Expected Rates of Renewable Energy Sources in Meeting of Energy Demands

Ferenc Kovács [1]

Ocakavany podiel obnovitelnych zdrojov energie pri naplneni energetickeho dopytu.
Taking the expected growth of the world's population and the estimated technological development and increase in living standards into account, the paper forecasts energy demands. On the basis of the actual production data of 380-400 EJ.year^{-1} in 2000 and data in publications, the author assumes the total energy demand to be 750-800 EJ.year^{-1} for 2030, 600-1,000 EJ.year^{-1} for 2050 and 900-3,600 EJ.year^{-1} for 2100.

The author analyses the appearance of the different energy types in the history of mankind giving the specific heat content and heating value of the different fuels. The environmental advantages, disadvantages, technical and economic limits of application involved in the use of primary renewable energy sources are also dealt with.

The analysis of the data in the different prognoses in publications gives the result that fossil fuels will meet 84-85 % of the total energy demand until 2030 in the foreseeable future. In 2050, the fossil rate may be 50-70 % and the rate of renewables may amount to 20-40 %. In 2100, the maximum fossil rate may be 40-50 % with a 30-60 % maximum rate of renewables.

On the basis of the results of investigation, the general conclusion may be that the realistically exploitable amount of renewable energy sources is not so unlimitedly high as many suppose. Therefore, it is an illusion to expect that the replacement or substitution of mineral fuels and nuclear energy can be solved relying solely on renewable energies.

Key words*: R*enewable Energy Sources, Energy Demands, maximum rate of renewables**,** maximum fossil rate**,** maximum rate of renewables

Introduction

In addition to other factors, the material well-being, living standards and culture of the society are decisively determined by the level of energy use. The natural conditions of the country have a considerable influence on features of the economy, as well. With the opening up of the world economy, other factors will also gain a decisive role, however. In spite of its scarce mineral resources and disadvantageous agricultural conditions, Switzerland is able to enjoy exceedingly high living standards. The same is true of Sweden despite of the decline in steel industry. Still, it can be stated that the production of minerals and the fulfilment of energy demands are fundamental factors in the improvement of the economy and living standards. The academician György Vajda investigates the fundamental issues of energy policy as well as the present and future tasks of energy supply in his two recent monographs [1, 2]. His books, covering the whole spectrum of the topic, provide the basis for this article, which gives an overview of the expected rates of the different fuels and energy sources for the wider professional public.

Expected Energy Demands in the 21st Century

The energy demands of mankind and the amount of energy available and used are not only characteristic of technological level in the narrow sense (operation of machinery and equipment, manufacturing processes, transport, heating, lighting, etc.) but also of other forms of human existence, cultural level and living standards in the broader sense. The level of development and living standards in the different countries (continents) are commonly characterised by specific energy consumption. Thus, while in 1994 specific primary fuel consumption was 325 GJ.person. year^{-1} in North America, 205 GJ.person^{-1}year^{-1} in Australia and Oceania, and 136 GJ.person^{-1}.year^{-1} in Western Europe, it only amounted to 35 GJ.person^{-1}year^{-1} in Central and South America, 24 GJ.person.$^{-1}$ year^{-1} in Asia and 13 GJ. person.$^{-1}$ year^{-1} in Africa ([1] p.29.) The relative rates of total energy consumption per year per person in relation to the unit (1.0) of world average are: United States 4.10; Western Europe 2.20; Hungary 1.50; China 0.33; India 0.11 and Black Africa 0.11. ([1] p.30.) Naturally, the extent of energy use depends on climate conditions, as well.

[1] Dr Ferenc Kovács, university professor, ordinary member of the Hungarian Academy of Sciences, Department of Mining and Geotechnology, University of Miskolc, Research Team of Geotechnology, Hungarian Academy of Sciences
(Recenzovaná a revidovaná verzia dodaná 3. 12. 2007)

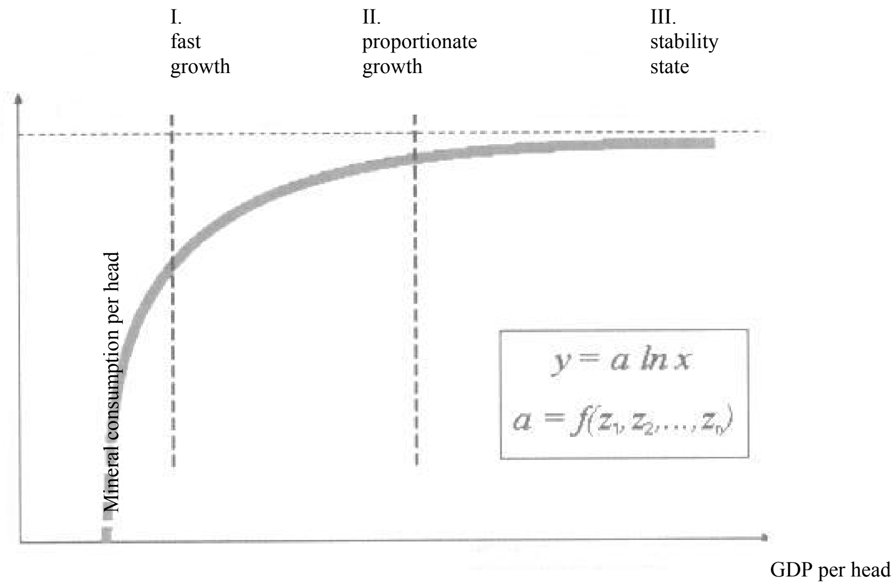

Fig. 1. Mineral consumption and GDP.

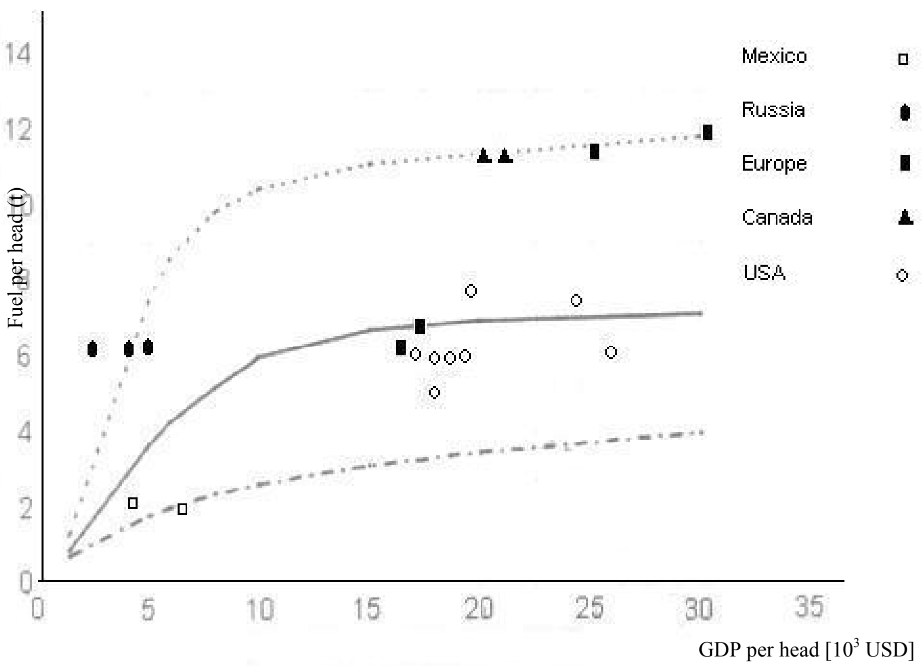

Fig. 2. Correlation of energy (fuel) consumption and national income.

Figure 1 shows what extent of change or increase in useful mineral consumption is attached to the different development levels of the society/economy ([3] Fig. 9.) At a lower development level, higher specific consumption levels belong to a high rate of increase, at a medium development level they belong to a proportionate rate of increase while at a higher development level the increase in demand becomes steady. Data in Fig. 2 (USA, Europe, Canada, Mexico) show that with lower national income levels – lower development levels – higher specific fuel consumption is needed for the same amount of increase in national income ([3] Fig. 7.) With a higher consumption level, the same specific fuel consumption results in a higher increase in GDP. Apparently, due to climatic differences, Russia, Northern Europe and Canada consume more fuel to ensure the same GDP than Mexico, Central Europe and the USA. With the same specific energy use, developed (rich) countries manufacture 'products' with higher intellectual content.

The long term energy demands of the world's population are basically determined by the number of population, specific energy use and the level of supply. The data above indicate that in our age the level of supply and specific energy consumption differ greatly in the different countries of the world displaying order- over 10 times – differences. However, the specification of total energy demand is difficult for two reasons. In one hand, in the different continents there is a different rate of increase in the number of population partly because of their different development levels and on the other hand, the increase in specific demands greatly depends on the present level of supply, as well. As most certainly, the increase in the number of population will take place in the 'developing' countries, where the increase in living standards, the progress to a higher level will take place with higher specific energy (fuel and raw material) consumption, the prognostication of the world's total energy consumption (increase) is only possible with considerable uncertainty. In spite of this, the problem will be investigated here on the basis of data taken from publications.

György Vajda links the world's total energy demand to the prognosis of world population ([1] pp.59. and 107.) In 2100, the world's total energy demand will be 3,600 EJ year^{-1} 'taking into account a moderate rate of increase'.

István Lakatos estimates the world's population to be 14 billion in 2100 (optimistic forecast), 10 billion (realistic forecast) or 7.5 billion (pessimistic forecast) ([4] Fig. 18.) According to the identical data in presentation [5] and publication [4], in 2000, the 6 billion people in the world consumed 384 EJ.year^{-1} energy with 0.5-0.6 living standards and 60 GJ.person^{-1} year^{-1} energy consumption. It is estimated that in 2100, the 8 billion people will need 1,600 EJ year^{-1} energy with 200 GJ.person^{-1}.year^{-1} specific energy consumption and 0.8 living standards as a result of the improvement in the latter.

According to Gergely Büki, the 21st century will be the century of energy. [6] He thinks that we can expect an escalation in energy supply problems, conflicts and tensions and in some cases explosions, too. Furthermore, he remarks that the expected development and problems in energy supply can naturally be forecast only with uncertainty. Here he refers to such inequalities in specific energy consumption as the gap between the USA's 295.6 GJ.person^{-1} year^{-1} and Africa's 16.5 GJ person^{-1}.year^{-1}. He says that the world's energy consumption was 442 EJ in 2003 and it is expected to be 758 EJ. year^{-1} in 2030, which means an annual 2 % increase.

Shashi Kumar gives the world's total energy consumption in 2002 to be 399 EJ .year^{-1} or 9.505 . 10^{6} toe (oil equivalent with a heating value of 42 MJ.kg^{-1}), and within it, he gives 4.7 . 10^{9} tons for coal production. [7] In the estimation of future energy demands, he takes different scenarios into account. On the basis of the increase in population and annual energy demands, he estimates energy demands in tons of oil equivalent (toe) and joule. The three alternatives are: strong, 1.72 % increase per year (A), medium, 1.34 % increase per year (B) and 0.74 % increase (C) restricted by environmental considerations (Tab. 1).

As regards the more remote future (2030, 2050, 2100), the sources consulted give considerably different predictions. The world's population is estimated to be around 7.5-9-12 billion in 2050 and 7.5-10-15 billion in 2100 (Fig. 3). Taking the 2000-2004 value of 370-445 EJ.year^{-1} as the starting point, the total energy demand is estimated to be 750-800 EJ.year^{-1} in 2030, 600-1,000 EJ.year^{-1} in 2050 and 900-3,600 EJ.year^{-1} (10^{18} J) in 2100 depending on the development scenario and ecological limitations. As we progress in time, the maximum deviation between the different scenarios increases to a round fourfold difference in the 2100 data (Fig. 4).

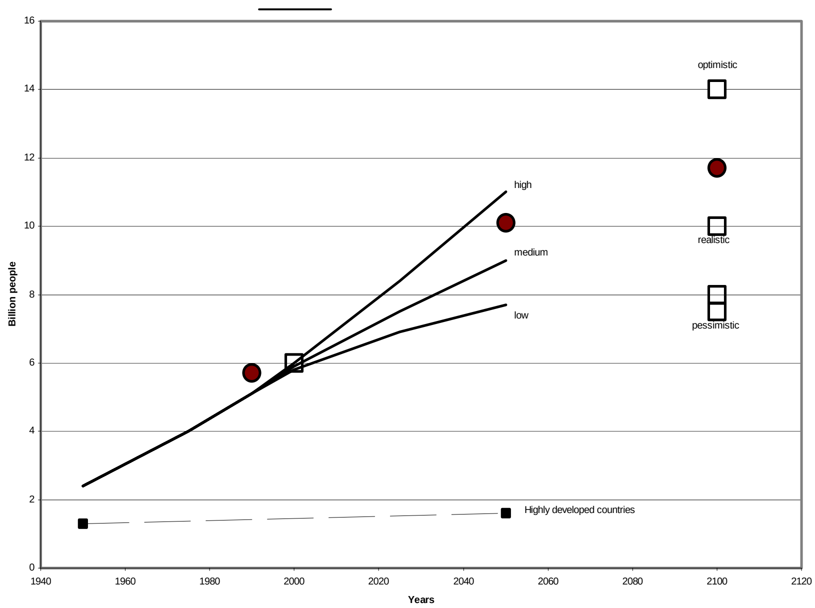

Fig. 3. *Prognoses for world population Vajda Gy.* ——— *; Lakatos I.* □*; S. Kumár* ●

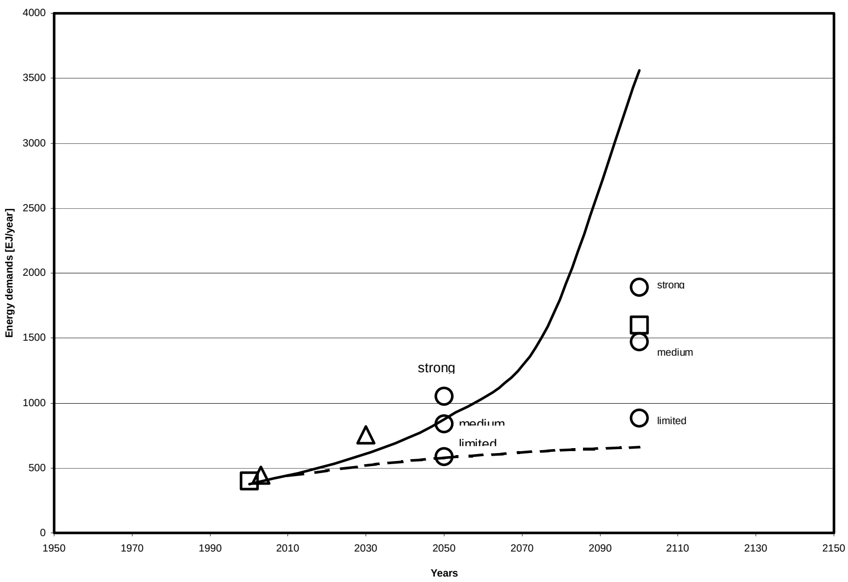

Fig. 4. *Prognoses for world energy demands Vajda Gy. ——— ; Lakatos I. □; Büki G. Δ; S. Kumár ○; I. Yantovska - - - -*

Table 1 Expected energy demands in 2050 and 2100 (Shashi Kumar [6])

Year	Characteristics	Increase in energy demands per year		
		Strong, 1.72 [%] **(A)**	**Medium, 1.34** [%] **(B)**	**Ecologically limited, 0.74** [%] **(C)**
1990	Population 10^9	5.3	5.3	5.3
	Primary energy demand 10^9 tons oil equivalent	9	9	9
	Energy demand (10^{18} J)	378	378	378
2050	Population 10^9	10.1	10.1	10.1
	Primary energy demand 10^9 tons oil equivalent	25	20	14
	Energy demand (10^{18} J)	1,050	840	588
2100	Population 10^9	11.7	11.7	11.7
	Primary energy demand 10^9 tons oil equivalent	45	35	21
	Energy demand (10^{18} J)	1,890	1,470	882

In the estimation of primary fuel demands and the expected rates of fuel types (fossil, renewable, nuclear), either some kind of average or several alternatives may/should be used. Probably, a 1,000-1,200 EJ. Year^{-1} approximate/average primary energy demand can be taken into account for 2050 and 1,500-2,000 EJ.year^{-1} for 2100. (György Vajda forecasts a 3,600 EJ.year^{-1} demand for 2100 even with a 'moderate rate of growth'!)

The appearance of the different fuels in the history of mankind

A considerable part of technological development in the history of mankind is constituted by the chronicle of the utilisation of heat emitted during combustion. The beginning was the utilisation of heat acquired by burning vegetable, animal or domestic wastes. The development of tools made it possible to produce firewood, which was the most important fuel in developed countries for a long time.

Ore processing and metallurgy used wood and charcoal in large quantities (in mining, wooden support structures were used) until there appeared (first in England and Holland) the danger of the destruction of forests so due to environment protectional (oxygen production) considerations, iron production was transferred to Sweden and Russia, abounding in wood at that time. (Today, the world's leading country in pig iron production is Brazil with 120 Mt per year. In this country, there are still jungles although pig iron is produced using coke.) The industrial revolution put an end to the dominance of firewood as a major fuel the extravagant cutting down of forests was not acceptable any more so coal became the major energy source as well as the main driving force in the first industrial revolution having an almost exclusive role in electricity production. The idea of the utilisation of water power also emerged with the appearance of electricity. (At the end of the 19 th century, coal from Tatabánya provided all the energy for the steam engines (furnaces) and the electrical system of the Hungarian capital, Budapest, thus making the city's sudden development possible.)

During the spread of internal combustion engines, mineral oil and oil products played an important role in transport, the chemical industry and the different applications of combustion technology. Besides coal and oil, in the middle of the 20 th century the utilisation of natural gas became important, and so did nuclear energy, almost at the same time.

In the replacement of hydrocarbons, especially engine fuels (primarily diesel oil), the most popular issue in our age is the use of biofuels. The production of biofuels requires valuable agricultural products (oil seeds, maize) and production areas, which limits its spreading to some extent (to replace diesel oil in Hungary, rape seed should be produced in three fourth of the fields). On the other hand, the diesel oil demand of production, the natural gas demands of artificial fertilisers and the energy demands of transformation into fuel consume a very high amount of hydrocarbons. While in the case of oil, production and transformation require 15 % of its energy content, in the case of maize ethanol this rate is 80 %. [8]

Experts favouring bioenergy and energy (grass) plantations conceal the fact that the production of vegetable fuels and the processes of ploughing-sowing-harvesting-transportation-preprocessing consume 80-90 % of the heat content of the plant, leaving only 8-12 % of its carbon (C) content to be utilised in the form of electrical energy. Such a use of the wood of forests is only economical if forests are freely available as national property and there are no expenses of plantation but only production costs. It may occasionally even be the case that the electrical energy produced is subsidised by the state.

Table 2 shows the heat value (specific energy content) properties of the different fuels (energy sources). At the same time, the table shows the chronology of the appearance and spreading of the different fuel types. The general tendency is that in order to meet the specific and absolute energy demands of an ever growing population, during its history mankind has put into use fuels with higher and higher specific energy content. Wood as a fuel (source of energy) played a decisive role in the ancient times and in the Middle Ages. Is it possible that it will gain ground nowadays with multiple state (taxpayer) subsidy at the cost of coal or nuclear energy-based electrical energy due to the fashion of the day, the environmental concerns – as if its carbon (C) content did not burn to become carbon dioxide (CO_2) ! And this would happen with the support of the same people who, in other occasions, argue for the protection of oxygen producing forests and against the effect of the cutting down of forests enhancing the risk of floods.

Tab. 2. Heating values of major fuels suitable for electrical energy production.

	Fuel	**MJ.kg^{-1}**
1.	Lignite (in natural form)	3.5-10
2.	Turf	6.5-17
3.	Wood	9-17
4.	Brown coal	21-25
5.	Charcoal	31
6.	Coke	25-31.5
7.	Black coal	25-33.5
8.	Anthracite coal	34.5-35.5
9.	Residual oil	38
10.	Natural gas	18-40
11.	Fuel oil	41-42
12.	Liquid fuel	42,000
13.	PB gas	45-47
14.	Natural uranium ore	500,000
15.	U 235 isotope	80,000,000
16.	Fusion (D, T)	400,000,000

The basic source of bioenergy is the energy of solar radiation. The energy demand of photosynthesis on the Earth is $3.2 \,.\, 10^{21}$ J.year^{-1}, 30 %-30 % of which is demanded to sustain the oceans, tropical and subtropical forests and life on the continents. Of the $1.\, 10^{21}$ J. year^{-1} demand of continental life, 2.5 % is that of agriculture and forestry with a 1 . 10^{18} J .$year^{-1}$ demand of nutritional energy. Gy. Vajda [1] calculates the potential energy that can be gained from biomass to be 230 EJ.$year^{-1}$, which amounts to 6.4 % of the 3,600 EJ.$year^{-1}$ total energy demand forecast by him for the year 2100 and only to 14 % of the 1,600 EJ. $year^{-1}$ demand. Naturally, it remains a question to what extent the potential opportunity may be realised.

The limitations and adverse environmental effects of the use of primary 'renewable' energy sources

Loud advocates of the use of primary RENEWABLE energy sources often argue against the use of fossil and nuclear fuels – with good intentions but in many cases non-professionally – only and exclusively referring to the environmental impacts, emphasising above all the formation of carbon dioxide and its partly real, partly exaggerated effects in the case of coal, oil and gas, as well as the risks of using nuclear energy, not mentioning (concealing) the disadvantages and problems involved in the use of the 'clean' energies. Namely, they do not mention that in its primary form solar, geothermal and wind energy cannot be transported and biomaterials and water power can only be transported with doubtful efficiency only. They fail to mention that nowadays disregarding transport demands for liquid and gaseous fuels, the energy type of decisive importance is electrical energy, which cannot be stored in a considerable amount. They fail to mention that solar and wind energy are only periodically available and when they are not, traditional power plants must make up for the lacking capacities which may occur unexpectedly due to meteorological changes (sunshine, wind), keeping surplus capacities on standby. They fail to mention that the energy density of renewable energy types is relatively low so they must be available in large quantities (number of pieces, surface, amount). They fail to mention that due to low energy density and low transformation efficiency, the production costs of electrical energy with these is 1.5-3.5 times as much as the specific costs of traditional (fossil and nuclear) primary fuels. They fail to mention that the use of renewable 'clean' energies also has adverse environmental impacts. The production and disposal of solar cells require toxic chemical substances, during the use of geothermal energy the lukewarm water containing minerals (salts) may damage underwater environment and the possible-desirable compressing back may require more energy than what can be gained from 'hot' water. The use of biomaterials and wood deprives nature of its 'oxygen factory' not to mention the fact that both the carbon (C) content of biomaterials and the hydrocarbon content of biodiesel burns to transform into carbon dioxide during utilisation.

One of the basic materials of biofuels, palm oil must be imported, primarily from Indonesia, which has specialised in palm plantation and oil production, and largely due to this, has become the world's third polluter after the USA and China. In this country, vast turf areas have been dried to plant palm-trees. From the turf, a horrendous amount of harmful substances get (have got) into the air in the form of the stored coal, carbon dioxide and methane [12].

During the production of biodiesel from vegetable oil, esterisation is, for example, done with sulphuric acid and during the combustion at high temperature of the residual material formed at the neutralisation of the acid with limestone milk, dioxin and other toxic substances are formed.

Certain actions by civil campaigners for the enhanced use of 'clean' energies verge on anachronism. They alarm against air and noise pollution in Budapest but do everything against the construction of the motorway ringroad, as well. In towns and villages, hired demonstrators protest against the construction of state-of-the art waste disposal sites and incinerators while the environment of the municipalities, forests and roads is covered with litter all over the country. Environmental activists shake the railings around nuclear power plants, claiming the right to assess power plant safety and at the same time they do their best to hinder the construction of absolutely clean hydroelectric power plants. On the Danube, for example, there are altogether 55 hydroelectric power plants, with 10 (ten) on the 220 km long Austrian section. We know how many there are on the Hungarian section although according to Austrian standards there could work two just on the Pozsony-Komárom section.

In relation to the possibilities and presently existing limitations of the expected use of renewable energies, it is worth quoting the monograph and study of two widely renowned experts who are at the same time autonomous personalities, as well.

György Vajda writes: 'If we do not want to disturb the order of Nature, we should only draw on a relatively small fraction of renewable energy sources for the purpose of energy supply. This fraction would be enough to cover a significant part of energy demands if two circumstances did not slow down the spread of renewable energies. One is high specific investment costs which restrict economic attractivity. With the exception of hydroelectric power plants, the other is low transformation efficiency, which means that many times more renewable energy is needed for the same level of service than fuel. ([2] p. 25.)

Furthermore, György Vajda writes:

'As a result of the subsidies, the utilisation of renewable energies will spread due to technological development, mass production and experience alleviating the obstacles of application. Under favourable circumstances certain solutions are already verging on competitiveness. However, not even the most successful development can change the situation that their realistic exploitability is not so infinitely large as many suppose. Therefore, it is an illusion to expect that mineral fuels and nuclear energy can solely be replaced or substituted by relying on renewable energies.

If every realistic possibility is taken into account, not even the whole of renewable energies could cover the world's present energy demands and would be able to cover only a fraction of the multiple demands at the end of the 21st century. Therefore, renewable energies represent an important possibility but mean only a contribution and not a radical solution to the problem of the world's energy supply.

... the considerable demand for resources (investment costs) involved also confirms that the quick spread of renewable energies cannot be forecast although it would be desirable.' ([2] p. 234.)

In his study, Gyula Csom writes: 'The increase in the rate of renewable energy sources simultaneously reduces Hungary's dependence on imports and improves the conditions of sustainable development including the attainability of environmental and climate protectional objectives. Without subsidies, however, the application of renewable energies is not yet profitable nowadays and especially in the case of wind power also causes system control problems. Partly due to leaving the latter out of consideration, renewable energies are overestimated in public opinion. Taking the outlined advantages and disadvantages into consideration together involves that in the application of renewable energies it is not reasonable to go beyond the tolerable level of subsidies which can still be handled by system control. In realistic assessment, the rate of the use of renewable energies may reach about 10% until 2030 in Hungary [9].

After the ideas of experts investigating the problems of energy supply, let me quote the opinion of Iván Gyulai ecologist, who warns against some nowadays very popular views also incorporated into international (EU) policy [12].

'The partial replacement of fossil fuels by bioethanol and biodiesel involves some quite rough consequences, as well.

In Hungary, too, authorities are of the opinion that wood combustion may at least partly provide a solution. The agriculture of the country may suffer due to it, biodiversity may decrease, which may be caused by the wood plantations established for energy supply purposes if their area grows.'

Those arguing for renewable energy sources also often mention that we should economise on fossil fuels (coal, mineral oil, natural gas) because they are available on the Earth in only a limited amount in order to take care of the needs of future generations. This view lacks any kind of rational considerations or economic principles. Economic rationality requires that anything that can be produced economically these days should be produced, sold and used because present profits will bring interests in the future and in all probability, the future production of the given stock will be more highly evaluated, not to mention the fact that due to technological development and the putting into use of new types of material and energy, the workability (economic) criteria of the majority of primary mineral raw materials will tend to toughen (in the long run) so the same raw material quality may be worth less at the same price in the future.

For example, if we index the price of mineral oil fifty years ago with the inflation rate of the dollar, the present oil price should be 70-80 USD but nowadays 40-50-60 dollar prices are quite common instead.

On the other hand, it is unecessary to spare coal for future use because the presently known coal reserves are enough for several hundred or even a thousand years and the general experience is that the newly explored reserves exceed the rate of production.

Thirdly, during its so far history, mankind has always found proper solutions to the current problems of the given period finding after stalks first wood, then coal, oil and gas, nuclear energy and solar cells and is beginning to discover fusion energy now. (Or perhaps we are beginning to discover sources of bioenergy again?)

Economising on fossil fuels is not really justified by the size of the presently explored reserves. Presently known mineral oil reserves seem to be enough for 40-60-80 years, those of natural gas for 60-80-120 years and coal reserves for 200-1,000-3,000 years. According to expert opinion: 'nowadays reserves increase faster than production.' ([1] p. 108.)

Facts and prognosis data in relation to the use of renewable energy sources

According to György Vajda, the world rates of primary energy use in 2000 were the following [1,2]:

Mineral oil 34 %, natural gas 22 %, coal 31 %, fossil altogether 82 %, nuclear energy 6 %, renewables altogether 7 %.

Facts for 2004 and prognosis for 2030 by Gergely Büki ([6] p. 13., Fig. 3):

In the determination of prognosis data, the author calculates with an identical rate of increase and an unchanged rate of percentage for fossil fuels, with a lower increase rate for nuclear energy and a higher one for renewables.

Referring to Exxon Mobil, József Pápai ([10] p. 2.) gives 37 % mineral oil, 26 % natural gas, 21 % coal, altogether 84 % fossil rate, 5 % for nuclear energy, 3 % for water, 6 % for biomass and 2 % for solar-wind energy, altogether 11% for renewable energies. These rates are essentially identical with those given by Gergely Büki.

Tab. 3. Facts for 2004 and prognosis for 2030 by Gergely Büki [6].

	2004			2030	
	EJ	**%**	**%**	**%**	
Mineral oil	174	37.5	86.2	33.0	84.0
Natural gas	107	23.1		25.0	
Coal	119	25.6		26.0	
Nuclear energy	28	6.0		6.0	
Renewables	36	7.5		10.0	

Shashi Kumar [7] gives the data for 1990 and prognosis for 2050. (Tab. 3) At the different alternatives, mineral oil and coal are taken into consideration with a decreasing and natural gas with an increasing rate until 2050. The rate of fossil fuels is estimated to be between 51-73 %, nuclear energy between 4-12 % and renewables (including water) between 22-39 %. In the ecologically restricted alternative (with a relatively low, $14 \cdot .10^9$ toe), the rate of renewables is 37-39 %.

The objective of the EU, and thus that of the developed countries of Europe, is to increase the rate of renewable energies to 12 %. ([2] p. 234.) Naturally, it is doubtful what this 12 % in 2010 represents for the world average. The population of Europe amounted to 8 % of the world's population while energy use in Europe was 18.1 % of that of the world (in 1994).

According to IEA data, in 2000 the rate of renewables was 18 % ([1] p. 105.) According to S. Kumar, this data is 18 % (1990), according to Gergely Büki, it is 7.5 % and the rate expected for 2060 is 30-40 % (IEA).

According to the data given by György Vajda, the maximum potential of renewable energies is 1,100 EJ: 3,600 EJ = 30.5 % in 2100. ([1] p. 107.) The world's annual realistically utilisable renewable potentials as the percentage of the total energy demand in 2100 according to the relative rates presented are 0.8 : (5-6) = 13-16 %, that is, a round half, 50 % of the maximum potential (30.5 %). ([2] p. 235. Fig. 23) If the expected total energy demand for 2100 is assumed to be 1,600 $EJ.year^{-1}$, then the maximum potential of the total renewable energies is 1,100 : 1,600 = 0.687 ≈ 69 %. Calculating with the former relative rate, a (1,600 : 3,600 = 0.44), (13-16 %) : 0.44 = 29-36 % maximum renewable rate may be expected for 2100.

Publication [1] also investigates the expected energy structure for the 21st century. According to the diagram in Fig. 4 in the book, the rate of mineral oil is 39 %, that of natural gas 23 %, coal 24 %, the total rate of fossil fuels may be 86 %, nuclear energy 6 % and the total rate of renewables (geothermal, solar, water) is 8 %. According to the study, the rates for 2050 will be the following: mineral oil 26 %, natural gas 21 %, coal 23 %, the total rate of fossil fuels 70 %, nuclear energy 12 % and the total rate of renewables will be 18 %. For the second half of the 21st century, the study forecasts a more significant change with mineral oil 9 %, natural gas 4 %, the total rate of fossils 43 %, nuclear energy 22 % and renewables 35 %.

On the basis of summing up the data presented, the estimated rates of renewable energies for the 21st century are the following (Tab. 4).

According summ of the data presented, prognosis are practically identical for the near future (2030), when the authors expect a rate of 84-86 % for fossil fuels and 10-14 % for renewables altogether. For the more remote future (2050), 'realistic' prognosis predict a 50-70 % fossil rate, 12-18 % for nuclear energy and 20-40% for renewables altogether. In relation to the remote future (2100), the view that mineral oil and natural gas reserves will 'soon' run out is more prevalent, so prognosis include considerably higher, 30-50-60 % renewable rates.

In relation to the expected, 'apparently high' rates of the presently known renewable energies in the remote future (2050-2100), it is justified to refer back to the fact that it is possible to utilise biomaterials with a relatively low, 10-20 % output efficiency (in the case of electrical energy or liquid fuel production). Furthermore, it should be repeated that the production in a higher order of biomaterials (wood, grass, rape, maize) may involve ecological problems, as well.

Tab. 4. Estimated rates (%) of renewable energies for the 21st century.

Author, reference	**2030**		**2050**		**2100**	
	Fossil	**Renewable**	**Fossil**	**Renewable**	**Fossil**	**Renewable**
Gergely Büki [6]	84	10				
József Pápay [10]	84	11				
S. Kumar [7]			51-73	22-39		
A. Füst – R. Hargitai [11]	86	14	70	30	43	57
IEA [10] (in 2060)				30-40		
György Vajda [1,2] (Absolute maximum)						30
György Vajda [1,2] (Realistic maximum)						13-16 % with a total energy demand of 3,600 EJ 29-36 % with a total energy demand of 1,600 EJ

This paper investigates the expected use of the presently known renewable energy types. The possible application of fusion energy production and newer (magnetic) energy sources as the opportunities of the remote future is not dealt with here.

References

[1] Vajda, G.: Energiapolitika. Magyarország az ezredfordulón. Stratégiai tanulmányok a Magyar Tudományos Akadémián. [‘Energy policy. Hungary at the turn of the millennium. Strategic investigations at the Hungarian Academy of Sciences.’] *Budapest, 2001. Magyar Tudományos Akadémia*.

[2] Vajda, G.: Energiaellátás ma és holnap. Magyarország az ezredfordulón. Stratégiai tanulmányok a Magyar Tudományos Akadémián. [‘Energy supply today and tomorrow. Hungary at the turn of the millennium. Strategic investigations at the Hungarian Academy of Sciences.’] *Budapest, 2004. Magyar Tudományos Akadémia Társadalomtudományi Központ.*

[3] Puchkov, L. A.: Mineral consumption and macroeconomics – strategic analysis. *20 th World Mining Congress 2005. 7-11 November, 2005. Tehran, IRSN ‘Mining and Sustainable Development’ pp. 51-59*.

[4] Lakatos, I.: Perspectives of Oil and Gas Production/Consumption in the 21st Century.

[5] Kovács, F.: Meddig és mit bányásszunk? [‘What and until when should we produce in mining?’] Mindentudás Egyeteme Vol.3. pp. 69 - 95. *Kossuth Kiadó, Budapest, 2004*.

[6] Büki, G.: A jövő és az energia. [‘Energy in the future.’] *Mérnök Újság Vol. XIII. (2006) No. 11. (November) pp. 12-15*.

[7] Shashi, K.: Global Coal Vision – 2030. 19th World Mining Congress, *1-5 November, 2003, New Delhi. Mining in the 21st Century – Quo Vadis ? pp. 137-148*.

[8] Varró, L.: Robbanómotor – még néhány évtizedig tart az olaj korszaka. [‘Combustion engines – the age of the oil will end in a few decades’] *Mérnök Újság Vol. XIV (2007) No. 1. (January) pp. 13-15*.

[9] Csom, G.: Energiapolitikai prioritások. [‘Priorities in energy policy.’] *Magyar Tudomány. Vol. 167. (2007). No. 1. pp. 4-10*.

[10] Pápay, József: Kőolaj- és földgáztermelés a XXI. században. [‘Oil and gas production in the 21st century’] *Bányászati és Kohászati Lapok. Kőolaj és Földgáz. Vol. 139. (2006) No. 3. pp. 1-12*.

[11] Füst, A., Hargitai, R.: A jövő potenciális energiaforrásai. [‘Potential energy sources of the future’] *Magyar Tudomány. Vol. 167. (2007). No. 1. pp. 62-72*.

[12] Gyulai, I.: Észak-Magyarország. 9 February, 2007. p.4.