AVAILABILITY AND UTILIZATION PROSPECTS OF RENEWABLE ENERGY SOURCES FOR RURAL ELECTRIFICATION IN PAKISTAN

Khanji Harijan[1]
Muhammad Aslam Uqaili[2]
Mujeebuddin Memon[3]
Bujo Mal Meghwar[4]

Abstract

Pakistan is an energy deficient developing country. Only half of the country's population has access to electricity through conventional power generation system. About 68% of the country's population lives in rural areas and most of them are yet without electricity. Conventional electricity generation includes 68.2% thermal, 29.5% hydel and 2.3% nuclear. There is huge coal potential in the country but has not been utilized to its full potential. Indigenous reserves of oil and gas are limited and the country heavily depends on imported oil. Thermal power generation also pollutes the environment. Rural electrification through existing centralized grid system is economically and technically unfeasible. This paper presents the availability of renewables such as hydel, solar, wind and biomass energy, and their utilization prospects for rural electrification in Pakistan. The study concludes that there is substantial potential of these renewables and they have also bright prospects for rural electrification in Pakistan.

[1] *Postgraduate Student, Department of Mechanical Engineering, Mehran University of Engineering and Technology, Jamshoro-76062, Sindh, Pakistan*

[2] *Professor, Department of Electrical Engineering, Mehran University of Engineering and Technology, Jamshoro-76062, Sindh, Pakistan*

[3] *Professor, Department of Mechanical Engineering, Mehran University of Engineering and Technology, Jamshoro-76062, Sindh, Pakistan*

[4] *Lecturer, Department of Geography, University of Sindh, Jamshoro-76062, Sindh, Pakistan*

Keywords: Electricity generation; Rural electrification; Renewables; Thermal power; Pakistan

Introduction

Energy is an essential ingredient of socio-economic development and economic growth. Electricity is the most versatile form of energy and is the key to the modern world. Its consumption leads to economic growth, improvement in the quality of life and standard of living. Currently, nearly two billion, or more than a third of the world's population, live without electricity. Most are the rural poor who reside in areas not yet reached by centralized electric power grids[1].

In Pakistan, about half of the population has access to electricity through conventional power generation system. Per capita electricity consumption is only $1/5^{th}$ of the world average and $1/10^{th}$ of the Organization for Economic Co-operation and Development (OECD) region as shown in Fig.1. Out of the 12.5 thousand villages/settlements, about 45% of the villages are still un-electrified[2]. The rural/village electrification programme is an integral component of total power sector development for the purpose of increasing productive capacity and the socio-economic standard of 68% of population living in the rural areas. Rural villages are scattered over a large area and located far from the main electric grids. They have low population density and require small load.

The supply, reserves and life time of Pakistan's conventional energy sources are given in Table 1[3]. Pakistan is an energy deficit country, which meets about 88% of its requirement from fossil fuels, of which 44% is from the oil. Indigenous reserves of oil and gas are limited and the country is heavily dependent on the import of oil. The oil import bill is a serious strain on the country's economy and has been deteriorating the balance of payments situation. Though there is huge coal potential in the country but has not been utilized to its full potential due to poor quality, lack of infrastructure, vested interests of anti coal lobbies, site disadvantages, transportation problems and financial constraints [4-5].

Thermal power generation is also a major source of environmental pollution. The environmental quality in Pakistan has been deteriorating rapidly. Power sector is a major source of air pollutants and contributes about 30% of CO_2 and 45% of the SO_2 emissions in the country. The main source of these emissions is due to heavy use of fuel oil and coal in the power generation[6]. Increase in the incidence of respiratory and

gastroenteric diseases and problem of desertification, deforestation, soil erosion, landslides, flash floods, droughts, acid rains and climatic change are sure sign of the degree of degradations of the environment[7].

Pakistan has an identified hydropower potential of over 38 GW of which only 16 % has been exploited so far. Future developments of large hydropower systems are constrained by a combination of techno-economic, environmental and socio-political factors and inter- provincial conflicts. Expansion in nuclear power generation behind the present capacity is uncertain due to high capital cost, and safety and security concerns[8].

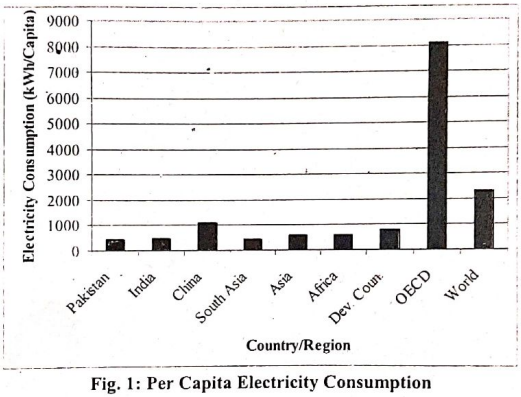

Fig. 1: Per Capita Electricity Consumption

Table 1: Pakistan's Conventional Energy Sources 2002-03

Source	Annual Supplies (MTOE)	Recoverable Reserves (MTOE)	Life Time* (Years)
Fossil	41.31	7660	200
Oil	18.02	39	2
Gas	20.77	505	25
Coal	02.52		
Measured		1790	873
Indicated		5419	2643
Hydro power	5.34	16 GW	~40% of current needs
Nuclear	0.42	-	
Total	47.06		

***With present rate of supplies**

Electricity demand in urban areas is also growing day by day due to rapid urbanization and industrialization, increase in per capita income, improvement in the standard of living etc. It has been projected that electricity demand in Pakistan will grow at 7-11% per annum [2]. The conventional power is even not sufficient for meeting the growing demand of electricity from the existing customers. Further more the extension of existing centralized grid system to far away from grid line rural areas with very low population density and small-scattered loads are economically and technically unfeasible [9]. Hence there are remote chances of getting grid connection to most of the rural population in the near future. This paper presents the availability of renewables such as hydro, solar, wind and biomass and their utilization prospects for rural electrification in Pakistan.

Electricity Generation Situation

Conventional Electricity Generation

Pakistan's total power generation installed capacity was about 17.8 GW on June 2003. Thermal plants make up about 69% of capacity, with hydroelectricity making up 28.4% and nuclear power 2.6% only as shown in figure 2. In 1960, the share of hydel electricity generation was 70% while that of thermal was only 30%. During 2002-03, 75,682 GWh of electricity was produced. The generation included 68.2% thermal, 29.5% hydel and 2.3% nuclear as shown in Table 1 [3].

The share of oil, gas and coal in thermal electricity generation was 32.2%, 35.7% and 0.3% respectively. Thermal electricity generation consumed about 12.41 MTOE of fossil fuels with 52% gas, 47.3% oil and 0.7% coal share. The power generation consumed about 33% of the oil, 31.2% of gas and 3.6% of the coal.

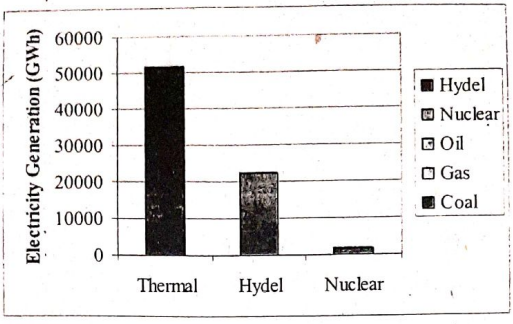

Fig. 2: Installed Electricity Generation Capacity

Table 1: Electricity Generation by Fuel

Fuel	Fuel Consumption (MTOE)	Power Generation (GWh)
Thermal	12.41	51,591
Oil	5.87	24,353
Gas	6.45	27,006
Coal	0.09	00,231
Hydel		22,351
Nuclear		01,740
Total		**75,682**

Renewable Electricity Generation

The present total hydel power installed capacity of 5,046 MW contributes 29.5% (22,351 GWh) of the total electricity generation. Out of the total hydel power installed capacity, the share of small hydropower is only 114 MW. The share of hydel electricity generation decreased from 70% to 29.5% between 1960 and 2002-03.[3]

Pakistan Council of Renewable Energy Technologies (PCRET) had installed around 250 micro hydel power plants of 4 MW capacity in remote areas of the North West Frontier Province (NWFP) and Federally Administrated Tribal Areas (FATA), making the use of small streams and natural falls. The PCRET has also initiated a program, with the funding of

Asian Development Bank (ADB), for installation of 100 micro hydel power plants of 5 to 50 kW in the Malakand Agency [3].

In biomass, only bagasse is used as a boiler fuel by sugar mills in Pakistan to co-generate (both steam and electric power) for mill operations. Presently there are 78 sugar mills in the country. More than 70% of power requirement in sugar mills is met by using bagasse. Sugar mills are capable of meeting their own power requirement through steam turbines [2].

Two wind turbine power units of 1 kW and 10 kW electricity generation capacities are working [10] and hundred wind power turbines will be installed next year in coastal areas of Balochistan and Sindh province respectively. About 14 wind turbine units of 300 W and 500 W capacities has already been procured and installed with the help of China, in remote coastal areas of these provinces [11]. The Ministry of Environment and Local Government has initiated a study on wind potential in the coastal area of Balochistan for installation of 15 MW wind power plant [6].

Eighteen solar Photovoltaics (PV) stations in different parts of the country were set up for village electrification in 1980s with an installed capacity of nearly 440 kW, majority of them are not performing as required because of lack of technical knowledge and follow up [12]. A proposal of project of installation of 1 MW solar thermal power plant in desert area of Pakistan with cost of US$ 5 million is under consideration. The Alternative Energy Development Board (AEDB) of Pakistan has targeted to meet 10% of country's total energy requirements through alternative energy by 2015 [13].

Availability of Renewable energy sources in Pakistan

Hydel Power

Pakistan has an identified hydropower potential of over 40 GW of which only 15 % has been exploited so far [6]. The Northern part of the country is also rich with small hydropower resources. It is estimated that the total potential of hydropower in the northern areas of Pakistan alone is above 500 MW [3]. There are a large number of sites in the high terrain where natural and manageable waterfalls are abundantly available. The recoverable potential in micro-hydropower (MHP) up to 100 kW is roughly estimated to be about 300 MW on perennial water falls in northern Pakistan. Besides, there is an immense potential for exploiting

water falls in the canal network particularly in Punjab and Sindh, where low head high discharge exists on many canals [14].

Solar Energy

Pakistan lies in favorable latitudes as far as solar radiation is concerned and have long sunshine hours and high isolation levels. Among all renewable energy sources the solar energy is the most abundant and widely spread in the country. Pakistan receives 16-21 MJ/m^2 per day of solar radiation as an annual mean value, with 19 MJ/m^2 per day over most areas of the country. This minimum level of solar radiation (16 MJ/m^2 per day) is higher than the world average (13 MJ/m^2 per day), which shows that Pakistan lies in an excellent solar belt range. The total available solar energy potential over the total geographical area (i.e. 796,095 km^2) of the country is 5.23 PJ/m^2 per year [15-16]. Pakistan's solar resource has been estimated as about 800 million MW [3].

Wind Energy

A significant part of the solar radiation, entering the earth's atmosphere, is absorbed by earth. It is estimated that 20% of the absorbed energy is used to heat atmospheric air and is the major cause of winds. Pakistan has considerable potential for wind power generation in the southern and coastal areas of Sindh and Balochistan provinces [3]. Its about 935 km coastline has steady winds with average speeds of 5-7 m/s throughout the year. Its mountainous north too provides ideal locations to site windmills. Similarly, the wind flow patterns in the plains during the monsoons and the winter anticyclone winds can provide economically feasible power.

Technically wind power can be generated at wind speeds of the order of 3 m/s with modern wind turbines [2]. Coastal and mountain areas are difficult and expensive places to reach with an electric grid. Wind energy can be utilized as a source of power generation where its potential exists, with proper maintenance infrastructure. The long coastal belt of Pakistan is a potential source for utilization of wind energy.

Biomass Energy

Biomass includes all organic plant materials, both cultivated and uncultivated (trees, grasses, crops), and organic wastes produced by humans and animals. There is substantial potential of biomass in the form of fuel wood, crop residues and other waste (animal, human and municipal waste) in Pakistan. Biomass can be converted to electricity by direct combustion in

boilers that produce high-pressure steam to run turbines. The agricultural crop residues can be burned in bio-power systems to produce electricity. Biomass can be an aerobically digested to create methane gas (biogas) for electricity production [17].

Currently about 1.5 thousand m^3 of forest firewood and 50 thousand tonnes of solid waste per day are generated in Pakistan [6]. The estimated potential of crop residue is 225 thousand tonnes per day and animal dung is more than 1 million tonnes per day. The total bagasse production has been estimated at about 13 million tonnes (2.65 MTOE) per year. The total rice husk production has been estimated at about 1.4 million tonnes (0.44 MTOE) per year [18].

Bagasse and rice husks are the most utilized agricultural residues for electricity generation in the world. Substantial amount of electricity can be generated using bagasse and rice husk as a fuel in Pakistan. An estimated 8.8 to 17.2 thousand million m^3/year of biogas can be produced from livestock residue, which is equivalent to 54.8 to 106.4 TWh/year. Biogas alone could supply at least about 550 kWh per capita to the rural population, which is equivalent to 1.5 times the current per capita electricity consumption in Pakistan [19].

Ocean and Geothermal Energy

Pakistan is blessed with a potentially rich long coastal belt. There is good potential of ocean tidal and wave energy in the coastal belt. Electricity can be generated from ocean tidal energy and ocean wave energy [20]. Unfortunately, no serious efforts had been made to tap this energy resource.

Geothermal energy comes from the continually produced heat within the earth that is brought to the surface as hot water or steam. It provides heat source for electricity generation using modular power plants. Nearly half of the world's developing countries have geothermal resources [21]. The Geological Survey of Pakistan has conducted a number of studies to estimate the potential of geothermal resources of the country and identified several sites where geothermal heat can be converted to produce commercial grade electricity. The identified sites are located in north Balochistan, Northern Areas, and in the Indus Basin. The total potential available from this resource is estimated to be less than 1,000 MW. At present, there is no geothermal plant operating in the country or even under consideration [3].

Utilization Prospects of Renewable Energy Source for Rural Electrification in Pakistan

Pakistan's rural areas are blessed with substantial potential of renewable energy sources such as hydro, solar, wind, biomass, and ocean energy[15-16]. Renewable energy resources are indigenous, abundant, self-generating, environment friendly and mostly free of cost. They are not subject to the fluctuation in price and availability common to fossil fuels. Renewable energy systems involve a one-time transportation and installation cost and, when installed, supplies reliable electricity. Renewable energy technologies are flexible, modular, and require a short lead-time for start-up and operation. Renewable energy sources are diffused and decentralized [22-23].

The use of renewables can provide energy independence, new employment opportunities in the rural areas and thus are capable of stemming the mass migration from rural to urban areas. Renewables use can improve the socio-economic conditions of the people in rural areas and can help in poverty alleviation [23]. The utilization prospects of individual renewable energy sources for rural electrification in Pakistan are discussed below:

Solar Energy

Solar energy can be converted into electricity by solar PV technology or solar thermal technology. Solar PV converts sun radiation directly into electricity using solar cells. This technology is ideal for areas away from gridlines. It is economically feasible for residential and small-scale commercial business electrification and water pumping for irrigation [9]. PCRET is the pioneer in establishing this technology in the country. It has facility to grow single crystals, cut crystals into wafers, process wafers into solar cells and finally laminate these into modules (solar panels). National University of Science and Technology (NUST) and other universities are also working on solar cell technology at research and development level. Now PCRET has developed the know-how and processing technologies in the field of solar cells, modules and systems [3]. The cost of solar PV has also dropped by two orders of magnitude during last 30 years. PV systems are currently cost-effective in some consumer products. The solar PV market is believed to be growing at the rate of 34% per annum. Costs of solar PV are expected to continue to decline in the future allowing PV devices to compete with large-scale conventional power generation. The technological maturity will increase its use in the

near future [23-24]. Solar PV has bright prospects for rural electrification in Pakistan. With 50% of Pakistan's population without electricity, this may be the only option for providing electricity to far flung villages [13, 25].

Solar thermal technologies collect the sun's radiant energy to create high-temperature at the source that can be converted into electricity via a number of thermodynamic conversion cycles. Solar thermal generation system is a proven technology in developed countries like USA, Germany and France, and it is providing electricity to grid systems on a competitive basis with conventional fossil fuel-fired thermal power plants. No solar power plants exist in the country at present. However, the country's geographic and climatic conditions, particularly its average year-round solar regime, indicate substantial potential for solar energy based applications, and the option's implementation is likely to be successful. In Pakistan these technologies are currently in the development and demonstration phase. Solar thermal technologies are generally simple and involve skills generally available in developing countries and, therefore, more appropriate for Pakistan [3].

Biomass Energy

Bagasse and rice husk can be used in sugar and rice mills in Pakistan as fuel for cogeneration for use at the sugar and rice mills and for sale to electric companies for rural electrification. In biomass, only bagasse is used as a boiler fuel by sugar mills in Pakistan to co-generate for mill operations. Rice mills can also utilize rice husk for producing steam and electricity [26]. Live stock residue can also be used for biogas production and further for electricity generation in rural areas [27]. The PCRET is putting in concreted efforts for the promotion of biogas technology and had installed a number of biogas plants. There is substantial potential of bagasse, rice husk and live stock residue in the country and the technologies for their conversion into electricity are also mature. There are bright prospects for electricity generation from these sources for rural electrification in Pakistan [26-28].

Wind Energy

Wind technologies convert the energy of moving air masses to rotating shaft power that can be directly used for mechanical energy needs or converted to electric power. This type of energy has proven the most cost-competitive for the bulk power market internationally. Wind power technology is a proven technology that has been used form ancient times

for grinding grain and drawing water for irrigation. Wind is the fastest growing renewable source of energy, with annual growth rate of 40% [7]. The costs of wind power generation systems have also dropped substantially in the past three decades. Technology continues to improve and prices will continue to fall as production capacity of wind power generation systems expands. Wind power technology is close to competing with fossil fuels and may be cheaper if environmental externalities are included [23]. Wind turbines for generation of electricity from a fraction of 1 kW to 2 MW are operating in various countries of the world.

Pakistan has been slow in the adaptation of this technology to mitigate the problem of acute shortage of power in deserts and coastal areas where wind energy is available in sufficient strength. Pakistan Council of Appropriate Technology (PCAT) has installed imported and locally made windmills at many locations. At present, PCRET is installing imported wind turbines in the coastal areas of Pakistan for electricity supply. PCRET is working for further promotion and transfer technology with the ultimate objective of achieving complete indigenous manufacturing of wind turbines in the country [3, 29]. The steps taken by PCRET indicate a substantial increase in wind power generation in the country.

Hydel Energy

Pakistan has an identified hydropower potential of over 40 GW of which only 15 % has been exploited so far. Future developments of large hydropower systems are constrained by a combination of techno-economic, environmental and socio-political factors and inter- provincial conflicts [8]. The small hydropower plants are one such alternative that has emerged as a desirable option especially for high terrain, where natural and manageable waterfalls are abundantly available. There is a tremendous potential for exploiting abundantly available waterfalls in the Northern Areas of the country. A number of perennial stream falls with reasonably sustained discharge over the year are available in the NWFP, Balochistan and Azad Kashmir. The population in these areas is isolated, thinly clustered and is located far from physical infrastructure [3, 14].

Besides, there is an immense potential for exploiting water falls in the canal network particularly in Punjab and Sindh, where low head high discharge exists on many canals. Perennial waterfall is channelized and allowed to fall on the turbine from the fore bay through penstock. The

rotor sometimes is also used for other mechanical work during day time. Hydel power generation is a mature and economical technology in Pakistan [14]. PCRET is working for further expansion in small hydro power plants. The steps taken by PCRET indicate a substantial increase in hydel power generation in the near future in Pakistan.

Pakistan's rural areas with very low population density, small scattered loads and good availability of renewable energy sources makes the region ideal for renewable energy based decentralized power generation. The geographical location, topography and local climate of the country are also in favor of renewables use. Renewable power technologies such as solar PV, wind-electric turbines, small hydro systems, bagasse and rice husk based co-generation and biogas based electricity generation technologies are ideal for providing electricity in rural areas of Pakistan. Renewable energy technologies have bright prospects for power generation and electrification in the rural areas [25-30]. It is high time to harvest the benefits of the renewable energies without damaging the environment and to reduce the burden on the national exchequer.

Conclusion

The paper concludes that:

- The grid connected conventional electricity could not reach most of the rural areas of Pakistan in near future. There is substantial potential of renewable energy sources such as small hydro, solar, wind and biomass in rural areas of Pakistan.
- Hydropower technology and co-generation using bagasse as fuel are mature technologies in the country. The solar PV, wind power and biogas technologies are progressing for their development and deployment in the country. The geothermal, ocean tidal and wave energy technologies are very much in their infancy.
- Renewable energy sources such as small hydro, wind power, solar PV and biomass (bagasse, rice husk and biogas) are the viable options for rural electrification in Pakistan. There are bright prospects for utilization of these sources for rural electrification in the country.
- A national renewable power policy should be formulated and announced which should lay down the targets and incentives for the generation of renewable power for rural electrification.

Acknowledgement

The authors wish to acknowledge Dr. R.S.Abro, Director, Solar Energy Research Center, Hyderabad and Dr..I.A.Raja, Professor (Foreign Faculty), COMSATS Institute of Information Technology, Abbottabad, Pakistan, for their cooperation and encouragement. Khanji Harijan also greatly acknowledges the Higher Education Commission, Ministry of Science and Technology, Government of Pakistan for their financial support and Mehran University of Engineering and Technology, Jamshoro, Pakistan for permitting with study leave to carry out this research work.

References:

1. Winrock International, "Electricity on Demand: Reaching Two Billion Cheaply With Renewably Energy", WI, 1998.
2. M.A.Uqaili, K.Harijan, and M.Mirani, "Demand Projections and Supply Options for Power Generation in Pakistan", Mehran University Research Journal of Engineering and Technology, Vol. 22, No. 4, Jamshoro, Pakistan, October, 2003, pp. 233-242.
3. "Pakistan Energy Yearbook 2003", Hydrocarbon Development Institute of Pakistan, Islamabad, November, 2003.
4. A.Kabir, "Emerging Energy Crises and Options", Dawn Economic and Business Review, 4-10 March, 2003.
5. M.A.Khaqan, "Future of Power Generation", Dawn Economic and Business Review, 18-24 February, 2002.
6. "Economic Survey of Pakistan 2002-03", Finance Division, Government of Pakistan, Islamabad, 2003.
7. P.Akhter, "Renewable Energy Technology-An Energy-Solution for Long-Term Sustainable Development", Science Technology and Development, Vol. 20, No. 4, 2001, pp. 25-35.
8. M.A.Uqaili, "Energy Modeling and Energy Policy in Pakistan", Ph.D. Thesis, Leeds University, U.K, 1996.
9. F.Mahar, "Solar Based Rural Electrification in Balochistan", Journal of Engineering and Applied Sciences, Vol. 20, No. 2, 2001, pp. 97-100.
10. P.Akhter, A.Mufti, I.A.Qazi, and Z.I.Zaidi, "Solar Energy in Pakistan: Country Paper", Proceedings, Asia-Pacific Solar experts meeting: Renewable energies for development, culture and environment, Islamabad, Pakistan, 18-21 December, 1995, pp. 170-189.
11. S.H.Nawab, "Wind Energy, the Future Resource", Dawn Economic and Business Review, 02-8 February, 2001.
12. Z.I.Zaidi, I.Ahmad, M.Abbas, M.N.Zakir, B.Raza, and P.Akhter, "Renewable Energy Technologies in .Pakistan: A Country Paper", Proceedings, workshop on Renewable Energy Technologies –

Dissemination and Market Development, Islamabad, Pakistan, 3-6 April, 2000, pp. 156-173.

13. U.K.Mirza, M.M.Maroto-Valer and N.Ahmed, "Status and Outlook of Solar Energy Use in Pakistan", Renewable and Sustainable Energy Reviews, Vol. 7, Issue 6, 2003, pp.501-514.
14. H Gull, "Micro Hydropower Projects of PCAT: Functions and Achievements". Proceedings, Workshop on Renewable Energy Technologies – Dissemination and Market Development, Islamabad, Pakistan, 3-6 April, 2000, pp. 197-200.
15. M.A.Ghaffar, "The Energy Supply Situation in the Rural Sector of Pakistan and the Potential of Renewable Energy Technologies", Renewable Energy, Vol. 6, No. 8, 1995, pp. 941-976.
16. I.A.Raja, and R.S.Abro, "Solar and Wind Energy Potential and Utilization in Pakistan", Renewable Energy Journal, Vol.5, No.1, pp. 583-586, 1994.
17. A.Koopmans, "Biomass Energy Resources for Power and Energy", Regional Wood Energy Development Programme, FAO Bangkok, Paper Presented at the Expert Consultation on Options for Dendro-Power in Asia, Manila, 1998, pp. 39-58.
18. S.C.Bhattacharya, P.Abdul Salam, and V.Singamsetti, "Potential of Biomass Energy in Asia", A Report of the Project Biomass Energy in Asia: A Study on Selected Technologies and Policies, Asian Regional Research Programme in Energy Environment and Climate I, AIT, 1997.
19. K.Harijan, M.A.Uqaili, and M.D.Memon, "Estimation of the Potential of Biogas Production from Livestock Residue in Pakistan", Mehran University Research Journal of Engineering and Technology, Vol. 23, No.4, Jamshoro, Pakistan, October, 2004, pp. 257-266 .
20. F.H.Mastoi, M.A.Uqaili, and S.A.Memon, "Electrical Power Generation from Ocean Waves", Journal of Engineering and Applied Sciences, Vol. 14, No. 1, 1995, pp. 133-140.
21. S.M.A.Hai, and I.Ali, "Geothermal Energy: Options for Energy Deficient Countries", Science Technology and Development, Vol. 16, No. 2, 1997, pp. 1-7.
22. H.J.Koch, "The Value of Renewables". Renewable Energy World, Vol.4 No.6, Nov-Dec 2001, pp. 33-45.
23. V.H.Antonia, E.L.Timothy, L.E.Jennifer, and M.K.Daniel, "Renewable Energy: A Viable Choice", Environment, Vol. 43, Issue 10, 2001, pp. 9-20.
24. R.Gross, M.Leach, and A.Bauen, "Progress in Renewable Energy", Environment International, Vol. 29, No. 1, 2002, pp. 105-122.

25. A.Kabir, "Prospects of Solar Energy in Pakistan", Dawn Economic and Business Review, 03-09 March, 2003.
26. M.A.Uqaili, K.Harijan, M.Mirani and M.D.Memon, "Renewable Energy Technologies for Rural Electrification in Pakistan: Status and Prospects", Proceedings, Electric Supply Industry in Transition: Issues and Prospects for Asia; An International Conference, AIT, Thailand, 14-16 January, 2004.
27. Majid ul Hassan, "BT to Light up Villages in Pakistan", Dawn Science dot com, Saturday, 14th September, 2002.
28. A.Kabir, "Prospects of Biogas Generation", Dawn Economic and Business Review, 13-19 October, 2003.
29. H.A.Siddiqui, "Prospects for Wind Power Generation", Dawn Economic and Business Review, 10-16 November, 2003.
30. S.M.Hasnain, and B.M.Gibbs, "The Potential and Prospects of Alternative Energy Resources in Pakistan", Clean and Save Energy Forever, Vol. 3, Kobe, Japan, September, 1989, pp. 1981-1985.