Development of Renewable Energy in Emerging Economies

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Chapter 1: Introduction

Whether the energy needs of a society depend on wood to provide the basic cooking and heating requirements of village life, or on the immensely varied fuel mix of the industrialized nations, with their highly complex production and distribution systems, civilization is impossible without an adequate energy supply. In industrialized societies the situation is further complicated by the competition between the use of fossil fuels as an energy source and their vital role as raw materials for the petrochemical industries, which produce plastics, fertilizers, animal feedstocks, pharmaceuticals, and industrial gases Thus the so-called energy problem has implications for the whole structure of modern society.

Strictly speaking, no energy problem exists. The basic laws of physics dictate that energy is conserved and can only be changed from one form to another or into matter (Brower, 2002). Fuel, on the other hand, is the accumulation of matter and therefore represents a store of energy. This energy is released in the form of heat when the fuel is burned in chemical or nuclear reactions, processes that cannot be reversed to regenerate the original fuel mass (at least not without the injection of more energy than was originally released).

As a consequence, a fuel problem does exist. If the supply of fuel is finite, not only will there be no energy supply when the fuel is exhausted, but all other processes that depend on it will cease. This will affect not only the obvious energy consumers in the United States and the rest of the industrial West but even developing agricultural societies, where the importance of oil-based fertilizer supplies is growing (Goldemberg, 2004). Several factors combine to make the problem an urgent one. World population is steadily increasing, which implies that the demand for energy will also increase, although not necessarily in proportion. Social, economic, and political pressure for economic expansion continues in industrialized countries. This implies an increased energy input.

The developing countries are becoming aware that their economic position could be improved by increased energy consumption, and they feel entitled to a larger share of the world's energy resources than they now receive. These pressures require that the world energy supply be increased, particularly if the aspirations of some areas are to be met without jeopardizing the living standards of others

It has long been recognized that the supply of the conventional fuels, coal, oil (petroleum), natural gas, uranium, and fuel wood, is limited and insufficient to sustain rapid rates of development. Although there may be debate about the exact length of time available before the effects of a worldwide shortage become apparent, there is agreement that such a shortage will occur. It is only a matter of time; in the case of oil, for example, the debate is not about whether but about when oil production will peak.

Nonrenewable Resources

Nonrenewable resources originate from two processes: (1) photosynthesis, which occurred many millions of years ago, followed by the fossilization of the plant and animal life that resulted, and (2) the formation of the Earth itself. The first gave rise to the fossil fuels coal, oil (petroleum), and natural gas; the second produced the fuels for nuclear energy, such as uranium for fission and lighter elements for fusion. These irreplaceable fuels represent an energy capital that must be invested wisely (Vesterby, 2001).

Two aspects are crucial to any evaluation of nonrenewable energy resources: availability and demand. If there is no demand, there is no energy problem, and reserves will last forever. If availability is limited, even the most stringent conservation measures may be inadequate to avoid problems. Both aspects must therefore be examined together. Also essential to an evaluation are the projected rate of increase in demand and the ability of fuel-producing industries to keep up (Goldemberg, 2004).

While perhaps most important in the long run, availability and demand are by no means the only questions associated with nonrenewable energy sources. The case of oil offers an excellent example of the pervasiveness and complexity of energy-supply problems. Oil currently provides between 40 and 50 percent of the world's energy. The situation would be relatively simple if each oil-consuming nation were capable of producing enough to meet its own needs. Complications arise because the nations that consume oil in large amounts do not necessarily produce it in comparable amounts. This situation came forcibly to public attention in the United States during the "oil shocks" of the 1970s, because the nation had passed rapidly from a state of self-sufficiency to one where more than half its oil supplies were imported (Youngquist, 2000).

The "oil shocks" of the 1970s were caused by the actions of the Organization of the Petroleum Exporting Countries (OPEC), a cartel of the major oil-producing nations other than Mexico, the United States, and the former USSR. In the 1960s these countries began the process of taking control of their own production, most of which had previously been leased to private oil companies. In the early 1970s, OPEC raised prices on crude oil to levels that had severe economic effects on all oil-importing countries. These effects were felt almost immediately, especially in developing countries. Higher prices for petroleum-based fertilizers meant that food-producing costs also rose. And because the financial resources of the industrialized world were now reduced by the heavy burden of oil costs, markets for the exports of the less-developed countries shrank, while at the same time the prices these countries paid for imported manufactured goods rose, further cutting into development plans. This widening ring of consequences well illustrates the extent to which the economies of modern nations depend on secure supplies of energy.

In the industrialized world the effects of OPEC oil pricing were somewhat less disastrous. In the United States, conservation and economic recession reduced oil imports to less than one-third of the total by the early 1980s and at the same time created downward pressures on the price of OPEC oil. By the century's end, however, over 60 percent of the oil consumed in the United States came from imports, although the issue of oil prices had not yet reappeared as a potential economic threat. Large-scale users such as France and Japan have always imported almost all the oil they consume (Kishore, 2003).

A cleaner-burning fuel than oil, natural gas seemed to be in abundant supply at the turn of the 21st century and, with the greatly enlarged network of gas pipelines, was rapidly growing in use (Goldemberg, 2004).

Because coal reserves are much larger and more widely distributed than petroleum reserves, it seems unlikely that any nation or group of nations could control coal production as OPEC controls the oil supply. Coal is thus clearly capable of furnishing a basic energy supply for far longer than oil or natural gas. In addition, it can supply petrochemical feedstocks, although at greater expense than oil. The heavy use of coal, however, would produce severe pollution problems because coal is a relatively "dirty" fuel. In the future, these problems will be felt more strongly in the newly industrializing nations as their need for energy increases. New, "clean coal" technologies are having some positive effect, as might future success in the processes of coal gasification and coal liquefaction (Schumer, 2001).

With nuclear fuels the demand possibilities are complicated by the potential use of breeder reactors, which convert otherwise useless uranium-238 to fissile plutonium-239. Breeder-reactor use complicates any calculations of the applicability of nuclear power to future energy supply (Brower, 2002). Other factors that complicate the issue even more are the toxicity of plutonium, the radioactive waste that is left as a legacy for future generations; and the fact that plutonium is the basic fuel for the atomic bomb, so that the proliferation of breeder reactors increases the possibility of irresponsible production of nuclear weapons and the risk of terrorism. Because of these concerns, the U.S. breeder-reactor program was ended by Congress in 2003. Although a few large commercial breeder reactors have been built outside the United States, they have all been subject to serious breakdowns, and none were operative at the turn of the century

Without the breeder reactor, uranium is comparable to oil as a fuel reserve. In the 1950s and '60s, during the era of nuclear-energy optimism, the world's meager supply of uranium was thought to be a factor limiting the proliferation of nuclear power reactors. By the 1990s, however, few new nuclear energy plants were being built, and forecasts predicted no shortage in uranium fuel.

The other nuclear option is fusion, the joining together of very light nuclei to make helium. This possibility shows enormous promise, and if present experiments are successful, energy problems could be solved for hundreds or even thousands of years. Each megawatt-year of electrical power generated from this process would apparently require 1.8 kg (3.96 lb) of natural lithium to supply the fuel; and it is estimated that 10 million tons of lithium are available, excluding that dissolved in the oceans (Goldemberg, 2004). Unfortunately, no fusion reactor has yet produced useful power output; all estimates of fusion power must therefore be viewed with a certain amount of caution. Even if one of the present experimental machines (such as the tokamak) were to work tomorrow, between 10 and 20 years would be needed to make a commercial prototype operational. After this the long process of increasing the number of plants and connecting them to the electrical system would have to be accomplished before fusion could even begin to make a real contribution (Vesterby, 2001).

Nonrenewable fossil fuels, coal, petroleum, and natural gas, provide more than 85% of the energy used around the world. In the United States, fossil fuels comprise 81.6% of the total energy supply, nuclear power provides 7.7%, and all renewable energy sources provide 7.3%. Wind power, active and passive solar systems, geothermal energy, and biomass are examples of renewable or alternative energy sources (Youngquist, 2000). Although such alternative sources make up a small fraction of total energy production today, their share is growing. Scientists estimate that easily extractable fossil fuels will be largely used up within the twenty-first century (known petroleum reserves will last less than 40 years at current rates of use). Nuclear power has several drawbacks, among which are military vulnerability, and waste disposal problems. Further, nuclear power technologies cannot be disseminated globally without disseminating at the same time all of the materials and much of the know-how for producing nuclear weapons. Achieving wider use of renewable sources of energy is thus, seen by many planners as key for a sustainable global economy (Goldemberg, 2004). In 2002, the 15-nation European Union declared its intention to shift away from both fossil fuels and nuclear power, with an initial goal of generating 12% of its total energy and 22% of its electricity from renewable sources by 2010

The exact contribution that alternative energy sources make to the total primary energy used around the world is not known. Conservative estimates place their share at only 3–4%, but some energy experts dispute these figures. U.S. energy analysts have argued that the statistics collected are based primarily on data supplied by large electric utilities and the regions they serve, and so do not fully account for areas remote from major power grids, which are more likely to use solar energy, wind energy, biomass, and other alternative sources. When these areas are taken into consideration, alternative energy sources may already contribute as much as 11% to the total primary energy used in, for example, the United States, where alternative use is lower than in most poor countries. Animal manure, furthermore, is widely used as an energy source in India, parts of China, and many African nations. When this is taken into account, the percentage of the worldwide contribution of alternative sources to energy production could rise as high as 10–15%.

Wind power

Although today considered an alternative energy source, wind power is one of the earliest forms of energy harvested by humans. Wind is caused by the uneven heating of Earth's surface, and its energy is equivalent to about 2% of the solar energy reaching the planet. The amount of energy theoretically available from wind is thus, very great, although it would be neither practical, wise, nor necessary to intercept more than a tiny percentage of the world's total windflow

Wind is usually harvested by windmills, which may either supply mechanical energy directly to machinery or drive generators to produce electricity. Youngquist (2000) says that energy must be carefully distinguished from electricity; electricity is not a source of energy, but a form of it. In processes that burn chemical or nuclear fuel to generate electricity, more energy is lost as low-grade heat than is delivered as electricity; a windmill, likewise, supplies less usable energy when it is used to generate electricity than when it is used to do mechanical work. Electricity has the positive qualities of being transmissible over long distances via powerlines and of being useful for many applications, lighting, motors, electronics, and so on, at its points of end-use (Brower, 2002).

The kinetic energy of wind is proportional to its velocity, so the ideal location for a windmill generator is in a place with constant and relatively fast winds and no obstacles such as tall buildings or trees. An efficient windmill can produce 175 watts of electricity per square meter of propeller-blade area at a height of 75 ft (25 m). The estimated cost of generating one kilowatt-hour (the amount of energy consumed by ten 100-watt light bulbs in one hour) by wind power is about eight cents, as compared to five cents for typical hydropower and 15 cents for nuclear power. California leads the United States in utilization of wind power, producing approximately 1.3% of its electric usage in 2000 from wind, enough to light San Francisco (Pimentel, 2003). Denmark leads the world in this respect, presently obtaining 21% of its electricity from windmills (and six more percent from other renewable sources).

Solar power

Solar energy can be utilized either directly as heat or indirectly after conversion to electrical power using photovoltaic cells or steam generators. Greenhouses and solariums are common examples of the direct use of solar energy, having glass surfaces that allow the passage of visible light from the sun but slow the escape of heat and infrared (Vesterby, 2001). Another direct method involves flat-plate solar collectors that can be mounted on rooftops to provide energy needed for water heating or space heating. Windows and collectors are considered passive systems for harnessing solar energy. Active solar systems use fans, pumps, or other machinery to transport heat derived from sunlight

Photovoltaic cells are flat electronic devices that convert some of the light that falls on them directly to electricity. Typical commercial photovoltaic cells convert 10–20% of the sunlight that falls on them to electricity. In the laboratory, the highest efficiency demonstrated so far is over 30%. Photovoltaic efficiency is important even though sunlight is free; higher-efficiency cells produce more power in a limited space, such as on a rooftop (Goldemberg, 2004). Thermal-electric solar systems have also been developed using tracking circuits that follow the sun and mirrored reflectors that concentrate its energy. These systems develop intense heat that generates steam, which in turn drives a turbine generator to produce electricity

Geothermal energy

Geothermal energy is heat generated naturally in the interior of the earth, and can be used either directly, as heat, or indirectly, to generate electricity. Geothermal energy can be used to generate electricity by the flashed-steam method, in which high-temperature geothermal brine is used as a heat source to convert water injected from the surface into steam (Schumer, 2001). The steam is used to turn a turbine and generator, which produces electricity. When geothermal wells are not hot enough to create steam, a fluid that evaporates at a lower temperature than water, such as isobutane or ammonia, can be used in a closed loop in which the geothermal heat evaporates the fluid to run a turbine and the cooled vapor is recondensed and reused. More than 20 countries utilize geothermal energy, including Iceland, Italy, Japan, Mexico, Russia, and the United States. Unlike solar energy and wind power, geothermal energy may contribute to air pollution and may raise dissolved salts and toxic elements such as mercury and arsenic to the surface (Brower, 2002).

Oceanic sources

Although there are several ways of utilizing energy from the oceans, the most promising ones are the harnessing of tidal power and ocean thermal energy conversion. The power of oceanic tides is based on the difference between the (usually) twice-daily high and low water levels. In order for tidal power to be effective, this difference in height must exceed about 15 ft (3 m). There are only a few places in the world where such differences exist, however, including the Bay of Fundy in Canada and a few sites in China (Vesterby, 2001).

Oceanic thermal energy conversion utilizes temperature differences rather than tides. Ocean temperature is commonly stratified, especially near the tropics; that is, the ocean is warmer at the surface and cooler at depth. Thermal energy conversion takes advantage of this fact by using a fluid with a low boiling point, such as ammonia. Vapor boiled from this fluid by warm surface water drives a turbine, with cold water from lower depths being pumped up to condense the vapor back into liquid. The electrical power thus generated can be shipped to shore over transmission lines or used to operate a floating industrial operation such as a cannery.

It is unlikely, however, that ocean-derived energy will ever make a large contribution to world energy use; the number of suitable sites for tidal power is small, and the large-scale use of thermal energy conversion would likely cause unacceptable environmental damage.

Biomass

Biomass, wood, dried animal dung, or materials left over from agriculture, is the oldest fuel used by people, and was initially utilized for space-heating and cooking food. These uses are still major energy sources in developing countries, especially in rural areas. Biomass can also be combusted in a boiler to produce steam, which can be used to generate electricity. The biomass of trees, sugar cane, and corn can also be used to manufacture ethanol or methanol, which are useful liquid fuels.

The potential use of biomass energy as a modern energy source, it is equally if not more important to recognize that whatever its merits, biomass is a major source of energy for people in developing countries today More than two billion people around the world, predominately the rural and the urban poor in the Third World, use biomass fuels to meet their daily needs. In many countries--especially Sub-Saharan Africa--biomass fuels account for over 80 percent of a country's total energy consumption. Much of this "unnoticed" energy is collected rather than purchased in rural areas. However, unofficial figures on the commercial trade of fuelwood and charcoal in Africa estimate it at about $5 billion a year.

Fossil fuel consumption does have its share of drawbacks. While an important source of energy for the rural poor throughout the developing world, biomass fuels burned in indoor stoves without proper ventilation, for example, cause significant levels of indoor air pollution--a major cause of disease and even premature death. In India alone it has been estimated that indoor air pollution causes about 400,000 to 500,000 premature deaths per year.

Nevertheless, it is clear that biomass is--and will remain--a major source of energy for many people in developing countries, and consequently energy specialists should accept this reality by seeking to improve the policies and technologies associated with biomass. This paper examines the implications of this growing body of evidence and presents the conclusions of much of the most recent research in three parts: a review of the several types of modern biomass use, an examination of the uses of biomass energy by urban and rural households in developing countries and a consideration of the prospects for using biomass energy in more modern and efficient ways.

Biomass has traditionally accounted for a significant proportion of total energy use. In developing countries, biomass is quite commonly used for cooking, and well over 90 percent of energy use in rural areas is attributed to biomass. Yet in addition to its traditional uses, biomass energy can serve more modern purposes.

The use of energy from animal and crop wastes has been promoted in many developing countries for years. The largest programs are in India and China, where the population pressure on land is very high. Methane is produced from agricultural and human wastes, providing high-quality fertilizer for crops and an excellent cooking and lighting fuel. Yet even though biogas has the potential to solve energy problems in rural areas, biogas programs have encountered problems. Three to four animals are necessary to sustain a "family" biogas digester. In many countries this is not a feasible option for about 90 percent of the rural population, because people do not have the requisite number of animals. In addition, collecting manure, running it through the digester, disposing of the output and keeping a constant flow of materials through the system to maintain gas pressure has proved difficult. Nonetheless, biogas will continue to be used with great benefit as an alternative in many rural areas.

The economics of substituting unprocessed residues for hydrocarbons in industrial or commercial combustion systems differ among countries and factories depending on oil prices and combustion equipment. Because current production systems often produce or consume residues inefficiently, there is considerable scope for the production of additional quantities of agro-industrial residues. Expanding the supply of surplus residues for this purpose requires an integrated three-pronged approach: augmenting industrial plant energy efficiency, increasing steam and power production from a given quantity of residues and improving the energy value of residues through drying and densification. Making each plant more energy-efficient requires a determination of possible residue savings and supply based on the existing plant configuration as well as an analysis of the most cost-effective modifications to each mill that would maximize surplus residue availability

Despite the economic and environmental advantages resulting from the use of agro-industrial residues, most countries do not yet avail themselves of them. First, existing policies, both with regard to pricing and power generation, discourage investment in co-generation. Second, the public and private sectors are often unaware of the feasibility of the biomass option. Third, even if they are aware of this option, government and industry officials are often wary of promoting an undemonstrated technology

There has been a significant and growing body of evidence concerning when and why people in developing countries use biomass fuels, and the associated problems and opportunities.(Jewell, 1980) Many urban areas in developing countries suffer from deforestation around their peripheries, and as a result, the price of fuelwood in urban markets can even be higher than that of petroleum fuels. In densely populated rural areas, fuelwood is often in such short supply that people descend the energy ladder to dung and straw. However, we now know these problems are localized,(Goldemberg,

2004) and many areas actually have biomass surpluses that could be utilized in new and different ways.(Pimentel, 2003)

As cities in developing countries rapidly grow, their households typically shift from using traditional biomass fuels, such as wood, to a succession of modern fuels--kerosene, liquefied petroleum gas (LPG) and electricity.(Jewell, 1980) Often, the manifestations of this transition are clearly visible in, for example, a proliferation of motor vehicles or of street vendors cooking food on petroleum-based stoves. Accordingly, energy development in developing countries has been typically conceptualized as a relatively straightforward passage through three stages: from a preponderance of traditional fuels, to mixed fuels, then to modern fuels

Upon closer examination, however, the specific patterns and evolution of energy use vary from city to city and within cities due to many factors that include petroleum import policies of individual countries, the level of local natural resources and tax and fiscal policies impacting the supply and demand of household fuels (Youngquist, 2000).

But biomass still does not get as much attention as "big oil" or "big power." Too often, the energy sector assistance programs of international development agencies tend to overlook the present importance and future potential of biomass energy for people in developing countries. Adequately addressing the potential problems and opportunities of biomass energy for rural and urban poor in the developing world will continue to be important in the 21st century

Other sources of alternative energy

Other sources of alternative energy, some experimental, are also being explored. Methane gas is generated from the anaerobic breakdown of organic waste in landfills and in wastewater treatment plants; this methane can be collected and used as a gaseous fuel for the generation of electricity. With the cost of garbage disposal rapidly increasing, the burning of organic garbage is becoming a viable option as an energy source. Incinerators doing this are sometimes known as "waste to energy" facilities. Adequate air pollution controls are necessary, however, to prevent the emission of toxic chemicals to the environment, a "landfill in the air" effect (Goldemberg, 2004).

Fuel cells are another rapidly developing technology. These devices oxidize hydrogen gas, produce electricity, and release only water as a waste product. Experimental vehicles (including buses) and medium-sized generating units are already running using this promising technology. Like electricity itself, however, hydrogen is not an energy source; hydrogen gas (H2) does not occur naturally on Earth in significant quantities, but must be manufactured using energy from fossil fuel, solar power, or some other source. Fuel cells have the advantage of producing electricity at their point of end-use from a concentrated fuel that does not produce pollution; if their fuel can be produced by nonpolluting means, such as from solar energy (Vesterby, 2001).

Although not in the strictest sense an alternative source of energy, conservation is perhaps the most important way of reducing society's dependence on nonrenewable fossil and nuclear fuels. Improving the efficiency of energy usage is an excellent way of meeting energy demands without producing pollution or requiring changes in lifestyle (though lifestyle changes may also ultimately be necessary, as nonrenewable energy stocks decline). If a society needs, for example, to double the number of refrigerators it uses from 10 to 20, it is far cheaper at this time to engineer and manufacture 20 refrigerators with twice the efficiency of the old ones than to manufacture 10 refrigerators of the old type and double the amount of electricity produced (Brower, 2002). New electric generation facilities of any type are expensive, and all, even alternative types, impose some costs on the environment. Experts have estimated that it is still possible to double the efficiency of electric motors, triple the efficiency of light bulbs, quadruple the efficiency of refrigerators and air conditioners, and quintuple the gasoline mileage of automobiles. Several European and Japanese automobile manufacturers are already marketing hybrid vehicles with extremely high gasoline mileage (40–70 + miles per gallon), and these by no means reflect the upper limit of efficiency possible.

The most common applications of renewable energy for rural (off-grid) energy services are cooking, lighting and other small electric needs, mechanical processes (that is, for turning shafts) in light industry, water pumping, and heating and cooling. These applications are summarized below. There is a growing literature on the economic development and social benefits of these renewable energy applications. Unfortunately, we are still far from understanding or achieving consensus on the magnitude or prevalence of such benefits.(Jewell, 1980)

Aside from traditional biomass-fueled cooking stoves, the applications receiving the most attention in the literature are biogas and solar home systems. Sixteen million households cook and light their homes with biogas, displacing kerosene and other cooking fuel. More than 2 million households light their homes with solar home systems, primarily in India, China, Sri Lanka, Bangladesh, and Brazil.

Productive uses of heat and electricity for small-scale industry, agriculture, telecommunications, health, and education in rural areas are small but growing areas of research and practice.(Pimentel, 2003) Examples of industrial applications include silk production, brick making, rubber drying, handicraft production, sewing, welding, and woodworking. Examples of agricultural and food processing applications include irrigation (water pumping), food drying, grain mills, stoves and ovens, icemaking, livestock fences, and milk chilling. Health applications include vaccine refrigeration and lighting. Communication applications include community cinema, telephone, computers, and broadcast radio. Other community applications include school and street lighting and drinking water purification. Despite this diversity of potential applications, existing projects are still small demonstrations, with few large-scale developments on replicable terms. In particular, applications of modern renewables to rural heating needs, such as cooking and agricultural processing from advanced solar or biomass technologies, are just beginning to attract the attention of the development community.

National rural electrification policies and programs, together with international donor programs, have employed renewable energy as an adjunct to "access" strategies (serving increasing percentages of rural populations who don't have access to central electric power networks). An estimated 360 million households worldwide still lack such access. The main electrification options include power grid extension, diesel generators connected in mini-grids, renewable energy connected in village-scale grids (solar, wind, and/or biomass gasification, sometimes combined with diesel), and household-scale renewable energy (solar home systems and small wind turbines). Often the cost of traditional grid extension is prohibitive. Interest in using renewable energy technologies to provide electricity to rural and remote areas as a cost-effective alternative to grid extension is gathering momentum in many developing countries.

Multilateral, bilateral, and other public financing flows for renewables in developing countries have reached about $500 million per year in recent years. The three largest sources of these funds have been the German Development Finance Group (KfW), the World Bank Group, and the Global Environment Facility (GEF). Other sources of public financing include bilateral assistance agencies, United Nations agencies, and recipient country governments. Financing for renewable energy in developing countries comes from an increasing number of local players, for example Grameen Shakti in Bangladesh, the Development Bank of Uganda, and Canara and Syndicate Banks in India.

The world's long, nearly total dependence on fossil fuels and hydroelectricity ensures that efforts to solve energy problems by switching to alternative sources will have to overcome a great deal of inertia, both economic and psychological. Such sources as solar power, wind power, and synthetic fuels suffer from the serious drawback that few major installations now exist A large network of plants would have to be constructed, at great cost, before these sources could begin to supply a significant share of the world's energy needs. In addition, these alternatives are handicapped by the engineering problems of converting the energy to a form useful to human beings. For example, although solar energy reaches the top of the atmosphere in amounts 10,000 times greater than all human production of energy, it reaches the Earth's surface at rates of only about 80 to 250 W/m2, and considerably less on cloudy days (Goldemberg, 2004). Thus any large-scale system based on solar-collector panels will be physically huge, causing problems of maintenance and land use. Wind power, wave power, and ocean-thermal-generation sources suffer from similar difficulties. In the long run these technologies may prove to be more efficient on a small scale, providing power and heat for small communities or even single buildings

Geothermal energy is widely exploited, but the proposals for expanding its utility by drilling into hot rocks have yet to materialize. Extraction of oil from shale and tar sands is at present limited to a few commercial sites; programs to convert coal and biomass to liquid fuels on a large scale have so far proved uneconomic. In addition, all power sources, including such supposedly clean ones as solar and wind power, have adverse effects on the environment that must be either accepted or overcome by engineering, generally at a high price. Finally, the inefficiencies of conventional energy converters, such as batteries, engines, and turbines, make even more essential the search for new ways of harnessing old and new primary energy sources (Vesterby, 2001).

Projections of future energy needs and supplies are highly uncertain, but even the more optimistic studies estimate that less than 10 percent of the world's energy in the year 2015 will be supplied by renewable sources. Most renewable technologies are still in the relatively early stages of development, whereas even that most standard of energy systems, the 1,200-MW fossil-fuel power station, requires ten years to build. Alternative sources may well hold the long-term solution, but in the short term the human race will apparently have to rely on conservation and existing technologies

Renewable energy resources are those which will replenish themselves naturally in a relatively short time and will therefore always be available. They include geothermal energy, hydroelectric power, peat, ocean thermal energy, solar energy, tidal energy, wind power, and fuel wood

Solar radiation is a renewable energy source that can be used to produce electricity, by means of solar cells, and heat, by means of solar collectors. Solar energy is also indirectly responsible for many other renewable energy sources. The ocean currents and winds are results of the uneven distribution of solar radiation over the Earth's surface, and the winds in turn produce waves whose energy can be utilized. In the case of ocean thermal energy, solar heating of the upper layers of the ocean produces temperature gradients that can be harnessed to generate electricity. The Sun also powers the hydrologic cycle, in which ocean water is evaporated, transported over the continents, and precipitated as rain or snow to form rivers, whose flow energy produces hydroelectric power. Finally, the energy locked in such renewable fuel sources as wood and peat is derived from the Sun by the process of photosynthesis (Brower, 2002).

Another renewable energy source is geothermal energy, which arises through the leakage of heat from the Earth's interior to the surface. Although this happens over the entire surface of the Earth at a very low average rate, leakage is much higher in certain locations. Prime examples are Yellowstone National Park in the United States and certain areas of Iceland, Italy, and New Zealand. At these locations, and in general where hot rocks are found at moderate depths, it becomes possible to tap the heat and use it for human purposes.

One or the other of two criteria is essential for the most efficient use of renewable resources: either they must be used at a rate less than their natural rate of renewal or they must periodically be allowed time to build up again. For example, if the rate of use of geothermal energy is low, this resource can be a continuous one, but if the rate is increased above that which can be replenished from below, the rocks cool and the energy source temporarily disappears. If left alone, the rocks will heat up and power can again be extracted. Similarly, a water mill operating on a flowing stream will be able to furnish only as much power as the stream can supply. If, however, the stream is dammed and the water mill put at the outlet of the dam, then it is possible to run the mill for a time at a power level greater than that supplied by the stream (Goldemberg, 2004). This will cause the level of the water behind the dam to fall, and it must be allowed to rise again before the process can be repeated. Thus, although the total energy available from the stream cannot be controlled, the rate of power can be modified.

A similar constraint limits the burning of peat. Peat represents the accumulation of partly decayed vegetable matter over hundreds or thousands of years, and it is estimated that it accumulates at the remarkably high rate of 3 metric tons per ha (about 1.3 U.S. tons per acre) per year Extensive exploitation, such as occurs in Ireland and Russia, results in the depletion of the reserve, which then must be allowed to build up again. The same is true of other fuels such as wood, which can be exploited for a limited time, after which the forest must be allowed to reestablish itself.

Renewable energy harvesting exploits the day-to-day energy income from the sun, avoiding the need to extract the stored energy content found in fossil fuels, and offers the option of centralized or distributed placement of facilities for resource conversion. Forms of renewable energy include wind power, biomass, low-head hydroelectrical, ground-source conversions and solar energy, thermal and electrical.

Wind as an energy source is continually renewed. Wind energy can be captured to yield two classes of useful energy supply: mechanical pumping or electrical generation. Pumping is achieved with low-speed devices, electrical production with high-speed devices. Wind machines can be noisy and must be located, for safety purposes, at some distance from nearby buildings.

Biomass includes cord wood, wood pellets, paper pellets, and switch grass. These products can be burned in fireplaces, stoves, furnaces or boilers as a primary fuel or as a fuel amendment , e.g., combined with coal. Their combustion releases pollutants, CO2 (carbon dioxide), SO2 (sulphur dioxide), NOX (nitrous oxides) (Schumer, 2001). Although the release of CO2 can contribute to the greenhouse effect, the CO2 released by the burning of biomass fuel can be offset by the sequestration of similar amounts of CO2 by the concomitant and/or subsequent growth of plant matter , analytically, a zero net load on the atmosphere. Nonetheless, the combustion of biomass still releases SO2 and NOX which can contribute to acid rain; additionally, some heavy metals can be precipitated into the ash, which can contribute to contamination of the solid-waste stream. For this energy source, issues of reliability and transportation efficiency can be raised (Youngquist, 2000). Growing season production and rate of growth may not readily match the times of need and/or rates of consumption. Temporary storage may be required. When large acreage of distributed production must be brought to centralized points of end use, the energy extraction can be offset by energy consumed in the moving of this bulk material (Vesterby, 2001).

Low head hydro is a form of electrical production at point-of-use. Typically, a waterfall of less than 20 feet or a stream flow at a minimum of 30 gallons per minute is sufficient to turn small-scale turbines. The capacity and consistency of such electrical generation typically matches well the times of need and rates of consumption for the point-of-use end-user; grid-based transmission loss is virtually non-existent (Pimentel, 2003).

In contrast, conventional electrical energy production is achieved with turbines spinning at high speed, generating power in large centralized facilities, which gain their dependability through a reliance on the predictable flow of large volumes of water held in a reservoir. The highly centralized placement of such large-scale hydro-electric dams necessitates connection over considerable distance to the end-user and is inefficient, since line losses are experienced

Ground source energy exploits the capacity of the Earth's mantle to store thermal energy. Specifically, soil can hold heat; in fact, soil temperatures remain very stable during the seasonal cycles whereas ambient air temperature can fluctuate substantially. Placement of heat-exchange coils in the soil can be used to extract energy during the heating season and to discharge (sink) energy during the cooling seasons.

Solar energy from the sun can be used as a thermal source, an illumination source and/or an electrical generation source. Direct or indirect thermal heating of spaces in buildings can be achieved with proper placement of windows. During winter heating seasons these windows can receive full sun; during summer cooling season, shading devices over such windows can block out the unwanted solar gain. Solar radiation (as direct beam and/or a reflected skyvault brightness) can be used to light buildings by properly placing skylights, roof monitors and/or window-integrated light shelves in the building shell. The use of such daylighting offsets the need for electrical lighting.

Solar radiation also can be converted directly to electrical power using photovoltaic cells. Batteries are used to store the electrical production, which occurs when the sun is shining, for use when the sun is not available. The electrical energy is stored in batteries as a direct current potential; it must be converted if used to power alternating current appliances. Use of these forms of renewable energy involves the balancing of individual interests with group interests. Concerns include atmospheric loading, surface water pollution, and/or micro climatic changes, as well as resource-based rights , solar, wind and water access.

In 1978, the United States became the first country to enact a national feed-in law; Denmark, Germany, Greece, India, Italy, Spain, and Switzerland followed with their own feed-in policies in the early 1990s. By 2005, at least 32 countries and 6 states/provinces had adopted such policies, half of which have been enacted since 2003. Among developing countries, India was the first to establish feed-in tariffs, followed by Sri Lanka and Thailand (for small power producers only), Brazil, Indonesia, and Nicaragua. Three states in India adopted new feed-in policies in 2004, driven by a national law requiting new state-level policies. During 2005 and 2006, new feed-in policies were enacted in China, Ireland, Turkey, the Canadian province of Ontario, and the U.S. state of Washington. Many countries continue to adjust their policies as technology costs and markets change.

Renewables portfolio standard (RPS) policies are expanding at the state/provincial level in the United States, Canada, and India. At least 35 states or provinces in these countries have enacted RPS policies, more than half of these since 2003 (Youngquist, 2000). A renewables portfolio standard requires that a minimum percentage of generation sold or capacity installed be provided by renewable energy. Obligated utilities are required to ensure that the target is met, either through their own generation, power purchases from other producers, or direct sales from third parties to the utility's