Renewable Energy Technologies for Developing Countries

Now and to 2023

By
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&
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FOREWORD

Energy flows from many sources, exists in a variety of interchangeable forms, and drives all systems. It is fundamental to the quality of our lives and today, we find ourselves totally dependent on an abundant and uninterrupted supply of energy for living and working. It is undoubtedly the key ingredient in all sectors of modern economies.

Fossil fuels and nuclear technologies, as a core source of global energy production since the beginning of the 1970’s, left behind a legacy of thousands of thermal, natural gas and oil fired power plants spread across the world. The carbon gas emissions and non-degradable nuclear waste produced by these plants have caused serious environmental problems such as the greenhouse effect leading to a virtual chain reaction of ozone depletion followed by global warming and climate change. Time and experience have shown that these energy production methods are non-sustainable. Instead, hope for sustainable energy production is to be found in renewable energy sources that are clean, cheap and ‘green’.

Renewable energy resources and technologies have the potential to provide long-lasting solutions to the problems faced by the economic and environmental sectors of a nation. Besides the overall global benefits, renewable energy systems can provide direct benefits at national and local levels, which justify their wide use in developing countries. They can contribute to substantial savings in import bills for fossil fuels. At the local level, availability of electricity contributes to improved productivity, and indirect positive effects are also visible in the form of the creation of new employment opportunities.

This book titled ‘Renewable Energy Technologies for Developing Countries – Now and to 2023’, which is written by Dr. M.M. Qureshi and Engr. Tajammul Hussain is a comprehensive document encapsulating the need, importance, options and impact of renewable energy technologies
in all spheres of economic and environmental livelihood. The authors have been keen on establishing policy options and alternatives both on the international and national arena. The thorough assessment of energy options with specific reference to various developing countries is especially commendable. The book is solid in terms of assessment, comprehension and analysis of the current energy situation of the world and provides logical and practical suggestions and recommendations for the future world energy assessment and policy.

In a nutshell, the authors have earnestly put together a sound document, which will serve as a reference for current and future policy makers, giving them a lead in determining the strategic path to follow. I sincerely believe that critical shapers of the economic milieu of our Member States and other developing countries will benefit from the deliberations of this book and hope that the various implementable options enlisted in it will be given due and serious consideration.

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CHAPTER 1

HISTORICAL BACKGROUND OF ENERGY CONSUMPTION IN THE PAST 50 YEARS

1. Energy as a Basis for Development

It is well-known today that technological and industrial progress is heavily dependent on the readily available energy, the enormous technological and industrial advancement of the so-called developed countries was primarily made through exploitation of Earth’s vast reservoir of fossil fuels. These fossil fuels, often imported from countries that themselves lacked the science and technology required for their effective utilization, helped the developed countries to attain affluence at an unprecedented pace. It also helped to control the destinies of other less developed countries of the world. The Industrial revolution developed the countries in two groups: (i) Manufacturing Industrially Developed, (ii) Developing Countries with raw material (Agrarian economy). Today, Developed nations, with one fifth of world’s population consume four-fifths of world’s fossil fuels.

In 1973, the oil-producing countries decided to increase the price of crude oil by a factor of five from 2 dollars to 10 dollars per barrel. This created a sensation and chaos in the economic situation of both the developed and the non oil-producing developing countries. It was soon realized that the indiscriminate and wasteful use of oil was no longer acceptable and that concerted efforts had to be made for embarking upon a programme of energy-conservation and urgent development of alternate resources of energy. The economic development of most developing countries has, since then, been greatly hampered by the ever-increasing prices of oil, see Figure 1(a), which shows that, in 1960 the oil prices were well below the cost-of living curve (Qurashi, 1983), whereas they

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were well above it in the late nineteen seventies, and still continue to rise, although with some fluctuations from time to time substantial inputs of Power are needed for nearly all industrial development. For the developing countries generally, the effect of higher oil-prices has been to make it difficult and, in some cases, nearly impossible to overcome power shortages by importing cheap oil, as they did in the past. The real cost of using oil by the developing countries is now many times higher in relation to the use of possible substitutes than it was before. Where alternative fuels exist, the change in relative costs is reflected in the prices of different fuels, so that consumers are encouraged to switch over from the more expensive to the cheaper ones. The changed pattern of energy-consumption is seen clearly in the Logarithmic plot shown in Fig. 1(b), which indicates zero growth-rate of per-capita energy-consumption for the top segment of developed countries.

2. Some Possible Alternative Strategies for Developing countries during the nineties

The growth of world’s per-capita energy-consumption from 1960 to 1985 / 1990 and thence projected on to 2020 A.D is shown in Figure 2, while the detailed world energy projections are given in Figs. 3(a) & 3(b). In the long term, the only real bottleneck preventing development is
shortage of energy. For the immediate future, this means shortage of oil, for which there is no substitute, and so various alternate strategies have to be examined. The fact that industrialized countries, notably the US, are the main oil importers, did place OPEC in a commanding position, at one time. Although the level of demand is being affected by conservation and substitution of other fuels in the industrialized and developing countries. A picture of the World Energy-Consumption from 1995 - 2005 with projection upto 2020 and required breakdown is shown in Fig. 4(a) & (b)

Source : A review of Energy Growth Pattern and conservation in Pakistan

Figure 1(b) : Logarithmic Plot for per capita energy-consumption (1984)

Figure 2 : Per-Capita Energy Consumption
Figure 3(a): World Energy-Consumption, 1970-2020


Figure 3(b): Projected Change in Energy-Demand by Region, 1999-2020

Source: McGranahan and others, 2000; Smith and Akbar, 1999

Figure 4(a)


Figure 4(b): Environmental Risk-Transition

Source: McGranahan and others, 2000; Smith and Akbar, 1999
TWO MAIN STRATEGIES: There have been two main strategies that have been considered world-wide:

a) The first alternative, the so-called Hard Path, is based on (i) the theory of ‘demand accommodation’ and demand will continue to increase rapidly and continuously for many years – and (ii) that this ever-increasing consumption of energy aggravates the problems of environmental pollution. Obviously, as oil drops off, the use of coal-based synthetic fuels would rise sharply. This is essentially a case of fuel switching or inter-fuel substitution, involving the use of more readily available indigenous fuel in place of (imported) oil. This would of course have to be coupled with intensified exploration for oil.

b) The Soft Path: In contrast, the other option – the ‘soft path’ – involves radical change in energy options, at the earliest opportunity. It has two aspects:

i) First, the consumption of non-renewable forms of energy should not be allowed to grow, and should be actually reduced: this is the ‘conservation’ aspect and involves also the environmental aspect of pollution (see Figure 4(b)).

ii) Secondly, as far as possible, there should be a shift in the consumption of energy away from non-renewable sources, such as coal, oil, gas, towards increasing use of renewables, i.e wind power, tidal power, biogas, solar and geothermal energies. This shift has to be of an appropriate magnitude that will fully take care of all the increases in future consumption from non-renewable sources.

The total energy-consumption may still remain at the present levels or may even continue to grow a little; but the gap should be filled by other sources, namely nuclear power and renewable sources of energy. It is anticipated that by 2100 A.D, renewable sources would contribute at least 20% to 30% of the world energy-consumption. We may even be optimistic and hope for a figure of 50% in some countries.

3. The Energy Transition (1980-95)

The challenge confronting the international community is to achieve an orderly and peaceful energy-transition from the present international economy, based primarily on hydrocarbons, to one based increasingly on new and renewable sources of energy. It has to be in a manner in which, consistent with the needs and options of individual countries and is socially equitable, economically and technically viable and is environmentally sustainable. The transition must be based on technological, commercial, financial and monetary modalities, consistent with the resolve of various Governments to establish a new International Economic Order, so as to accelerate the development of Third-World countries and to promote balanced global development. An effective energy-transition should conform with the principle of full and permanent sovereignty of each country over its natural resources, and should be implemented in accordance with its long-term national plans and priorities.

Primary Concept: The Primary Concept of Sustainable Development is to: “Meet the needs of the present without compromising on the ability of future generations to meet their own needs” (Our Common Future, the World Commission on Environment and Development, 1987)

4. A Review of Energy Growth-Patterns and Conservation since 1980 in Developing Countries

There are about 2 billion people (1/3rd of the world’s population) in the Third World who lack access to adequate, affordable, clean and convenient energy services. The index of distribution of wealth clearly show that the richest of the world use 55% of final primary energy while the poorest (20%) uses only 5 per cent. Exclusion from modern energy-services is generally associated with poverty and environmental degradation.

The results of such comparisons show that by 1982, 72 per cent of the drop in non-electric energy demand and 29.5 percent of the drop in

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electric demand can be attributed to the actual, as opposed to the assumed, prices. This is the cost-effective energy conservation, which represents only a part of the eventual adjustment one can expect in the gradual replacement of energy-consuming equipment.

Fig. 5&6 clearly indicate increase of energy use and consumption as per growth of economy from 1970-2000 with projections upto 2020; the highest energy-consumption projected will be in “Developing Asia” due to highest growth in economy. The rates of economic development are amongst the most important determinants of energy-demand in the long term. The World Energy Consumption (WEC) study predicts an increase in global energy-need in the range of 1.5 to 3 times by 2050 and 2 to 5 times by 2100. Taken together, energy requirements are envisaged to increase at lower rates than economic growth. This means that energy-intensity is presumed to decline across all scenarios; by 2100, it will fall between 80 and 20 per cent of the 1990 levels. This translates into annual declines of about 0.8% and more than 1.5%, with a median of about 1 percent. Thus, the lowest future energy-intensity improvements of 0.8% a year are in line with the historical experience of industrialized countries.

To sum up, technology is the key indicator of economic development and is essential for raising the standard of living, but it also should be environment friendly. Technology development and its application needs RD&E, which in turn, needs investments. The energy infra-structure grow consistent by part of it will be shared by renewables, specially new emerging RETs, such as Hydrogen and Fuel Cell technology. Improvement in technology will gradually shift us from the fossil fuels to renewable energies, around 10% to 15% by 2020 and, hopefully 30% by the year 2050.

**Global Energy-Economy :**

- 50% energy is consumed by 16% population
- 1.6 billion people have no access to commercial energy
- 55% increase in global energy-demand between 2000 and 2020
- Share of Developing Countries: 2000 (35%), 2020 (50%), 2100 (70%)
Figure 5: World Energy-Consumption by Types of Natural Resources 1970-2020

Figure 6: Total World Energy-Consumption in three cases, 1970-2020

5. “World Energy Projection System”, 2001 E.I.A. Report (Figure 5).
CHAPTER 2
THE CASE FOR RENEWABLE SOURCES OF ENERGY

1. Some basic considerations

The development and utilization of new and renewable sources of energy must be viewed in the context of the present and future energy-transition. New and renewable sources of energy can make a significant contribution, but their role and potential in the short term should not be overstated. It has been estimated that new and renewable sources of energy at present meet only 5-10 per cent of global energy-requirements, which may hopefully go up to 30% by the year 2050 A.D\(^1\). So, in the foreseeable future, hydrocarbon-supplies will continue to play a very important role in meeting the global energy-demand, although over a long period of time, that role will decline to facilitate the energy-transition, a process should now be set in motion to ensure the most efficient identification, exploration, assessment, development and utilization of various energy sources, including new and renewable sources of energy, which must be considered as dynamic variables that will tend to increase with the development, refinement, and popularization of technologies.

One may here consider the “struggle for existence” of the various energy-forms, as seen by Cesare Marchetti\(^2\) of I.I.A.S.A., see Figure 7, as

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a schematic indication of global trends in the various energy-technologies over the span 1850 up to 2100 A.D. This shows quite distinctly that in the recent past, the useful span of any one form of fossil energy has been of the order of 250 years, with an outstanding popularity over 50 years or so, the latest so far being gas (followed perhaps by nuclear energy).

A similar pattern is seen emerging for nuclear energy (with likely peaking around 2090 A.D) and appears likely for the newer (renewable) energy technologies (peaking after 2100 A.D), shown by the double line in the right-hand part of Figure. 7. Thus, there has to be more or less continuous effort for development of new renewable forms of energy.

(Figure - 7 : Showing the schematic representation by C. Marchetti of the rise and fall of the market shares of various energy-forms over the period from 1850 to 2100 A.D.

(Date of prediction : October 1982)

The development of new and renewable sources of energy opens up the prospect of increasing indigenous energy-supply and thereby contributing to greater self-sufficiency. The development of new and renewable sources of energy also creates new options to respond to the energy requirements of the rural, industrial, transport, domestic and other sectors, in accordance with national goals, priorities, and provides for a more diversified and decentralized pattern of energy-supply. Like any energy source or product, new and renewable sources of energy are themselves both an “input” and an “output” of the development process.
The role of new and renewable sources of energy should therefore be perceived as a dynamic interaction between resources, technologies and present and future requirements for energy, all serving national objectives for economic and social development.

2. Agreement at World Summit on Sustainable Development, Johannesburg, 2002:

Diversify energy-supply by development of advanced, cleaner, more efficient, affordable and cost-effective energy technologies, including fossil fuel technologies and renewable energy technologies, hydro included, and their transfer to developing countries on concessional terms as mutually agreed.

3. The environmental concerns and energy

The Present Situation: The conventional energy-generation options can damage air, water, climate, land and wild life, through particulate and gaseous emissions, as well as through raising levels of harmful radiations. Renewable Energy Technologies (RETs) are much safer. This is the current driving force in development and deployment of RETs.

The impact of energy-systems, through particulate matters, gases and radiation, occurs all around, from household level to global scale. This includes harvesting, combustion (fossil fuels as well as renewables), health effects, green-house gases, biomass, coal, oil and gases, hydropower and other renewables. Nuclear dangers contribute to various types of environmental concerns for human society at a local, national, regional as well as global level. The emissions caused by humans can be categorised into two type: (i) energy-related activities: including combustion, extraction, processing and distribution of fossil fuels and biofuels and (ii) due to non-energy activities, burning agriculture-waste industrial process, deforestation and uncontrolled waste burning. This does not include volcanic activity, which contribute 76% Nitrogen Oxide. Energy related activities pollute with 56% non-methane organic compounds, 46% CO
and 34% Methane. The Global distribution of particulate matter in the air in urban areas is shown in Figure 8, which has been taken from the 2000 UNDP World Energy Assessment Report\(^3\)(a). Further,

- Sulphur and Nitrogen Oxides play a role in the formation of acid-deposition, because they can be changed to acid in the atmosphere and can cause acid-rains. These being a major precursor to the formation of regional tropospheric ozone can cause climate-change. Carbon Dioxide gas also acts as an indirect greenhouse, with potential of global warming. In addition, Carbon Monoxide is toxic to human and is a critical component of many photochemical reactions in the atmosphere and it also reduces the ozone production.

- Non-methane volatile organic compounds consist of a variety of chemical species and are very important in the chemistry of atmosphere, due to the fact that these can destroy ozone.

- Ammonia can help to neutralize acid in the atmosphere; but when it falls on the land, it can be converted into acids. Ammonia largely comes out of animal waste, fertilizer and combustion. Most ammonia-emissions are recorded from Asia and other developing countries, due to the rural nature of these countries.

- The latest energy-projections indicate that global Sulphur dioxide is likely to stay constant roughly between 1990 and 2020, at about 59 teragrams of Sulphur. This problem has been shifted to the developing world, with emission in Latin America, Africa and Middle-east expected to increase 30% between 1990 and 2020. The problem is in Asia, where it is already as high as 17 teragram (1990-2020). China is the largest contributor to Asian Sulphur-dioxide emissions, emitting about half of the Asian continent, because of the extensively used coal-fired power

Note: In many cases, PM10 levels have been entirely estimated from measurements of total particles.
Source: WRI, 1998; WHO, 1998b

Figure 8: Global Distribution of Urban PM$_{10}$ Concentration
plants, which can easily be replaced with natural gas in order to control the emission.

- Ozone is an important air pollutant that can cause damage to crops, trees and human health. It is a major component of the harmful smog that forms around suspended particles during periods of high temperature, intense solar radiation, low wind-speed and in the absence of precipitation. High concentrations are common in mega cities of Southern Asia, viz Bangkok, Hong Kong, Mumbai and Shanghai.

Two most important human-caused problems associated with environmental pollution at the global scale, are:

(i) **Emission of Greenhouse gases and**

(ii) **Depletion of Ozone**

The most important greenhouse gases naturally present in the Earth’s atmosphere are water vapour, carbon dioxide, Methane and Nitrous Oxide, although water vapors cause large part of the greenhouse effect. Energy-systems generate two-third of the human-caused greenhouse gases, which are linked to potential climate change. It can have direct impact on human health and the Earth’s ecosystem.

**Projection for the future**: Some projections for Industrial Carbon Dioxide emissions are shown in Figure 9. In 1995, developing countries were contributing 27% of emission, whereas they will share equally (50%) with the industrialized countries in 2035. However, per-capita emission from developing countries will remain smaller than that from industrialized countries. W.H.O estimates that air pollution causes 2.7-3 million pre-mature deaths a year i.e 5-6% of global mortality.

In order to keep the levels of emission below those in future, significant improvement in energy-system are required globally, and one of the simplest solutions to the problem is to enhance the use of RETs with lowest emission. Table 2.1 is a summary of some I.P.C.C. Scenarios for stabilizing levels of Carbon dioxide levels over the 300 years from 2075 to 2375 A.D.
An illustration of the environmental risk-transition between scales is seen in the figure 10(a), which plots the relationship between urban PM$_{10}$ (particulates smaller than 10 microns in diameter) concentrations and country development status as indicated by their UNDP Human Development Index (a function of income, literacy, and life expectancy). Superficially, urban PM$_{10}$ concentration seems to follow the so-called

<table>
<thead>
<tr>
<th>To stabilize concentrations at (parts per million by volume)</th>
<th>450</th>
<th>550</th>
<th>650</th>
<th>750</th>
<th>1,000</th>
</tr>
</thead>
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<tr>
<td>By about the year</td>
<td>2075</td>
<td>2125</td>
<td>2175</td>
<td>2200</td>
<td>2375</td>
</tr>
<tr>
<td>Cumulative emissions in 1990-2100 would need to be in the range of (billions of tones of carbon)</td>
<td>550-750</td>
<td>750-1,100</td>
<td>970-1,270</td>
<td>1,090-1,430</td>
<td>1,220-1,610</td>
</tr>
<tr>
<td>Average emission in 1990-2100 would be in the range of (billions of tones of carbon per year)</td>
<td>5.7-5.9</td>
<td>7.9-9.0</td>
<td>10.2-10.8</td>
<td>10.0-11.8</td>
<td>12.7</td>
</tr>
<tr>
<td>And peak emissions (billions of tones of carbon per year)</td>
<td>9.5</td>
<td>11</td>
<td>12.5</td>
<td>13.5</td>
<td>15</td>
</tr>
<tr>
<td>In the year</td>
<td>2012</td>
<td>2030</td>
<td>2050</td>
<td>2060</td>
<td>2075</td>
</tr>
</tbody>
</table>

Table 2.1: IPCC Scenarios for Stabilizing Carbon Dioxide Levels, 2075-2375

An illustration of the environmental risk-transition between scales is seen in the figure 10(a), which plots the relationship between urban PM$_{10}$ (particulates smaller than 10 microns in diameter) concentrations and country development status as indicated by their UNDP Human Development Index (a function of income, literacy, and life expectancy). Superficially, urban PM$_{10}$ concentration seems to follow the so-called
Kuznets environmental curve – that is, they first rise during development, reach a peak, then decline. (The curve (see figure 10(a)) is named after the Nobel Prize-winning economist Simon Kuznets, who noted in the 1960s that many countries go through a period of increasing income inequality during development before becoming more equitable). From the standpoint of the risk-transition, however, this curve only addresses the community scale in the form of ambient urban air-pollution. It ignores what happens at other scales, which may be more important.

![Environmental Risk Transition](image)

Source: McGranahan and others, 2000; Smith and Akbar, 1999

**Figure 10(a): Environmental Risk Transition**

The main concern about particulates is their impact on human health. From a health standpoint, it is not so much urban concentrations that are critical but human exposure, which is a function of not only where the pollution is but also where the people are. Because people spend a lot of time indoors and in other places close to local sources of pollution-exposure patterns can be quite different from patterns of ambient pollution. Thus, as shown in the figure-10(b) the household sources dominate exposure in the poorest countries, therefore the pattern of exposures is quite different than that of urban ambient concentrations. Instead of rising and then falling, exposures decline continuously – illustrating that the Kuznets curve misses the actual trend, meaning that
the overall risk tends to fall even though community risk rises because of the shift of household to community impacts.

![Figure - 10(b): Urban particulate concentrations, human exposure, and national development](image)

3. Rural Energy

   a) The Basic Problem

   The fundamental issue involved in the efficient use of non-conventional energy sources is to bring about the integration of socio-economic changes with technological innovations, which essentially should be made simple, easy to understand and operate (maintain) by the agrarian population. Most of this agrarian population is either illiterate or semi-literate in the developing countries. In view of this basic issue, the problem here is mainly the identification of available technologies, their testing to make them suitable in the local situations and for their acceptability in relation to their costs as well as, the financial or technological capacity of the rural people to operate, maintain and repair the hardware involved.

   The technological problems of adaptation and innovation, to match the available technologies and hardware with the local circumstances, may prove to be serious constraints to many developing countries in implementing their programmes. However, these problems will need to be divided into manageable proportions, in terms of (i) what is available for immediate application, and (ii) what needs further Research and Development. Technologies are available, even in many developing countries, for simpler application of both direct and indirect solar energy. In regard to the first
category, the critical technological problems are providing the appropriate software for use in primary consumption of the energy made available from alternative non-conventional sources.

The rural energy problems revolve mainly around lack of proper level of education and knowledge amongst the farmers, leading to the continued adoption of old customs and traditions handed down from generations. In order to break the shackles of these old traditions, radical measures have to be adopted, particularly in the matter of improving the level of their scientific and technological education, through visual aids and other effective techniques, and the introduction of new concepts in close collaboration with them.

Present Status of some Renewable Energy Applications in Third World Countries

Majority of world’s population about (80%) live in the developing countries but use only 30% of global commercial energy. The energy usage increase with increase in population living standards and development. Realization is growing to make use technologies which it can lead to rural development, as well as keep the air pollution low. Experienced gained in RET application is presented tabular form, refer to table 5.2 or 2.2. This indicates that five areas of application at rural include residential and community lighting, small industry, agriculture, gas based power generation, cooking & water heating and transportation (alternate fuels). Biomass (traditional fuel) accounts for 30-50% of primary energy-supply in many developing countries.

Rural Resident/Community Lighting/Telephony, Radio and TV

Developing countries have 40% population (about 400 Million) of the developing countries reside in rural area with no electricity. An estimate of 1.1 Million Solar Home System and Solar lanterns exist in rural areas of developing countries.

Solar Home Systems

The figures in some developing countries are as follows:
India: 450,000, China: 150,000, Kenya: 120,000, Morocco: 80,000, Mexico: 80,000, South Africa: 50,000.

Bio-Gas digester convert animal waste into fuel gas for lighting, heating, cooking & electricity generation in China, India and Nepal has now largest manufacturing industries for biogas plants. China leads with 7.5 Million household biogas plants, 750 large & Medium scale industrial Biogas plants and a network of rural “biogas service centres” to provide maintenance & support. Micro-hydro power are installed in China, India, Nepal and Pakistan (500). Micro Windpower (100-5000 W) has also been installed in China (150,000) India, Pakistan and Nepal.

RETs for Industry, Agriculture

Major application of RETs is in the field of agriculture, such as for pumping water for drinking, education and health care centres. Such pumps are installed in India (20,000) Ethiopia, Thailand, Mali, Philippines, Morocco and Pakistan.

Grid-based Power Generation

- Small Hydro Power : Nepal, Pakistan, India, China, Egypt and African countries
- Biomas Power : China, India, Indonesia, Malaysia etc.
- Wind Power : China, India, Syria, Jordan and some African countries

Hotwater & Cooking (Biomass Stove)

China, India, Egypt, Cypres, Pakistan, Bangladesh, Nepal, Iran, Syria, Jordan, Turkey etc and African countries.

Transport Fuel (Bio Fuel)

Ethanol, Brazil, Kenya, Maldeve and Zimbabwe

PV home system / Lantern / Mini-grid and Biogas

Provided better basic amenity of life including:
- Clean water for drinking
- Hygenic condition
- Lighting System
- Better Living condition
- Supported Small Industry / Entrepreneurs
- Education
- Tele-communication
- Better living condition for women
- Income-generation / Economic
- Better standard of living

Rural Entrepreneur Development and Business Opportunity are also developed for sustainability.

(b) Some Useful RETs for Rural applications

The essential distinction between the generation of energy from non-conventional sources and its actual application must be constantly kept in view, so that an excessive pre-occupation with the problems of developing energy supplies from alternative sources will not overshadow the equally important technological problem of creating the necessary conditions for mass application of alternative energy supplies.

Wood and dung constitute the main sources of rural energy in developing countries. (See Fig. 11 for biomass as a cooking fuel)\(^3\)\(^b\) The possibilities of finding immediate substitutes for these are limited. The replacement of such non-commercial fuels, at present, often implies a transition to petroleum products, which are themselves becoming increasingly costly in foreign exchange and therefore, less available. On the other hand, large-scale dependence on wood has resulted in depletion of forests, soil run-off and erosion, desertification and a steady decline in crop-yields. The plantation of quick-growing trees and energy forests is, therefore, a matter that deserves serious consideration for implementation on a massive scale.

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The cumulative impact of the effective use of even small amounts of energy in rural areas can be considerable. Agricultural productivity, rural industries, health, communications and educational opportunities could all benefit from the availability of even lower-power devices, thus leading, perhaps, to a slowing of the rural exodus and improving the prospects for balanced economic development. Estimates of the amount of energy required to provide subsistence vary with specific circumstances. Thus, per-capita levels of energy consumption range from 11,000 kilograms coal equivalent (kgce) per annum in North America to between 5 and 10 percent of that figure in developing countries, even when non-commercial energy is included. Several studies concur that a per-capita consumption of about 400-500 kgce/annum would coincide with the minimum provision of food and shelter in a rural agricultural setting.

The combined pre-capita commercial and non-commercial energy consumption, which ranges from 480 kgce/annum for agricultural non-exporters to 1,600 kgce/annum for industrialized developing countries, leaves some 75 percent of the world population at or below the energy consumption level necessary to meet basic human needs. A target of 2,000 kgce/a i.e. 2 T.C.E. per annum, which was the world average in 1979 and which corresponds to the energy consumption of an economy with an annual per-capita GNP of $1,800, would thus be quite an appropriate compromise.

Source: World Bank 1996

Figure 11 : Use of Biomass as a cooking fuel relative to GNP per capita in 80 countries

4. Appendix

The Renewable Energy Technologies and Problems Associated with them. While all RETs derive their energy from the sun’s energy, they can broadly be grouped into categories, based on the intermediate carrier material, viz.

a) Mini-Hydro
b) Geothermal
c) Direct Solar–Thermal; low-temperature heat, Photovoltaic energy
d) Biomass Energy
e) Ocean Energy

<table>
<thead>
<tr>
<th>Technology</th>
<th>Average cost (U.S. cents per kilowatt hour unless otherwise indicated)</th>
<th>Comments</th>
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<tbody>
<tr>
<td>Wind (electric power)</td>
<td>5-13</td>
<td>Costs declined fivefold from 1985 to 1995</td>
</tr>
<tr>
<td>Biomass</td>
<td>5-15</td>
<td>Steam cycle of 25 megawatts Brazil data. Declined by factor of three since 1980s.</td>
</tr>
<tr>
<td>Ethanol</td>
<td>2-3/gallon ($ 15-25 gigajoule)</td>
<td></td>
</tr>
<tr>
<td>Photovoltaic systems</td>
<td>20-40</td>
<td>Based on costs of $ 5-10/peak watt. Costs have declined 5-fold since 1980, 2-fold since 1990. Medium and long-term storage a major issue. With battery storage, cost of $ 8-40/peak watt in off-grid, stand-alone applications are commonly reported; see chapter 7.</td>
</tr>
<tr>
<td>Insolation, 2500 kilowatt hours/square metre</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insolation, 1500 kilowatt hours/square metre</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insolation, 1000 kilowatt hours/square metre</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal solar (electric power)</td>
<td>10-18</td>
<td>Parabolic troughs. Latest vintages, around 1990, in high insolation areas only.</td>
</tr>
<tr>
<td>Geothermal</td>
<td>3-10</td>
<td>Costs vary greatly with location.</td>
</tr>
<tr>
<td>Gas-fired, combined-cycle power plant</td>
<td>3-5</td>
<td>Higher figure is for liquefied natural gas.</td>
</tr>
<tr>
<td>Grid supplies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Off-peak</td>
<td>2-3</td>
<td>Depends on spikiness of peak.</td>
</tr>
<tr>
<td>Peak</td>
<td>15-25</td>
<td></td>
</tr>
<tr>
<td>Average, urban areas</td>
<td>8-10</td>
<td></td>
</tr>
<tr>
<td>Average, rural areas</td>
<td>15 to &gt; 70</td>
<td>Rural areas in developing countries.</td>
</tr>
</tbody>
</table>

Note: All figures are rounded. Estimates are adjusted to 10 percent discount rates.
Source: Based on the author’s interpretations of the following reviews, of more than 500 papers and studies: Mock, Tester, and Wright, 1997, on geothermal; Larson, 1993, on biomass; Ahmed, 1994, on solar and biomass; Gregory, 1998, on several technologies, including fossil fuels; World Bank, 1996, on renewable energy and grid supplies in rural areas; and chapter 7 of this report. Refer to those sources for details and qualifications.

Table - 2.2 : Use and Comparable Cost of Selected Renewable Energy Technologies, 1998
- Hydro-electric (a) and Geothermal (b) energy are the oldest known and have both been developed and utilized in regions where these are abundantly available. What is important is how to extend their use by using smaller units, e.g. Mini-Hydro (100 kw to 1000 kw) and Micro-Hydro (10 kw–100 kw) for far-flung areas, to counteract the drastic deforestation end.

- Direct conversion (c), which involves three main alternatives viz:
  i) Low-temperature Heat (for water-heating)
  ii) Solar Thermal Power-Plant
  iii) Photovoltaics

These are at various stages of development, the first two being already commercially viable in many countries, while the third, although scientifically neat and tidy, is presently viable only for remote areas, where grid-electricity is not feasible.

Biomass Energy is one of the most attractive and abundantly available in nearly all developing countries, and is now almost competitive, with the conventional sources.
CHAPTER 3
THE CHANGING ECONOMICS OF RENEWABLE ENERGY TECHNOLOGIES

1. Introduction

With the general scenario of renewable energy resources for developing countries, we can now attempt to estimate some economics of the more important renewable energies, with special reference to the global situation, as well as that in the Third-World countries. Reliable data is not available in most of the cases, and its projections even to the year 2020 A.D. are brought with numerous uncertainties. Nevertheless, it is not difficult to see that at least four types of Renewable Energies, namely hydro-electricity, biomass, wind and direct solar energy, deserve immediate attention. The chapter gives substantial data on these four types of energies, followed by a brief account of the position of geothermal and ocean energy. There are several sources of techno-economic data on renewable energy, possessing a fair degree of reliability, from 1980 onwards, which have been used frequently in this chapter. These sources are:

1. Renewable Energy Conference at Rio de Janeiro\(^\text{1}\) in 1992
2. World Renewable Energy Conference VI, 2000\(^\text{2}\)
3. Kyoto Protocol, 2001\(^\text{3}\)
4. World Summit on Sustainable Development (WSSD), Johannesburg 2002\(^\text{4}\)
5. World Energy Assessment - 2001 UNDP\(^\text{5}\)

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\(^1\) Renewable Energy Conference at Rio de Janeiro, 1972.
\(^3\) Kyoto Protocol, 2001.
\(^4\) World Summit on Sustainable Development (WSSD), Johannesburg 2002.
\(^5\) “World Energy Assessment” 2001 UNDP.
Other valuable sources of data include:


ii) Energy and the challenge of sustainability, UNDP, 2000\(^7\)

It must of course be remembered that given the present state of information, the cost estimates that follow can only give a rough idea of the relative magnitudes, within ± 20%, in favourable cases.

2. Some estimates of the economics of the most likely renewable sources in developing count

A) Hydro-power

As already noted earlier, the world-wide projections show that, of all the renewables taken together, 20-30% contribution (i.e. 5-6% of the total energy-consumption) in 2050 A.D. would come from hydro-electricity. The position is described below in some detail for the four most significant renewables, viz. hydro, bio-mass, solar energy and wind energy, with special reference to developing countries (Pakistan, China, India and some African countries).

Hydro-Power in Pakistan

Hydro-electric power is one of the better known and well-utilized renewable energy sources. The theoretical potential of hydro-power in Pakistan has been estimated to range between 20,000 and 30,000 Mega Watts. However, it is anticipated that due to financial and technical limitations, only 8,000 to 10,000 MW might be exploited in the next 20 years\(^8\). About 30,000 M.W of hydro-energy are presently available to the

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nation, mostly in the northern regions of Pakistan. But as stated earlier about 8,000 M.W has become exploitable by the turn of the 20th century out of this huge potential for a variety of economic and technical reasons.

**Mini Hydel**: Small power houses of 50-500 kW capacity are of great significance for towns in the far away hilly areas of the developing countries, where it is not easy or economical to take the National Electricity Grid, but where sizable streams or rivulets provide hydel potential of up to 1 Megawatt (1,000 kW) at each site. The construction of medium-size (100 to 1000 kW) hydro-electric dams at places such as Khapalu, Skardu, Bunji, Chilas, Kalabagh, Chashma, Panjar, Kohala, Naran, Kunhar, Kalam posses vast potential (even as high as 30,000 M.W) of hydro-electric energy-generation. (For example, a dozen such sites have so far been exploited by the Pakistan Government, and generators in various multiples of 50 and 100 kW have been installed for domestic and small industries at Chitral, Gilgit, Natar, Chalt, Baltit, Skardu, etc.)

The generation-costs with these so-called “mini-hydel” plants are of course greater than those for large hydro-electric power stations by a factor of 3 to 5, because of increased capital costs per kW installed, but this is more or less offset by the relatively lower costs of transmission lines, in the case of units of 50 to 200kW, provided the organization is run on an efficient cooperative basis.

![Outer casing of 25 kVA Bank Turbine manufactured in Lahore, Pakistan](image)

**Figure 12**: Outer casing of 25 kVA Bank Turbine manufactured in Lahore, Pakistan
Micro Hydropower – Recent Experience in Pakistan

The small hydropower plant is one alternative that has emerged as a desirable option, specially for hilly terrain, where natural and manageable waterfalls are abundantly available. There is a tremendous potential for exploiting these abundantly available waterfalls in the Northern Areas of the country. A number of perennial stream falls, with reasonably sustained discharge over the year, are present in the NWFP, Baluchistan and Azad Kashmir. The population in these areas is isolated, thinly clustered and is located far from physical infrastructure. However, the potential of these areas to contribute to the development of the country and the requirement to provide basic amenities to the population, engenders a socio-economic need for retrieving them from the past neglect. Some details are given below. Besides, there is an immense potential for exploiting waterfalls in the canal network, particularly in Punjab plains, where low-head but high discharge exists on many canals.

Perennial waterfall is channelized and allowed to fall on the turbine from the fore bay, through a penstock. The rotor sometimes is also used for other mechanical work during day time. In this field, PCRET, Islamabad, has made the following achievements:

- Number of units installed 236
- Potential Generation/MW 2.8 MW
- Number of units under installation 15
- Potential to be generated 250
- Sites identified for further installation 20
- Number of requests pending 500

The turbines are designed and manufactured according to the site requirements, while the generators made in China are acquired from the

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local market. The civil works; including the excavation, construction of power channel, power house, erection of electric poles, and distribution network are done on self-help basis by the beneficiaries themselves. The PCRET provides mechanical equipment, as well as technical expertise and supervision.

(B) Biomass, biogas

Biomass energy is obtained by converting animal and agricultural waste to useful fuels, which is renewable, environment-friendly and a sustainable source. The technology is quite simple and easy to adopt in developing countries. Most of the third-world countries have agrarian economy and have expertise to grow forests, which can be easily converted into fuels. Even in the USA, 3.4% of their primary energy has been met through biomass, which is equivalent to 2% of Gasoline used. Current biomass-energy takes separate distinct forms, which includes distillation to produce alcohol, and fermentation to produce gasses through various types of Biogas digesters, which can directly be used for cooking, heating and running of power generators. UK is considering to use biomass-waste as an option and policy-objective for achieving around 10% energy needs through alternate resources by 2010.

Biomass can play a great role, not only by providing energy to the population of the thirdworld, but also to improve the general quality of life, specially from a gender point of view, and it can also help improve the health-conditions, as well as stop the cutting of the wood from forests.

i) Biogas

(The anaerobic fermentation of agricultural and human wastes to produce biogas (about 60% methane) has great potential in the rural areas of all the developing world. It is especially attractive, because it combines cleanliness with the conversion of the animal-dung into good quality, clean fertilizer. It provides a possibility of stopping the environmental damage, resulting from deforestation caused by indiscriminate lopping of trees and burning of wood as fuel for cooking and heating.) The biogas has a
calorific value of 600 Btu/cuft. A family-size unit, based on 3 to 5 animals (i.e. 50 to 80 Kg of wet dung/day), costs between Rs.4,000 and 8,000 in 1980, depending on design and location\textsuperscript{10}. A family-oriented programme would serve perhaps 15% to 25% of the rural population; so it seems desirable to promote community-based plants. The technology is well-understood and has been adopted in several countries (see Figure 13), but optimum designs and operating conditions have to be worked out in various regions/areas. Two difficulties in popularizing biogas technology are (i) the capital outlay, and (ii) the messy nature of the inputs, these need attention. Initially the governments should install biogas-plants in each and every village, as a model plant, for demonstration. Participation of NGOs and social workers to increase awareness and to train local technicians, who can be used to install such plants. India, China, Nepal are the best examples where this exists has been very successful.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure13.jpg}
\caption{Indian Design Biogas Plant in Islamabad, Pakistan}
\end{figure}

With amortization of the components over 15 to 20 years, and making an allowance for the equivalent prices of cow-dung and the digested fertilizer, PCRET (Ex PCAT) found (in 1980) a net operating cost of Rs.1.5 ± 0.3 per day, taking fertilizer price at Rs.2.5 for 50 Kg and using the same figure as the equivalent “price” of the cow-dung. This plant

\textsuperscript{10} Ibid., pp. 144-149 and 255-268
gives us about 70 cuft. of biogas containing 60% of methane, which corresponds to 2 Kg coal, normally costing Rs.3 or Rs.5, in the form of Kerosene today. At this rate, the initial investment can be seen to be recovered in three to four years. In actual fact, the economy is even better, because the fertilizer produced is invariably worth more than the cow-dung fed into it, and the biogas thus, turns out to be often a bonus. Most agricultural wastes can also be fermented in biogas digesters.

If we could utilize the waste from only half of the estimated 80 million animals (cows, buffaloes and goats/sheep) in Pakistan, this process of biogasification could provide 600 million cuft. of biogas everyday, giving 400 thousand million Btu/day, i.e.150x10\(^{12}\) Btu/annum. This corresponds to the energy from 8 million tons of coal and is approximately one third the total consumption of non-commercial fuels in Pakistan\(^{11}\). (see Table 3.2)

<table>
<thead>
<tr>
<th>Fuels</th>
<th>Domestic</th>
<th>Commercial</th>
<th>Inudstrial</th>
<th>Total</th>
<th>T.E.C. (millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dung Cake</td>
<td>45,799.51</td>
<td>-</td>
<td>-</td>
<td>45,799.51</td>
<td>2.41</td>
</tr>
<tr>
<td>Firewood</td>
<td>153,588.52</td>
<td>4,981.89</td>
<td>1,237.85</td>
<td>159,808.26</td>
<td>8.39</td>
</tr>
<tr>
<td>Charcoal</td>
<td>288.00</td>
<td>479.10</td>
<td>-</td>
<td>767.10</td>
<td>0.04</td>
</tr>
<tr>
<td>Bagasses</td>
<td>2,621.34</td>
<td>-</td>
<td>45,975.11</td>
<td>48,596.45</td>
<td>2.55</td>
</tr>
<tr>
<td>Cotton Sticks</td>
<td>18,807.89</td>
<td>-</td>
<td>-</td>
<td>18,807.89</td>
<td>0.99</td>
</tr>
<tr>
<td>Bura (Saw Dust)</td>
<td>3,806.82</td>
<td>-</td>
<td>-</td>
<td>3,806.82</td>
<td>0.20</td>
</tr>
<tr>
<td>Shrubs</td>
<td>16,463.93</td>
<td>8.88</td>
<td>-</td>
<td>15,472.81</td>
<td>0.87</td>
</tr>
<tr>
<td>Weeds</td>
<td>845.39</td>
<td>-</td>
<td>-</td>
<td>845.39</td>
<td>0.04</td>
</tr>
<tr>
<td>Tobacco Sticks</td>
<td>138.11</td>
<td>-</td>
<td>-</td>
<td>138.11</td>
<td>0.01</td>
</tr>
<tr>
<td>Total</td>
<td>242,359.51</td>
<td>5,469.87</td>
<td>47,212.96</td>
<td>295,042.34</td>
<td>15.50</td>
</tr>
<tr>
<td>% Share</td>
<td>82.14</td>
<td>1.85</td>
<td>16.01</td>
<td>100</td>
<td>- -</td>
</tr>
</tbody>
</table>

Source: Renewable Sources of Energy in Pakistan

**Table 3.2 : Consumption Non-commercial Fuels in Pakistan (Btu x 10\(^9\))**\(^{11}\)

Various fermentation-schemes have also been developed for producing fuel-gas from municipal wastes, at costs ranging from $5 to $15 per million Btu, at a capacity of 2,000 tons of waste/day, which is quite competitive with present prices of fuel oil. But extensive field-trials are still required, under the conditions prevailing in developing countries.

**Use of Biomass Energy in Africa**

Women and children suffer from negative health effects due to smoke generated by the use of wood in cooking. Deforestation is one of the biggest problems in Africa. The Renewable energy development, specially the use of Biogas technology, afforestation and plantation can help improve the basic amenities of life and improve the environment.

Africa is the world’s largest sample of energy and they had 3% of the total energy-consumption in OECD countries and estimated 205 tons of oil equivalent of Biomass in 1995, according to International Energy Agency. Most of the biomass energy is used in Sahara, Africa, 15% of the South Africa and 86% of the Sub-Sahara\(^{12}\).

**(C) Solar energy**

The sunshine-distribution map of the world shows that most developing countries occupy a favourable position as regard to solar energy. The present applications of solar energy are, however, limited by various factors, which include the non-developed or untested state of certain technologies and the necessity of large areas for the installations.

A brief discussion on some promising options follows hereafter:

**(i) Generation of Electricity through Solar Cells (Photo-Voltaics)**:

The solar cell device is only a P-N junction, where electric-field separates the electron-hole pair created by absorption of a photon when sunlight shines on it. This generates an E.M.F and a current flows through the external circuit. This device directly converts sunlight into electricity (D.C). The intensity of solar radiation varies from 1,000 watts
per square meter to 800 watts/sq. meter on the equator and varies with solar “insolation”. The average monthly “insolation” varies by 25 per cent (June to December) close to the equator. There are, however, some barriers to rapid commercialization of the technology.

<table>
<thead>
<tr>
<th>Technology</th>
<th>Symbol</th>
<th>Characteristic</th>
<th>Record efficiency laboratory cells (percent)</th>
<th>Typical efficiency commercial flat-plate modules (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single crystal silicon</td>
<td>sc-Si</td>
<td>Wafer-type</td>
<td>24</td>
<td>13-15</td>
</tr>
<tr>
<td>Multi-crystalline silicon</td>
<td>mc-Si</td>
<td>Wafer-type</td>
<td>19</td>
<td>12-14</td>
</tr>
<tr>
<td>Crystalline silicon films on ceramics</td>
<td>f-Si</td>
<td>Wafer-type</td>
<td>17</td>
<td>(8-11)</td>
</tr>
<tr>
<td>Crystalline silicon films on glass</td>
<td></td>
<td>Thin film</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Amorphous silicon (including silicon-germanium tandems)</td>
<td>a-Si</td>
<td>Thin film</td>
<td>13</td>
<td>6-9</td>
</tr>
<tr>
<td>Copper-indium/gallium-diselenide</td>
<td>CIGS</td>
<td>Thin film</td>
<td>18</td>
<td>(8-11)</td>
</tr>
<tr>
<td>Cadmium telluride</td>
<td>CdTe</td>
<td>Thin film</td>
<td>16</td>
<td>(7-10)</td>
</tr>
<tr>
<td>Organic cells (including dyesensitised titanium dioxide cells)</td>
<td></td>
<td>Thin film</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>High-efficiency tandem cells</td>
<td>III-V</td>
<td>Wafer-type and thin film</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>High-efficiency</td>
<td>III-V</td>
<td>Wafer-type and thin film</td>
<td>33 (tandem)</td>
<td>28 (single)</td>
</tr>
</tbody>
</table>

Note: Numbers in paranthesis are results from pilot production of first commercial production.

Table 3.6: Important Photovoltaic Solar Cell and Module Technologies

This high-tech, high capital-investment industry is presently not suited for manufacturers in most developing countries. However, Prototype generators are now available, in various capacities up to 10 kW, and are undergoing field tests in a number of situations, many with the cooperation of UN agencies. There are various PV technologies as indicated in Table 3.6. Single-Crystal Silicon is the leading commercially produced technology. Photovoltaic system includes modules of solar cells, electronic control, support-structure and battery storage (Balance of System). The size of photovoltaic system varies from 50 Watts to one kilowatt for stand-alone system, 500 Watts to 5kW with grid-connected and 10kW to several Mega-Watts grid connected system. Since Photovoltaic System is an intermittent (based on sunlight) source of energy, stand-alone systems are equipped with a battery-bank, to provide energy during the night. The cost analysis is given in Table 3.7.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Modules</td>
<td>3-4</td>
<td>1-2</td>
<td>0.5-1.0</td>
<td>≤0.5</td>
</tr>
<tr>
<td>Balance of system</td>
<td>2-6</td>
<td>1-2</td>
<td>0.5-1.0</td>
<td>≤0.5</td>
</tr>
<tr>
<td>Turnkey systems</td>
<td>5-10</td>
<td>2-4</td>
<td>1-2</td>
<td>≤1.0</td>
</tr>
</tbody>
</table>

Note: Prices are 20-40 percent higher than costs production. Source: Green and Others, 1999

Table 3.7: Possible Cost of Grid-Connected Photovoltaic Systems, Based on different evaluations of photovoltaics production technologies (approach 1) (1998 Dollars per Watt)

The global production of PV cells and modules has grown 36% (42% in Europe) during 2002. The total production in 2001 was 390 MW (see table-3.8). The main problem is the high cost. The price of conventional silicon-cell is still falling, as the production increases, but it has not yet reached the level of $300/kWe where such generators can be regarded as economically viable.
ii) Solar Thermal Energy:

The sun’s heat can be used directly to heat fluid for various purposes, including water-heating, space heating, and can also be used for generating steam for industrial use, as well as in conventional turbine to generate electricity.

These include flat plate, combined storage tank and vacuum-tube technologies, used for water-heating.

Solar Electricity

Sunlight (1kW/Sq.m) can be concentrated through various processes (Tower, Trough and Parabolic Reflector) by many times, which enables us to convert water into steam or any other fluid to a high temperature used by Solar-Thermal power-plants, which could generate sufficient energy to supply the world’s demand of entire electricity. The high-temperature fluid can be passed through a conventional thermal-power turbine, to convert its heat into electricity. Egypt, India, Mexico and Morocco plan to install integrated combined-cycle solar-plants within the period 2002-2004. The cost of power-generation is US$ 0.12 - 0.20/KWh, indicating cost-competitiveness as compared to fossil fuel. It has behind it more than 100 years of experience and well-demonstrated technology, with nine solar-thermal power-plants of parabolic trough type, feeding over 9 billion KWh of solar-based electricity into the Californian grid (USA).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>16.5</td>
<td>16.4</td>
<td>21.2</td>
<td>35</td>
<td>49</td>
<td>80</td>
<td>128.6</td>
<td>171.22</td>
</tr>
<tr>
<td>US</td>
<td>25.64</td>
<td>34.75</td>
<td>38.85</td>
<td>51</td>
<td>53.7</td>
<td>60.8</td>
<td>74.97</td>
<td>100.32</td>
</tr>
<tr>
<td>Europe</td>
<td>21.7</td>
<td>20.1</td>
<td>18.8</td>
<td>30.4</td>
<td>33.5</td>
<td>40</td>
<td>60.66</td>
<td>86.38</td>
</tr>
<tr>
<td>ROW</td>
<td>5.6</td>
<td>6.35</td>
<td>9.75</td>
<td>9.4</td>
<td>18.7</td>
<td>20.5</td>
<td>23.42</td>
<td>32.62</td>
</tr>
<tr>
<td>Total</td>
<td>69.44</td>
<td>77.6</td>
<td>88.6</td>
<td>125.8</td>
<td>154.9</td>
<td>201.3</td>
<td>287.65</td>
<td>390.54</td>
</tr>
</tbody>
</table>


Table 3.8: World cell/module production, consumer and commercial (MW)
All the concentrating solar-thermal power-technologies rely on the following basic key elements, concentrators, receiver, transport-storage, and power conversion described below:

The **concentrator** captures and concentrates solar radiation, which is then delivered to the receiver. The **receiver** absorbs the concentrated sunlight, transferring its heat-energy to a working fluid. The **transport-storage** system passes the fluid from the receiver to the powerconversion system; in some solar-thermal power-plants, a portion of the thermal energy is stored for later use. As **conversion-systems** for these plants, Rankine, Brayton, Combined or Stirling cycles have been demonstrated successfully, and two emerging solar-thermal power-generation concepts are discussed further here:

- The **parabolic trough** or solar farm, consists of long, parallel rows of identical concentrator-modules, typically using trough-shaped glass mirrors. Tracking the sun from East to West by rotation on one axis, the trough-collector concentrates the direct solar radiation onto an absorber-pipe, located along its focal line. A heattransfer fluid (HTF), typically oil at temperatures up to 400°C, or even water up to 520°C, is circulated through the pipes. The HTF then drives a conventional steampower process.

- The **solar central receiver** or **power-tower** is surrounded by a large array of twoaxis tracking mirrors (heliostats), which reflect direct solar radiation onto a fixed receiver, located on the top of the tower. Within the receiver, a fluid (water, air, liquid metal and molten salt have been tested) transfers the absorbed solar heat to the power-block, where it is used to heat a steam generator. Advanced high-temperature “power-tower” concepts are now under investigation; these heat pressurized air to over 1,000°C and feed it into the gas-turbines of modern combined cycles.

**Solar Thermal Energy for Water and Space Heating**

It may be noted that more than 100 million of collector-area is installed in Europe and 18% growth had been noted between 1994 and 99. At the end of 2000, a total 11.7 million sq. meter of collector-area was
installed in Europe. A survey\textsuperscript{14} showed the following details:

- China = 4 million m\textsuperscript{2}
- India = 2 million m\textsuperscript{2}
- Turkey = 430,000 m\textsuperscript{2}
- Israel = 400,000 m\textsuperscript{2}
- South Korea = 40,000 m\textsuperscript{2}
- Mexico = 11,000 m\textsuperscript{2}
- USA = 25,000 m\textsuperscript{2}

\textbf{Solar Water-Heating System:}

A solar water-heater uses Sun’s energy rather than electricity or gas to heat water, thus reducing the monthly utility bill. When installed properly, solar-water heaters are more economical over the life of the system than heating water with electricity, dedicated heat pumps, heat recovery units or propane. There are about 10 million households with solar hot water systems in the developing countries. In Pakistan, the solar systems used are only at the research level in the laboratories. Three types of solar systems are used: pumped integral Collector Storage (ICS), and thermosiphon solar water-heating system.

\textsuperscript{14} Werne Weiss, “Time to come inform the cold the Solar Thermal Market in Europe”, REW July August 2002, p. 92.
The direct circulation system circulates potable water from the water storage tank through one or more collectors and back into the tank. The solar collector is the main component of solar system. It is usually a metal box with insulation and a black absorbing plate that collects solar radiation and heats the water. The circulating pump is regulated by an electronic controller, a common appliance timer, or a photovoltaic (PV) panel.

The Integral Collector Storage systems (ICS), the solar water storage system is built into the collector. The potable water in the collector unit is heated by the sun and delivered by water pressure to an auxiliary tank (which contains non-solar back-up heating) or directly to the point of use.

A Thermo-siphon system has a tank mounted above the collector (normally on the roof) to provide a natural flow of water through gravity. Hot water rises through pipe in the collector, which is mounted below the tank; heavier cold water sinks to the lowest point in the system (the collector), displacing the lighter hot water, which rises to the tank. The ICS and thermosiphon systems are simple since they use no pumps or controllers and water always flows through the collector. There are about 10 million household with solar water systems in the developing countries.

iii) Small-Scale Uses:

*Vegetable Dehydration*: Various designs of solar dehydrators have been tried all over the world. PCSIR has made a significant change recently in Pakistani design which incorporates a solar-heated air current,
using a flat-plate collector. The hot air produced thus rises convectively, enters the dehydration-chamber, and removes the evaporated moisture, without adversely cooling the dehydrating batch. Thus both cleanliness of the product and fueleconomy are ensured. These units have considerable application for hygienically drying vegetables in villages, and fruits in remote areas, which can then be packaged for marketing.

**Solar Cooking** : Numerous designs of Solar Cookers have been developed and tested, varying in cost from US$ 2 to US$ 40 per unit. About 800,000 small scale industries developing solar cookers, are also functioning in the developing countries. The essential features are a set of reflectors or a curved mirror for catching and concentrating Sun’s rays onto the actual cooking chamber, and in some cases, a heat-storage material to enable the cooker to be used when the sun is not shining.

![Solar Cooker](image)

**Figure 17 : Solar Cooker**

(D) **Wind energy**

The non-uniform distribution of heat due to solar energy causes the movement of hot and cold air over the earth’s surface, the winds being more abundant on some areas of the earth than on others. An equivalent of 100 billion watts per year of wind energy is available on the earth. At sea, the winds are even stronger than on the surface of land. On suitable windy regions and particularly in coastal areas, windmills can be installed to produce mechanical energy. Traditionally, windmills have been in use in China, Iran, the Mediterranean and Northern Europe for a variety of purposes. Simple windmills can be locally fabricated from local materials, but many modern high-speed, horizontal as well as vertical axis machines have been designed, to give much higher efficiencies than the traditional designs.
Source: Michael Grub and Niels Meyer, 1994

NB: The total potential (land with an average wind speed above 5.1 m/s at 10 m height) has been reduced by 90% to take into account other uses, population density etc. The assessment does not include Greenland, the Antarctic or offshore areas. Figures not available for OECD Pacific Region (Australia, New Zealand and Japan) or the Middle east.

Figure 18: The World's wind resources. World total = 53,000 TWh

<table>
<thead>
<tr>
<th>Region of the World</th>
<th>Average annual growth in electricity demand 1997--2020</th>
<th>Electricity demand by 2020 (TWh/year)</th>
<th>20% of 2020 demand (TWh/year)</th>
<th>Wind resource (TWh/year)</th>
<th>Factor of the resource exceeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>OECD Europe</td>
<td>1.9 %</td>
<td>4515</td>
<td>903</td>
<td>Land: 630 Offshore 313</td>
<td>1.04</td>
</tr>
<tr>
<td>OECD North America</td>
<td>1.3 %</td>
<td>5729</td>
<td>1146</td>
<td>14,000</td>
<td>12.2</td>
</tr>
<tr>
<td>OECD Pacific</td>
<td>1.5 %</td>
<td>1745</td>
<td>349</td>
<td>3600</td>
<td>10.3</td>
</tr>
<tr>
<td>Latin America</td>
<td>3.8 %</td>
<td>2041</td>
<td>408</td>
<td>5400</td>
<td>13.2</td>
</tr>
<tr>
<td>East Asia</td>
<td>4.5 %</td>
<td>2081</td>
<td>416</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Asia</td>
<td>5.1 %</td>
<td>1695</td>
<td>339</td>
<td></td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>5.1 %</td>
<td>3691</td>
<td>738</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle East</td>
<td>4.0 %</td>
<td>907</td>
<td>181</td>
<td>N/A</td>
<td>20.3</td>
</tr>
<tr>
<td>Transition economies</td>
<td>2.6 %</td>
<td>2615</td>
<td>523</td>
<td>10,600</td>
<td>61.3</td>
</tr>
<tr>
<td>Africa</td>
<td>3.4 %</td>
<td>864</td>
<td>173</td>
<td>10,600</td>
<td>9.6</td>
</tr>
<tr>
<td>World</td>
<td>2.7 %</td>
<td>25,883</td>
<td>5177</td>
<td>49743</td>
<td></td>
</tr>
</tbody>
</table>

Table 3.9: Available wind resources and future electricity demand
Many countries have been over the last few decades, taking keen interest in the generation of wind power particularly remote areas, which cannot be supplied from the main electrical networks at reasonable costs. For this purpose, wind-surveys in various countries have been undertaken e.g. in France, Germany, Great Britain, Ireland, Spain, Denmark, Somaliland, China, Egypt, Israel, India, Australia, U.S.A., Canada, Canary Isles, Tabago, Uruguay and former U.S.S.R. A wind speed of at least 6 to 10 miles per hour is considered to be suitable. Anemometers have been used to define areas considered favourable from the point of view of wind-speed and which lack power-supplies.

If the wind energy produced, is in the form of electricity, it can be fed into the local or sub-grid network directly. Wind energy is now a growing energy-source, providing sustainable and pollution-free renewable energy. 14 Million houses around the world are connected with windpower (facilitating about 35 million people). There are about 55,000 wind-mills installed and 70,000 people are employed in this industry globally. It is an industry worth US$ 5 billion and is growing at a rate of 40% per year. Wind-energy can supply 12% of the word’s electricity. The wind-resources are shown in figure 17 and available world-wind resources and future electricity demand. The total installed capacity around the world in 2001 was 24,900 MW. The growth between 2002 & 2007 is estimated to be 25% per annum, thus going up to 120,600 MW by the end of 2007. By 2020, an installed capacity of 1,260 GW could well be achieved.

Most common power-plants in the world are thermal, large scale Hydro power-plants, or nuclear-reactors developed in the middle of this century. It took 40-50 years for these to become the main technologies. Similarly wind-energy is capable of becoming the mainstream source of electricity. The cost per unit (kWh) of wind-electricity has already came down from 16.9 cents/kWh to 6.15 cents/kwh during the period 1981-1995. With the introduction of 500 kW turbines, the cost has been further reduced and with 2.5 MW, the cost will further be reduced to 3.61 cents/kWh and

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investment cost to $765/kW (less than thermal power-plant). Moreover it is expected that the cost will further decrease to 2.62 cent/kWh by 2010. (investment = US$555/kW). By 2020, it may be 2.11 cents/unit and investment cost to be reduced to 447 per kW. This is most viable and promising renewable energy for developing countries in accordance with its wind resources.

![Figure 19](image)

**Figure 19**: Schematic design of an ideal geothermal system. Not to scale

(E) **Geothermal energy**

It is well known that as we travel towards the center of the earth, the temperature rises due to the geology of the gases of earth and this effect is known for sunshield. Human beings are using Geothermal resources for over 10,000 years. In the past which includes Romans, Japanese, Turkish, Icelanders, Central European and the Maori of New Zealand made most use of it.

The hot springs were used for heating and space heating in the era of Roman Empire. Chinese Kingdoms, Turk’s and Ottomans were some of the early users of
various healthcare treatments. This custom has been extended to geothermal spas in Japan, Germany, Iceland, America and New Zealand. In 1977 Boric Acid was discovered in the hot pools and these minerals were being used in 1810; nine factories were built in 1816 to 1835. A flourishing Chemical industry at Chaudes-Aigues in France, the world’s first geothermal heating system was established in 14th century and it is still working. The first plant of Geothermal Electricity was installed in Italy between 1900 and 1902. The plant was 250 kW and commissioned in 1993, which was followed by New Zealand, Mexico and US in 1960. Now, the world’s geothermal power-generating capacity has increased from 800 (in 1999) Megawatt to 1423 Megawatt, and is expected to reach over 11,000 Megawatt by 2050.

Geothermal energy within the earth is the energy produced through geological phenomena, such as earthquakes and volcanoes, and human being would be using only a fraction of it.

The Geothermal energy is the heating source which may be available at a relatively less depth of earth 5-10 Km, where we can get a high geothermal grid and high geothermal energy in producing system.

Geothermal Energy is a clean renewable energy, sustainable and independent of both time and weather; and operatable 24 hours a day. In 1998, percentage of Geothermal Energy was 42% of the total electric power installed and 70% of total electricity generated by other renewable energy.

It can be converted directly into electric energy or it can be used as a heating source. The electricity can be produced through conventional system out-points. The capacity of such plants varies from 2.5 – 5 Megawatt using steam, (at least 150OC) . The larger plants of 55-60 Megawatt capacity are also very common, where electricity can be generated from low to medium temperature (steam) of the Geothermal Energy.

In year 2000, the total capacity of Geothermal plants, all over the world, has increased to 1,141 Megawatt since 1915. It is expected that by the year 2050, this will rise to 11,414 Megawatt). There are about 20 countries, which produced Geothermal electricity in 1995, including
countries from the developing world, viz China, Ethiopia, El Selvadore, Guatemala, Indonesia, Kenya, Philippines, Pourtagal. Now, 58 countries are utilizing geothermal energy in direct application, with a total capacity of 15,000 Megawatt. The distribution is as under\textsuperscript{16}

1. 42% for Geothermal heat pumps
2. 31% for Space heating
3. 11% for Bathing
4. 9% for Greenhouses
5. 3% for Industrial
6. 1% for Agricultural

Worldwide Resources of Geothermal potential

The growth-rate for installed electric capacity from 1940 to 1960 was 5.6% annually, and dropped due to the world war, then back during 1960-1970 period to 5.8% per annum and then increased in 1970-80 to 12%, but in 1980-90 dropped to 10.7%. It is very interesting to note that from 1990 onward, this has declined 2.3% per years, which may be due to slowdown of world economy. The average growth-rate over 20 years has been 8.6% per year.

Conclusion

Geothermal energy is one of the oldest forms of renewable energy with the longest industrial history. Worldwide, geothermal power could serve the electricity needs of 865 million people or about 17% of the world’s population. 39 countries have already been identified that could be powered 100% through geothermal resources, mostly in Africa, Central and South America and the Pacific – representing 620 million people (according to UN population data for 1998).

CHAPTER 4
THE MAJOR OPTIONS FOR VARIOUS CATEGORIES OF COUNTRIES

1. The Present Situation

It is well known that nearly all renewable energy sources on the earth, e.g. hydro, biomass, ultimately derive their energy from the sun, which itself gets energy from the basic fusion reaction that converts Hydrogen into Helium, with the release of 2 neutrons and a tremendous amount of energy. The basic differences between the various forms of renewable energy lie in the fact that (a) the vehicle is readily available, e.g. biomass, wind or water, and (b) the overall cost of obtaining the energy in a usable form for industry, transportation is relatively low.

In 2001, China was far ahead in Solar Thermal Systems and Biogas and Small / Micro Hydropower plants while India has excelling in the region in Wind Power as per the figures of 2001. These figures given in Table 4.1 reflect the growing importance of renewable-energy sources in the region¹, which comprises both developing and developed countries.

During the last two decades, a tremendous amount of work has been done on the various renewable-energy technologies, so that today many of them are commercially viable and even available in units of medium to large size. A summary of the overall picture, as of now, is presented in the accompanying Table 4.2, taken from World Energy Assessment: Energy and the Challenges of Sustainability”, in 2000 by UNDP² report.

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Table - 4.1: Renewable Energy Technologies in Selected Asian Countries as of December 2000.

<table>
<thead>
<tr>
<th>Country</th>
<th>Solar thermal system (1000m²)</th>
<th>PV system (mW&lt;sub&gt;p&lt;/sub&gt;)</th>
<th>Wind power plants (mW)</th>
<th>Small/micro hydropower plants (mW)</th>
<th>Power plants (mW)</th>
<th>Biogas plants (1000 units)</th>
<th>Improved cook-stoves (1000 units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh</td>
<td>0.15</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>82</td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>5000</td>
<td>6.00</td>
<td>344</td>
<td>20,000</td>
<td>800</td>
<td>6800</td>
<td>180,000</td>
</tr>
<tr>
<td>India</td>
<td>467</td>
<td>50</td>
<td>1167</td>
<td>217</td>
<td>272.74</td>
<td>3000</td>
<td>32,000</td>
</tr>
<tr>
<td>Indonesia</td>
<td>-</td>
<td>5</td>
<td>0.5</td>
<td>54</td>
<td>178</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Japan</td>
<td>57</td>
<td>3.6</td>
<td>75</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Korea</td>
<td>-</td>
<td>0.48</td>
<td>-</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Malaysia</td>
<td>-</td>
<td>2</td>
<td>0.15</td>
<td>24</td>
<td>200</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nepal</td>
<td>10</td>
<td>1.08</td>
<td>0.02</td>
<td>11.46</td>
<td>-</td>
<td>49.28</td>
<td>250</td>
</tr>
<tr>
<td>Pakistan</td>
<td>-</td>
<td>0.44</td>
<td>-</td>
<td>20</td>
<td>-</td>
<td>4.13</td>
<td>68</td>
</tr>
<tr>
<td>Philippines</td>
<td>-</td>
<td>0.52</td>
<td>0.06</td>
<td>70</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>6</td>
<td>-</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>Thailand</td>
<td>50</td>
<td>5</td>
<td>0.2</td>
<td>128</td>
<td>1230</td>
<td>10</td>
<td>500</td>
</tr>
<tr>
<td>Vietnam</td>
<td>-</td>
<td>0.47</td>
<td>0.1</td>
<td>95</td>
<td>-</td>
<td>3.08</td>
<td>-</td>
</tr>
</tbody>
</table>

The plant size of small/micro hydro plants varies widely across Asian countries, from 5kW in Vietnam to 50 MW in China; they are classified as ‘small/micro’ because they receive special incentives from the corresponding governments for their implementation, these also includes waste-fired power plants.

### Table 4.2: Current Status of Renewable-Energy Technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Increase in installed capacity in past five years (percent a year)</th>
<th>Operating capacity, end 1998</th>
<th>Capacity factor (percent)</th>
<th>Energy production 1998</th>
<th>Turnkey investment costs (US$ per kilowatt)</th>
<th>Current energy cost of new system</th>
<th>Potential future energy cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass energy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electricity</td>
<td>-3</td>
<td>40 GWs</td>
<td>25-80</td>
<td>160 TWh (o)</td>
<td>900-3,000</td>
<td>5-15 c/kWh</td>
<td>4-10 c/kWh</td>
</tr>
<tr>
<td>Heat</td>
<td>-3</td>
<td>&gt;200 GW</td>
<td>25-80</td>
<td>&gt;700 TWh (th)</td>
<td>250-750</td>
<td>5-15 c/kWh</td>
<td>1-5 c/kWh</td>
</tr>
<tr>
<td>Ethanol</td>
<td>-3</td>
<td>18 tin litres</td>
<td>420 PJ</td>
<td></td>
<td></td>
<td>8-25 $/GJ</td>
<td>6-10 $/GJ</td>
</tr>
<tr>
<td>Wind electricity</td>
<td>-30</td>
<td>10 GWs</td>
<td>20-30</td>
<td>18 TWh (o)</td>
<td>1,100-1,700</td>
<td>5-13 c/kWh</td>
<td>3-10 c/kWh</td>
</tr>
<tr>
<td>Solar photovoltaic</td>
<td>-30</td>
<td>500 MWS</td>
<td>8-20</td>
<td>0.5 TWh (o)</td>
<td>5,000-10,000</td>
<td>25-125 c/kWh</td>
<td>5 or 6-25 c/kWh</td>
</tr>
<tr>
<td>Solar thermal</td>
<td>-5</td>
<td>400 MWS</td>
<td>20-35</td>
<td>1 TWh (o)</td>
<td>3,000-4,000</td>
<td>12-18 c/kWh</td>
<td>4-10 c/kWh</td>
</tr>
<tr>
<td>electricity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-temperature</td>
<td>-8</td>
<td>18GWth (30 min m²)</td>
<td>8-20</td>
<td>14 TWh (th)</td>
<td>500-1,700</td>
<td>3-20 c/kWh</td>
<td>2 or 3-10 c/kWh</td>
</tr>
<tr>
<td>solar heat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydroelectricity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large</td>
<td>-2</td>
<td>540 GWs</td>
<td>35-60</td>
<td>2.510 TWh (o)</td>
<td>1,000-3,500</td>
<td>2-8 c/kWh</td>
<td>2-8 c/kWh</td>
</tr>
<tr>
<td>Small</td>
<td>-3</td>
<td>23 GWs</td>
<td>20-70</td>
<td>90 TWh (o)</td>
<td>1,200-3,000</td>
<td>4-10 c/kWh</td>
<td>3-10 c/kWh</td>
</tr>
<tr>
<td>Geothermal energy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electricity</td>
<td>-4</td>
<td>8 GWs</td>
<td>45-90</td>
<td>46 TWh (o)</td>
<td>800-3,000</td>
<td>2-10 c/kWh</td>
<td>1 or 2-8 c/kWh</td>
</tr>
<tr>
<td>Heat</td>
<td>-5</td>
<td>11 GWs</td>
<td>20-70</td>
<td>40 TWh (th)</td>
<td>200-2,000</td>
<td>0.5-5 c/kWh</td>
<td>0.5-5 c/kWh</td>
</tr>
<tr>
<td>Marine energy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tidal</td>
<td>0</td>
<td>300 MWs</td>
<td>20-30</td>
<td>0.5 TWh (o)</td>
<td>1,700-2,500</td>
<td>8-15 c/kWh</td>
<td>8-15 c/kWh</td>
</tr>
<tr>
<td>Wave</td>
<td>-</td>
<td>exp. phase</td>
<td>20-35</td>
<td>-</td>
<td>1,500-3,000</td>
<td>8-20 c/kWh</td>
<td>-</td>
</tr>
<tr>
<td>Current</td>
<td>-</td>
<td>exp. phase</td>
<td>25-35</td>
<td>-</td>
<td>2,000-3,000</td>
<td>8-15 c/kWh</td>
<td>5-7 c/kWh</td>
</tr>
<tr>
<td>OTEC</td>
<td>-</td>
<td>exp. phase</td>
<td>70-80</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Heat embedded in steam for hot water in distinct heating often produced by combined heat and power systems using forest residues, black liquor, or bagasse.

An examination of this Table 4.2 shows that Low-temperature Solar Heat, Hydroelectricity, Geothermal Energy and, to some extent, Solar-Thermal electricity are already in the viable stage. Energy from Biomass, Wind-Electricity, Photo-voltaic Electricity and Marine-Energy are seen to be the next on the list. Using the above-mentioned table from the UNDP report, we may summarise the estimated costs of these RET’s in chart 4.3.

<table>
<thead>
<tr>
<th>Category</th>
<th>Range of Cost / Unit / (kWh)</th>
<th>Type of RETs</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5 ± 2 cents / kWh</td>
<td>Geothermal and mini-hydro</td>
</tr>
<tr>
<td>B</td>
<td>9 ± 3 cents</td>
<td>Biomass; wind; low temp / solar heat; Tidal and Ocean - current energy</td>
</tr>
<tr>
<td>C</td>
<td>14 ± 4 cents</td>
<td>Solar-Thermal, Biomass ethanol; also wave energy</td>
</tr>
<tr>
<td>D</td>
<td>50 ± 14 cents</td>
<td>Photovoltaics (PV)</td>
</tr>
</tbody>
</table>

Chart 4.3 : Currently Usable RETs

On the basis of cost / kWh alone, the relative grading, as per the foregoing table, leads to the following three presently available groups, which fall broadly in the, more or less, viable groups of; (A) 5 c/kWh, (B) 9 c/kWh and (C) 14 c /kWh, followed by photovoltaics at >30 c /kWh: The first two groups are already competitive with present costs of electricity generation, while Solar-thermal and Biomass Ethanol are also expected to become viable after a decade or two as further clarified in Table 4.3. Electricity generation through Photo-voltaic Systems, on the other hand, presently costs around 40c/kWh, but may possibly become competitive after two decades or so; presently, it is feasible for remote and desert areas.

2. The Basis for Prediction and Planning

The World Energy Council (WEC) Statement 2000 emphasized the need to increase the use of new renewable-energy sources wind, solar, geothermal, oceanic, but excluding modern biomass. The question to be studied in detail is: which ones are most suitable for which countries conditions? The decision would rest primarily on three factors, namely:
i) The cost of energy (kWh)
ii) The capital cost, and
iii) The ready availability of the relevant material for production (biomass, wind, solar radiation, water, etc.)

Combining the above tabulated information (Table 4.4) with data on availability in specific areas and the local socio-economic conditions, the following tentative assignment of options for four broad areas of the Developing World may be proposed (see chart 4.5). In doing this, one can of course, at best make an educated guess, but the relative merits of the various Renewable-Energy Technologies are expected to be more or less stable for the next decade or two. The choice between Mini-Hydro and Biomass in any particular place or region, would be dictated by availability and terrain, whether hilly or forest.

<table>
<thead>
<tr>
<th>Presently viable</th>
<th>Viable in near future</th>
<th>Special applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 c / kWh</td>
<td>9 c / kWh</td>
<td>14 c / kWh</td>
</tr>
</tbody>
</table>

Table 4.4: Viability of Renewable Energies

It is clear that mini-Hydro Bio-mass and Solar-thermal are probably the most viable RETs for all four regions of the developing world. For Biomass and mini-Hydro, the choice depends on the terrain, whereas solar-thermal is applicable in almost all the regions, in general, and sun-belt countries in particular. Needless to say, Photovoltaics are currently in the market, specifically for far-flung areas and special applications like tele-communication and refrigeration of medical supplies.

Wind power can only be applicable where the required wind-velocity, sustained over a sufficient period, with appropriate density, is available along coastal areas or even further into territorial water-systems of the oceans. This needs extensive survey in individual countries of the developing world.
The ocean/ wave-energy\(^5\) may also be exploited in the near future wherever facilities are available. However, serious sustained development-efforts would be needed for economic exploitation of these particular renewable resources. Perhaps several neighbouring countries could get together for jointly launching such a project. The first commercial wave (OWC) 500kW power-station was installed and commissioned at Islag, Scotland, in 2000. It is estimated that there are some 2-3 million MW worth of power in the waves on all the coastlines in the world. A 60kW system (RVCo Hydroventuri, UK) has been working in North of England since June 2002. It is performing within 3% of the design capacity. Australian had planned to instal (Energetech) (OWC) wave turbine at Port Kembla by the end of 2003.

<table>
<thead>
<tr>
<th>REGION</th>
<th>RETs in order of priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFRICA</td>
<td>i. Mini Hydro</td>
</tr>
<tr>
<td></td>
<td>ii. Biomass</td>
</tr>
<tr>
<td></td>
<td>iii. Solar Thermal</td>
</tr>
<tr>
<td></td>
<td>iv. Ocean and Wind</td>
</tr>
<tr>
<td>SOUTH ASIA</td>
<td>i. Mini Hydro</td>
</tr>
<tr>
<td></td>
<td>ii. Biomass</td>
</tr>
<tr>
<td></td>
<td>iii. Solar Thermal</td>
</tr>
<tr>
<td></td>
<td>iv. Wind</td>
</tr>
<tr>
<td>MIDDLE EAST</td>
<td>i. Wind</td>
</tr>
<tr>
<td></td>
<td>ii. Solar Thermal</td>
</tr>
<tr>
<td></td>
<td>iii. Mini-Hydro</td>
</tr>
<tr>
<td></td>
<td>iv. PV - for Isolated Villages</td>
</tr>
<tr>
<td>SOUTH AMERICA</td>
<td>i. Mini Hydro / Geo-thermal</td>
</tr>
<tr>
<td></td>
<td>ii. Bio-mass &amp; Wind</td>
</tr>
<tr>
<td></td>
<td>iii. Solar Thermal</td>
</tr>
<tr>
<td></td>
<td>iv. Ocean and PV</td>
</tr>
</tbody>
</table>

Chart 4.5 : Proposed RETs for Specific Developing Countries/Regions


Energy is a basic necessity for socio-economic uplift that leads, and is leading, to sustainable development. The goal of energy depends upon: **Accessibility, Acceptability and Availability** (3A strategy) for both developed and under-developed countries. Accessibility means to provide clean-energy at affordable prices for all people. Availability relates to reliable source and security. Acceptability of an energy-source relates to public attitude, social and cultural circumstances.

Keeping in view the **3A principle**, the policy of renewable-energy may be designed for each country to satisfy the basic needs of their people and to achieve the target growth-rate in their economies. The overall aim should be to provide sustainable modern energy for all the segments of population, at the latest by 2020 (goal set by WEC) or 2030, with special focus on the developing world (targeting 2 billion poor people currently without light). The energy-policy would naturally vary from country to country, but general guidelines can be given, as follows:

i. Assessment of various Renewable-Energy Resources through surveys.

ii. Establishment of Institutional arrangements to develop these resources

iii. Development of appropriate technical manpower

iv. Regulatory frame work to encourage development of entrepreneurship

v. All energy options must be kept open to develop Renewable Energy Resources and their technologies in future.

vi. Promotion of energy-efficiency tools

vii. Allocation of funds for R & D

viii. Cost-reduction, to cater for needs of the poor

ix. Awareness-programme for rural areas

x. Relaxation of Taxes/Duties, to make RETs competitive

xi. Encourage RET industry with incentives.
RETs can be promoted, based on the above guidelines. However, this has to be supplemented with a **yearly action-plan**, so that the whole population can be benefited. All RETs should be used to satisfy needs of the common man, in accordance with its Availability, Accessibility and Acceptability. RET-based local industry should be encouraged to achieve self reliance and sustainability. Financial institutions may be set up to finance projects for indigenous development and sustainable credit-facilities should be made available for launching such projects in the field of Renewable-Energy Technology, through small and medium entrepreneurs.

While the Developed countries have already set their targets to generate, say, 10% of their energy needs from renewables by the year 2010, it is a massive task to bring Renewable energy to millions of rural families in the developing world. This may require thousands of small entrepreneurs to engage in the RETs business and would need extensive training and capacity-building, but can also be a major source of employment and mobilizing the economy. The G-8 report estimated that about one billion people will be serviced with their basic energy-needs, of which 800 million will be from developing countries served by 2010. The G-8 plan hopes to serve 2 billion people by 2015.

The enormous potential of renewable energy sources can meet many times the world energy demand. These can enhance diversity in the energy-supply market, contribute to long-term sustainable energy-supplies, reduce harmful emissions and create new job-opportunities, as well as, offer manufacturing-opportunities, especially in the developing world.
CHAPTER 5
RESEARCH, DEVELOPMENT AND DEMONSTRATION OF RENEWABLE-ENERGY TECHNOLOGIES

1. Some basic considerations

The pace and extent of the contribution of new and renewable sources of energy and related technologies will depend, to a large extent, on scientific research directed towards their development and widespread utilization. The present R&D expenditure on renewable-energies is 6-8% of the total expenditure on Research & Development in Energy, of which about half goes to nuclear energy. While such research is expanding rapidly world-wide, the coordination and information-sharing is poor; duplication is widespread, and certain important aspects are relatively neglected and receive little attention. Moreover, currently the bulk of research is being carried out in developed countries, much of it will later on be extensively re-adapted for use in developing countries.

One may here consider the “struggle for existence” of the various energy-forms, as seen in the eighties by Cesare Marchetti\(^1\) of I.I.A.S.A., as a schematic representation of global trends in various energy-technologies, from 1900 up to 2100 A.D. Figure 7 (Chapter 2). This shows quite distinctly that in the recent past, the useful span of any one form of fossil-energy has been of the order of 250 years, with an outstanding popularity over 50 years or so, the latest item so far being natural gas.

A similar pattern is emerging for nuclear energy and also appears likely in future for the newer renewable-energy technologies (peaking after 2100 A.D), shown by the double line in the right-hand part of Figure 7 (in Chapter 2). Accordingly, there has to be a more or less continuous effort for development of new renewable forms of energies. This effort should be at national, as well as regional and international levels, and an action plan until year 2020 or 2030 should be worked out for every developing country.

2. Components of the R; D&D Programme

National policies and plans should be developed and are urgently needed, in order to enhance the indigenous scientific and technological capabilities of developing countries, so as to enable them not only to fully and independently exploit their own resource-potential, but also to enter into collaborative research, development and demonstration effort, which should be closely coordinated with the related education and training programmes. The following are some basic steps and activities that shall be given consideration:

a) Select promising technologies, with a view to launch concerted efforts to accelerate their development, increase cost-effectiveness and widen their applicability;

b) Identify the area and need of research, with special reference to the economic, social and environmental implications of emerging technologies, such as employment-potential;

c) Establish or strengthen institutional mechanism for (i) national Renewable Sources of Energy for developing countries; (ii) Regional capacity, including the private sector, where appropriate, for undertaking and coordinating research, development and demonstration activities, on the basis of a review initially to be undertaken at national, sub-regional and regional levels, to enable present capabilities and existing resources to respond to identified needs and priorities, in particular those of developing countries;
d) Establish or strengthen institutional linkages between research and development activities and the production-sector (to have public investments and industrial property systems, etc.);

e) Consider undertaking testing-programmes for increasing the ability of prospective consumers, producers and investors, to make knowledge-based decisions regarding technological options;

f) Establish criteria for technical and economic evaluation of new and emerging technologies that may help national experts to identify their potential at specific locations;

g) Identify and implement demonstration-projects relating to new renewable-energy technologies, including those which can be undertaken on a collaborative basis, with the consideration that it will further stimulate research and development; the training of specialists, and increase industrialization.

3. Proposals for developing countries

**Renewable Energy**

Electric power capacity\(^2\) (1,500,000 MW) was 45% of world electric power (3,400,000) in year 2000, the developing countries’ (table-5.1). World’s fossil-fuels account for about twothird of generating capacity, with the remaining one-third being composed of large hydro (20%), nuclear (10%) and other renewable energy (3%). Electric energy-consumption in the developing world is increasing with economic growth and the developing world will need to double its current generation-capacity.

Renewable energy faces stiff competition from other generation of distributed technologies, especially those based on natural gas and gas-turbines (and perhaps natural gas supplied fuel-cells in the future). Provided a gas supply exists, gas seems to remain the fuel of choice for small self-producers, because of short construction lead-times, low fuel and maintenance costs, and modular technology. New “micro-turbines” are lowering the capacity-threshold at which natural gas fuelled self-generation becomes viable.

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Notes:
(a) “Small hydro” is usually defined as 10MW or less, although the definition varies by country, sometimes up to 30 MW;
(b) Biomass figures omit electricity from municipal solid-waste and landfill gas; commonly, biomass and waste are reported together.

On the other hand, as households and business entrepreneur take more interest in distributed Solar PV, either by taking advantage of government subsidy-programs or decide to pay the extra cost themselves, “net metering” that allows “stored” kilowatt-hours over the utility connection and power sales at retail-tariff levels, is becoming more widespread. For example, 30 states in the U.S. now have net-metering laws, and California allows users with up to 1-megawatt loads to use net-metering. A net-metering law was recently passed in Thailand, in general few other developing countries have come to consider net-metering.

**Policies for promoting Renewable Energy**

There are a number of specific ways for incorporating renewable-energy in the energymix, which can boost its use in many countries:

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a) Fossil-Fuels Subsidy: In developing countries, most of the fossil-fuels are subsidized. These subsidies may be reduced gradually, to make renewable-energy marketable with costcompetitiveness.

b) Access to Transmission: An open-access transmission-system may allow power-wheeling between buyer and seller that provides open access to customers. Transmission-services should not discriminate against, or give unfair advantage to, specific ownership or certain types of generation. For example, in India open-wheeling policies have been credited with helping catalyze the wind-energy industry; industrial firms may even produce their windpower in regions with good wind-resources and transfer the power over the transmissionsystem for the use in their own facilities – or for sales to a third party. Similarly, in Brazil, reduction of fees for transmission-wheeling has been credited with promoting and giving boost to the small-hydro industry.

c) Environmental Policy: Emissions standards, monitoring requirements, and other aspects of environmental policy can be integrated to strengthen power-sector changes. For example, enforced emission-monitoring can promote “green power” markets. Major power-sector changes occur using political leverage, to incorporate environment friendly policies. Advocates of renewable energies should anticipate this opportunity.

d) Renewable-Energy Pricing: The electricity feed-in laws in Germany, and similar policies in other European countries in the 1990s, required purchase of renewable-energy power at a fixed price. For instance, in Germany, power producer could sell the utility at 90% of the retail market price. Feed-in laws led to a rapid increase in installed-capacity and development of commercial renewable-energy markets in particular in Germany and Spain. Partly because retail prices have been falling with competition, making renewable-energy producers and financiers more wary, the new German Renewable Energy Law now change pricing to that based on production-costs, rather than retail prices. One of the criticisms of historical feedin approaches was that they had not encouraged cost-reductions or innovation; this new German law includes provisions for
regular adjustments to prices, in response to technological and market developments (Shepherd⁴ 1998; Wanger⁵ 2000; Sawin⁶ 2001).

e) Distributed Energy Systems: Renewables are likely to play a larger role in power-systems, dominated by the distributed model than the central station paradigm. However, successful deployment of distributed renewables in an unbundled system, requires that at least one player can capture system-benefits. Some of the ways that distributed energy can be supported are:

- Financing mechanisms for renewable energy
- Common interconnection standards
- Standard power-purchase agreements and tariffs
- “Net metering” schemes for residential consumers
- Reduced bureaucratic procedures for grid-connections and/or metering
- Upgrades energy tariffs in distribution-system

Distribution change system can substantially change the economics of generation of distributed renewable-energy. Solar-photovoltaic power, is perhaps the most significant. Although only about 20% of global PV production was used on grid in 1998 (mostly for government-sponsored rooftop markets). Such policies can enhance PV application at individual, community, regional and national levels.

GEF Support to Renewable Energy in Developing Countries

GEF supported renewable-energy projects in developing countries from 1991 to 2000. Seventeen (17) projects were implemented through

World Bank, UNDP and ADB. Nine (9) projects promote a wind-power in Cape Verde, China, Costa Rica, India, Kazakhstan and Sri Lanka, Six promote biomass and biogas power generation in China, Cuba, Hungary, Mauritius, Slovenia and Thailand, one promote power from biomethanation in India and one promotes Geothermal power in Philippines. In general, GEF projects take five main approaches to promoting Grid-connected renewable-energy: (a) demonstratable technologies, and their commercial and economic potential; (b) build capacities of project-developers, operator and regulatory agencies; (c) develop regulatory and legal frameworks that create financing mechanisms for project developers; (d) develop national plans and programmes informed by institutional and business models piloted in projects.

4. Some typical examples

The use of renewable technologies has increased in the developing countries and its countrywise status (2000) is given in the table 4.1 (chapter 4). China leads in solar thermal system, followed by India. In the case of PV, India is far ahead (50 MW); China, Indonesia and Thailand are also playing a significant role. Following examples are the successful Renewable Energy projects in the developing countries and lesson learned:

a) Wind and small hydropower in India

By 2000, almost 1200 MW of wind-capacity had been installed in India, virtually all of that by the private sector, due to favourable investment/tax policies and a supportive regulatory framework. Domestic wind-turbine manufacturers have emerged, many of them joint-ventures with foreign partners.

During 1990s, GEF and World Bank directly financed 41 MW of wind-turbine installations and 45 MW of mini-hydro capacity in India, through the Renewable Energy development project. Following lessons were learnt:

i) Indian Renewable Energy Development Agency (IREDA) sponsored 35 MW of wind project and 65 MW of mini-Hydro projects. Many financial institutions offered financing for Wind farms.

ii) Regulatory investment-tax credit and Government commitment, as well as GEF’s role, had influenced technology-transfer and market-development.

iii) Another lesson is that more understanding is needed about the relative effectiveness of production-based incentives, relative to capacity-based incentives. In the 1990s, one-year 100% investment tax-depreciation, provided large economic gains, for installation of wind-farm capacity, regardless of the electricity-generation from that capacity. This incentive is shifting, as capacity-based tax-incentives have decreased, due to the reduction in marginal corporate-tax rates, from 55% in 1992/93 to 35% in 2000. At the same time that power tariffs, production-based incentives, have continued to rise. In addition, IREDA offers incentives for wind-farms it has financed, to achieve higher capacity-factors and attracted investment and played role in enhancing market.

b) Bagasse Power In Mauritius

World Bank/GEF Sugar Bio-Energy project (1994-96) provided technical assistance and technology demonstration, to promote private / public sector cooperation in power-plants. Electricity-generation from bagasse increased from 70 GWh/yr in 1992 to 118 GWh/yr by 1996. This project triggered the private-sector to setup power-plants based on Bagasse at their own.

One of the lessons the Mauritius project has how to create an investment-climate for renewable energy power projects, and create public/private partnerships that can lead to supportive regulatory frameworks. In this case, the project led to the establishment of a framework for the development of independent power-producer (IPP) and an administrative focal point for private/public sector partnership in IPP development. The
evaluation of project showed that the project’s major accomplishment was-
progress in helping to establish an institutional and regulatory framework
for private power-generation in Mauritius, and the provision of technical
studies and trials, to support technologies for improved bagasse production
and improved environmental monitoring. Another lesson may be that
technical demonstration has less influence on promoting markets for a
technology than other types of project- interventions (in this case the
planned demonstration bagasse-plant that was never constructed).

c) Small hydro power plant in Sri Lanka

One of the lessons from the Sri Lankan project is that variable power-
purchase tariffs can hinder market development. In this case, tariffs were
tied to short-run avoided utility-costs based on the international price of oil.
In 1997 and 1998, tariffs were set to be equivalent to 5 cents/kWh and
hereafter mini-hydro development flourished. However, because of the
downturn in oil prices in 1998-99, prices were only the equivalent of 3.5
cents/kWh in 1999. And this fluctuation had seriously hurt the longer-term
and unresolved dispute [on tariff calculation-methods] have caused a deep
slump in mini-hydro development”, said a project-status report in 2000.

d) Wind-power in China

The emerging experience from the World Bank/GEF Renewable
Energy Development project in China, highlights the pressing need to
address regulatory frameworks and find ways to reduce risks to project-
developers. The project was designed to finance four newly formed windfarm
companies for the construction of 190 MW of wind-farms in Inner
Mongolia, Hebei, Fujian, and Shanghai provinces. These companies were
to be jointly owned by the State Power Corporation and subsidiary electric-
power utilities (at regional, provincial or municipal levels) and were to sell
power to utilities under power-purchase agreements, developed through the
project. The costs of wind-generated electricity from these wind companies
would be higher than those of conventional electricity generation, but
utilities in three provinces (Hebei, Fujian and Shanghai) were initially willing to purchase this wind-power from the project developers. At least at small scales, the added costs of wind-power were marginal, relative to total utility-revenue for these three large utilities.

However, a planned 100-MW wind-farm in Inner Mongolia, as part of that project, was cancelled in 2000, because the smaller Inner Mongolia utility was unable to sign power-purchase agreements with neighboring provinces, for sale of wind-power, which could not be absorbed within the Inner Mongolia grid itself. Originally, the North China regional power company had agreed to purchase wind-power from Inner Mongolia, but when the North China power company was split into three provincial utilities and given an explicit mandate to operate on strictly commercial terms, Inner Mongolia was unable to persuade any of these three provincial utilities to sign power-purchase agreements with it, for the higher-cost wind-power. And being unable to use this power itself – given the small size of the Inner Mongolia grid (but abundant wind resources) – it proved unable to undertake this investment. The lesson may be that government has to provide subsidy to match it with other resources of energy as well as to enhance the economic market size.

e) Nepal’s Biogas Programme

Biogas Support Programme\(^8\) (BSP) is an example of a successful collaboration between government and private sector and donor agencies. The BSP was initiated in 1942, by Netherlands Development Organization and funded by Dutch Development Cooperation. The programme was closely associated with Agriculture Development Bank and Gobar Gas Company of Nepal.

About 86% of 21.5 M population (estimates of 1995) reside in rural areas of Nepal; the per capita GDP in 1995 was about US$200. Annual per-capita consumption of primary-energy in Nepal was estimated at 271 Million GJ in total; out of this 90% was from wood (72%) followed by agricultural waste residue (16%), animal waste (9%), electricity (0.4%) and LPG (0.1%).

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The BSP in Nepal was divided into two phases. Phase-1 was implemented from 1992 to July 1994 and install 7000 Biogas plants for farmers. The second phase covered 13,000 plants from 1994 to 1997. Financial subsidy was provided to farmers through Asian Development Bank. The total of (approximately) 49000 units were constructed up to 1998 and are benefiting more than 200,000 members of rural households. Biogas plants are being efficiently used in P.R. China, where over 5 million plants are installed, as against 2.7 million in India.

f) Bio-Ethenol as an alternate fuel for transport (Brazil a role model)

Developing Countries are using Gasoline and Diesel as a fuel for transport which causes pollution, and resulting environment damages as well as a lot of foreign exchange is spent on the import. The alternate fuel for transportation can be Bio-Ethanol. In Third World countries, Brazil, Kenya and Malawi are the top three users and producers of Bio-ethanol. Brazil represents 2/3rd of global ethanol production, while Kenya uses 60% of its sugarcane produce for ethanol. In comparison Malawi produces 40% for automobile consumption.

Thermal properties of Bio-ethanol include; higher heating value of 6,400 Kcal/kg; an ignition temperature of 35 degrees centigrade and a specific heat of 0.60 Kcal/Kg °C more than gasoline. Brazil can be a role model in the Third World countries using Bio-ethanol as alternate fuel for transport which resulted in it saving foreign exchange, as well as creating job opportunities, this is because of appropriate policy framework and its implementation.

Following are some of the key policies and steps taken by the Brazilian government from 1975 to 2000:

1. Encouraged private investments with provision of low-interest loans on Bio-ethanol production units.
2. Guaranteed Purchase (By State Oil Companies)
3. Sales Tax incentives for Bio-ethanol using vehicle
4. Subsidy on Bio-ethanol (To make compatible with Gasoline)

The implemented policy from 1975 to 80s achieved the goal of 20% ethanol mix in the Gasoline, for transportation. During 1980-1989 period
The majority of cars were converted on the Bio-ethanol. The production of Bio-ethanol increased rapidly to the level of 13-16 billion litres per year in late 90s. The Brazilian Government gradually increased the subsidy as the production of ethanol as well as its market grew by late 90s. Now Bioethanol is 1/3rd of the total fuel consumed by cars and light trucks in Brazil. Brazil’s Bio-ethanol fuel-programme provided economic social and environmental benefits. In production of ethanol, Brazil has already saved US$33 billion from the period 1976-1986 and created employment for 700,000 workers in rural areas. This also helped in improvement of the quality of air and reduced emissions. Brazil Bio-ethanol fuel programme was successful and has economic social and environmental impact due to its appropriate policy framework and its implementation over the past 28 years as indicated in the following table 5.2.

<table>
<thead>
<tr>
<th>ECONOMIC IMPACT</th>
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<tbody>
<tr>
<td>Commercial</td>
</tr>
<tr>
<td>350 Private Companies producing Ethanol</td>
</tr>
<tr>
<td>2% Bio-ethanol in gasoline blend – 1980</td>
</tr>
<tr>
<td>13-16 billion litres/year Production of bio-ethanol in 1990</td>
</tr>
<tr>
<td>Selling Price of Anhydrous ETOH=25$ / barrel</td>
</tr>
<tr>
<td>Gasoline Price (in Brazil) (160$/M3)=35 $/barrel</td>
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<tr>
<td>Subsidy reduced over 25 years through price regulation</td>
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<tr>
<td>High Energy Fuel (70% of gasoline)</td>
</tr>
<tr>
<td>Production</td>
</tr>
<tr>
<td>Cost of product decline (because of size of production)</td>
</tr>
<tr>
<td>Estimated Potential / world ethanol production 2 billion t/year</td>
</tr>
<tr>
<td>World ethanol production 21 Million li/year</td>
</tr>
<tr>
<td>Brazil ethanol production 13 billion li/year</td>
</tr>
<tr>
<td>Brazil consumption 12.4 billion li/year</td>
</tr>
<tr>
<td>Average Bio-ethanol production energy ratio (energy output/energy input)= 9.2 (Brazil)</td>
</tr>
<tr>
<td>USA – 2nd largest production = 5.5 billion li/year</td>
</tr>
<tr>
<td>Other vital statistics</td>
</tr>
<tr>
<td>Ethanol 1/3rd of total fuel for transportation</td>
</tr>
<tr>
<td>1976-96: Brazil saved US $33 billion on oil imports</td>
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<tr>
<td>700,000 employment</td>
</tr>
</tbody>
</table>


| Table 5.2 : Economic Impact of Bio-ethanol |

g) Renewable Energy in Africa

Africa, with about 13% of the world’s total population, accounts for about 2% of world economic output and its energy-consumption in 1997 was 11.4 Quadrillion BTU, whereas its production was 26.5 QBTU, in the same year. Energy-demand growth in Africa averaged 2.7 annually from 1980 to 1997, with slightly faster annual average 3.1% from 1990 to 1997. Africa’s commercial energy consumption is small for a variety of reasons, some of these include; low per-capita incomes, low level of industrialization, ownership and uses of vehicles (around 20 cars per 1000 people) and penetration of electrical appliances, like refrigerators, freezers, air conditioners. Commercial energy-production in Africa has nearly doubled since 1970, and is forecast to increase 68% by 2020. Production has remained constant (at around 7%), as a share of the world total. Some details are as below:

i) Energy Consumption:

- African commercial-energy-production is distributed very unevenly throughout the continent. Around 99% of Africa’s coal output, for instance, is in southern Africa (mainly South Africa). Natural-gas production, on the other hand, is overwhelmingly concentrated in North Africa (mainly Algeria and Egypt). Crude-oil production is concentrated in North Africa (Algeria, Egypt and Libya), West Africa (Nigeria), Central Africa (Gabon), and southern Africa (Angola). East Africa produces almost no oil, gas or coal.

- As of 1997, Africa consumed around 26,300 Btu of commercial energy per 1997 dollar of GDP, and 14.9 million Btu per person. This compares with world averages of about 13,600 Btu per 1997 dollar of GDP and 65 million Btu per person, respectively.

- In 1997, Africa accounted for 3% of total world commercial energy-consumption. In that year, Africa accounted for 3.8% of world coal-consumption, 3.4% of oil, 2.4% of natural gas, and 2.4% of hydroelectricity.

- Compared to the rest of the world, Africa has very low levels of electricity-consumption per person. This is due mainly to poorly developed power-distribution grids and to heavy use of biomass in the residential sector.
Energy consumption patterns vary greatly between southern Africa and the rest of Africa. Most significantly, southern Africa depends heavily (68%) on coal, while the rest of Africa is dominated (60%) by oil.

ii) Energy Production:

- Africa produces significant amounts of commercial energy – about the same amount as South America. Energy-production varies greatly by subregion within Africa. Most importantly, oil and gas make up 23% of southern African energy-production, compared to 97% in the rest of Africa.

- Only South Africa has nuclear power-production. Overall, nuclear-power accounts for 1% of African energy-demand.

- Natural gas makes up a little less than one-sixth of Africa’s commercial energy-output. Almost all (96%) of this is concentrated in only 5 countries (Algeria, Egypt, Libya, Nigeria, and Tunisia).

- Hydroelectricity/others account for 3% of Africa’s total energy-production, spread out widely throughout the continent.

- Nearly two-thirds of Africa’s commercial energy-output is oil. Oil production (including crude oil and natural gas liquids) is heavily concentrated, with 5 countries (Algeria, Angola, Egypt, Libya, and Nigeria) accounting for 88% of the continent’s total oil output.

h) Major African Environmental Challenge: Use of Biomass Energy

Africa is the world’s largest consumer of biomass-energy calculated as a percentage of overall energy-consumption (fire-wood, agricultural residues, animal wastes and charcoal).

- Biomass accounts for as much as two-third of total African final energy-consumption. In comparison, biomas accounts for about 3% of final energy-consumption in OECD countries.

- Africa consumed an estimated 205 million tons of oil-equivalent (Mtoe) of biomass and 136 Mtoe of conventional energy in 1995, according to the International Energy Agency.
Most of Africa’s biomass energy-use is in sub-Saharan Africa. Biomass accounts for 5% of North African, 15% of South African, and 86% of sub-Saharan (minus South Africa) consumption.

Wood, along with charcoal, is the most commonly used form and it is the most detrimental to the environment.

South Africa is unique in sub-Saharan Africa as biomass accounts for only 15% of its energy-consumption. There is a range of energy options available in South Africa: biomass, kerosene, coal, liquefied petroleum gas (LPG), and solar power. This range of choices reflects the country’s high level of economic development, relative to other African countries.

**Wood as Traditional Fuels:**

- Deforestation is now one of the most pressing environmental problems faced by most African nations, and one of the primary causes of deforestation is utilization of wood as fuel.
- Women and children suffer disproportionately from negative health-effect, due to the smoke generated with the use of fuelwood for cooking (smoke is a carcinogen and causes respiratory problems). About 75% of wood harvested in sub-Saharan Africa is used for household cooking.
- Production of traditional fuels is often insufficient to satisfy the rising demand. Fuel available to the poorest communities is expected to decline, which will intensify environmental degradation in those communities.
- End-use efficiency for most traditional fuels is low. A high concentration of fuels is needed to produce a low level of energy, and a significant share is wasted.

**Photovoltaic/Solar Power**

- Several African nations have made considerable advances in the use of photovoltaic (PV) power.
- In Kenya, a series of rural electrification and other programs has resulted in the installation of more than 20,000 small-scale PV-
systems since 1986. These PV systems now play a significant role in decentralized and sustainable electrification.

- The direct conversion of solar into electrical energy with solar (PV) cells does not at this stage seem to be an economic proposition. The recently developed Amorphous Silicon-Technology holds considerable promise, but further developmental work in this direction is imperative, especially for the use in small units for communications, lighting and water-pumping.

**Solar-Energy**: Over one billion people live in underdeveloped economic conditions around the world, between latitudes 35° N and 35° S. In general, greatest amount of solar energy is found in two broad bands around the earth between latitudes 15° and 35° north and south of the equator, and three approaches to the utilization of this solar energy are: (a) use of low-grade heat, (b) direct conversion to electric energy and (c) Photosynthetic and biological conversion processes. The technology of low-grade heat devices only has so far been developed to such an extent that they have immediate application. However, the urgent RD&D needs are:

a) a realistic assessment through field trials on a continuous basis, of the impact of these devices under our social and economic conditions; the need for research and development to improve these should be kept under review; (The priorities of application are: hot water (e.g. for process heat), providing drinking & irrigation water, crop drying and cold storage of agricultural products, and space heating);

b) Available data on commercially manufactured solar water-heaters of small, medium and large capacities, as well as solar distillation, should be widely disseminated with a view to select appropriate types and their local production;

c) Techno-economic studies should be undertaken to improve the efficiency of solar water-heaters by: (i) use of reflectors, (ii) modified collector-design, and (iii) architectural integration.

CHAPTER 6
SOME OTHER LIKELY RENEWABLE SOURCES FOR DEVELOPING COUNTRIES

1. Geothermal energy

The organized utilization of geothermal energy, from hot springs & underground steam, for the production of electricity, and the supply of domestic and industrial heat, dates from the early years of the twentieth century. Since geothermal energy must be utilized or converted in the immediate vicinity of the resource, to prevent excessive heat-loss, the entire fuel cycle, from resource-extraction to transmission, is located at one site. This reduces costs and the risks of the environmental impacts of fuel cycle, and also facilitates environmental protection-measures (in contrast, the different stages of the coal, oil, natural gas and nuclear fuel cycles are normally located at widely separated sites). Unlike fossil-fuel or nuclear-power production, geothermal energy is not a technology that requires massive infrastructure of facilities and equipment or large amounts of energy input. The capital cost runs around $500,000 per M.W. and the electricity thus, costs 15 mils/kwh, which is almost as cheap as hydro-electricity. Both the total quantity of gases in the fluid and the relative concentration of their constituents, depend on the geochemistry of the underground reservoir. Geothermal steam contains carbon dioxide, hydrogen sulphide, ammonia, methane, hydrogen, nitrogen and boric acid. In steam dominated fields (for example, the Geysers, California, and Larderello, Italy), composition of discharged steam corresponds to that at depth. However in high-temperature water-dominated fields, the proportion of gas in the steam depends on the extent to which steam has flashed from the original high-temperature
water. The gases (except ammonia) are predominantly concentrated in the steam-phase and the gas/steam ratio decreases with increasing steam-proportion in the discharge.

Worldwide development of geothermal electric power and direct heat utilization is given in table 6.1. The total power of installed geothermal power-plants by 2000 in the world (see Table 6.2 below) was 7974.06 MWc. Worldwide, geothermal power can serve the electricity need of 865 Million people, or about 17% of world population. Moreover, 39 countries have America and the Pacific. The cost of geothermal energy is 2-10 US Cents per kWh.

<table>
<thead>
<tr>
<th>Year</th>
<th>Installed Energy (MWth)</th>
<th>No. of countries</th>
<th>Participants reporting</th>
</tr>
</thead>
<tbody>
<tr>
<td>1940</td>
<td>130</td>
<td>1</td>
<td>Italy</td>
</tr>
<tr>
<td>1950</td>
<td>293</td>
<td>1</td>
<td>Italy</td>
</tr>
<tr>
<td>1960</td>
<td>386</td>
<td>4</td>
<td>+NZ, Mexico &amp; USA</td>
</tr>
<tr>
<td>1970</td>
<td>678</td>
<td>6</td>
<td>+Japan &amp; USSR</td>
</tr>
<tr>
<td>1975</td>
<td>1,310</td>
<td>8</td>
<td>+Iceland and El Salvador</td>
</tr>
<tr>
<td>1980</td>
<td>2,110</td>
<td>14</td>
<td>+China, Indonesia, Kenya, Turkey, Philippines &amp; Portugal</td>
</tr>
<tr>
<td>1985</td>
<td>4,764</td>
<td>17</td>
<td>+Greece, France &amp; Nicaragua</td>
</tr>
<tr>
<td>1990</td>
<td>5,832</td>
<td>19</td>
<td>+Thailand, Argentina &amp; Australia, Greece</td>
</tr>
<tr>
<td>1995</td>
<td>6,797</td>
<td>20</td>
<td>+Costa Rica</td>
</tr>
<tr>
<td>2000</td>
<td>7,974</td>
<td>21</td>
<td>+Guatemala, Argentina</td>
</tr>
</tbody>
</table>


Table 6.1: Worldwide development of geothermal electric power

A planned survey of the geothermal potential of the relevant countries should be carried out; in which the programme should include:

collection and tabulation of data on the hot springs of the country, as well as analysis of the fluids produced by these springs. Appropriate RD&E studies can then be initiated.

2. Ocean-energy

Ocean-energy has only recently received serious attention, most study work has been done only in the last ten years or so. Although energy-generation from water currents is not a new concept, the technology needed for large scale energy-generation has now become feasible. The energy of ocean offers a number of possibilities for commercial exploitation and developments have been picking up pace.

Estimates suggest that there is some 2-3 million MW worth of power in the waves, breaking on all the coastlines of the world. Although it would not be feasible to exploit all of this, coastlines facing the open ocean to their west are particularly good sites for wave energy and therefore, there is significant development of the technology in Northern Europe and North America.


Computer-generated image of an array of axil flow tidal current turbines of a kind under development by Marine Current Turbines Ltd in the UK, showing how a system might be maintained by raising it above the sea surface Image: Marine Current Turbines Ltd

Figure - 6.1
There have been many systems proposed for utilizing the energy from the oceans, but perhaps the greatest potential for ultimate utilization exists in OTEC, i.e. Ocean Thermal Energy Conversion OTEC which utilizes the fact that the ocean’s surface-water is warmer than water in its depths (an

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OTEC plant works like a heat engine, but with a small temperature differential of 15° to 20°, compared with 500° C or more for a steam turbine or an internal combustion engine. Fig. 6.1 (page 223, REW/July - August 2002) is a computer generated image of an array of axial flow tidal current turbines of a kind under development by Marine Current Turbines Ltd in the UK, showing how a system might be maintained by raising it above the sea surface image: Marine Current Turbines Ltd.

**OTEC**: Development work and demonstration units are needed for both types of plant, viz closed-cycle, using a volatile working fluid, and open-cycle, in which the warm surface water is turned into steam by lowering the pressure, and after driving a generator, it is later condensed by the colder water. (The second type also produces fresh water as a by-product).

The process depends on the difference of temperature between deep-sea layers, where the temperature is 7-8° C at a depth of 1,000 meter, and sea-surface layer, where it is 30° C. This difference in temperature is employed to generate electricity. The technology of OTEC is based on the Ocean’s functioning as both absorber and heat-sink for solar radiation. Because of incomplete mixing, temperature-differences of up to 40°F (or 22°C) exist between surface and deep waters near the equator. The basic idea of OTEC is to use this absorbed heat and this temperature-difference to drive a large heat engine. Usually, the heat-engine proposed is a closed-cycle, latent-heat absorber, using a suitable working fluid, like ammonia, propane or a chlorofluorocarbon(cfc).

Some idea about the capital cost and the energy-cost for large plants can be estimated. For a power-generating station of 250 Mega-Watt size, the capital cost would be around dollars 3,500 per kWe, but this can come down to dollars 2,500 if more plants are built. This compares unfavourably with capital cost of around dollars 450 per kWe, for coalwaste power plants and dollars 575 per kWe for nuclear plants. But if energy-costs are compared, these OTEC costs compare favourably with oil and are only slightly above the cost of coal and nuclear power generation. Energy cost was estimated in 1984 at 39 to 43 mils/kWh for OTEC-generated electricity versus 28 mils for nuclear, 36 mils for coal and 90 mils for oil.
Development work and demonstration units are needed for both types of plants, viz closedcycle, using a volatile working-fluid, and open-cycle, in which the warm surface-water is turned into steam by lowering the pressure and, after driving a generator, is later condensed by the colder water. The second type also produces fresh water as a bye-product. The National Institute of Oceanography, in Karachi, had considered some plans to undertake a survey of likely sites for OTEC plants off the Pakistan coast.

The biggest advantage of OTEC systems is that the heat is absolutely free. Probably the biggest disadvantage is the necessity for large heat-exchangers and cold-water conduits. Both these requirements are due to the enormous quantities of water that must be handled by any productive system. The process of converting the difference of temperature between deep and surface water-layers of ocean into electricity has been studied for several decades by the Department of Energy in U.S.A. and is being pushed for warm coastal regions, such as Florida, Hawaii and Guam. This process is now feasible in various islands and peninsular areas along the earth’s tropical belt, which have the highest and the most efficient thermal gradients. Such areas are the most potential places for the initial OTEC development. To give a few examples, Puerto Rico is one such place; Hawaii is another. Potential sites exist in the continental shelf off the shores of many countries all over the world.

The first land-based OTEC plant has been built at Nauru, a small island in the South Pacific. A consortium of three Japanese firms has undertaken to build this plant on the island, at a cost of 4.3 million dollars, and it was expected to deliver 1.5 Mega Watt after 1983. The Nauru plant uses Freon gas as its working fluid in titanium heat-exchangers as its working fluid. Cold bottom-water is drawn from a 900 meter long, 70cm. diameter, polyethylene pipe; 30oC water is drawn directly from the ocean surface. The U.S. Department of Energy is thinking of constructing a 40 Mega-Watt plant, which was expected to be completed in the late nineties at an estimated cost of 250 million dollars, but this figure is bound to rise considerably due to inflation.
Tidal & wave-energy:

Wave-power is by no means a new concept. It is estimated that, since 1856, over 350 patents were granted for wave-power utilization by 1973. Today, wave-energy is only used on a small scale to power buoys; the average power-output of these systems range from 70 to 120 W. Because there are no large scale wave power stations existing today, it is difficult to assess the environmental effects of harnessing this energy-source. Wave power-plants will produce no change in water-salinity or require fresh-water for operation. The most direct environmental impact is to calm the sea; since these will act as efficient wave-breakers, this has beneficial effects in several locations near harbours, offering safe anchorage at times of storms and/or protecting shorelines from erosion. However, the calming of the sea might have adverse biological effects, because of the absence of waves and associated mixing of the upper water-layers.

Tidal power can be harnessed at specific sites, where the tidal amplitude is several metres and where the coastal topography is such as to allow the impoundment of a substantial amount of water with a manageable volume of civil works. There are atleast, six tidal power-stations operating today; the largest is on the Rayee River in France, with 24 turbines of 10 Megawatts each. (Some sites on the Pakistan coast are worth exploring). Tidal energy may be pollution-free, in that it does not add pollutants, either to atmosphere or water, but it will change ecology of its tidal basin and, to some degree, may also affect the tidal regime on the seaward side of the development. The extent of these effects would of course depend on the magnitude of the tidal power development. Some of the determental effects on ecosystems attributed to river hydro-plants would be equally applicable to tidal power stations. Potential sites for tidal power-stations have been surveyed in about two dozen countries of the world, including China, Brazil, Burma, India and Russia.
The present status\textsuperscript{4&5} of tidal and marine renewable technologies is given in the table 6.3. A number of short-term demonstration and commercial schemes are underway, e.g a 300 kW grid-connected horizontal-axis tidal current turbine in U.K. and 250 kW vertical axis in Canada.

<table>
<thead>
<tr>
<th>Technology</th>
<th>Maturity</th>
<th>Load Factor (%)</th>
<th>Installed capital cost (c/kW)</th>
<th>Installed capital cost (c/kW)</th>
<th>Unit cost of electricity (Eurocent/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal barrage</td>
<td>Mature</td>
<td>20-25</td>
<td>4000-5000</td>
<td></td>
<td>10-13</td>
</tr>
<tr>
<td>Wave-shoreline OWC</td>
<td>Demonstration</td>
<td>26</td>
<td>2100</td>
<td></td>
<td>-10</td>
</tr>
<tr>
<td>Wave-near-shore OWC</td>
<td>Demonstration</td>
<td>29</td>
<td>1500</td>
<td></td>
<td>-8</td>
</tr>
<tr>
<td>Wave-Offshore-point absorber</td>
<td>Demonstration (commercial-2005)</td>
<td>34-57</td>
<td>1800-3000</td>
<td></td>
<td>4-10</td>
</tr>
<tr>
<td>Tidal current turbine</td>
<td>Demonstration</td>
<td>21-25</td>
<td>1800-2100</td>
<td></td>
<td>4-10</td>
</tr>
<tr>
<td>OTEC</td>
<td>Research</td>
<td>80% + (?)</td>
<td>Not clear</td>
<td>20+</td>
<td></td>
</tr>
<tr>
<td>Salt gradient</td>
<td>Not feasible</td>
<td>80% + (?)</td>
<td>Not predictable</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Marine biomass</td>
<td>Not feasible</td>
<td>80% + (?)</td>
<td>Not predictable</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>


\textbf{TABLE 6.3 : Present status of Marine renewable energy technologies}

It may be added that one of the countries seriously considering a scheme for generating electricity from wave-energy is Mauritius, where the sea-waves at Riambel bay vary from 5 ft to 9 ft in height. The energy from these could be harnessed with a sloping wall, 5 Km long in the Indian Ocean, using coral reef as a base. The sloping wall would provide minimum resistance to the incoming sea-waves, which would crash over the wall and fill the enclosed reservoir, to a height of about 8 ft. above sea-level. This water would then drive turbo-rams or water-wheels, located in the

\textsuperscript{4} Sciencedotcom, Dawn, Pakistan, Feb. 8, 2003.
\textsuperscript{5} Peter Fraenkel, “Energy from the oceans preparing to go on-stream” REW / July-Aug 2002, p. 225.
side walls of the enclosed reservoir. Part of this energy can then be used to pump the remaining water to a high-level reservoir, which would operate a conventional hydro-electric power plant. In this way, with a capital investment of about US$ 40 million, some 20 MW of electricity can be generated at a cost of only 30 mils per kW/h. The possible fish output from the reservoir is estimated at 1,000 tons/ annum and its value may well exceed that of the electricity.

Tidal-wave power-generation has several advantages over conventional resources. Some of the primary advantages are: it is a renewable source of energy; it is pollution-free; it can produce energy all round the year (24x7x365 hours / annum). Interestingly, the peak output coincides with peak energy-demand. Moreover, water is a free resource. Above all, it is highly efficient (coal/oil efficiency = 30 per cent, tidal power efficiency = 80 per cent).

Some of the potential sites of the world so far surveyed are given below:
1. Siberia, Russia
2. Inchon, Korea
3. Hangchow, China
4. Hall’s Point, Australia
5. New Zealand
6. Anchorage, Alaska
7. Panama
8. Chile
9. Punta Loyola, Argentina
10. Brazil
11. Bay of Fundy
12. Frobisher Bay, Canada

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13. England
14. Antwerp, Belgium
15. LeHavre, France
16. Guinea
17. Gujrat, India
18. Burma
19. Semzha River, Russia
20. Colorado River, Mexico
21. Madagascar

The current challenge in younger and experimental renewable energy-sources is that although they have great potential in serving the energy-needs of developed and developing countries alike, they first need to prove their full commercial viability. However, rapid research and development of these areas and the number of companies working on potentially commercial technologies is a strong sign that these new renewable energysources hold great promise for the future.
CHAPTER 7

ENERGY POLICY AND PLANNING

Situation in Developing Countries:

Developing countries generally do not have elaborate policies to support development of renewables energy technologies. They lack plans and strategies, laws and regulatory frameworks, market mechanisms, financial tools, and incentives. However, some have already developed comprehensive plans and policies amongst these are, Chinese Renewable Energy Plan; India’s Renewable Energy Programme; Korea’s Basic Plan for Renewable Energy Technology Development and Dissemination, Thailand’s Small Power-producer Program, Argentina’s Renewable Energy and Rural Markets Program, Morocco’s Global Rural Electrification Programme; and Chile’s Rural National Electrification Program. Certain international development programs for developing countries are designed to promote renewable energy with the active role of bilateral and multilateral assistance-agencies, international financial institutions (IFIs) or private foundations.

Affordable commercial energy is a necessity of life, when integrated with the developmental activity, to improve water-supply, agriculture, education, health, and transport. The broad policy to encourage sustainable energy-systems can greatly help in the economic development of the third-world countries. Key components of the overall strategy for this include: improving efficiency of fuels, making electricity available in rural, as well as in urban areas for economic development, providing de-centralized energy-option, financing rural energy-production, and developing new institutional structures and public and the very important private partnership.

Many Renewable Energy Technologies are today at, what may be called, the “take-off” stage. Therefore, it is highly important to undertake
long-term planning, with effective policy-measures. These may be broadly grouped under the following heads: (1) **International**, (2) **National Assessment & Planning**, (3) **Public/private participation and financial Investments**. These are discussed separately as follows:

1. **International**

   In order to accelerate application adaptation, and transfer of the mature technologies to the developing countries viz energy for mutual benefit to all, taking into account their special needs of the following measures are required on an international level:

   a) Identify and keep under review, with respect to mature technologies, the utilization of new and renewable sources of energy, their role within sectoral programmes and, where appropriate, establish or strengthen institutional arrangements to promote their application;

   b) Strengthen / establish measures to promote and facilitate the accelerated transfer of technology on new and renewable sources of energy, especially from developed to developing countries, in order to enhance the contribution of these sources to the total energy-supply of developing countries;

   c) Support measures to increase economic and technical cooperation among developing countries, including the undertaking of joint programmes of activities;

   d) Develop national capabilities to undertake, inter alia, the manufacture, adaptation, management, repair and maintenance of devices and equipment related to technologies for the assessment and utilization of new and renewable sources of energy;

   e) Strengthen the ability of developing countries to make financial and technical evaluations of the different elements of the technologies, thereby enabling them to better assess, select, negotiate, acquire and adapt technologies required to utilize new and renewable sources of energy;
f) Formulate innovative schemes for investments in the area of manufacturing equipment for new and renewable sources of energy, especially the establishment of joint industrial programmes among interested countries, for the manufacturing and commercialization of relevant capital goods;

g) Strengthen national capacity to review and assess domestic, fiscal, regulatory, sociocultural and other policy-aspects, required to accelerate the introduction of technologies related to new and renewable sources of energy;

h) Support, as appropriate, demonstration-projects related to the application of new and renewable sources of energy and technologies, prior to a decision on commercial operation and widespread implementation.

All the above measures would require sizeable investments. These can be ensured, provided each country decides to invest an appropriate percentage (from 5% to 10%) of its energy-expenditure on short and medium-term development of renewable energy technologies. This will need public consensus, followed by appropriate legislation.

2. National energy assessment and planning

The role of energy, especially that of new and renewable sources of energy, in meeting the needs of countries, can best be determined in the context of national energy-planning, an essential element of which is national energy-assessment. It is an especially acute problem with respect to the data-infrastructure pertaining to energy-demand and resource-inventories, as well as the impact on the ecology, which can provide the basis for assessing the possible future role of new and renewable-energy sources and related technologies, as well as developing national energy-policy and plans. Action plan is required as follows:

a) Map, survey and undertake other appropriate activities to determine the full range of physical resource-endowment, using, whenever possible, standardized methodologies for collecting data, processing and storing as well as for dissemination;
b) Determine, in a dynamic way, energy-supply and demand and energy balances, and projections of future energy-requirements;

c) Identify, and keep under review, mature and near-term promising energy technologies, as well as ongoing research, development and demonstration activities, and carefully assess their economic, socio-cultural and environmental cost, potential and benefit;

d) Strengthen and/or establish institutional infrastructure to collect, maintain, analyze, classify and disseminate information on all the above, as well as information pertaining to the policy, programme and project decision-making process, the legislative framework and related procedures (and their impact on energy supply and use patterns), and the availability of financing.

The strengthening of national capacities should embrace elements such as:

a) Establishment or strengthening of appropriate national institutional arrangements;

b) Adequate research and development programmes, to support the scientific and technical capacity to develop, choose and adapt technologies, including testing and demonstration facilities and research focal-points in new and renewable sources of energy;

c) Specific programmes, to promote the exploration, development and utilization of new and renewable sources of energy, taking into account (as appropriate) social, economic and environmental considerations;

d) Programmes to encourage the efforts of national, public and private entities in interested countries (as appropriate) to expand the development and utilization of new and renewable sources of energy.

e) Mobilization of adequate resources;

f) Develop qualified personnel, for specialized education and training programmes, equally accessible to men and women.
g) Development and strengthening of industrial capacity to manufacture adapt, repair and maintain energy-related equipment.

3. Financial investment and public/private partnership

Based on experience\(^1\) (World Bank/GEF and other international and national agencies) derived from Chapter-5, the following are general and financial principles that should be adopted in formulation of energy policies and action-plans.

1. Governments must create enabling environment, to provide choice of Alternate/Renewable Energy to its population;
2. Reduction of Governmental subsidy on fossil fuels;
3. Promotion of environment-friendly alternative/renewable energy-sources, through demonstration;
4. Promotion of Financial for renewable energy;
5. Regulate law, tax-exemption investment, which can attract local and foreign partnership for investment;

Based on these principles, specific policies for incorporating renewable energy within the power-sector re-structuring can be implemented in many developing countries. One of the important challenge is that international agencies and developing countries may work together, to develop national energy-policies and action-plans, using experience, suitable to their own situation. This can be summarized\(^2\) as under:

a) **Encourage Independent Power Producer** : Private-sector involvement and investment in the renewable-energy power-sector are

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greatly facilitated by establishing a transparent and stable regulatory framework. Establishing these conditions can assist in promoting and developing renewable-energy market development. In many countries, utility regulatory frameworks exist that allow fair competition.

b) **Reduce Subsidies on Fossil-Fuels** : Most of the developing countries provide subsidies on fossil fuel, which should be reduced, to create a more “LEVEL” playing field. This will make renewable-energy technologies more competitive in the market.

c) **Environmental Standards** : Environmental standards should be implemented on both old and new plants. This will help to promote environment-friendly renewable technologies; improve emission standards, monitoring requirements and other aspects, which can further strengthen the power-sector.

d) **Renewable Energy Quotas** : All developing countries should set minimum percentage of renewable energy power consumed / produced on the total national energy-requirement. The national plan should provide further encouragement with a “renewable energy year.” These programmes have been adopted in some European countries, viz. Denmark, Italy and Netherland, and are being proposed e.g in Japan, India and Portugal. Netherlands does have a national target to produce from renewable sources, 17% of all electricity produced from energy in 2020.

e) **Guaranteed Market** : One of the effective ways to facilitate and encourage the use of renewable energy products by governments is to provide subsidies that can be reduced over time. This would allow renewable-energy products to find a foothold in the market and expand to create a stable economic market of their own. For this to be made entirely successful it is important for governments to buy renewable energy products themselves. This will not only help to establish a guaranteed market but will also provide the required “demonstration effect” to win the trust of other buyers. Building the public sector as well as organizations encourage implementation of renewable energy technologies for demonstration and help to increase the marketability (market size).
As a whole, European policy calls for 12% of energy supply from renewables by 2010. China and India also have national goals: in China, renewables should account for 5% of annual energy being added by 2010, and in India this percentage is 10% by 2012, and in order to achieve this goal every country needs to set aside an appropriate percentage of national expenditure on energy-sector for relevant research, development and extension. Every country/region should set its own goal and adopt appropriate resources for achieving this.

Conclusion:

We may summarize the immediate needs, as follows:

i) Development of National Policy Framework

ii) National Plan indicating priority-projects for demonstration.

iii) Fund Allocation

iv) Private - Public Participation

v) Regulatory measures:
   - Incentives
   - Financing System for Private Sector
   - Market Development (Economic Size)