MULTITRACES

MULTIDISCIPLINARY TRAINING IN CIRCULAR ECONOMY AND SMART VALORISATION OF THE RURAL AREA FOR NEW BUSINESS MODELS

Co-funded by the Erasmus+ Programme of the European Union

NATURAL RESOURCES VALORISATION
RENEWABLE ENERGY SOURCES IN RURAL AREA

(UBc contribution)

Solar energy/ Wind energy/ Biomass/ Geothermal energy/ Hydropower

THE CONNECTION BETWEEN CIRCULAR ECONOMY, BIOECONOMY AND RENEWABLE RESOURCES OF ENERGY

The circular economy is an economic model which comes from the biosphere, where everything can become a resource for the next level of the trophic chain.

The basic principles of the circular economy are:

- the wastes are raw materials;
- resilience through diversity;
- energy from Renewables sources;
- think from a systems perspective.

The European Commission defines the bioeconomy as *the production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, bio-based products and bioenergy.*

The two concepts, the circular economy and the bioeconomy, are distinct from several points of view, but in principle have common goals: efficient use of non-renewable sources - a combination of reduction, reuse and recycling activities respectively the use of renewable sources in an intelligent and efficient way.

An important objective resulting from the principles of the two models is development and support for rural areas by adding value to goods that are produced by the agricultural, forestry, fisheries or waste sectors.

A BRIEF INTRODUCTION ABOUT ENERGY RESOURCES

The word ***energy*** comes from the Greek ενέργεια (***working***). In Latin – ***energia*** (***activity***).

The concept of ***energy*** is fundamental due to the connection between matter and motion - production and transformation of different forms of matter movement.

Primary energy consists of all the energy that is in the original source. Primary energy is the energy that has not undergone any process of conversion or transformation.

Primary energy
- → **conventiona**l - finite sources (***crude oil, coal, natural gas and nuclear fuels***)
- → **renewable** sources - continuously generated by natural systems (***hydraulic, solar, wind, geothermal, tidal, wave, biomass***).

Gross theoretical potential - the energy that would become available through the conversion into useful energy of all natural renewable flows, with an efficiency of 100%.

Technical potential - the share of the gross theoretical potential that can be converted into useful energy, taking into account the level of technological development and the possibility of its use by human society.

Economic potential - the share of the technical potential that can be converted into useful energy, taking into account economic profitability.

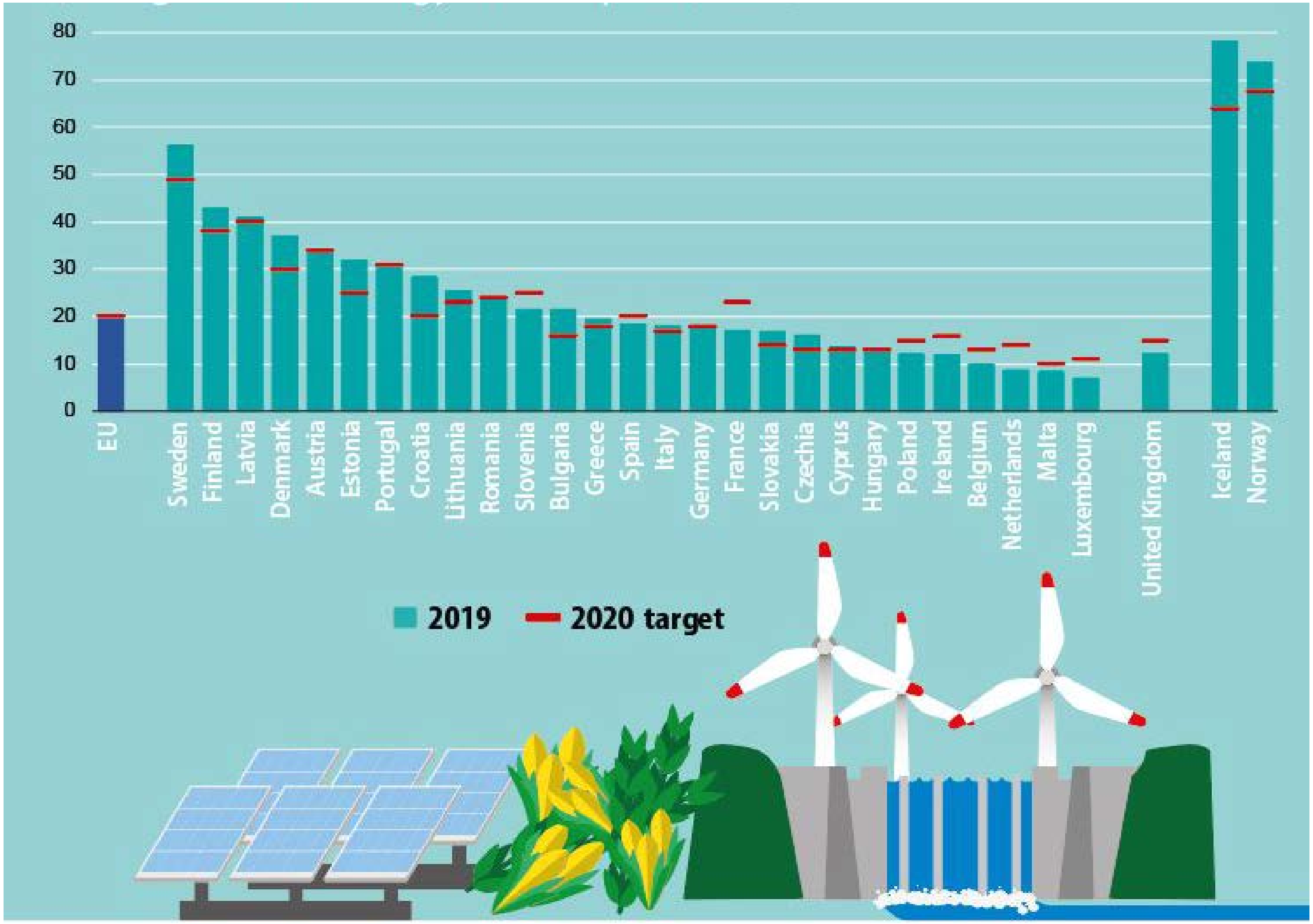


Fig.1. Share of energy from renewable sources, 2019 (% of gross final energy consumption), Source, Euroatat

The share of energy from renewable sources in gross final energy consumption, 2010-2019 for ***Greece, Spain, Italy and Romania***, in %:

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Greece	10.1	11.2	13.7	15.3	15.7	15.7	15.4	17.3	18.1	19.7
Spain	13.8	13.2	14.3	15.3	16.2	16.3	17.4	17.6	17.5	18.4
Italy	13.0	12.9	15.4	16.7	17.1	17.5	17.4	18.3	17.8	18.2
Romania	22.8	21.2	22.8	23.9	24.8	24.8	25.0	24.5	23.9	24.3

Solar energy

The sun - the most important source of energy on Earth. In one second the Sun radiates more energy in space than mankind has consumed since its appearance on earth: 3.86x1026 J.

The value accepted of the solar constant is approximately 1360 W/m^2, representing an average annual value, measured with the help of scientific research satellites. The Earth's atmosphere and Earth's surface interact with solar radiation, producing a series of transformations of solar radiation.

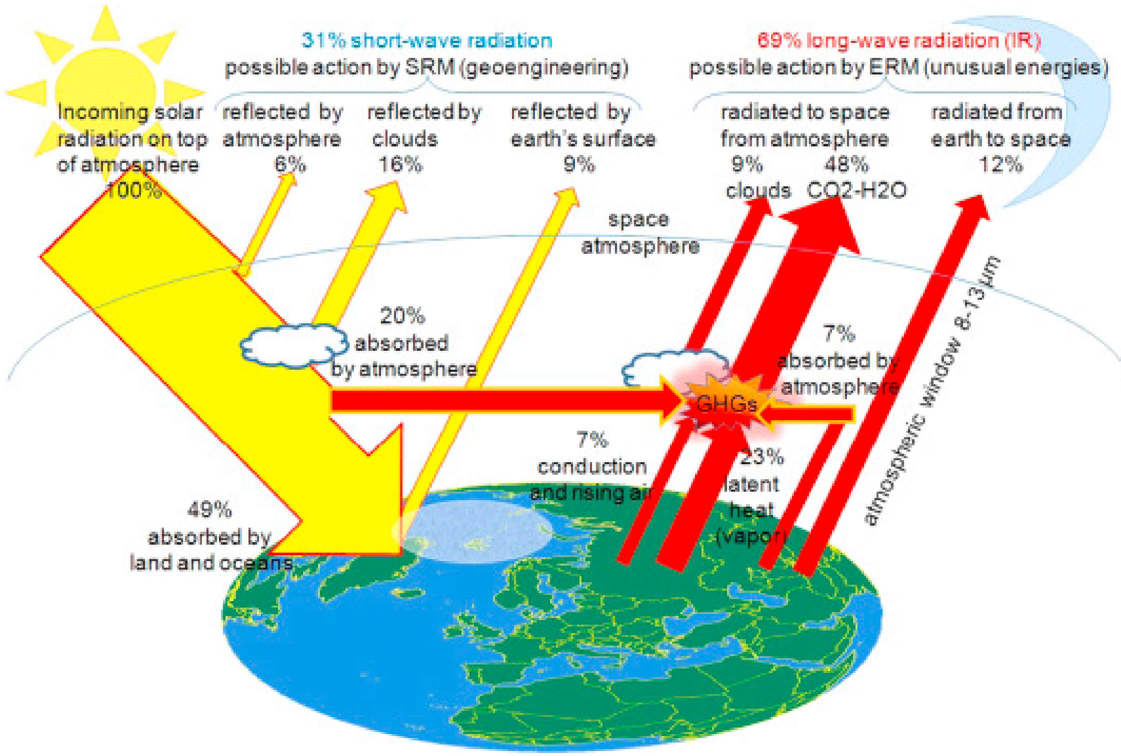


Fig. 2. Principal energy fluxes, Source, https://www.sciencedirect.com

The mechanisms by which the intensity of solar radiation changes as it passes through the atmosphere, are ***absorption and diffusion***.

X radiation and part of the ***ultraviolet radiation*** are almost completely absorbed (retained, filtered) in the atmosphere.

A part of solar radiation is reflected by the Earth 's atmosphere or some of its components (the air molecules and certain categories of clouds). By reflection, some of the solar radiation is dissipated, the mechanism of this process is called Rayleigh diffusion, and this phenomenon represents the radiation of the celestial vault.

Direct radiation is the component of atmosphere radiation that is neither reflected nor scattered, and which directly reaches the surface. This is the component that produces shadows.

Global radiation from the Sun, on a horizontal surface at ground level in one serene day, represents the sum of direct radiation, diffuse radiation and reflected radiation.

Direct solar radiation depends on the orientation of the receiving surface.

Diffuse solar radiation can be considered the same,

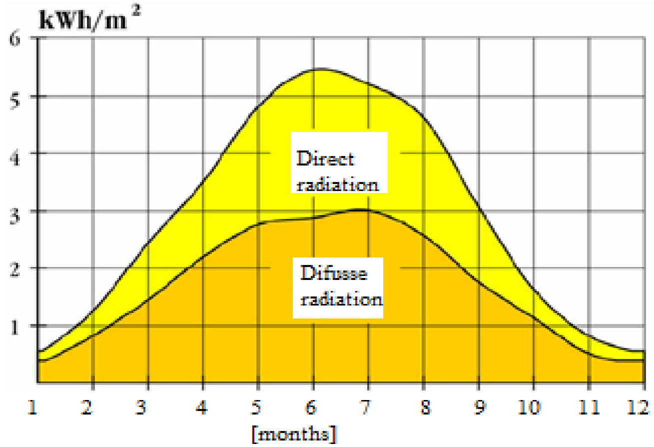


Fig.3. The ratio between diffuse and direct radiation. Source, http://www.termo.utcluj.ro

The solar radiation that reaches the Earth consists of:

- visible radiation from 0.38 to 0.78 microns,
- ultraviolet (UV) radiation from 0.28 to 0.38 microns,
- infrared (IR) radiation from 0.78 to 2.5 microns.

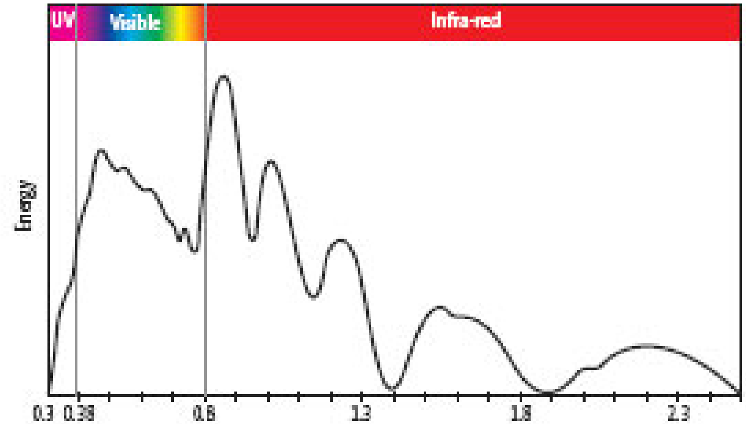


Fig. 4. The overall spectrum of solar radiation according to EN 410

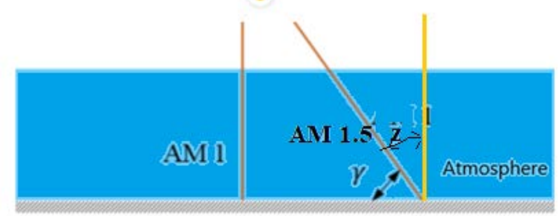
According to the standards, the photovoltaic modules are evaluated for an air mass index - AM of 1.5.
It quantifies the reduction in the power of light as it passes through the atmosphere and is absorbed by air and dust.

AM has the value 0 (before entering the Earth's atmosphere), in which case the irradiance is the solar constant, respectively 1360 W / m².

AM =1 corresponds to a trajectory perpendicular to the Earth's surface (the shortest path of radiation, through the atmosphere, to the Earth's surface).

AM =1.5 attests that the path of radiation through the Earth's atmosphere is 50% longer than for AM =1, which corresponds an angle $\gamma = 41.8°$

$$AM = \frac{1}{\sin\gamma} = \frac{1}{\cos z}$$



Aspects related to the conversion of solar energy into other forms of energy

Tthe solar energy can be converted into other forms of energy in 4 ways:

1. Photomechanical energy conversion;
2. Photothermal conversion;
3. Photochemical conversion;
4. Photoelectric conversion.

Photomechanical energy conversion is applied in the field of space energy. The solar sail motor is a new application common to satellites. After the satellite or spacecraft reaches interstellar space, due to the interaction between photons and large reflecting surfaces, propulsion occurs through the impulse given by the photons to the interaction.

Photothermal conversion determines the climatic and meteorological conditions in various geographical areas, the formation and the preservation of the water cycle on the earth, an essential phenomenon for the existence of life on the planet. Photothermal conversion has many practical and industrial applications.

Photochemical conversion (along with photothermal conversion) use the solar energy in two ways: directly by light excitations of the molecules of a body, or indirectly through plants (photosynthesis) or the transformation of animal manure. Lately, the fuel cell sector has developed a lot as industrial applications.

Photoelectric conversion has multiple applications in both terrestrial and space energy. The direct conversion of solar energy into electricity is done by photovoltaic effect, with the help of photovoltaic cells.

Solar energy
Aspects related to the conversion of solar energy into other forms of energy

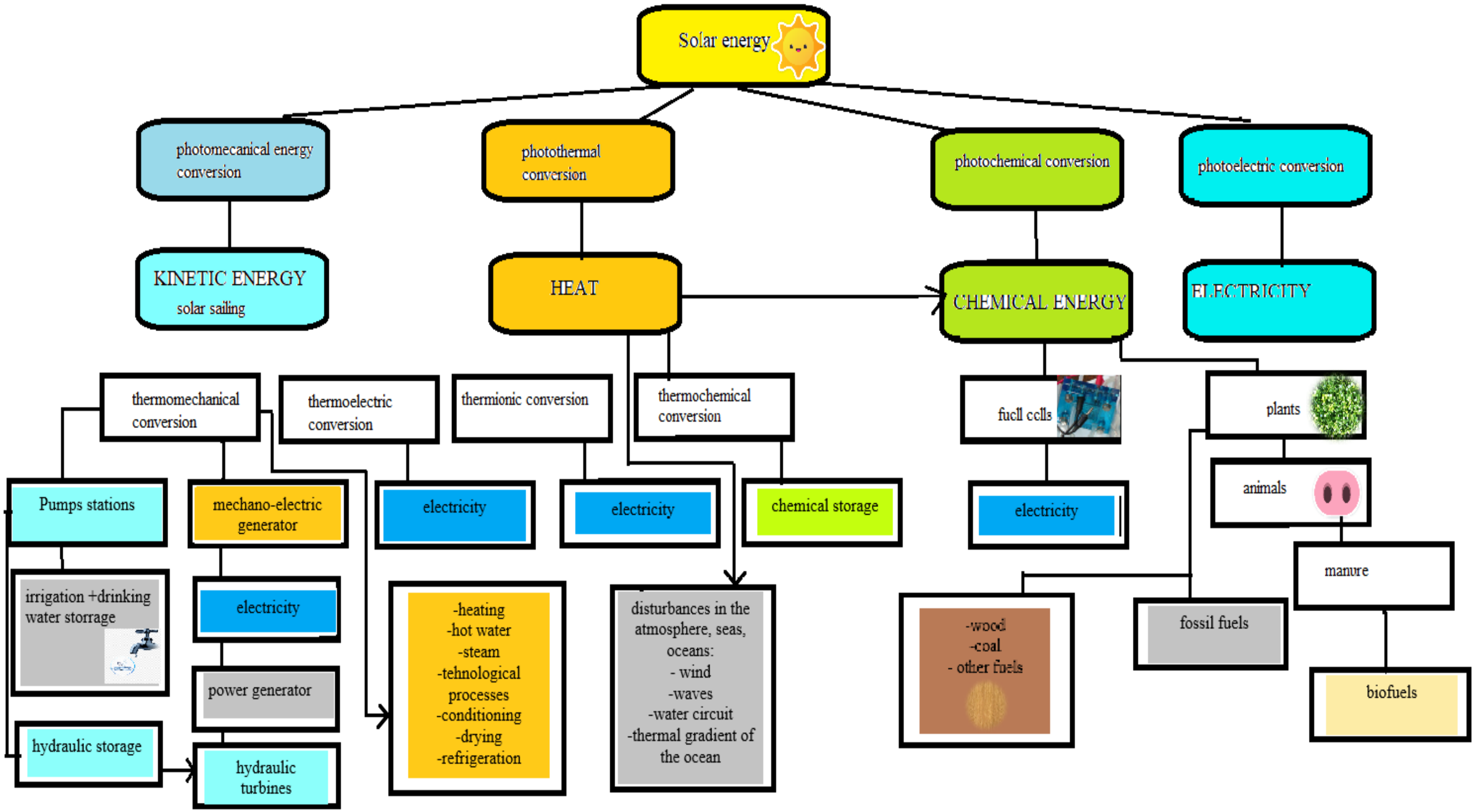
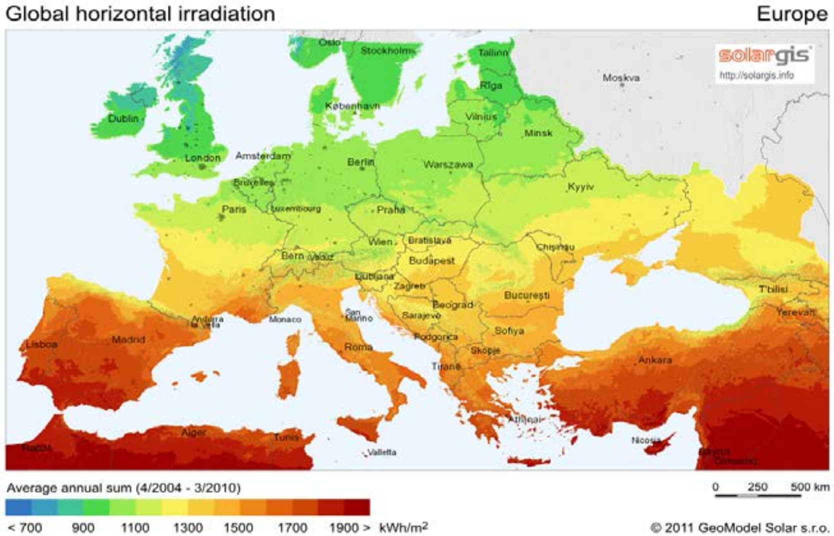
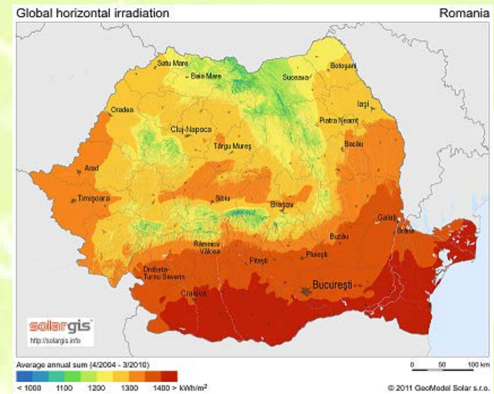
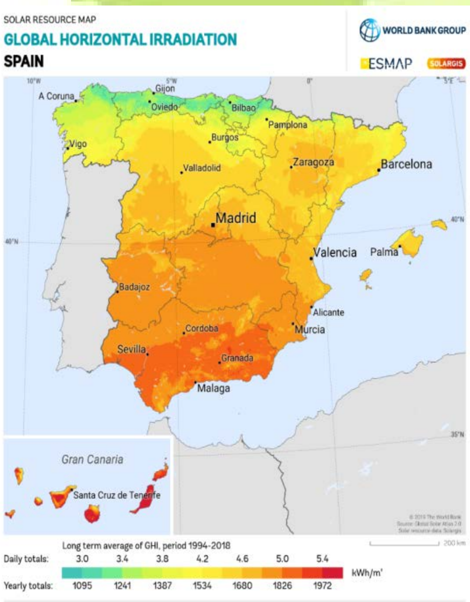


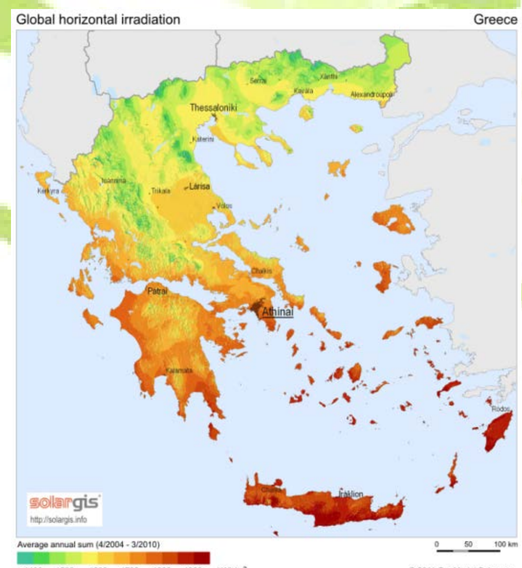
Fig.5. The conversion of solar energy in other forms of energy

Solar energy









http://multitraces.ub.ro

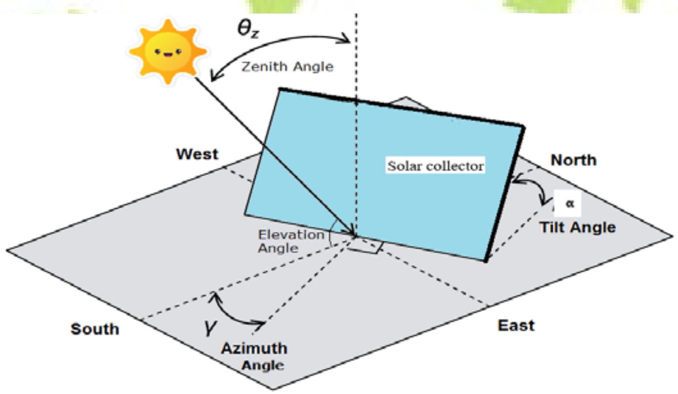
Capturing the sunlight for heat production

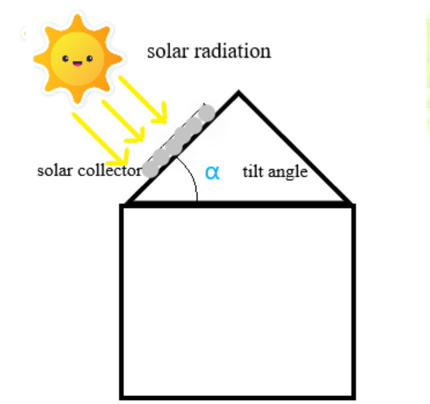
There are two major categories:

- ***CSP - Concentrating Sun Power*** - solar energy is concentrated by using mirrors or lenses and used to increase the temperature of a thermal agent, subsequently used for electricity production, in an industrial scale system;
- ***LPC - Low Power Collectors*** - generally intended for small - scale use, generally for obtaining hot water (low power domestic or industrial applications).

For the rural area of great importance are the various types of low power collectors.
For a highest possible efficiency, the orientation of the collectors position towards the Sun must be correct.
The position of the solar collectors is defined by two angles:

- the angle of inclination to the horizontal (tilt angle), α,
- the azimuth angleγ, which represents the orientation towards the south direction.



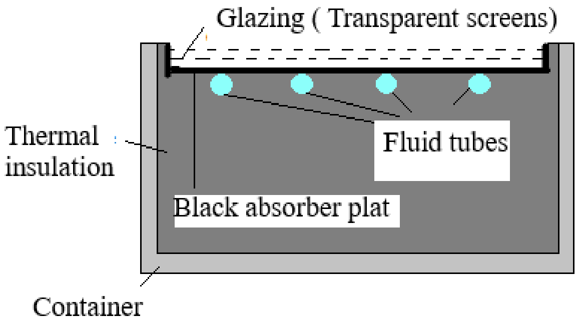


For residential applications, the most common solar collectors are:

- Flat solar collectors;
- Vacuum tubes solar collectors;
- Heat pipe solar collectors.

The flat solar collector

- *open circuit* - the heat transfer fluid from the consumer's installation is the same as the one circulating through the panel pipes - radiator principle;
- *closed circuit* - the primary circuit (corresponding to the solar panel) is separated from the secondary circuit by the consumer through a heat exchanger.



The solar radiation absorbed by a collector per unit of absorption surface is equal to the difference between the incident solar radiation and the optical losses. The heat losses of the collector in the environment by conduction, convection, and radiation are determined as the product of the heat transfer coefficient U_L and the difference between the average temperature of the absorbent plate T_p and the temperature of the environment T_a. At steady state the useful energy output of an surface collector A_c is given by the difference between the absorbed solar radiation and the heat loss.

$$Q_u = A_c \times [I - U_L \times (T_p - T_a)]$$

Vacuum tubes solar collectors

Battery-mounted glass tubes. Heat pipe collectors have a wing-shaped Cu pipe with an absorbent element inside. These types of collectors have been on the market for over 25 years and are of several types:

- Tube-welded absorption surface,
- Absorption surface not welded to the tube;

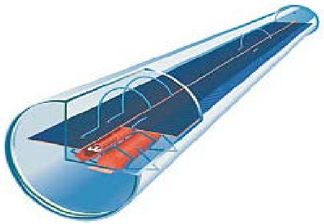
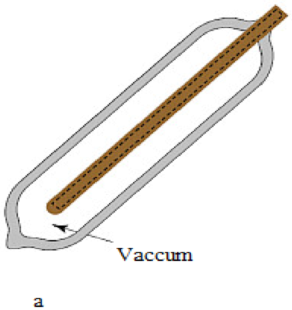


Fig.10. Tube-welded absorption surface (left), Absorption surface not welded to the tube (right)



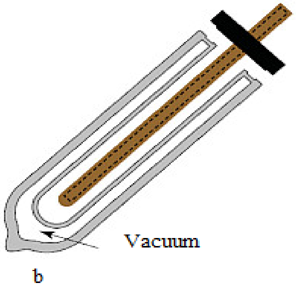
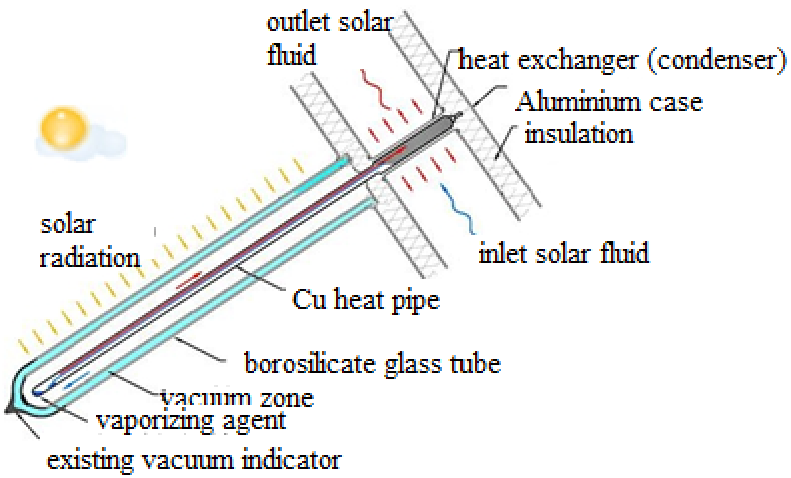


Fig.11. Collector with completely vacuum tube, b. Collectorwith a not completely vacuum tube

Heat pipe evacuated tubes collector



At the top of the panel is an insulated metal cylindrical tank, which holds the vacuum glass tubes. The tubes have double walls, between them being a vacuum. Due to the vacuum, the heat transfer to the environment is reduced. Inside the outer walls of the glass tubes is an absorbent material that increases the ability to capture solar radiation. In the cylindrical metal tank, the warmer water, with a lower density, will rise to the top, and the water with a lower temperature will remain at the bottom of the tank and will flow through the glass tubes, will receive heat from the Sun. It will heat up and becoming less dense it will climb into the tank at the top (the thermosyphon effect).

Examples of heat production systems using solar collectors for rural houses

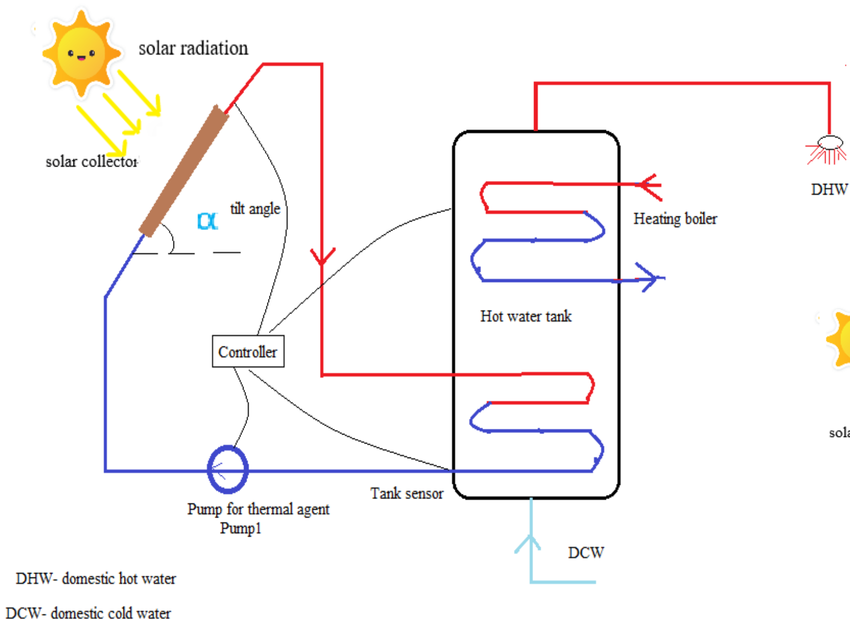


Fig.13. Schematic diagram for solar domestic hot water system

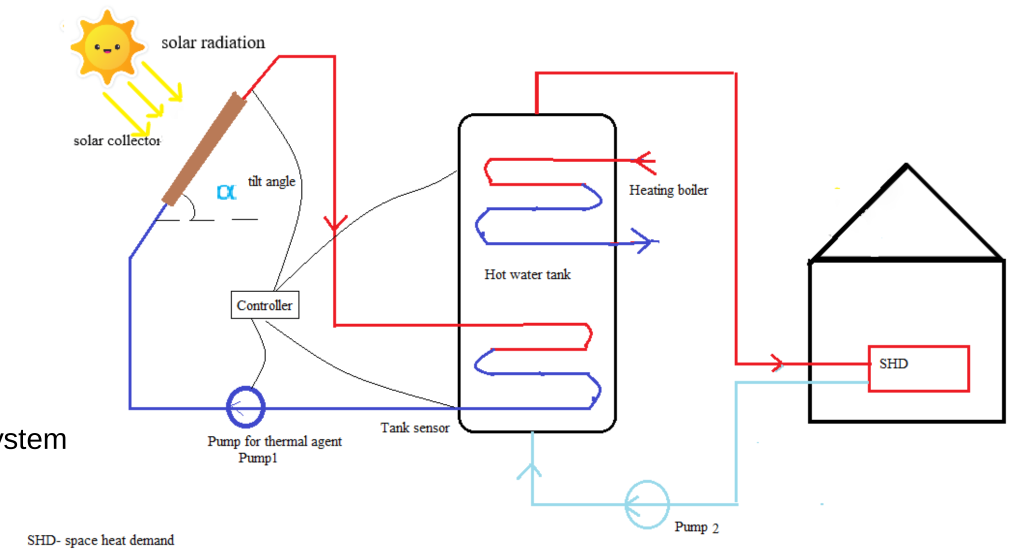


Fig.14. Schematic diagram scheme for solar heating system

Solar power is the conversion of the sunlight into electricity (the photoelectric conversion). This conversion can take place indirectly using concentrated solar power, directly using photovoltaic panels or combination. Concentrated solar power systems use lenses or mirrors and solar tracking systems to focus a large area of sunlight into a small beam. Photovoltaic cells convert light into an electric current using the photovoltaic effect

Agrivoltaic *(agriculture – photovoltaic)* is a new term, used for the first time by Adolf Goetzberger and Armin Zastrow in 1981 and established in vocabulary in 2011. This word means co-developing the same area of land for both photovoltaic power as well as for agriculture.

Fig.15. Agrivoltaic beekeeping project in Spain

Photovoltaic cell – operation principle

The word photovoltaic consists of the Greek word for light and the name of the physicist Allesandro Volta. This word refers to the direct transformation of sunlight into electricity through solar cells. Solar cells are the main components of a photovoltaic panel system.

Solar energy
Solar power

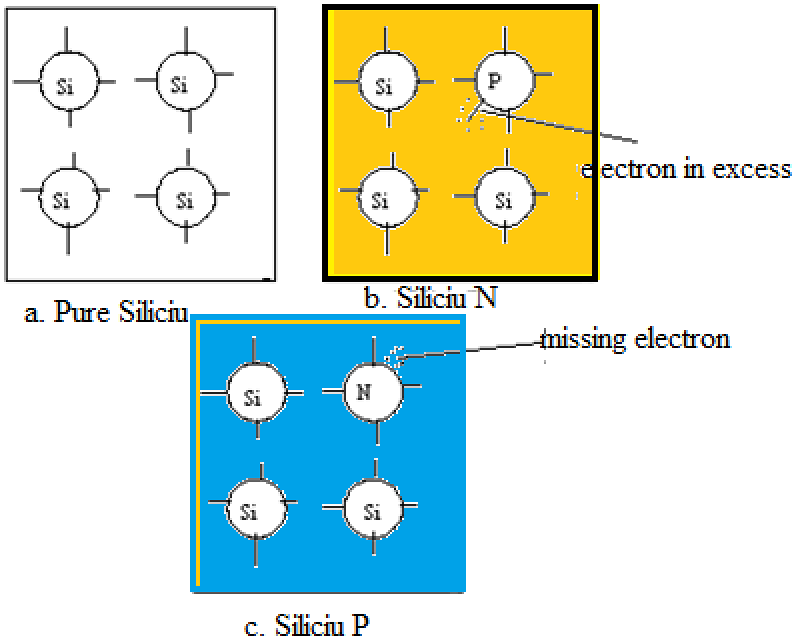


Fig.16. The schematic of Siliciu atom (4 electrons on the outer layer)

$$E_f = h \times \nu$$

h=6.62607015×10^{-34} J·s (Planck constant;)
v - photon's frequency.

The cell consists of two or more semiconductor layers between 0.001 and 0.2 mm thick, doped with certain chemical elements to form "p" and "n" junctions.

Structura celulei PV este similară cu cea a unei diode. Când stratul de siliciu este expus la lumină, va avea loc o „agitație” a electronilor din material și va fi generat un curent electric.

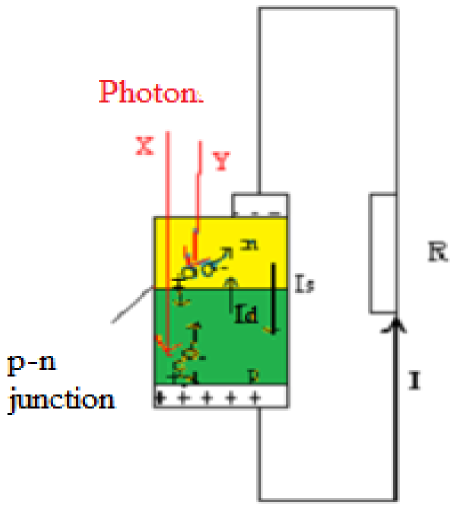


Fig.17. Simplified diagram of a photovoltaic cell

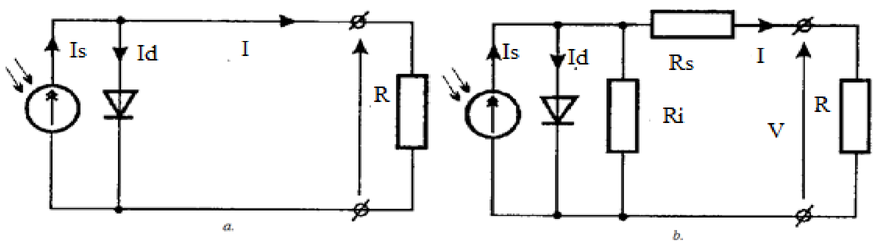


Fig.17. The electrically equivalent diagrams of the photovoltaic cell
a. simplified diagram, b, complete diagram

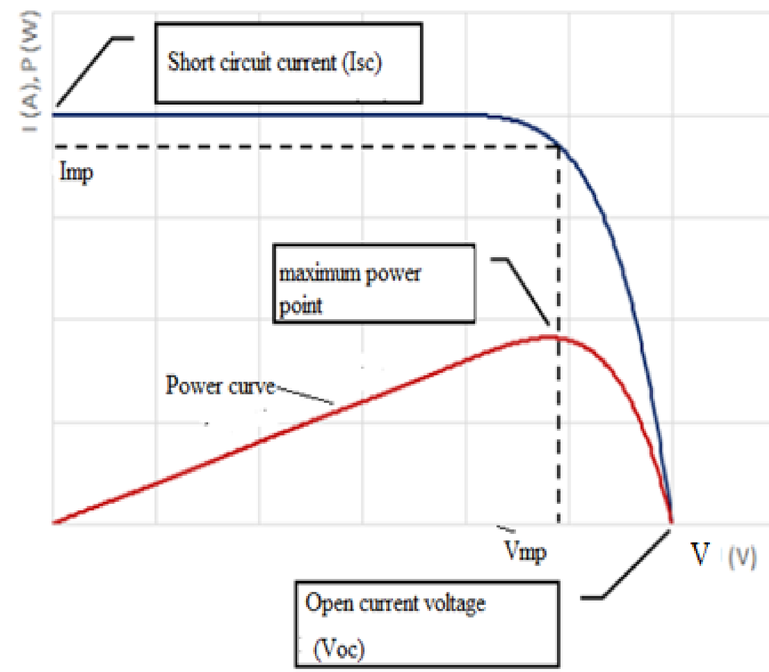


Fig. 18. The characteristics of the cell

The standard test conditions:
- Solar irradiance 1000 W/m^{2,}
- -airmass AM=1.5,
- Temperature of the cell 25^{0}C.

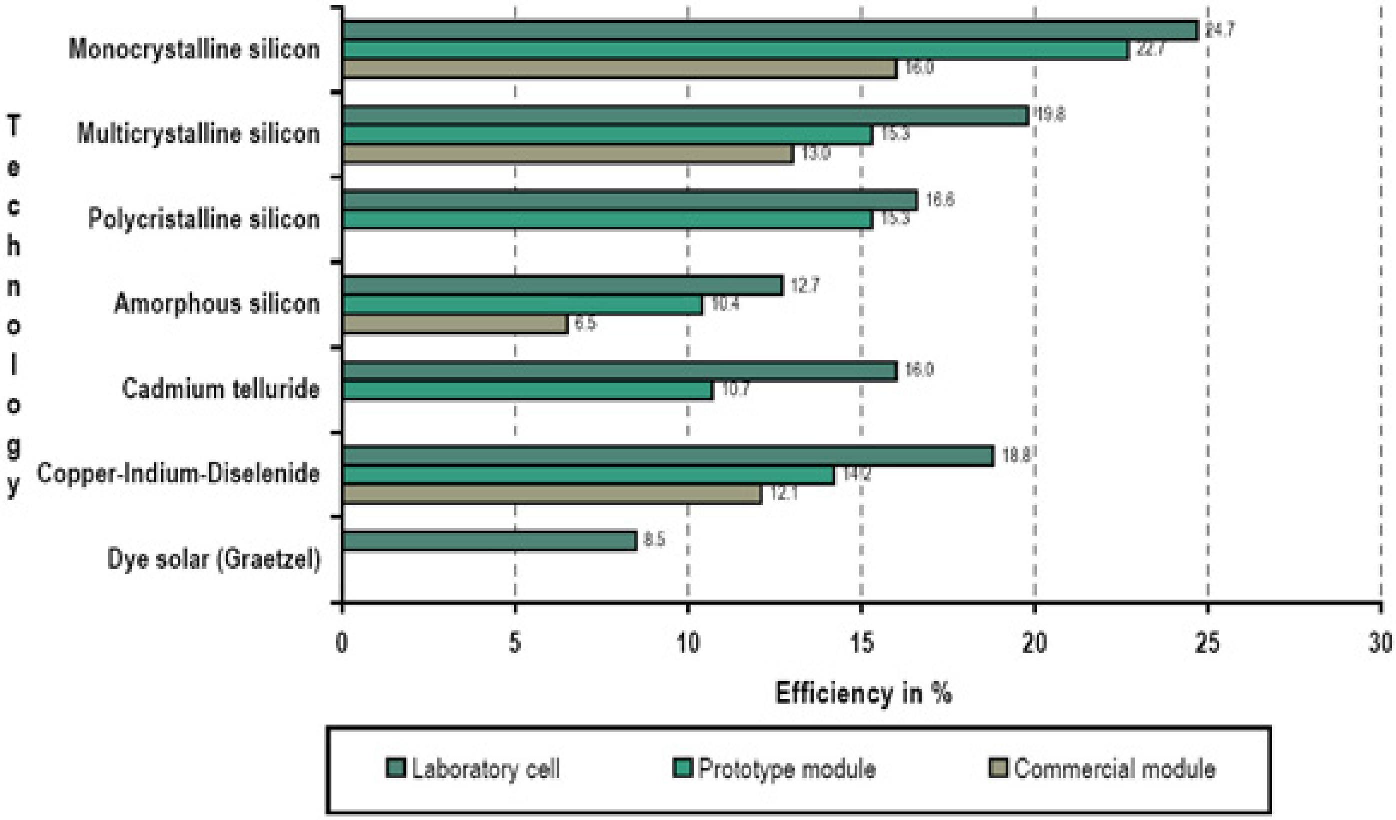
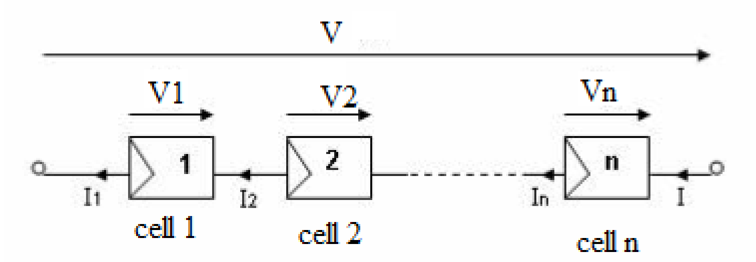
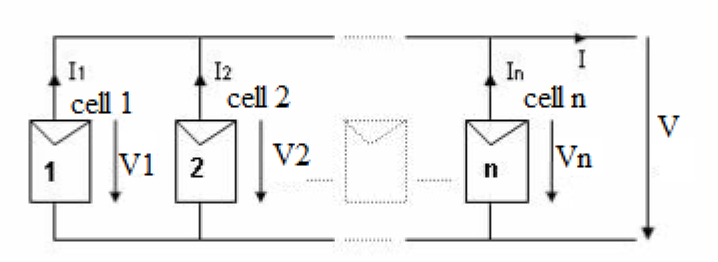


Fig. 19. Efficiency of photovoltaic cells depending on the manufacturing technology.

The connecting of photovoltaic cells



V=V1+V2+….+Vn , [V]
I=I1=I2=….=In, [A]



V=V1=V2=….=Vn , [V]
I=I1+I2+….+In, [A]

Fig.20. The series/paralel connected photovoltaic cells

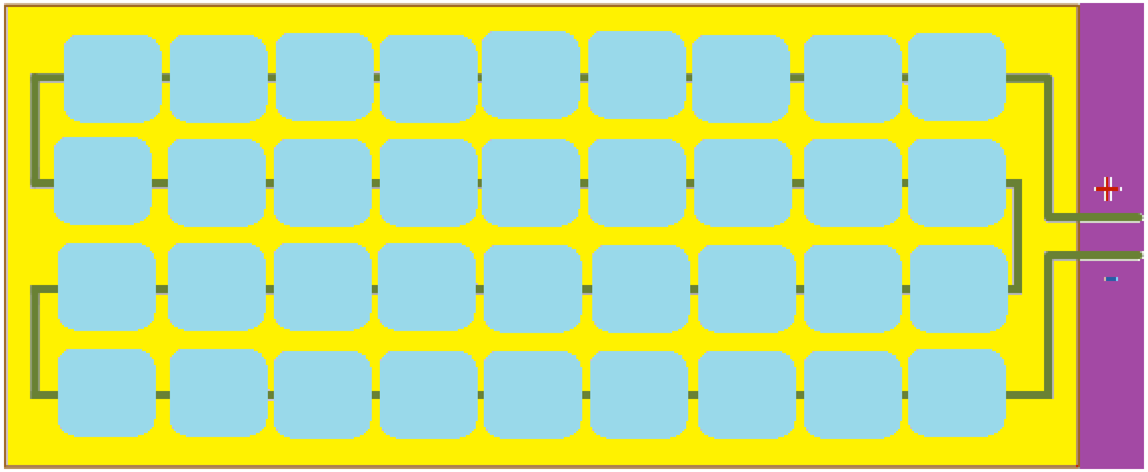


Fig.21. 36 Cells Photovoltaic PanelFig.2.28. 36 Cells Photovoltaic Panel

Some examples of PV panels systems for rural area

The photovoltaic systems are divided into two large groups:

- ***Off-grid PV systems or stand-alone PV systems***;

These systems feed consumers which are not connected to the main electrical grid. These systems are used in areas without electricity (small rural areas) and can generate the power and run the appliances by themselves. In principle, the energy produced by the PV panels is stored in the batteries, and from there it is provided with the help of an inverter DC-AC, to household users at 220 V

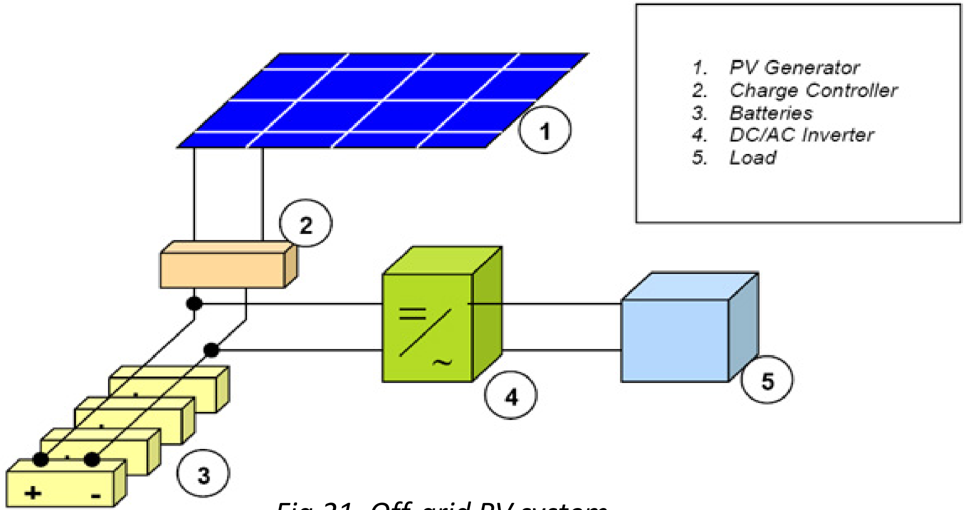
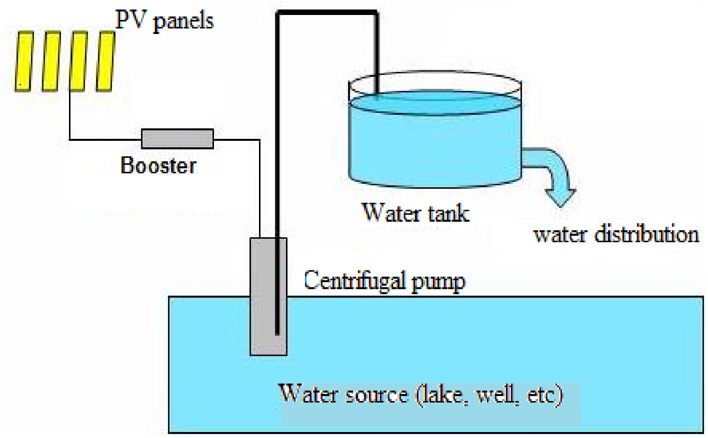


Fig.21. Off-grid PV system



- ***On-grid PV systems***

The on-grid PV systems or grid-connected PV systems are used in areas with electricity. In principle, the energy produced by solar panels is delivered in the national grid and at the same time used for home applications.

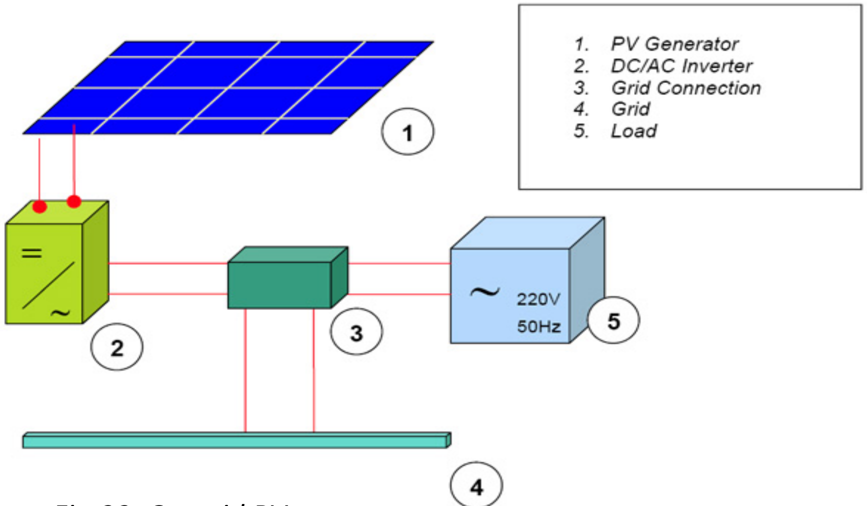


Fig.22. On-grid PV system

- ***Hybrid systems*** - independent of the electrical distribution network. Consist of a photoelectric generator, associated with a wind turbine or generator set with an internal combustion engine, or both. Biogas is also used.

Fig. 23. Hybrid system from campus of Vasile Alecsandri University

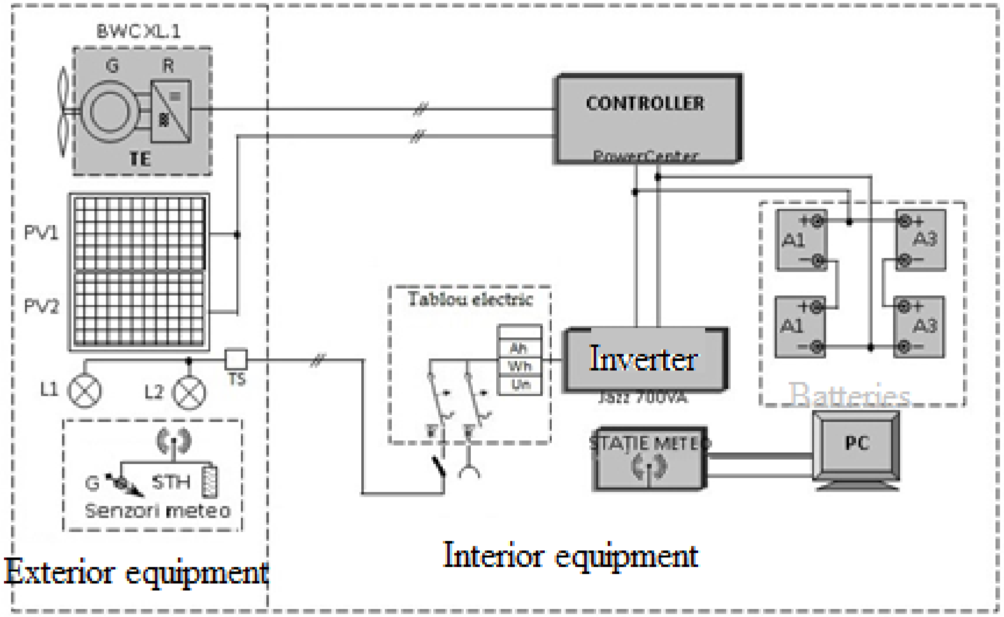


Fig. 24. The diagram of hybrid system the, Vasile Alecsandri University

Wind energy

Wind energy is the most rapidly expanding source of energy in the world.
The main advantages of wind power are:

- Lack of pollutant emissions and greenhouse gases,
- Does not require any combustion process to obtain this form of energy;
- Does not involve the generation of waste;

The cost per unit of energy (€/MWh) produced with this technology has declined substantially in recent years, making it competitive with traditional generators in most of the electricity markets worldwide.

Technical aspects of wind energy:

- the wind intensity and the wind speed variation in time
- the variation in wind speed with altitude
- the wind direction

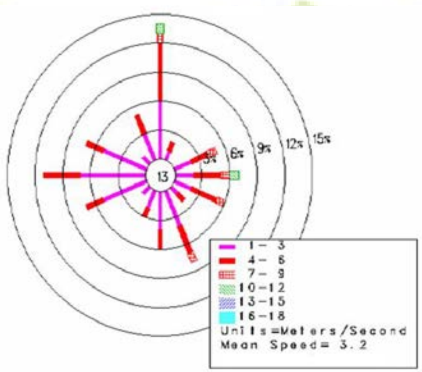
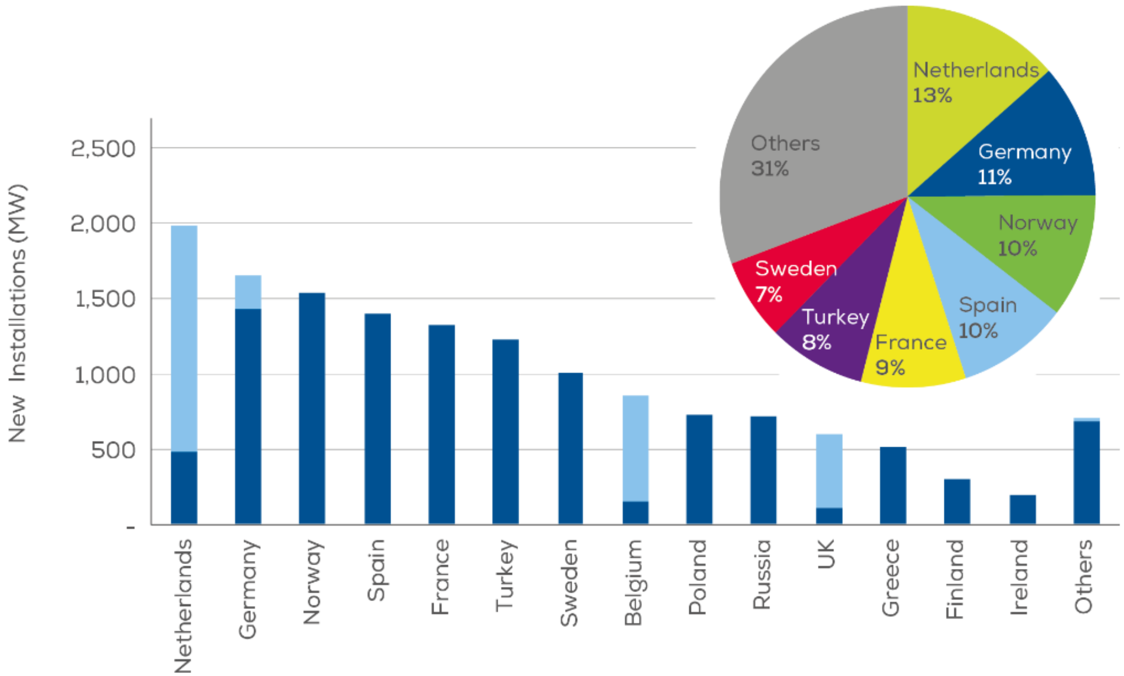


Fig. 25. Example of the wind rose diagram

Wind energy



	Netherlands	Germany	Norway	Spain	France	Turkey	Sweden	Belgium	Poland	Russia	UK	Greece	Finland	Ireland	Others
Offshore	1,493	219	-	-	-	-	-	706	-	-	483	-	-	-	17
Onshore	486	1,431	1,532	1,400	1,318	1,224	1,007	152	731	713	115	517	302	196	688
Total	**1,979**	**1,650**	**1,532**	**1,400**	**1,318**	**1,224**	**1,007**	**858**	**731**	**713**	**598**	**517**	**302**	**196**	**705**

Fig. 26. New wind installations in Europe, 2019

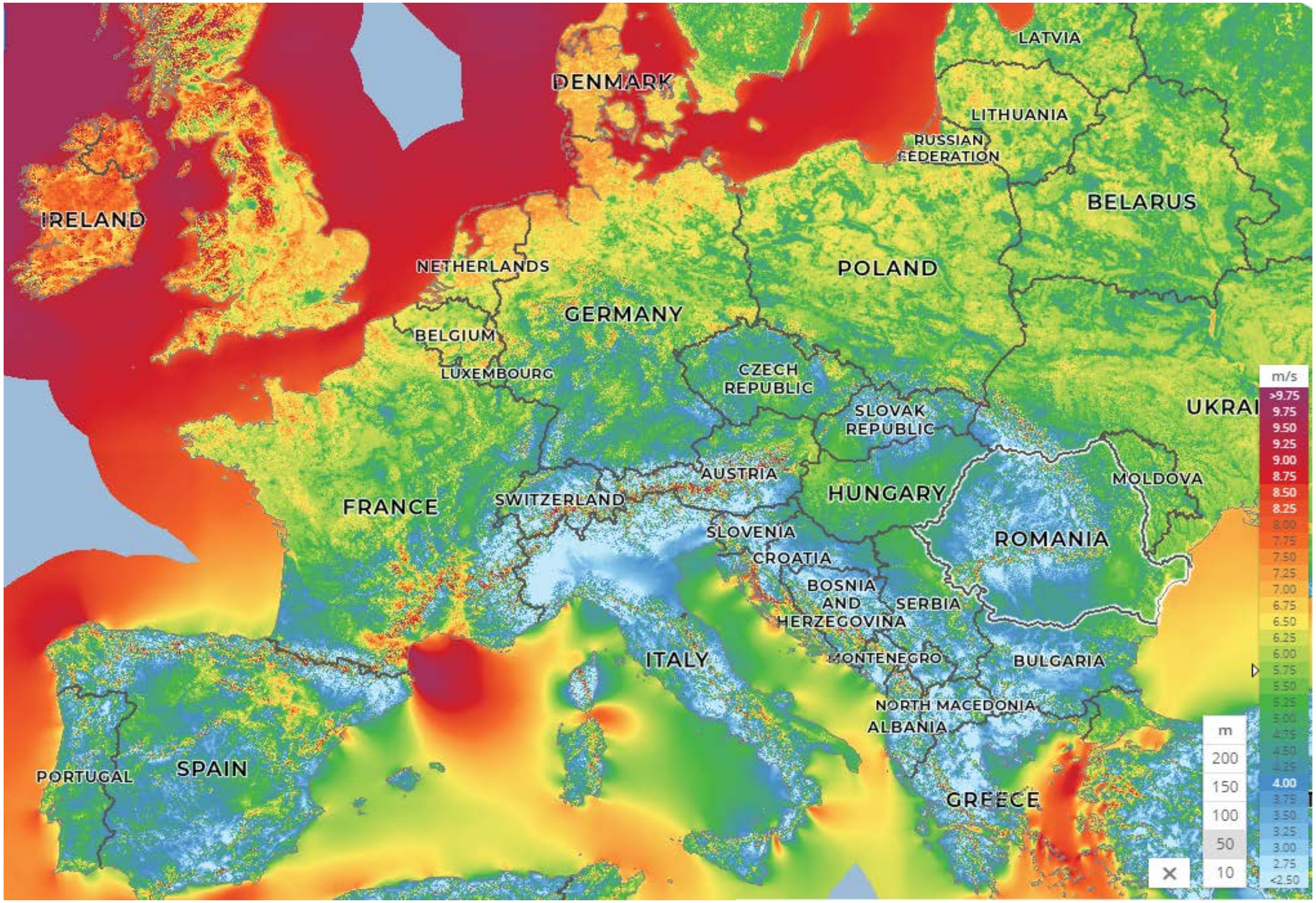


Fig.27. The wind map for Europe at a height of 50 m

Wind energy

In rural environment are two possible types of wind installations, mainly:

- the development of wind farms, which can be connected to the network and which can provide electricity for a community made up of several families
- a small wind turbine that would provide energy needs for a home. This can be combined with other energy producing systems.

The types of small wind turbines

- ***Small vertical axis turbines (VAWT – ”vertical-axis wind turbine”)***
    - ✓ Marilyn Wind Turbine
    - ✓ Darrieus wind turbine
    - ✓ Lentz turbine
    - ✓ Savonius wind turbine

Fig. 28. Small vertical axix turbines
From the left: Marylin turbine, Darrieus-Savonius, Lentz turbine, Savonius turbine

- ***Small horizontal axis turbines (HAWT – ”horizontal-axis wind turbine”)***

Category

❖ Number of bladed:
- quick turbines, which can have 2-3 blades;
- slow turbines, which have multiple blades, their number can be from 3-18.

❖ The placement of the blade:
- placed blade against the wind - "upwind" (first encounters wind blades and nacelle then),
- located downwind paddle - "downwind" (wind meets first nacelle and blades then).

❖ Depending on the equipment used in the conversion process
- with speed multiplier (gearbox), equipment that connects the hub of the wind turbine and electric generator;
- without speed multiplier, the hub of the turbine shaft is coupled directly to the generator

Fig. 29. Wind turbines with many

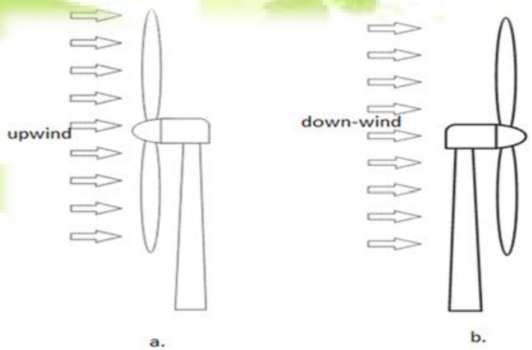


Fig. 30. The location of the turbine blades relative to the direction of the wind: a. upwind turbine, b. downwind turbine

Wind energy conversion system with horizontal axis turbine

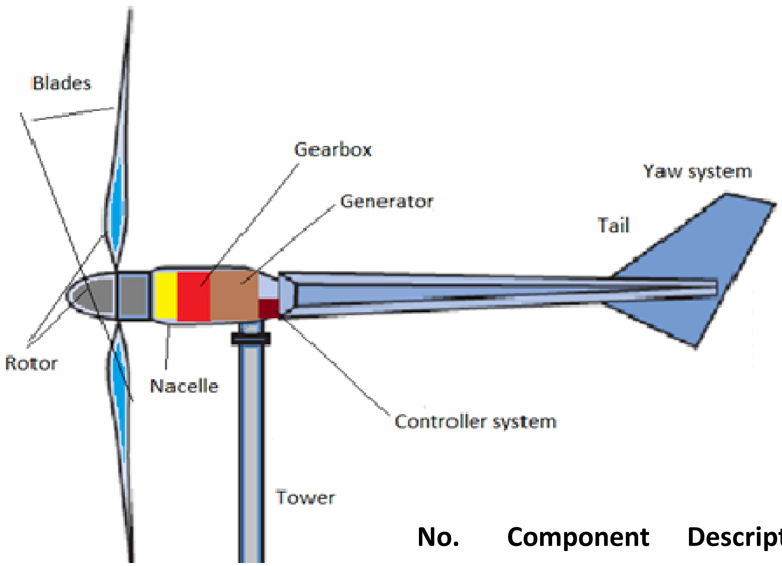


Fig. 31. Components of small horizontal axis wind turbine

No.	Component	Description
1	***Rotor***	The rotor is formed from the main-shaft and its blades. The blades made from composite materials mixed with fiberglass have an aerodynamic shape.
2	***Generator***	The generator transforms mechanical energy of rotational into electricity.
3	***Gearbox***	The gearbox serves in adjusting the rotation speed of the rotor. It is used in small wind turbines with outputs greater than 10 kW.
4	***Nacelle***	In the nacelle are mounted the generator and the gearbox.
5	***Yaw system***	The yaw system assures the orientation of the nacelle to the wind direction.
6	***Controller***	The electronic control system monitors the overall operation of the turbine
7	***Tower***	The tower supports the guidance system, the nacelle and the rotor of the wind turbine.

The batteries for wind or hybrids system are of a special construction regarding the free maintenance and the fact that it supports a large number of charge-discharge cycles.

The most common types of storage batteries in photovoltaic systems, wind systems and hybrid systems are lead-acid batteries. Recently, there have been developed Li-Ion batteries and nickel - cadmium (Ni-Cd) batteries for high capacity. Lead-acid batteries continue to be the main option for energy storage, having the advantage of price and availability.

Types:

- ***VRLA*** - Valve-Regulated Lead-Acid Batteries - encapsulated batteries
- ***GB-*** Gel Batteries - sealed at the factory, use sulphuric acid turned into a gel form (they do not leak or spill), easily transported and require no maintenance.
- ***AGM*** (Absorbed Glass Mat) lead-acid batteries, sulphuric liquid acid electrolyte is absorbed into mats fibers glass so they would not leak, even if cracked.
- ***OPzS*** (liquid electrolyte) or ***OPzV*** (gel)- are tubular plate batteries, also called gel batteries, made especially for off-grid applications and have excellent deep discharge characteristics. The positive plates in tubular cells are made of rods protected in a ‘tubular’ sleeve – not a flat plate – which gives them an exceptionally long life cycle.

The power inverters transform stored energy from the batteries or from generated energy DC current from the wind turbine at 12, 24 or 48V into alternating current at the necessary voltage and frequency.
There are two types of inverters:

- ***grid-tie*** inverters and
- ***stand-alone*** inverters.

Small wind electric systems used in rural areas

- *Household installations* - a domestic system of production and use of direct and alternating current using a small wind turbine

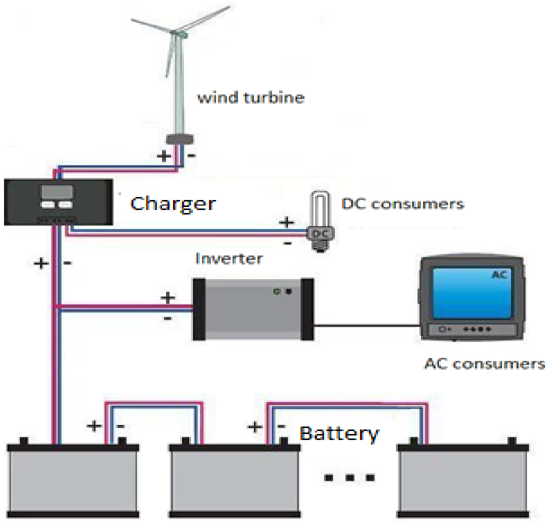


Fig. 32. Simple system of using wind energy for a residential house.

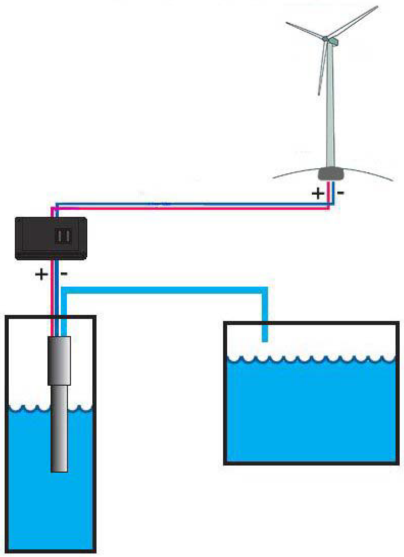


Fig.33 Water-pumping windmills

- *Water-pumping installations* - used in areas where water is in limited quantities, but there is ground water in depth and wind blows regularly.

Biomass

The **biomass** is the biodegradable part of products, waste and residues from agriculture, including plant and animal substances, forestry and related industries, as well as the biodegradable part of industrial and urban waste. From an energetic standpoint, biomass is the most abundant renewable resource on the planet. It includes absolutely all the organic matter produced by the metabolic processes of living organisms. Biomass is the first form of energy used by man, with the discovery of fire.

General data:

•total mass (including humidity)   - over 2,000 billion tons ;
•total mass of terrestrial plants – 1,800 billion tons;
•total mass of the forest – 1,600 billion tons;
•the amount of energy accumulated in the terrestrial biomass - 25,000 * 10^{18} J;
•annual biomass increase - 400,000 million tons;
•speed of energy accumulation by terrestrial biomass;3000 * 10^{18} J per year (95TWt);
• total annual consumption of all types of energy - 400 * 10^{18} J per year (22TWt);
• biomass energy use - 55 * 10^{18} J per year (1.7TWt).

There are five basic categories of material:

•Vergin forestry, arboricultural activities, wood processing,
•energy crops: high yield crops grown specifically for energy applications,
•agricultural residues: residues from agriculture harvesting or processing,
• food waste, from food and drink manufacture, preparation and processing, and post-consumer waste,
•industrial waste and co-products from manufacturing and industrial processes.

The biomass categories:

•***Primary biomass*** - produced by agriculture and forestry. It includes energy crops and agricultural crops such as short rotation trees, grasses and aquatic plants.

•***Secondary biomass***: biomass such as straw, stover and crop residues that is generated as a result of harvesting and processing of primary biomass such as lumber, pulpwood, and grains. It also includes processing residues and by-product streams from food, feed, fibre and materials production.

•***Tertiary biomass***: post-consumer residue streams from urban activities such as fats, greases, oils, construction and demolition debris/wood, as well as animal manure and other by-products from concentrated animal feed operations.

Forms of biomass energy recovery (biofuels)

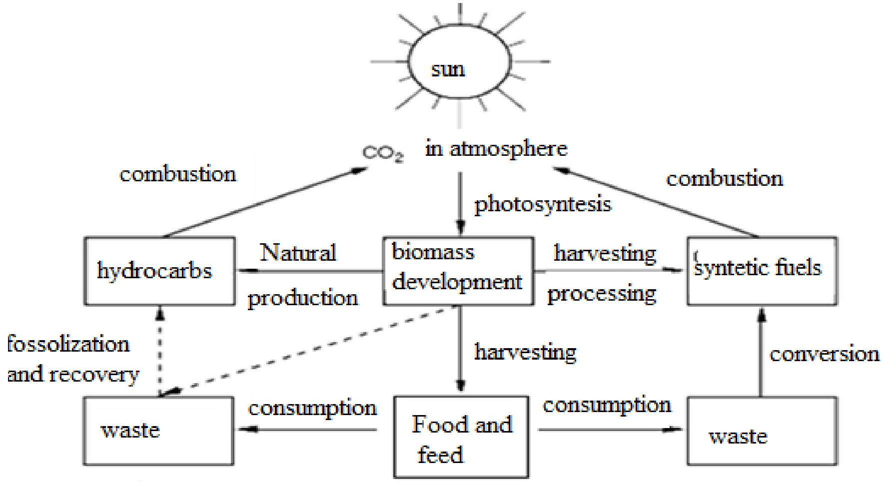


Fig. 34. Biomass transformation

Biomass transformation

Forms of biomass energy recovery :

- ***direct combustion*** with thermal energy generation.
- ***pyrolysis combustion***, with singaz generation (CO + H2).
- fermentation, with generation of biogas (CH4) or bioethanol (CH3-CH2-OH) - in case of fermentation of sugar products; biogas can be burned directly, and bioethanol, mixed with gasoline, can be used in internal combustion engines.
- ***chemical transformation*** of vegetable oil biomass by treatment with an alcohol and generation of esters, for example methyl esters (biodiesel) and glycerol. In the next step, the purified biodiesel can burn in diesel engines.
- ***enzymatic degradation*** of biomass with ethanol or biodiesel. Cellulose can be enzymatically degraded to its carbohydrate-derived monomers, which can then be fermented to ethanol.

Fig. 35. Biomass examples

Wood waste - renewable energy source in rural area

All materials with ligno-cellulosic structure (wood, straw, wood sawdust, paper, wood fibers) are important energy resources.

Disadvantage:

- very low density - difficulties in handling, transport, storage - increased costs,
- large variations in the humidity of the material - difficulties in the operation and regulation of the processes in the power plants in which they are used.

Solution:

- drying and compression of the material (densification) at very high pressures - woody biofuels with a uniform structure, (pellets and briquettes). Ș

Advantages of wood biomass densification:

- increasing the density of the compressed material (from 80-150 kg / m3 for straw or 200 kg / m3 for wood sawdust up to 600-700 kg / m3 for the final product);
- higher calorific value and a homogeneous structure of compressed products;
- low moisture content (less than 10%).

Calorific values for wood waste

Combustible	Net calorific value [GJ/tonă]	Net calorific value [kWh/kg]	Density Kg/m^3	Energy/volum MJ/m^3	Energy/volum kWh/m^3
Wood sources (30% maximum umidity)	12.4	3.5	250	3100	870
Wood choping (20% maximum umidity)	14.7	4.1	350-500	5200-7400	1400-2000
wood (solid –very dry)	19	5.3	400-600	7600-11400	2100-3200
Wood pellets	17	4.8	650	11000	3100
Energy willow (25% maximum umidity)	13	3.6	140-180	1800-2300	500-650

Pellets

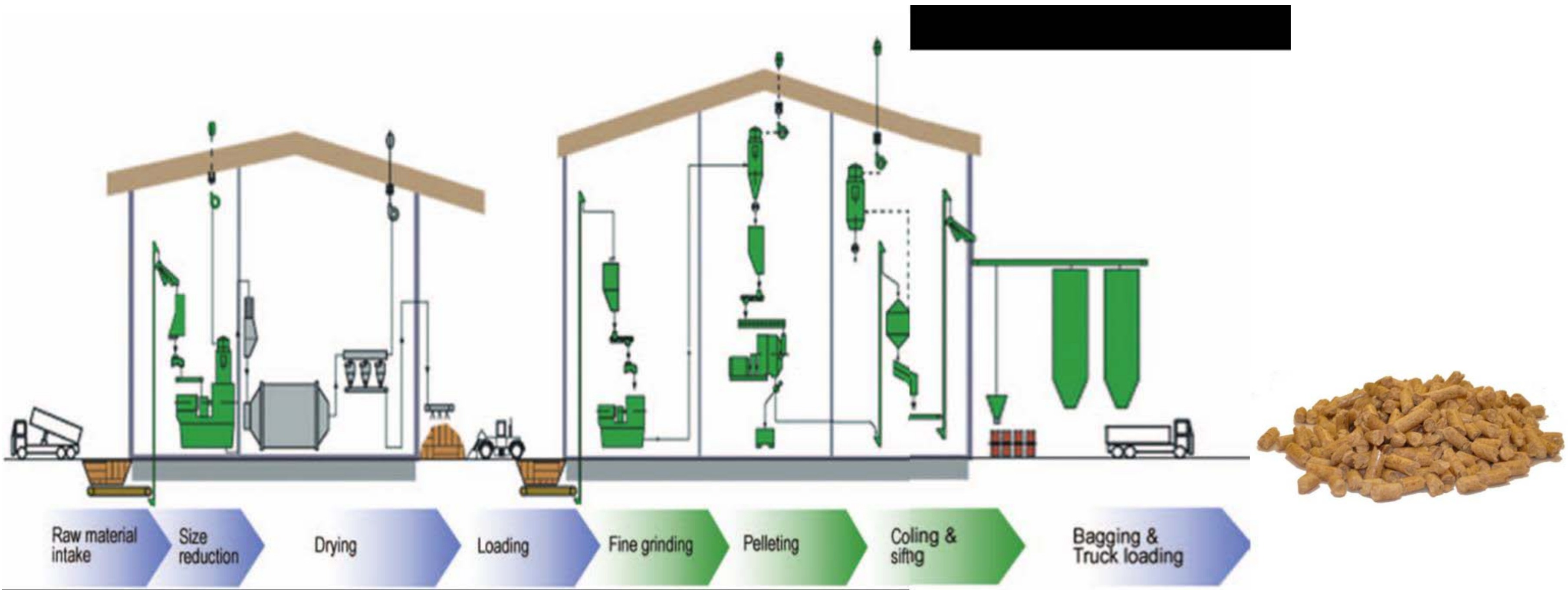


Fig.36. The pelletizing process

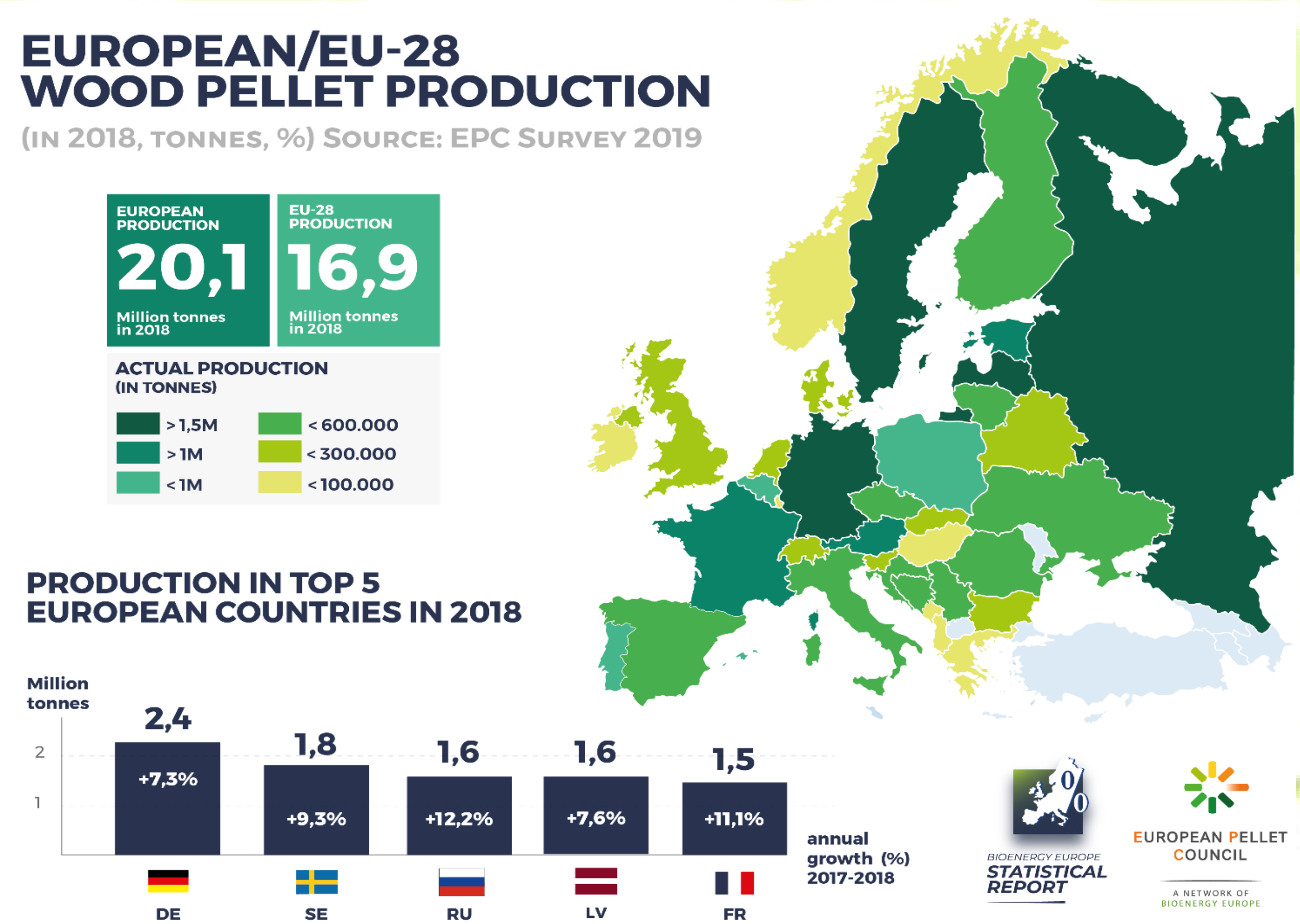


Fig.37. The wood pellet productiion in uropa/Eu-28 in 2018,

Source: https://epc.bioenergyeurope.org/about-pellets/pellets-statistics/european-production

In rural areas, biomass for heating is traditionally used in stoves where wood logs or briquettes are burned to make heat at a decentralized level and with a low efficiency of up to 45%. In addition to stoves, small boilers can use similar types of fuel for small central heating units in the household. These systems can use small fuels, such as pellets or wood chips, which allow automatic feeding. In recent years, with the development of modern power plants using wood pellets, the efficiency of these systems has increased to almost 90%. Medium-sized central heating systems in small grids use fuels that allow automatic feeding, such as pellets or wood chips, and typically use hot water boilers to produce heat with up to 90% efficiency. Larger central heating systems and industrial plants powered by solid biomass typically use cogeneration technologies for heating.

Biomass can be converted to **biogas** through a process called anaerobic digestion (AD). This is a staged biological process in which various types of microorganisms decompose digestible biomass in the absence of oxygen. Biomass is converted to biogas, which contains mainly methane (CH_4) and carbon dioxide (CO_2) and much smaller amounts of hydrogen (H_2) and hydrogen sulfide (H_2S). At the end of the process, the remaining digestate is often rich in nutrients such as ammonium and phosphate and can be used as fertilizer. Methane-producing microorganisms are found in various places in nature, such as the stomachs of ruminants (cattle). To initiate the process of anaerobic digestion in a biogas plant, an inoculum (cow dung) can be introduced into the raw material.

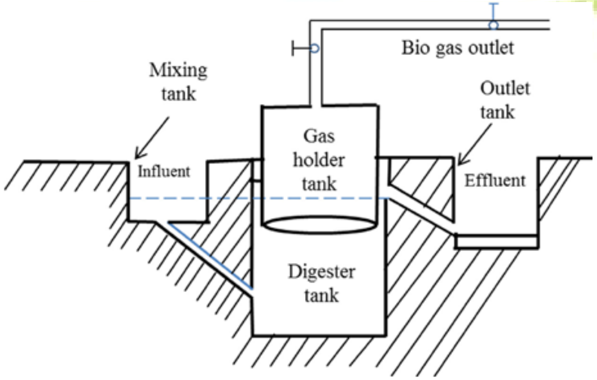
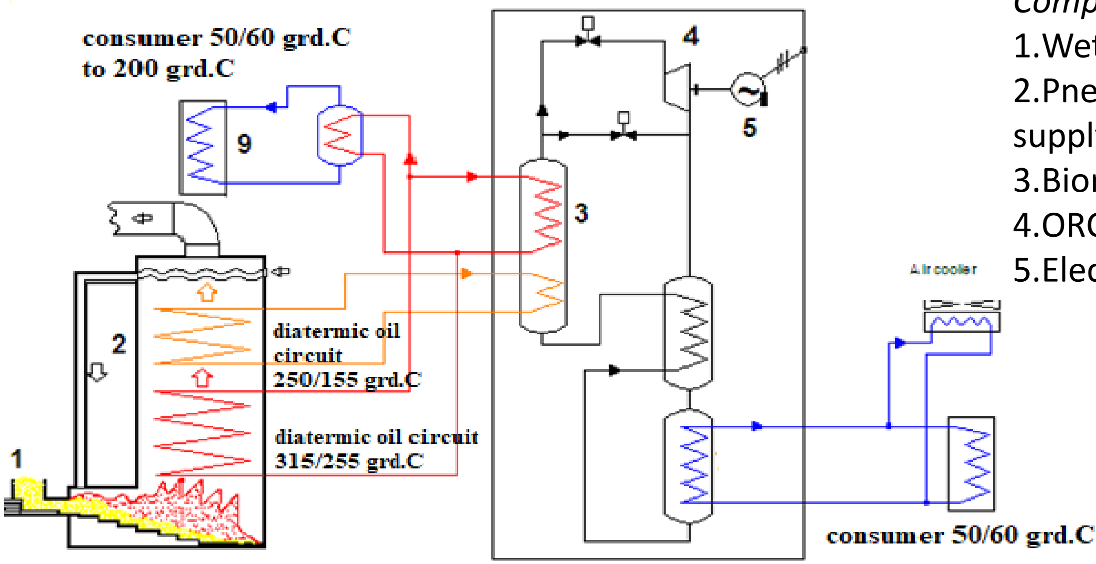


Fig.38. Scheme of a biogas plant

Biomass burning and energy production. Micro- cogeneration plant

CHP or cogeneration is a process of energy transformation in which useful electricity and heat are produced simultaneously, in a single process



Components parts:
1.Wet fuel silo
2.Pneumatic transport installation for boiler supply
3.Biomass boiler
4.ORC module (Organic Ranking Circuit)
5.Electrical generator

Fig.39. Thermal scheme for the cogeneration plant

Cogeneration advantages:

- energy efficiencies above 80%,
- primary fuel economy,
- less pollution and the possibility of controlling and reducing pollutants,
- low cost for energy produced in cogeneration plants.

The Earth has a and a metallic hot and liquid inner core consisting of molten sheath core generating the magnetic field. The temperature of the earth increases with depth, in the inner core reaching more than 4500°C [39]. But the core does not only generate the earth's magnetic field, it also generates heat, which can be used as a renewable energy source.

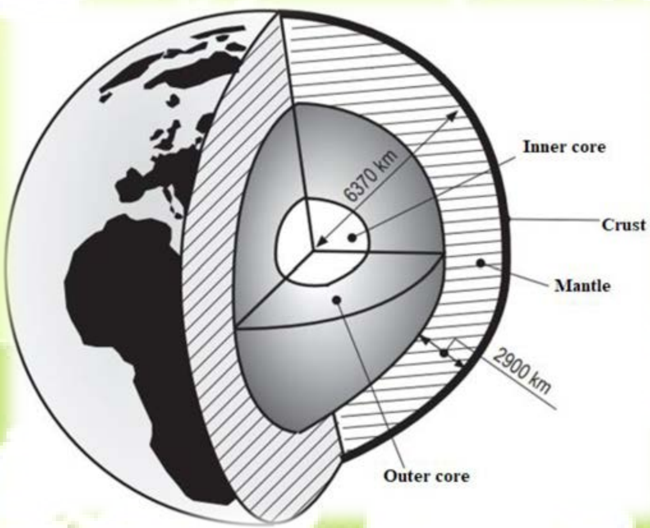


Fig. 40. The interior of the Earth

The high temperature at the boundary of the outer core (liquid), with the mantle, can reach over 4500 °C and due to the high pressure it causes the rocks to melt but also to heat them to the level of the earth's crust, where the water contained in it can reach temperatures higher than 350 °C. Consequently, it can be said that geothermal energy is the thermal energy generated and stored in the earth.

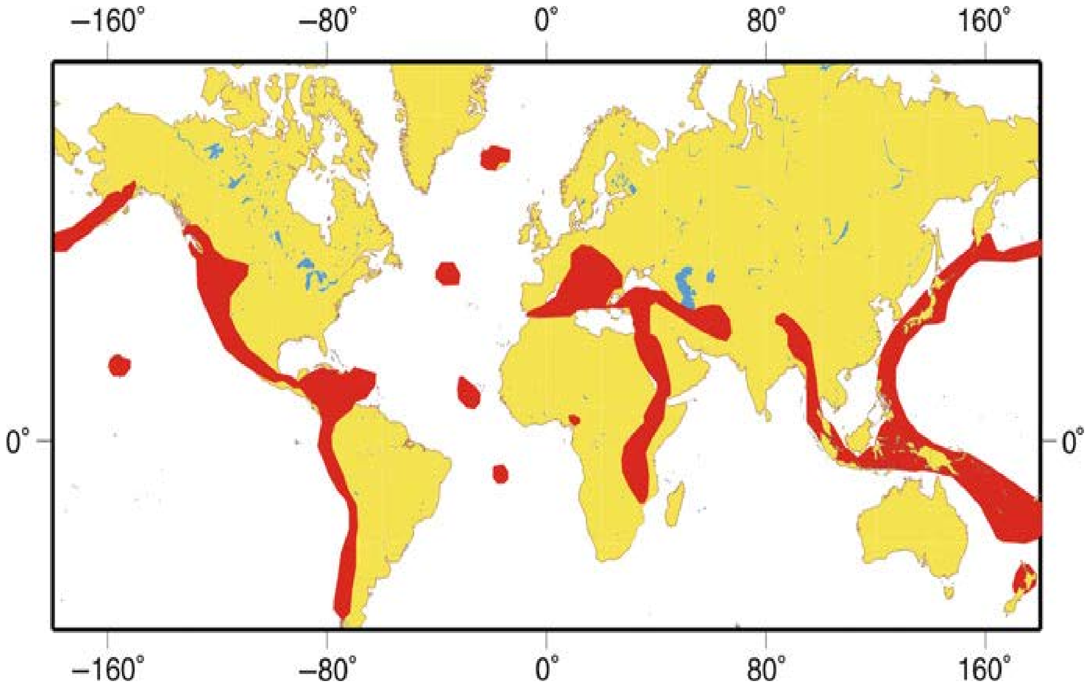


Fig.41. Geothermal regions (in red)

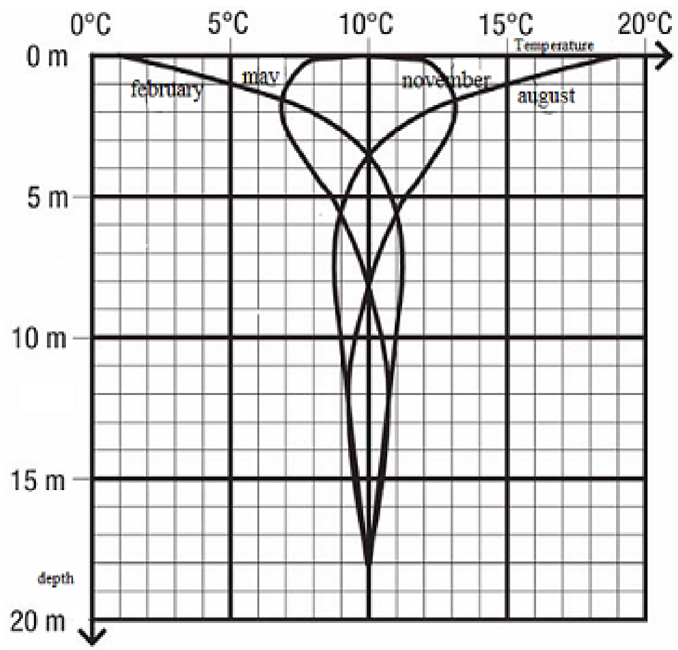


Fig.42. Variation of the temperature in the upper earth crust

Example of geothermal power plant

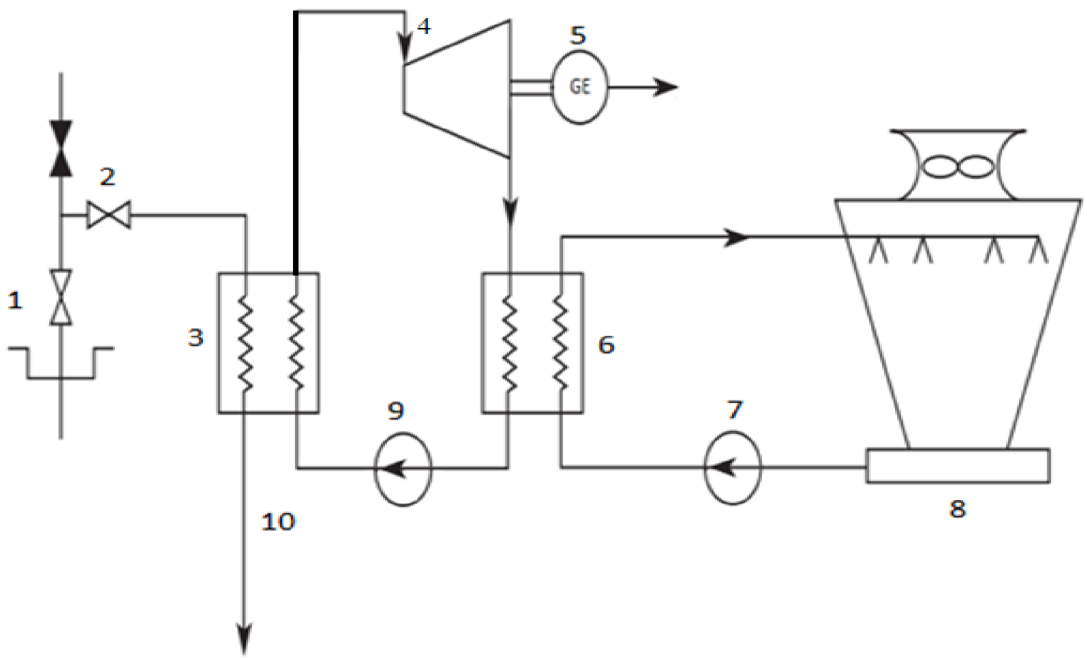


Fig. 43. Binary cycle power plant: 1 –well production, 2 –pressure regulation valve, 3 –heat exchanger, 4 –turbine, 5 –electric generator,6 –condenser, 7 –cooling water pump, 8–cooling tower, 9 –condenser pump, 10 –Injection well.

Ground source heat pumps (GSHP)

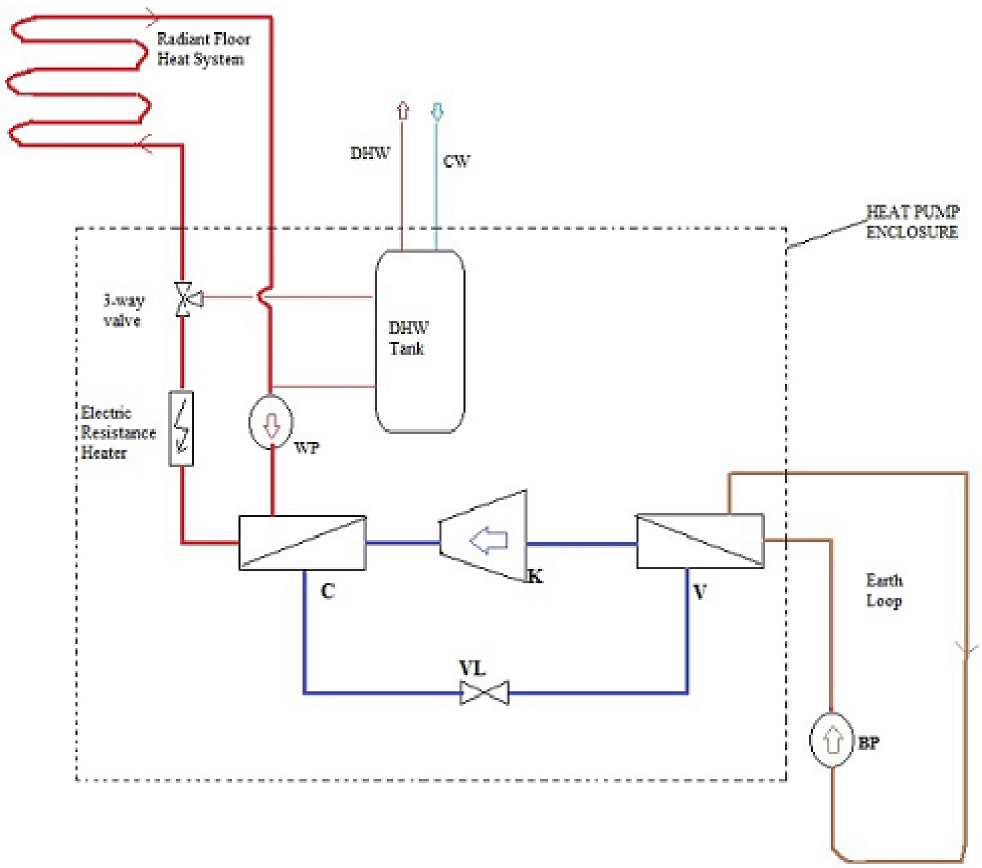


Fig.44. Ground source heat pumpoperating diagram. Component parts: V- evaporator; K- compressor; C- condenser, VL- expansion valve; DHW Tank- boiler for domestic hot water, WP- water circulation pump; BP- brine circulation pump

1. Evaporator (vaporizer) V - the refrigerant fluid absorbs heat from brine from ground loop and evaporates. The evaporator is a heat exchanger.
2. Compressor K- it compresses refrigerant vapors and thus raises their temperature to high values.
3. In condenser C, compressed refrigerant gas is condensed to a liquid and the heat is absorbed by the circulating water in heating system. passes through it and turns into a liquid, which is then introduced into the heating system.

4.Depressurizer (expansion valve) - the above liquid passes through this system which greatly reduces its pressure and thus its temperature. The cycle starts again.

The ground source heat pumps GSHP system has three important components:

- a heat pump;
- a soil connection;
- heating distribution system.

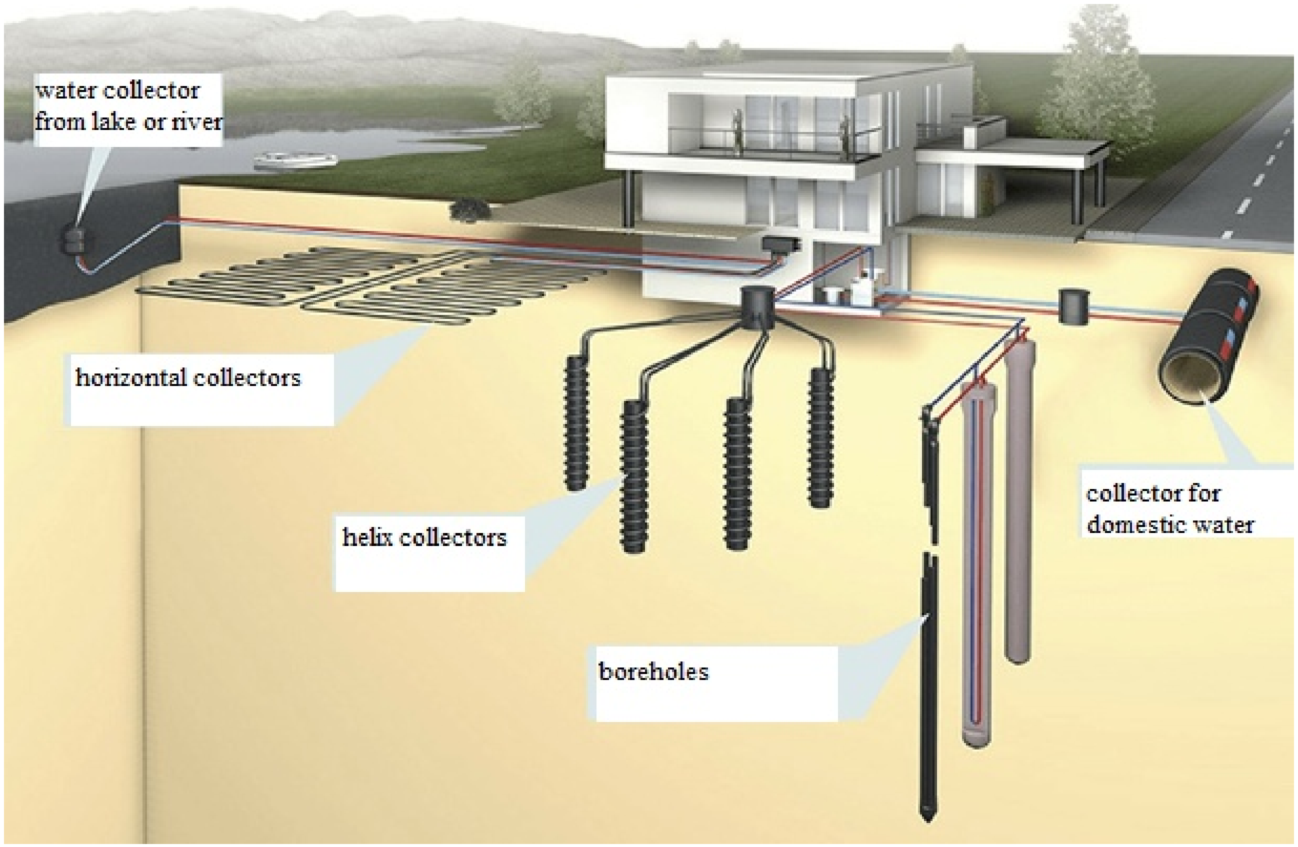


Fig.45. Types of geothermal heat pumps

Hydropower

Solar energy evaporates seawater producing clouds. When the drops end up having a mass large enough, gravity pulls water back to the Earth's surface in the form of rain. If this rain falls on high ground and reaches the streams and rivers that flow rapidly there is the ability to extract some of their energy by arranging part of their course so that the water passes through a hydraulic turbine that drives an electric generator, using water to produce electricity.

Characteristics of micro hydropower plants:

- They are suitable for low power requirements, decentralized (light industry, private farms and enterprises, rural communities) and for operations outside the main network;
- Requires low voltage distribution networks and possibly sub-regional micro-networks;
- They can be used in private property, in co-ownership or common property, with a semi-skilled labor need and common administration;
- The short period of construction with local materials and the use of the skills of the population in the area, can have a significant impact on the quality of rural life;
- Their flexibility, in terms of adapting to variable loads depending on the tributary flow, makes them a privileged component in any integrated energy system;
- The plants have a very long period of use. Some are over 70 years old and still in working order. Plants ready to be put into operation recently can last even longer and can serve consumers for generations without polluting the atmosphere;
- Investments in micro hydropower plants have proven to be safe and profitable for several decades.

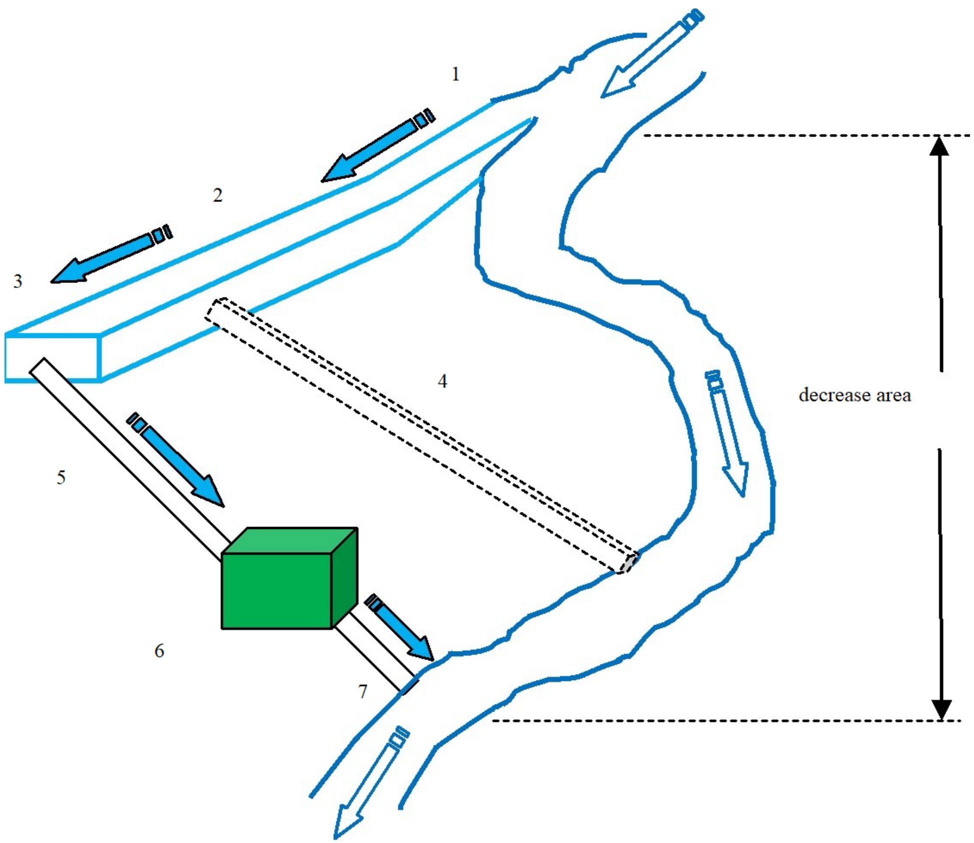


Fig.46. The components of the micro hydropower plant

1. the storage system
2. supply channel
3. a stabilization tank
4. overflow channels
5. forced pipe
6. hydro turbine and power plant
7. downstream channel

Geothermal energy