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Keynote Paper

ENERGY AND ENVIRONMENT IN THE TWENTY-FIRST CENTURY

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Abstract Energy and environment, both are essential for our survival on the planet earth to ensure a decent standard of living and good health. However, there is a price for the comfort that we strive hard to achieve. It took forty years to realize that CFC (Chlorofluorocarbons) causes Ozone depletion. Similarly, greenhouse gases and acid rain are realities that we have to contain to provide a cleaner environment for the future generation. Fossil fuels are essential but their application can be limited to areas where high temperatures are required. Prices of fossil fuels should be controlled to prevent its random usage. Solar thermal applications may be considered for areas where low temperatures are involved, as the technology is proven. For the immediate future, CNG usage should be encouraged in automobiles, at least, until such time when Hydrogen fuel or any other non-polluting fuel takes over. Even for power production, natural gas should be encouraged. It is probably the time to consider offering incentives for the use renewable energy resources, as the users are doing a favour not polluting the environment.

Keywords: Energy, environment, sustainability, renewable energy.

INTRODUCTION

For the existence of mankind, the use of energy in different forms is considered fundamental. The environmental problems that have emerged in recent years can be attributed to the ways mankind has been using the energy resources. Although the environmental pollution may be of different types, the emission from combustion of fuels in power plants and automobiles are considered probably the most worrying, when the impact of the air quality on health is considered (Brown et al.,2001, Elliot,1997). The use of fossil fuels: coal, oil and gas is, generally, seen as having a major impact, resulting in events such as global warming.

It has been almost thirty years since the oil crisis of the 1970s. A review of the energy forecasts and expert studies of the early 1990s conducted by various researchers reveals a rather interesting consensus that only minor changes in energy consumption will occur during the next few decades (Lenssen and Flavin, 1996, WEC, 1993). Currently, the

world is going through a period of rapid change: everything from new IT to the rise of genetic engineering, and the breakdown of traditional social structure reshaping modern
economies and lifestyles. The world energy economy is likely to move towards a more efficient, decentralized and cleaner energy system, a cleaner version of today's fossil fuel. The energy landscape has also been changed significantly due to the recent emergence of natural gas, which shows considerable environmental advantages and an abundant global supply. In addition, the recent developments in wind power, solar energy, and a host of other renewable resources are turning these resources into economically viable options. Fuel cells and hydrogen fuel are also likely to play a major role in the future energy strategy.

During the last century, the developing countries, with more than three-quarters of the world's population, accounted for only one-fifth of the CO_2 released to the atmosphere. The per capita emission of industrial countries is about 10 times more than those in developing countries. However, as the latter nations become more industrialized, they become central to any effort to stabilize the environment. If emissions in 2025 are to remain at the level of 1990, emission from developing countries will increase, as they surge ahead with development activities. Moreover, a steep decline in emissions is likely to occur in developed nations due to the adoption of energy efficient systems and new energy resources.

As the developing nations struggle to improve their conditions and try to attain the status of industrialized nations, they will have opportunities for using higher and more energy efficient technology. Countries with heavy concentrations of the world population, such as China and India, will probably have more ambitious programmes on solar thermal, photovoltaic and

Hydrogen programmes. Most of the countries with agro-based economy will find significant utilization of solar energy, as the technology is already proven.

This paper discusses the pattern of conventional energy usage in the future, its impact on the environment and the role of renewable energy resources to achieve sustainable energy strategies for tomorrow's world.

ENERGY UTILIZATION

Energy plays an important role and provides a driving force for the development of modern civilization. Sun, the source of all forms of energy, produces energy by nuclear fusion. Every year, the earth receives 5.6 x10 ^{15} GJ of energy from the sun leading to a production of 2 x10 ^{11} tons of organic materials by photosynthesis [Afgan et al., 1998]. Over billions of years, since the creation of planet earth, there has been immense accumulation of energy in the form of different hydrocarbons. In recent years, the pattern of energy production and usage has gone through enormous changes. Table 1 shows the global primary energy consumption and the contribution of different sources in the year 1992 [Elliott, 1997]. Figure 1 shows the pattern of usage of different forms of energy since 1850 [Farinelli, 1994].

Table 1- Global consumption of different primary energy resources in 1992

Fuel resources	Global (%)	UK (%)
Oil	33	8
Coal	22.8	60 (47 in 1995)
Gas	18.8	4.0 (16 in 1995)
Biomass	13.8	
Hydro	5.9	2
Nuclear	5.6	21

Source: British Petroleum, BP Statistical Review of World Energy, BP Corporate Communication Service, 1993

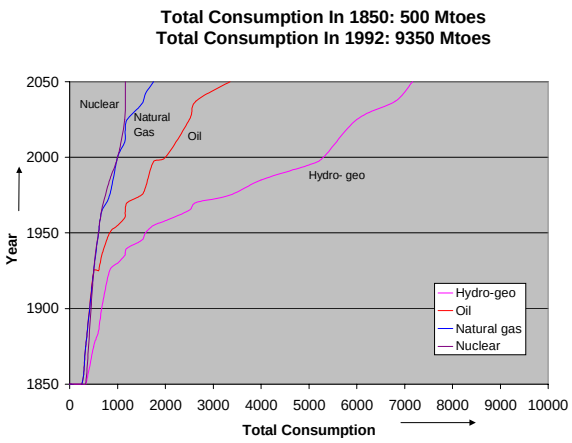

Fig.1 Pattern of energy consumption over the years

The pattern of demand and supply may vary from year to year within a country. However, the global usage (percentage), which represents aggregate patterns of a large number of countries do not appear to change rapidly. Similar patterns of energy consumption and energy use have been found in 1994. An overall upward trend in global energy is noticed; the 1995 figure showed 1.8% rise. Also, energy usage is likely to increase with per-capita gross domestic product (GDP) [Medows, 1972], as shown in Figure 2, while the world population grows, as illustrated in Figure 3 [Keating,1993]. Considering a range of energy scenarios developed to map out possible patterns of long-term supply and demand, it is found that the energy demand is likely to increase threefold by the year 2060.

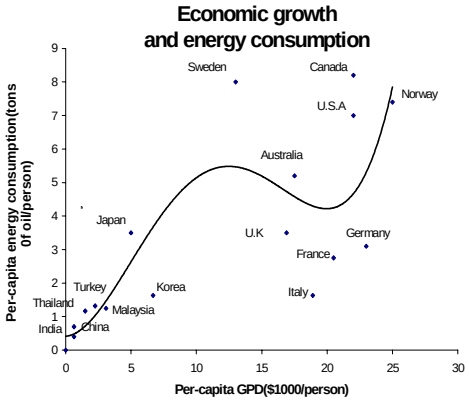

Fig. 2 Increase in energy consumption with GDP

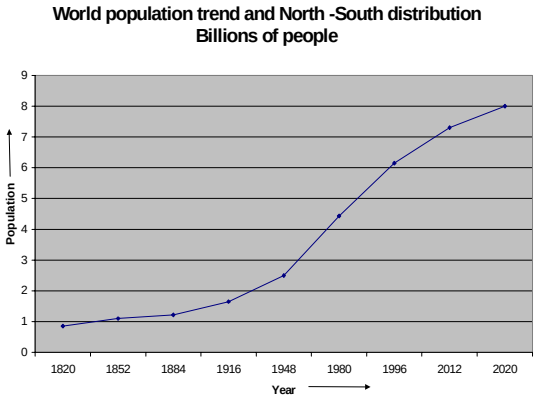

Fig. 3 The trend of world population growth

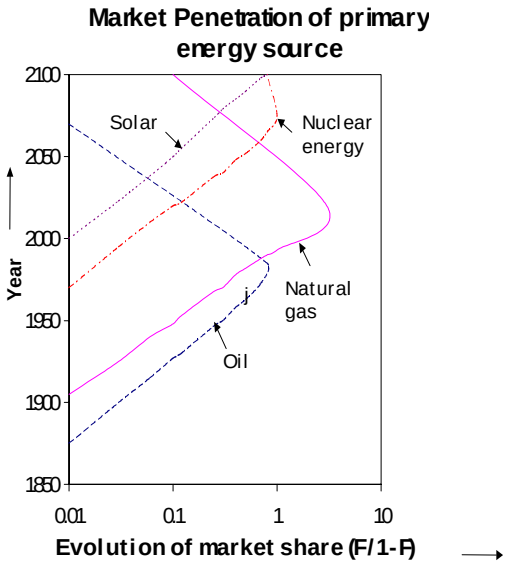

Fig. 4 Evolution of market share of different forms of energy resources

*F denotes the fraction of the market share taken up by each of the primary sources at a given time.

It is commonly known that the energy consumption depends upon two parameters: the amount of energy consumed per person and the growth of pollution. Figure 4 shows the contribution of different forms of energy during the course of time.

In relation to prices of other commodities, the price of crude oil has not changed much over the last 30 years. Effectively, it has declined, as shown in Figure 5, making it affordable even to low temperature applications. Probably, it has been fair to the developing countries, and while considerable benefits went to the developed world, the environment went through a very rough ride nevertheless.

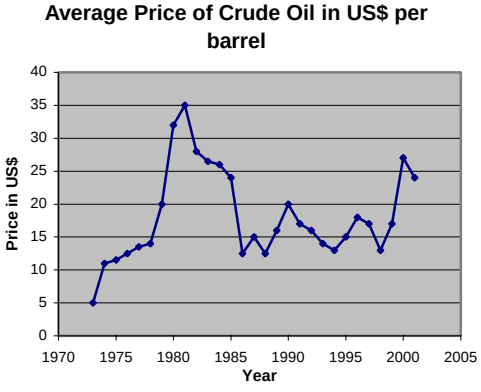

Fig. 5 Variation of prices of crude oil over the last 30 years

IMPACT ON ENVIRONMENT

The environmental issues received a lot of attention in the early 1970s, although some issues became prominent earlier. For instance, the environmental pollution from coal burning, which resulted in the formation of disastrous smog in 1950, which lead to thousands of deaths in London.

Similar problems were encountered in other areas. Acid rain, due to acid emission from power plants caused primarily by sulphur contents in coal and oil resulted in considerable environmental damage. The acid emissions, which are a result of the combustion of fossil fuels can be prevented relatively easily, although at a cost. The next issue, the greenhouse gases (CO_2) that confronted nations, had no obvious remedial measures. Carbon dioxide (CO_2) is a fundamental product of combustion of all fossil fuels. All fossil fuels contain varying amount of Hydrogen and Carbon. Coal contains a high proportion of carbon and produce CO_2 and heat, when subjected to combustion. Natural gas is made up of one atom of carbon and four atoms of H resulting in lower CO_2 , as the hydrogen converts to water. Table 2 shows the production of green house gases formed by some common fossil fuels.

Table 2- Release of CO_2 due to combustion of fossil fuels [Elliott, 1997]

Fuel	kg of CO_2/GJ of heat
Coal	120
Oil	75
Natural gas	50

At the Rio Earth Summit in 1992, the international framework convention on climate was agreed upon by the world's governments, signed by 160 countries, to try to get carbon dioxide emissions back to 1990 levels by the year 2000. Five years after the signing of the agreement, the governments met again in Kyoto in December 1997 to negotiate further action to protect the climate. The current Kyoto agreement goes further to achieve an additional cut of 5% in greenhouse gas emissions from industrialized countries by 2012 over 1990 levels.

Unlike acid rain, the control of CO_2 is much more difficult. CO_2 travels up into the upper atmosphere (the troposphere). It forms a screen, which allows solar radiation to pass through it but not the radiation from the earth, resulting in greenhouse effect. This leads to global warming melting icecaps leading to a rise in sea level. As a result of global warming, the climate patterns are likely to change, hence, affecting the growth of crops. Climate changes become more erratic and floods may be very severe in some parts of the world.

DEVELOPMENT OF SUSTAINABILITY

All forms of energy technologies have some environmental impacts, however, the nature of the impact may be different. The goal should be to develop a set of energy technologies, which can meet human needs for a reasonably long period without causing detrimental effects on environment. Some of the criteria developed over the years may be described as follows [Elliott, 1997]:

(1) **Fuel reserve and resource availability**: the technology should not use fuel, which runs out within a short span of time.
(2) **Energy Efficiency**: the efficiency of energy generation and utilization should be maximised, while potential new sources of energy are identified and fully developed.
(3) **Matching supply with demand**: selection of fuel and energy generation and supply should match the consumer demand.
(4) **Renewable energy**: although it is considered a key element in sustainable future without an impact of global environment, the local effect associated with the application of renewable energy technology should be minimized.

For sustainable development, a lot of importance is placed on the role and the use of science in supporting an efficient and prudent management of the environment for the survival and future development of mankind. It is considered essential that importance be placed on the long-term perspective and global changes. Therefore, there is a need for frequent interaction among political, industrial, governmental, educational, cultural and spiritual authorities participating in the efficient realization of the objectives.

Efficiency improvement of processes in power generating systems is considered one potential area, where a lot of activities have taken place. A significant improvement in the efficiency of energy system can still be achieved by introducing hybrid (mixed) systems. These energy systems include power or heat generating units, energy transport and storage systems, and energy utilization systems. When considering energy resources, there are several options that may be taken into consideration for the optimization of energy systems. The potential use of renewable energy systems has been given considerable importance for power or heat generating units in the overall energy systems. Due to abundant supply and low cost, renewable energy sources show great potential to be included in the overall energy strategy.

RENEWABLE ENERGY RESOURCES (RES)

As stated earlier, RES meet the requirements of sustainability. Hence, the long-term strategy of energy systems will rely to a great extent on renewable energy. The renewable energy resources and its availability are considered bountiful, which is reflected in the presently available technologies in the field of RES exploitation and use [Berkovski, 1989, Lenssen and Flavin, 1996]. The RES may appear in the following form:

- Solar energy
- Geothermal energy
- Biomass energy
- Wind energy
- Hydro energy

Solar Energy

There are three main areas where solar energy applications appear:

- thermal applications: heating and cooling using conventional collectors.
- thermal power production: solar electricity using reflecting devices to concentrate energy in a thermal energy carrier.
- direct electricity: direct conversion of solar energy to electricity using photovoltaic cells.

Solar energy resources are unlimited. Solar energy received at the earth surface is 3000 times as large as the current energy consumption by mankind. The amount available is considered enormous but in a diluted form. Hence, solar energy shows a great potential in low temperature ($<100^{o}$ C) thermal applications.

In the area of heating and cooling using solar energy, the technology has attained a certain degree of maturity, where it is unlikely to see any dramatic change in the foreseeable future affecting its potential application [Zafran, 1993, Kwschik, 1993]. Solar thermal processes for temperature $<100^{o}$ C is considered cost effective (US 4.6 cents/GJ). Solar power production, particularly for remote areas, in the range of 50W - 1kW is commercially available at a competitive price. The direct conversion of solar energy, solar photovoltaic, is a proven technology although a reduction in production cost is desired before it becomes commercially competitive, unless the application is intended for remote areas. Estimated cost of electricity obtained from photovoltaic power plant ranges from US 23 - 33 cents/kWh but it is expected to go as low as US 2.2 - 2.4 cents/kWh [IPCC, 1996, Afgan et al.,1998].

For heating and drying applications in developing countries, both domestic and industrial, solar energy is considered economically viable [Hawlader et al.,1990, Hawlader et al., 1987]. For water heating in domestic application, the payback period is about 2 years [Hawlader et al., 1990]. Solar assisted heat pump (HP) water heating systems are gaining popularity both in domestic and industrial applications [Hawlader et al., 2001]. Figure 6 shows the schematic diagram of such a system, where an evaporator acts as the collector of solar energy. As the temperature of the evaporator is low, the efficiency is much higher than the conventional collector.

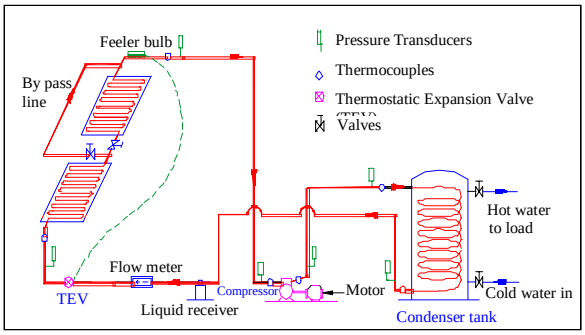

Fig.6 Schematic of solar HP water heating system [Hawlader et al., 2001]

Geothermal Energy

Geothermal energy resources exploitable at current prices relate to those aquifers close to the volcanic zone [Fridleifsson and Freston, 1993,, Dickson and Fanelli,1995], having a total installed capacity of 71,000 MW. Hot water directly used for heating purposes is estimated at about 13 Mtoe/year. The cost of electricity produced from geothermal energy resources is about US 4 cents/kWh. For the generation of heat, the cost is about US 2 cents/kWh [IPCC,1996].

Biomass Energy

Biomass energy resources provide about 14% of the world energy equivalent to 25 million barrels of oil/day [Hall, 1991]. For developing countries, it is considered one of the most important sources of energy. Energy production through Biomass can be obtained from different conversion processes. Biomass can be converted into solid, liquid and gaseous fuels using biological and thermochemical conversion processes. Wood, charcoal, crop and forestry residual, and agro-industrial and municipal waste are examples of solid Biomass fuels. Liquid derived from Biomass are mainly ethanol and methanol. Biogases obtained from anaerobic digesters and examples of gaseous fuels. The cost of energy produced from biomass is about US 2 cents/GJ [IPCC, 1996].

Wind Energy

The wind energy resources of the world is estimated to be about 300 TWh/year [Sesto et al.,1993]. It is strongly influenced by meteorological conditions and location. The minimum velocity required for a wind power plant is about 6.5 m/s. The probability distribution is also an important factor and should be about 20 to 40%. For a large number of applications, small sized wind turbine generators are used and most of the applications are limited to isolated locations. These energy resources are suitable for water pumping, desalination and integration with other renewable energy resources and energy storage should be an integral part of the system. Energy cost from wind resources may be as low as US 6 cents /kWh [IPCC,1996].

Hydro Energy

Hydro energy resources show an estimated gross theoretical production capacity of about 30 million GWh/year. The present production capacity of the existing plants is only about 2.2 million GWh [Jiandong et al., 1995]. Most of the applications are limited to developing countries (about 54%) with the developed countries producing only about 7%. The financial capacity of the developing countries limits large scale utilization of hydro power.

TECHNOLOGIES OF THE 21ST CENTURY

The recent emergence of natural gas as the most rapidly growing energy source has brought about a considerable change in energy landscape. Due to reduced environmental impact and abundant supply, natural gas is likely to be the fuel for the early part of the 21st century. A considerable displacement of oil and coal is likely to occur due to wider use of natural gas and the availability of more efficient and decentralized cleaner energy delivery systems.

The development in recent years are making solar energy, wind power and other renewable enegy resources economically viable. About 25,000 wind turbines are spread across USA and Europe and tens of thousands of Third World villages are provided with electricity from solar cells [Lenssen and Flavin, 1996, Afgan et al.,1998].

A viable alternative was developed in 1990 to the gasoline powered internal combustion engine. Vehicles made of lightweight synthetic materials and run on gas turbine, fuel cells and flywheel are emerging from engineering laboratories around the world. With the kind of fuel economics (four or five times the current level) and pollution reduced to a merely 5% of the existing permitted level, these vehicles appear to enter into the market by the end of the decade ushering in an era previously unthinkable. A new paradigm for

assessing and managing future developments will emerge due to the accelerating pace of changes in energy system demands. Most of the new energy technologies are relatively small devices that can be subjected to mass production in factories leading to a faster pace of change. In this way, the production cost can be reduced and on-going innovation will be rapidly applied to new products

CONCLUSIONS

Renewable energy cannot completely replace fossil fuels but its application can be reduced to an extent, where rapid deterioration of the environment can be arrested. There should be incentives and encouragement for the use of renewable energy resources and penalty for the random use of fossil fuels. Solar energy is in a diluted form and its applications should be considered for areas where low grade thermal energy is required. Hydro-power generation should be encouraged wherever possible. Fossil fuels have been too cheap and its price control is required to prevent random usage. Considerable damage to the environment has already been done and it is high time to apply moderation and price control to prevent excessive use of fossil fuels. A balanced use of fossil and renewable energy resources, even if it means a slower development, should be encouraged to leave an environment for our future generation where they can live in good health and comfort.

REFERENCES

Afgan, N.H., Al Gobaisi, D., Carvalho, M.G. and Cumo, M., "Sustainable Energy Development". *Renewable Energy Reviews*, **2**, 235-286 (1998).

Berkovski, B., "Renewable Energy Resources". UNESCO contribution to International Co-operation, Fuelling 21st Century.

Brown, M.A., Levine, M.M., Short, W. and Koomey, J.G.," Scenarios for a Clean Energy Future". *Energy Policy*, **29**(14), 1179-1196 (2001).

Dickson, M. and Fanelli, M., "Geothermal Energy". UNESCO Energy Engineering series, Berkovski, B.(ed), John Wiley and Sons (1995).

Elliott, D., "Energy, Society and Environment-technology for a sustainable future". Routledge, London (1997).

Farinelli, U., "Alternative Energy Sources for the Third World: Prospective Barriers, Opportunity". Pontifical Academy of Science, Plenary Session (1994).

Fridleifsson, I.B. and Freston, D., "Geothermal Energy Research and Development". World Solar Summit, UNESCO (1993).

Hall, D.O., "Biomass Energy". Energy Policy, 711-737(1991).

Hawlader, M.N.A. ,Uddin, M.S. and Low, E. S., "A PC Based Simulation and Optimization Program for Domestic Solar Water Heater". *ASEAN J on Sc and Tech.Dev.* **7**(1) 43-61 (1990).

Hawlader, M.N.A., Ng, K.C., Chandratilleke, T.T., Sharma, D., and Kelvin Koay, H.L., "Economic Evaluation of a Solar Water Heating System". *Energy Convers Mgmt*, **27**(2) 197-204 (1987).

Hawlader, M.N.A., Chou, S.K. and Ullah, M.Z., "The Performance of a Solar Assisted Heat Pump Water Heating System". *Applied Thermal Engineering*, **21**, 1049-1065 (2001).

Intergovernmental Panel on Climate Changes (IPCC), Second Assessment Report (1996).

Jiandong, T., Naibo, Z., Xianhuan, H. and Huishen, D., "Mini Hydropower". UNESCO Energy Engineering Series, Berkovski, B.(ed) John Wiley and Sons (1995).

Keating, M., Agenda for change, centre for our common future (1993).

Kwschik, B.G., "Solar Energy and Agriculture". World Solar Summit (1993).

Lenssen, N and Flavin, C.,"Sustainable Energy for Tomorrow's World". *Energy policy*, **24**(9), 769-781(1996).

Medows, D., Medows, H., Randers, D.L. and Behrens, J., The limits of growth.. New York: Universe Book (1972).

Sesto, E., Casale, C. and Mari, G., "Wind Energy-Present Situation and Future Prospect". World Solar Summit, UNESCO (1993).

World Energy Council (WEC), Renewable energy resources: Opportunities and constraints 1990 - 2020, London (1993).

Zafran, M., "Solar and Health". World Solar Summit, UNESCO (1993)