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A Pathway for Sustainable Energy Development in Pakistan and Other Developing Countries

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Abstract

Pakistan is facing a severe energy crisis nowadays and a large proportion of population still have no access to electricity, which is essential need of modern-day life. To overcome energy shortage, the country needs to diversify its energy mix portfolio through use of hydropower, solar photovoltaic, solar thermal, geothermal, biomass, and wind. These alternative sources of energy and technologies can help in electrifying the off-grid communities in the southern and western deserts and the northern hilly areas of the country. The development of renewable energy technologies will reduce dependency on primary energy resources for power production and will benefit the economy of the country. In this paper, the current energy scenario of Pakistan and potential alternatives to overcome the energy shortage are discussed in detail from variety of aspects. Pakistan has a large potential of the renewable energy sources, which can be utilized to overcome the energy crises. But these resources are not been utilized properly due to poor policies and infrastructure barriers. The diversification of existing energy resources is very important for development and implementation of energy efficient technologies in the country.

1. Introduction

The future global energy demands cannot be fulfilled by the use of only non-renewable resources because of changing lifestyle and rapid increase in population. The productions of electricity from fossil or nuclear fuels induce substantial social and environmental costs. On the contrary, the usage of renewable sources has far less adverse environmental impact and lower costs of realization. The energy cost from different resources can be divided into a number of categories which must be considered while comparing technologies. The seven most effective categories for comparison of different technologies are shown in Figure 1 [1]. The global share of renewable energy in the power sector is increasing with time. The hydroelectric generation being the oldest and most mature form of bulk power generation has a share of 15.3% whereas only 5% was contributed by other renewable generations. The changing global scenario of power generation over the years is presented in Figure 2 [2, 3]. The increasing diversity of energy sources over time shows that various countries will have wider energy options available to them as compared to past. Figure 3 summarizes an overview of energy access in developing Asian countries. It can be observed that at present much areas still need to be electrified which arises the need to properly utilize the available renewable energy sources.

Renewable energy generation has initial cost disadvantages when compared with non-renewable fossil fuel sources of energy production [4]. But over the life cycle these technologies are effective in term of both financially and environmentally. The cost of renewable technologies is

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decreasing rapidly as it can be observed from Figure 4 for solar cell. The cost of a PV solar cell has decreased rapidly over the years.

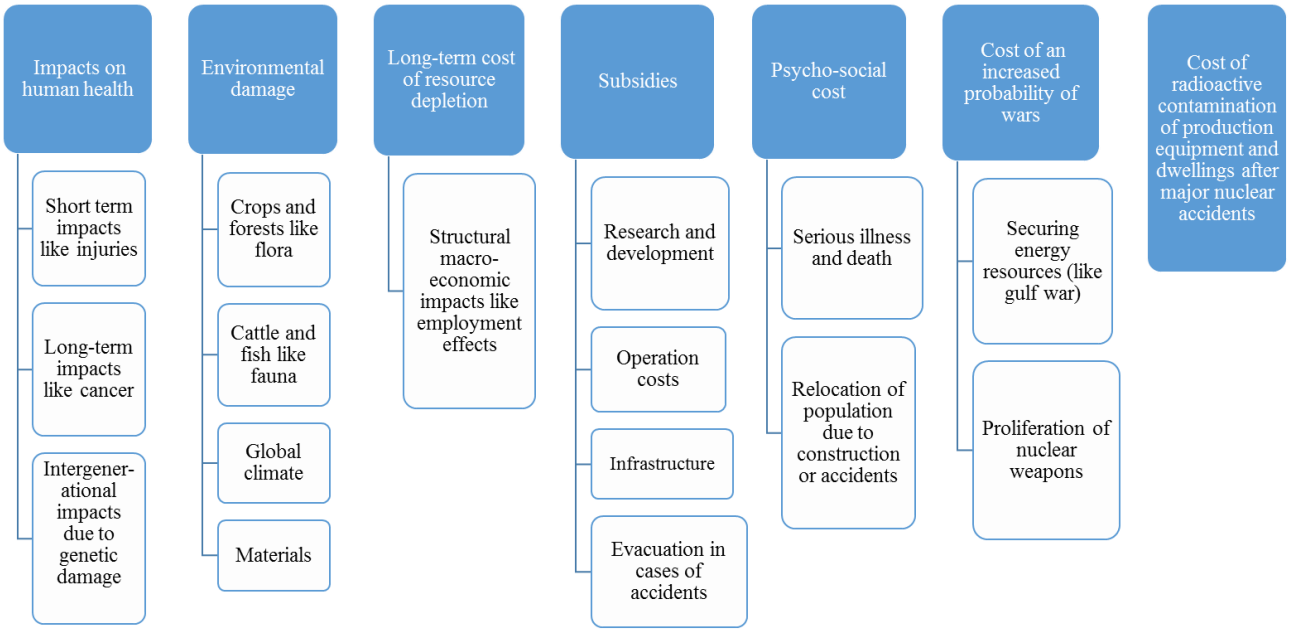

Figure 1. Categories for comparison of different technologies [1].

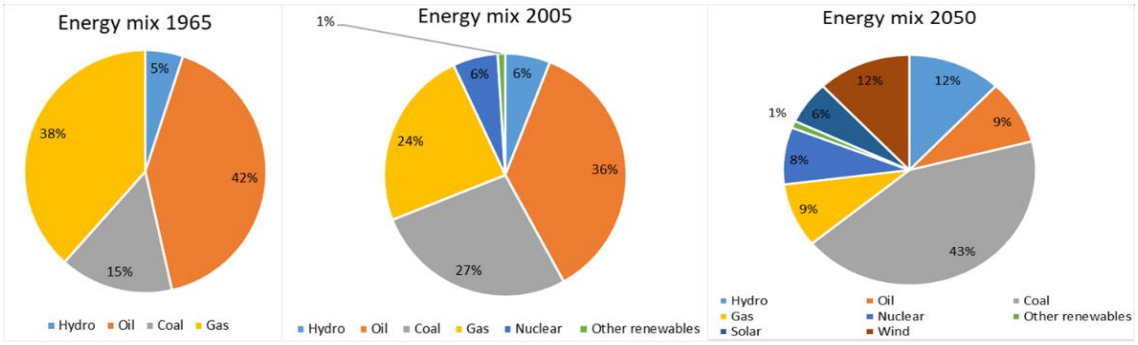

Figure 2. Changing global scenario of power generation [2, 3].

The electricity production in Pakistan mainly depends on conventional sources of fuel whereas the share of renewable energy in the total energy mix is virtually negligible. Approximately 94,653 GWh of electricity is being generated by oil and gas. The main contributors in the energy mix are thermal power, hydel and nuclear [5, 6]. The common perception about the use of renewable energy resources is the cost disadvantage but the increasing prices of fossil fuel in Pakistan and the abundant availability of renewable energy resources may help in achieving the grid parity. Pakistan has a great advantage of weather condition as the sun shines throughout the year and therefore country has a great potential for solar energy. However, in order to increase an environment-friendly solar energy production, many policy decisions and steps needs to be taken

by the governments of Pakistan. A proper financial support system such as tax rebate, feed-in tariff, grid connectivity, and a mechanism to provide sufficient funds should be ensured by government [7].

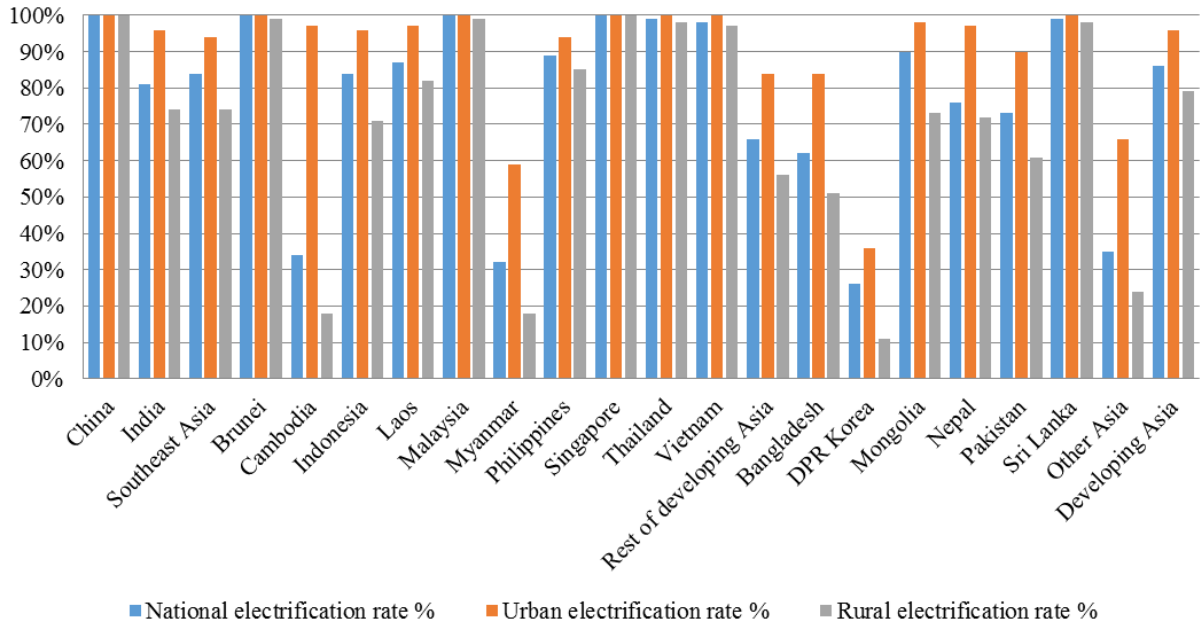

Figure 3. Electricity access in developing Asia - 2016. (*Source: IEA, World Energy Outlook 2016*).

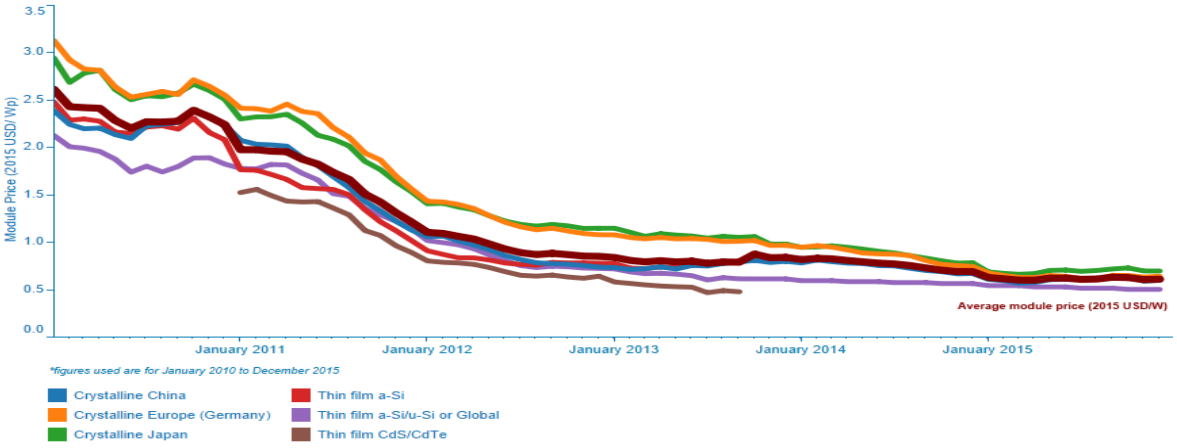

Figure 4. Cost of PV cell over the time. (*Source: IRENA*).

Fossil fuel is a widely used method to produce electricity, but a large amount of CO_2, NO*x* and CO*x* emissions are caused by fossil fuel-based generation of electricity. A greenhouse gas emission tax can help for the development of renewable energy sector and the other option is Feed-in-Tariff (FiT). FiT is the commonly used renewable energy policy worldwide and considered as one of the most attractive ways to boost the renewable energy deployment by providing security to investors. Thailand was one of the first Asian countries to introduce the FiT program called Adder. This provision provides additional subsidies to renewable energy

developers and investors on top of the normal energy prices that power companies would receive when selling electricity to the power utilities.

Different policies are proposed over the years to meet power demands of Pakistan but are not implemented yet. The energy mix of the country mainly compromises of expensive furnace which is not sustainable. The world, even the neighboring countries like India is moving towards alternative and sustainable solutions. A comparison of Pakistan's energy mix with India and world is presented in Figure 5. There is a need to implement policies to make the energy mix of the country sustainable and beneficial.

In this paper, the main reasons for the energy shortfall in Pakistan are being discussed and potential solution is presented. An increased use of fossil fuel for power generation is not only a burden on economy of the country but also eco-unfriendly option. Pakistan has a vast potential of renewable energy technology which if harnessed properly could overcome energy shortfall issues.

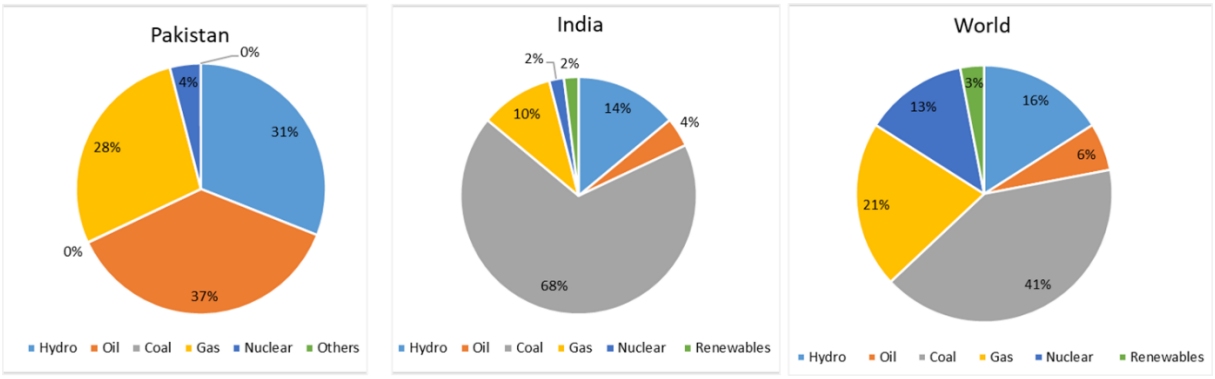

Figure 5. Comparison of energy mix. (*Sources: Overseas Investors Chamber of Commerce & Investments (OICCI) Pakistan, Energy Sub Committee, NEPRA's State of Industry Report 2013*).

2. Energy resources and their contribution

The primary energy supply of Pakistan in the financial year 2009-2010 was 63.088 million tons of oil equivalents (MTOE). Energy resources like natural gas, oil, hydro, nuclear, coal, and liquefied petroleum gas (LPG) contributed 48.8, 31.4, 11.8, 7.3 and 0.6% of primary energy supplies respectively [8]. Nearly 87% of the energy dependency was on the fossil fuels and the remaining on Hydro and Nuclear and only less than 1% share was given to renewable energies. The installed generation capacity increased by just 0.92% from 2003-2010 whereas the energy demands increased by almost 12%.

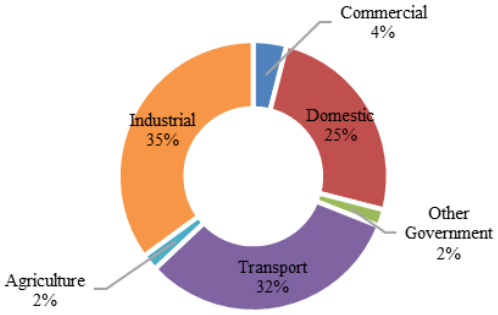

Figure 6. Sector-wise energy consumption in Pakistan [10].

This increased electricity demand and supply gap has caused huge economic losses to the nation as a whole and industrial sector in particular. As a result of reduced production from industries, the export sector of the country is affected tremendously [9]. The sector wise energy consumption is shown in Figure 6 [10].

3. Energy scenarios and its impacts

According to the Pakistan Electric Power Company, the real-time power shortfall in May 2012 reached to 6,000 MW while the known estimated demand was 15,000 MW [11, 12].

The statistics of Hydrocarbon Development Institute of Pakistan (HDIP), 94,653 GWh of electricity was generated during 2010-11. The share of thermal power was 62.5% followed by hydel (33.6%) and nuclear (3.9%). In thermal power generation oil had the largest share of 35.1% followed by natural gas 27.3% and coal 0.1% as shown in Figure 7. Solar and wind power are planned to be integrated in the power system but as of now only hydel power is connected to the grid power system. The electricity deficit or the gap between the supply and demand is increasing every year, as it can be observed from Figure 8 [13]. The economy of the country will also be severely affected by the projected demand-supply deficit by 2030. The overall exports have also been reduced due to this shortfall in energy supply. The present energy situation is affecting the industrial output negatively and crippling the economy of the nation. The economic indicators show that the economy of Pakistan is costing 2.5 billion USD each year due to this energy shortfall. This factor alone is responsible for about 2% annual burden on the GDP of the country. Additionally, about 400,000 people within Pakistan loose employment opportunities each year [14] which is another shock to the national GDP. The World Bank survey revealed that the electricity shortage is a major obstacle of the business retardation in Pakistan which accounts for around 66.7% followed by corruption 11.7% and crime 5.5%, [15]. Small businesses are almost paralyzed in the country as stated by Leiby and Siddiqui et al. [16, 17].

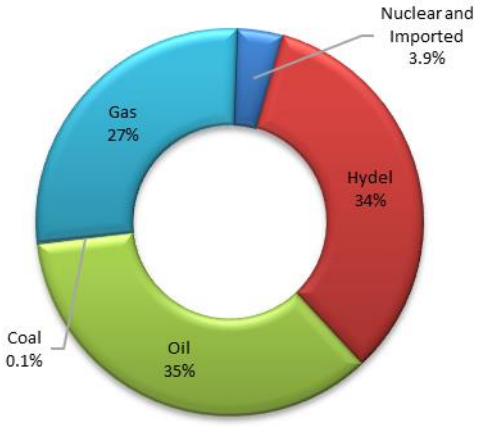

Figure 7. The electricity generation share by source in Pakistan.

The increased demand in electricity is a long-term contributing factor to the increased power shortages during the past three decades. In 1980s, the average growth rate in electricity demand was about 11% per year which declined to 4% per year by the 1990s. In the present scenario the growth rate has reached to about 6% per year as shown in Table 1 [18]. The rapid growth in electricity demand was aggravated by subsidized tariffs, which declined by 24% in real terms during the 1980s as given in Pasha and Malik [19]. The major increase of electricity

consumption of 23% was reported in the domestic sector during 1980-1981 and 46.5% in 2010-2011. The consumption of electricity by sector is shown in Figure 9 [5]. Another major reason of shortfall in electricity production is that the share of public sector in power production dropped to less than 3% which was around 28% in 1980s [20]. Table 2 presents a summary of electricity scenarios in Pakistan [21]. The estimations show that the shortfall in electricity may increase to 8,000 MW by year 2017 and 13,000 MW by 2020 [22].

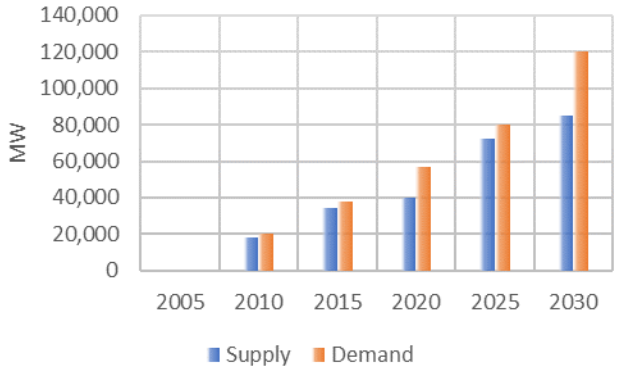

Figure 8. Peak electricity demand vs. supply projections for Pakistan [13].

Table 1. Demand and supply growth rates of electricity (ACGR %) [18].

Years	Demand	Supply	
		Installed capacity	Generation
1972-1980	8.6	8.3	8.9
1981-1990	10.9	6.8	9.9
1991-2000	4.2	8.5	5.4
2001-2008	6.1	1.5	5.0

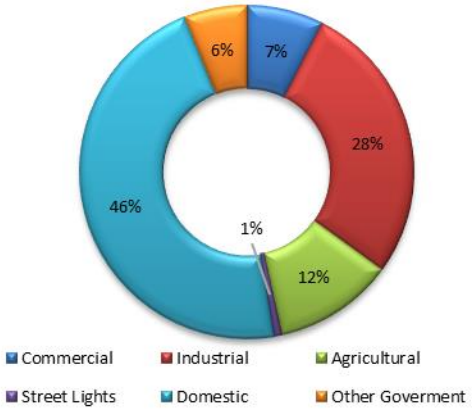

Figure 9. Electricity consumption by sector, 2010-2011 [5].

Table 2. Historic demand and corresponding generation capacity [21].

Fiscal year	Computed peak demand(MW)	Supply (MW)	Surplus/Shortfall (MW)
2001-2002	10,459	10,894	435
2002-2003	11,044	10,958	−86
2003-2004	11,598	11,834	236
2004-2005	12,595	12,792	197
2005-2006	13,847	12,600	−1247
2006-2007	15,838	13,292	−2546
2007-2008	17,398	12,442	−4956
2008-2009	17,852	13,637	−4215
2009-2010	18,467	13,445	−5022

4. Renewable energy project proposals

In spite of the potential and importance of solar energy in the government circles, the economic position of Pakistan and poor governance does not allow providing grants for the development and promotion of this technology. Therefore, in order to promote these technologies, the support of international funding agencies is very important. Some of the funded projects by different organizations in the country are shown in Figure 10 [23]. Currently plug and play PV technology is employed in Pakistan for standalone highway emergency telephones, rural telephone exchanges, cathodic protection, microwave link repeater stations, cellular towers, refrigeration for vaccine and medicines in hospitals etc. Along with this the Public Health Department has installed almost 20 solar water pumps for water drinking purposes in far remote areas of Baluchistan [24]. The total installed capacity of such photovoltaic applications is around 1000 kW [25].

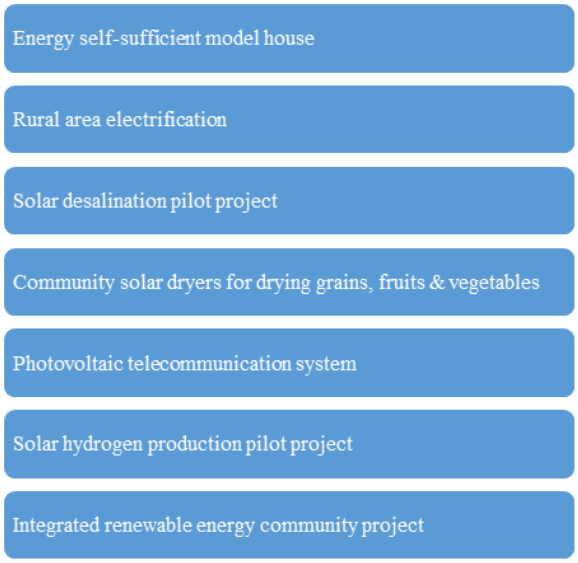

Figure 10. Solar energy project proposals [23].

It is believed that for installing solar PV appliances like water pumps, streetlights etc., the average daily solar radiation in the least sunny month should be greater than 3.5 kW/m^2 on a horizontal surface (International Solar Energy Society). Pakistan receives an average of almost 7.6 hours of sunshine per day with average solar radiation of 5-7 kW h/(m^{2}day) over more than

95% of its area with persistence factor of over 85% [26]. Therefore, the conditions for harnessing solar energy are excellent for the sustenance of solar applications.

The national policy provided the fixed and running budget of US$ 2.2 billion of the mega project of 1,400 MW in Ghazi Barotha Dam (hydropower project) or 1.571 million per/MW of installed capacity whereas the solar thermal power system is expected to cost only US$ 670,550 per MW of installed capacity around 40% of the cost of hydropower installation. This confirms a direct saving in capital investments through the operational and maintenance cost of both the systems may be the same [27]. The efficiency of solar systems is about to be increased with time and hence will cause further decrease in its capital. Some of the developments related to solar energy technology carried out by Pakistan Council of Renewable Energy Technologies (PCRET) and Alternative Energy Development Board (AEDB) to benefit the society are presented in Figure 11 and 12 [28]. The details of different research and development organizations and manufacturers across the country are illustrated in Figure 13, 14 [29].

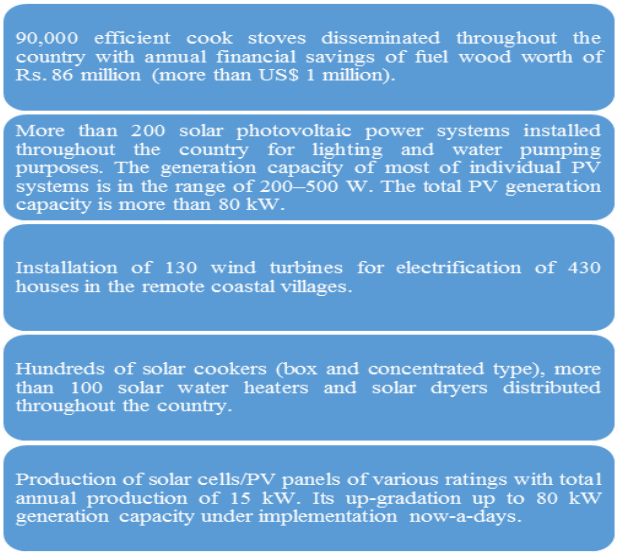

Figure 11. Developments by PCRET [28].

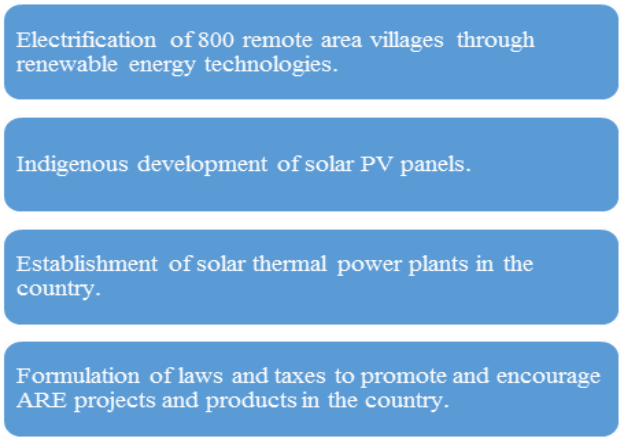

Figure 12. Developments by AEDB [28].

Figure 13. Information about national organizations related to renewable energy [29].

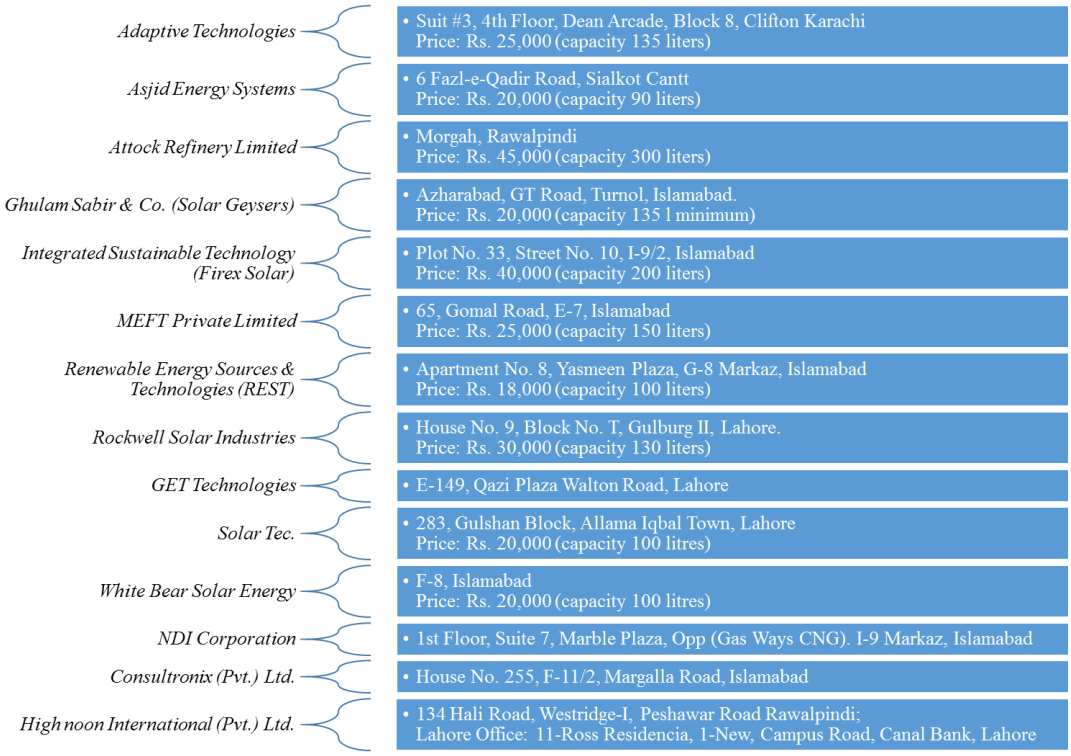

Figure 14. Details and location of manufacturers of solar appliances in Pakistan [29].

5. Recommendations

In order to make the solar energy technologies acceptable for the community, the following suggestion are made:

- Pakistan is blessed with high solar energy intensities and long hours of sunshine duration and must contribute at least 10% of its energy demand through solar energy technologies. To achieve this goal, favorable policies and laws needs to be framed and enforced by the Government which can encourage and attract local and foreign investments to meet the set solar deployment goals.
- Government organizations are working in the implementation of solar energy for more than two decades but most of the projects are still in infancy stage hence actions need to be taken for proper implementation.
- The technology adoption and installation quality need to be improved. International standards should be followed for designing, manufacturing, installing, and commissioning of the renewable energy related projects and applications.
- Safety measures should be given priority and proper training should be given to engineers, technicians, and support staff involved with renewable energy related projects and applications to minimize accidents and miss happenings.
- National agenda, interest, and progress should be the priority of the law and policy makers, organizations, institutions, and all decision makers involved in the process of renewable energy-related project realization.
- Government must pay attention to provide and promote the reliable, efficient, and low-cost technologies in the country. Subsidies and tax benefits should be provided to achieve these goals.
- Students should be provided financial assistance and to be encouraged to take part in renewable energy related research projects at school, college and university levels.
- Renewable energy awareness programs should be advertised through television, writing articles in print media, conducting symposia, conferences and exhibitions.
- For proper training of local manpower, international cooperation should be sought.

6. Conclusions

In this paper, status of present energy scenarios and its impacts have been discussed from the perspective of overcoming energy crisis in the country. In order to enhance the energy production in the country, the government should make the policies in three steps which should be interlinked through loop. The first element in the loop is to frame rules and regulations and set a renewable energy achievable target, the second element is to provide subsidies to encourage investors and the last element is to find the investors. If the financial resources are not sufficient to fund the program, then look back to the first step and reset the targets. This three-tier loop/model is important for long term and continuous and sustainable development of renewable sources of energy in Pakistan and in any other country.

7. References

[1] O. Hohmeyer, The social costs of electricity-renewables versus fossil and nuclear energy, International journal of solar energy, vol 11(3-4), pp. 231-250, 1992.

[2] World Energy to 2050. Forty Years of Decline (http://www.paulchefurka.ca/WEAP2/WEAP2.html) (Acessed on July 01, 2017).

[3] A. B. Awan and Z. A. Khan, Recent progress in renewable energy-Remedy of energy crisis in Pakistan, Renewable and Sustainable Energy Reviews, vol 33, pp. 236-253, 2014.

[4] S. Tongsopit and G. Chris, An assessment of Thailand's feed-in tariff program, Renewable Energy, vol 60, pp. 439-445, 2013.

[5] HDIP. Hydro-carbon Development Institute of Pakistan, Pakistan Energy Book, 2012.

[6] N. H. Mirjat, M. A. Uqaili, K. Harijan, G. D. Valasai, F. Shaikh and M. Waris, A review of energy and power planning and policies of Pakistan, Renewable and Sustainable Energy Reviews, vol 30(79), pp. 110-27, 2017.

[7] M. M. Rafique and S. Rehman, National energy scenario of Pakistan-Current status, future alternatives, and institutional infrastructure: An overview, Renewable and Sustainable Energy Reviews, vol 31(69) pp. 156-67, 2017.

[8] A. K. Basit, Pakistan energy yearbook, Government of Pakistan, Ministry of Petroleum and Natural Resources, Dec. 2010.

[9] H. S. Pervez, Potential of green house gas abatement of domestic lighting in HESCO region, M.E Thesis, Mehran University Jamshoro (MUET), EL Dept., July 2011.

[10] HDIP. Hydro-carbon Development Institute of Pakistan, Pakistan Energy Book 2014.

[11] Z. Ebrahim, Pakistan energy shortfall fuels row over coal power plants, The Guardian 2012.

[12] T. E. Tribune, Countrywide energy shortage as PEPCO increases loadshedding, 2011, (http://tribune.com.pk/story/154420/countrywide-energy-shortage-as-pepco-increases loadshedding/)(accessed on March 10, 2017).

[13] IEEEP. Renewables and electric power deficit, 2012 (www.ieeep.org.pk/) (accessed on Febraury 9, 2017).

[14] S. Aziz, State of the Economy-Emerging From Crisis 2008, Beacon House National University publication, 2008.

[15] Corporation, IF. Enterprise Surveys-Pakistan, The World Bank 2007.

[16] R. Leiby, Pakistan's power crisis May eclipse terrorist threat, The Washington Post, 2012(http://www.aboardthedemocracytrain.com/pakistans-power-crisis-may-eclipse-terrorist-threat) (accessed on March 9, 2017).

[17] R. Siddiqui, H. Jalil, M. Nasir, W. Malik and M. Khalid, The Cost of Unserved Energy: Evidence from Selected Industrial Cities of Pakistan, PIDE Working Papers, pp. 75 2011.

[18] State of the Economy: Emerging from the Crises Beaconhouse National University, Lahore 2009.

[19] H. Pasha and S. Malik, The economic cost of power outages in the industrial sector of Pakistan, Energy Economics, vol 11(4), pp. 301-318, 1989.

[20] State of the Economy: Pulling Back from the Abyss, Third Annual Report, Institute of Public Policy, 2010.

[21] Pakistan Power Sector: A Profile & Opportunities. 2010 (http://www.sari-energy.org/) (accessed on March 12, 2017).

[22] M. Shahbaz, Electricity Consumption, Financial Development and Economic growth Nexus: A Revisit Study of Their Causality in Pakistan, Munich Personal RePEc Archive Paper no. 35588. 2011.

[23] M. Asif and T. Muneer T. Life cycle assessment of built-in-storage solar water heaters in Pakistan, Building Services Engineering Research and Technology, vol 27(1), pp. 63-69, 2006.

[24] Ministry of Finance, (www.finance.gov.pk/) (accessed on March 7, 2017).

[25] M. A. Sheikh, Renewable energy resource potential in Pakistan, Renewable and Sustainable Energy Reviews, vol 13(9), pp. 2696-2702, 2009.

[26] M. Asif, Sustainable energy options for Pakistan, Renewable and Sustainable Energy Reviews, vol 13(4), pp. 903-909, 2009.

[27] U. K. Mirza, N. Ahmad and T. Majeed, An overview of biomass energy utilization in Pakistan, Renewable and Sustainable Energy Reviews, vol 12(7), pp.1988-1996, 2008.

[28] U. K. Mirza, N. Ahmad, T. Majeed and K. Harijan, Wind energy development in Pakistan, Renewable and Sustainable Energy Reviews, vol 11(9), pp. 2179-2190, 2007.

[29] A. W. Bhutto, A. A. Bazmi and G. Zahedi, Greener energy: issues and challenges for Pakistan-solar energy prospective, Renewable and Sustainable Energy Reviews, vol 16(5), pp. 2762-2780, 2012.