

Wind Power and Smart Grid as an Environmental Obligation in Context of Energy Security for Pakistan

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ABSTRACT

This paper presents a review on why Pakistan needs wind power. Future demand of the energy in Pakistan is predicted by using the population growth rate and per capita energy consumption of the last few years. Wind potential of Pakistan is compared with the other sources used for power generation along with the benefits of wind power generation for government and utilities. A brief introduction of wind role in future smart grid and techniques to implement it. Installation of wind power plants as an environmental obligation, obstacles to development of wind power and their solutions are discussed.

INDEX TERMS— Wind energy, Pakistan, Smart grid, Demand side management.

1. INTRODUCTION

Abundant, reliable, secure and cheap supply of electricity is vital for progress of any nation [1]. Industrialization is normally followed by increase in per capita consumption. If the power infrastructure is not expanded enough to meet increased energy demand; economy suffers, especially the manufacturing sector, followed by the increase in import and decrease in export. Rapid growth in per capita consumption (i.e. from 206.6 KWH in 1986 to 472.6 KWH in 2006 as shown in Fig. 1 [2]) with high population growth rate results in large increase in electricity demand. Till to date fossil fuel accounts for more than 80% of the world energy supply but these reserves are dwindling.

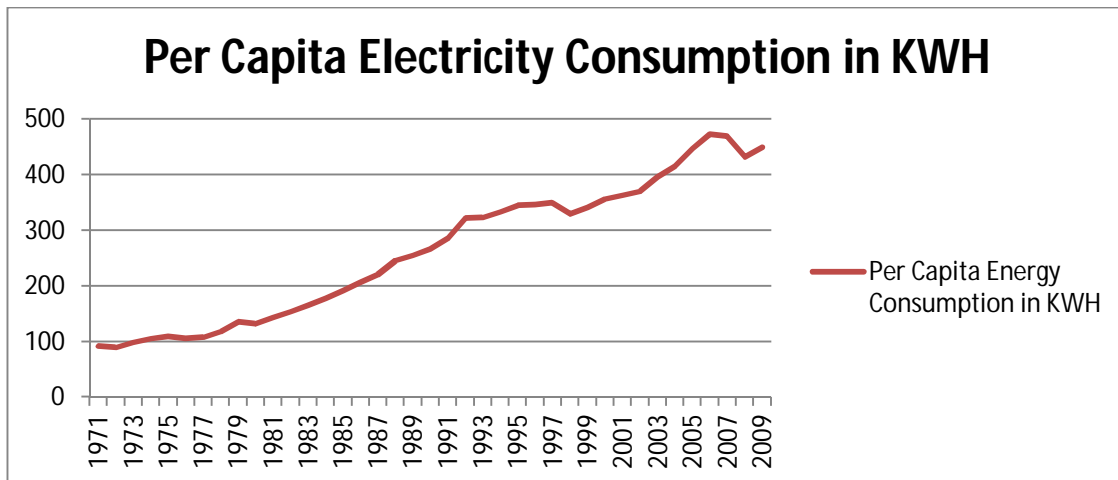


Fig. 1 Per Capita Energy Consumption of Pakistan in KWH

Non-exhaustible energy resources like renewable are exploited to much lesser extent. According to International Energy Agency(IEA) statistics 13.1% of primary energy supply of the world, 19.5% of global electricity generation and 3% of global energy consumption for road transport is meet by renewable in 2009 [3]. Wind is becoming most important renewable sources because of its environmental friendly behavior, free of cost availability and immunity to political instability in international market. Also wind power generation cost over life cycle is comparable with conventional energy sources [4]. For Pakistan, wind is good choice as its low-cost and surplus in Coastal areas. Other renewable source comparable to it is hydro power but in Pakistan it becomes difficult to exploit them because of difference of unanimity among province on its use. Fossil fuel reserves of Pakistan are

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either getting exhausted or have already drained. Also price hike in fossil fuel cost in international market make it difficult for Pakistan to import them in large quantity. An environmental concern on the fossil fuelled power generation by the various segments of the society is also pursuing the government towards the clean energy resources. In light of this changing scenario, Pakistan energy mix is very much dependent on renewable energy [5].

Smart Grid is the integration of the latest digital, control and communication technologies to the existing power grid in order to improve the system reliability and functionality. Smart grid will offer bidirectional flow of power and information as compared to the unidirectional power flow of old grid. Integration of the renewable and distributed generation is a key issue for future green energy. Wind power as one of the most important and abundant renewable source will play a decisive role for centuries to come. Smart grid implementation starts from installation of smart meters [6]. Wireless sensors like ZigBee, Bluetooth and Wi-Fi etc. are important for Demand Side Management (DSM) for utilities [7]. Demand side management will be affected by the integration of the wind energy generation in the smart grid.

In this paper literature review is presented in section 2. An overview of Pakistan's energy mix is described in section 3 while wind potential is indicated in section 4. Environmental friendly behavior of different power sources is compared in section 5. Challenges for wind power, smart grid and steps by government are discussed in sections 6 and 7 respectively. Conclusions are drawn in section 8.

2. Related Work

M. Asif has presented a review of the sustainable energy options for Pakistan in [8]; taking wind energy as optimal choice. He considered wind power as the best because of its huge potential and low operational cost. Harijan et al has calculated the potential of wind power in coastal area of Balochistan province which is 42.5 TWh annually equal to half of the nation's total annual production [9]. Aman et al has studied the potential of wind in Karachi region for eliminating power shortage in KESCO region [10]. Possibility of wind for irrigation purpose is discussed in [11] which is also a feasible and cost effective option for Pakistan as huge sum of Power is utilized for these purposes. Wind power plant yield fluctuates because of stochastic nature of meteorological parameters. To compensate the variability in output of wind power plant different techniques are used like energy storage [12], reserve generation [13] or Demand Side Management (DSM) techniques [14]. DSM is a cost effective techniques in which the consumer lower their consumption because of incentives provided by utilities. The energy storage system and reserve generation add cost to per unit of power produce which becomes unbearable for majority of population in a developing nation. DSM lowered the demand in peak hours [15] thus ensuring the reliability of the power system. There are many home energy management schemes for DSM [16]. Some of them use power line carrier [17] for communication among home appliances while other uses Zigbee [18]. Analysis of demand response technique for a system with high wind penetration has been done in various countries like Germany [19], Spain and UK [20], USA [21], Portugal [22], Netherland, Japan, Mexico and Brazil [23]. We have presented an overview of Pakistan's energy sector in context of environmental obligations, wind power development and smart grid implementation. Wind potential is assessed and challenges for integration of this resource to national grid are briefed.

3. Energy Mix of Pakistan

Energy mix of the Pakistan shows its heavy dependence on fossil fuel for generation of the electricity i.e. 61.94% as shown in Fig. 2 [24]. This situation is considerable because of exhausting indigenous reservoir of natural gas and increasing prices of oil in the foreign markets. Also the energy needs of the world are multiplying many folds over the last 50 years which mean less available oil for the developing countries because of low affordability. Also the pollution related to burning of fossil fuel is much high than the renewable resources. Electricity generation is the largest contributor of many dangerous gases like nitrogen and sulphur oxides which causes smog and acid rain. Also it is the largest contributor of mercury and carbon dioxide emission. Power generation also has significant impacts on water quality and biodiversity especially large dams are considered as an environmental hazard [25]. Analysis of NEPRA Report 2012 depicts the nuclear; gas and hydro are just cheaper than the wind energy as shown in Fig. 3 [24].

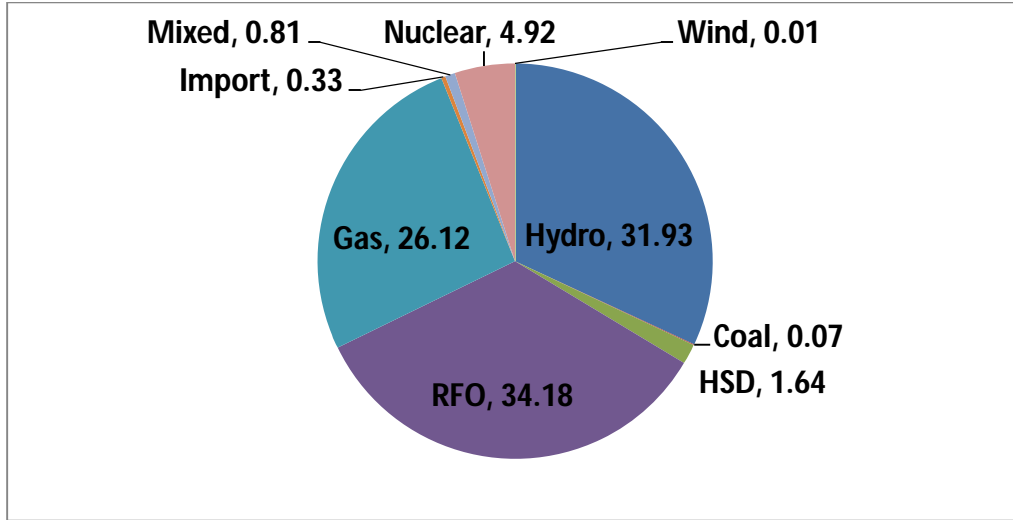


Fig. 2 Percentage of Electricity Produce by Fuel in 2011

Coal in Pakistan is yet to be used for power generation on large scale. Also there are concerns about the pollution created by the burning of coal. Our natural gas reserves are rapidly draining and Hydro cannot be utilized at large scale because of differences of the provinces. Also majority of Pakistan is a densely populated, so huge displacement of population will be needed for construction of dams.

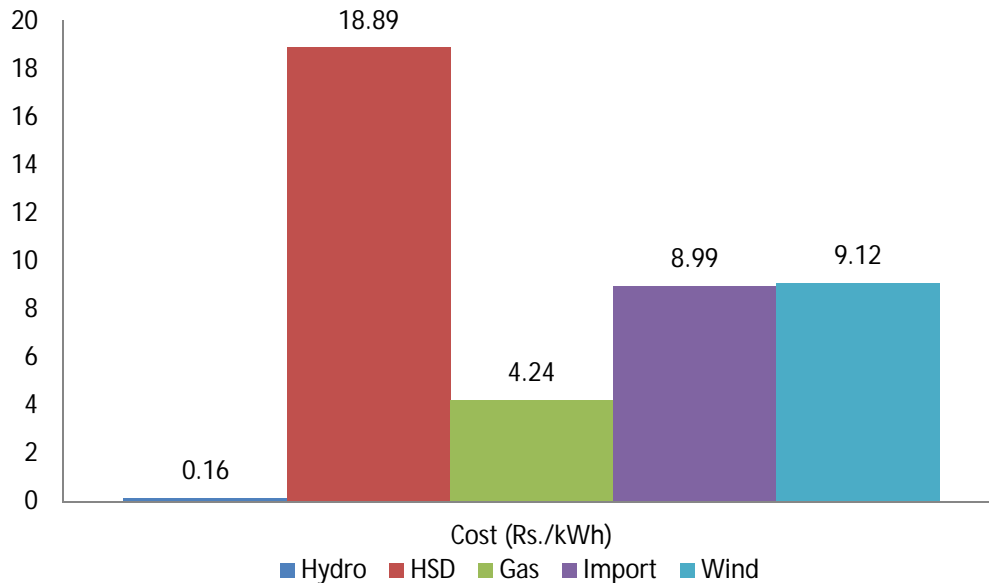


Fig. 3 Comparison of Average Unit Costs

Environmentalists accuse large hydro dams of destroying marine ecosystems. Also the main purpose of Pakistan's dams is for agricultural usage not for power generation. The kerosene oil and diesel cost about twice the price of the wind power. Wind power is cheap but as majority of the wind farms are installed by the private sector so high prices are offered to cover up initial high costs, risk margins and also for a suitable profit for the investors.

Table I indicates the top ten oil-using countries for electric power generation and Pakistan is at 8th position in this [26]. This depicts that we rely too much on costly oil for power generation. Saudi Arabia, Iran, Mexico, Kuwait are oil-exporting countries so they have their local large supply of oil. Indonesia and Egypt are self-sufficient in oil so they can utilize their local at very subsidized rates. India, Japan, USA are among the top 10 economies of the world

so even this huge amount of oil utilization is very less as compared to their production so they are little effected by high priced oil generation.

TABLE I
Top Ten Oil using Countries for Electric Power Generation

Countries	TWH from Oil
Saudi Arabia	129
Japan	97
USA	48
Iran	46
Mexico	44
Kuwait	43
Indonesia	35
Pakistan	33
Egypt	31
India	26

A. Gas scenario

It's clear from Table. II the electricity production from gas is on decline [27] i.e. from 56.54% of total electric production in 2006-2007 to the 44.88% in 2010-2011. In TOE 8,640,101 in 2006-2007 to 6,493,766 in 2010-2011. This is about 25 % decline in gas usage. According to the energy information administration (EIA) Pakistan's natural gas reserves in 2011, were about 30000 billion cubic feet while the consumption of 2011 was 1383 billion cubic feet [28] so the gas reserve will be depleted in 21 year if the consumption level remain same.

TABLE II
Fuel Consumption for Thermal Power Generation
in Ton of Oil Equivalent (TOE)

Fuel	2006-07	2007-08	2008-09	2009-10	2010-11
Gas	8,640,101	8,492,919	7,830,065	7,106,962	6,493,766
% share of Gas	56.54	54.88	51.3	45.08	44.88
Furnace Oil	6,521,503	6,741,614	7,210,211	8,339,330	7,827,500
% share of Furnace Oil	42.62	43.56	47.23	52.9	54.1
Diesel Oil	45,125	168,449	173,947	262,499	105,160
% share of diesel oil	0.3	1.09	1.14	1.67	0.73
Coal	73,551	72,568	50,341	56,141	43,169
% share of Coal	0.48	0.47	0.33	0.36	0.3
Total	15,280,280	15,475,550	15,264,564	15,764,932	14,469,595
Annual Growth Rate (%)	18.72	1.28	-1.36	3.28	-8.22

B. Oil scenario

The usage of costly oil is increasing, if we combine the total usage of kerosene oil and diesel oil i.e. from 42.62% of total electric production in 2006- 2007 to the 54.1% in 2010-2011. In TOE, 6566628 in 2006-2007 to 7932660 in 2010-2011. This is about 17 % increase in oil usage electricity mainly because of gas shortfall. EIA data shows Pakistan's oil reserves in 2011 were about 28 billion barrels, our consumption is about 366 thousand barrels

per day and our production is just 61.66 thousands barrel per day [28]. This show that indigenous energy supply is just 16.85% of total demand.

4. Overview of Pakistan Energy Demand and Supply

According to National Transmission and Dispatch Company (NTDC) statistics of last five years, there is a huge gap in supply and demand as shown in Table. III which is about 1/3 of the total demand, in year 2012 it is about 6325 MW deficit on supply side in peak hours. NEPRA report 2012 [24], display that the supply demand gap will not be eliminated till 2017. In the same NEPRA report it’s also mentioned that the trend of load shedding will continue in 2020. However, its duration will be lesser as compared to current National Transmission and Dispatch (NTDC) practice. NTDC projections show that growth rate will be 7 %, same as 2006-2012 period, a recession for country economy.

TABLE III
Supply and Demand Difference of Last 5 Years

Financial year ending 30th June	Generation Capability (MW)	Demand during NTDC System Peak Hours (MW)	Surplus/ (Deficit) (MW)
2008	12,442	16,838	-4,396
2009	13,637	17852	-4,215
2010	12,751	18,467	-5,716
2011	13,193	18,521	-5,328
2012	13,733	20,058	-6,325

5. Wind Potential of Pakistan

A large wind belt in district Thatta is identified which is the southern district of Pakistan along the Arabian Sea coast. Alternative Energy Development Board (AEDB) believes that this corridor has potential of 60,000 MW of wind power which can be exploited [29]. Coastal belt of Pakistan is indicated feasible for wind energy. AEDB also estimates that almost 5,000 villages can be electrified through wind energy in Sindh, Baluchistan and northern areas. About 1% of the total area of Pakistan has excellent wind potential of 41290 MW with average wind speed of 7.4 m/s. If we develop half of this potential; it will be more than our current total demand as shown in Table. IV. These calculations are based upon the assumptions: Installed capacity per km² is 5MW and total land area of Pakistan has been taken as 877525 km² [30].

TABLE IV
Wind Potential Good to Excellent Conditions at 50 M

Wind resource utility scale	Wind Class	Wind Power W/m ²	Wind Speed m/s	Land Area km ²	Percent Windy Land	Total Capacity (MW)
Good	4	400-500	6.9-7.4	18106	2.1	90,530
Excellent	5	500-600	7.4-7.8	5218	0.6	26090
Excellent	6	600-800	7.8-8.6	2495	0.3	12480
Excellent	7	>800	>8.6	2720	0.1	2720
Total				26362	3	131,800

6. Wind Resource Potential Areas

In Pakistan, according to National Renewable Energy Laboratory (NREL) USA report [30] the main areas for wind power plant development are as following: In Southeastern Sindh, areas in Thatta, Hyderabad and Karachi district. In Northern Indus Valley, areas near Islamabad, Mardan and Kalar Kahar regions. In southwestern Pakistan, hills and ridges in the Chagai area, Nokkundi and Makran. Wind corridors of central Pakistan and hilly areas near Quetta also have reasonable potential.

7. World Wind Power Future Plans

In 2020, China is expected to have 100 GW of wind power installed capacity [31]. By 2030, renewable supply increases to 11% of world electricity [14]. Europe plan is 240000 MW and an annual output of 720 TWH up to 2020, which will meet one-third of the consumption demand in Europe [32]. India can become an example for Pakistan as both share the same shore line and many of Indian wind farms are located in the adjacent areas of Pakistan. India has plan to increase its power generation from wind to 89 GW by 2020 and by 2030 it would have 191GW against 18 GW now, this would save 179 tons of CO₂ annually by 2020 [33].

8. Scenario as Pakistan Producing 20% of its Power in 2040 by Wind Power

Wind energy generation will contribute almost 20–25% of the installed capacity in several developed countries by 2020 [32]. NREL USA is currently working on its 20% wind scenario in America in which 20% of total electricity will be generated by the wind and its implication on grid [26]. According to NEPRA report, we can feasibly induct 30-40 % wind penetration in our system because of excellent wind condition in disperse area. Also bulk of wind potential is available near the largest load centre of the country that is Karachi and densely populated Hyderabad city.

9. Benefits for Government

In each Government will be able to meet Kyoto protocol carbon emission targets. Majority of Pakistan CO₂ emission comes from the power generation sector. Increasing share of wind power will lessen our carbon footprint. The country can also get loan and benefits through Clean Development Mechanism (CDM); in which the industrialized country will have to lessen CO₂ emission preferably in their own country and if not possible for them then invest in any plan of lessening CO₂ emission in any developing country. The development of wind energy will enhance energy security of country as imports are subject to market situations which may be different in different circumstances. So adding local wind power will strengthen the national security as we will be less affected by any future conflict in the oil producing nations. Also as majority of our imports are from Karachi so in case of any war with hostile neighbors in case of naval blockade the economy of the country will suffer less. Coastal areas of Pakistan are very thinly populated except the city of Karachi and Gawadar. Wind energy development will open the possibilities of the stand alone systems for dispersed population [34, 35]. Connection of this population to national grid will be expensive as compared to wind stand alone systems [36]. So the best way is small diesel electric generator with micro wind turbine that will provide the remote consumers in rural and coastal areas electrification at least initial and long term cost [37,38,39]. Wind resources and technologies are also immune to volatility of prices as wind electricity prices are almost recession proof, price hike and other such phenomenon. Major hurdle for the industry to meet its export target is power failure .Small and medium size industry is unable to generate its own power because of limited resources and high cost. This situation is decreasing export which means less foreign exchange. On the other hand there is a strong internal demand, dependent upon imports. Job opportunity will be available to thousands because of manufacturing, installation and maintenance jobs in wind industry.

10. Environmental Friendly Behavior of Wind and Other Power Sources

Nuclear power is one of the cheapest energy sources but its environmental cost is too high. Nuclear power production damages environment during mining operation, transportations and also waste disposal. In case of accidental leak as in case of Fukushima Daiichi (Japan) and Chernobyl (former USSR) the damage is enormous which can take thousands of human lives plus enormous damage to the environment. Thermal power plants (Natural Gas and diesel and Coal), damage environment especially as their burning produce large amount of CO₂ during operation along with the damage to environment during Mining operations, transportations and waste disposal. Oil refineries are one of the major sources of water and air pollution. Normally the transportation of crude oil is carried by tanker ships and locomotives each of which burns additional fossil fuels. In past there were environmental disaster due to leakage of crude oil in sea water whose latest example is deep water horizon oil spill also called as BP disaster in which total of 4.9 million barrels of crude oil pollute the sea water and endanger the marine ecosystem of Gulf of Mexico. Hydel power on large scale has lot of effect on nature especially because their potential exists in the regions which are habitat of the wild life. Emissions Produced by 1 kWh of electricity based on life cycle analysis are summarized in table. V [40].

TABLE V
Emissions Produced by 1 kWh of Electricity Based on Life Cycle Analysis

	Greenhouse gas		
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	emissions gm equiv CO₂/kWh	SO₂ milligram/KWh	NO_x milligram/KWh
Hydro	2-48	5-60	3-42
Coal(modern)	790-1182	700-32321	700-5273
Nuclear	2-59	3-50	2-100
Natural gas (CGST)	389-511	4-15000	13-1500
Biomass(Forestry, waste combustion)	15-101	2-140	701-1950
Wind	7-124	21-87	14-50
Solar	13-731	24-490	16-340

11. Performance Challenges for Wind Development and Smart Grid

Each of the wind turbines in a wind power plant has different output even if they are in the same locality and rated power due to the meteorological factors. Hence no wind power plant can produce the power at its rated capacity throughout the year making wind power plant capacity factor dependent on site wind speed and other meteorological parameters [41]. Wind power plant reliability is generally improved by increasing the hub height as the wind speed increase given in the following equation [42].

$$\frac{V(h)}{V(hr)} = \left(\frac{h}{hr}\right)^\alpha \quad (1)$$

Where V (h) is the wind speed at the height (h), V (hr) is the wind speed at the reference height (hr) and α is the power law exponent. The exponent is an empirically derived coefficient that varies with parameters such as surface roughness, wind speed, temperature [42]. Non availability of data at proper hub height is also a major challenge for wind energy development. There is a lack of expert engineers because wind power is new for country and also no practical training centers are available to train engineer/technician for this field [43]. Pakistan’s soft image has been ruined due to the terrorism which has directly impact on the economy because foreigners refrain from investment in a destabilized state [44]. The amount of energy provided by wind is stochastic in nature depending on wind speed, turbine type and nature of load. So for system reliability, study should be done to assess the effects of wind power generation on system’s reliability [45, 46]. Therefore there should be a reserve generation to tackle this which by should be at least 5-15% of wind installed capacity. Although the initial cost of wind power is very high as compared to other sources but this will be offset by lower bills on fuel costs as wind is a free resource for power generation.

Wind power is depending on wind speed which is naturally uncertain because of metrological phenomenon [47- 49]. Thus forecasting of wind speed is very important for the unit commitment and reliability of the power system .Variation in wind speed causes variation in voltage and frequency. Also wind power has to be cut off grid in case of very high wind speed which may cause unacceptable shocks to thermal units in the system [50]. Smart grid implementation has been started by the installation of smart meters in big cities of the country; however the whole advanced metering infrastructure needs a lot of investment. Policy issues and management hurdles are enhancing the difficulties for smart grid.

12. Steps by Government

The Government of Pakistan (GOP) wants to diversify its energy mix on war footing basis to ensure the security of its energy supplies as imported oil is subject to market risk i.e. uncertainty of supply and price. The 2006 Renewable Energy Policy is a best effort by government to attract private investment for wind power development. It includes relaxation in income tax, duty free imports and rates are offered in USD for saving investor from devaluation of local currency [51]. Asian Development Bank (ADB) on request of Government of Pakistan has agreed to fund \$200 million to investors for establishment of wind and other renewable energy power plants. The development of wind projects will be difficult, in the context of Pakistan’s economy, without funding of ADB. First 49.5 MW Wind Power Project has been inaugurated on Dec 24, 2012. This project is completed by FFC Energy Limited (FFCEL) a subsidiary of FFC Fauji Fertilizer Company comprises of 33 Nordex S77 wind turbines of 1.5 MW capacity each [52].

Based on the historic wind data, the annual energy yield of the plant (FFCEL) is 145 GWH or 145 million units, good enough for fulfilling annual electricity needs of 30 thousand average homes. All this electricity is produced from 100% green and renewable resources.

CONCLUSION

In this paper, we have reviewed the Pakistan's energy sector in the context of wind energy, its feasibility and demand side management in smart grid. It has been revealed that fossil fuels are no more a viable energy option because of dwindling resources, high cost and environmental concerns. The country needs cheap energy for economic and social uplifting. Oil imports are burden on foreign reserve and also a risk to our energy security. Huge wind potential of 41290 MW with excellent conditions exist which needs immediate attention for development. Wind power is environmental friendly as compared to nuclear, hydel and fossil fuel.

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