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Energy Options for the World and the South Asia Region

HILAL A. RAZA[1]

WORLD ECONOMY, ENERGY DEMAND AND FOSSIL FUEL RESOURCES

World Economy

The world of today is witnessing a considerable change. The economic and political forces which have already played a vital role in the post war period, are again causing a clear and definite transformation. According to the World Bank forecasts, the economy of the third world countries will grow at nearly 5% per year during the next ten years compared with around 2.7% for the developed countries. Such an enormous and persistent gap will obviously alter the world economy. According to these estimates, the share of developing countries, together with those of the former Soviet block, in today's global economy is to rise from the present 44% to more than 50%, overtaking those of the developed countries. Considering the economic size of the individual countries, the world's top 15 economies in the year 2020 will contain those 9 countries which are presently classified as developing economies with China surpassing the USA to take the top of the table.

World Energy Demand

According to projections made by the World Energy Council's Commission on *Energy for Tomorrow's World - The Realities, the Real Options and the Agenda for Achievement*, the world energy demand is to rise from the present 8.8 billion tonnes of oil equivalent (TOE) to 17.2, 16, 13.4 or 11.3 billion TOE in 2020 as per the four scenarios A, B, B1 and C, respectively (WEC, 1993). Case A assumes a slightly higher global economic growth rate between 1990-2020, while case C was largely ecologically driven. Between the two is case B which was initial reference based on which the modified reference case B was developed taking into account the likely possibility of delayed energy intensity reduction measures (Table 1).

Out of these four scenario cases, case B1 seems most logical in which the rise in energy consumption from the 1990 level to 2020 is predicted as 7.2 billion TOE (an increase of 82%) of which the present developing countries will account for 5.2 billion TOE that is 72% of the total growth in the energy demand (Table 2). It is estimated that the developing countries' total energy consumption will increase three times from 2.6 billion TOE in 1990 to around 7.8 billion TOE in 2020 at a rate of 3.77% per annum as against 0.87% in developed countries and 1.08% in the former Soviet block countries. As a result of this tremendous growth in their energy requirement, the developing countries are expected to demand about one-half of the world's total energy production in 2020, compared to less than one-third now and about 22% in 1960. This is a major transformation which is taking place and has important implications on the global energy scene.

An interesting aspect of the future energy demand is the effect of population growth on the rise in energy demand. With only eight developing countries, namely, China, India, Pakistan, Bangladesh, Brazil, Indonesia, Mexico and Vietnam accounting for more than a half of the population growth during the next three decades, the future energy demand in these countries will have more direct and significant impact on the global energy systems.

The WEC Commission has further established that oil will continue as the main fuel in the energy mix comprising around one-third of the energy use. The almost four times increase of oil consumption in the developing countries will be required by the increasing mobility demanded by growing population, urbanization and needs for transport. Natural gas use will grow dramatically being cleaner and abundant fuel while indigenous coal in many countries will be put to use. Hydro resources will greatly increase (unless there is major environmental opposition), but nuclear

[1] Hydrocarbon Development Institute of Pakistan, Islamabad.
Secretary General, South Asia Geological Congress Central Secretariate, Islamabad.

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Table 1. World energy demand (Source: WEC, 1993)

WEC Scenario	A	B	B1	C
	High Growth	Modified Reference	Reference	Ecological Driven
Annual Economic Growth Rate	3.8%	3.3%	3.3%	3.3%
Possible Total Demand in 2020 (Billion TOE)	Very high 17.2	High 16.0	Moderate 13.4	Low 11.3

Table 2. Energy demand growth in WEC, case B-1 (Source: WEC, 1993)

	Billion TOE			
	1960	1990	2020	Growth During 1990 to 2020
Developing Countries	0.7	2.6	7.8	5.2
Others	2.6	6.1	8.2	2.0
Total World	3.3	8.8	16	7.2
Percentage Share of Developing Countries	22%	29%	48.5%	72%

contribution will continue to be modest into the next century on account of high capital and technological requirements. In any case, fossil fuels will continue to dominate the energy scene world-wide for the next several decades.

World Fossil Fuel Resources

We have seen the eruption of the economic transformation igniting the energy challenge and that the fossil fuels are to meet this challenge in the future. Let us now take a look at their availability to see if they will be able to sustain the high growth in consumption.

At the existing rate, fossil fuels can be expected to last well into the next century. The global proven reserves are: oil - 137 billion tonnes, gas - 142 trillion cubic meters and coal - 1039 billion tonnes (British Petroleum Company, 1994). The remaining life of these energy sources assumed at present rate of consumption is 43 years in the case of oil, 65 in the case of gas and 236 for coal. This means that coal reserves are to last twice as

long as the combined reserves of oil and gas at current levels of reserves and production. These reserve estimates are in no way the final upper limits of availability but are the known economically exploitable resources at the present prices and technology, which are bound to increase with advancing exploration techniques. For example, in recent years Pakistan has added some 180 billion tonnes to its coal resources through a well planned coal exploration programme.

NEW FUELS AND TECHNOLOGIES

The ultimate finite nature of fossil fuels, their uneven distribution across the world, and the environmental and efficiency concerns regarding their use highlight the need for exploring new and cleaner alternate fuels.

Clean Coal Technologies

Coal has a long standing reputation of being a dirty fuel with difficulty in handling and utilization. The main concern in mining and transportation of coal is the dust emission. It is also necessary to control acid run off and avoid silting of natural water courses. During combustion, coal gives off oxides of nitrogen and sulphur which are the main contributors of acid rain. Large emissions of carbon dioxide together with methane and the oxides of nitrogen cause the environmental problem of greenhouse effect. All these reasons have forced coal scientists to evolve new technologies to utilize this abundant source of energy in an efficient and environmentally sound manner. Most of these technologies pertain to power generation which is the single most important area of coal utilization. The technologies are:

Integrated Gasification Combined Cycle (IGCC). Fine coal is gasified by reacting with steam and air to form raw fuel gas which is cleaned and purified to remove particulate matter, elemental sulphur and acid gas. The gas is combusted in a gas turbine while exhaust is used to produce steam in a heat recovery steam generator which is fed into a steam turbine for extracting supplementary power.

Integrated Gasification with Fuel Cells (IGFC). Coal is gasified with maximum hydrogen production. The gas is cleaned and fed to negative electrode while

Table 3. Estimated major coalbed methane resources (After Rice et al., 1993)

Country	Coal Resources (billion tonnes)	Coalbed Methane Resources (trillion cubic feet : TCF)
Russia	6500	480-3200
China	4000	850-990
United States	3950	310
Canada	7000	170-2152
Australia	1700	222-396
Germany	326	85
United Kingdom	190	57
Kazakhstan	170	28
Poland	160	85
India	160	28
Southern Africa	150	28
Ukraine	140	57
TOTAL:	24446	2400-7420

oxygen is fed to the positive electrode. An external electric current is generated as a result of electrochemical reaction.

Pressurised Fluidised Bed Combustion (PFBC)._ A fluidised bed combustor produces steam which is used for power generation while flue gases are cleaned to drive a gas turbine. About 75% of the power is derived from steam turbine while the remaining from gas turbine.

Direct Coal Fired Turbine (DCFT)._ Pulverised coal is fired at high temperature in slagging combustor wherein ash is separated as molten slag. Hot gases are cleaned and fed into a gas turbine to extract power.

Unconventional Natural Gas

Coalbed Methane._ Coalbed methane has been produced on commercial scale in the United States since 1981 and has attracted world-wide attention as a potential clean energy source. Present US production of coalbed methane is nearly 2.5 billion cubic feet per day with reserves estimated at 15 trillion cubic feet (TCF). The gas is a product of the coal diagenesis through biogenic and thermogenic processes generating large amount of gas. This gas is stored in the coal matrix upon and within the molecular structure of the coal. As a result, coal has the ability to hold much more gas than the same rock volume of a conventional reservoir in which gas occurs as a free or dissolved phase (Rice et al., 1993).

Major resources of coalbed methane are associated with large reserves of coal. Since most of the coal is concentrated in Canada, China, Russia and the United States, coalbed methane can be found in sizeable quantity in these countries. However, sufficient quantities of coal also exist in various other countries offering a promising coalbed methane potential. The total global resource of coalbed methane is estimated around 2,400 to 7,400 TCF assuming the total coal resource to be around 25 trillion tonnes (Table 3).

Gas from Tight Reservoirs._ Low permeability gas reservoirs are gas-bearing rocks that usually have an in-situ permeability to gas, exclusive of fracture permeability, of less than 0.1 millidarcy (mD). Such reservoirs contain very large amount of gas. Gas from these reservoirs is rapidly emerging as a major source of energy (Law and Spencer, 1993). Studies have shown that in USA alone such in-place gas resources may exceed 5,000 TCF but are at least 430 TCF, and the recoverable gas is estimated to range from less than 200 TCF to more than 550 TCF. Tight gas reservoirs occur at very shallow to very deep depths and consist of a wide range of rock types including sandstone, siltstone, shale, sandy carbonate rocks, limestone, dolomite and chalk. They are commonly abnormally pressured. and the gas accumulations, are regionally pervasive and mostly independent of structural or stratigraphic traps. Natural fractures play a prominent role in the economic production from these reservoirs. Wells drilled into tight gas reservoirs commonly require artificial hydraulic fracturing unless extensive fracturing is present. Because of the ability of slant and horizontal drilling techniques to intersect natural fracture system, the technology of deviated drilling offers promising potential for developing a new energy source which is environmentally benign and abundantly available.

Gas in Deep Basins._ Deep gas is generally referred to that produced from more than 15,000 feet deep reservoirs. There are large volumes of such resources which are regarded as the major source of gas production in the future especially in areas where conventional exploration has reached a level of maturity. However, the high cost of exploration and production are going to be the limiting factor in utilizing this resource.

Gas Hydrates._ Gas hydrates are naturally occurring solids comprising water molecules surrounding a methane molecule in certain conditions of pressure and temperature. Natural gas hydrates occur world-wide in polar regions associated with onshore and offshore permafrost, and in marine sediment of the outer continental margins in many parts of the world. The total amount of carbon available in this way is estimated to be twice the total amount of carbon found in all known fossil fuels on earth. Todate, methane has been recovered in one instance from a field in western Siberia but production costs have been astronomical. Technology needs to be developed to tap this important source of energy in an efficient and cost-effective way (McCabe, et al., 1993).

Unconventional Oil

Tar Sands._ This is heavy, viscous oil deposit found at or near earth's surface. With an API gravity of 5 to 15 degrees, it is typically found in highly porous sands. The hydrocarbon potential of these reserves are immense but the present technology does not allow commercial extraction as low oil prices render it unfeasible. At present, Canada is the only country where oil is being extracted in appreciable quantity from tar sands while Ghana, Ivory Coast, Madagascar, Romania, Syria and Venezuela are known to have large resources of tar sands.

Oil Shales._ Oil shale is a fine grained sedimentary rock that yields oil on heating. The difference between tar sands and oil shale is that oil is free in tar sands and occurs within the pores whereas in oil shale it is contained within the complex kerogen structure from which it may be distilled. The world reserves of oil shales are estimated to be of the order of 30 trillion barrels and the USA alone contains over 700 billion barrels. Extraction of oil from shale has been carried out in many parts of the world including Europe, Australia and South Africa. Presently, Russia and China have appreciable shale oil extraction industry while Brazil is also involved on a limited scale.

Hydrogen

Hydrogen as a fuel has the biggest advantage of being the cleanest if compared against conventional fuels such as methane, coal and petroleum. Its combustion leaves no harmful gases, only water vapour. The problem, however, is its occurrence, as no large natural reserves can be found in the earth's crust. It is not a fossil fuel. This means that all the hydrogen required needs to be manufactured, the simplest of which is to electrolyse water to release hydrogen and oxygen. But this needs input of energy by burning fossil fuels and, therefore, renders hydrogen an uneconomical fuel besides adding carbon dioxide during its production. Hydrogen has the great potential of storing energy and converting very efficiently into other forms of energy, that is, mechanical, thermal or electrical. This, combined with its clean nature makes it suitable in pollution sensitive areas such as domestic heating, cooking etc.

Any large scale application of hydrogen as a fuel will require technological advancements in solar photo-voltaic or other renewable forms of energy such as wind energy or hydro-electric to produce hydrogen in an efficient and cost effective manner. The use of hydrogen will likely be limited if it has to be created by burning fossil fuels (McCabe et al., 1993).

Renewables : Conventional and New

Conventional renewables currently account for nearly 90% of total renewable consumption in the world. These include traditional biomass such as fuelwood, crop residue, dung etc.(60%), and large scale hydro (30%). The World Energy Council(WEC) in its recent study to

Table 4. Commertial energy indicators of countries of South Asian region (Source: World Bank, 1994)

	1980-92 Annual Growth Rate %		1992 Energy Use Kg OE PerCapita	Energy Imports as % of Mechandise Export 1992
	Energy Production	Energy Consumption		
Bangladesh	13.6	8.5	59	21%
Bhutan	n.a	n.a.	15	n.a.
India	7.0	6.8	235	26%
Iran	6.9	7.0	1256	Nil
Maldives	n.a.	n.a.	n.a.	n.a.
Nepal	15.0	8.4	20	23%
Pakistan	7.3	6.9	223	21%
Sri Lanka	7.6	1.3	101	12%
Turkey	4.0	5.3	948	26%

explore the potential of new and conventional renewables in the global energy concluded that such energy may range between 2.9 to 3.3 billion TOE by 2020 depending upon the willingness, behavioural patterns, technological capacity and political climate prevalent at that time (World Energy Council, 1994).

Regarding the new renewables - solar, wind, geothermal, ocean and small hydro, there is a lot of uncertainty and incoherence in global policy and co-ordination to effectively enhance their contribution. But it must be emphasised that new renewables should be introduced well before the economic lifespan of the existing energy systems. As a result of the current low international oil prices and sufficient availability, any investment and efforts in developing commerciality of new renewables seems highly unlikely. The WEC Study, therefore, concluded that the share of new renewables which was 0.16 billion TOE in 1990, would range between 0.5 to 1.3 billion TOE by the year 2020 depending upon requisite policy support and initiative.

ENERGY RESOURCES AND CONSUMPTION OF SOUTH ASIAN COUNTRIES

The energy situation in South Asian region is analysed. To create a contrast, two Asian countries namely, Iran and Turkey are also discussed along with the countries of the South Asian region.

The countries of South Asia have a wide diversity in their endowment of energy resources (Table 4). At the same time, most of these countries are very marginally explored. For example in Pakistan, one oil/gas well has been drilled for every 1000 square kilometer sedimentary basin area whereas this figure is 900 for Texas. The potential for new fuels and new technology applications has practically not been evaluated at all. On the other hand, due to economies growing between 4 to 6%, and the population growing between 2 and 3% per annum, the energy needs of these countries (except Sri Lanka) have been increasing in the range of 5 to 9% annually, using more than 20% of their export earnings for energy imports (Table 4). Iran on the other hand is endowed with vast oil and enormous natural gas resources.

Commercial energy consumption in many countries of the South Asian region is still low by international standards. The per capita consumption of energy in these countries is way lower than Iran, Turkey and other parts of the world like East Asia/Pacific and Latin America. Since most of the South Asian countries are under-developed with limited or no industrialisation, their per capita energy consumption is bound to grow substantially no matter what conservation measures are adopted. The challenge is to fuel our economies, and then to keep on refuelling them with increasing amounts of energy.

STRATEGY TO IMPROVE ENERGY SITUATION IN SOUTH ASIAN REGION

The following ways and means are suggested to meet the future energy challenge of the South Asian countries:

Accelerated Exploration Programme

The first and foremost way of alleviating the energy problem in South Asian region in the medium term is to accelerate exploration and exploitation programmes to develop our indigenous fossil fuel and hydro resources. Major limiting factors are the technology and finances. It has been estimated that a massive investment of some $ 30 trillion will be required in developing countries, including the South Asian to meet the energy needs upto 2020 with almost 50% share needed in oil, gas and coal development. Such a large investment can not obviously be met from own resources or borrowings, hence the need to involve private sector participation. This would require improvements in regulatory and fiscal arrangements. Many countries including Pakistan have already started the restructuring process with positive response (Raza, 1994).

Regional Cooperation

The need for cooperation among regions is now being globally felt (Bender and Raza, 1995). Cooperation in the field of energy has assumed an important role in Europe where regional countries are interconnected by electricity and oil and gas pipelines to optimize their requirement. Similar attempts are being made in the ASEAN region where a gas pipeline is to connect the member countries with surplus and deficient capacity to meet the regional requirement.

The South Asian region can be a strong case for regional cooperation in energy by utilizing surplus energy resources of the region among energy deficient countries for the betterment of all. It is known that Iran has one of the largest gas reserves in the world while neighbouring Pakistan and India find it hard to satisfy energy requirement of the growing industry and trade. Gas pipelines linking the Iranian and Central Asian regions with ready markets in Pakistan and India will prove highly beneficial and cost effective.

Similarly, cooperation on regional level can also take the form of sharing technology and information. Countries of the South Asian region may share their experiences in energy development with other regional countries who often face the same situation or challenges with a view to achieving efficient resource utilization.

Application of New Technologies

The application of new technologies should be emphasised in the South Asian region. New and emerging technologies are already showing marked improvements in terms of efficient energy resource utilization and environmental conservation. The clean coal technologies offer a renewed hope for efficient utilization of abundant coal with minimal environmental effects. Also, new avenues of natural gas extraction such as from tight reservoirs and coalbeds warrant serious consideration. However, the problem with technology is that it is costly and, therefore, hard to acquire by many countries in this region. South Asian countries may, therefore, find it extremely useful to indigenize a technology for application in the whole region to make it cost effective and adaptable.

Institutional Development

The problem with the countries of the South Asian region as with other developing countries is either a lack of, or an inadequate level of, institutional development to provide the knowledge and expertise in managing structural changes and introducing new technologies. If they are to meet this energy challenge, the countries will need to strengthen their institutional capabilities. Particular emphasis should be placed on providing research and development support to get solutions for energy development in a more indigenous and domestically suitable manner.

The South Asian countries may also establish a pool of energy experts to cater to the collective needs of the region. Similarly, individual experiences may be shared in developing managerial capacity at the local level. Human resource development is an important aspect that should be focused at. Growing specialisation needs well trained manpower for well defined jobs. Developing human resource potential at the regional level would enable all the countries in increasing the number and scope of services of their experts in the field of energy.

Efficiency Improvement and Environmental Protection

While comparing with the energy utilization practices in the developed world, it is evident that there is a lot of potential in the South Asian countries for overall efficiency improvement and adopting measures to combat environmental degradation. There are many barriers to introducing greater efficiency in energy provision and use. The policy, for a start has been such that energy efficiency has long stood at a low priority. The artificially low and often subsidised energy pricing has left little or no incentive and motivation in introducing efficiency measures. The situation is improving with prices reflecting the true cost of energy to the consumers.

The energy conversion processes have generally been in-efficient based on domestic technology and practices. Many studies have shown that energy efficiency can really pay back in terms of savings in fuel and capital involved in mobilizing additional energy resources. The countries have therefore a strong case to consider implementing efficiency measures even if it requires importing technology and equipment. For example, the high efficiency Combined Cycle Gas Turbines (CCGT) have revolutionised the power generation industry by doubling the plant efficiency.

Growing environmental awareness coupled with the conditionalities now being attached by many donor agencies in introducing environmental conservation measures in all the new energy projects means that the problem is being well addressed. The issue, however, remains with the earlier projects which are the real threat in terms of pollution. Better environmental legislation realizing the environmental costs would induce environmental conservation measures in these schemes to reduce emissions and wastes.

CONCLUSIONS

The growing economic development and improving standards of living are posing a challenge to global energy supplies. The problem is further compounded by rapid population growth in the developing countries. Since the present developing countries are expected to consume more than half of the global energy in the next three decades, there is a strong need to develop the existing energy resources particularly the conventional fossil fuels and at the same time, develop new fuels and technologies to meet the growing energy requirement in a sustainable manner.

Technologies already exist to extract clean energy from coal such as the Integrated Gasification Combined

Cycle , Integrated Gasification with Fuel Cell, Pressurised Fluidised Bed Combustion and Direct Coal Fired Turbine. Similarly, new avenues for extracting gaseous fuel containing high methane content may be explored as it is the cleanest of all the fossil fuels. Coalbed methane which exists with large coal deposits may be exploited along with its extraction from presently difficult areas such as tight reservoirs and deep basins. Tar sands and oil shales offer another option of utilizing viscous fluids for energy. Hydrogen, gas hydrates and new and conventional renewables are other possible energy resources that demand serious consideration. The problem with all these new fuels and technologies is their un-economic extraction in the present energy economics scenario. New technology and improved procedures may, however, change their economic potential.

The energy problems of the countries of South Asian region are similar to other developing countries, only a little worse. Concerted efforts may be made collectively by the regional countries to meet this growing energy challenge. Accelerated exploration programme with active private sector participation would help develop domestic energy resources. Regional cooperation among South Asian countries can play a vital role in optimally utilizing regional energy resources. Similarly, technology and information should be shared to make them affordable and maximize their utility. Institutions in these countries also need strengthening specifically aimed at human resource development. While efforts may continue in developing additional energy resources, there is a strong need to focus attention on energy conservation and environmental aspects in energy conversion and use. The countries are now realizing the potential and benefits, and are resorting to measures for conservation of energy resources and the environment.

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