Overview of Renewable Energies for Future Development in Thailand

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ABSTRACT

Energy will continue to play an important role in the future. A rapidly increasing availability of energy at reasonable price is one of the key issues for development.

The deterioration of local and global environmental conditions and the increasing recognition of the threats posed by man-produced enhancement of the greenhouse effect have become the main driving force towards the development of energy alternatives and improvements in the efficiency of energy use.

The economically accessible potential for renewable energy sources (RES) can be grossly assessed from known climatic data and broad assumptions of population and energy demand growth. In Asia, there is a very substantial potential contribution to the energy balance of the region, ranging from 25% to 35 % of the total energy needs [1]. Many technologies for the utilization of renewable sources of energy offer solutions that are already cost-effective in several situations. They include, mainly, biomass, solar, geothermal and wind energy.

This paper is intended to provide a brief overview and assessment of renewable energy, demonstrating the role that it may play in the policy of future energy planing. The technical information concerning each application is outside the scope of this paper. It can be expected that the future energy budget of Thailand, as well as of the world and of developing countries (DC) in particular, depend not on one or another hegemony's source as in the past, but rather on a much greater effort toward increased efficiency of energy utilization and, on the supply side, on the co-existence of several sources, to be used in different proportion according to local needs, opportunities and applications. Thailand, which is facing a major energy transition, being less bound by investments made in the past, has the opportunity of greater flexibility. Finally, from a scientific point of view, the RES might contribute partially to solving the present economic crises in Southeast Asian countries by increasing awareness of environment and efficient use of whatever energy source are available.

I. INTRODUCTION: MOTIVATIONS FOR ALTERNATIVES

In the past, at any time one form of energy has been predominant over the others. As a new, more convenient, form of energy became available it gradually replaced the former. Will this be the case also for the future? Natural gas, nuclear and renewable energies have been indicated in turn by their supporters as the inevitable hegemony's energy source of the future. It is the opinion of the author that the trend is towards an era of more open options, with several sources coexisting, to be used in a greater or smaller proportion according to local needs and opportunities, to changing conditions over time, and to different applications. The key to such a future is increased flexibility.

The most important limit to the use of energy today derives from preoccupation with environment and climate, underlined by the Climate Convention at the Earth Summit of Rio de Janeiro in 1992. Many negative effects on the environment derive, directly or indirectly, from the energy cycle. In recent times, the local effects (which have always been recognized) are accompanied by increasing preoccupation with regional and global effects [2].

Acid rain, deriving from the release of sulfur and nitrogen oxides in the combustion of fossil fuels (particularly, but not only, coal) occur up to many hundred of kilometers away from the polluting source and have adverse effects on agriculture, forests, lakes and on the conservation of manufactories and works of art. Reducing the emissions is feasible (although at considerable cost) for large installation, such as power plants; but it is much more difficult for smaller uses, such as domestic cooking.

Other energy-related environmental problems derive from oil spills from tankers, which are often the cause of major ecological disasters; from nuclear accident, which in the case of Chernobyl have spread radioactive products over half a continent; and the contribution to deforestation and desertification deriving from the non-sustainable use of firewood [3].

Actually, two opposite trends can be observed on a world's scale. Countries which have indigenous resources of coal tend to extend its use, to curb the need to import hydrocarbon fuels (and oil in particular). On the other hand, the use of natural gas as a replacement for oil and especially coal, is one way of reducing the emission of carbon dioxide (the major greenhouse gas, GHG) and local or regional pollution [4].

Renewable energies are by definition sustainable. Although they are not free of environmental concerns, their effects on the environment are generally smaller than those of traditional energy sources. It is therefore to be expected that the long term energy scenario will rely heavily on renewable energy sources (RES).

The total availability of RES is very large [1,5]. In principle, they could supply many times the total energy needs of the world. In practice, their availability is limited by a number of constraints. Besides the initial phase of mis-appreciation, such obstacles are mostly of a non-technical nature, derive from incentives for the use of fossil fuels and from energy prices that do not reflect the costs paid by the community (indirect and social costs, damage to the environment, etc.). If put on an equal footing with other energy sources (the so-called level playing field), renewable should be able to compete on the market even with today's technologies; and research and development effort to improve these technologies or to develop new ones would make this competition even more favorable to renewable energies.

Among the features of RES, the most important one might concern their wide-spread distribution. Even if solar irradiation, wind energy, biomass, etc., differs very much from one country to another, no region of the world is deprived of one or another form of RES in quantities that could contribute very significantly to their energy budget. This is well in line with the quite recent concept of de-concentration or de-centralization of decision making - a striking character of RES - fighting against old habits, even in the occidental countries.

Lastly, although some applications of RES are based on simple, locally available technology, in many cases they require advanced and sophisticated technology. The best solution can derive from the blending of traditional and advanced technology.

In Thailand, since 1977, non-conventional energy production and utilization development have been accelerated by many concerned agencies and academies. In 1994 [6], 26.2 % of total energy consumption came from RES but mostly from biomass such as fuelwood (8.9%), charcoal (10.2%), rice husk (1.0%) and bagasse (6.1%). While the part of other non-conventional energy resources is rather weak, about 1400 kW of photovoltaic systems, 35,000 m^2 of solar hot water systems and around 6,000 wooden low-cost wind turbine pumps [6-8] have been installed.

2. BIOMASS

Rough estimates of the amount of biomass grown annually world wide show that, in terms of energy content, the amount is equivalent to about 28,900 ExaJoules (10^{18}) which is about 8 times the annual world consumption of energy from all sources (3,590 EJ) [8]. Although biomass appears to represent a very large energy source, a large part is not available.

Fortunately, the quantities of biomass used for energy purpose in some countries are increasing due to the measure taken to control the quantities of CO_2 gas released into the atmosphere. There is no net emission of CO_2 into the atmosphere if biomass is produced for energy purpose. Moreover, combustion of biomass usually produces very little amounts of SO_2 and NO_x compared with combustion of fossil fuels. As a consequence, biomass is regarded as a clean fuel.

The energy utilization of biomass can be seen under two complementary points of view: the source of biomass and the technology used for its transformation and utilization.

- Biomass for energy use can derive from residues or by-products of food or other production, or it can be cultivated (energy crops)[9]. Food industries, which are often the first step towards industrialization, produce organic wastes that may be transformed into methane (through anaerobic digestion) or used for heat and/or electricity, which in turn can be used at least in part by the same industry (co-generation). The sugar (and the ethanol) producing industries, for instance, generate large quantities of bagasse, which up to now have been only partially used; the same applies to parts of the plant that are not directly employed in the food processing.

- Technologies for the transformation and utilization of biomass cover a wide range, from well-established technologies such as direct combustion to those in the research stage, like enzymatic hydrolysis of cellulose materials to produce ethanol or biomass gasifiers coupled to combustion turbines to produce electricity. All these technologies have witnessed improvements in the last years, and the cumulated experience is today much greater than ten years ago (for instance, the United States alone has more than 8000 MWe in biomass-powered electric generation capacity). Reference [10] provides more information concerning the different well-established technologies for biomass electricity generation.

Very simple technologies based on local materials and capabilities have not always lived up to expectations. One example is anaerobic digesters: the simple, backyard type widely diffused in some countries (notably China) has shown problems in operation and endurance, and has in many cases been replaced by systems that are still simple, but use somewhat more sophisticated technologies. The blending of improved and even advanced technology with traditional concepts is proving a successful approach in this field [11].

The co-generation technology, which enables industries with biomass residues as by-product to generate electricity and heat for their own consumption, has become popular in Thailand since 1991, as legislation was passed enabling the government utility to purchase privately-generated electricity

(Small Power Producers SPP). This has been intensified due to the Energy Conservation Act of 1992 (ENCON). It is estimated that most applications of cogeneration generally produce reductions of 20% to 30 % in the energy bills with pay-back periods, depending on the initial investment, from a few months up to 2-3 years [12,13].

The current capacity of cogeneration in Thailand [14] is estimated at 875.5 MWe, of which 664.6 MWe is being generated. The total potential capacity of cogeneration in the country is estimated at 3,098 MWe. However, the result of the financial analysis, indicated the financial potential to be just half of the estimated technical potential, or about 1,514 MWe.

In order to assess the biomass requirements for use with a gasifier, there is a rule of thumb is that 1 kg of air-dried biomass gives 3 to 3.6 kWh heat, or 0.7 to 0.9 kWh electricity plus 1.4 kWh heat [8].

Apart from producing more personnel with sound knowledge and experience in biomass energy, other remedical measures should include: creating incentive for the private sector to improved the existing technologies through research and development or using new and more efficient technologies; setting up a working group consisting of representatives from all agencies involved in biomass energy to plan and provide systematic and continuous funding support for research and development; promoting the use of biomass energy by introducing financial and tax incentives including carbon and sulfur taxes; creating awareness of the potential of biomass energy and increasing the use of biomass energy through other promotional efforts.

2.1 Fuelwood and Charcoal

In Thailand, the actual consumed amount of charcoal is 4,458 KTOE and of fuelwood is 3,902 KTOE. Due to the low heating value of fuelwood and charcoal (in the range of 4-6 MJ/m^3) compared to natural gas (approximately 35 MJ/m^3), the efficiency of systems is often below 10%, both when wood is burnt directly and when it is transformed into charcoal. Thus, research and development took place to improve the performance of cooking stoves [15], both fuelwood and charcoal, and charcoal making kilns [16]. Three types of charcoal making kilns have been improved; $2m^3$ mud kiln, $8m^3$ and $20m^3$ brick kilns. Wood savings of 2 tons per ton of charcoal produced (ie. from 7 tons of wood for 1 ton of charcoal to 5 tons of wood) have been achieved.

Despite these positive developments, the situation today is not much better than it was 10 years ago. The trend towards deforestation and desertification has continued, especially in semi-arid and mountainous regions. The growing stock of the natural source is depleted greatly by over exploitation and the expansion of protected forest. Further improvement in fuelwood uses should be based on an assessment of past programs, learning from past failures. Moreover, such programs should be framed in a broader context, including programs to prevent barriers for commercialization and market penetration. Many difficulties have to be overcome to implement such integrated programs, including problems of tenure of land, tree species chosen for reforestation programs, the use of wood for other productive activities and the need to formulate effective policies for managing resource substitution.

In some cases, where inversion of deforestation cannot be readily attained, it may be necessary to shift to different energy sources altogether. Agricultural residues may be an alternative, which is already extensively exploited. In other cases where liquefied gas (LPG) is available, its high intrinsic efficiency in small scale applications may justify its penetration for the basic uses of rural families.

In order to supply sufficient wood, it is necessary to grow trees in degraded forest community land, private land, and as homestead trees. Moreover, trees can be grown as agroforestry. Use of selected germplasm with suitable management practices will ensure better growing stock. It is also necessary to update technology for charcoal production.

The total production of these sources is in the North and the North-East of the country. Eucalyptus camaldulensis is the selected germplasm for suitable growing stock in Thailand. The average production is about 380 stock per rai or 22 cubic meters per rai (1 hectare equals 6.25 rai). This means that about 30,000 square kilometers (6.0% of land surface area in Thailand) would be needed for electricity generation of about 165 x 10^6 kWh/day at the present time. Data from the Department of Energy Development and Promotion (DEDP) indicated that about 28 million cubic meters of estimated reserve biomass equivalent to 6 million tons of crude oil would be needed to generate 3,600 MW of electricity per year. However, today's price of stock, about 700 Bath per ton, renders this option uneconomical [17]. If the price of stock decreases to a range of 300-400 Bath per ton, this fuel option will be attractive.

Small scale wood and charcoal gasification systems for power generation are not used to any significant extent except in countries that are experiencing power shortages and where the cost of biomass is low such as Brazil and India. In many countries including Thailand there are still demands for reliable crop residue fueled biomass gasification systems for water pumping. This is because the utilization of crop residues makes gasification systems more economically feasible.

2.2 Rice Husk and Bagasse

The production of rice husk as well as bagasse is directly related to rice and sugar cane production. At present, both rice and sugar are facing marketing constraint. Thus, production is expected to decline in the coming years, which consequently, would affect the availability of rice husk and bagasse. Despite this constraint, in Thailand the total available amount is still relatively high. In fact, the surface area of rice planting is more than 60 x 10^6 rai which is capable of producing 20 x 10^6 tons of paddy rice from which about 5 x 10^6 tons of rice husk can be obtained. Based on the characteristics of rice husk (average heating value and density are about 3,880 kcal/kg and 106 kg/m^3, respectively), the potential amount of energy available from rice husk is 7 times more than that of available wood. Actually, only 87% of rice husk is used for industry consumption and the remaining 13% of is discarded as waste.

The total production of sugar cane is about 48 x 10^6 tons per year, from which 14.4 x 10^6 tons of bagasse are left over. Supposing that the corresponding amount of bagasse residue, about 1.7 x 10^6 tons per year (12 % of total bagasse), is used for power generation, it is possible to generate 360 x 10^6 kWh of electricity (at pressure 23 bar, temperature 360 °C).

Gasification of rice husk appears to be a promising method for obtaining an alternative energy resource. So far over 100 units of direct heat gasifiers have been sold and put to use for paddy drying in rice mills.

2.3 Other Residues like MSW

Considerable amounts of Municipal Solid Waste (MSW) are generated. While the average per capita discharge in Bangkok stood at 0.95 kg per capita in 1990, it has been estimated that by the year 1995 this amount may have increased to about 1.26 kg/per capita per day and to 1.5 kg/capita/day by the year 2000 [18]. Based on data of the Pollution Control Department (1996) and assuming that the figure of 1.26 kg/capita/day is valid for all urban areas in Thailand, the annual amount of MSW generated in Thailand will be about 6.5-7 million tons. On an average an estimated 7.5% is recycled; however, the potential recycling rate could be as high as 40% [19]. Again, as is the case of agro-residues, these figures need to be looked into far more critically in order to assess the energy as well as other potentials of MSW.

3. SOLAR ENERGY

Direct thermal uses of solar radiation, or its indirect uses through thermodynamic cycles, involve a large number of different technologies and applications. Some of them have made good progress in the last decade, some are still of uncertain success, others are being abandoned [20].

In Thailand, the amount of energy from sunshine is rich and virtually regular all the year round (average daily intensity of solar radiation is about 17 $MJ/m^2/day$ corresponding to 4-5 $kWh/m^2/day$). About 35,000 m^2 of solar collectors which produce 2.5 million liters of hot water per day, equivalent to energy production of 94,000 kWh per day and about 3600 KW of Photovoltaic systems have been installed.

3.1 Solar Thermal Process

Solar water heaters have made steady technological progress. At present, using a flat plate solar collector with an efficiency of 30%, only 2.6 m^2 of collector area is needed to raise 100 litters of water about 40 °C in temperature. Outgoing fluid temperature up to 70-80 °C (which is sufficient for many applications) can be obtained with flat plate collectors. However, their acceptance is slower than anticipated. To overcome this, technical improvement should concern more economical methods for producing the collectors, better and simpler control systems and more rugged and reliable components. Efforts are necessary to provide cheaper and better installation and maintenance services.

Solar dryers are now receiving serious considerations in Thailand. They are built according to simple schemes and using inexpensive materials but, in the near future, they should include at least control and temperature regulation to achieve optimum results.

Solar cookers have drawn much attention and raised hopes as a substitute for inefficient wood-stoves. The results have so far been mostly disappointing, especially due to the difficulty of coping with local habits (such as cooking at early morning or at night, or cooking in-door) and for the lack of availability in cloudy weather. As a consequence, interest in this technology is generally declining. For Thailand, solar cookers seemed to be inappropriate for the preparation of meals due to the relatively high temperature needed for cooking. Investigation of their performance and feasiblity are under study at KMIT.

By concentrating solar radiation and using special materials, temperatures well above 100°C can easily be reached. Fluids at such temperatures can be used in a number of applications, including refrigeration (by means of absorption coolers), desalination (e.g., by a multiflash process), steam for industrial uses, electricity generating through thermodynamic cycles, etc. Applications of all these types have been reported, and in many cases they have been a technical success. However, their aplication is for the time being very limited essentially due to the extra-costs involved by the moving mechanical parts and sun-tracking lenses or mirrors. Neverless, this alternative is of interest only in climatic conditions in which the sky is very clear, and the direct radiation from the sun is much greater than the diffused radiation. Therefore, it is not appropriate for Thailand's climate. The applicability of concentrating systems in remote areas with limited technological capability is also often questioned.

The solar pond is a technique that not only allows collecting solar energy but also storing it as heat for relatively long periods. They may be economically interesting when rather special circumstances occur: in particular, when salt is freely available and natural enclosures can be used for the pond. A number of solar ponds exist or are being built in several countries. The largest (Israel) generates 5 MW of electric power. Others are being used for desalination and for heat storage. This option has to be considered more in future applications.

3.2 Passive Space Cooling

The main application of passive solar energy is temperature control in buildings. In cold countries, space heating sometimes amounts to 40% of the national energy consumption. On the contrary, the main share in consumption of electricity in some tropical countries is in air conditioning. However, the massive use of air conditioners does increase considerably the electricity demand and causes pollution when the required energy is generated. Indirectly the CFCs that are released after disposal of the equipment, will damage the ozone layer.

The use of passive solar energy in buildings has the recognized advantages of other renewable energies, and it can provide people with climatically attractive houses and a low energy bill. The European Community, amongst others, has started programs to stimulate passive solar technology. At present, about 13% of the total energy consumption of European buildings has been covered by passive solar energy. By the year 2010 however, passive solar energy is expected to provide the equivalent of 50% of the energy [21]. Usually the behavior of the occupants has a significant influence on the energy consumption in a building; increasing their awareness with respect to energy saving will generally lower energy consumption considerably. This also involves a major change of attitude in architects and building engineers.

For instance, in warm humid climates such as in Thailand, where the relative humidity often exceeds 90% with high temperatures (upper 30°C levels), with relatively high rainfall levels, low-to-moderate wind speeds and medium to strong solar radiation levels, lightweight and open building construction methods are usually most appropriate. Natural cooling mechanisms can be used, such as:

- solar control; to prevent direct solar irradiation from reaching the interior. Permanent, movable or seasonal shading devices can be used.
- avoiding external gains by a thermal insulation of the building.
- avoiding internal gains by using high efficiency appliances and energy saving lamps (such as compact fluorescent lamps) [21].

To remove hot air from inside the building, natural ventilation should be used as much as possible. When an airduct in the roof is applied (used for thousands of years in buildings in the Middle East), hot air will rise and escape through the duct, and cooler air is attracted into the building. Various other means of natural ventilation are possible [21].

The first results of researches undertaken in KMIT showed that if the modern new roof structure was used to act as a solar collector, the requirement of cooling energy would be considerably reduced [22,23]. Different configurations of solar chimney using the house's structure (walls and roof) were presented at the second ASEAN Renewable Energy Conference [24]

Additional costs for passive solar features over normal design vary from 0% for window relocation to 20% if sun-spaces are included. For many passive solar applications, payback periods of less than ten years have been achieved. School buildings can be particularly interesting since they are occupied only during daytime. In addition, features for passive solar energy do not require much maintenance.

This option of passive use of solar energy seems to be the most attractive for Thailand as well as for the ASEAN countries.

3.3 Photovoltaic

Photovoltaic (PV), a direct conversion of solar energy into electricity, is much more expensive in general than other technologies but has long been considered a very promising source for two reasons: it is a highly innovative technology, and therefore has a high potential for cost reduction; and secondly, it is nearly independent of scale. Thus, PV has an intermediate market: though its current cost is much higher than conventional sources for bulk electricity production, because it is already competitive for certain applications, and the size of this intermediate market is increasing rapidly as the price of PV systems decreases. For example, the supply of power to areas not connected to the grid which are mostly in the rural areas where people often can not afford a Diesel generator. Hybrid systems, combining PV and Diesel generators, with PV providing between 35% and 70% of the energy, have come into limited use recently. Such systems can greatly reduce the need for electric storage. Other kinds of hybrid systems, like PV and wind or PV and biomass are also being explored. Some "Stand Alone" systems are already commercialized [25]

Costs of PV modules have decreased by a factor of 10 over the past 15 years. A significant reduction in price can be obtained if large numbers of units are purchased. In such cases, the price may go down to US$ 4.5 per W_p (1992). PV costs are expected to decrease to around US$ 1 to 2 per W_p by the year 2000. This decline should result both from a scale factor (the largest industrial plants now produce a few MW per year) and from a shift to new technologies. Actually, amorphous silicon (a-Si) has production costs much lower than X-Si, but its characteristics of low efficiency and initial degradation have made it unsuitable for the general energy market. Other materials are being investigated as candidates for PV cells; among them, gallium arsenide (GaAs), copper indium dieselenide (the so-called CIS) and cadmium telluride appear most promising and receive most attention today [24].

The total capacity of solar cell manufacturing industry all over the world is now over 53 MW per year. It is expected that the expansion capacity, which is led by the United State of America, will be 150 MW per year within the next 3 years. The total installed capacity of solar cell system assembled so far is over 25 MW and the largest capacity in the world which is situated in the United States of America is 7 MW [26].

The existing three solar cell manufacturers in Thailand are only doing module encapsulation with mostly imported material and the total production capacity of the biggest one is approximately 2 MW per year [24]. In 1992, the total installed capacity of solar cell systems was approximately 1400 kW [27] which divided almost among applications for telecommunications devices (360 kW), water pumping (379 kW for some 350 units) and battery charging for remote off-grid sites (374 kW). Recently, an additional 600 units of PV water pumping have been installed.

Though Thailand claims that about 95% of the country has already been electrified, grid electricity is usually only brought to the center of the villages and not to the locations where energy supply is also needed, such as more remote hamlets and water pumping stations [28]. Due to this practice, the actual number of connected households is estimated to be about 70%. Extensions of power lines are expensive and this means that there is a large scope for PV lighting to individual homes, not only for battery charging stations, but also for Solar Home Systems (SHS). A SHS with one 20 Watt lamp can be purchased for less than Bath 8,000 [28]. A recent study of 1 MW PV grid-connected system showed its viablity for a specific location in Thailand [29]. The Electricity Generating Authority of Thailand (EGAT) is equiping 10 individual houses with PV grid-connected system with 2.5 kW each for demonstration purpose. Operation of these systems is expect to start at the begining of 1998.

From the 21st century onward, it is believed that the cost of solar cells can be reduced to compete with the conventional thermal power plant while the cost of fossil fuel will increase and the measures to protect the environments will be more stringent. The large commercial generation use of solar cell systems may become one of the good choices and be implemented in the future.

At present, PV modules are generally less than 1 m^2 in size and deliver between 50 W and 150W of electric power. Therefore, a PV array of 1 km^2 surface area would generate approximately 165,000 kWh per day. That means if we use 1000 km^2 of surface area (0.2% of Thailand surface area), the corresponding generated capacity fed to the national grid will be 165 x 10^6 kWh/day.

4. GEOTHERMAL ENERGY

Geothermal energy is steadily extending its contribution to the world energy balance. Since 1980, geothermal electricity generation capacity at the world level has increased from 2000MW to 5830 MW (from 500 MW to 2000 MW in developing countries). At the world level, projections for the next 10 years indicate an annual growth rate of the order of 6% for power production and 4% for direct uses [30].

Although geothermal energy is close to being a mature technology (its first applications for electricity generation are nearly a century old) constant progress is being achieved. Technical improvements of the last decade concern, for instance, the ability of load modulation in an economic and efficient way in both steam-and water dominated situation, even for relatively small plants; the building of simple and reliable single and double flash systems at moderate cost installed in remote locations (such as in Tibet, Bolivia and Hawaii); at the higher range of the technology, the development of techniques quite different from those of the oil industry for drilling deep wells (400 m and beyond) through hard, hot rocks; the improvement of material sand sealing techniques; the possibility of drilling multiple wells branching off a main well at great depths; the drilling of quasi-horizontal wells; and the improvement of geophysical and geochemical prospecting and evaluation methods.

For longer term, the hot dry rock (HDR) technology has made some steps forward, although a significant demonstration is still lacking (and hoped during the next decade). This technology consists of injection watering, a deep, hot and dry formation through one well and recovering it as steam through another well. The major difficulty consists of connecting the two wells through a system of fractures, having large surfaces for heat exchange but little dispersion of the injected water. If this challenge can be met (as theoretical considerations and some small scale experiment would indicate), the availability of HDR technology would allow extending the resource bases for geothermal energy to many more countries, since dry geothermal deposits are much more common than wet ones.

Hot dry rock geothermal resource is the main research and development interest of U.S.A., UK., France, Germany and Japan. When there is a research and development breakthrough, new dimensions of world energy resources will be opened.

The present geothermal electricity generation of the world is 9500 MWe, besides other direct agricultural and industrial uses. Because geothermal energy is clean, indigenous and has small environmental impact, exploration and development activities are increasing.

Thailand has more than forty medium-enthalpy geothermal resources scattered throughout the country, particularly in the North. These geothermal resources have high energy potential for multipurpose uses, including electricity generation, agroindustry, health resorts, tourism's, etc.

Thailand is the first country of the Southeast Asian region to operate a binary-cycle geothermal power plant [31]. Thailand can take a leading role in exploration and development of medium-enthalpy geothermal resources if strong support is continuously provided.

The major problems facing geothermal energy development of the country are personnel, administration and budget. Technical personnel involved are mainly from related fields with no specialized training. Administrations of the projects are not properly organized and with no definite designated responsibilities. Research and development budget are not in continuity.

It is expected that, after 1997, Thailand can produce approximately 12 million kW, of electricity from geothermal resources. This is equivalent to annual oil savings of 3 million liters. The thermal energy can also be further used in drying and cooling of agricultural products [32], equivalent to thermal energy from crude oil of 0.5 million liters annually.

5. WIND ENERGY

Wind is the renewable energy source that is in closest competition with conventional energy sources for the production of electricity and mechanical power, at least where appropriate wind regimes are available [33]. Even when environmental, land-use, and systems constraints are taken into account, wind power could accommodate a substantial portion of global electricity demand, perhaps 20 %. In 1994, the installed wind generation capacity was 3,350 MW in the world, of which 1,700 was in North America and 1,500 in Europe; the contribution of developing countries is, for the time, being negligible.

Since the power that is carried by the wind per unit area is proportional to the third power of its velocity, the convenience of wind generation depends very much on the velocity of the wind that can be expected on the average in a given location. The ideal situation involves high abridged wind velocities (e.g. 8 m/s), constant or slowly varying wind direction and absence of sudden gusts. However, as wind regimes are very variable, not only on a regional scale but also because the presence of vegetation has important effects, it is therefore necessary to have accurate evaluations and measurements of the actual conditions on each site considered for the installation of wind turbines.

Wind power technology has evolved very notably during the last decade. Most of this evolution and of the new applications of wind machinists concentrated in industrial countries and adapted to their conditions. Wind farms providing electricity to the grid have been built in California (over 1500 MW), in Denmark (300 MW) and in some other locations. The cost of the electricity produced is close to (or smaller than) the avoided cost of providing extra power from conventional sources, in particular coal-fired stations with state-of-the art pollution abatement. The average size of the machines employed has risen steadily in the last ten years from a few tens of kW to a few hundred kW. Large scale machines, of several MW of power, are still at an experimental stage, and it is not sure whether they will eventually become more economical than medium-sized ones, except perhaps where space is scarce or in off-shore applications.

Recent technological developments include advanced airfoils, variable speed machines that employ solid state advanced electronic power conditioning systems, and continuing development of new materials that yield lighter, stronger components. Energy capture has been increased 10% or more, while capacity factors that ten years ago were in the range of about 15% are now as high as 35%. All these improvements are directly reflected in lower generating costs.

Smaller machines, up to a few kW, have long been used in many countries to pump water for human and cattle use and for irrigation and to charge batteries. In industrial countries, this practice has declined with the spread of rural electrification, but is gaining popularity again and the declared goal of the European Wind Energy Association (EWEA) is to have 10% of Europe's electricity generated by wind power by the year 2030 [34]. This will be equivalent to 100 GW, or 250,000 wind generators each rated at 400 kW, a typical size for today's wind power machines.

The interest in these applications is large in developing countries. Wind pumps are economically attractive, at least for drinking water, even when wind regimes are not very favorable (e.g., 3.5 m/s average velocity).

Thailand installed about 5,800 wooden low-cost wind pumps, locally made, and eight demonstration electricity generation wind turbines of 22 kW size at Phuket, south of Thailand, in 1993. Five wind turbines for electricity generation at kW size are imported, the rest are at the research and development stage and locally constructed. The problems facing the researchers are mechanical part design and production. However all wind turbines have no standard test results, both in laboratory and field tests.

The average wind velocity measured over 17 years varies between 1.6 m/sec-3.0m/sec (from wind statistic data of the Meteorological Department, Ministry of Communications). Isochart maps with mean annual wind speeds were published in 1995 [35]. Especially in the southern coastal area, the average yearly wind speed is around 3 m/sec.

With average wind speeds below 6 m/s, the application of wind energy on a larger scale for electricity generation is not economically viable. However, according to DEDP [34], areas that are considered suitable for the application of wind mills are the coastal area and central plains, the Chao Phaya valley, the northern inter-mountain basin and the Korat plateau. DEDP has reported on four imported wind turbines for electricity generation demonstration projects [36]. Capacities range from 1 kW to 18.5 kW, the latter being part of a hybrid system with 5 kW photovoltaic power (PV) at Phuket island.

6. CONCLUSION: APPLICATIONS OF RENEWABLE ENERGIES

Renewable energy sources (RES) might be part of the solution to the greenhouse effect, together with energy efficiency policies, and particularly demand side management. RES can be used for different applications that include practically every facet of final energy use. The product or technology considered can yield directly electricity, or mechanical power, or chemicals to be used as fuels. The related cost of a unit of energy of RES is a function of the product. This cost is negligible when sun's energy is simply used to improve houses thermal comfort by inducing natural ventilation or significant when sun's energy is converted into electricty to run a fan to ventilate the housing.

In lab-scale studies, almost all of RES had been shown, at least, feasible with a relatively high potential. However, how effective such schemes would be in real applications and large scale utilizations will have to await for full-scale testing. To this end, the Thai Government should promote research and development activities for the commercialization of new technologies developed by universities, national research institutes and other laboratories to a level where private industries can take over and commercialize them. This could be done under the framework of a demonstration and promotion master plan for RES production and utilization during the first period. It should aim to cover commercialized non-conventional energy supply as well as environment conservation; improving the quality of life continuously and creating non-conventional energy production and utilization as permanent and efficient energy resources.

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