REVIEW OF SUSTAINABLE ENERGY DEVELOPMENT

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ABSTRACT

This paper presents an overview of the sustainable energy development and aims to emphasize the important aspects of the relevant activity. A short introduction to the present energy outlook with a survey of available data is presented. Also, special attention has been given to the definition of sustainability and its generic meaning. In this respect, particular attention is given to the discussion on different aspects of sustainability in the present world scenario. In order to present an engineering approach to sustainable development, a review has been made of sustainability criteria as they are of importance to future energy-related products.

The main emphasis of this paper is on reviewing the potential development in energy-engineering that may lead to sustainable energy development. Seven major areas having relevance to sustainable energy development and with specific problems are listed. These are: energy resources development; efficiency assessment; clean air technologies; information technologies; new and renewable energy resources; environment capacity; and mitigation of nuclear power threat to the environment.

A sound education system is an important milestone for any nation to achieve economic development. In this respect, special focus was needed to consolidate the concepts of sustainable development education system. Distance-learning education system is envisaged as the potential option for dissemination of knowledge and information on new energy technologies.

1. INTRODUCTION

Energy resources have always played an important role in the development of a society [Marchetti C,1995]. Since the Industrial Revolution, energy has been a driving force for the development of civilization. Technological development, consumption of energy and the increase in the world-population, are interrelated. The Industrial Revolution in the nineteenth century, resulted in a drastic increase in both population of the world and its consumption of goods and services [Marchetti C., 1979].

Boltzmann, one of the fathers of modern physical chemistry, wrote in 1896 that the struggle for life is not a struggle for basic elements or energy, but a struggle for the availability of negative entropy in energy-transfer from the hot Sun to cold Earth [Boltzmann, 1896]. Energy and matter constitute Earth's natural capital and many suggest that this natural capital is being rapidly degraded. The contemporary economic theory does not adequately account for the significance of natural capital in techno-economic production.

Our use of natural material resources is associated with no loss of matter as such. Basically, all Earth's matter remains with it but in a form in which it cannot be used easily. The quality or useful part of a given amount of energy is invariably degraded due to use, thus resulting in increased entropy.

The industrial development was based on the thinking that energy-resources are unlimited and there are no connected repercussions that might affect human welfare/development. It has been recognized that the pattern of the energy-resource usage has been strongly dependent on the technology-development. In this respect, it is instructive to observe [Marchetti C., 1991] the change in the consumption of different resources throughout the history of energy-consumption. Worldwide use of primary energy-sources, since 1850, is shown schematically in Figure-1 [Marchetti C. 1991]. 'F' indicates the fraction of the market taken by each primary-energy source at a given time. It could be noticed that two factors have had an effect on the energy-pattern in the history. The first is related to the technology development and the second to the availability of the respective energy-resources. Obviously, this pattern of using a certain energy resource is developed under constraint due to the total level of energy-resources consumption and reflects the existing social structure, both in numbers and diversity [Afgan, N.H., et al, 2009]. The world energy-consumption from 1850 to 1992 is shown graphically in Figure-2 [Farinelli, U., 1994].

Looking at the present consumption-pattern of energy- resources, it can be noticed that oil is the major contributor, supplying about 40% of the total energy share. Other major contributor are, coal and natural gas, supplying around 30 and 20%, respectively, of the energy, while nuclear energy contributes about 6.5%. This means that the current fossil-fuel supply is about 90 % of the total present energy-use. During the last several decades, our civilization has witnessed changes that are questioning our long- term prospects. Fossil-fuels (non-recyclable) are exhaustible natural resources. In this respect, it is of common interest to learn how long

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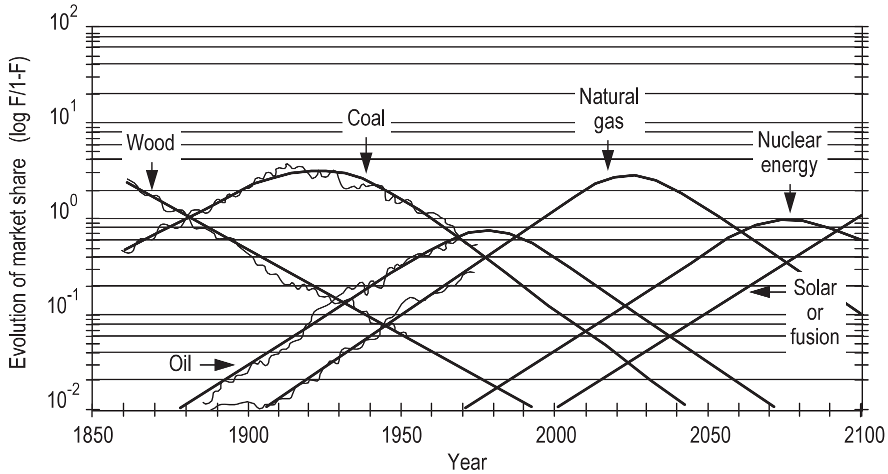

Figure - 1: Market Penetration of Primary Energy Sources

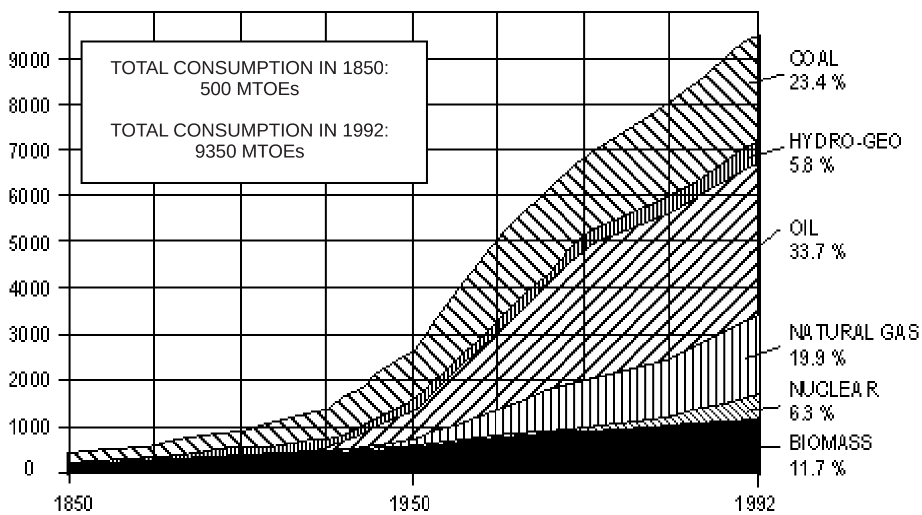

Figure - 2: World Energy-Consumption

will the fossil-fuel resources remain available, as so far they are the main source of energy for our civilization. This question has attracted the attention of a number of distinguished authorities that are trying to forecast the future energy scenario. The Report of the Club of Rome 'Limits to Growth', published in 1972 [Medows D. et. al, 1972], was among the first studies that pointed to the finite nature of fossil-fuels. After the first and second global energy crises, the world community at large has become aware of the expected physical exhaustion of fossil-fuels. For now, the amount of fuel available is dependent on the cost involved. For oil, it was estimated that proved amount of reserves has leveled off at 2.2 trillion barrels produced under $ 20 per barrel over the past 20 years. Over the last 150 years, we have already consumed one-third of that amount or (about 700 billion barrels) and are left with only 1.5 trillion barrels. If compared with the present consumption rate, it means that oil is now available only for the next 40 years. Figure-3 shows the ratio of discovered resources to the yearly consumption of the fossil-fuels over the period 1945 to 1990.

From this figure it can be noted that in 1994 coal was available for the next 250 years and gas for the next 50 years. Also, it is evident that as the fuel consumption is increasing, new technologies aimed at the discovery of new resources are becoming available, leading to a slow increase of the time-period estimated for the depletion of the available non-renewable energy sources.

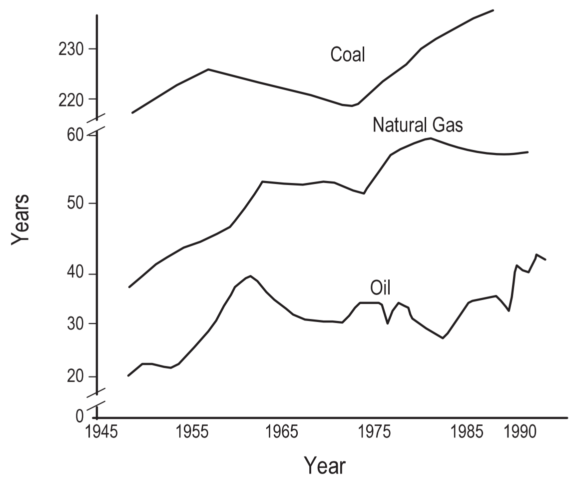

Figure - 3: Residual Life Forecast of Energy Resources

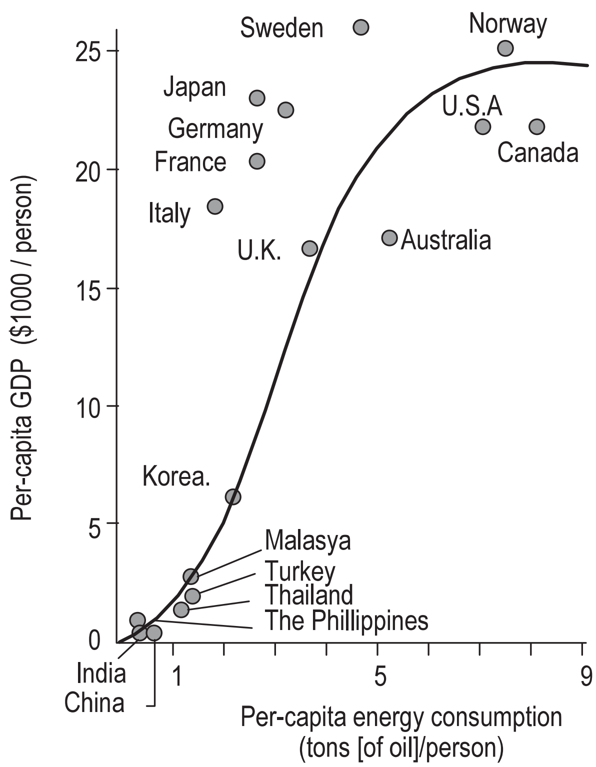

Figure - 4: Economic Growth and Energy-Consumption

It is known that 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 (GDP) and energy consumption per capita. Figure-4 shows the relationship between economic growth and energy-consumption for a number of countries, in 1990 [Keatiny M., 1993].

A number of scenarios are used to predict trends for the world's economic development. With the assumption that the recent trend in the economic development will last 50 years, and the demographic

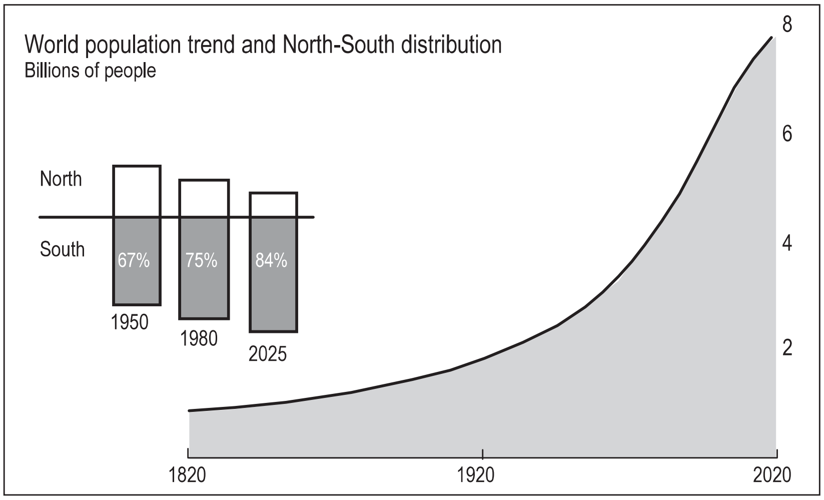

Figure - 5: Demographic Forecast of Human Population

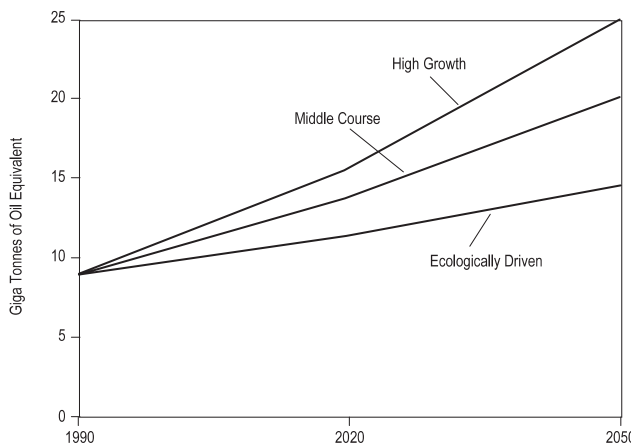

Figure - 6: Future Energy-Consumption Forecast

forecast of the growing human population is as shown in Figure-5 [WEC Message for 1997], the future energy-consumption could be estimated as shown in Figure-6.

Comparing the availability of energy resources at different points of time in history, it can easily be foreseen that the depletion of the energy resources is an imminent process, repercussions of which our civilization will have to face in the near future. Nevertheless, whatever the level of accuracy of our prediction methods and models is, it is obvious that any inaccuracy in our calculations may affect only the time- scale but not the essential understanding that the depletion-process of energy-resources has begun and needs to be addressed urgently.

Scarcity of natural resources and economic growth are in fundamental opposition to each other. The study of the contemporary and historical beliefs showed [Barnett H.J., Morse Ch., 1963], that:

a. Natural resources are economically scarce and become increasingly so with the passage of time;
b. The scarcity of resources hampers economic growth.

2. ENVIRONMENT

Use of the primary energy-resources is a major source of emissions [Mackey R.M., Probert S.D., 1996, Price T., Probert S.D.,1995, Mackey R.M., Probert S.D,1995]. 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 gases

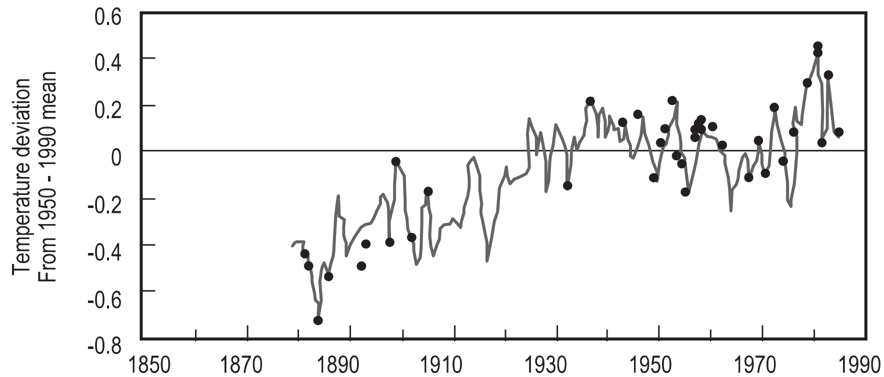

Figure - 7: Global Warming Trend (1880-1990)

emitted from the combusted fuels have accumulated to an extent that serious damage is being done to the global environment. The accumulated amount of CO_2 in the atmosphere is estimated at about 2.75 x 10^{12} tons.

The trend of global warming from 1880 to 1990 is shown in Figure-7 [Hought R.A., Woodwell G.M, 1989]. It is quite obvious that further increase of CO_2 will lead to disastrous effects on the environment. Also, the emission of SO_2, NO_x and suspended particulate matters will substantially contribute to exasperate the effect of the emissions of these gases on the environment.

On a global scale, coal will continue to be a major source of fuel for the electric-power generation, and many developing countries, such as China and India, will continue to use inexpensive, abundant, indigenous coal to meet growing domestic needs [Wu, K.,Li, B., 1998; Painuly, J.P., Rao, N., Parickh J, 1990]. This trend greatly increases the use of coal worldwide as economies in the other developing countries, continue to expand. In this respect, the major long-term environmental concern about coal-use has changed from acid rain to greenhouse gas emissions, primarily of carbon dioxide due to combustion.

It is expected that coal will continue to dominate China's energy usage in the future. In 1993, China had produced a total of 1.114 billion tons of coal. Since China is the third biggest energy-producer in the world, USA and Russia being the first and the second, its contribution to the global accumulation of the CO_2 will be large if the respective mitigation strategies are not adopted. The example of China is important for the assessment of the future progress of the developing countries and their need for accelerated economic development.

3. SUSTAINABILITY AND SUSTAINABLE DEVELOPMENT

The energy resources are the bricks for building our civilization [Sustainable Energy Strategy, 1995]. Their polyvalent use has offered a great service to the society. Sadly however, production and consumption of energy are going hand-in-hand with certain 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 cleanly and efficiently as possible. Crucial importance is added to this need due to the rapidly growing world population and the need for accelerated economic growth of the developing countries. This is the reason why energy takes a centre-stage in the debate surrounding an important dilemma of today: how to achieve economic development and a habitable environment simultaneously in a world that is undergoing rapid changes.

In the last few years, 'sustainability' has become a buzzword in the discussions on the resource-use and environment policy. The word 'sustainability' has its roots in the Latin word 'sustinere', meaning 'to hold up'. Before any further discussion on 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? Some definitions of the concept are as follows:

a. *Development that meets the needs of the present, without compromising the ability of future generations to meet their own needs.*
   World Commission on Environment and Development (Brundtland Commission) [Report of the United Nations Conference on Environment and Development, 1992];

b. *The development that 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.*
Agenda 21, Chapter 35 [Science for Sustainable Development, 1992];

c. B*alancing of economic, social environmental and technological considerations, as well as the incorporation of a set of ethical values.*
Council of Academies of Engineering and Technological Sciences [Declaration of the Council of Academies of Engineering and Technological Sciences];

d. *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.*
Earth Chapter [The Earth Chapter, 1995];

e. *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.*
Thomas Jefferson, September 6, 1789 [Jenkinson, C.S. White House].

All five definitions emphasize a specific aspect of sustainability. Definitions a) and e) both imply that each generation must bequeath enough natural capital to permit future generations to satisfy their needs. The common meaning of all these definitions is that we should spare our descendants the ability to survive well and meet their own needs.

Definitions b) and c) are more political pleas for the actions to be taken at global, regional and local levels, in order to stimulate the United Nations Organization, Governments and local authorities to plan development programmes in accordance with the available scientific and technological knowledge. In particular, in definition c), the ethical aspect of the future development actions to be taken to meet the needs of sustainable development should be noted.

Definition d) is based on the religious beliefs fulfilling the responsibilities and duties towards nature and, hence, the Earth. In this respect, it is of interest to note that the Old Testament, in which the story of creation is told, is a fundamental basis for Hebrew and Christian doctrines of the environment. In the world of Islam, nature is the basis for human consciousness. According to the Quran, while humankind is God's vice-gerent on Earth, God is the Creator and Owner of nature. But human beings are his trusted administrators; they ought to follow God's instructions, that is, acquiesce to the authority of Prophet Muhammad (PBUH) and to the Quran regarding nature and natural resources.

Sustainable development focuses on the role and use of sciences in supporting the prudent management of environment and for the survival and future development of humanity [Curzio A.Q., Zobali R,1996, Domingos J.J.D., 1994, Sustainable Concept as Applied within Countries (Norway),1998].

It is recognized that scientific knowledge should be used to articulate and support the goals of sustainable development, through scientific assessment of current conditions and future prospects for Earth's system. The Rio Conference suggests the following as means to achieving sustainable development:

a. Strengthening the scientific bases for sustainable management;
b. Enhancing scientific understanding;
c. Improving long-term scientific assessment; and
d. Building up scientific capacity and capability.

It is essential for implementation of a programme based on these to be long-term and conforming to the global changes of life-support systems. In particular, there is a need for a constant interaction with governmental, industrial, political, educational, cultural and religious authorities participating in the realization of such a programme. It is of crucial importance for the realization of such a programme, that 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 the developing countries will overcome any deficiency by an academic approach in dealing with the problems, which are related to their environment.

4. SUSTAINABLE ENERGY DEVELOPMENT

It is beyond the scope of this paper to dwell on all the characteristic entities for the definition of sustainability. Energy is one of the essential commodities required for human life and is affecting the achievement of sustainable development [Cafier G.,Conte G.,1995]. For this consideration, we will focus our attention only to the entities which are in direct correlation with energy-sustainability, which calls for a balance in: i)

Natural resources; ii) Environment-capacity; iii) Population-increase.

Since the Brundtland Commission in its 1987 report, “Our Common Future”, warned of growing threat to Earth against increasing world poverty, environmental degradation, disease and pollution, it has become indispensable for the scientific community to pay increasing attention to the subjects related to these problems. Five years later, the United Nations Organization Conference on ‘Environment and Development’ was held in Rio de Janeiro. An unprecedented number of world leaders met to discuss and map the road to 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 sustainable development.

In the assessment of sustainability in energy use, the current trends in consumption-change has to be taken into consideration, which is reflecting the current change in energy-consumption for the reference period. In order to form some kind of 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 their use, which may be classified into 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 the 21st century. Conclusions drawn from this analysis have become a driving force for the development of the plan for a sustainable energy supply-system. Even if there are a number of options taken into consideration, the common issues are as follows:

4.1 Prevention of the Energy-Resources Depletion with Scarcity-Index Control

All the scarcity-models show that the energy- resource scarcity is in direct relation to the industrial production output. In this respect, the efficiency of resource-use and technology development is 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 [Mitro B., Lukas N., Fells I.,1998, Trennman J., Clark A., 2004]. As regards the technology-development, long-term research and development is needed. In some cases, it will require social adjustments, in order to meet the requirements of the new energy-resources.

The availability of energy resources is limited by two factors: capital to be invested in exploring new resources and developing technologies for energy resources. From recent experiences it was learnt that there is a direct correlation between capital invested in exploration and the value of the available resources. It was proved that a fixed amount of 18 $/t is needed for exploring 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 first is the geological survey, 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, based on the ultrasonic scattering or earthquakes generated by local explosions. The main limitation in the development of new software is the speed and memory-size of computers. It can be expected that, with 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 resource-body.

From the beginning of exploration of energy-resources, the existing drilling-technology was limiting the acquisition of new resources. The development of drilling technology has marked a new direction for the discovery of new resources. A recent example of new drilling-technology has led to a gas resource in the Bay of Mexico. Also, North Sea gas-resources are being discovered as a result of the new off-shore drilling technology. The same has been proved in the discovery of new gas resources in Algeria. The deep-sea drilling has become one of the global issues, which may possibly remove the scarcity problem of energy resources for the next few centuries. It should be mentioned that 2/3 of the Earth’s surface is covered by deep sea, so the breakthrough in deep-sea technology may lead to a substantial change in the energy-resource scenario of the world.

4.2 Efficiency Assessment

The potential improvement of the energy-conversion process is a driving force for its development [Hein K. 1995, Hanjalic K. et. al, 2007]. 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. Taking into account the law of thermodynamics, the technology improvement appears as a significant factor responsible for an entropy change in the energy-system. The application of the principle of Carnot, therefore, allows us to determine an absolute limit to any transformation of the deposit of free energy [El-Sayed Y., R.Evans, 1970, Sama D.A., 1994].

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 helped address the increase of energy prices. It was proved that this approach has resulted in the increase of efficiency of energy-use upto 10 to 20 % in a number of European countries. The main emphasis has been given to the evaluation of efficiency of different technologies and utilization of energy. It is of great importance that effort be directed to the evaluation of the technological processes for energy-saving [EU White Paper, COM (95),682,1995, Furfare S.,1995]. Also, a new development of products is recently under consideration for the minimum use of energy. In accordance with one of the criteria for sustainable development, products have to meet the requirement related to the minimum use of energy. A favourable example for this achievement is the development of a new lighting system, with fluorescent lamps, which offer a saving of about 40%, in comparison with traditional light bulbs.

Cogeneration of heat and electricity is one of the potential means to improve the efficiency of the energy-resource utilization. Cogeneration plants, in conjunction with desalination in regions where water and energy are needed, are an example.

Recent projects with gas-fired cogeneration plants have demonstrated an extremely high efficiency [Darwish M.A., 1995]. 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 development of new energy systems.

4.3 Clean Air Technology Development

Combustion is an irreversible thermodynamic process, with a high degree of 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 that might lead to an efficiency increase of the combustion process. Among these are:

4.3.1 Catalytic Combustion

The low-temperature catalytic combustion of lean natural-gas mixtures represents an effective method for heat generation [Klvana D. et. al,1995]. Coexistence with the reactant catalysts enhances the chemical reaction, but is stoichiometrically independent of the reactant. Among the processes of catalysis, there is the absorption into the catalysis reaction at the catalyst surface and the liberation of the chemical products. Zeolite is a catalyst widely used in chemical industry. Detailed behaviour of the catalyst has not been fully understood. In particular, it is expected that the catalytic combustion may lead to an efficient use of the fuel-cell technology. The catalysis mechanism at the interface between electrode and electrolyte ensures the electron-transfer from the input hydrogen molecule to the electron metal. The search for low-cost alternatives has not been very successful but, lately, the good performance of some active compositions of La, Ni, Co, and O (LSNC powder) leads to promising results.

4.3.2 Fluidized Bed Combustion

Recent progress in the fluidized-bed combustion has led to substantial development of the new energy-system [Van Swaaj W.P.M., Afgan N.H., 1985]. In the combustion that is made to take place in fluidized beds, coal is depressed in a mass of its ashes and absorbent lime, and the concoction is exposed to a temperature of 850^{o}C.

The bubbling alternative offers a good thermal design. In principle, this is a clean option for electricity-generation with medium and good quality coal. The energy efficiency of a bubbling boiler in the Rankine cycle with steam turbines is similar to that of the conventional pulverized-coal power plant. A 350 MWe bubbling atmospheric fluidized-bed power-plant is an option with a very good performance with medium and high-quality coal.

The second alternative of the fluidized-bed combustion power-plant is the circulating-fluid design, offering a high degree of operating flexibility in coal-quality use. It is a complex design, which includes fuel chambers, large cyclone, recovery-boiler and, in some cases, outer ash cooler. This option reduces the energy-efficiency as compared to the present pulverized-coal plant. A factor significantly contributing to these problems is the high electric-energy consumption in auxiliary services, particularly for the ventilator for recirculation. The efficiency of the existing circulating fluidized-bed plants is about 30%. A 250 MWe plant is in operation with low-quality coal. The use of circulating fluidized-bed boiler technology is rapidly increasing due to its ability to burn low-grade coal, while meeting the required NO_x, SO_x and particulate emission requirements.

The pressurized fluidized bed combustion boiler is an option, offering a 10% increase in efficiency over conventional pulverized-coal fired plants. It is a compact plant, with moderate specific investment, using high-quality material and is conceived for medium and good quality coal.

4.3.3 Low NO_x Burners

The present, advanced energy-technology is focused on further improvements in the emission-control [Mitchelfelder S., 1997]. In principle, there are two approaches: the first one is by reorganization of combustion-processes in burners, and the second one is by post-combustion processes in furnaces.

In order to minimize the emissions of SO_x, NO_x and particulates, a new burner-design is envisaged to meet the requirements for minimization of initial NO_x formation. It is expected that the new burners in properly designed new furnaces [Durao D.F.G., et. al, 1992, Weinberg A,1995], will reach 370 to 490 mg/Nm^3, which is the limit for present emission control.

Further NO_x reduction can be achieved through furnace staging. Here the boiler combustion-zone is opened close to the stoichiometric chemistry condition and the balance of air is added in the upper furnace through an overfire airport. NO_x emission can be lowered through post-combustion technologies, such as selective catalytic reduction. NO_x is reduced with molecular nitrogen and water, as well as by reduction with ammonia, in the presence of a catalyst.

Numerical modeling of the processes in combustion-chambers has become important in design and analysis of tools [Carvalho, M.G. et. al, 1988; Carvalho M.G.,1988; Coelho P.J., Carvalho,1986] for improving air-distribution in power-plant burners. Numerical modeling allows the analysis of designs for optimal modifications of turning vanes, flow splitters, perforated plates and burner shrouding. Also, numerical models of boiler furnaces [De.Jong B., 1995] are available as computational fluid-dynamic software, which allows practical analysis of power-plant furnace behaviour with minimum emissions of SO_x, NO_x and particulate. Retrofitting of existing power-plants with advanced combustion technologies will lead to substantial increase in efficiency and minimize harmful emissions into the environment.

4.3.4 New Boiler Designs

Coal-fired boiler power-plants will continue to be one of the major contributors of energy in the future. Modern pulverized coal-fired systems, presently installed, generate power at net thermal efficiency ranging from 34 to 37 %, while removing up to 97 % of uncontrolled air-pollution emissions. A new generation of pulverized coal-fired boiler technologies is currently under development, which will permit a generating efficiency in excess of 42 %. In this respect, further development is needed for improvements to reduce the emissions and expand the operability. To achieve high thermal efficiency, special attention has to be paid to the load cycling operation. In this respect, a low-emission boiler-system based on the diagnostic monitoring of process-parameters and expert systems is under development.

The development of high-performance power-systems is an ultimate goal for upgrading pollution-control, with corresponding combustion-system improvements and the control of SO_x and NO_x, through the implementation of new burner-design and post-combustion emission control.

Also, the implementation of the boiler numerical codes for the determination of process parameters will be used as a tool for the efficiency-control and early diagnostic function monitoring. This improvement in heat and mass-transfer research [Afgan N., 1995] has substantially contributed to new boiler- designs and will lead to the increase in availability of modern power-plant systems [Bergles A.,1985].

4.4 Development of Intelligent Energy Systems

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

4.4.1 Expert-System in Energy Engineering

The expert-system development in energy-engineering is focused in two directions: (i) expert-system for energy system design and (ii) knowledge- based for on-line diagnostic [Application, ed. by W. Rohsenow, J. Hartnett, E. Ganic, 2002; Leontiev A.I., 1993; Goldstein R.J, 1971]. 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 designs. 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 used in the design of thermal equipments is demonstrated by the heat-exchanger design [Makansi, J. 1997]. Further developments of knowledge-based system to design energy-system will improve efficiency and reliability.

The knowledge-based system for fault-diagnostics 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.

There have been several attempts, which have proved the possibility of using knowledge-based systems in the fault diagnostics of thermal power-plants. The efficiency-monitoring and respective logistic-evaluation of the diagnostic parameters have been demonstrated to be good and reliable tools for the advanced diagnostic of operational deficiency. The boiler-fouling and tube-leakage knowledge-based system prototypes demonstrated the possibility of detection of the processes leading to the degradation of power-plant-efficiency [Afgan N. H., et. al, 1991]. The diagnostic systems are based on the online monitoring of diagnostic variables and their fuzzyfication.

4.4.2 Fuzzy-Logic Control

The new fuzzy-logic control-system proved to be a qualitatively efficient system [Jamshidi, M., 1971]. While similar control-systems designs are based on hit and trial; the knowledge-based controller is ‘ad hoc’ at present. A gap exists between solid theoretical results, such as stability and controllability. A real-time implementation of intelligent control-system uses fuzzy logic, neural networks, generic algorithms, expert-systems, etc.

4.4.3 Intelligent Energy Systems

The generic design procedure to be adopted for the intelligent product design of the thermal equipment has to be in line with the definition of indicators for the assessment and optimization of the specific design. In order to provide the design criteria 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 [Afgan N. et. al, 1991; Afgan, N., Carvalho, M. Coelho, G., P, 1996; Afgan, N.H., Carvalho, M.G., 1996]. These indicators should be based on optimization of the efficiency of respective thermal equipment, resource-use assessment and validation, environment-capacity use and degradation, modular structure with multi-purpose elements, end-of-life assessment and economic justification of specific designs.

4.5 New and Renewable Energy Sources (NRES)

Besides taking steps for improving the efficiency of power-generating units, there is a great need to introduce sources of the energy in the energy mix for optimal results. The connected 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 also be based on the use of renewable-energy resources. Renewable energy is available in abundance. New technologies based on these resources highlighted below exhibit a great deal of promise viz sustainable energy development:

4.5.1 Solar Energy Resources

Solar energy can be exploited in three main modes:

- By enhanced absorption of solar energy in collectors, which provide low-grade heat;
- By using reflecting devices to concentrate the solar energy in a heat-carrier, which is then used to generate electricity; and
- By converting sunlight directly into electricity.

Solar energy resources do not have clear limits. The annual influx on the Earth's surface is 10,000 times the current human energy-consumption; the fraction of energy reaching the land surface is 3,000 times as large, and so even 35% of this could generate 1,000 times more energy than our current demand. As we can notice, the resource of solar energy is huge but diluted. In scientific literature, it is assessed that feasible tool-use of solar energy from the technical standpoint is approximately as shown below [Zafran M., 1993]:

i)	Thermal solar for	170 MTOE/year
ii)	Decentralized electric solar	450 TWh/year
iii)	Network electric solar	230 TWh/year

In the local resources evaluation for these three solar energy systems, one could take into consideration its minimum and maximum installation capacity as described below:

	Minimum	Maximum
Solar power plant	50 kW	10 MW
Thermal solar	150 kW	80 MW
Decentralized electric solar	30 kW	5700 kW

From the present status of development, the following capacities can be taken into account .It should be noted that for insolation lower than qR = 4 kWh/m^2/day, it might be difficult to adopt the same method of validation.

Solar-energy use is demonstrated in three options: solar thermal, solar photovoltaic and solar power-plant. Solar-thermal energy-production plant have now reached an industrial level and are available in world markets [Fritz, W., 2000; Berkovski, B. 1989, Afgan, N. 1989, Zafran, M., 1993; Best, Kwschik, 1993].

The solar photovoltaic system is well-advanced in its demonstration stage, with a variety of applications. It has been demonstrated in three levels, namely:

The first level is not an energy-intensive application and has no significance for its consideration for the energy-source strategy point of view. The second option is being used as the only energy-source in various remote areas and has been demonstrated as a reliable energy-source.

Solar power plants are under development. They are available as photovoltaic-cell modular units and can be installed when the power-demand requires a system augmentation.

4.5.2 Geothermal energy resources

Resources exploitable at current energy-prices correspond to aquifers in narrowly localized volcanic zones [Fridleifsson I.B., Freston D., 1993; Dickson M., Farnelli M., 1995]. Presently, installed and "under-construction" plants provide a total electrical capacity of 7,100 MW (high enthalpy energy). Low enthalpy hot water to be used directly for heating is estimated at about 13 MTOE/year.

Levels	Power
Ubiquitous solar cell	not fixed
Solar unit for electronic application	50W - 1 kW
Solar units for irrigation	5 - 60 kW

These two groups of geothermal-energy systems are limited by the temperature and flow-capacity of individual well. From the experience, the following limits are adopted:

	Min.temp [°C]	Min. capacity [m^3/h]
High-enthalpy geothermal	90	2,900
Low-enthalpy geothermal	35	1,000

Particular resources-evaluation requires a specific assessment of the respective aquifer-volume, in order to estimate uncertainty in the lifetime of the geothermal energy-system. It is desirable the volume of the aquifer should exceed several times the capacity needed for the respective system lifetime. The local resource-evaluation for the geothermal system should also account for the land required for the brine to be deposited during the lifetime of the plant.

Conventional electric-power production is limited by fluid temperatures above 140°C, but a considerably lower temperature may be used with the application of binary fluids. Geothermal electric-energy plants have proved to be very reliable sources of energy. They are used in 21 countries with a total world installed-capacity of 6,017 MW distributed over 330 individual turbine-generator units.

The geothermal power plants are built in four versions, namely: direct steam plants, flash steam plants, binary plants, and hybrid plants.

Direct steam plants are used with vapour-dominated resources. Steam from production-wells is gathered and transmitted via pipelines directly to a steam turbine. In most direct-steam plants, the capacity of the turbine is greater than five MW.

Hybrid plants are also used in various ways to achieve a higher efficiency or to overcome the potential problems related to geofluid characteristics. The examples of hybrid plants are: direct steam/binary units and flash steam/binary units.

4.5.3 Biomass Energy Resources

Biomass provides about 14% of the world energy or about 25 million barrels of oil-equivalent per day (Mboe/day) [Wereko-Brobby Ch.Y.,Hagen E.B Hall D.O., 1995]. It is the most important source of energy, especially for developing countries. Various applications of biomass energy may be for lighting, water filtration, cooking food and irrigation.

Biomass energy can be obtained through different means of biomass-conversion processes. The great versatility of biomass as a resource is evident from the range of wet to dry materials, which can be converted into various solid, liquid and gaseous fuels, using biological and thermo-chemical conversion processes. Solid fuels are wood, charcoal, crop and forest residuals, agro-industrial and municipal wastes and briquettes. Biomass-derived liquids are mainly ethanol and methanol. Gases are mainly biogases from anaerobic digesters, gasifiers-producing gases that can be used for electricity generation. There are two processes involved in biomass conversion, namely: bioconversion process and thermal process. The bioconversion processes are alcoholic fermentation and anaerobic fermentation. The thermal processes are pyrolysis and combustion of the biomass.

In this analysis, priority will be given to technologies that are demonstrated at industrial scale and could be used as reference for the technological assessment of their maturity. In this respect, bioconversion technology for the ethanol production falls in a category of technologies that are presently available commercially. For the ethanol production, there are three available options:

	Capacity [l/day]
Micro system	< 200
Mini system	200 - 20 000
Macro system	> 20 000

Ethanol is being used as a fuel for automobiles in many countries in the United States, Europe and Africa.

4.5.4 Wind Energy Resources

The world's exploitable wind resources are estimated at about 300 TWh/year [Walker J.F., Jenkins N., 1995, Sesto E., et al., 1993]. These are rather heterogeneous and strongly depend on the geographical location. It was recognized that the most economical wind-turbines are those with a rating between 1kW and 350 kW. This requires that the wind velocity at the potential location of the wind power plant should be a minimum of 6.5 m/s with an availability of 25 - 40%. In this respect, the wind energy to be used for electricity production will depend on the single-unit production of the specific size, but the total installed capacity may be dependent on local demand or grid capacity. Grid-connected turbines, in the form of wind farms, are a prospective entity for the use of wind for electricity production. In connection with this approach, the land occupied by wind farms is to be brought under consideration as local resource of the specific location. It is estimated that wind farms with a capacity of 4 to 8 MW could be installed on an area of 1 km^2. In defining the resource conditions for wind-energy utilization, the following parameters are to be kept in view:

i) Average wind velocity at the specific location; and
ii) Probable distribution of wind velocity.

The wind-turbine technology is available in two arrangements of the rotor, in relation to the direction of wind, namely:

- Horizontal-axis wind turbine
- Vertical-axis wind turbine

The horizontal-axis wind turbine, in which the direction of the wind is parallel to the axis is technologically more developed. At present, horizontal-axis wind-turbine generators represent approximately 95% of the capacity installed in wind plants. The developed wind-turbine plants are presently in operation and resulting in new turbines that could be classified in the following three categories small, medium and large sized wind turbine:

- Small-size wind-turbine generators are used in a large number of applications. Most of these applications are limited to the energy supply for isolated dwellings: pumping, desalination, and integration with diesel and other renewable-energy resources. In all these applications, the storage capacity is an essential factor.

- Medium-sized wind-turbine generators are commercially available and connected to the grid. The configuration of the plant is conventional and the blades are made of glass-fibres, reinforced with plastic or laminated wood bonded by epoxy resin, with power-regulation by adjusting the pitch of the blades.

- The technology of large-size wind-turbine generators is still under development. Prototypes of the turbines having a capacity up to 4 MW and rotor diameters of up to 100 m are available in some countries. The results obtained have confirmed the feasibility of large wind-generators, but have also shown that these machines are still far from being as efficient as medium-size machines.

Wind Turbines	Capacity	Diameter [m]
Small-size	100 kW	< 20
Medium-size	100kW - 1MW	20 - 50
Large-size	> 1MW	> 50

4.5.5 Hydro-Energy Resources

It is estimated that the gross theoretical production of hydro energy is about 30 millions GWh/year, with an exploitable production of about 13 million GWh/year [Jiandong, T., et al., 1995; Cazenave, P. et al, 1993]. The present production of the existing plants is of the order of 2.2 million GWh/year. The main reason for the large disparity between exploitable and present production is the financial capacity of the countries. The average percentage of hydro-electric energy-production for developed countries is 7% while for developing countries it is 54%.

In many countries, emphasis is laid on the utilization of the small-scale hydropower potential. The total capacity of the mini/micro power-plant is about 1.5 % of the total installed hydropower potential. An equal amount of small-scale plant-capacity is currently in the planning stage.

According to UNIPEDE classification, there are three types of hydropower plants

Size	Power [kW]
Small power plants	< 10 000
Mini power plants	< 2000
Micro power plants	< 500

Accordingly, there are the following three main types of hydro turbines, depending on the water-flow rate and available height of waterfall:

Type	Height [m]
Kaplan turbines	2 - 20
Francis turbines	5 - 200
Pelton turbines	50 - 1000

- In Kaplan turbines a mechanical momentum is produced by helical blades formed to develop a pressure-difference at the front and rear surface of the blades.
- The Francis turbine is designed to uptake the water radial flow, through fixed blades into

rotating blades on the turbine rotor.

- The Pelton turbine is designed in the form of one- row double spoon blades, exposed to the injected water-stream.

Inventories of suitable hydropower sites have been established for many areas and a vast catalogue of the exploited sites is available. The best sites have already been explored. There is still a lack of knowledge of the potential of small-plant sites.

4.6 Environmental Capacity for the Combustion Products

The sustainability is also closely related to the environmental capacity of our planet. It has been shown that the natural processes in the biosphere exhibit the maximum rate of change. This rate of change exceeds the contemporary rates of the parameters defining the anthropogenic impact to the environment and, by four orders of magnitude, the mean rate of change of the parameters defining the geophysical processes [Kyoto Protocol, 1992]. The concentration and the rate of change of chemicals involved in the biochemical cycles may be characterized by the changes in the concentrations of organic and inorganic carbon compound. The capacity of biologically active organic and inorganic carbon chemical species in the environment is 10 times larger than their annual primary production. Therefore, it may be expected that this resource of environment-capacity could be considered in the next 10 years if only synthesis or decomposition of organic matter is taking place (in the absence of all the life processes).

The fluxes of the organic material produced by the synthesis and decomposition processes in the biosphere are within the accuracy of one hundredth percent (0.001%) of the anthropogenic fluctuation resulting in the environment in the geological time-scale. This slow change in the environment on the geological time-scale can be compensated by biological processes leading to the biosphere-control of the chemical composition of the environment. Since the preservation of the biosphere is affecting the biodiversity of our planet, it is of primary interest in long-term evolution to have 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 ensure 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 changes that are introduced by human activity. 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. At the same time, it is essential to the economic and social development for improved quality of life. Several threats have been recognized as signals for potential hazards to the environment.

The emission of air-pollutants is usually considered in three groups, namely: carbon dioxide, nitrogen oxides, and sulphur oxides. The adverse effects of these 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 noting the increase in 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 [Marchuk, G.I., Kondrotyev, K.Ya.,1992].

4.7 Mitigation of Nuclear-Power Threat to the Environment

The nuclear power-plants are very beneficial in order to mitigate the greenhouse effect, because they have no exhaust gases [Marchetti, C, 1993]. But it is known that the present nuclear power reactors have the potential to be enormous sources of radioactive emissions. Besides affecting the immediate surroundings, these hazardous events may lead to regional and even global threat to the environment. The low probability of this kind of event has been the only barrier to the increase of their disastrous effects in the global environment. Examples recently noticed require a different approach to face and master such potential hazardous events. Human society is not in a position to base its existence on the man-made probability actions, that may cause hazards beyond retification.

Opponents to nuclear energy stress two points that they consider crucial: the possibility of major radiological releases following an accident; and the enormous heritage of long-lasting radioactive wastes for the future generations. Obviously, both these points are very relevant to the sustainable development of this form of energy. Both need to be discussed separately. Even if the chain-reaction during the accident has been broken 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 the reactor vessel. Against these possible accidental chains, a 'defense indepth' strategy has been developed with three main lines: a 'preventive line', a 'protective' line, and a 'mitigative' line. This strategy worked for Three-Mile Island accident, with external releases of a few curies of radioactivity, but did not work for Chernobyl event due the absence of external containment and many other design-deficiencies.

Present reactor-designs for the second line of defense 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 etc to operate it [Nenat J.C., et. al, 1996, Three Mile Island Unit # 1, 1995]. The present trend of the designers is to increase the percentage of passive safety-systems, so as 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 for a deterministic approach, instead of the more scientific probabilistic one, for gaining the acceptability of common people who believe in the old saying "if it can happen, it will happen" [Cumo M.,1995].

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 to guarantee an easy and total decommissioning of the metal pieces at the end of its useful life. All these characteristics meet the requirements of sustainability.

The second 'point of fear' of nuclear opponents related to the long-lasting wastes is still open 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 into the (short life) radionuclides. The radionuclides with long lifetime can be converted into short-life isotopes by their mutation through nuclear reactions: (a) in high-flux nuclear reactors; or (b) in a coupled device of subcritical nuclear reactor, in which a beam of high-energy particles is introduced by means of a powerful accelerator. The total amount of long-lasting wastes will be substantially reduced to be conveniently placed in suitable geological formations that remained dry and intact for millions of years. A device of this type has been recently proposed by Rubbia, with a subcritical fast reactor cooled by lead in natural convection, fed by spallation neutrons generated by a beam of protons accelerated to 1 GeV [Rubbia et al., 1995]. The conceptual design of fast-neutron operated as high-power energy amplifier is ADS.

5. SUSTAINABILITY EDUCATION

People around the world recognize that current economic development trends are not sustainable and that public awareness, education and training are the keys to move towards sustainability. Beyond that, there is little agreement. People argue about the meaning of sustainable development and whether or not it is attainable. They have different visions of what sustainable societies will look like in the future and how they will function.

It is interesting to note that while we have difficulty envisioning a sustainable world, we have no difficulty identifying what is unsustainable in our societies. We can rapidly create a laundry list of problems – inefficient use of energy, lack of water-conservation, increased pollution, abuse of human rights, overuse of personal transportation, consumerism, etc. But we should not chide ourselves because we lack a clear definition of sustainability. Indeed, many truly great concepts of the human world – among them democracy and justice – are hard to define and have multiple interpretations in cultures around the world [Aleksander Lingen et. al, 2006].

Education is an essential tool for achieving sustainability [Saif R. Samady, 2006]. Development of a sound education-system is a milestone towards any economic development. In this respect, sustainable energy development will require special attention to be devoted to designing a new education-system.

An important distinction is the difference between education *about* sustainable development and education *for* sustainable development (ESD). The first is an awareness lesson or theoretical discussion. The second is the use of education as a tool to achieving sustainability. In our opinion, more than a theoretical discussion is needed at this critical juncture in time. While some people argue that 'for' indicates indoctrination, 'we think for' indicates a purpose. All education serves a purpose, otherwise society would not invest in it. Driver education, for example, seeks to make our roads safer for travelers. Fire-safety education seeks to prevent fires and tragic loss of lives and property. Similarly, ESD promises to make the world more livable for this and future generations. Of course, a few will abuse or distort ESD and turn it into indoctrination. This would be antithetical to the nature of ESD, which, in fact, calls for giving people knowledge and skills for lifelong learning to help them find new solutions to their environmental, economic, and social issues.

Information and computer technologies have become essential tools for the presentation and dissemination of information, knowledge and entertainment visualization. New development in this field is opening many different areas to the large exposition. In particular, it was seen as the advanced promotion of advertisement, music, entertainment, arts and, to a lesser extent, in education. It is almost impossible to imagine any modern product without a multimedia presentation. Now, most of the products are rated by the success of its multimedia presentation. It has become obvious that human perception is multidimensional and comprises listening, seeing and eventually, touching. Quality of each of the approaches to human perception is strongly effecting its adoption and reception. There is no doubt that the multimedia approach has gained great role in conveying the message to human recognition. The multimedia approach may activate all perception-channels to convey the message to a more effective human adoption. It has been demonstrated in the entertainment industry, in particular, that the multimedia approach has gained high visibility in public as large multimedia have opened a new process of democratization of all those values being reserved for the nobility. The exposition in some museums used to be accessible only to those in the near surrounding or those who are able to afford high travel expenses. Now, masterpieces from different museums are made available in the multimedia environment on CD with a high-quality reproduction and the respective audio introduction.

Education has been to a lesser extent exposed to the multimedia environment. There are, however, excellent language courses with video presentations and multimedia editing. Also, similar elementary teaching for children has been successfully presented and introduced in the education. Graduate and post-graduate education has undergone only limited success in presenting learning-material in the multimedia environment. There are some good examples proving that the future presentation of high-technology knowledge will become a demanding tool for progress and economic development in many countries. It is obvious that the present educational system with classical methods of teaching will not be able to meet the future requirements of higher education. A number of concerns have been expressed about the potential options, which may lead to the development of new higher education system. One of those options is the distant-learning system. It has been recognized that the distant-learning education may become a powerful tool and may offer challenge for a new development of higher education system [Afgan N.H., 1991].

6. CONCLUSIONS

It is concluded that:

a. The present energy-strategy requires adoption of new criteria to be followed in the future energy-system development. No doubt, there is a link between energy-consumption and environment capacity reduction. This is an alarming sign, which has recently become the leading concern for our near and distant future. Together with social aspects of the future economic development, it is of paramount interest for the modern society to implement the concerned resolutions adopted by world-leaders, before it is too late.

b. Modern engineering science has to be oriented towards those areas that may directly assist us in our future energy-planning. In this respect, there is a dire need to orient attention towards the global aspect of energy-development. Modern technologies will help adopt essential principles of sustainable energy development. With the introduction of appropriate renewable-energy resources in our energy-future and with relief from nuclear energy threat, it will be possible to comply with the main principles of a sustainable energy strategy.

c. Finally, in order to promote sustainable energy development, the respective educational system is required. It was recognized that the present energy educational system is not geared to meet future needs of knowledge dissemination. It is clear that the best possible option for the future education-system is the distance-learning with multimedia telematic system.

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