RENEWABLE ENERGY AND SUSTAINABLE DEVELOPMENT OF SOCIETY

I. Bostan, academician, V. Dulgheru, Dr.Sc., prof., V. Bostan, Dr.Sc., prof., I. Sobor, PhD, prof.
Technical University of Moldova

INTRODUCTION

Can you imagine life without television, cars or computers, without being able to prepare your food every day, without lighting in the house, without heating during the cold seasons of the year, etc.? But all this is the result of creative activity of scientists and inventors, especially during the last two hundred years. All this may disappear during the first half of the present century, following the drastic depletion of natural reserves of fossil fuels. Increased energy consumption leads to a continuous increase in the volume of extracting fossil fuels, which provides more than 85% of energy use today. Currently, the annual energy consumption is equivalent to more than 11 billion tons of conventional fuel (t.e.p.) or 459 EJ ($459 \cdot 10^{18}$J), of which only 15,4% is of non-fossil origin. As the world population increases and the level of energy endowment of the economy grows, simultaneously, this figure is steadily increasing, which fact will have serious consequences. Most acceptable fuels, economically, - oil and natural gas - are supposed to be about exhausted in 30-50 years.

Today, most of the energy needed for daily consumption is produced by burning fossil fuels - coal, oil and natural gas. Several million years, plants and animals decomposing led to the formation of fossil fuels, which, however, were consumed during about 200 years, practically. Millions of years, Earth's atmosphere formed a whole plant system, and during a 200 years period, but, particularly in the last 100 years, the environment was seriously jeopardized and the world is facing an ecological disaster.

In 1960, 3000 TWh of electricity were produced and consumed. In 1970 it increased up to 6,000 TWh. 150 000 TWh were consumed in 2000. Even, if it is possible to reduce electricity consumption in industrialized countries (U.S., Germany, Japan etc.) by 1/2, and at the same time to increase consumption per capita, by only 25% of global electricity, in India, China etc. - third world countries, the overall demand would double from the today's one. What energy sources are able to meet these requirements? Increasing power generation by burning traditional fossil fuels would further endanger the ecological impact. Expectancy of power engineering professionals is based on finding new solutions and processes that would meet the energy needs of mankind in the coming decades or centuries. At the forefront, nuclear energy solutions have been related to, but after the power failures (the U.S. Three Miles Island and Chernobyl in Ukraine), the need to develop alternative solutions, environmentally friendly, has become an imperative.

The concept of energy efficiency (or energy optimization) became, at present, one of the main concerns of mankind on the whole world. With the first oil crisis of the early '70s, human society began to realize more than ever the need for a sustainable strategy by increasing the efficiency of energy use and implementing energy efficiency programs taking into account the depletion of fossil fuel reserves on Earth. Today, we speak of a global energy policy and a concerted strategy to reduce harmful emissions into the atmosphere, based on concrete economic and technical solutions for rational use of fossil fuel reserves (which still have the main share of energy production) and valorization of renewable energy resources on a large scale, the so-called "*clean*" energy or non-conventional energy, as an alternative to the current system of fuel reserves on Earth. Renewable energies (solar, wind, hydro, etc.) are environmentally friendly but today they are not able to meet these ever-growing needs.

These two serious issues - the energy crisis and environmental impact, are global problems of humanity, which settlement falls on the shoulders of engineers. Because the world is so dependent on energy, because most of Earth's population uses fossil fuels to meet energy needs, which causes a high degree of environmental pollution, it is strictly necessary to seek new sources of sustainable and environmentally friendly energy. Energy sources producing the least possible pollution will be found. Since all traditional energy sources pollute the environment, renewable energy is practically devoid of this negative effect of environmental pollution.

Diversification of energy sources becomes an economic and environmental imperative. These alternative energies are called renewable energy. What are these alternative sources of energy? The best known renewable energy sources are solar energy (direct, photovoltaic and thermal), wind (as a derivative of solar energy), hydraulic (using potential and kinetic energy of water), geothermal, bioenergy, etc.

Renewable energy can be used both as a centralized and largely decentralized energy source. Decentralized sources are particularly advantageous, especially for rural and isolated consumers. At the same time, according to UN information, about 2 billion people lack access to electricity, while about 40 countries have no national electricity networks. The cost of the network is bigger in proportion of 4:1 or more to the cost of power plants. From this point of view, promoting decentralized energy sources is advantageous, as key programs of rural electrification and poverty reduction in rural areas.

Disadvantages of decentralized energy systems: functioning instability and inability of electricity storage and redistribution, distribution networks having the role of electricity storage, too.

With a clear emphasis of the policy and actions, by contribution of a panel of international experts, the current status of renewable energy impact and future potential is set up, which includes social, political, economic, environmental and technological aspects.

Special attention is paid to energy potential, history of development and production of renewable energy conversion systems: solar, wind, hydro, sea waves. Today the European Parliament declared a clear signal how to promote renewable energies in the EU until 2020 in order to achieve 25% share of primary energy. At the same time, the European Council on Renewable Energy (ECRE) has been established for this purpose. "*Parliament's vote today is an historic opportunity for the Commission to test citizens' demands for renewable energy. Together with the Parliament, leaders in building and securing legislative proposals for all three sectors must be: for electricity, heating and biofuel. The Commission should focus its attention on eliminating gaps in EU legislation for renewable energy - heating and cooling*", said Oliver Schafer, policy director of ECRE. Leaders in research and professionals in various fields of renewable energies have met at EUREC Agency (European *Renewable Energy* Research Centres *Agency)* to completely redefine the position of renewable energy conversion technologies in the context of meeting global energy needs and recommend directions for development technology for each branch based on that analysis.

Aspiring to the future, Freeman Dyson of the University of Oxford, has justified that technological exchanges fundamentally alter our ethical and social arrangements and that three new technologies that are growing rapidly - renewable energy, genetic engineering and global communication, have the potential to create a more uniform distribution of global health today.

Developing countries that have low or inadequate resources of oil and coal, which also for the purpose of solving energy problems have cleared large areas of forests, are in a situation of using non-conventional energy resources, such as solar, hydraulic, wind, or combined with conventional fuels for higher efficiency.

Increased costs associated with fuel procurement, transportation and maintenance of engines, coupled with difficulties in quantifying the environmental costs make renewable energy an attractive alternative to combustion engines fuel-based generators.

The efforts of researchers are increasingly targeted to revitalization of existing technologies to reduce energy consumption and waste production, and also to use unconventional energy sources where possible. Desire to have more efficient production processes in terms of energy consumption has occurred, especially after the energy crisis of 1970, which led to rapid price growth.

During about 200 years, mankind has created a great energy complex and difficult to imagine, providing basic services: lighting, heating, refrigeration, transport, technological processes, etc. Modern standards of welfare, education and health can not be maintained without energy. However, it was recognized that the emergence of modern energy is guilty of many environmental problems. It is necessary to find a compromise between the growing demand for energy services and the critical need to protect the environment. In the opinion of the authors of this paper, the solution is to return humanity to renewable energy sources. In this way, it will naturally repair the chain, broken 200 years ago. The nineteenth century was the century of steam, the twentieth century – of the electricity, and the twenty-first century will be the century of renewable energy or will not be at all.

In contrast to exhaustible fossil and nuclear fuels, which are basically stored energy sources, deposited along many million years, renewable energy sources (RES) are defined as *„energy obtained from existing fluxes in the environment and which have a permanent and reproducing character"*. Unlike renewable energy, fossil fuels energy is embedded (closed) and it can be released as a result of human activity. By releasing the energy stored in fossil or nuclear fuels the environment is polluted by wastes, the greenhouse effect increases, and thermal pollution of the environment occurs too. These two properties are shown in Fig. 1. Renewable energy flux has a closed character and fossil energy has an open character. In the case of RES use the

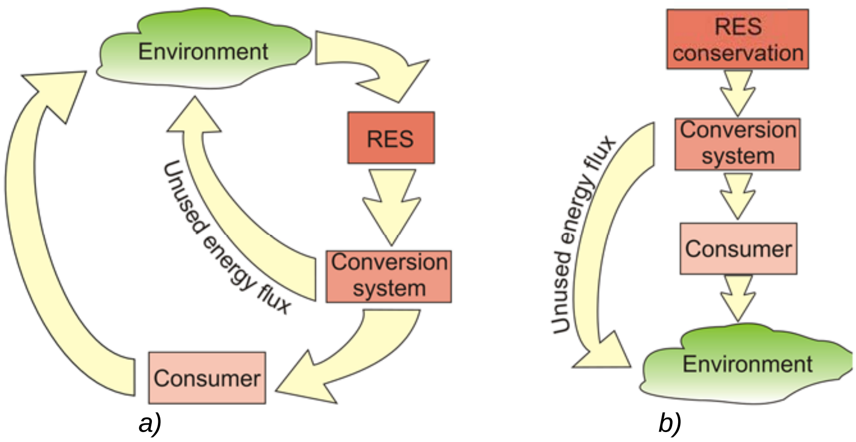

Figure 1. Energy fluxes circulation: *a)* renewable; *b)* fossil sources.

energy flux generated by the environment is transformed with the help of conversion unit into another form of energy necessary for the consumer. Then it reverses (according to energy conservation law the quantity of energy remains unchanged) in the same environment and its thermal balance remains unvaried.

When using a fossil source of energy, the energy stored in the fuel is released to the power unit, used by the consumer and then emitted into the environment, producing thermal pollution. At the same time, carbon dioxide is eliminated as product of carbon burning, stored into fossil fuels during millions of years.

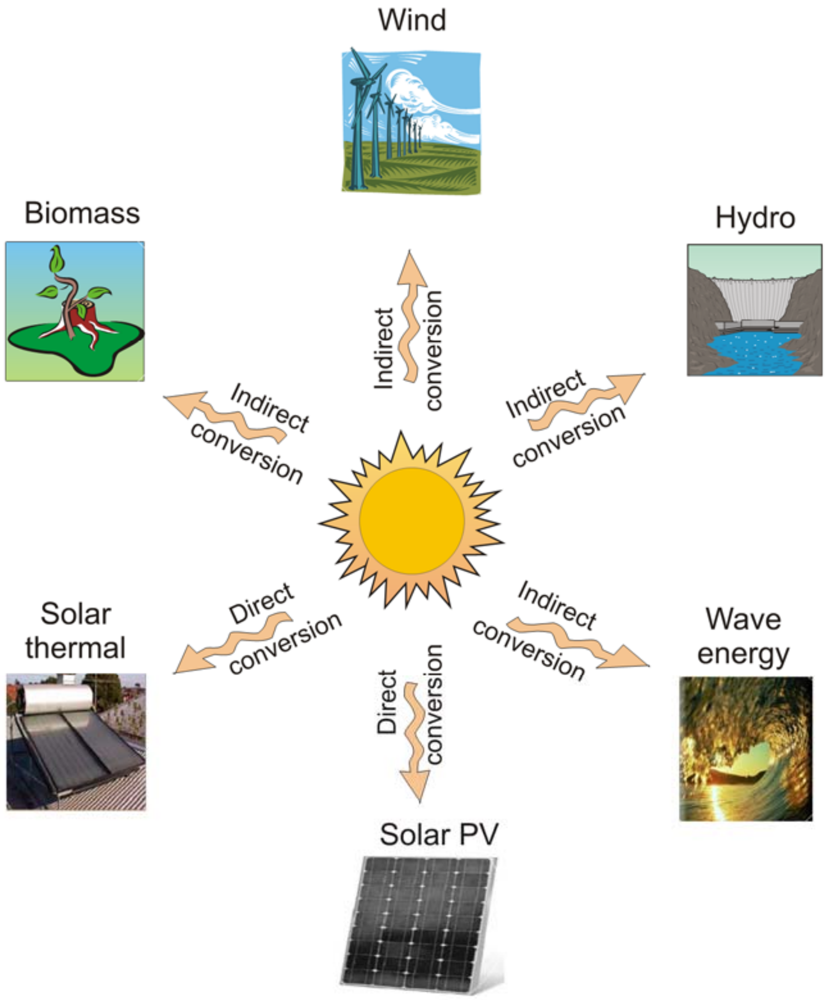

Figure 2. Main forms of solar energy.

Solar energy – the main renewable energy source. Depending on the origin, RES are divided into two groups: the first one includes solar energy and itsderivatives – wind, hydraulic, biomass energy, tide energy, thermal energy of the planet's ocean. Fig. 2 lists the main forms of solar energy: thermal and photovoltaic (PV), energy obtained as the result of solar radiation direct conversion into heat, and electricity, respectively, and the other forms of energy obtained indirectly from solar energy.

The Sun, as an energy source, the characteristics of solar radiation in the outer space and on the Earth's surface, methods for estimating the available solar radiation are described below. The second group of RES is not of solar origin and includes only two forms of energy: geothermal and tide energy. Solar radiation, absorbed directly by solar collectors, can produce heat water, can heat buildings, and can dry medicinal herbs, fruits and vegetables. Buildings can be designed and built in such a way so as more solar energy is captured for heating and lighting. This concept lies at the basis of the so-called technology for solar energy passive use. Concentrated by special reflectors, solar radiation can generate thermal energy with temperatures higher than 300^{0}C, that, in its turn, can be used to produce electricity. Such solar thermal plants are in commercial use in the USA.

Conversion technology in which solar radiation is transformed directly into thermal energy is often called thermal-solar energy.

Solar radiation can be transformed directly into electrical energy with the help of photovoltaic modules. The last 10 years, PV solar technology developed dynamically, with an annual growth rate varying between 25 – 40 %. Costs of PV modules are decreasing. New technologies for production of PV cells and modules integrated into buildings' roofs will change in the next years the modern concept of living houses electricity supply.

The difference of air mass temperature leads to a difference of pressure, and, as consequence, significant air currents develop, directed to the Polar Regions or, otherwise said, the wind blows and it can be transformed into mechanical energy by means of wind turbines. The last 20 years wind technology developed at a large scale and is considered the most advanced, compared to all so-called conversion technologies of "*new*" renewable energies.

Hydraulic energy exists under two forms: potential energy (water falling, usually with dams building) and kinetical energy (water flowing without building dams). During the last years, water kinetic energy conversion systems advanced in their development, in particular, concerning the optimization of conversion efficiency parameters of the working element (the rotor).

Friction forces between air currents and the water surface of the seas and oceans generate waves with kinetical energy. The technology of **wave energy** conversion is at the beginning of its development. In some countries (Great Britain, France, etc.) demo projects have been designed and executed already.

Renewable energy sources are the most important alternative energy sources considered as the *"energy of the future"*. When scientists will define the limits of possibilities for renewable energy technologies, the efficiency and cost of conversion systems, it will be possible to quit the use of energy generated by fossil fuels burning. The question is: what are the world reserves of renewable energy? According to estimates, the reserves of renewable energy are enormous (Fig. 3) [1]. But, only part of this energy can be converted. There is the concept of power potential: theoretical, technical and economical. The highest theoretical potential is given to solar energy, reaching an enormous quantity – 89000TW. The wind energy – a derivative of solar energy is on the second place with 370 TW. Global energy of sea waves reaches the value of about 200 TW, compared to current global consumption of 15 TW. Global energy needs could be met by only 0,0002% of solar energy; 0,04% of wind energy; and 0,01% of sea energy. The technical potential of the mentioned renewable energy sources equals the maximum quantity of converted energy provided by the technical systems, and is determined by recent degree of system efficiency. The economic power potential equals the quantity of converted energy, justified from the economical point of view.

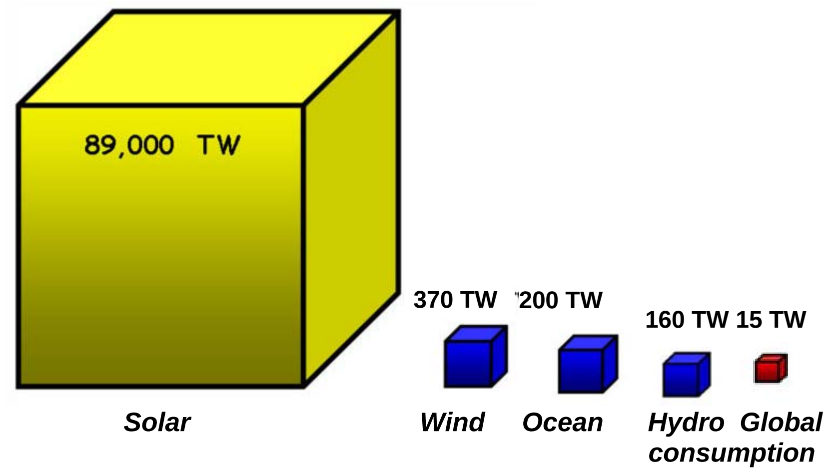

Figure 3. Solar and wind power potential.

Renewable energy has been used by man since the oldest times. The burning of biomass for heating and lighting was practiced from prehistoric times, without mentioning the use of organic products as energy for survival. Wind mills and water mills employed natural resources during many decades, as earliest source of energy production for agriculture and small-scale industrial processes.

Modern technologies for renewable sources conversion have different stories. The development of wind technologies began at the end of the XIX-th century in Denmark. The interest in these technologies increased highly during the two world wars because of limited access to fossil fuels. Since the 50s photovoltaic cells (solar) have been developed due to investment as result of their fulminating use in space flying systems, in materials technology and science, followed by the reduction of prices till the level accepted by the consumers. The basic motivation for the expansion of renewable energy was the oil crisis of 1973 and 1979 – 80. Due to the support of political leaders in various countries, research and development of new technologies increased. James E. Carter was the first politician to welcome the use of solar energy as response to the energy crisis of 1973. Wind, sea waves and solar technologies were supported by investments with the increase of their application level.

As well, the European Union is in a difficult situation, as by imports of 82% of oil and 57% of gas it is the world leader in this respect. With a balance „*reserves/consumption*" equal to 3,0 (a very low coefficient according to the world standards), the European Union is exposed to an energy vulnerability, which fact has determined it to seek ways of improving its energy security.

Renewable energy is the energy derived from regenerative sources that for all practical applications cannot be exhausted. Nowadays, renewable energy sources have an 18,4% share in the world energy consumption. The primary source of renewable energy is solar radiation, i.e. solar energy.

Solar, wind and hydraulic energy are traditionally used widely both in developed and under-developed countries. However, significant electricity production from renewable energy sources started relatively not so long ago, reflecting major treaties on climate change and pollution, fossil fuel depletion and social, political and environmental risks related to fossil fuels and nuclear energy consumption. Many countries and organizations promote renewable energy by subsidizing it and reducing taxes.

Transition to technologies based on renewable energy is dictated both by the ongoing increase of oil and gas prices (with no chance of their decrease in the future), and by understanding issues of the world climate change. During the last 30 years, solar and wind energy systems have developed rapidly, significantly reducing capital costs and the cost of generated energy, continuing improvement of system performances. In fact, the cost of fossil fuels and renewable energy, as well as growing social and environmental costs favoured large-scale rapid evolution of dissemination and development of renewable energy market.

Development and use of renewable energy sources bring a diversity to energy consumption markets and contribute to long-term reliability of sustainable energy supply, as well as to the reduction of emissions into local and global atmosphere, and propose attractive commercial options for specific services promotion in satisfying energy needs, particularly in under-developed countries and in rural areas, helping to develop new opportunities for the labor market.

How renewable energy is divided by forms of renewable sources? Fig. 4 portrays this distribution. Nowadays, renewable energy is dominated by micro hydropower and biomass, used as fuel for cooking and heating, especially in the under-developed countries from Africa, Asia and Latin America. New renewable energy sources (solar, wind, geothermal and micro hydropower) contribute with just 2%. Undertaken studies and designed scenarios researched the contribution of renewable energy sources to the world energy needs supply, underlining that in the first half of 21 century the contribution of RES will grow from 20 to 50% [2,3]. 80% of energy demand of Western industrial societies is focused on building's heating and maintenance, and on vehicles (cars, planes, trains) operation. The majority of renewable sources are used to generate electricity. Iceland is the world leader in renewable energy due to plenty hydro- and geothermal energy sources. About 99% of country's electricity is produced from renewable sources, and most urbanhome heating is of geothermal origin.

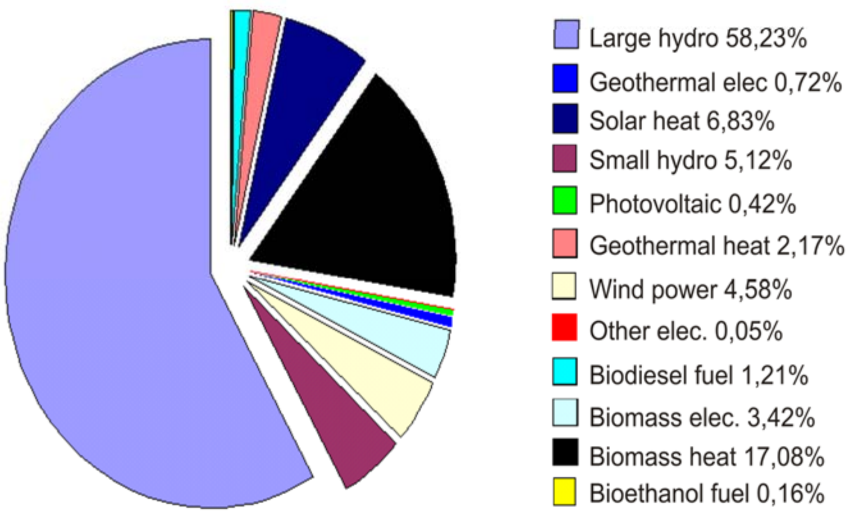

Figure 4. Global renewable energy in 2005.

Leaders of „*green*" energy production are USA, Canada, Germany, Japan. China ant other. Denmark is the initial leader in the generation of wind energy. USA is on positions 1 – 3 in all 4 nominations: hydro-, geothermal-, wind- and photovoltaic solar energy. This fact is partially justifying its burden as biggest energy consumer and the most important factor of increasing greenhouse gas concentration.

1. SOLAR ENERGY

Designing a system for solar energy conversion into thermal energy or electricity is based on accurate assessment of the solar radiation in the given location and on the knowledge of solar radiation properties. The Sun is the closest star to the Earth, at the average distance of $1,5x10^{11}m$. The geometric relations of the *"Sun - Earth"* system is shown in Fig. 5. The sun's energy is the result of several nuclear fusion reactions, the main beng the process in which hydrogen (four protons) merges and forms helium. The mass of alpha particle (helium nucleus) is less than the mass of four protons, the difference in mass is converted into energy according to Einstein's formula $E=mc^2$.

Sun's diameter is about 110 times bigger than the Earth's diameter: $1,39x10^9m$, and respectively, $1,27x10^7m$. The solar core, with a radius of about *0,23R* (*R* – radius of the solar disk) and a volume up 15% of the total, is a thermonuclear fusion reactor. Its temperature is estimated at $(8 - 40)x10^6\ {}^oK$ and 90% of energy is released. The core has a density *100* times bigger than water density and its mass is *40%* of the total mass. At a distance of *0.7 R* from the Sun core, the temperature falls to $130\ 000^oK$ and the density drops to $70\ kg/m^3$. The area between *0,7* and *1,0R* is called the convection zone (it is considered that the thermal convection processes are the main ones). The temperature falls to 5000^oK and density is very low - about 10^{-5} kg/m^3.

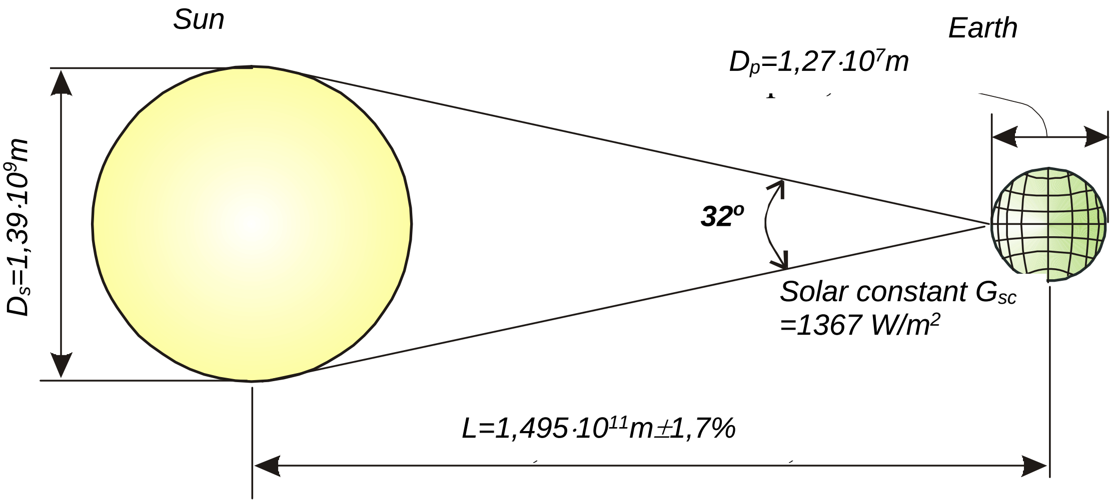

Figure 5. Geometry of the „*sun-earth*" system.

The earth revolves in orbit around the sun, that is approximately circular (circumference deviation does not exceed 1.7%). The average distance between the sun and the earth (Fig. 2.2), called the astronomical unit is equal to $1,495x10^{11}m$. The sun, as viewed from the Earth's surface, represents a disk with an angular diameter 32'. Solar radiation can be modelled with that of an absolutely black body with actual (effective) temperature of about 5777^OK (it is a model introduced in physics to characterize the radiation spectrum of a body with a constant temperature T [5]). Calculations of the absolutely black body radiation and measurement results show that 6.4% of energy is carried by ultraviolet band of electromagnetic waves ($\lambda = 0 – 0,38\ \mu m$), 48.0% - by the visible band ($\lambda = 0,38 – 0,78\ \mu m$) and 45.6 % - by the infrared band ($\lambda > 0,78 \mu m$). It is important to know the energy spectrum of solar radiation in order to understand the effects of atmosphere on the radiation coming from the sun and make a correct choice of materials for solar collectors or photovoltaic cells.

In terms of energy, solar radiation is of interest, which, in fact, is a mix of electromagnetic waves ranging in the wavelength range ($0,2$-$2,5$) μm. Wave energy with a length more than $2,5\ \mu m$ can be neglected. Some definitions, below, will be helpful to properly understand this chapter. ***"Irradiance"*** is measured in ***W/m²*** and is the **momentary power flux density** of solar radiation. For example, the irradiance equal to 1000 W/m2 means that an energy flux equal to 1000 J falls every second on one square meter of surface. ***"Irradiation"*** is measured in ***MJ/m²*** or ***kWh/m²*** and is the ***energy density*** of solar radiation. It is obvious that irradiation is the irradiance integral within a defined period of time - one hour, day or month. In most cases in the literature, the first term is replaced with ***"power density of solar radiation"***, and the second – by ***"solar radiation: hourly, daily, monthly or yearly"***.

In the calculation of photovoltaic systems the energy density of solar radiation, measured in ***kWh/m²***, is often expressed as ***"peak sun hours"***, which means ***"the time"*** in hours with a power density ***1 kW/m²*** required to produce a daytime solar radiation equivalent to that obtained after the integration of energy density during the day.

Analytical relationship between the power density, temperature and wave length is given by Planck's formula [6]:

$$W_\lambda = \frac{2\pi hc^2}{\lambda^5} \cdot \frac{1}{e^{hc/\lambda kT} - 1} \;,\; W/m^2, \qquad (1)$$

where $h = 6{,}63x10^{-34}\ W s^2$ is the Planck's constant;

$k = 1{,}38x10^{-23}$ is the Boltzmann's constant;

$c = 299722458\ m/s$ is the speed of light in vacuum.

Analytical expression (1) allows modelling of solar radiation with high accuracy. It is the radiation power density on the surface of the sun. Running the distance of about 150 million km (see Fig. 5), total extraterrestrial power density (at the boundary between the Earth's atmosphere and the outer space) decreases to a value called the **solar constant**. The solar constant S is the energy received from the sun per a unit of time for a surface perpendicular to the sun, located at the average distance between the sun and the earth, outside the atmosphere. In fact, due to orbital eccentricity of the earth, extraterrestrial radiation varies. Based on measurements taken in the late '90s of the twentieth century, the World Radiation Centre (WRC) has accepted the mean solar constant equal to $1367\ W/m^2$, with the uncertainty of 1.0%.

Conventional air mass, *m*, characterizes the way of solar beam through the atmosphere to the sea level. For the extraterrestrial space or if the land would not have the atmosphere, $m = 0$. At the Equator, while the sun is in its zenith, the solar beam runs the shortest distance, $m = 1$. For zenithal angles θ_Z (zenithal angle - the angle between the vertical circle and direction to the sun), between 0^0 and 70^0, the air mass m can be calculated by the expression

$$m = \frac{1}{cos\theta_Z}. \qquad (2)$$

If θ_Z is equal to 60^0, the air mass $m = 2$, i.e. the solar ray will run a way through the atmosphere twice bigger than if $\theta_Z = 0^0$. Obviously, in the second case, the solar beam will be more mitigated and it will carry less energy. This explains the decrease of solar radiation intensity in the northern hemisphere, and in the southern hemisphere, respectively, compared to the equatorial zone.

„Beam or direct radiation", is the received radiation from the sun without being scattered by the atmosphere. The shadow of an object appears only when direct radiation occurs. Further, direct radiation will be marked with B.

„Diffuse radiation". The solar ray passing through the atmosphere is scattered, i.e. diffused in all directions. Diffuse radiation is always present, even on a clear day this component is about 10%. In this case, solar rays are scattered by the molecules of oxygen, carbon dioxide, dust particles, etc., and the sky becomes blue. If the sky is overcast then direct radiation is zero, and the effect of diffuse radiation is present only. Because of the diffuse radiation, the light penetrates even through a window facing the north.

"Global solar radiation". The sum of the two components makes the global radiation ***G*** on some surface. In most cases, it is measured and used as the notion of global radiation on a horizontal surface.

"Albedo or reflected radiation". Usually, one operates with the radiation reflected by the earth's surface, which falls on the solar collector or photovoltaic panel. In most cases, this component is not taken into consideration, except for collectors or bifacial photovoltaic panels (both surfaces are operating – the one oriented to the sun and another oriented to the earth's surface). Thus, the total radiation incident on the surface of a body would be equal to the sum of direct radiation that is diffused and reflected.

Solar radiation on the earth surface. Above it was mentioned that the radiant power density S in the outer space is constant and equal to $1367\ W/m^2$. Each period, the earth gets the same amount of energy calculated by multiplying the surface S with the surface exposed to irradiation and with the period, we are interested in (a second, a minute, an hour etc.). The surface exposed to irradiation is equal to πR^2, where R is the radius of the earth, and the total area of the globe - with $4\pi R^2$. Thus, the average radiant power density S_{med} collected by the earth will be:

$$S_{med} = \frac{S}{4} = \frac{1367}{4} = 342\ \ W/m^2 \qquad (3)$$

Further the analysis of solar radiation properties on the earth surface will be done, on the assumption that the average radiant power density at the boundary between the Earth's atmosphere and the outer space is constant. The solar rays passing through the atmosphere are subject to significant changes. Some are absorbed by the molecules of air, others - scattered (diffuse component) and some enter the atmosphere without being affected (direct component) and are absorbed or reflected (reflected component) by objects on the earth's surface. Two major effects influence very much the extraterrestrial radiation that runs the atmospheric layer:

- **diffusion** of sunlight by molecules of air, water and dust.
- **absorption of sunlight** by molecules of ozone O_3, water H_2O and carbon dioxide CO_2.

Diffusion of solar radiation is caused by the interaction of electromagnetic wave with wavelength λ and the molecules of air, water and dust. The intensity of interaction depends on the length of the pathway run by the beam through the atmosphere defined by the air mass *m* (see expression 2), the number of particles and their size in comparison with the wavelength λ. According to Rayleigh's theory [4], the diffusion coefficient, which is due to the interaction of the sun ray with the air molecules, is proportional to λ^{-4} and is significant for the wavelengths less than *0,6 μm*. Phenomena related to ray diffusion by molecules of water, dust, etc., are quite complicated, their detailed description being given in [3]. The absorption of sun rays by the atmosphere is due to ozone, oxygen, water and carbon dioxide molecules. Spectral radiant power distribution (Fig. 6) is presented for two cases: 1. *m=0*, extraterrestrial radiation, i.e. the upper boundary of the atmosphere and 2. at the sea level for $m = 1,5$ (azimuthal angle $\theta_z = 48^0$, angle of sun elevation above the horizon, $\alpha = 42^0$). There is a **strong absorption band of ultraviolet radiation** with a wavelength less *0,3 μm* by the molecules of ozone (the ozone layer is the protection screen of the biosphere from the killing ultraviolet rays), a **high transparency** of the atmosphere in the visible band $0,4 < \lambda < 0,76$ *μm*, and a strong absorption of spectrum band infrared radiation. In other words, our atmosphere is transparent to visible band radiation and is opaque - in the infrared band. Because of these two effects, solar radiation on the earth's surface decreases significantly and the irradiation or instantaneous power density peaks about *1000 W/m²*, which takes place at noon, under clear sky.

The sun and the global energy balance. The sun is the main source of energy that defines the climate on the earth. In accordance with expression (3), every square meter of the outer covering of the atmosphere receives *342 W*, of which *31%* or *106 W* is immediately reflected into the space by the clouds, the atmosphere and the land surface (see Fig. 6). The rest, i.e. *236 W/m²*, is absorbed by the land, ocean surface water and, partially, by the atmosphere, warming them. The earth's surface delivers into space the same quantity of energy (*236 W/m²*), but already in the infrared wavelength band: partly, the atmospheric cover, the clouds and water vapours, which, condensing, become cooler and transmit heat to the atmosphere (see Fig. 7). Due to the exchange of energy between the Earth's surface, the atmosphere and the outer space, a constant average global temperature of about 15^0C maintains at the sea level, which decreases rapidly with height increasing, reaching - 58^0C in the upper troposphere. A natural question arises: to which physical phenomena this balance is due to and can it be damaged? The answer is found addressing again the theory of absolute black body, which is modelling either the sun with actual temperature of 5777^0C or the earth with effective temperature equal to T_e.

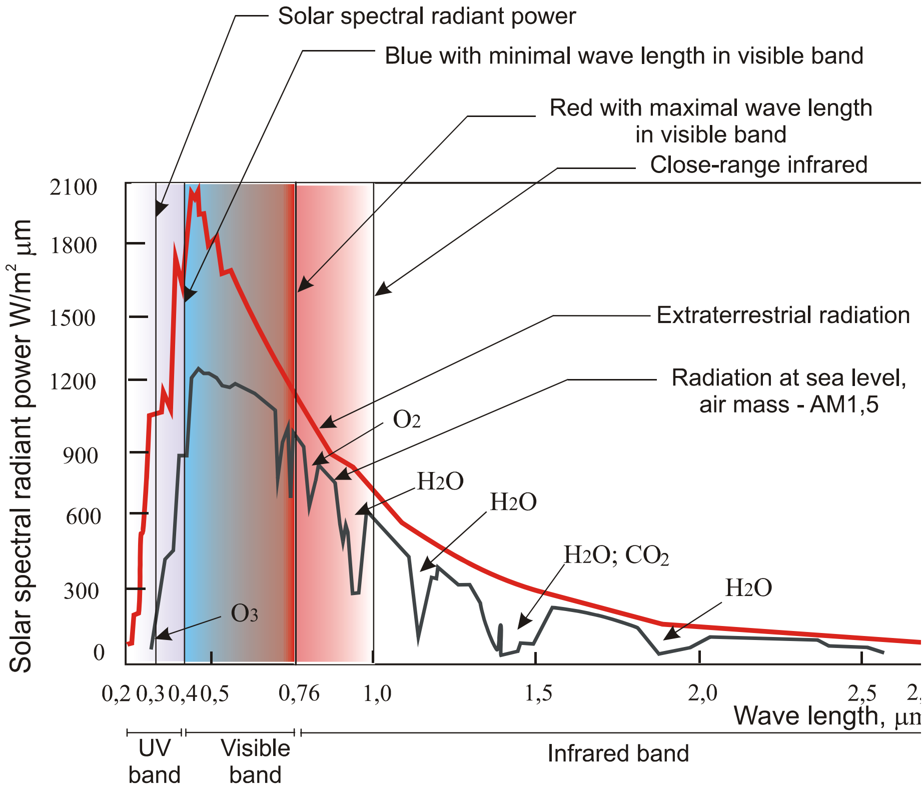

Figure 6. Spectral distribution of power flux (radiant) density.

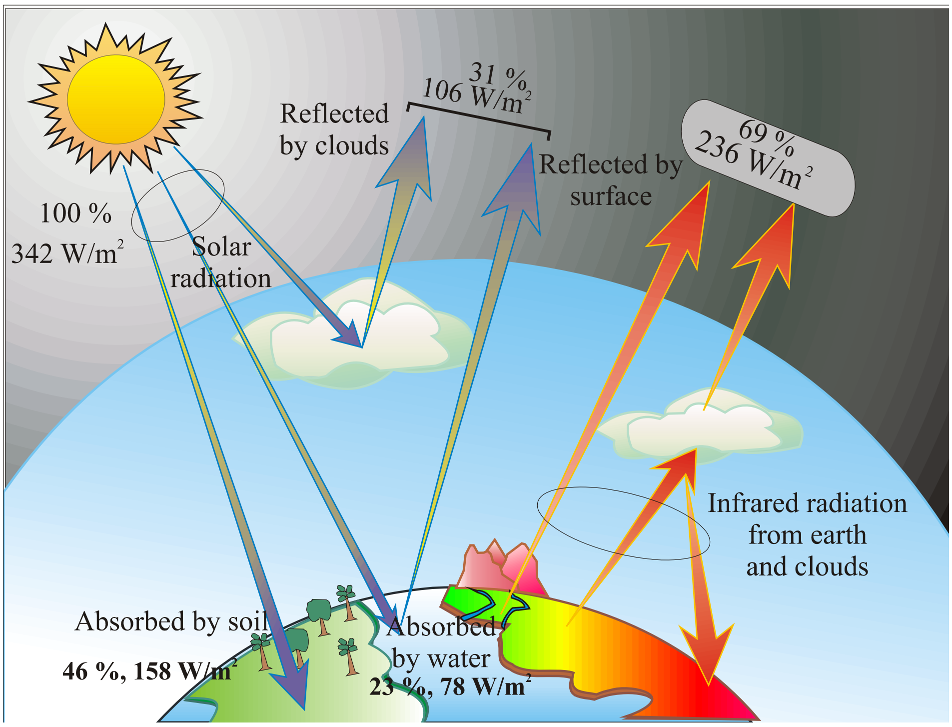

Figure 7. Simplified balance of energy fluxes in the „*earth surface-atmosphere*" system.

Greenhouse effect simulation. The Earth's atmosphere contains several gases called greenhouse gases (GHG): carbon dioxide CO_2, methane CH_4, nitrogen oxide N_2O, and water vapours H_2O. A common property of GHG lies in their absorption by its molecules in the infrared band radiation emitted by the earth's surface, atmosphere and clouds. The certain molecule begins to vibrate and, in its turn, emits the same spectrum of infrared radiation which is absorbed by other greenhouse gas molecules. Thus, the phenomenon of absorption - emission - absorption leads to energy conservation in the lower layer of the atmosphere. In other words GHG has the same role as the glass roof of a greenhouse. The term "*greenhouse effect*" was introduced by meteorologists from the early nineteenth century, at that time had no negative implication and was used to describe the natural greenhouse effect due to which the average temperature on the Earth remains constant and is about 15^{0}C. The greenhouse effect has a crucial role in maintaining life on earth. If the greenhouse effect would not occur then the temperature on the earth's surface would be determined by the balance between the quantity of energy released by the earth to space and the received one from solar radiation. In accordance with the Stefan-Boltzmann's law [1] the amount of energy emitted by a body with effective temperature T_e is determined by the relationship

$$We = \sigma \cdot A \cdot T_e^4 , \quad (4)$$

where $\sigma = 5{,}67x10^{-8}\ W/m^2\ K^4$ is Stefan-Boltzmann's constant; A – body area.

Equation (4) is obtained as a result of the integration of expression (1) of the spectral power density. In the case of earth $We = 4\pi\ R^2\sigma T^4_e$. In addition, the earth receives from the sun a quantity of energy equal to 0,69 S/4 (see equation (3) and Fig. 6). In condition of thermal balance, the quantity of the received energy equals the amount of energy emitted from where we get the actual temperature of the earth's surface T_e:

$$Te = \sqrt[4]{\frac{0{,}69S}{4\sigma}} . \quad (5)$$

For $S = 1367\ W/m^2$, from (5) we obtain the effective temperature of the earth's surface $T_e = 254^oK$ or -19^0C. It is clear that life on earth in such conditions as it exists would not be possible.

Since the second half of the twentieth century and, especially, nowadays, it is often spoken of the so-called *"greenhouse effect"*, but already with a negative sense, linked primarily to the phenomenon of *"global climate change"*. From the point of view of environmental professionals that is due to the anthropogenic impact on the natural balance.

Heat balance of the earth can be damaged by either natural or human activity. Volcanic eruption causes a sudden increase in dust in the upper layers of the atmosphere, burning fossil fuels leads to increased GHG emissions, massive cutting of forests, urbanization, introduction of new agricultural land lead to changing the refraction coefficient (albedo). Because of these effects, the variations of energy flows received and transferred by the earth's surface occur. These variations can be negative or positive. In both cases, the climate system will respond to establish a new thermal balance. Positive changes will tend to establish a higher temperature of the earth's surface and negative changes will tend to opposite effects. Recent studies show a predominance of positive change and global warming occurs.

Photovoltaic panels orientation systems. It is known that the efficiency of a photovoltaic system depends largely on the orientation of the solar panels toward the sun standing both in azimuth and zenith. For this purpose they use different driving mechanisms. Because the motions of rotation around the two axes must be very slow (in the azimuthal plane the device must revolve from 10 to 16 ½ hours), the gear ratio of these mechanisms (if done on the basis of gears) must be very high. Planetary gears (most common for such cases) should include 3 to 4 steps, which considerably increases the number of elements and hence their cost. In order to simplify construction and reduce costs of these orientation mechanisms, the research team of the Department of Fundamentals of machine Design, at the Technical University of Moldova, designed and patented the self-orientation solar unit conceptual diagram [7]. The photovoltaic panel is oriented to the sunlight, being rotated in azimuthal and zenithal planes by driving mechanisms with precessional transmission (Fig. 9). Very broad cinematic options of precessional transmissions ensure very slow rotation around the two axes (one revolution in 24 hours).

Figure 9. PV installation with orientation to the sun.

2. HYDRAULIC ENERGY

The existence of water on the Earth has conditioned the emergence and development of life. From the times immemorial, man has chosen a place to live near rivers and lakes to meet their natural needs in water, but also for carrying out basic irrigation works. Floating or rowing led human thought by observation, to use water force and energy. Thus, the mechanical power of running water can be considered one of the oldest tools.

The inevitable increase of global energy consumption and the risk of a major environmental impact and climate change as a result of burning fossil fuels opens wide prospects for the exploitation of renewable energies. Hydropower, as a renewable energy source, will have an important role in the future. International research confirms that the emission of greenhouse gases is substantially lower in the case of hydropower compared to that generated by burning fossil fuels. From the economical point of view, the utilisation of half of the feasible potential can reduce the emission of greenhouse gases by about 13%; also it can substantially reduce emissions of sulphur dioxide (main cause of acid rains) and nitrogen oxides.

Hydraulic energy is the oldest form of renewable energy used by man and has become one of the most currently used renewable energy sources, being also one of the best, cheap and clean energy sources. Hydraulic energy as a renewable energy source can be captured in two extra power forms:

– potential energy (of the natural water fall);

– kinetic energy (of the water stream running).

Both extra power forms can be captured at different dimensional scales. Table 1 presents a simple classification of hydraulic plants according to the electrical energy output.

Hydropower, in general, has become now the most important source of clean renewable energy, economically feasible. Hydroelectric power plants, integrated in multifunctional schemes, have performed various works such as irrigation, water pumping, etc. It is clear that hydropower will play an important role in the future both in terms of ensuring energy supply and water resources development. Under these options, it is necessary to develop these resources in conformity with the social, economic, technical and environmental standards. It is easy to forecast that global energy needs, especially electricity, will grow significantly during the twenty-first century, not only under demographic pressure, but also because of rising living standards in the underdeveloped countries, which will be 7 billion people in 2050 (78% of total population). Primary energy consumption will grow by mid-century, and growth will be higher for electricity [8]. From the point of view of this situation more alternative energy sources will be required, however, for

Table 1. Classification of hydroelectric power plants according to electrical energy output.

Large scale hydro power	More than 100 MW, usually connected to a large electricity network
Medium scale hydro power	15–100 MW, usually connected to a large electricity network
Small scale hydro power	1–15 MW, usually connected to a large electricity network
Mini hydropower	about 100 kW, often is isolated, but sometimes can be connected to a large electricity network
Micro hydropower	From 5 kW to l00 kW, usually for a small community or rural industry
Pico-hydropower	From several hundreds of watts to 5 kW, usually for remote (isolated) consumers

environmental considerations, an important priority must be given to developing, technically, the full feasible potential of environmentally friendly renewable sources, in particular, hydropower. Of all renewable energy sources, hydro (or energy of the running water) has been mostly exploited, although lately the implementation of hydropower schemes in developing countries was temporarily halted for financial, social or environmental reasons. Currently only a small part of hydropower potential is used in the developing countries: 5% - in Africa, 8% - in Latin America, and 9% - in Asia. Nowadays, China operates approximately 10% of its enormous exploitable potential (about 378 GW), which is the largest in the world. Taking note of the rise of macro hydropower in the twentieth century, it has had a large development in the countries with considerable hydropower potential. Today, hydropower provides about one fifth of the global electricity needs. If the remaining hydro power potential would have been used, the overall needs of mankind in electricity could be satisfied.

Macro-, mini- or micro hydropower? Global hydro power energy today is about 715000 MWe, or about 19% of global electricity (16% in 2003). However, macro hydro power is not a major option for future energy production in the developed countries in terms of industrial purposes for various reasons, such as the environmental one.

Construction of dams on rivers created major environmental and social problems. Development of huge artificial water reservoirs by damming the Earth's major arteries has led to climate and wildlife change in the region, to misbalancing of migration processes of some species of fish, to creating some generating sources of greenhouse gases (the formation and elimination of methane in the atmosphere). More recent studies of large water reservoirs created by hydroelectric dams have shown that the processes of decay of aquatic vegetation can lead to the emission of greenhouse gases quantities in the atmosphere that are equivalent to the emissions from other electrical energy sources [9]. For example, in tropical regions, macro hydro power can lead to greenhouse gas emissions, comparable with emissions of an electric power plant based on fossil fuels. According to Philip Fearnside (researcher at the National Research Institute of Brazil), during the first 10 years of operation, hydroelectric power plants could produce four times more gas emissions than a thermal power plant. These data cast doubts on the plans to build dams in the underdeveloped countries, including the 5 billion U.S. dollars project proposed for the Congo River. On the contrary, small hydroelectric power plants without dams and reservoirs are not sources of greenhouse gases.

A more efficient use of hydraulic energy, in terms of environmental and social impacts, is the conversion of kinetic energy of running river water without dams' construction. What are the main advantages of this type of energy? First, the relative simplicity of these energy conversion systems. Also, the density of water is considerably higher than, for example, air density, and, thus, contains a greater amount of energy in itself. The kinetic energy of water is available 24 from 24 hours. It does not create noise pollution of the environment and doesn affect aquatic creatures. The new Laws of the environment affected by the danger of global warming consider hydraulic energy obtained from small stations much more relevant. The use of hydropower potential at very small-scale is substantiated and in terms of its cost. The analysis of economic viability of the most widely used types of energy with a capacity of 10 kW, made by the U.S. Office of Technology Support, is presented in Table 2. In the case of micro hydroelectric power the negative environmental impacts associated with large hydroelectric power stations are also eliminated.

Table 2. Analysis of economic viability of various forms of energy of 10kW capacity

Form of energy	Cost
Micro hydro	0,21$/kWh
Wind	0,48$/kWh
Diesel	0,8$/kWh
Network extension	1,02$/kWh

These mini-hydroelectric power plants can meet energy needs of consumers, particularly in rural areas. Local industry should be encouraged to use this power for its sustainable development. This is a technology with enormous potential, which should exploit water resources to meet, in the first place, the needs of consumers in rural areas with little access to conventional sources of energy. An important success in this respect belongs to the countries of Latin America, which at the end of construction and according to the prognosis will double their annual energy production. According to experts, the cost of 1 kW of installed capacity of micro hydro electric power plants is $ 400-500 with an efficacy of 40-50% and the redemption period of 1-2 years.

Micro hydroelectric power plants have been used extensively in the past for various practical applications or to supply electricity to towns. Later, due to low cost of fossil fuels, to the economic level of macro-hydroelectric power and massive quantities of energy required, micro hydroelectric power plants have been partially abandoned. In remote areas the installation of diesel units or the network mapping was preferred instead of micro hydroelectric power plants. The basic argument was high investment costs. Today, when the price of fossil fuels and the expenses for environmental protection grow continuously, micro hydroelectric power plants win in the competition related to energy supply, primarily, of remote localities and isolated objects. Also, they offer additional advantages because they are environmentally friendly, does not require big additional civil engineering works, such as access roads, temporary houses for workers, etc.

Not everybody is lucky enough to have a river near his home, but for those who fall into this category, micro hydro turbines are the most reliable and cheap source of alternative energy. A small turbine can produce energy as long as there is water non-stop, regardless of weather conditions.

In this context, the following advantages of micro hydroelectric power plants are highlighted:

• suitable for small power requirements, decentralized (light industry, farms and private enterprises, rural communities) and for operations external to the main network;

• require low-voltage distribution networks and, eventually, micro sub-regional networks;

• can be used as private property, in co-ownership or joint ownership with a semi-qualified labour force required and with a joint or separate administration;

• short period of construction using local materials and skills of people in the area can have a significant impact on the quality of rural life;

• their flexibility, particularly in regard to adapting to variable charges depending on the inflow rate, making them a prime component in any integrated power systems;

• plants can operate a long period. Some have been built 70 years ago and are still running. Plants that are ready to become operational in the near future can register even longer life and serve consumers over several generations without polluting the atmosphere;

• small investments in hydroelectric power plants have proved to be safe and reliable for several decades.

Production of electricity, using water as primary source, is an energy conversion process in which water is an effective means of transmission and transformation of the flow gravitational potential energy into mechanical and electrical energy.

Potential or kinetic hydraulic energy?

The means of water use and exploitation have evolved from a historical epoch to another, from one nation to another, in relation to the natural conditions, depending on the level of production relationships and forces. Thus, water energy uses has marked stages of development of the social systems from the primitive to modern society.

Historical research, ancient engravings and writings show that in ancient times in India (by about 4000 years before Christ) and China (about 5000 years ago) [2,3], dams and canals were built thousands of kilometres long, serving for irrigation and navigation. The Chinese hydraulic wheels, invented and used during the Han Dynasty to grind grains, served to use energy supplied by the water velocity from canals and rivers. Those hydraulic wheels turned the linear velocity of water V into rotational motion with angular velocity ω of a shaft on which paddles were thrusted, at first primitive, then, over time, improved in the form of blades. Last several thousands of years people living in the valleys of the Himalayas have used water mills, or *chakki* for different usages. Water mills are much older than the wind mills.

The first hydraulic transformer was known about 4000 years ago. It served to raise water at height H with the help of primitive buckets, attached to a paddle wheel. In low position the buckets filled with water and after rotation, reaching the top positions, emptied into a water trough located at H meters above the water trough.

The analysis of hydraulic energy conversion systems has demonstrated the opportunity for the development of ***water kinetic energy conversion systems*** compared to potential energy conversion systems. A number of advantages are observed obviously. *Technical advantages*: relatively simple hydraulic energy conversion systems. *Economic* *advantages*: the cost of civil engineering works is reduced considerably. *Ecological advantages*: absence of dams and storage basins. The analysis of existing micro hydroelectric power plants for river water kinetic energy conversion has pointed that there are reserves to increase the efficiency of the utilized turbines. Betz coefficient, equal to 0,59, represents the maximum theoretical efficiency of the hydraulic energy conversion. The majority of the existing systems provides an output factor (coefficient) for water kinetic energy in the value range of 0,2. Only certain modern systems exceed the efficiency by over 30%. In this respect there are sufficient reserves to increase the efficiency of the flow hydraulic turbines, which become more and more attractive to the engineers and inventors in the field. Therefore, the Centre for Renewable Energy Conversion Systems Design was set up at the Technical University of Moldova.

Conceptual diagrams of kinetic hydraulic energy conversion systems. To avoid the construction of dams, it is possible to use the river kinetic energy by utilizing water flow turbines. This type of turbines can be mounted easily and are simple in operation. Their maintenance costs are rather convenient. The stream velocity of 1m/s represents an energy density of 500W/m^2 of the flow passage. Still, only part of this energy can be extracted and converted into useful electrical or mechanical energy, depending on the type of rotor and blades. Velocity is important, in particular, because the doubling of water velocity leads to an 8 times increase of the energy density. The section of Prut River is equivalent to 60 m^2 and its mean velocity in the zones of exploration is (1-1,3) m/s, which is equivalent to approximately (30-65) kW of theoretical energy. Taking into account the fact that the turbine can occupy only a part of the riverbed, the generated energy could be much smaller. There are various conceptual solutions, but the issue of increasing the conversion efficiency of the water kinetic energy stands in the attention of the researchers. The analysis of the constructive diversion of micro hydroelectric power plants, examined previously, does not satisfy completely from the point of view of water kinetic energy conversion efficiency. The maximum depth of blade's immersion is about 2/3 of the blade height *h* in a classical hydraulic wheel with horizontal axle (Fig. 10). Thus, only this surface of the blade participates at the transformation of water kinetic energy into mechanical one. As well, the preceding blade covers approximately 2/3 of the blade surface plunged into the water to the utmost *(h''≈2/3h')*, that reduces sensitively the water stream pressure on the blade. The blade, following the one that is plunged into the water to its utmost, is covered completely by it and practically does not participate in the water kinetic energy conversion. Therefore the efficiency of such hydraulic wheels is small.

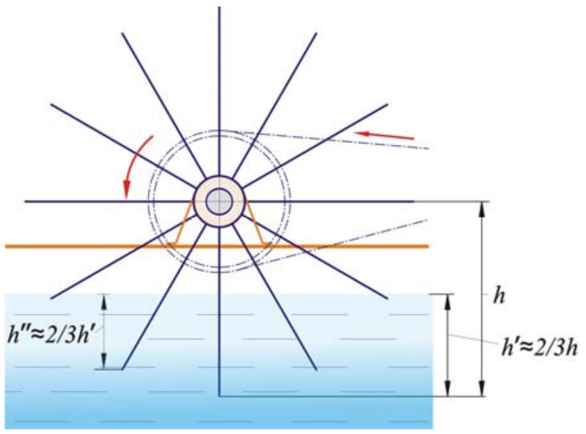

Figure 10. Conceptual diagram of the water wheel with rectilinear profile of blades.

Insistent searches of authors have lead to the design and licensing of some advanced technical solutions for outflow micro hydroelectric power plants. They are based on the hydrodynamic effect, generated by the hydrodynamic profile of blades and by the optimal blades' orientation towards water streams with account of energy conversion at each rotation phase of the turbine rotor (Fig. 11). To achieve this, it was necessary to carry out considerable multicriteria theoretical research on the selection of the optimal hydrodynamic profile of blades and the design of the orientation mechanism of blades towards the water streams.

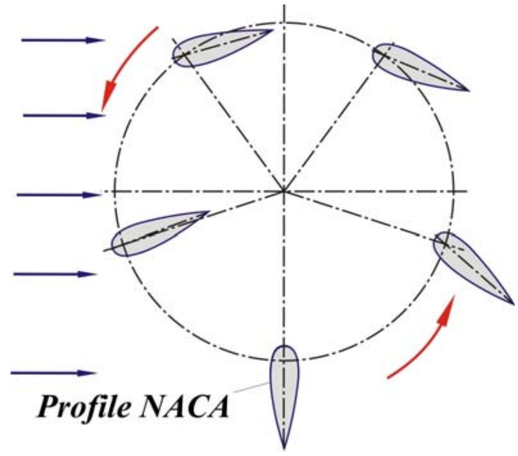

Figure 11. Conceptual diagram of the water rotor with hydrodynamic profile of blades with its orientation towards the water streams.

The main advantages of these types of micro hydroelectric power plants are:

- reduced impact on the environment;
- civil engineering works are not necessary;
- the river does not change its natural stream;

- possibility to produce floating turbines by utilizing local knowledge.

Another important advantage is the fact that it is possible to install a series of micro hydro power plants at small distances (about 30-50 m) along the river course. The influence of turbulence caused by the neighboring plants is excluded.

The results of investigations conducted by the authors (on the water flow velocity in the selected location for micro hydro power plant mounting, on the geological prospects of the river banks in the location of installing the anchor foundation and on the energy demands of the potential consumer) represent the initial data for the conceptual development of the micro hydro power plants and the working element.

The conceptual development of the plant structures with hydrodynamic profile of the blades was performed on the basis of three conceptual diagrams:

- Micro hydropower plant with pintle and blades fixed on the vertical axles anchored by steel structure;
- floatable micro hydro power plant with pintle and blades fixed on the vertical axles;
- floatable micro hydro power plant with horizontal axis and blades fixed on the horizontal axles.

In order to increase the conversion factor of water kinetic energy (Betz coefficient), a number of structural diagrams of floatable micro hydro power plants has been developed (fig. 12) and patented [2,3,9,10]. The micro hydropower plants comprise a rotor with vertical axis and vertical blades with

Figure 12. Microhydropower station for the river kinetic energy conversion into electrical and mechanical energies.

hydrodynamic profile in normal section. The blades are connected by an orientation mechanism towards the water streams direction. The rotational motion of the rotor with vertical axis is multiplied by a mechanical transmissions system and is transmitted to an electric generator or to a hydraulic pump. The mentioned nodes are fixed on a platform installed on floating bodies. The platform is connected to the shore by a hinged metal truss and by a stress relieving cable.

The micro hydropower plant is a complex technical system that includes constructive components with distinct functions: rotor-turbine that draws off a part of the water kinetic energy at its interaction with the water flow; mechanical transmissions for the transformation of the converted energy; pumps and generators for useful power generation, etc. The conversion efficiency of the micro hydroelectric power plant depends on the performances of each component.

The main phases (in successive order) are as follows:

- design of the functional concept of the micro hydroelectric power plant;
- theoretical research of the factor of influence on the water kinetic energy conversion efficiency;
- particular research and design of the working element for the water kinetic energy conversion efficiency;
- research and design of the units participating in the transformation of converted energy into useful energy;
- manufacturing and separate experimental research on the units;
- design and manufacturing of the micro hydroelectric power pilot-plant;
- experimental research on the units as integral technical system and the evaluation of the similarity of functional and constructive parameters that have been theoretically and experimentally determined;
- introduction of partial modifications in the project documentation;
- development of the execution technologies and manufacturing of the micro hydroelectric power plant, as a final industrial product.

The functional and constructive parameters of the hydrodynamic rotor, multiplier, generator and hydraulic pumps, adopted within the carried out research separately on each working element, demand experimental research of their functioning as an integral system, in real conditions. The experimental research on the units of the micro hydroelectric power plant as an integral system aims at the increase of the conversion efficiency of the water flow kinetic energy into useful energy by introducing the relevant constructive modifications in the project documentation of the final industrial product.

3. WIND AS ENERGY SOURCE

Wind energy has been used by mankind over thousands of years. For over 3000 years the windmills have been used for pumping water or grinding (milling). And nowadays, in the century of information technologies, nuclear energy and electricity, thousands of windmills are used for pumping water and oil, for irrigation and production of mechanical energy to drive low-power mechanisms on different continents**.**

Nowadays, the phrase "*use of wind energy*" means, primarily non-pollutant electrical energy produced at a significant scale by modern *"windmills"* called *wind turbines*, a term that attempts to outline their similarity to steam or gas turbines, which are used for producing electricity, and also to make a distinction between their old and new destination.

The attempts to obtain electricity from the wind date back over a hundred years since the late nineteenth century. But a true flourishing of this technology is registered only after the 1973 oil crisis. An unexpected increase in oil prices has forced the governments of developed countries to allocate substantial financial resources for research, development and demonstration programmes. Over 20 years, worldwide, a new technology, a new industry and, in fact, a new market - the market of the Wind Energy Conversion Systems (WECS), have been developed.

If in 1973 the main incentive for the development of WECS was the oil price, today another incentive is added - the tendency of mankind to produce "*clean*" or "*green*" electricity with little or no carbon monoxide emissions. The year 1993 was marked as the beginning of a wind boom characterized by an annual increase of over 20% of installed power capacity. Thus, in 1999 the global capacity increased by 4033 MW, which was a record for the wind energy sector. It is rather significant as it exceeded the world installed nuclear power capacity in the same year, for the first time [1]. In the period 1996-2006 the global capacity has increased more than 12 times and has reached 73,904 MW in 2006 (Figure 13) [11].

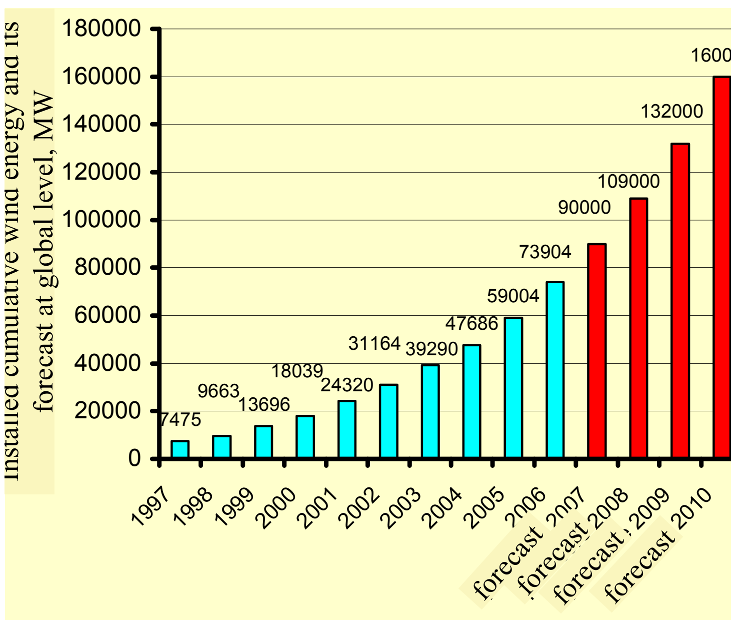

Figure 13. Installed cumulative wind energy and its forecast at global level**.**

The undisputed global leader is the European Community EU-27 with a 65% share, followed by the USA India and China. Such a spectacular development knows no other global industry sector worldwide. With the launch of the European Technology Platform on wind energy issues the EU Commissioner A. Piebalgs said [12]: *"Wind energy technology is certainly one of the fastest growing and plays an important role, contributing to create a sustainable and competitive energy policy in Europe"*. In 2005, the EU countries produced about $69{,}5\cdot10^6$ MWh of wind electrical energy or more than 26 times the electricity consumption of Moldova in 2005. The wind provides electricity to more than 35 million households in the EU, but very few know it – a symptom which indicates a lack of knowledge about this technology. Globally, by 2020 about 12% of the produced electricity will be of wind origin. Table

Table 3. World most advanced countries and companies in the wind technology.

Country	**Installed wind power, MW**	**World share, %**	**Company**	**Wind market share, %**
Germany	20622	27,9	Vestas, Denmark	27,4
Spain	11615	15,7	Gamesa, Spain	15,5
USA	11603	15,7	GE Wind, USA	15,3
India	6270	8,5	Enercon, Germany	14,5
Denmark	3136	4,2	Suzlon, India	7,5

3 lists the most advanced five countries and five global companies in the field of the wind energy.

Small power wind turbines. Small wind turbines should be mostly robust and simple, have maximal resistance and little maintenance, and optimal wind energy conversion efficiency. Given the topical interest and relatively high costs of imported wind turbines, a team of authors developed two types of small power wind turbines. The wind turbines with servo motors have the ability to track wind direction and remove the bladed rotor out of the wind action at wind speeds exceeding 15-25 m/s. The advantages of these turbines compared to vane wind turbines are:

- angular positioning stability of the bladed rotor at dynamic fluctuations of air currents direction;
- bladed rotor protection from overloads, caused by wind speeds exceeding the highest allowed values.

Figure 14. Wind turbine with mechanical orientation to the air currents.

Based on the study of wind energy potential and specific orographic terrain surface of Moldova, characterized mainly by gorges oriented along North-South direction, the authors developed the concept of a three-bladed rotor with asymmetric aerodynamic profile [2,13]. Theoretical research on the developed rotor was carried out using modern software ANSYS CFX5.7 and Autodesk MotionInventor. As a result, the basic parameters of the aerodynamic profile characterizing the efficiency of wind energy conversion by the rotor blades were determined.

Taking into account that across the gorges the excesive costs the authors have designed a prototype wind turbine with mechanical orientation to the air currents (fig. 13). Construction simplicity of the wind turbine leads to about 20-30% cost reduction compared to turbines with electronic guidance devices.

The choice of three blade rotor scheme provides a greater dynamic stability, minimizing related vibrations and sonic background, thus resulting a longer life period of all components. Direct connection of the rotor to the generator ensures rotor start up at lower wind speeds, production of a larger amount of energy, requires less demanding maintenance compared to turbine multiplier case. Specially designed permanent magnet generator combines efficiency with the simplicity of construction. The outer coverage of blades featuring asymmetric aerodynamic profile, also the gondola cone are manufactured from composite materials reinforced with glass fibre employing modern technologies in the CESCER laboratory.

Solar, wind and kinetic hydraulic energies supply of the dripping irrigation system. The electricity supply of agricultural land irrigation systems from the public power grid becomes inefficient, that is why various autonomous sources of energy (solar, wind and kinetic hydraulic) are becoming more widespread. Figure 15 shows a drip irrigation system powered by electricity from a wind turbine 1. Centrifugal pump 2 with productivity parameters Q (m^3/h) and pumping height H corresponding to the needs for irrigation is supplied with electricity from a wind turbine generator 1. Centrifugal pump 2 sucks water from the lake (or river) and pumps it into the system through the fertilizing dispenser 3 and filtering device 4 connected consecutively in the pump discharge pipe. Fertilized and filtered water under pressure is pumped into the pipe network 5. The irrigation system must include a water storage tank 6 located at an altitude higher than the irrigated ground. Water in the tank may be used during the periods when the wind speed is insufficient to produce the demanded electricity. Subject to the launch of a new generation of electric batteries on the market, more efficient and cheaper, the irrigation systems equipped with batteries could be an alternative that will load at times when irrigation is not appropriate.

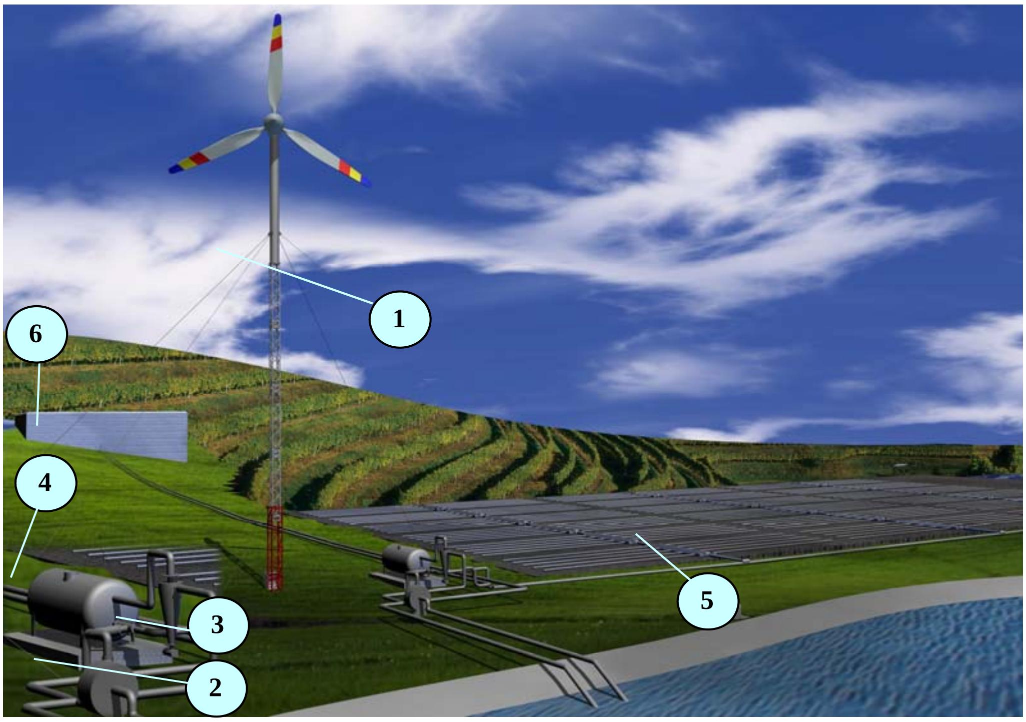

Figure 15. Drip irrigation system powered with electricity produced by the wind turbine.

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