for efficiency of the project as an investment
2. The criteria does not express good enough the impact of the duration of the operational period. Comparison of two projects with different exploitation period can be insecure
3. During ranking and selection of projects it does not express immediate different ratio of the investments. For example, project A with total benefit of 102 mil € and costs of 100 mil € has equal net present value as project B with total benefit of 12 mil. €, and overall value of costs 10 mil. €.

5.4.3. Calculation of Profitability Index - PI – Benefit/Cost ratio - BCR

Another indicator which is used for valorization of project is **Profitability Index – PI** or frequently known as **Benefit-Cost ratio – BCR**. With the application of this method the third weak side of the method net present value is overcome, which does not express well the relative ratio of the investments.

With the application of this method, profitability index of project A totals 1,02, while profitability index of project B totals 1,2. This is a good indicator that project B is better as an investment comparison with project A, which can be intuitively concluded due to increased risk for implementation of the same profit in project A as in project B but with 10 times bigger engaged capital.

Profitability index is calculated as quotient of present value of all cash income values and present value of all cash revenues in the project. It is calculated according to the following formula:

$$PI = \frac{B}{C} = \frac{\sum_{i=0}^{n} \frac{B_i}{(1+s_a)^i}}{\sum_{i=0}^{n} \frac{C_i}{(1+s_a)^i}}$$

If the investments are taking place only in the initial year, which is most frequent and real case during establishment of photovoltaic system for production of electrical energy, profitability index is calculated as a quotient between the present (actualized/discounted) value of the operational cash-flows and present value of initial investments.

$$PI = \frac{\sum_{j=1}^{n} \frac{B_{nj}}{(1+s_a)^j}}{I_0}$$

B_{nj} - net profit of the year , after the deduction of all costs, including taxes

I_0 - initial investment

s_a - Actualization rate rate(discount rate);

Obviously, investment is acceptable if profitability index is bigger than 1,0. If profitability index is lower than 1,0, investment is not acceptable for implementation. In case where profitability index is equal to 1, the project is on the border line of acceptability. The criteria for acceptability of the investment according to this criteria are presented in Tab. 5.4.

Tab.5.4. Criteria of acceptability of project according to profitability index (Benefit-Cost method)

If...	So...	Then...
PI > 1	Investment will increase the income of the household	Project can be accepted
PI < 1	Investment will decrease the income of the household	Project should be rejected
PI = 1	Investment will not either increase nor decrease the income of the household	Decision cannot be reached based on this factor. Other additional factors should be taken into account

In case of comparison of two projects using Benefit-Cost method, from economic aspect more acceptable is the in which profitability index is bigger.

5.4.4. Case Study – construction of home photovoltaic system

Construction of home photovoltaic system has as a primary goal to produce electrical energy that will satisfy the needs of the household. Although in Macedonia there is still no suitable legal regulation existing for balancing, households in the periods when it produces more energy from own sources should transfer it to the distribution grid. In the period when the photovoltaic system produces less electrical energy than needed, the shortage should be undertaken from the distributive grid.

Basically, home photovoltaic plants are installed on the roof constructions of the houses. They have relatively small capacity, several kWp and are connected to the grid via inverter. In pic. 5.7 there is a scheme of home photovoltaic system installed on a roof house and directly connected to the distribution grid.

These decentralized system are most commonly connected to the low-voltage level of the grid. The balance between the requested energy in households and the one produced in the photovoltaic generator is compensated through the grid.

When we talk about set up of solar modules on curved roofs, then it must be emphasized that because of the heat there will be additional losses of energy. If the modules are placed at a distance of 10 cm of the roof, it is estimated that the loss is between 1.5% and 2.5% in relation to the systems that are mounted under even plane tilt but are completely separated. If the systems are integrated on the roof due to lack of ventilation the losses will be between 4% - 5% in relation to separated solar systems.

In the analyzes that will be presented next in this Guide, the economic aspects of the construction of home photovoltaic systems will be analyzed with installed power of 3, 4 and 5 kWp. In addition, the prices of produced electrical energy will be formed on the basis of the price of electrical energy which in an expensive tariff totals 5,56 denars/kWh and in cheap tariff is 2,78 denars/kWp. To these prices should be included VAT, which is 18%. In Tab. 5.5 are presented the prices of delivered electrical energy for the consumers in the first tariff group in the Republic of Macedonia, that are applied for October 2017.

On the basis of these data the average price of the produced electrical energy that is used in households has been established and will be substituted with electrical energy produced by a home photovoltaic system with a value of 0,1€/kWh (1€= 61,5 den).

In Tab. 5.6 are presented the basic parameters used in the performed analyses of this guide so we can get a real picture of cost-effectiveness of the investment and proposed measures for getting closer the PV systems for production of electrical energy to households. Degradation of solar panel totals 0,5 – 1% annually. In these analyses the coefficient of degradation is adapted to be 0,8 % on an annual basis.

Tab.5.5. Basic input suppositions for analysis of a home PV system

Installed power	**Price €**	**E (kWh/year)**	**Maintenancee €/год**
3 kWp	4000	4200	60
4 kWp	5000	5600	75
5 kWp	6000	7000	90

In Tab.5.6. is presented the time necessary for return of the investment for typical home PV systems with installed power of 3 kWp, 4 kWp and 5 kWp, depending on the actualization rate which is in range of 0-5%. From the results we can see that even we disregard the time dimension of money the period of return of investment is longer than 10 years. The return time of the investment is shorter for PV systems with bigger power. The real analyses, with actualization rate of 4% show that the time of return of investment is longer than 15 years. This proves the need of additional subsiding by the state of potential investors in order to encourage these green investments so that households can be included in the production of electrical energy for own needs.

	0%	1%	2%	3%	4%	5%
3 kW	11,82	12,94	14.22	16,10	19,13	27,73
4 kW	10,91	11.78	12,88	14,33	16.43	20,19
5 kW	10,38	11,16	12,12	13,37	15,08	17,83

Tab.5.6. Necessary time return of investment depending on actualization rate and installed power for home PV system

In Tab. 5.7 is presented the present net value of the project (in €) depending on the number of exploitation years of PV system во зависност од бројот на години на експлоатација на ФВ – системот at sa=2% and sa=4%

Tab.5.7. Net present value for actualization rate of sa=2%

	15 years	20 years	25 years.	30 years
3 kW	167,24	1126,80	1914,34	2551,09
4 kW	631,32	1935,34	3010,79	3884,79
5 kW	1095,40	2744,68	4107,24	5218,47

Tab.5.8 Net present value of project for home PV plant depending on years of exploitation and installed actualization rate of sa=4%

	15 years	20 years	25 years	30 yers
3 kW	-501,94	87,42	484,27	728,99
4 kW	-260,93	549,89	1104,03	1455,31

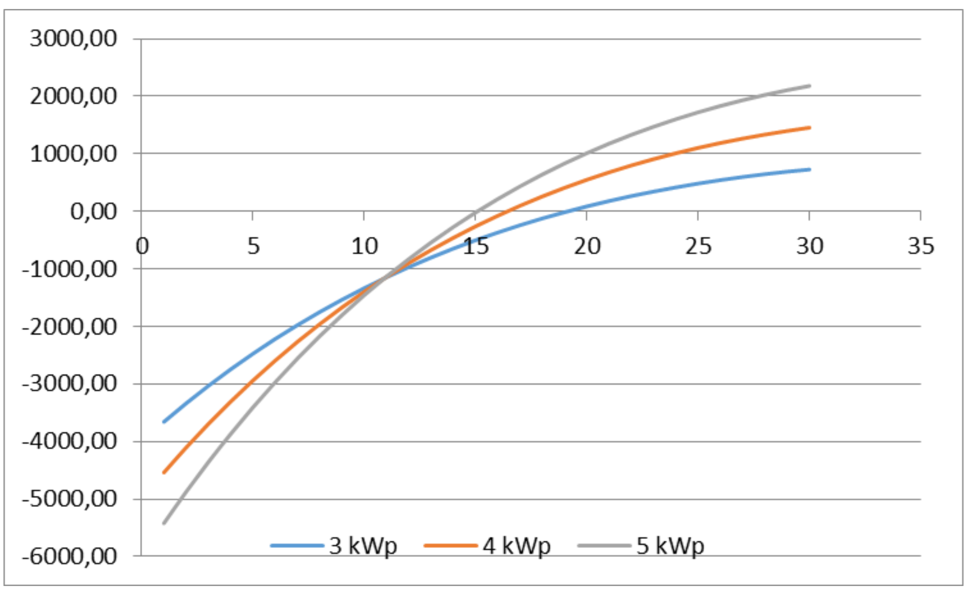
5 kW	-19,91	1012,36	1723,79	2439,40

From the analyses it can be concluded that the investment in PV system is a long-term cost-effective investment. Cash-flow analysis shows that this system starts to generate profit after 15 years of exploitation. In addition, bigger cost-effectiveness has the investment in home PV system with bigger installed power due to the smaller specific costs per installed kWp.

Significant benefit is realized if the period of exploitation of PV system is 25-30 years. This indicates if PV panels are produced with longer age and lower rate of degradation, this will significantly increase the investment efficiency. Also, as a risk that can improve the economic performances of the investment is the rise of electrical energy prices, which in the Republic of Macedonia has a social element.

From the aspect whether to invest now or after several years, the estimation of the investor should encompass also analyses of the trends in efficiency increase of PV panels, decrease of their price and accumulation of experiences in exploitation of home PV systems that will lower the investment risk.

The cash-flow of home PV system depending on installed power for actualization rate of sa=4% is presented in the following picture:



Pic. 5.7 Cash-flow for home PV system depending on installed power

From the performed analyses it can be concluded that if households are to be encouraged to install solar panels on the roofs, stimulating mechanisms are essential. Therefore, the state should predict subsides for home PV systems in amount that will enable the return time of the investment to be reduced to 7-8 years. It is estimated that if the subsidy is on a one-time basis 25-30% of the value of the initial investment, these systems will become more attractive for the citizens.

Next in the Guide are made additional two analyses that have as a purpose to encourage the investors having in mind the real expectations for decrease of prices of photovoltaic systems and increase of the price of electrical energy on the market.

First a calculation is made of the time necessary for the return of the investment and net present value depending on the installation and actualization rate at a presumption that the prices of photovoltaic system are lower for 20 % of those presented in Tab. 5.9. Namely, for the photovoltaic system with installation of 3 kWp the price is adopted to be 3200 €, for 4 kWp the price is 4000 €, and for installation of 5 kWp the price is 4800 €. During calculation of net present value, which is an indicator for realized profit before taxation, it is assumed that the time of exploitation of the photovoltaic system is 20 years. The results from the calculation are presented in Tab. 5.9 and Tab. 5.10 separately.

TABLE 5.1 – Necessary time for return of investment depending on the actualization rate and installed power of the home photovoltaic system (decreased prices of PV system for 20%)

	0%	1%	2%	3%	4%	5%
3 kW	9	9,58	10,26	11,08	12,13	13,55
4 kW	8,35	8,83	9,41	10.07	10.90	11,96
5 kW	7,97	8,40	8,93	9,51	10,22	11,12

TABLE 5.2 – Net present value for the period of exploitation of 20 years expressed in euros depending on the actualization rate and installed power of the home photovoltaic system (decreased prices of PV system for 20%)

.	0%	1%	2%	3%	4%	5%
3 kW	3534	2803	2167	1612	1127	701
4 kW	5059	4083	3236	2497	1850	1282
5 kW	6584	5364	4305	3380	2572	1862

Additional analyses have been performed in order to determine the impact of the electrical energy price on the economic indicators of the project. Since it is expected that the price of electrical energy will grow, in tab. 5.11 and 5.12 are presented the time of return of the investment and expected net present value, if it is assumed the prices of the photovoltaic system are lower than 20% of the electrical energy price and the price of electrical energy is increased for 20% and totals 0,12 €/kWh.

TABLE 5.3 – Necessary time for return of investment depending on the actualization rate and installed power of home photovoltaic system (decreased prices for PV system for 20%, increased prices for electrical energy for 20%)

	0%	1%	2%	3%	4%	5%
3 kW	7,28	7,65	8,06	8,54	9,1	9,77
4 kW	6,76	7,08	7,43	7,83	8,30	8,83
5 kW	6,46	6,75	7.06	7,42	7,83	8,30

TABLE 5.4 – Net present value for the period of exploitation of 20 years expressed in euros depending on the actualization rate and installed power of the home photovoltaic system (decreased prices of PV system for 20%, increased prices of electrical energy for 20%)

	0%	1%	2%	3%	4%	5%
3 kW	5073	4195	3432	2767	2184	1673
4 kW	7111	5940	4923	4036	3260	2578
5 kW	9148	7685	6413	5305	4334	3482

The analysis of the results shows that the time for return of the investment that totals about 8 years is completely acceptable for these types of projects. Also, on longer periods, by investing in home photovoltaic system a profit can be realized that corresponds to the profit if these resources are invested in a bank with an interest rate of 3,5-4%.

Also, the economic cost-effectiveness of the investments are expected in the future to be increased and interest in their installation due to:

- Need for provision of own production from renewable sources
- Construction of home photovoltaic systems that will supply more households
- Provision of subsidies and grants through EU funded projects