Chapter I. OVERVIEW

1.1. Theoretical, technical and economical energy potential

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"* [1]. 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. 1.1. Renewable energy flux has a closed character and fossil energy has an open character. In the case of RES use the 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.

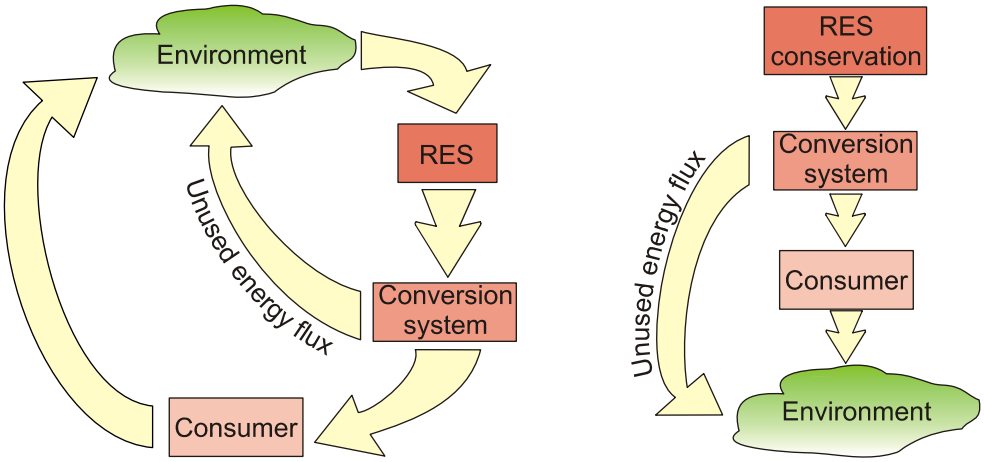

Figure 1.1. Energy fluxes circulation: *a)* renewable; *b)* fossil sources

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.

Solar energy – the main renewable energy source. Depending on the origin, RES are divided into two groups: the first one includes solar energy and its derivatives – wind, hydraulic, biomass energy, tide energy, thermal energy of the planet's ocean. Fig. 1.2 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 thermal energy of the planet's ocean is not described because its technology is in the inception phase of development. 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 in Chapter 2. 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

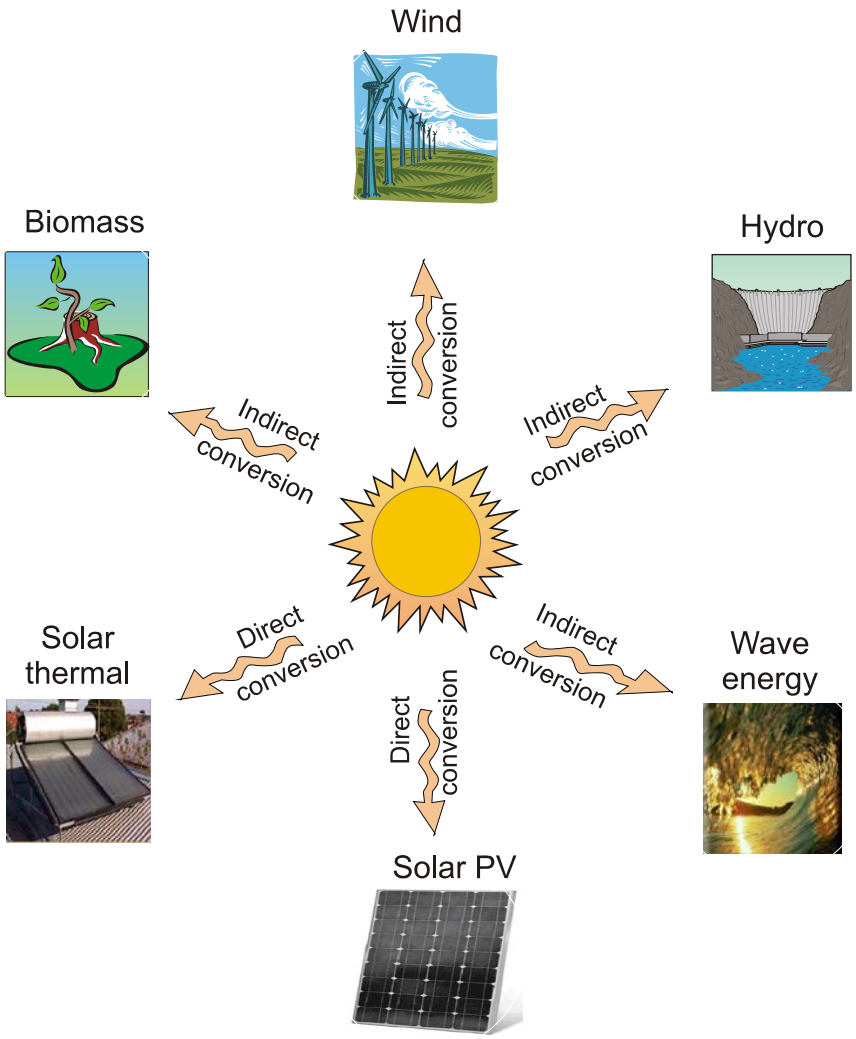

Figure 1.2. Main forms of solar energy.

technology for solar energy passive use. Concentrated by special reflectors, solar radiation can generate thermal energy with temperatures higher than 300^{o}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. Issues relating to this technology are described in Chapter 2.

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. Photovoltaic conversion of solar energy is examined in Chapter 3.

Another form of solar energy is biomass. The potential of biomass in Moldova, way stouse the biomass for energy purposes, biomass in the European Union, power supply systems, based on biomass are described in Chapter 4.

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. Wind energy is described in Chapter 5. 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). Hydraulic energy is described in Chapter 6. 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. 1.3) [2]. But, only part of this energy can be converted.

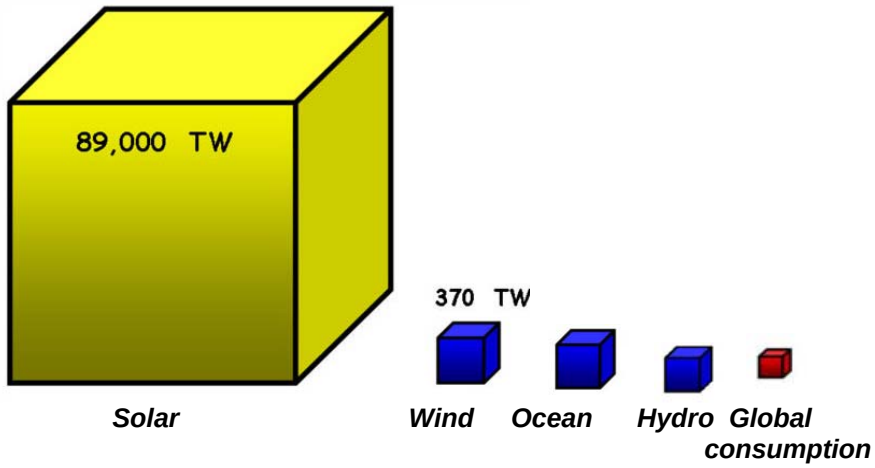

Figure 1.3. Solar and wind power potential.

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.

Renewable energy conversion systems possess multifunctionality, in the case of remote consumers, particularly. Fig. 1.4 shows both possibilities - for renewable energy transformation into other forms, and for its storage (for example, water pumping into storage tanks when electricity is not demanded, hydrogen production, etc.).

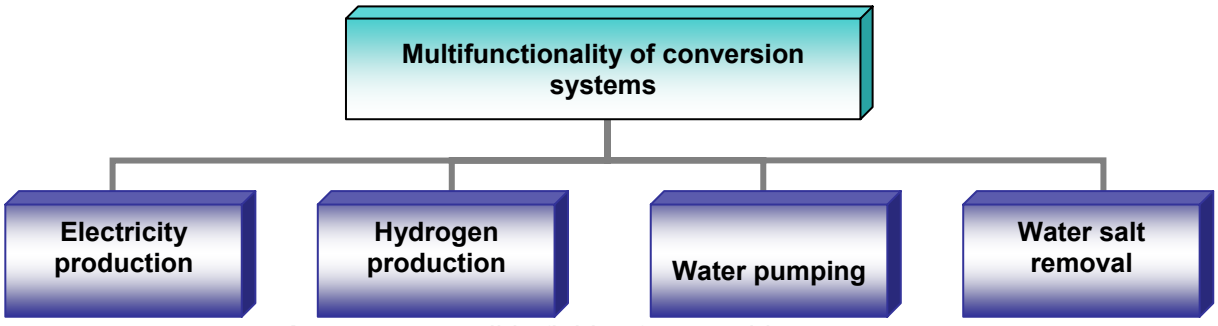

Figure 1.4. Possible fields of renewable energy use.

1.2. Global renewable energy – its present and future

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 favored 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. 1.4 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%.

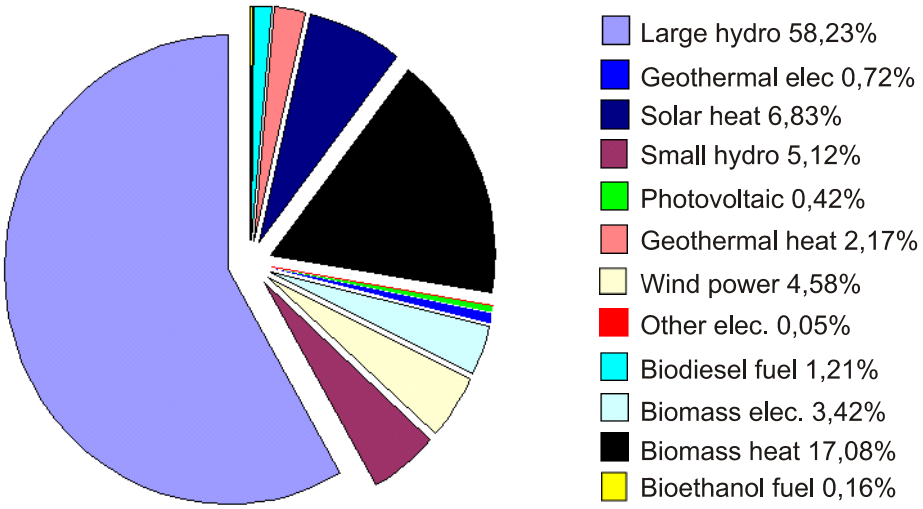

Figure 1.4. Global renewable energy in 2005.

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 urban home heating is of geothermal origin. Leaders of „*green*" energy production are given in Table 1.1. One can see that 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.

Denmark is the initial leader in the generation of wind energy and remains the nation with the highest level of wind energy production per capita. Germany has started to develop its wind capacities later – in the middle of the 1990s by injecting generous subsidies and now it has about one third of the world capacity generating wind electrical energy. Spain was

Table 1.1. Renewable electricity production top countries (2000).

No.	Hydro-	Geothermal	Wind	PV Solar
1	Canada	USA	Germany	Japan
2	USA	Philippines	USA	Germany
3	Brazil	Italy	Spain	USA
4	China	Mexico	Denmark	Australia
5	Russia	Indonesia	India	Netherlands

mainly on the second position in wind electrical energy generation, but in 2002 was outrun by USA which became the second nation with the highest level of wind energy installed capacity. Table 1.2 lists the top 5 programs for the use of green energy launched by US Department of Energy. Joint renewable energy source in the top 5 programs is wind energy.

These encouraging actions of US Department of Energy resulted in the production of 6% of total USA energy from renewable energy sources in 2004. In Israel most living houses are supplied with hot water generated from solar energy and new technologies are being developed for the generation of renewable energy from wastes. Dynamics of geothermal energy increase in 1990 – 2005 is shown in Table 1.3.

Table 1.2. Top 5 programs of green energy use, USA Department of Energy.

No.	Program	Resources used	Production, mln. kWh/year
1.	Austin Energy	Wind, natural gas	435,1
2.	Portland General Electric	Geothermal and hydro-, wind	339,6
3.	PacifiCorp	Wind, biomass, solar	234,2
4.	Florida Power & Light	Biomass, wind, solar	224,6
5.	Sacramento Municipal Utility District	Wind, natural gas, micro-hydro, solar	195,1

Table 1.3. Geothermal energy installed generation capacities.

Country	1990 MWe	1995 MWe	2000 MWe	2005 MWe
China	19,2	28,78	29,17	28
San Salvador	95	105	161	151
Iceland	44,6	50	170	202
Indonesia	144,75	309,75	589,5	797
Italy	545	631,7	785	790
Japan	214,6	413,71	546,9	535
Kenya	45	45	45	127
Mexico	700	753	755	953
New Zealand	283,2	286	437	435
Nicaragua	35	70	70	77
Philippines	891	1227	1909	1931
Russia (Kamceatka)	11	11	23	79
USA	2774,6	2816,7	2228	2544
Total	**5831,72**	**6833,38**	**7974,06**	**8912**

1.3. Experience of European countries in RES promotion and use

Certain countries like Denmark, the Netherlands, France, and Germany have long traditions in renewable energy conversion, in particular wind and hydraulic ones. As a whole, the European Union focuses on the use of renewable energy as an alternative to conventional energy. In the 90s of the last century the European Union launched a global strategy for its countries concerning the development, promotion and implementation of RES. Lack of coherent and transparent strategy with a well-defined and ambitious objective is a serious impediment for RES use. They could not influence the Community energy balance in any way. A first step in the development of the strategy was the presentation of the first version of Strategy, the so-called Green Paper in 1996 [3] "*Énergie pour l'avenir: les sources d'énergie renouvelables*", that was presented to large public debates beginning with 1997. The Green Paper generated multiple reactions from Community institutions, governments and national organizations, companies and agencies, interested in RES development. During this period of consultations the European Commission has organized two conferences to discuss a number of formulated issues and developed proposals. After public debates on the Green Paper, the Strategy was amended and finally published in the White Paper [4]: Livre Blanc "*Énergie pour l'avenir: les sources d'énergie renouvelables. Une stratégie et un plan d'action communautaires*".

EU strategic objectives. The objectives and EU policy on energy and necessary resources to reach these objectives are described in the EU White Paper. Three main objectives for energy policy are envisaged:

- competitiveness capacity building;
- security of energy sources supply;
- environmental protection.

RES promotion is underlined as one of the decisive factors for achievement of the mentioned objectives. Being indigenous, RES will have an important role in decreasing the level of dependence on import and will be quite positive in increasing the security of supply. In 1995, the EU dependence on energy sources import was 50 %, by 2020 it will be 70% if no measures taken.

The main objective of this Strategy is to provide 12 – 15 % of the gross national consumption by 2010 from renewable sources. Compared to 1997, the share of RES will double; 23,5 % of total electricity will be produced by RES. The highest growth rate will have: photovoltaic energy – by 130 times, wind energy – by 19 times, solar thermal (solar collectors) – by 15,4 times. Three forms of RES (biomass, hydro and wind) have the highest share both in gross electricity consumption and in electricity production (see Tables 1.4, 1.5). Compared to 1995, it has been envisaged the renewable energy will reach 675 TWh by 2010, which means 23,5% of the total energy production, that is a growth of about 70% (Table 1.4).

Table 1.4. Current and future production of renewable electricity in EU, European Commission, 1997.

Form of energy	1995		2010	
	TWh	% of total	TWh	% of total
Wind energy	2,00	0,20	83,00	2,80
Hydraulic energy	307,00	13,00	355,00	12,40
Solar energy	0,03	–	3,00	0,10
Biomass energy	22,50	0,95	230,00	8,00
Geothermal energy	3,50	0,15	7,00	0,20
Total renewable energy	337,00	14,30	675,00	23,50
Total	**2366,00**	–	**2870.00**	–

The achievements of these countries are partially based on their geographical advantages. It should be noted that Germany has no good wind energy resources (for example, in Great Britain these resources are bigger but achievements are more modest). Some other factors played an important role in the achievement of this level of conversion of wind energy and other renewable energy.

Today, renewable energy conversion might be more extensive than fossil fuel burning. The technologies employing fossil fuels are well-known, but renewable technologies are new. Politicians and scientists actively discuss which the optimal mechanism/mechanisms are to achieve the goals of renewable energy policy implementation.

The number of those who consider that renewable energy is not cost efficient is quite big. This is due to the fact that fossil fuel prices do not include current and future costs related to global ecological changes [5]. As well, the efforts undertaken to extract oil from big depths are increasing but the cost of renewable energy technologies will reduce together with the increase of investments and capacities expansion [6].

The majority of renewable energy policies envisage market stimulation that, in its turn, demands technologies with increased efficiency and reduced cost. Many instruments of

Table 1.5. Renewable energy gross consumption in the European Union, Mtep.

Forms of energy	Consumption 1995				Consumption forecast for 2010			
	Mtep	%	Substitu-tion value	%	Mtep	%	Substitution value	%
Gross total consumption	**1366**	**100**	**1409**	**100**	**1583**	**100**	**1633**	**100**
Wind	0,36	0,02	0,9	0,06	6,9	0,44	17,6	1,07
Hydro:	26,4	1,9	67,5	4,8	30,55	1,98	78,1	4,78
•macro	23,2	–	59,4	–	25,8	–	66	–
•micro	3,2	–	8,1	–	4,75	–	12,1	–
Photovoltaic	0,002	–	0,006	–	0,26	0,02	0,7	0.05
Biomass	44,8	3,3	44,8	3,12	135	8,53	135	8,27
Geothermal	2,5	0,2	1,2	0,1	5,2	0,33	2,5	0,15
• electricity	2,1	–	0,8	–	4,2	–	1,5	–
• heat	0,4	–	0,4	–	1,0	–	1,0	–
Solar thermal	0,26	0,02	0,26	0,02	4	0,25	4	0,24
Total RES	**74,3**	**5,44**	**114,7**	**8,1**	**182**	**11,5**	**238,1**	**14,6**
Solar passive	–	–	–	–	35	2,2	35	2,1

energy policy have been applied, most employed being the share instrument, contractual and fixed-tariffs instruments and low-credit taxes. The share instrument, known as Renewables Standard Portfolio (RSP), advises governments to oblige companies and other consumers to use a part of consumed electricity from renewable sources. Companies avoiding this obligation should pay fines for each unit of electricity. This leads to an increase in renewable energy capacities and, as a result - to the decrease of prices. This instrument is used by majority of states in the USA, in Great Britain, Italy, Belgium and other European countries. In USA this instrument is applied at federal level as well. Contractual instruments assist governmental authorities in obliging companies to accept renewable electricity on the basis of a governmental contract. Examples of such instruments in practice are UK Non-Fossil Fuel Obligation, Alternative Energy Demand in Ireland and EOLE in France.

Regarding the tariff instrument the government fixes the price for each unit of produced electricity by means of technologies classified as renewable. Due to the fact that fossil fuels are still cheaper, this price is higher for renewable electricity and these tariffs are not functional economic generators. Various tariffs can be defined for various technologies. The government can subsidize or can impose beneficiary companies to buy the produced electricity without transferring its costs to consumers.

The main advantage of all these instruments is to impel renewable energy technologies, which fact will reduce the impact of human activity on the environment.

According to the forecast given in Fig. 1.6 [7], renewable energy sources will grow considerably starting with 2000. It is expected that total volume of renewable energy will increase about 3 times in 2050 compared to 2000. The increase of wind and hydraulic energy use is shown in the diagram.

EU Strategy concerning RES use is supplemented with an action plan that coordinates, defines and mobilizes both Community and member countries' activities. In fact, the action plan is a supporting instrument for RES harmonizing Community actions under energy market liberalization. These measures refer to common rules for internal electricity market and are described in [8]: „*Directive 2003/54/CE du Parlement européen et du Conseil du 26 juin 2003 concernant des règles communes pour le marché intérieur de l'électricité*". This Directive envisages only one instrument for favorable approach to RES electricity, according to article 11, 3rd paragraph: *„A member state can require the owner of distribution grid, in the case this owner chooses production equipment that priority is given to renewable energy*

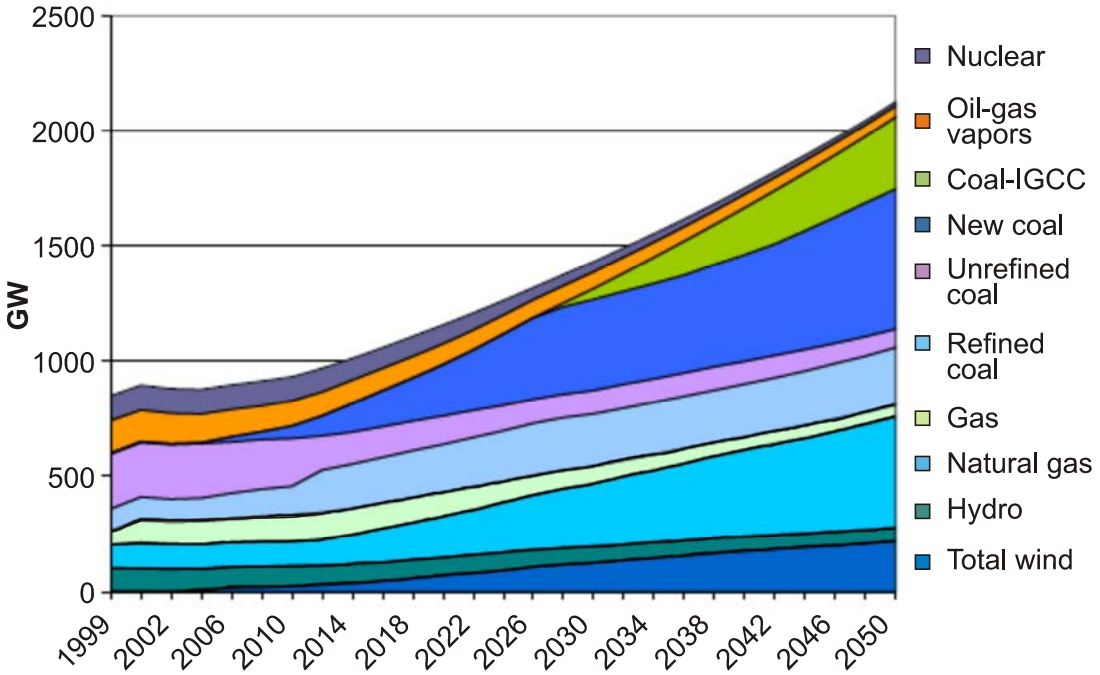

Figure 1.6. Dynamics of global energy development by sources till 2050.

sources, to sources based on waste use or to sources of electrical and thermal energy cogeneration".

This provision is an exception from the fundamental rule defined in the same article, paragraph 2: „*The selection of production units and the use of interconnections are done on the basis of criteria with account of economic priorities concerning electricity production*".

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