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SUSTAINABLE ENERGY DEVELOPMENT

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The paper presents an overview of the sustainable energy development and is aimed to emphasize the important aspects relevant to this activity. A short introduction, related to present energy outlook with a survey of available data, is presented. This gives the possibility to assess the motivation for a sustainable energy development.
Special attention is devoted to the definition of sustainability and its generic meaning. In this respect, particular attention is devoted to the discussion of different aspects of sustainability in the present world. In order to present an engineering approach to the sustainable development, attention is devoted to the review of sustainability criterions as they have to be introduced in the future products.
The main emphasis is given to review a potential development in the energy engineering science which may lead to a sustainable energy development. Seven major areas are listed with specific problems and their relevance to the sustainable energy development. This includes the following areas: energy resources and development; efficiency assessment; clean air technologies; information technologies; new and renewable energy resources; environment capacity; mitigation of nuclear power impact to the environment.
The education system is the milestone for any economic development. In this respect, the sustainable energy development will require special attention to be devoted to the new development of education system. The distance learning education system is envisaged as the potential option for the knowledge dissemination of the new energy technologies.

Key words: energy, energy resources, new and renewable energy resources, environment, nucler power

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ENERGY resources have always played an important role in the development of the human society [1]. Since the industrial revolution the energy has been a driving force for the modern civilization development. Technological development and consumption of energy, along with the increase in the world population, are interdependent. The Industrial Revolution, began a drastic increase both in consumption and population of the world [2].

The history of life on the Earth is based on the history of photosynthesis and energy availability [3]. The history of our planet lies on the capture of the solar energy and its conversion by photosynthesis in plants and phytoplankton as organic molecules of high energy content. The plants convert this energy into other organic compounds and work by biochemical processes. By capturing the solar energy photosynthesis paves the way for biological evolution.

The Sun is an enormous machine that produces energy by nuclear fusion. Every year the Sun sends $5.6 \cdot 10^{24}$ joules of energy to the Earth and produces $2 \cdot 10^{11}$ tons of organic material by photosyntesis. This is equivalent to $3 \cdot 10^{21}$ joules/year. Through the billions of years since the creation of the planet Earth this process has led to the accumulation of an enormous energy in form of different hydrocarbons. Mankind's energy resources rely heavily on the chemical energy stored in the fossil fuel. Table 1 shows assessed energy resources [4].

All natural resources are, in theory, renewable but over widely different time scales. If the time period for renewal is small, they are said to be renewable. If the renewal takes place over a somewhat longer period of time that falls within the time frame of our lives, they are said to be potentially renewable. Since renewal of certain natural resources is only possible due to geological processes, which take place on a long time scale, for all our practical purposes we should regard them as non-renewable. Our use of natural material resources is associated with no loss of matter as such. Basically all earth matter remains with the earth, but in a form in which it can not be used easily.

The abundant energy resources at the early days of the industrial development of the modern society have imposed the development strategy of our civilization to be based on the anticipated thinking that energy resources are unlimited and there is no other limitations which might affect human welfare development. It has been recognized that the pattern of the energy resource use has been strongly dependent on the technology development. In this respect it is instructive to observe [5, 6] the change in the consumption of different resources through the history of energy consumption. Worldwide use of primary energy sources since 1850 is shown in Fig. 1 [5]. F is the fraction of the

Table 1. World non-renewable energy resources in 1995

	Total [10^9 tons]	CPE [%]	North American [%]	Latin America [%]	West Europe [%]	Africa [%]	Asia-Pacific [%]	Middle East [%]
Oil	95	11.5	4.9	13.5	3.2	7.9	2.7	56.3
Gas	85	41.5	8.3	3.7	3.5	6.1	6.2	26.7
Coal	530	46.6	26.6	0.6	9.8	7.5	8.9	0.00

market taken by each primary-energy source at a given time. It could be noticed that two factors are affecting the energy pattern in the history. The first is related to the technology development and, the second, to availability of the respective energy resources. The world energy consumption is shown in Fig. 2 [7].

Looking at the present energy sources consumption pattern, it can be noticed that oil is a major contender, supplying about 40% of energy. Next, coal supply is around 30% , natural gas 20% and nuclear energy 6.5%. This means that current fossil fuel supply is 90% of the present energy use. In the last several decades our civilization has witnessed changes which are questioning our long-term prospect. Fossil fuel, non-recyclable is an exhaustible natural resource that will be no more available one day. In this respect it is of common interest to learn how long fossil fuel resources will be available, as they are the main source of energy for our civilization. This question has attracted the attention of a number of distinguished authorities, trying to forecast the energy future of our planet. The Report of the Club of Rome "Limits to Growth", published in 1972 [8], was among the first ones which pointed to the finite nature of fossil fuel. After the first and second energy crisis the community at large has become aware of the possible exhaustion of fossil fuels. The amount of fuel available is dependent on the cost involved. For oil it was estimated that proved amount of reserves has, over past twenty years, leveled off at 2.2 trillion of barrels produced under $ 20 per barrel. Over the last 150 years we have already used up one-third of that amount, or about 700 billion of barrels which leaves only a remaining of 1.5 trillion of barrels. If compared with the present consumption, it means that oil is available only for the next 40 years. Fig. 3 shows the ratio of the discovered resources to the yearly consumption for the fossil fuels [7].

From this figure it can be noticed that coal is available next 250 years and gas for the next 50 years. Also, it is evident that as much as the fuel consumption is increasing, new technologies aimed to the discovery of new resources are becoming available, leading to a slow increase of the time period for the exhausting of the available energy sources.

It is known that the energy consumption is dependent on two main parameters. Namely, the amount of energy consumed per capita and the growth of population. It has been proved that there is a strong correlation between the Gross Domestic Product and Energy consumption per capita. Fig.4 shows the economic growth and energy consumption for a number of countries, in 1990 [8].

There is a number of scenarios which are used for the forecast of the world economic development. With the assumption that the recent trend in the economic development will be conserved in the next 50 years, and considering the demographic forecast in the increase of human population, the future energy consumption could be calculated, as shown in Fig. 5.

Compared with the available resources it is easily foreseen that the depletion of the energy resources is an immanent process which our civilization will face in the near future. Nevertheless, whatever is the accuracy of our prediction methods and models, it is obvious that any inaccuracy in our

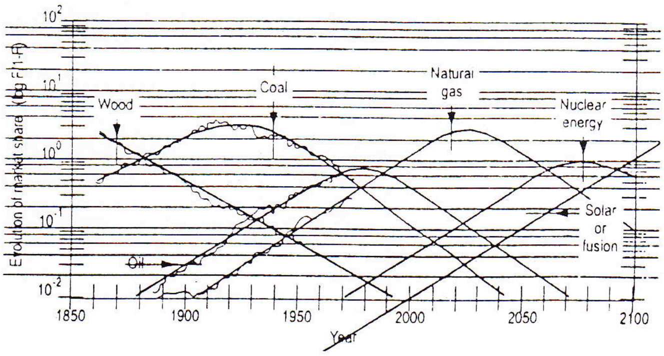

Figure 1. Market penetration of primary energy sources

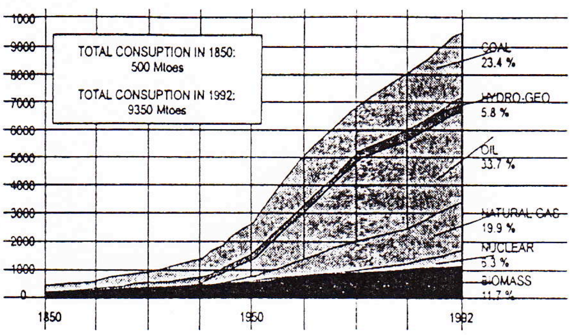

Figure 2. World energy consumption

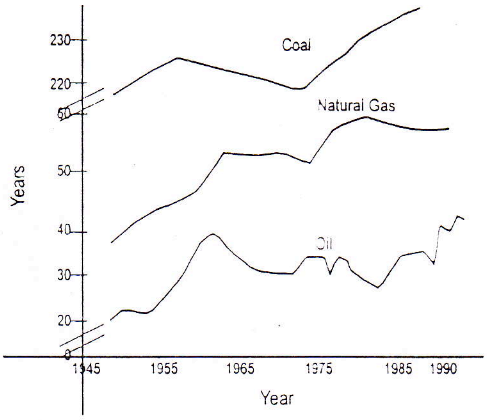

Figure 3. Residual life forecast of energy resources

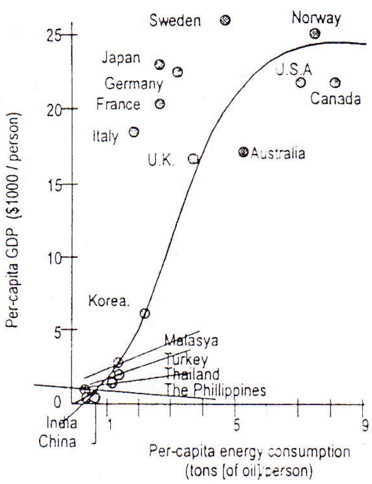

Figure 4. Economic growth and energy consumption

calculation may affect only the time scale but not the essential understanding that the energy resources depletion process has begun and requires the human action before adverse effects may irreversibly enforce.

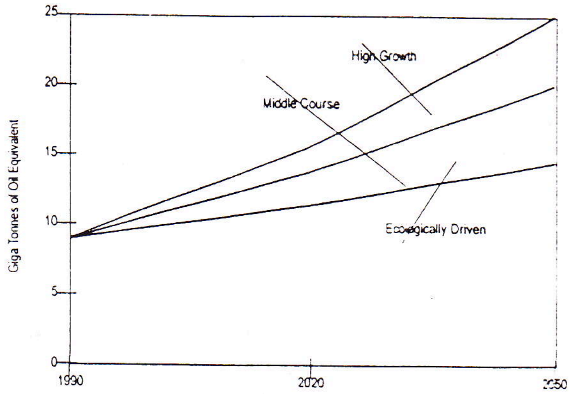

Figure 5. Future energy consumption forecast

Natural resources scarcity and economic growth are in fundamental opposition to each other. The study of the contemporary and historical beliefs showed that: (1) natural resources are economically scarce, and become increasingly so with the passage of time; (2) the scarcity of resources opposes economic growth. There are two basic versions of this doctrine. The first, the Malthusian, rests on the assumption that there are absolutely limits; once these limits are reached the continuing population growth requires an increasing intensity of cultivation and, consequently, brings about diminishing returns per capita. The second, or Ricardian version, viewed the diminishing returns as current phenomena reflecting the decline in the quality of resources brought within the margin of a profitable cultivation. Besides these two models, there is also the so called "Utopian case" where there is no resources scarcity. There have been several attempts to apply these models to the energy resources in order to define the correlation between specific energy resources and economic growth. The substantial questions related to the scarcity, its measurement and growth are: (1) whether the scarcity of energy resources has been and/or will continue to be mitigated and (2) whether the scarcity has "de facto" impacted the economic growth.

ENVIRONMENT

Primary energy resources use is a major source of emissions. Since fossil fuels have demonstrated their economic superiority, more than 88% of primary energy in the world in recent years has been generated from fossil fuels. However, the exhaust gases from combusted fuels have accumulated to an extent where a serious damage is being done to the world global environment. The accumulated amount of CO_2 in atmosphere is estimated at about $2.75 \cdot 10^{12}$ t. The global warming trend from 1900–1990 is shown in Fig. 6 [9].

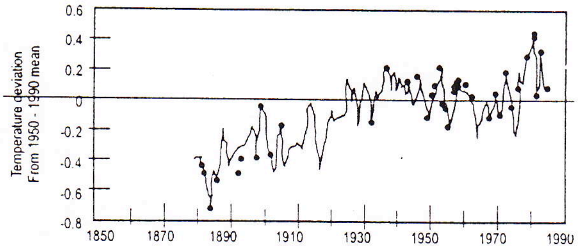

Figure 6. Global warming trend 1900–1990

It is rather obvious that the further increase of the CO_2 will lead to disastrous effects to the environment. Also, the emission of SO_2, NO_x and suspended particulate matters will substantially contribute to exasperate the effect on the environment.

In a world scale, coal will continue to be a major source of fuel for the electric power generation. Many developing countries, such as China and India, will continue to use inexpensive, abundant, indigenous coal to meet growing domestic needs. This trend greatly increases the use of coal worldwide, as economy in the other developing countries continues to expand. In this respect the major long-term environmental concern about coal use has changed from acid rain to greenhouse gas emissions - primarily carbon dioxide from combustion. It is expected that coal will continue to dominate China's energy picture in the future. The share of coal, in primary energy consumption is forecast to be no less than 70% during the period 1995–2010. In 1993 China has produced a total of 1.114 billion tons of coal, in 2000 it is planned 1.5 trillion and in 2010 it will be 2.0. Since China is the third largest energy producer in world, after USA and Russia, its contribution to the global accumulation of the CO_2 will be substantial if the respective mitigation strategies will not be adopted. The example of China is instructive in the assessment of the future development of developing countries and their need for accelerated economic development.

SUSTAINABILITY

As it has been shown, the energy resources are the bricks for building our civilization. Their polyvalent use has offered a service to human society, leading to the welfare commodity for a decent level of human life. Sadly, however, production and consumption of energy are going hand in hand less than welcome side effects. This is the reason why society has recognized the importance of intelligent energy use with a sensibility that the required energy services be provided as clean and efficient as possible. Crucial importance is added due to the rapid growing world population and the need for accelerated economic development of developing countries. This is the reason why energy takes a centre stage in the debate surrounding one of today's main dilemmas: how to combine economic development with a habitable environment in a world that is undergoing rapid changes as a result of population growth and economic development of the developing part of the world.

Lately, in a few years, "sustainability" has become a popular buzzword in the discussion of the resources use and environment policy. The word sustainability has root in the Latin – sustinere, meaning "to hold up" by world inhabitants, present and future ones. Before any further discussion of the subject, it is necessary to define and properly assess the term we are going to use. It should be emphasized that the definition is needed in order to clarify the concepts. So, what is sustainability ? Among the terms most often adopted there are the following:

(a) for the World Commission on Environment and Development (Brundtland Commission) [10]:

"development that meets the needs of the present without compromising the ability of future generations to meet their own needs";

(b) for the Agenda 21, Chapter 35 [11]:

"the development requires taking long-term perspectives, integrating local and regional effects of global change into the development process, and using the best scientific and traditional knowledge available";

(c) for the Council of Academies of Engineering and Technological Sciences [12]:

"It means the balancing of economic ,social environmental and technological considerations, as well as the incorporation of a set of ethic values";

(d) for the Earth Chapter [13]:

"The protection of the environment is essential for human well-being and the enjoyment of fundamental rights, and as such requires the exercise of corresponding fundamental duties";

(e) Thomas Jefferson, Sept. 6, 1889:

"Then I say the earth belongs to each generation during its course, fully and in its right no generation can contract debts greater than may be paid during the course of its existence" [14].

All five definitions stand for the emphasis of specific aspect of sustainability. Definition (a) and (e) imply that each generation must bequeath enough natural capital to permit future generations to satisfy their needs. Even if there is some ambiguity in this definition, it is meant that we should leave our descendants the ability to survive well and meet their own needs. Also, there is no specification in which form resources are to be left and how much is needed for the future generations, because it is difficult to anticipate the future scenarios.

Definitions (b) and (c) are more politic plies for the actions to be taken at global, regional and local levels in order to stimulate the United Nation Organization, Governments and Local Authorities to plan development programs in accordance with the scientific and technological knowledge. In particular, it should be noticed in definition (c), the ethic aspect of the future development actions to be taken to meet sustainable development. Definition (d) is based on the religious believes playing the responsibility and duties toward the nature and the Earth.

SUSTAINABLE DEVELOPMENT

Since the Brundtland Commission, in its 1987 report Our Common Future, warned of growing threat to the Earth from pervasive world poverty, environmental degradation, disease and pollution, it has become indispensable for the scientific community to pay an increasing attention to the subjects related to these problems. Five years later the United Nation Organization Conference on Environment and Development was held in Rio de Janeiro. An unprecedented number of world leaders met to discus and map the road to the sustainable development. Among the Documents adopted at the Rio Conference is the "Agenda 21", a blueprint on how to make development socially, economically and environmentally sustainable. Agenda 21 calls on governments to adopt national strategies for the sustainable development.

Sustainable development focuses on the role and the use of sciences in supporting the prudent management of the environment and for the survival and future development of humanity. It is recognized that scientific knowledge should be applied to articulate and support the goals of sustainable development, through scientific assessment of current conditions and future prospects for the Earth system. The program areas which are in harmony with conclusions and recommendations of this International Conference on an Agenda of Science for Environment and Development into 21st Century, are:

(a) Strengthening the scientific bases for sustainable management,

(b) Enhancing scientific understanding,

(c) Improving long-term scientific assessment,

(d) Building up scientific capacity and capability.

It is essential for the implementation of this program that it be focused on the long-term perspectives and the global changes of life support systems. In particular, there is a need for a constant interaction with governmental, industrial, political, educational, cultural and spiritual authorities participating in the realization of the program. It is of crucial importance that, in the realization of the program, an active role be given to scientists from developing countries. Since the major part of the population increase is expected in the developing part of the world, the participation of scientists from developing countries will bridge deficiency in dealing with the problems which are immanent to their environment by an academic approach.

Even, sustainability development has become a political movement with a strong connotation related to the existing differences among the continents, regions and countries, its strength should be seen in the promotion for the salvage of the planet, the only place for our human civilization. In this respect, the determination of the interested parties, including the United Nation Organizations, government organizations, non-government organizations and religious organizations, to recognize the sustainable development as the path for the creation of the future of new generations, is a guarantee for the economic prospectives and social development.

There are several ways in which the ideas of sustainable development are presented and interpreted. Ecocentric interpretations indicate a conspicuous degree of reference to the ecosystems. Anthropocentric interpretation tends to put humans at the center of the issues. Others such as biocentric interpretation focus on the protection of the elements of the biosphere. Our main concern in this general setting is energy and whatever we do for and with energy may be reflected in any of the above mentioned perspectives and interpretations. While this concern for sustainability in the energy sphere should include considerations at the global level, more importantly, there is the need to look at it as a regional issue in the overall global scenario. There are several perspectives on this. Figures 7 and 8 attempt to distinguish sustainable and unsustainable development.

ENERGY SUSTAINABILITY CRITERIONS

There has been a number of attempts to define the criterions for the assessment of the sustainability of the market products. In this respect the Working Group of UNEP on Sustainable Development has come out with qualitative criterions for the assessment of the product design [35, 36].

Having those criterions as bases, we would like to introduce them as a specific application in the energy system design. In this consideration energy system is taken as the entity which should comply with sustainability criterions.

Energy system design is defined as:

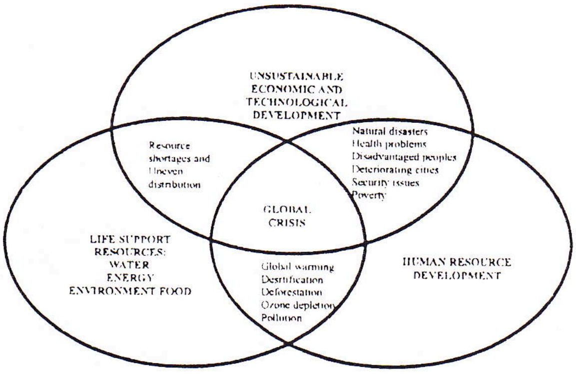

Figure 7. The consequences of unsustainable development

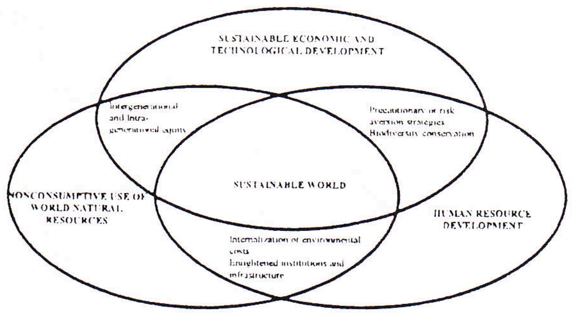

Figure 8. Sustainable development

Strategic design

The strategic design will require holistic planning that meets and considers all interrelated impacts e.g. logistic, space planning and resource planning. As regard the energy system, it may be interpreted as: mixed energy concept with optimization of local resources, urban and industrial planning with transport optimization, use of renewable energy sources.

Optimized design

The design optimization of the energy system means the selection of the structure and design parameters of a system to minimize the energy cost under conditions associated with available materials, financial resources, protection of the environment and government regulations, together with safety, reliability, availability and maintainability of the system.

Design of dematerialization

This will imply that the energy system, plant and equipment are designed with optimal use of information technology in order to prevent duplications, prevent operational malfunction, assure rational maintenance scheduling. Dematerialization in the design may be seen as the introduction of knowledge based systems, use of virtual library, digitized video, use of on-line diagnostic systems, development of new sensor elements and development of new combustion technologies.

Design of longevity

A complex energy system is commonly composed of different subsystems and individual equipment elements. It has been recognized that the life tie of the elements and subsystems is not equal. In this respect, optimal selection of the life cycle for elements and subsystems may lead to the retrofitting procedure which will reflect need for the sustainable criterion application. Examples for this criterion can be seen as: modular design of subsystems, standardization of elements, lifetime monitoring and assessment, coordination of suppliers and buyers.

Life cycle design

This will mean that the energy system and its subsystems have to be designed to meet sustainability through every stage of the life cycle. It is known that the energy system is designed to work under different conditions in order to meet load changes, environment change, social changes, etc. It is obvious that there will be different cycles for each of the mentioned time scale processes. In this respect the system has to fulfill its function without failing to meet sustainability requirements.

ENERGY SUSTAINABLE DEVELOPMENT

In order to reach the goals indicated by the sustainable energy development the efficiency in the energy conversion use has to meet several criterions [17]. The potential for the efficiency improvement is generally underestimated. Most of the energy conversion systems consider the efficiency improvement as a separate process and their analysis reflects only the potential improvement of the process but not the potential for the efficiency improvement obtained by an exergy analysis of the energy system. Fossil fuel energy resources use is mostly conversion to heat by the combustion processes. Since the combustion process is taking place at temperatures between 900 – 1300 °C and over 40% of heat is used as low temperature, it is indispensable to take into consideration the thermodynamic assessment of the efficiency in order to bring in line energy conversion processes and energy demand to obtain the optimum fuel utilization.

In the definition of sustainability it is of substantial importance to envisage its broad aspect which composes versatility of the components to be taken in consideration. In this respect, wholeness of sustainability has to include definitions of those components which are linked to specific parameters to be taken into a consideration of the assessment of sustainability of specific situations in global, regional and local environments. There is a number of characteristic entities which will be used to define the wholeness of the sustainability: life diversity, natural resources, environment capacity, population increase, social disturbances and ethic changes. For this consideration we will focus our attention only to those characteristic entities which are in direct correlation with energy sustainability measurement. In this group are included: (i) natural resources; (ii) environment capacity; (iii) population increase.

Each of these entities has to be defined with specific parameters which can be used to determine characteristic indicators for global assessment. The possible use of indicators is characterizing the changes which are determined by the maximum values technically feasible. It is reflecting the difference between the state of the entity with the maximum availability and respective current state of the entity. If applied to the individual energy resources there is a difference between known maximum exploitable resources with known technologies and current resources to be obtained with present technological capacity. Possible changes are functions of the technological development in the resource discovery. This implies that there are two means for the increase of the resources, namely, by additional capital investment for the discovery and by the new technology for the resource discovery.

In the assessment of sustainability, the current consumption change has to be taken into a consideration which is reflecting the current consumption change in the reference time period. In order to form some kind of the resource indicator for sustainability measurement a ratio between the current change and the maximum potential change has to be established. Its trend will give the measuring parameter for the resource depletion in time. It is known that the current consumption of the energy resources strongly depends on the efficiency of thier use, which may be classified in two groups. The first one is the possible efficiency increase due to the change in the efficiency of primary energy source conversion and the second one is due to the change in the efficiency of the final energy use.

A number of authoritative studies have presented forecasts for the energy supply in 21st century. Conclusions drawn from this analysis have become a driving force for the development of the plan for the sustainable energy supply system. Even if there is a number of options taken into consideration, common issues are the following:

Prevention of the energy resources depletion with scarcity index control

Whichever the scarcity model is used, the energy resource scarcity is in direct relation to the social production output. In this respect, the efficiency of resources use and technology development are of fundamental importance. It is obvious that the efficiency of the energy resource use is a short-term approach, which may give a return benefit in the near future. As regards the technology development, a long term research and development is needed. In some cases it will require respective social adjustments, in order to meet requirements of the new energy sources.

The availability of energy resources is limited by two factors: capital to be invested in prospecting of new resources and prospecting technologies for energy resources.

From recent experiences it was learned that there is a direct correlation between capital invested in prospecting and the amount of the available reserves. It was proved that a fixed amount of 18 $/t is needed for new energy reserves. In many developing countries this is a limiting factor for the availability of energy resources.

The prospecting technology is composed of three phases. The geological subway based on the real prospecting and respective diagnostic techniques for electromagnetic waves detection. The resolution of the instrument employed is one of the limitations, and it is under consideration for further development.

The second phase of prospecting technology is related to software for the design of the resource body. The main limitation in the development of new software is the speed and memory size of computers. It can be expected that with the further development of computer technology this problem will be overcome. Also, new numeric schemes will substantially contribute to the accuracy and time expectation for the prediction of the size of resources body.

From the beginning of the energy resources exploration, the drilling technology was the limitation in the achievement of new resources. The development of drilling technology has marked a direction for the discovery of new resources. The deep sea drilling has become one of the global issues, which may remove the scarcity problems of energy resources for the next few centuries. It should be mentioned that 2/3 of the earth surface is covered by deep sea so that the breakthrough in deep-sea technology may lead to a substantial change in energy resource picture in the world.

Efficiency assessment

The potential improvement of the energy conversion process is a driving force for its development [18]. In the assessment of the conversion process a promising tool is the exergy analysis of the energy system. The exergy analysis is based on the maximum potential availability and its use for the assessment of the conversion process. By definition, the exergy is a parameter for the validation of the efficiency of the energy conversion process and system.

Following the first energy crisis, many countries have organized an energy efficiency assessment campaign with the aim to improve the efficiency and gain saving which has contracted the increase of energy price. This approach has resulted in the increase of efficiency of energy use between 10–20% in a number of European countries. The main emphasis has been given to the evaluation efficiency of different technologies and utilizations of energy.

The effort directed to the evaluation of the technological processes for energy saving is of great importance. In accordance with one of the criterions for the sustainable development, products have to meet the requirement related to the minimum use of energy. Also, cogeneration of heat and electricity is one of the potential means to improve the efficiency of the energy resource utilization.

Recent projects with gas fired cogeneration plants have demonstrated an extremely high efficiency [19]. The increased gas resources may lead to further development of highly efficient power plants for electricity production. The cogeneration will play a special role in the development of new energy systems.

Clean air technology development

The combustion process is an irreversible thermodynamic process with a high degree of availability losses in the energy conversion cycle. In this respect there is a potential opportunity to increase the energy conversion efficiency by improving the combustion process. There are a number of potential combustion technologies which might lead to an efficiency increase of the combustion process. Among those there are:

(a) Catalytic combustion [20],
(b) Fluidized bed combustion [21],
(c) Low NO_x burners [22],
(d) New boiler designs [23].

Development of intelligent energy systems

The recent development of artificial intelligence has opened the possibility to utilize those achievements in the energy sustainable development. There are three major paths, namely: expert system development in energy engineering; new control based on fuzzy logic and respective reasoning; intelligent thermal system design.

Expert system in energy engineering

The expert system development in energy engineering is focused in two directions: expert system for energy system design and knowledge-based for on-line diagnostic [24, 25, 26]. It has been shown that the expert systems for energy system design can be an efficient tool in selection, optimisation and assessment of power plant design. Also, expert system logic can be used in energy system planning, including optimization of the energy system, reflecting the potential use of renewable energy sources. An example of expert system use in the design of thermal equipments is demonstrated by the heat exchanger design [27]. Further developments of knowledge–based system for design of energy systems will promote the increase of efficiency and reliability.

The knowledge-based system for the fault diagnostic in energy systems has proved to be a powerful tool for the evaluation of system parameters in order to forecast a potential malfunction of system elements. Fig. 9 shows a schematic representation of expert system for fouling assessment.

There are several attempts which have proved the possibility of knowledge-based systems in the diagnostic of thermal power plants. The efficiency monitoring and respective logistic evaluation of diagnostic parameters has been demonstrated to be a good and reliable tool for the advanced diagnostic of operational deficiency. The boiler fouling and tube leakage knowledge–based system prototypes demonstrated the possibility of the detection of processes leading to the degradation of power plant

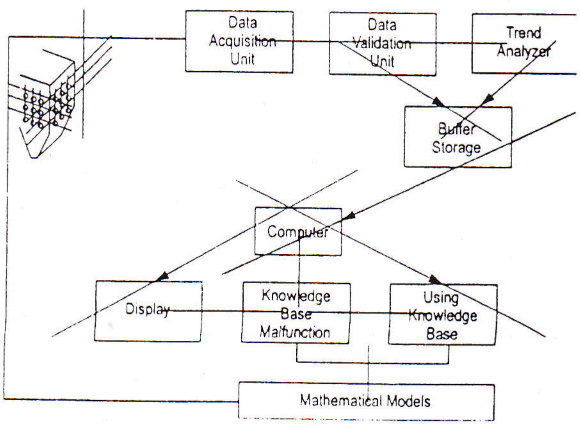

Figure 9. Knowledge-based system for power plants

efficiency [25]. The diagnostic systems are based on the on-line monitoring of diagnostic variables and their fuzzyfication for the reasoning retrieval of the cases representing diagnostic results.

Fuzzy logic control

The new fuzzy logic control system is demonstrated to be a qualitatively efficient system for the on-line control of energy systems [28]. While similar model-based control systems designs are trial and error, the knowledge-based controller is "ad hoc" at present time. A gap exists between solid theoretical results such as stability, controllability etc. A real-time implementation of intelligent control systems uses fuzzy logic, neural networks, generic algorithms, expert systems etc. A common definition of fuzzy control system is that it emulates a human expert. Under this situation, the knowledge of human operator would put in form a set of fuzzy linguistic rules. These rules would produce an approximate decision, like a human would. Fig. 10 shows a block diagram of fuzzy control systems.

Intelligent energy systems

The present world has learned that some of the basic assumptions are not valued and so require a new approach for adjustment to their future development. There have been world scale meetings emphasising the need for the economic order to meet contemporary development within the limits recognised by irreversible changes in energy resources and environment capacity.

New measurements called "Indicators of sustainability" are designed to provide information for understanding and enhancing the relationships between the economic energy use, and environmental and social elements inherent in long-term sustainability.

There are different terms used in the consideration of the product design. The "clean" design is used in the widest sense of all management as well as technical decisions related to specification, planning and development of products. The "eco" design refers to the processes of systematic incorporation of environmental life cycle consideration into product design.

"Intelligent product" design comprises the specifications reflecting resource life cycle, environmental cycle, product life cycle, end of life and clean design. The generic design procedure to be adopted for the intelligent product design of the thermal equipments require the definition of indicators for the assessment and optimization of the specific design.

In order to provide the design criterions reflecting complex requirements imposed by the intelligent design, it is necessary to define the respective indicators to be used in the evaluation of the specific design of thermal equipment [29]. These indicators should be based on the optimization of the efficiency of respective thermal equipment, resource use assessment and validation, environment capacity use and degradation, modular structure with multipurpose elements, end of life assessment and economic justification of specific designs. Fig. 11 shows schematic presentation of Intelligent energy system.

In order to evaluate the validation of the indicators the thermal equipment will be used. In this respect, the criterions will be adapted for the specific thermal equipment. It is aimed to develop the algorithm with the indicators to be used for the assessment of design. The assessment will be made for a number of selected products presently on the market to be evaluated within the frame of the criterions for intelligent design.

New and renewable energy sources (NRES)

Besides the possibility offered by the efficiency improvement of processes in power generating units, there is a great challenge to increase the efficiency of energy systems by introducing energy mixed systems. The energy system includes power or heat generating units, energy transport systems, energy storage systems and energy end-use systems. From the energy resources point of view there is a number of options which might be taken into consideration for the optimization of the energy

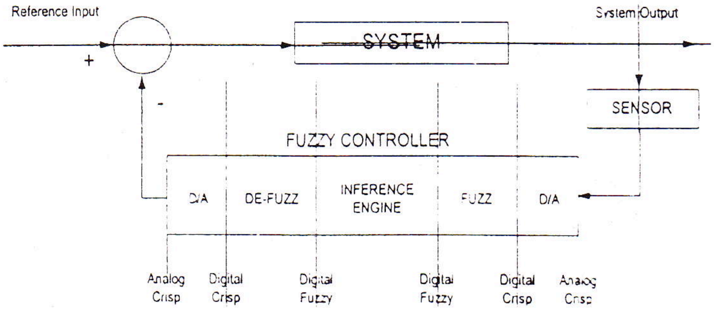

Figure 10. Block diagram of fuzzy control system

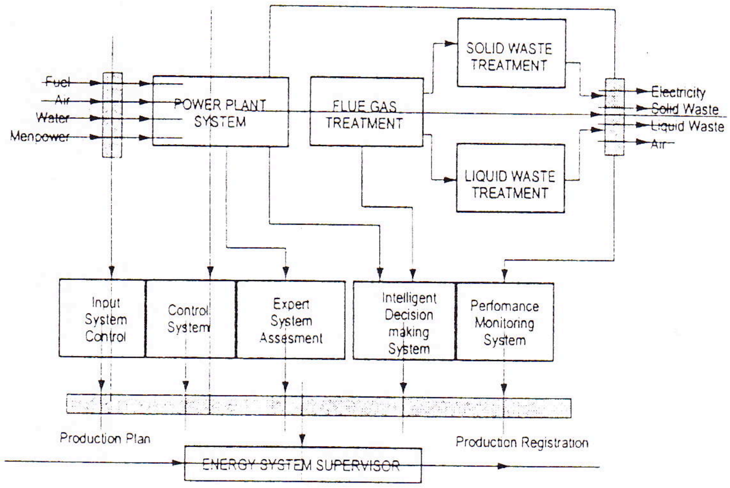

Figure 11. Scheme of intelligent energy system

system. In this respect, high interest is shown to the potential use of the renewable energy resources as power or heat-generating unit in the energy system. The immanent advantages of the renewable energy resources due to their availability and low cost impact, are promoting the renewable energy source to be included in the energy system.

Renewable energy sources by definition, meet the requirements of sustainability. It is therefore expected that the long-term energy strategy will rely on renewable energy resources. The total availability of the renewable energy resources is very large. This picture reflects the presently available technologies in the field of renewable energy resource use and exploitation [30]. Very promising alternatives are envisaged with the promotion of new technologies under development:

(a) Solar energy resources [31, 32],
(b) Geothermal energy resources [33],
(c) Biomass energy resources [34],
(d) Wind energy resources [35],
(e) Hydro energy resources [36].

Environment capacity for the combustion products

The sustainability is closely related also to the environment capacity of our planet. It has been shown that the natural processes in the biosphere possess the maximum rate of change. This rate of change exceeds by orders of magnitude the contemporary rates of the parameters defining the antropogenic impact to the environment and by four orders of magnitude, the mean rate of change of the parameters defining the geophysical processes. The concentration and the rate of change of chemicals involved in the biochemical cycles may be characterized by the changes of organic and inorganic carbon. The capacity of biologically active organic and inorganic carbon chemical species in the environment is equal and ten times larger than their annual primary production. Therefore it may be expected that this resource of environment capacity could be considered in the next ten years if only synthesis or decomposition of organic matter is taking place. This means that all life processes will end.

The fluxes of the organic material produced by the synthesis and decomposition processes in the biosphere are within the accuracy of one hundredth percent of the antropogenic fluctuation resulting in the environment in the geological time scale. This slow change in the environment in the geological time scale can be compensated by biological processes leading to the biosphere control of the chemical composition of the environment. It is known from the Le Chatelier principles that any external perturbation of the equilibrium state of a system will induce the process to compensate for these perturbations. The compensation of the perturbations in the environment can be obtained by the synthesis and decomposition of the organic processes in the biosphere. Since the preservation of the biosphere is affecting the biodiversity of our planet it is of primary interest in long-term evolution, to have the control of the organic processes in the biosphere. For this reason, the preservation of the biosphere is the main requirement for the global ecological security for the sustainable development of our planet.

In order to observe the sustainability of the environment, the ecological system has to be monitored and followed with modern methods and techniques. It is obvious that an interdisciplinary approach is needed to understand all aspects of the changes which are introduced by human activities. In this respect the world energy system is responsible for the production and emission of a number of chemicals which are proved to have adverse effects on the environment.

The energy use is a major source of emissions. In the same time it is essential to the economic and

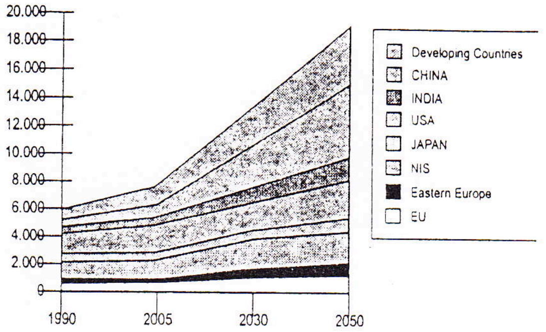

Figure 12. OECD scenario for CO_2 emission

social development for improved quality of life. There have been recognized several threats as signals for potential hazard to the environment. The emission of air pollutants is usually considered in three groups, namely: carbon dioxide, nitrogen oxide, and sulphur oxides.

The adverse effects of the emission gases are recognized by two processes: the greenhouse effect leading to global warming and depletion of the ozone layer in the stratosphere. The global warming is observed by the increase of the mean earth temperature. It can be noticed that recent changes in concentration of CO_2 in the atmosphere are correlated with the changes in the global temperature. This has led a number of specialists in the field to conclude that the damage is irreversible. Fig. 12 shows estimated trend of CO_2 production.

Mitigation of nuclear power impact to the environment

Besides effects of energy systems on the environment, by the emission of flue gases in the atmosphere due to the combustion of organic fuels in power production plants, there are possibilities which are immanent to some old power plant systems to have hazardous effects on the environment in a very short time with long lasting consequences. The nuclear power plants are very beneficial in light of greenhouse effects because they have no exhaust gases. But, it is known that present nuclear power reactor have the potential possibility to be enormous sources of radioactivity emissions. Besides the effecting the immediate surroundings, these hazardous events may lead to regional and global impact to the environment. The low probability of this kind of events has been only barrier to the disasterios event to spread its consequences to the global environment. Examples recently learned are requiring different approach to face and master potential hazardous events. Human society is not in position to lean its existence on the man made probability actions without possibility for any correction.

Opponents to nuclear energy outline two points that are crucial for them: the possibility of major radiological releases following accidents and the heavy inheritage of long lasting radioactive wastes for future generations. Obviously, both these points are very relevant for the sustainability development of this form of energy. Let's discuss separately both. Major accidents may be generated by a reactivity excess (Chernobyl) [37], or by a loss of coolant (Three Miles Island) [38] or by a loss of flowrate or by anticipated transients without the interruption of the nuclear chain. Even if the chain reaction during the accident has been stopped with a prompt insertion of control rods, the radioactivity decay residual heat, if not adequately removed to a heat sink, may cause the melting of the core threatening the integrity of reactor vessel. Against these possible accidental chains a "defence in dept" strategy has been developed with three main lines:a "preventive line", a "protective" line, and a "mitigative" line. This strategy worked at Three Mile Island accident with external releases of few curies of radioactivity, but did not work at Chernobyl due the its absence of external containment and many other design deficiencies.

Present reactor designs for the second line of defence have a majority of "active" safety systems and a minority of "passive" ones. An "active" system needs an external energy supply for intervention and a "passive" one is based on physical laws like natural convection, thermal dilatation, stress-strain relations [39]. The present trend of designers is to increase the percentage of passive safety systems to counteract the possible accidental chains, proposing the so called "advanced passive" reactors for a transition period from the first to the second generation of nuclear reactors. This trend is also associated with a preference of a deterministic approach instead of the more scientific probabilistic one, for better gaining the acceptability of common people who often remember the old saying "if it can happen, it will happen".

A design of the second generation of nuclear reactors with 100% passive safety systems already exists. i. e. the MARS (Multi-purpose Advanced Reactor Inherently Safe). Fig. 13 shows a schematic representation of the MARS reactor.

This reactor has been conceived for small electric networks and for co-generation purposes, to increase the overall efficiency and multiply the possibilities of utilization. It is modular and assembled in small parts that are totally built and controlled with quality assurance, produced in factories. In this way the construction time is shortened, the related cost reduced, and the assembly procedures inverted in order at the end of useful life, to guarantee an easy and total decommissioning of the

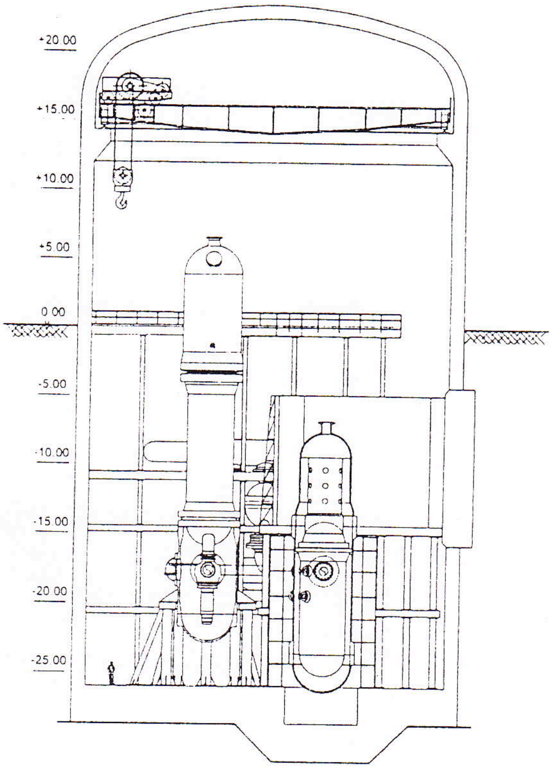

Figure 13. Multi-purpose advanced reactor inherently safe (MARS)

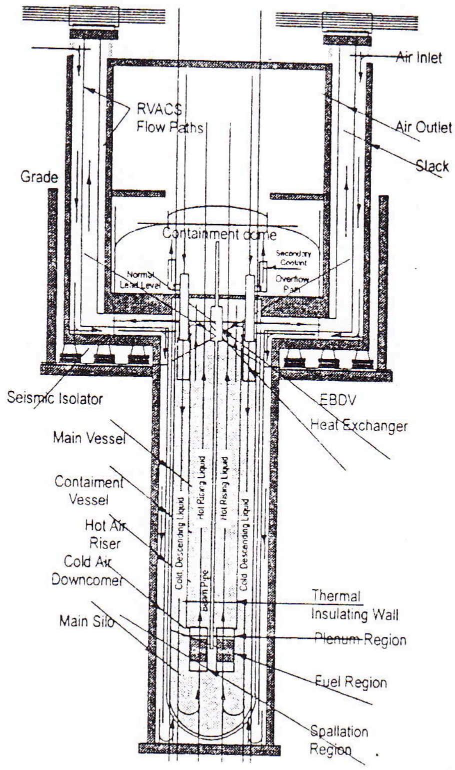

Figure 14. Energy amplifier

metal pieces. All these characteristics meet the requirements of sustainability.

The second point of the fear of nuclear opponents, related to the long lasting wastes, is still opened to interesting solutions. It is possible to separate the long-life radionuclides (actinides) from other radioactive fission products. The actinides may be recycled in "ad hoc" reactors and converted in the short–life radionuclides. The radionuclides with long lasting lifetime can be converted into short life isotopes by their mutation through nuclear reactions in high flux nuclear reactors or in a coupled device of subcritical nuclear reactor in which a beam of high energy particles are injected by means of a powerful accelerator. The total amount of long lasting wastes will be substantially reduced so to be conveniently placed in suitable geological formations, which remained dry and intact for million of years in the past.

A device of this type has been recently proposed by Rubbia and co-workers [40], with a sub-critical fast reactor cooled by lead in natural convection, feeded by spallation neutrons generated by a beam of protons accelerated till 1 GeV. Fig. 14 shows a schematic representation of the conceptual design of this fast neutron operated high power energy amplifier.

ENERGY EDUCATION AND SUSTAINABILITY

The contemporary development of the information technology has substantially contributed to the promotion of new means of dissemination information and its multiple use.

The information may have different forms and the knowledge of them is generated by the scientific and technological research. The knowledge is transferred by the education system. In this respect the scientific and technological development from one side and education system from other side can contribute to the information exchange in any socio-economic system. So, we can consider socio-economic changes in the two processes, namely: the generation of information by the scientific and technological development and the exchange of information by the education process. In this case, to have the harmony in the global system, between the use of its resources and at the same time to take care of the preservation of environment [41, 42]. Also, we can say that the sustainable development of our civilization will require, beside using the immediate action to preserve resources and environment capacity for the future generations, to devote a substantial attention to the science and technology development, as well as the development of the education process. The science and technology development has to be focused to these problems, which will affect the consumption of available material resources and environment capacity.

In the development of the sustainability issue there are three fundamental dimensions which have to be taken into consideration in the assessment, namely: knowledge dissemination science and technology development and exploration of new resources. The knowledge dissemination, implies the development of the respective education system which will meet increasing demand for continuos refreshment of the knowledge in order to follow the contemporary development of new technologies.

The life long education is presently recognized as a continuous learning activity to follow the needs of modern society. It can be seen as the education system with different levels in accordance with the aim, need and individual perception capability. In particular, the aim of lifelong education is diversified by specific requirements of the professional scope. These programs of lifelong education could be aimed to increase the fundamental knowledge of the specific subject or to the design or technical operation guidance for the respective equipment, system or structure.

There are different educational schemes which are suitable for an organized approach to the life long education. Distant learning [43] has been introduced in the education system as the associate system to bridge difficulties arising from the lack of space for all those wishing to enter the high education institution. In this respect, the distance learning education methodology has proved advantages, which are of interest to be exposed to the public at large in order to be evaluated through its application in the lifelong education. In particular, it becomes relevant to take the advantages available by the modern communication systems, which are offering large possibilities to convey information to any distance, as desired.

It is also recognized that the present education system is too rigid to accommodate new challenges of the lifelong education system [44]. To assimilate the distant learning education with a modern information technology and its prominence at this time it is important to realize the changes in relationships between high education and society. It is obvious that the present status of the higher education system will no longer enjoy a monopoly on the provision of learning service.

Particular attention has to be devoted to the postgraduate education, which is socially independent and can be organized without the personal interaction between the teacher and the learners and learners among themselves, as it is necessary for undergraduate education. In the context of the need for efficient and appropriate timing of postgraduate education, the demand and perspective of multimedia distant learning education is of high expectation. Technology oriented postgraduate education programs will be linked into regional, national and international networks and will be a great possibility for the integrated education environment, leading to the democratization of the world education system.

The modern development of the information technology is opening a possibility to use the distant learning methodology for postgraduate education. A limited number of qualified teachers for the specific subjects of modern technology is one of the limitations for the knowledge dissemination in the field, needed for the promotion of economic development. The scarcity of competent teachers in specialized disciplines can be adequately subsidized by the respective use of distant learning methodology, which will allow the exposition of the valuable professionals in the field to larger audiences.

Energy and environment engineering education

The energy and environment problems in the contemporary world are the challenging engineering fields requiring the constant increase of our attention in order to meet the increasing demands and also face the potential adverse effects on the environment. In this field, a new strategy is in the development which compulsory requires the respective efficiency of the systems, increases the global energy system structure use of new and renewable energy sources, meets a new social aspect of the energy and environment. Also it will better understand in deep all consequences which possibly promote global changes in the environment. These requirements could be met only with the respective education systems which will be able to accommodate the needs for an increasing number of specialists with the high level of education.

It is becoming obvious that the present energy and environment engineering education system is facing difficulties in many countries to meet a forthcoming demand. Even more, in a number of developing countries this problem is open and will require an outside assistance to be overcomed. In this respect, the future energy development strategy has to include the development of the respective energy education system, which will ensure its promotion and practical application. It is of paramount interest to the society to combine its effort in the economic development with the change in the structure of the education system.

The engineering education is closely linked with the economic development. The promotion of new technology advances by the use of information technology is immanent to the further development of the engineering education. In particular, the increase of the engineering knowledge leading to the larger number of the engineering specializations is only the tip of the iceberg of the problem in engineering education. In this respect, the energy and environment engineering education is of primary interest for the modern society.

Efficiency, reliability, new energy sources and environment are among those issues of energy engineering which are to be recognized as the main driving forces to increase the demand from the energy systems.

The efficiency of the energy systems has been recognized since Sady Carnot has defined the Second Law approach for its assessment. In this respect, it has become important to understand the quality of energy in order to obtain the maximum from a potential source of energy. The exergy analysis has become a powerful tool for the engineering evaluation of the respective energy system. The Second Law efficiency assessment requires the knowledge about principles of the exergy analysis, technical characteristics of the respective system and equipment. The correct efficiency evaluation of the system will require also a social aspect of the energy cost, which include the environment interaction with the respective energy system.

The reliability and safety of the energy systems have become the main issue of the adverse effects, which might have regional, national and global effects. It is a complex issue which requires in deep knowledge about the system, its functionality and limitations. This knowledge is required at different stages of the energy system development including design, construction and operation. The risk evaluation is a specific issue, which has to be introduced at each stage of the development. Learning about reliability and safety aspect of the energy system requires a high degree of sophistication of all the subjects to be taught in the normal engineering curriculum. It is known that any malfunction of the energy system leading to the degradation of reliability and the decreasing safety margins of the system is result of complex processes, which are time dependent and interrelated. This implies that in order to gain the knowledge needed for the assessment of reliability and safety of the energy system, the engineering education programs should include time and space dependent processes with the respective mathematical and numerical tools to be used in modern computer systems.

The new and renewable energy sources are based on modern achievements in the physics and chemistry. So, it is immanent to the new energy sources assessment and evaluation to have the respective knowledge in these fields. In particular, the engineering aspect of the new and renewable energy sources should be emphasized in order to introduce them in the strategy of the energy system development. For this reason it is necessary to design the energy education programs taking into consideration the need of society to introduce the new energy sources in the everyday life.

The increased environment concern in the modern society has led to the internationally recognized requirements for the higher attention to the adverse effects of human activity towards its surrounding. In view of the impact of energy systems on the environment increased emphasis is given to the assessment of such impacts at the stage of energy programming and the project design in order to take into consideration environment problems caused by the energy production, transport and consumption. It is needed to include subjects as biology and social sciences in the engineering education.

Lifelong education in energy engineering

It is known that the need for upgrading professional capability of the manpower in engineering is the result of constantly growing demand for the increase of efficiency of technical system and increasing awareness of the environment problems [45]. The organized effort is streamed to meet challenges for the benefits obtained with a new approach to future technical systems and their incorporation in the human environment without adverse effects. One of the lines in this effort is a new lifelong education system. In order to meet this requirement the distant learning education methodology with multimedia is proved to be easily accommodated for the on-job training for the Industry-University co-operation. The education programs could be designed for specific needs and adapted in the on-job environment with limited teaching assistance.

As most of the postgraduate education programs are closely linked to the specific technology developments, it is of great interest to the design respective courses having in mind the customer interest and local environment. The energy engineering postgraduate courses in this respect have to be aimed to meet the recent strategic demands in the modern development of the global energy system. The variety of options for the specific programs will require a polyvalent approach in the design of the respective postgraduate energy engineering program [46]. It will have to accommodate the different disciplines oriented modules, to be used in the construction of multiple options as required by the individual learners. With this approach, it will be possible to launch the individual education programs, which are to be custom-made to the specific need of the individual learners or their employers. The future learners will have the opportunity to connect themselves to any available education programs in the world network designed as a part of the global system. In this respect, the lifelong engineering education is at the beginning of network formation, which will, similarly to the existing Internet or similar global network, offer the education commodity to any individual wishing to increase his/her competency in the specific field of interest.

CONCLUSIONS

It is shown that present energy strategy requires adaptation of new criterions to be followed in the future energy system development. No doubt that there is a link between energy consumption and environment capacity reduction. This is an alarming sign, which recently has become the leading theme for our near and distant future.

Modern engineering science has to be oriented to those areas which may directly assist in our future energy planning. In this respect, it is a demanding need that our attention be oriented to the global aspect of the energy development. Modern technologies will help to adopt essential principles of the sustainable energy development. With the appropriate renewable energy resources introduction in our energy future and with the increase os safety of nuclear energy, it will be possible to comply with the main principles to be adapted in the sustainable energy strategy.

In order to promote the sustainable energy development the respective education system is required. It was recognized that the present energy education system can not meet future demand for the knowledge dissemination. It was shown that the potential option for the future education system is the distance learning with multimedia telematic system.

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ОПРАВДАНИ ЕНЕРГЕТСКИ РАЗВОЈ

У раду је дат преглед оправданог (одрживог) енергетског развој са циљем да се истакну значајни аспекти везани за ову активност. Дат је кратак увод, везан за актуелну енергетску перспективу на основу прегледа расположивих података. То омогућује да се прикажу мотиви за оправдани енергетски развој. Специјална пажња је посвећена дефиницији оправданости и основном значењу овог појма. У том смислу, посебна пажња је посвећена дискусији различитих аспеката оправданости у садашњем свету. У циљу приказивања инжењерског приступа оправданом развоју, приказани су критеријуми оправданости који морају бити уграђени у будуће производе.

Акценат је стављен на приказ потенцијалног развоја у енергетским наукама, који може да доведе до оправданог енергетског развоја. Приказ обухвата седам главних области са својим специфичним проблемима и њиховим утицајем на оправдани енергетски развој. То су следеће области: енергетски извор, ефикасност, технологије које обезбеђује чист ваздух, информационе технологије, нови и обновљиви извори енергије, капацитет животне средине и повећање сигурности у нуклеарној енергетици.

Систем образовања је камен темељац сваког економског развоја. У том смислу, оправдани енергетски развој захтева да се посебна пажња посвети изградњи новог система образовања. Образовање на даљину је једна од могућих опција ширења знања о новим енергетским технологијама.

Кључне речи: *енерѓија, енерѓетски извори, нови и обновљиви енерѓетски извори, животна средина, нуклеарна енерѓија*