EUROPEAN ACADEMIC RESEARCH
Vol. VI, Issue 12/ March 2019

Impact Factor: 3.4546 (UIF)
DRJI Value: 5.9 (B+)

ISSN 2286-4822
www.euacademic.org

Dynamics of renewable energy in Pakistan: Tidal energy as a future prospect

AMBREEN INSAF
Department of Applied Physics, University of Karachi, Pakistan
M. AHSAN UDDIN
Department of Economics, University of Karachi, Pakistan
MIRZA SALMAN BAIG
Department of Applied Physics, University of Karachi, Pakistan
MUSHTAQ AHMED
Department of Mathematics, University of Karachi, Pakistan

Abstract

The economic interest for a developing country is to know when their national income becomes equivalent to national income of developed country and how. The geographical location, natural resource and energy resources may help them in this regard. The largely used form of energy is the electrical energy upon which majority of the firms and society bases on this energy.

Conventional sources of electricity such as oil and gas are limited, expensive and unsustainable, not to mention hazardous for the environment. So, there is no question that renewable energy is the future. Pakistan is blessed with a geographical location where all types of renewable energy are available in abundance. Renewable energy in Pakistan has enough potential to meet the electricity demands of the country. Further, this potential will help to solve power shortage, pollution and high electricity production costs. In fact, if Pakistan can fully harness its renewable potential, it can become an electricity exporter.

Pakistan has initiated harnessing electricity from wind energy, solar energy, hydel energy and bio energy. An overview of each of them has been given. It has not yet exploited the potential of tidal energy. In fact, almost nothing has been done so far in the field of tidal energy. In this study, we present recent scenario of renewable energy in Pakistan

and some recent studies on tidal energy potential in Pakistan. Moreover, the details present in this paper provide sufficient evidence for tidal energy as a prospective candidate of renewable energy in Pakistan.

Keywords: Tidal Energy, Renewable Energy, Wind Energy, Solar Energy, Hydel Energy, Biomass

INTRODUCTION

Energy has become one of the most important drivers of the modern world and one of the main economic sectors that determines the prosperity of countries [1]. Pakistan is a developing country and one of the major challenges it is facing, as a country, is meeting the ever-rising consumer and industrial energy demands. Electric energy has become one of the most indispensable resources for both producers and consumers in the modern economy. Unfortunately, the primary sources of electric energy worldwide and in Pakistan are nonrenewable and are projected to run out, or at least create a significant shortage, in the coming years. Renewable energy resources are considered the leading solution to this problem.

Pakistan is a developing country; the development rate can be determined by per capita consumption of electricity. If per capita consumption of energy has an increasing rate, no matter how slow it is, this indicates the progress and development of the country. Fig. 1. shows year-wise per capita consumption of energy; it shows good rate of increase from 1970 to 2006. In 2006, per capita consumption of energy was at a peak of 488.56 kWh. Between 2007 and 2016 per capita consumption of energy did not cross this maximum. The fluctuations during this period are evidence of stagnation. The average value in this period was 444.51kWh. Pakistan's progress remained static during this period. The last few years were the worst in terms of energy crisis. Industries and people

alike have been facing a massive load-shedding problem. In fact, in some parts of the country the load shedding was up to 18 hours per day.

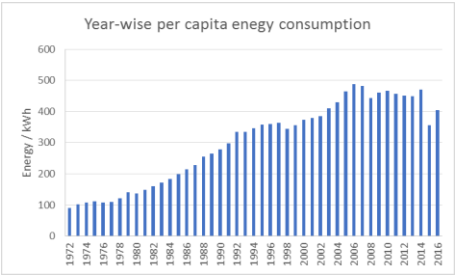

Fig. 1. Electric Power consumption per capita in Pakistan [2-4]

Fig. 2. shows percentage contribution of various energy mix (Gas, Oil, Hydro + Nuclear, Coal and LPG) in energy consumption for the years 2006-2015. The percent contribution of each of the energy sources is more or less constant. There is no significant change in each energy mix over the last ten years. The renewable energy contribution is not shown as it was added recently in energy mix.

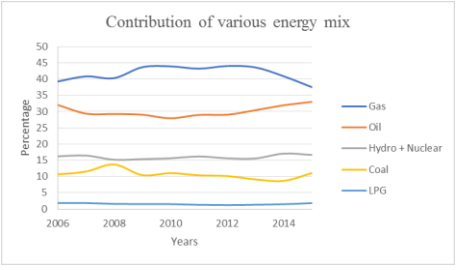

Fig. 2. Contribution various energy resources in energy mix. between 2005-2015.

The causes of energy crisis in Pakistan

The causes of energy crisis are not new and were expected because of increasing population and increasing use of modern technologies. Modern technologies are ubiquitous. The demand of energy directly links with rapid growth in these technologies. To be specific, electricity has become a basic need as it is

essential for lighting and temperature control in houses. As compared to past, now almost every house is equipped with a television; hence more electricity is needed. Computers and internet devices also require electricity. As time passes more and more houses, institutions and offices are being equipped with air-conditioners. The number of users of cordless and cell phones has increased exponentially in near past. Furthermore, in thickly populated areas, people have established micro industries for additional income. Some other causes for the energy crisis are as follows:

(i) Economic and political instability
(ii) Fluctuation of oil prices
(iii) Faulty distribution system
(iv) Aging of equipment
(v) Unproductive efforts
(vi) Mismanagement of energy resources

Renewable energy in Pakistan

There are two main organizations which deal with renewable energy resources. Firstly, Pakistan Council of Renewable Energy Technologies (PCRET) established in 2001. The main objective of its establishment was to carry out research and development (R & D) in the field of renewable energy [5]. The second organization is Alternative Energy Development Board (AEDB), established in 2003. Its main purpose is to promote and encourage development of renewable energy technologies in Pakistan, and to accelerate the adoption of renewable energy [6-7]. Both PCRET and ADEB have been playing their role in promoting and implementing renewable energy projects. In the following sections a brief introduction of each of renewable energies and their present status in Pakistan is given.

Wind Energy

Wind Power has been utilized to provide pump water and to prepare flour from grains. Though this technology is thousands

of years old, in last few decades when world energy resources depleted quickly, it re-emerged as an important energy resource. Wind power is not only environmentally friendly, it is also cheaper than conventional energy resources. According to Ackermann and Söder the cost of electricity generated by wind power has fallen to about 1/6 in last 35 years [8].Till 2013 Pakistan had not exploited wind energy, but in 2013 Pakistan started producing energy from wind farms. The first ever official and commercial wind farm was set up at Jhimpir, which started production in 2013. In southern parts of Pakistan (coastal areas of Sindh and Blaochistan provinces), a great potential of wind resources exist. Till the end of 2015, Pakistan was producing electricity from wind stations at various places of Jhampir and Gharo. Both Jhampir and Gharo are in Sindh Province. Currently, six different wind stations are producing 308.2 MW of electricity [9].

Eight different wind farms are expected to begin production within this year and the expected production is 477 MW. All eight wind farms are installed in Sindh Province; six at Jhimpir and two at Gharo. Fourteen other wind farms are under construction; some of them are expected to produce electricity in the mid of next year, while some would yield production in first quarter of 2019. Two of the fourteen wind farms are in process of development of feasibility study. An additional 663 MW electricity is expected to be generated from these fourteen wind farms. YEL wind farm at Jhimpir is expected to develop 50 MW soon. Most of the wind farms projects are owned by private companies. Sachel energy development (Pvt.) Limited started a project at Jhimpir, which would produce 50 MW of electricity.

Hydel power

Perhaps the oldest method of producing power is hydroelectricity. Hydropower, like all other renewable energies, is also natural and sustainable source of electricity. It is a

clean, environment-friendly and economical source of electricity. Hydropower plants have long lives and lower maintenance and operating costs. In 2000, energy produced through hydropower means was roughly 6% of that produced by oil [10]. The generation of electricity through hydropower has been growing worldwide. In particular, Norway and New Zealand are producing more than 99% and 75% of their electricity from hydropower [11]. In 1947, when Pakistan came into being, there were two hydro power stations: one in province of Khyber Pakhtunkhwa at Malakand and other was in the province of Punjab at Renala. The total hydropower capacity at that time was 10.7MW [11-13]. After 1960's Indus Water treaty, Mangla and Tarbela dams were constructed. The hydropower stations at these dams have installed capacity of 1000 and 3478MW, respectively. In 2004 Ghazi Barotha hydropower station was constructed with an installed capacity of 1450MW [14].

Fortunately, Pakistan is blessed with huge hydropower potential; both natural fall water flow systems and canals for irrigation display this potential. Fig. 3. shows year-wise production of electricity through hydro power from 2005-2006 to 2014-2015. It is evident from the fig. 3. that during last decade no substantial change occurred in hydropower generation.

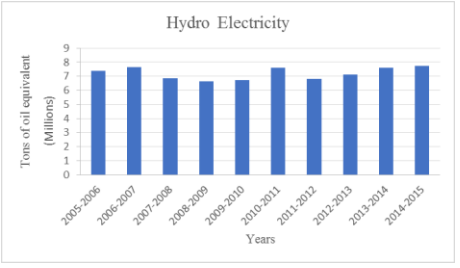

Fig. 3 Year wise electricity generation from hydro power.

At present 128 hydropower stations are operational in Pakistan; whereas 877 power stations are in the process of implementation and 1500 are in the process of development.

There are 815 potential sites with generation capacities between 0.1 MW to 40 MW. Fig. 4. shows the number of potential sites and hydropower potential in various provinces. A huge potential is present in Gilgit-Baltistan and Khyber Pakhtunkhwa provinces. The potential is very low in Sindh and Balochistan. Pakistan government encourages people to install small and mini hydropower stations. In Khyber Pakhtunkhwa some such projects are owned by local people, which utilize an abundant source of water.

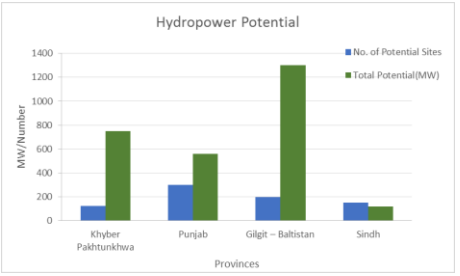

Fig. 4. Province wise number of hydro power potential sites and corresponding hydro power potential

Bio Energy

Bio energy, also known as biomass, is one of the oldest methods of generation of energy. It is renewable energy produced from garbage, crops, wood and some organic matter [15-16]. Billions of tons of crop residue are produced worldwide; this residue can be used to replace conventional means of energy generations [16-18]. Some important advantages of biomass energy [19-20] are as follows:

- One of the advantages of biomass over fossil fuels is its lesser emission of Greenhouse gases. The amount of carbon dioxide released in the atmosphere from biomass energy conversion is just equivalent to the amount absorbed by plants during their life cycle.
- Biomass can be converted into methane, ethanol, biodiesel and heat energy, each of which has unique applications.

- Biomass is abundant, because its ingredients such as garbage, crop residue etc. are present in plenty.
- Biomass energy generation reduces the waste produced naturally and by human beings.
- The cost incurred in Biomass energy generation is sufficiently lower than fossil fuel energy generation.
- Biomass energy conversion is possible at domestic level.

There are some disadvantages of biomass [21-22]. Firstly, it is not good for regions where plants are not in abundance since more Green-house gasses will pollute the atmosphere. Also, it is costly as compared to other renewable energies; the increased cost is due to installation and transportation of its ingredients. The domestic biomass users may cut plants which can result in deforestation. Further, it needs an abundant source of water.

Being an agricultural country Pakistan has a huge potential of biomass energy, especially in rural areas. In rural areas, tons of crop residue becomes available every year [23]. In Pakistan live-stock, agriculture and forestry are main sources of biomass [24]. About 652 million kg of manure is produced per day from cattle and buffalos that can produce 21 million biofertilizer per year and 16.3 million cubic meter biogas per day [25]. In 1979, Pakistan Council of Renewable Energy Technologies (PCRET) initiated Biogas Technology projects. In the start of the project, twenty-one small units of biogas were installed. These units were imported from China. The program was suspended due to various technical reasons. In later stage, 1200 family size Indian design units with some modification were launched on public and private cost. This program was successful and got positive response from the public. PCRET launched another program in 2007 as well and with a subsidy of Rs. 17000, 2500 biogas plants were installed.

According to PCRET [5], 19.125 Million m^3 biogas can be produced daily by anaerobic fermentation of dung through installation of about 3.825 million family size biogas plants.

This is sufficient to meet the cooking-heating requirement of 44% rural masses and to produce 57.4 million kg of nitrogen enriched bio-fertilizer per day or 21.00 million tons of bio-fertilizer per year. Bio-fertilizers are an essential requirement for sustaining the fertility of agricultural lands. The Government of Pakistan has asked PCRET to launch mega project on the biogas technology by installing 25,000 biogas units all over the country to not only cater the needs of cooking but also for agriculture and commercial purposes in order to meet the shortage of gas and electricity in the country.

The World Bank and Alternative Energy Development Board (AEDB)-Government of Pakistan are implementing a Renewable Energy Resource Mapping activity covering all parts of Pakistan. The main focus will be on Punjab and Sindh provinces. The project is funded by World Bank's Energy Sector Management Assistance Program (ESMAP). Total budget of the project is US $ 4.35 million. Punjab and Sindh have great potential of biogas; biogas is being produced from some projects installed in these provinces. At present biogas projects are producing 201MW in Punjab (Rahim Yar Khan 133.75MW, Layyah 41MW) and Sindh (Ghotki 26.35MW). The status of biogas in Pakistan is shown in fig. 5.

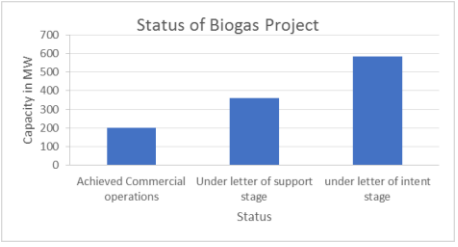

Fig. 5. Status of Biogas in Pakistan [9]

Solar energy

By Solar energy we mean energy received from sun. Various nuclear reactions at sun produce enormous energy. Two main parts of solar energy are (i) heat energy and (ii) light energy

[26]. Both light and heat energies coming from sun are renewable energies that can be utilized to provide heat and light to houses and to generate electricity. Solar power is a much better source of clean energy [27]. It can be harnessed with solar heating, photovoltaic, artificial photosynthesis and solar thermal electricity. Solar energy is the best source of energy available because of simple installation, predictable power outputs, long system lifespan and low maintenance [28]. In the upper atmosphere the earth receives 174 petawatts of solar radiation. About 70% is absorbed by clouds, oceans, and land masses, and the rest is reflected. Pakistan is blessed with one of the highest solar irradiances in the world and can thus produce a large amount of electricity using solar power [29].According to The Institution of Engineers Pakistan, Karachi Centre (IEP) an average annual solar irradiance of 5.5 kWh/m^2/day and over 50,000 megawatts of solar energy resources is estimated. On the other hand, the Islamabad Chamber of Commerce and Industry estimates Pakistan's solar potential to be 100,000 megawatts. Pakistan's current average electricity demand is about 27000 megawatts, and the amount of solar power available through sunlight round the year in the entire country alone can easily meet this demand.

There are 24 existing solar power projects, these projects started in 2011 to 2015 and are expected to be commissioned next year. Sixteen projects are laid in the province of Punjab and eight in Sindh Province. Pakistan intends to increase solar power generation capacity to 1556 MW by the end of 2018. The yearly cumulative capacity of solar power generation is shown in fig. 6.

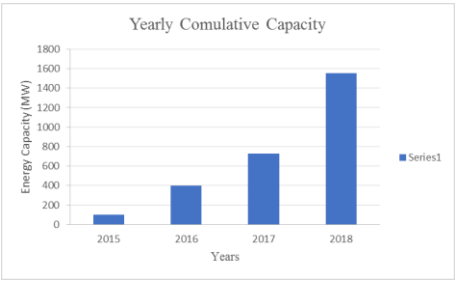

Fig. 6. Year wise cumulative capacity of Solar power in Pakistan.

Tidal Energy

Tidal energy or tidal power is the energy produced by tides and ocean waves. Tidal energy is clean sustainable energy for future generations [30]. Tidal energy is the result of (i) gravitational pull of sun and moon on sea water (gravitational force of moon on earth is approximately twice of that between earth and sun), and (ii) due to centrifugal forces between earth-sun and earth-moon systems [30]. Gravitational forces produce a bulge of water from earth to moon whereas centrifugal forces produce another water bulge along earth, the two water-bulges together cause tides. The tides and waves both are oscillating energy. At present, turbines are used to generate energy from incoming and outgoing waves. In tidal current turbine both kinetic and potential energies can be harnessed from tides for generation of electricity.

Tidal energy has great potential and is highly predictable source of electricity generation, hence, is less challenging than other forms of renewable energies [31-35]. In different regions of the world, extremely high tidal currents are observed, where tidal current up to 7 m/s is formed [35]. In the last few decades, tidal energy has been used as an alternative to fossil fuel to produce electricity in many countries [38]. France was the first country to use tidal energy on a large scale to produce electricity. In 1967, at La Rance tidal barrage was constructed [31].

Inhabitants of coastal areas in Pakistan are living the worst life because of shortage of electricity. Indigenous capabilities of harnessing tidal power to generate electricity could uplift the socio-economic conditions of these inhabitants. So far very little research has been done on tidal energy potential in Pakistan. Only limited surveys were carried out by National Institute of Oceanography, Pakistan. The typical current velocity shown by the survey is 2.05-2.57 m/s but at some places it could be found as high as 4.11 m/s in creeks that extend from Korangi Creek near Karachi to Kajhar Creek near the Pakistan-India border. A total of 1100kW power generation is expected to be generated from these creeks. The Kalmat Khor and SonmianiHor also have good prospects to harness tidal energy in the Balochistan province coastal belt [36].

According to PCRET and AEDB tidal energy has not been explored and exploited yet in the country. Pakistan has about 1000 km long coastline with complex network of creeks in the Indus deltaic area. Thetidal heights along the Pakistan coast vary between 2 to 5 meters. The power resource potential of the coastline is a great asset for future energy supply in Sindh and Balochistan provinces of the country which needs to be exploited.

Insaf et al. conducted two studies for estimation of tidal energy potential at two different locations of Karachi, Ghizri and Jhari [30,37]. It is estimated that 2.29 MW (with tidal turbine efficiency of 40% and using one way generation scheme only) electricity can be generated in summer by using tidal range technology with a proposed basin area of 5.02 km^2 at Ghizri creek (see fig.7), Karachi. Moreover, 4.96 MW electricity can be produced during summer by using tidal range technology with a proposed basin area of 7.68 km^2 at another potential site; Jhari creek (see fig. 8), Indus delta, Sindh province.

Fig. 7. Ghizri Creek

Fig. 8. Jhari Creek

A study on tidal resource arrangement was carried out at MianiHor (see fig. 10) [38]. MianiHoris located inSomiani Tehsil of Balochistan province. The lagoon is more than 40 km long. The site has appreciable tidal potential, and with the use of proper tidal technology enough electrical power can be generated which could meet the requirement of villages nearby and other locations. Another study was carried out on Hajambro creek (see fig. 9) [39], which is in District Thatta of Sindh province. The creek is 10 km long. This creek has great potential to cater electricity need of people living around the site. Due to the lack of basic necessities people have continuously been migrating to other cities. If tidal energy is harnessed properly at Hajambro, the migration could be stopped.

Fig. 9. Hajambro Creek

Fig. 10. Miani-Hor Greek

There are seventeen major creeks in Indus Delta region including four mentioned earlier, and it is estimated that power generated from all these creeks would be around 84.32 MW. Therefore, total 86.61 MW power could be generated from Karachi and Indus Delta region using tidal range technology. This power could be utilized in providing electricity to about 145,000 to 165,000 households living around these two sites.

CONCLUSION

Globalization in its wake has brought forth an interconnection between energy, economics and politics. Energy is instrumental in shaping the lives of people in this era of cutting edge technologies and no economy can surge forward without uninterrupted and continued electric supply. Efficient, cost effective and continued source of renewable energy supplies are gifts of nature and they need to be harnessed to meet the ever-growing demands of mankind. Energy demand in 21st century has increased manifold leading to shortages in consumption and production. The best possible solution is to exploit renewable energy resources which are in unlimited supply and can be used to bridge the gap between demand and supply. Worldwide consensus has evolved on safe resources energy which nature has gifted to mankind.

Pakistan is geographically located in a blessed region, where all sorts of renewable energy sources are available in unlimited volume. Balochistan, Sindh, and Northern areas are best for wind energy farms. Khyber Pakhtunkhwa and Punjab are enriched in hydel power. Sindh and Punjab have great potential of biogas. Therefore, the entire country has enormous potential of renewable energy.

The recent studies on assessment of tidal potential show encouraging results for harnessing tidal energy in Pakistan and it is proposed as a new candidate for renewable energy mix in the country. However, more investigations and surveys are

required along the coast, where there are natural tidal lagoons. Surveys and investigations are also particularly required in creek region of Sindh province where there is a significant potential of extracting tidal stream energy.

REFERENCES

[1] Suganthi, L., & Samuel, A. A. Energy models for demand forecasting—A review. Renewable and sustainable energy reviews 2012; 16(2):1223-1240.

[2] https://www.indexmundi.com/facts/pakistan/electric-power-consumption(Accessed 10 Nov. 2017)

[3] https://photius.com/rankings/2015/energy/electricity_consumption_per_capita_2015_1.html(Accessed 10 Nov. 2017)

[4] https://tradingeconomics.com/pakistan/electric-power-consumption-kwh-per-capita-wb-data.html (Accessed 10 Nov. 2017)

[5] http://www.pcret.gov.pk/Services.html (Accessed 13 Nov. 2017)

[6] Mirza, U. K., Ahmad, N., Majeed, T., &Harijan, K. Wind energy development in Pakistan. *Renewable and Sustainable Energy Reviews* 2007; *11*(9): 2179-2190.

[7] http://www.aedb.org/index.php(Accessed 13 Nov. 2017)

[8] Ackermann T, So¨ der L. Wind energy technology and current status: a review. Renew Sustainable Energy Rev 2000;4(4):315–74.

[9] http://www.aedb.org/index.php/ae-technologies/wind-power/wind-current-status(Accessed 13 Oct. 2017)

[10] World Commission on Dams. Dams and development: a new framework for decision-making. UK: Earthscan Publications Ltd.; 2000.

[11] Mirza, U. K., Ahmad, N., Majeed, T., &Harijan, K. Hydropower use in Pakistan: past, present and future. Renewable and Sustainable Energy Reviews 2008; 12(6): 1641-1651.

[12] Javaid, M. A., Hussain, S., Maqsood, A., Arshad, Z., Arshad, A., & Idrees, M. Electrical energy crisis in Pakistan and their

possible solutions. International Journal of Basic & Applied Sciences IJBAS-IJENS 2008; 11(05): 38.

[13] Bhutto, A. W., Bazmi, A. A., & Zahedi, G. Greener energy: Issues and challenges for Pakistan-hydel power prospective. Renewable and Sustainable Energy Reviews 2012; 16(5): 2732-2746.

[14] Government of Pakistan. Pakistan Economic Survey 2004–05 and 2005–06. Islamabad, Pakistan: Economic Advisers Wing, Ministry of Finance; June 2005 and June 2006.

[15] Demirbaş, A. Biomass resource facilities and biomass conversion processing for fuels and chemicals. Energy conversion and Management 2001; 42(11): 1357-1378.

[16] Paine, L. K., Peterson, T. L., Undersander, D. J., Rineer, K. C., Bartelt, G. A., Temple, S. A., &Klemme, R. M. Some ecological and socio-economic considerations for biomass energy crop production. Biomass and Bioenergy 1996; 10(4): 231-242.

[17] Grande, J. D., Karthikeyan, K. G., Miller, P. S., & Powell, J. M. Corn residue level and manure application timing effects on phosphorus losses in runoff. Journal of environmental quality 2005; 34(5): 1620-1631.

[18] Balat, M., &Ayar, G. Biomass energy in the world, use of biomass and potential trends. Energy sources 2005; 27(10): 931-940.

[19] Sims, R. E., Rogner, H. H., & Gregory, K. Carbon emission and mitigation cost comparisons between fossil fuel, nuclear and renewable energy resources for electricity generation. Energy policy 2003; 31(13): 1315-1326.

[20] Abbasi, T., & Abbasi, S. A. Biomass energy and the environmental impacts associated with its production and utilization. Renewable and Sustainable Energy Reviews 2010; 14(3): 919-937.

[21] Han, J., & Kim, H. The reduction and control technology of tar during biomass gasification/pyrolysis: an overview. Renewable and Sustainable Energy Reviews 2008; 12(2): 397-416.

[22] Omer, A. M. Energy, environment and sustainable development. Renewable and sustainable energy reviews 2008; 12(9): 2265-2300.

[23]Meryem, S. S., Ahmad, S. S., & Aziz, N. Evaluation of biomass potential for renewable energy in Pakistan using LEAP model. Inter. Jour. of Emerging Trends in Eng. and Develop 2013; 1(3): 243-249.

[24]Malik, S. N., &Sukhera, O. R. Management of natural gas resources and search for alternative renewable energy resources: A case study of Pakistan. Renewable and Sustainable Energy Reviews 2012; 16(2): 1282-1290.

[25]Amjid, S. S., Bilal, M. Q., Nazir, M. S., & Hussain, A. Biogas, renewable energy resource for Pakistan. Renewable and Sustainable Energy Reviews 2011; 15(6): 2833-2837.

[26]Glaser, P. E. Power from the sun: Its future. Science 1968; 162(3856): 857-861.

[27]Singh, G. K. Solar power generation by PV (photovoltaic) technology: A review. Energy 2013; 53: 1-13.

[28]Mekhilef, S., Saidur, R., & Safari, A. A review on solar energy use in industries. Renewable and Sustainable Energy Reviews 2011; 15(4): 1777-1790.

[29]Mirza, U. K., Maroto-Valer, M. M., & Ahmad, N. Status and outlook of solar energy use in Pakistan. Renewable and Sustainable Energy Reviews 2003; 7(6): 501-514.

[30]Insaf, A., Baig, M. S., Kausar, A., Rauf, T., Shahzad, M., Khan, S. A., & Uddin, Z Estimation of various tidal parameters and possibility for harnessing tidal energy along the southeast coastal area of Karachi, Pakistan. Science International, 2016; 28(1):179-185

[31]MontllonchAraquistain, T. TIDAL POWER: Economic and Technological Assessment 2010.

[32]Wright, J., Colling, A., & Park, D. (Eds.). Waves, tides, and shallow-water processes (Vol. 4). Gulf Professional Publishing 1999.

[33]Bryden, I. G., Grinsted, T., & Melville, G. T. Assessing the potential of a simple tidal channel to deliver useful energy. Applied Ocean Research 2004; 26(5): 198-204.

[34]Bahaj, A. S. Generating electricity from the oceans. Renewable and Sustainable Energy Reviews 2011; 15(7): 3399-3416.

[35]Rourke, F. O., Boyle, F., & Reynolds, A. Tidal energy update 2009. Applied Energy 2010; 87(2): 398-409.

[36] Zaigham, N. A., & Nayyar, Z. Prospects of renewable energy sources in Pakistan. Renewable Energy Technologies and Sustainable Development 2005; 65-86.

[37] Baig, M. S., Uddin, Z., &Insaf, A. An Initial Tidal Power Resource Estimation at Jhari Creek of Indus Delta, Sindh, Pakistan. Journal of Basic and Applied Sciences 2017; 13: 545-550

[38] Ambreen Insaf, Zaheer Uddin, Mirza Salman Baig, "An initial assessment of tidal energy resources using GIS for MianiHor, Baluchistan province, Pakistan" (Submitted to Renewable Energy)

[39] Mirza Salman Baig, Zaheer Uddin, Ambreen Insaf, Anila Kausar. Tidal energy resources assessment using GIS technique at Hajambro creek of Indus delta, Sindh, Pakistan, (Submitted to Current Science)