ENERGY CONVERSION, CONSUMPTION AND CONSERVATION

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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 jeopardy-zed and the world is facing an ecological disaster.

The Law of Conservation of Energy is one of fundamental laws of physics: *in physical processes energy cannot be destroyed or decreased, it can be converted (transformed) from one form of energy to another* [1]. Table 1. lists several processes of energy conversion from one form to another [2].

Table 1. Conversion of various forms of energy.

Forms of energy:	**to chemical**	**to thermal**	**to electrical**	**to electro-magnetic**	**to mechanical**
from chemical	Plants, Food stuffs	Burning, Anaerobic digestion	Battery, Fuel cell	Candle and votive candle radiation, Phosphorescence	Human and animal muscles
from thermal	Pyrolytic gasification	Heat pump, Heat exchanger	Thermocouple	Fire	Gas turbine, Steam turbine, Memory materials
from electrical	Battery, electrifier	Boiling plate, toaster, iron	Converter, frequency converter	Fluorescent lamp, Luminescent diode	Electrical motor, electromagnet
from electro-magnetic	Photosynthesis	Solar collector	Photovoltaic cell	Laser	Solar radiation pressure
from mecha-nical	Crystallization (formation of solid crystalline out of liquid)	Friction brake	Generator	Firestone	Water wheel, windmill, pendulum, flywheel

In this context some questions arise: What is primary energy? What is energy consumption? When energy is consumed the following things occur: the conversion of chemical energy stored in coal, oil, natural gas, wood or of the energy stored in the atomic kernel, or the conversion of water kinetic and gravity energy, or wind kinetic energy, or the conversion of solar radiation energy into heating and lighting of our houses, or into electrical energy to make machine-tools operate or into kinetic energy to move the vehicles. In other words, energy consumption is equivalent to energy conversion. Energy conservation means the production of more goods and services by converting a small quantity of primary energy into heating, electricity, lighting (electromagnetic energy), etc.

Primary energy is all energy contained in the original sources. Nowadays, the main original

sources are fossil fuels (coal, oil and natural gas), biofuels – wood, wooden wastes, agricultural waste, manure, etc. Other sources can be added, like hydraulic and geothermal energy, and other sources of renewable energy such as solar and wind energy, and nuclear energy as well. Consumers are interested in the satisfaction of their energy needs: they need thermal energy for heating and cooking, electrical energy for lighting, transportation and production of goods, etc. The quantity of supplied energy, the form of useful energy needed, the amount of energy losses and the price to pay for the used energy are important things for consumers. Fig. 1 and 2 show the three notions of energy (primary, supplied and useful), for two systems of electrical energy production – from natural gas at a condensation thermal power station (fig. 1.) and from conversion of solar energy into electrical energy using photovoltaic modules (PV). In both cases three devices are used: the electric bulb, the compact fluorescent lamp (CFL) and the electrical motor. The efficiency of devices is equal to 5, 20 and 90 %, respectively.

For systems based on fossil energy sources the biggest losses occur at the production of electrical energy (about 66%), followed by losses in the electrical networks at transportation and distribution, and losses in the devices. The last can be quite significant, if device efficiency is small. For example, for an electric bulb the global efficiency of energy conversion equals to 1,5% only, in other words, from 100 units of primary energy only 1,5 units are applied usefully, and 98,5 units bring about atmosphere thermal and gas pollution with the greenhouse effect. Global efficiency of a CFL lamp is 6%, and for an electric motor – 26,7 %.

National [3] and international statistics published data about the production and consumption of various forms of energy sources. Data is presented both in natural measurement units and in conventional measurement units. The concept of *„consumption of primary energy sources"* is applied in economic estimations, in the determination of energy efficiency and in the specific energy consumption, etc. The above concept contains all forms of the consumed energy – fuel, electrical or thermal energy obtained from the fossil sources, from the nuclear or hydraulic energy, from the energy of various forms of biomass, or from geothermal, solar and wind energy, etc. It is important to know generally accepted agreements concerning the presentation of statistical data related to the consumption of primary energy resources. UNO, International Energy Agency (IEA) and some countries recommend the following methodology for primary energy resources calculation [4,5]:

1. primary energy used for the production of electrical energy at thermal power stations (TPS: energy of fossil fuels is transformed into steam thermal energy, then into mechanical energy and, finally, into electrical energy) is defined as the result of multiplying the quantity of the produced electrical energy by 3 or division by 0,33, that in fact is the average efficiency of the thermal power station;

2. Contribution of primary energy to the production of hydraulic or wind electrical energy or from other renewable sources is considered equivalent with the quantity of electrical energy. In other words, in the case of electrical energy production from renewable sources, the efficiency of the conversion process is not taken into consideration.

Obviously, the value of the conversion process efficiency is very important in this case too (fig. 2). The higher the efficiency, the lower the unit cost of the produced electrical energy. As well, the overall efficiency of energy conversion is defined as the relationship of the useful energy to the solar primary energy incident on the surface of the PV module. It should be mentioned that useful energy is relatively bigger than in the case of fossil primary energy use. The agreement to use the above accepted concept of primary energy aims at outlining the fact that for the production of one unit of electrical energy from a renewable source, the same unit of primary energy will be spent, which circulates in the environment and does not change the balance of nature. The methods of energy (fossil or renewable) conversion are characterized by the efficiency factor *E*. The higher efficiency *E*, less primary energy will be spent at input for the production of one energy unit at output.

Efficiency factor ***E*** is determined by the mathematical relation:

$$E = \frac{E_{useful}}{E_{primary}} 100\%. \qquad (1)$$

The biggest part of primary energy sources on Earth belongs to fossil fuels based on carbon. World reserves of fossil fuels (oil, coal, gas) estimate at approximately [6] (BBEP – billions of barrels equivalent petroleum; MB – millions of barrels; MBEP – millions of barrels equivalent petroleum):

- oil: from 1050691 to 1277702 millions of barrels (from 167 to 203 km³);
- gas: from 171040 to 192720 km³ (6,8 · 0,182 = 1,239 BBEP);
- coal: 1081279 million tons (1081279 · 0,9 · 4,879 = 4,786 BBEP),

Daily consumption of fuels in 2002 (7,9 is the conversion ratio of tons equivalent petroleum in barrels equivalent petroleum BEP):

- oil: (10230 · 0,349) ·7,9/365= 77 MB/day;

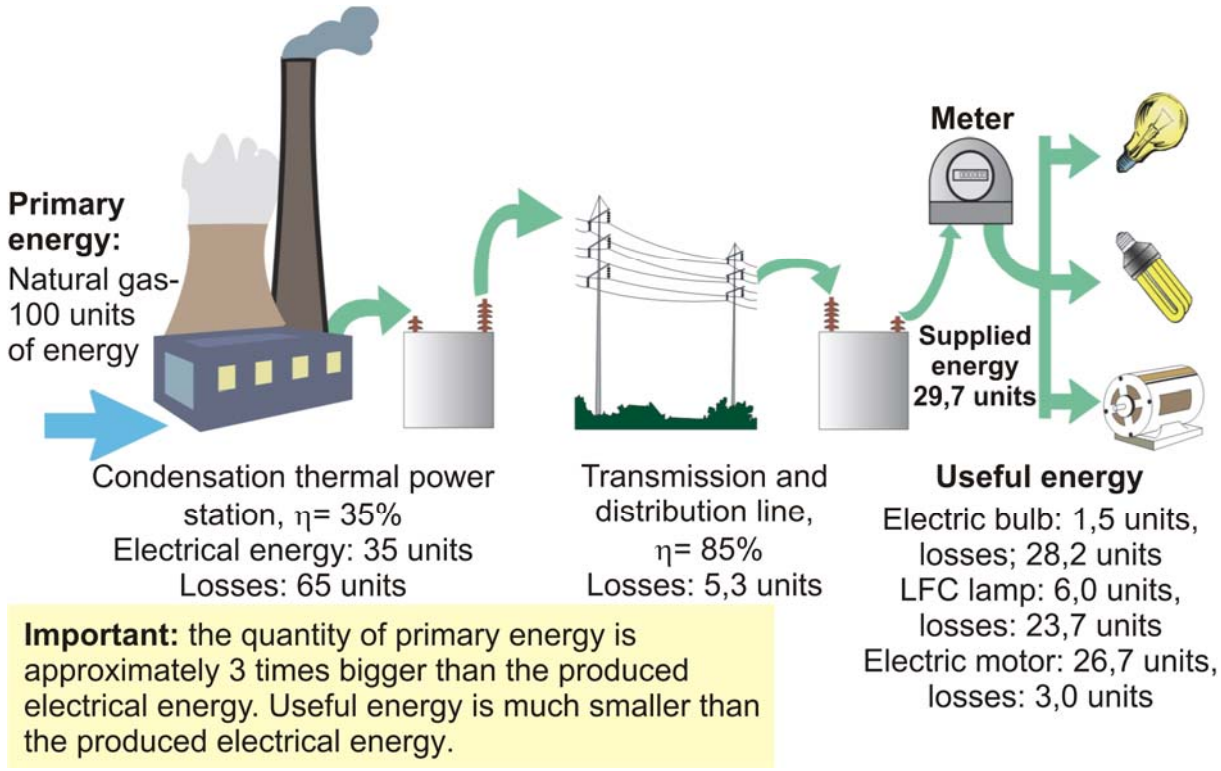

Figure 1. Primary, supplied and useful energy: the case of energy from fossil sources.

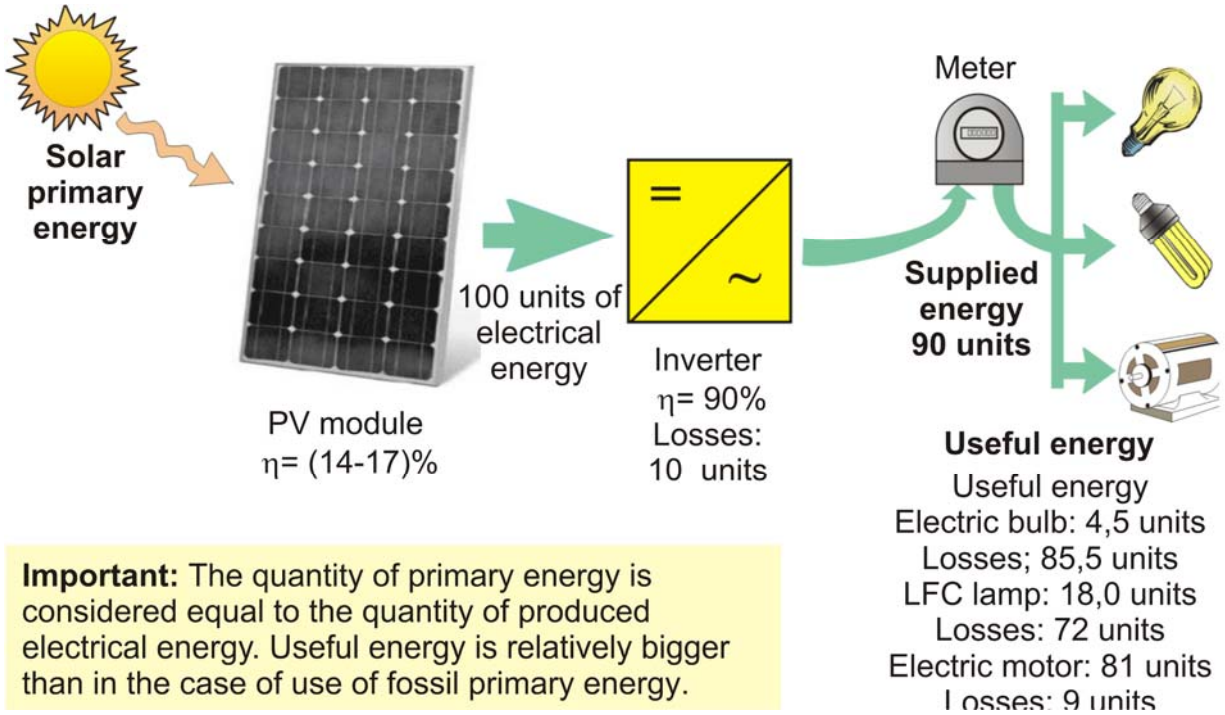

Figure 2. Primary energy, delivered and useful: the case of renewable energy.

- gas: (10230 · 0,212) · 7,9/365= 47 MBEP/day;
- coal: (10230· 0,235) · 7,9/365= 52 MBEP/day.

According to the most optimistic forecast done by *Oil & Gas Journal*, *World Oil* [7] these reserves of fossil fuels will last for:

- **32 years –** oil;
- **72 years –** gas;
- **252 years** – coal.

World reserves of oil and gas, distributed among the biggest producers, are given in table 1.2

Table 2. World reserves of oil and gas, January 2005.

[6]. To note the fact that these estimates were done according to constant daily fuel consumption for year 2002. Natural gas is the most environment friendly fossil fuel and might be a partial solution to the climate warming and atmosphere pollution issues (Table 3).

Natural gas could be largely used in future for the production of hydrogen from methane (CH_4), necessary for the functioning of fuel cells that will substitute gradually internal combustion engines.

	Crude oil (billion of barrels)		**Natural gas** (Millions of cubic km)	
Countries/Regions	*Oil & Gas Journal*	*World Oil*	*Oil & Gas Journal*	*World Oil*
North America	214771	40874	7477,7	7752,4
Central and South America	100595	75973	7096,9	7837,3
Europe	17613	18125	5497,1	5419,3
Eurasia	77832	89898	55314,4	79978,9
Middle East	729341	708289	71448,3	72030,9
Africa	100784	112410	13498,8	14185,8
Asia and Oceania	36246	36244	10875,8	12036,4
World Total	**1277182**	**1081813**	**171940**	**192720**

Table 3. Atmosphere pollution by fossil fuels burning (kg emissions per TJ of consumed energy).

Emissions	**Natural gas**	**Oil**	**Coal**
Nitrogen oxides	43	142	359
Sulphur dioxides	0.3	430	731
Solid particles	2	36	1 333

Source: US Environmental Protection Agency; American Gas Association (AGA).

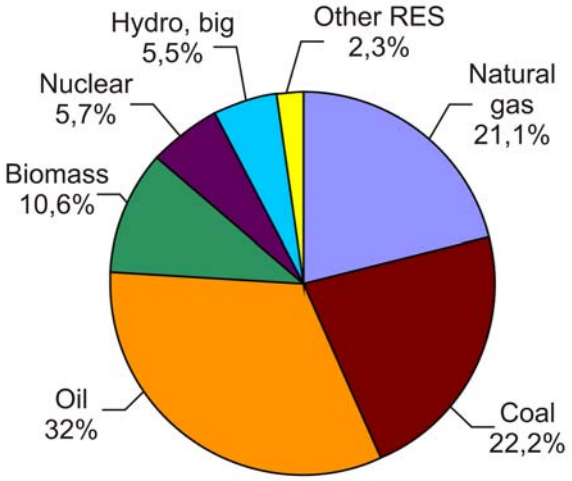

Figure 3. World consumption of primary energy**:** 2002, 451 EJ.

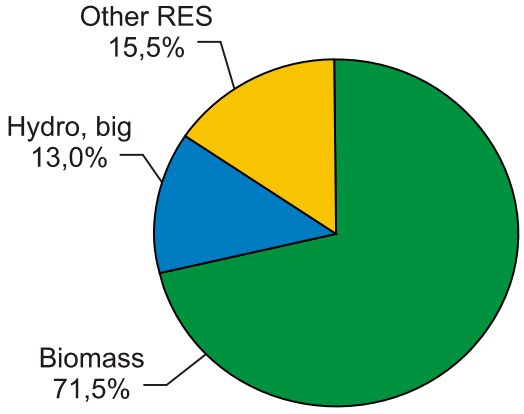

Figure 4. Structure of RES consumption in the world: 2002, 69,4 EJ.

There are other estimations too. According to the estimations of ARAMCO, presented at a workshop organized by OPEC in 2005, until now it was extracted about 1 trillion barrels or approximately 18% of the proven reserves of 5,7 billion barrels of oil. These quantities are estimated

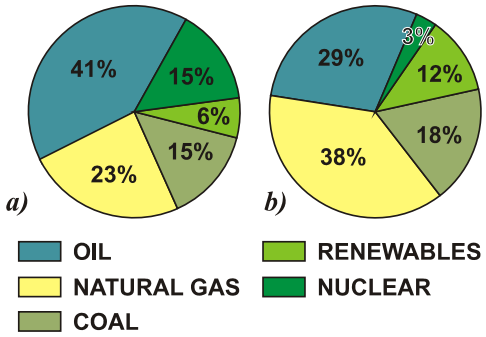

Figure 6. Primary energy consumption in EU member countries (a) and Romania (b).

to maintain the recent level of consumption for a 140 years time. *„Still, this should not impede the development of alternative sources of oil, because energy demands supplementary energy sources"* mentioned the reporter.

Oil, coal and gas made up 78,7 % of primary energy production in 2002 (fig. 3).

World consumption of primary energy of all forms increased in the former century more than 10 times and, in 2002, it reached about 451EJ ($451x10^{18}$J) or 10800 mln. t.e.p. [www.bp.com/ centres/ energy2002/ index.asp and www.undp.org/ seed/eap/ activities/wea]. The share of renewable energy sources (RES) equals (15,4 %). Fig. 4 shows the structure of primary energy consumption from renewable sources: traditional biomass supplies 71,5 %, hydraulic energy – 13,0 %, other renewable sources – 15,5 %. The concept of *"other renewable sources"* includes geothermal energy, wind and solar energy, micro- and mini-hydro energy, new forms of energy from biomass – liquid and solid biofuels, biogas.

According to the 2004 estimations of the US Department of Energy, the consumption of fossil fuels is increasing continuously, as these fuels continue to be the main energy sources used in the world (see fig. 5). The coming of such nations as China and India on the world market of fuel consumption confirms the hypothesis of future growth of daily consumption of fossil fuels. These countries are very big consumers as their population makes about half of the Earth's population.

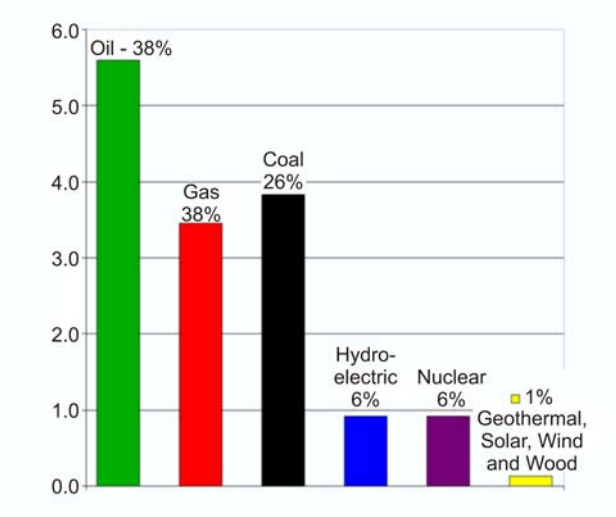

Figure 5. World energy needs supply in TW, 2004. USA Department of Energy.

The same information, for EU countries and Romania, is presented in fig. 6. Renewable energy has reached 13,8% of the world primary energy of 9958 Mtep in 2000 [8].

The consumption of renewable energy has increased by 2% in the last 30 years. At the same time, the term *„other categories"* refers to new renewable sources and includes geothermal, solar, wind, and other energy that has grown by 9%. In comparison with the lowest consumption in 1971, the wind energy increased by 52%, followed by solar energy - by 32%. About 58% of the renewable energy is consumed by the domestic, commercial and public sectors.

Renewable energy sources have reached the volume of 19% in 2000 (fig. 7) and are on the second place in the world production of electrical energy (after coal - 39%), followed by nuclear energy (17%), natural gas (17%) and oil (8%). The biggest share of renewable electrical energy belongs to hydraulic energy (92%), produced by large hydro stations constructed in dams. For the time being, the world production of electrical energy is environment unfriendly, and this is an issue for researchers to consider as well as the issue of energy resources exhaust.

In the long run, the world production of fossil fuels will reach a maximum growth, followed by a continuous reduction until it will reach the lowest level. Afterwards, the extraction will become disadvantageous economically or impossible from the engineering point of view. Countries, importing energy sources, will found themselves in difficult situation. The curve in fig. 8 shows an example of oil production decline forecast, based on the Hubbert peak theory of maximum [9,10]. The highest rate on the curve was estimated on the basis of production

and exploration rates. Hubbert peak theory is based on the fundamental observation that oil reserves are limited. Hubbert has developed a method for modeling the knowledge about oil reserves and extraction rate. At first, viewed with skepticism, nowadays this method is used widely by oil producing companies to forecast the future of the oil industry. Hubbert envisaged correctly the maximum rate of the world oil production half a century before the event occurred. Still, it's a topic to discuss which fossil fuel will be considered as *"the fuel of the future"*. In the opinion of some experts none of the traditional fossil fuels can be considered as *„the fuel of the future"*, because of their reserves depletion

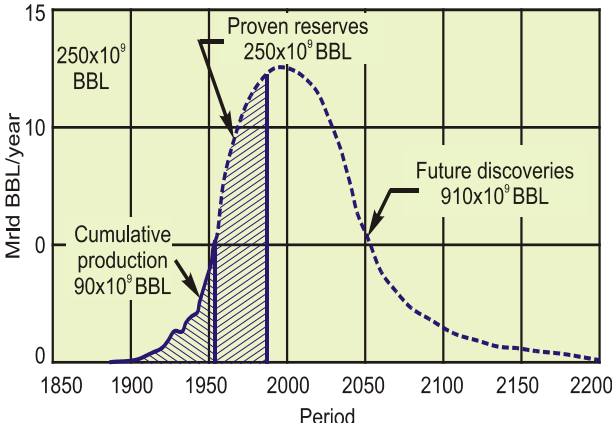

Figure 8. Curve of oil production, suggested by M. K. Hubbert in 1956.

(except coal) in the near future. Although coal reserves are relatively big, the impact of coal burning on the environment is so big that the use of coal in the current form has no future. Further on some graphs of oil production in several oil producing countries are presented. The standard Hubbert curve is taken as the starting point (fig. 9,a). Coordinates ***x*** and ***y*** replace the scales of time and oil production. The curve is drawn on the basis of equation:

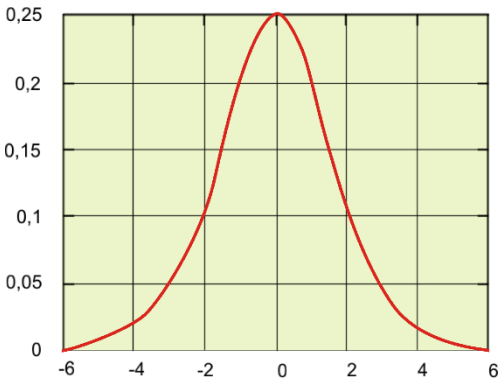

Figure 9. Hubbert curve.

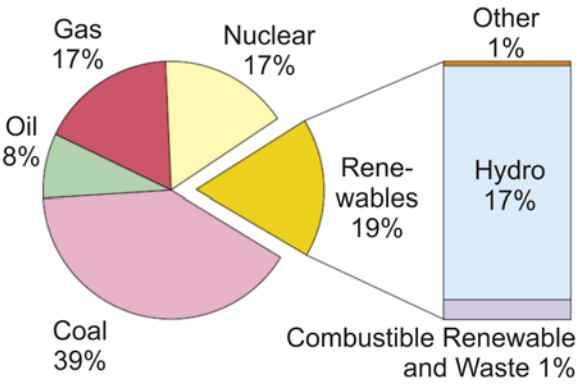

Figure 7. Share of renewable energy in global production of electrical energy.

$$x = \frac{e^{-t}}{\left(1+e^{-t}\right)^2} = \frac{1}{2+2\cosh t}. \tag{2}$$

As result of the investigations Hubbert came to the conclusion that, after the discovery of fuel reserves (oil, coal and natural gas), at the beginning, the production grows provisionally exponential, more efficient facilities being installed. After reaching the highest rate, the decline of production follows, described by a provisionally exponential curve.

Having the data of oil production from the past times, Hubbert curve can be drawn by approximating data and it can be used to estimate future production. In particular, data of maximum rates of oil production or the total quantity of the produced oil can be estimated likewise. Cavallo [9] defined Hubbert curve used to forecast the maximum rate of oil production in the USA:

$$Q(t) = \frac{Q_{max}}{\left(1+ae^{bt}\right)^2}. \tag{3}$$

where Q_{max} are the total available reserves; $Q(t)$ – cumulative production, a and b are constant.

Maximum annual production is defined by the relation:

$$t_{max} = \left(\frac{1}{b}\right) ln\left(\frac{1}{a}\right). \tag{4}$$

Other methods were applied to define the maximum rate of oil production and they give almost the same results, as the whole. According to ASPO (Association for the Study of Peak Oil and Gas) (fig. 10), both conventional and unconventional production will reach the maximum rate in the year 2007 [11]. About 30% of unconventional fuel for cars (Diesel fuel, in particular) is produced from coal.

Geographical distribution of hydrocarbon reserves continues to be unchanged with a big concentration of oil in the Middle East (65%) and OPEC countries, and a more or less distribution between the Russia (37%) and the Middle East (35%)

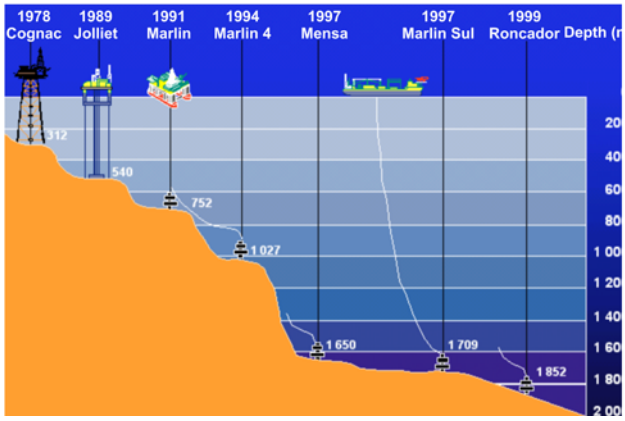

Figure 11. Depth records at exploring offshore oil.

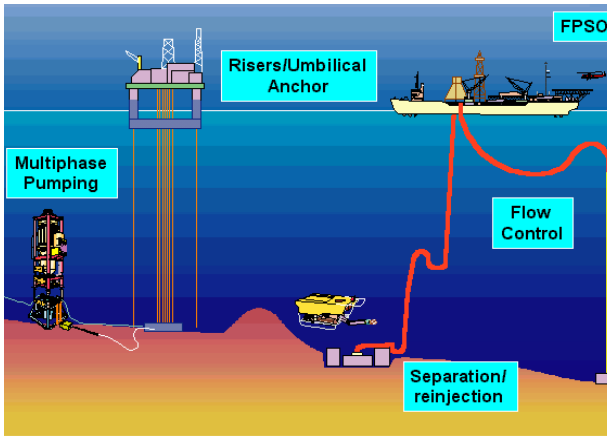

Figure 12. Key-technologies for oil drilling from deep deposits.

for gas. The newly discovered world reserves of about 500 mln billions of barrels of oil are concentrated in 29 oil deposits areas, including 7 coastal areas at drilling depths over 1000 m and 29 gas deposits areas, 8 of which located in the Middle Asia and 5 in Australia. From the total of 29 gas areas 5 are located at depths over 1000 m. 50% of newly discovered gas deposits are concentrated in 10 countries, on the one hand, in Iran and Saudi Arabia, on the other hand, in Brazil and Angola.

The new oil deposits are explored at bigger and bigger depths. The depth of coastal exploration increased from 300 m in 1978 to 1900 m (fig. 11) in 1999. During these 20 years the depth of continental shelf oil production continued to be limited by technological aspects. Nowadays, the potential of oil resources at depths have not been defined yet. But the issues of technological exploitation of these resources are significant: high pressure, low temperature, considerable depths, constant presence of ocean currents, etc. The use of conventional coastal solutions for big water depths is inconceivable, and new technologies are demanded.

The majority of companies producing offshore oil have a drilling experience of about 3000 m. The achievement of these objectives depends on the technological challenges for the next 5–10 years. An option of a future technology is shown in fig. 12.

We hope that the exhaustion of oil and natural gas reserves, the increase of difficulties related to their exploitation that will lead inevitably to price growth and to the understanding the threat of the ecological disaster towards which the mankind is

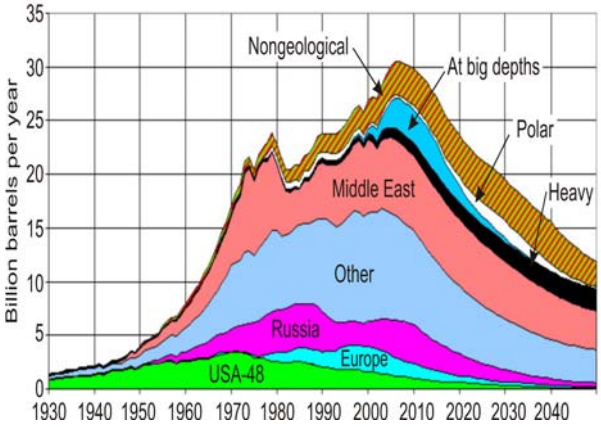

Figure 10. Estimation of maximum share of oil and gas production, 2004 (conventional and unconventional).

straightening, will change the balance in favour of renewable energy sources friendly to the environment. The world energy crisis leads to the growth of prices as result of partial dissatisfaction of current needs. The prices on oil on the world market have increased constantly with some fluctuations.

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.

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