Recent Development and Sustainability of Wind Power Sector in Pakistan

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Abstract

In Pakistan, the wind power sector has gained considerable attention over recent years. However, instead of sufficient renewable energy resources, the share of wind power within the national power generation mix is negligible. The gap between supply and demand has increased significantly (6,000 MW) over the last decade, resulting in an urgent need to assess future supply and demand and consider a feasible, if not sustainable power generation mix. For this reason, the most recent developments in wind power and sustainability were assessed against the selected environmental economic and social indicators. Notably, the wind power sector in Pakistan has gained considerable foreign and local attention in the last five years. Many projects are presently in progress and operational at various stages and locations. Furthermore, it is expected that by 2030, wind power energy generation will constitute more in the country's power generation mix, more than the planned target of 5% by 2030. There is a high possibility that the utilization of wind for power generation can enhance overall climate change resilience.

Keywords: Power generation, wind power, renewable energy, sustainability.

1 Introduction

Electricity is required for the social wellbeing and economic development of a country. Electricity is a highly versatile form of energy that fuels the performance of almost every sector of an economy [1]. In 2016, the installed capacity of electricity in Pakistan was 23,101 MW (Figure 1) comprising of hydro 30.24%, thermal 64.17%, nuclear power 4.9%, Import 0.41% and a small portion of wind-generated power, 0.27% [2].

Over the last decade, the gap between supply and demand has significantly increased (Figure 2). The leading causes of this shortfall include theft, misuse and overuse of electricity by domestic households and industrial sectors, substantial line (infrastructure) losses, low institutional capacity, corruption, mismanagement and political controversy over mega power projects [3]. The government has continued to increase the country's reliance on thermal power generation, and subsequently, electricity prices have risen.

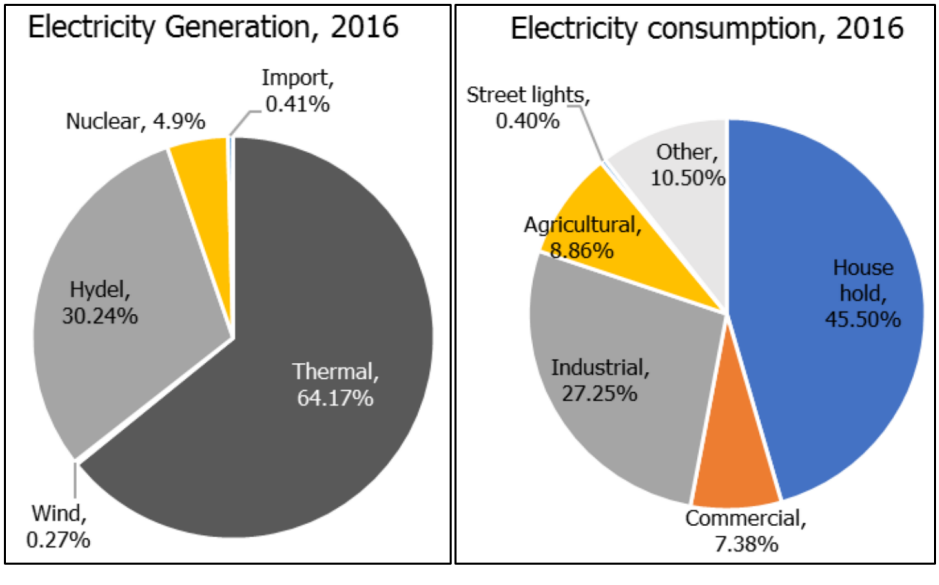

Figure 1 Electricity consumption 2016, adapted with permission from Pakistan economic survey 2015-2016 [2]

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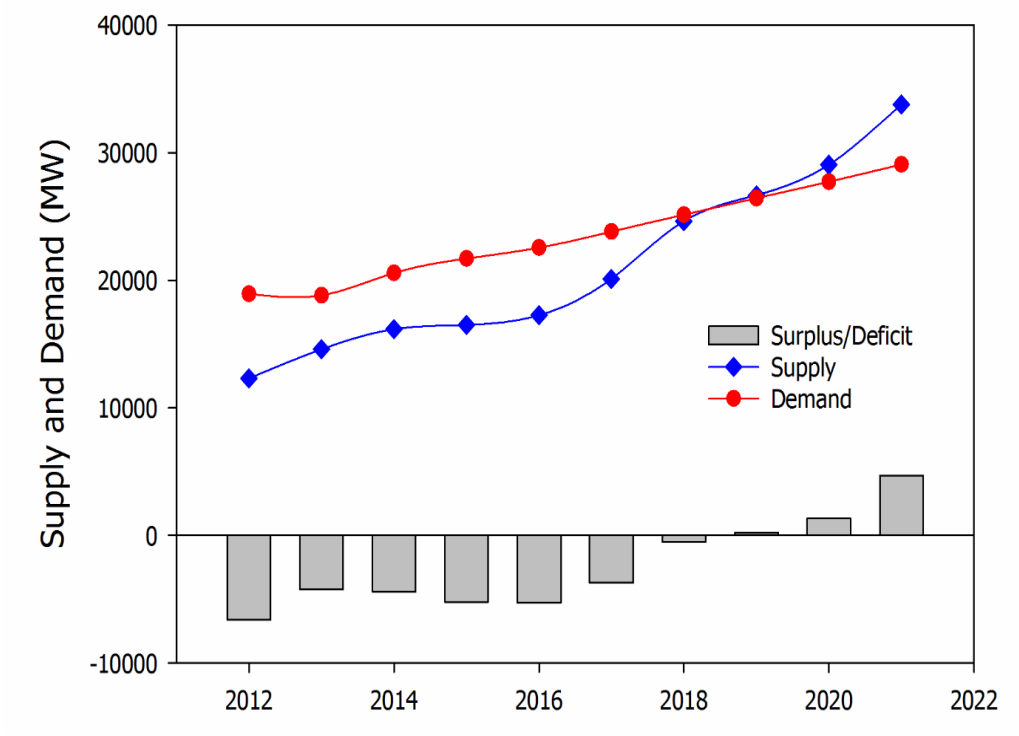


Figure 2 Electricity demand and supply. Source: adapted with permission from NEPRA state of industry report 2016 [4]

In 2009, the estimated financial loss to the economy was expected to be USD 3.8 billion, which was about 2.5% of the gross domestic product (GDP) [5]. Other estimates indicate that the potential energy shortages of 3,000 to 6,000 MW, have cost the country up to 4% of GDP over the last few years. Therefore, to address this gap, the Pakistan Government has planned to establish various projects to improve the supply and demand for energy. Indeed, by 2018, it is anticipated that 16,564 MW will be added to the national grid system which will help to decrease the present power shortage, and by 2020, the total capacity is expected to rise to 35,000 MW. The China-Pakistan Economic Corridor (CPEC) agreement includes numerous power projects which are expected to have a positive impact on the country's growth and economic development especially the energy sector.

While renewable energy can play a significant role to help cope with the existing power crisis, the production and contribution of renewable energy at this stage is quite limited. Notwithstanding, there is a dire need to increase electricity production using renewable energy to fill the supply-demand gap.

1.1 Future Power Generation mix

According to the National Power System Expansion Plan for 2011 to 2030 [6], the expected power demand between 2029 and 2030 will be 98,120 MW. The projected power generation mix (Figure 3) under the base case by 2030, consists of 37% hydropower, 34% of steam turbines using Thar coal, 11% Natural Gas, 6% Oil, 6% Nuclear, 5% Wind and 2% imports.

Table 1 Generated electricity from renewable energy resources (GWh)

Years	Total Electricity	Renewable Energy	Wind Power
2011-12	99,295	6	6
2012-13	98,655	32	32
2013-14	105,698	272	263
2014-15	108,916	811	458
2015-16	111,997	1549	786

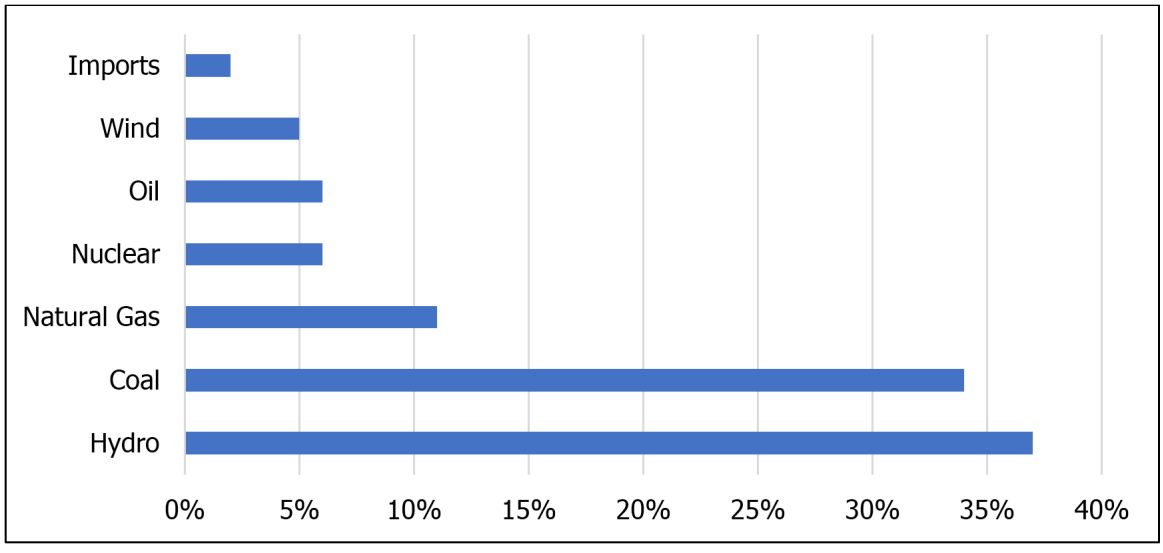


Figure 3 Power generation mix 2029-2030 (Base Case) Source: National Power System Expansion Plan 2011-2030 [6]

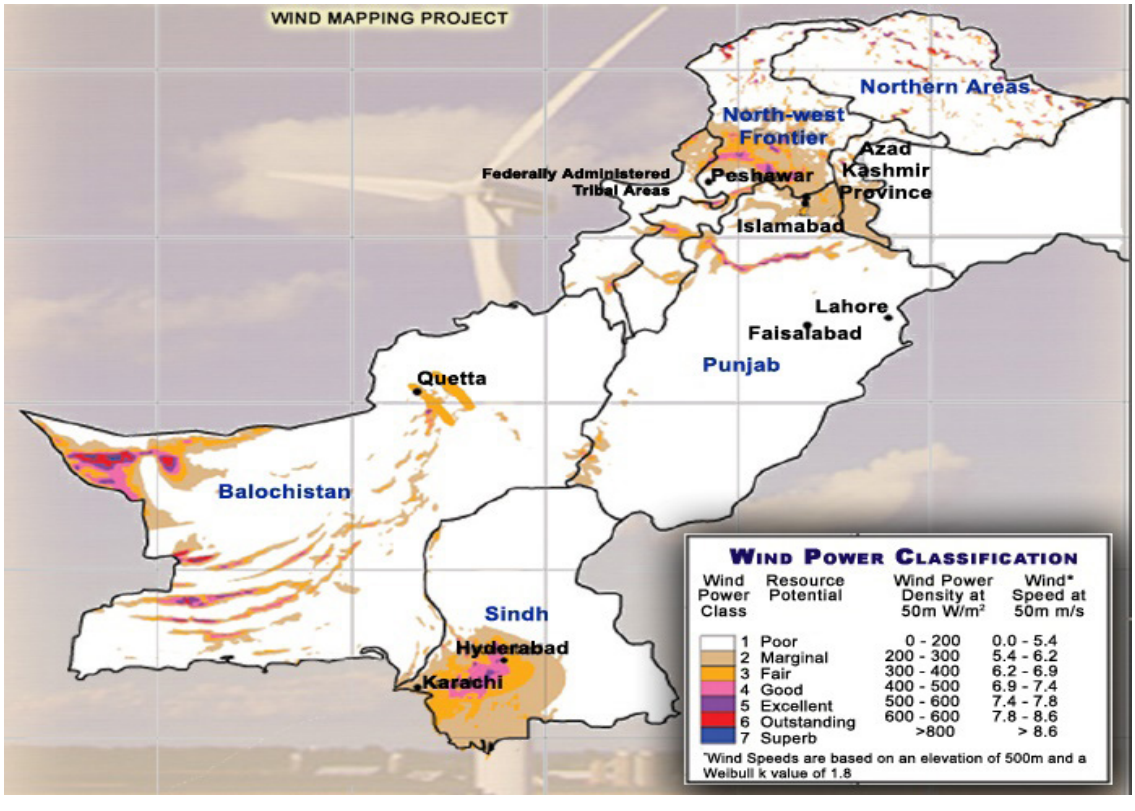


Figure 4 Potential wind power sites, Pakistan Meteorological Department [8]

1.2 Wind Energy Potential

The total wind energy potential of Pakistan is estimated to be 349,315 MW [7]. The Coastal Belt of Sindh is blessed with a wind corridor that is 60 km wide and 180 km long. Accordingly, using wind energy, this corridor (Figure 4) has the potential to generate 50,000 MW of electricity [8]. There are also additional wind sites available in Baluchistan Khyber Pakhtunkhwa and Gilgit Baltistan.

Small wind power turbines once installed, will be able to electrify remote villages which cannot be connected to the national grid system. It is estimated that wind energy could electrify more than 5,000 villages in Sindh, Baluchistan and Gilgit Baltistan [9].

1.3 Wind Power Sector Development

Between 2011 and 2012, the total contribution of wind power in the national grid was 6 MW which increased significantly to 786 MW in 2015-2016 (Table. 2). Currently, there are 15 operational wind power projects in progress, with a further 13 new wind power projects (Table. 3) planned to add 614 MW of electricity to the national grid by 2018-2019 [2].

The Alternative Energy Development Board (AEDB) is aiming to ensure that 5% of the total national electricity will be generated using renewable energy resources by 2030. Furthermore, to achieve this target, the AEDB is creating investment opportunities and is fast-tracking the establishment of several administrative functions to oversee wind power projects. Also, the Pakistan Council for Renewable Energy Technologies (PCRET) is actively involved in activities related to the development and promotion of renewable energies. The PCRET has so far, installed 155 small-scale wind turbines (0.5 KW to 10 KW) with an overall capacity of 161 KW in Sindh and Baluchistan, electrifying 1,560 houses and nine coast guard check posts. It is further estimated that wind energy can electrify more than 5,000 villages in Sindh, Baluchistan

Table 2 Operational wind projects [11]

Name of Project	Capacity (MW)	Location
FFC Energy Ltd.	49.5	Dist. Thatta
Zorlu Enerji Pakistan Pvt. Limited	56.4	Dist. Thatta
Three Gorges First Wind Farm Pakistan (Pvt.) Limited	49.5	Dist. Thatta
Foundation Wind Energy – I Ltd.	50.0	Dist. Thatta
Foundation Wind Energy – II Ltd.	50.0	Dist. Thatta
Sapphire Wind Power Company Ltd.	52.8	Dist. Thatta
Yunus Energy Ltd.	50	Dist. Thatta
Metro Power Company Ltd.	50	Dist. Thatta
Tapal Wind Energy Pvt. Limited.	30	Dist. Thatta
Gul Wind Energy Ltd.	50	Dist. Thatta
United Energy Pakistan Pvt. Limited.	99	Dist. Thatta
Hydro China Dawood Power Pvt. Limited.	50	Dist. Thatta
Master Wind Energy Pvt. Limited.	50	Dist. Thatta
Tenaga Generasi Ltd.	50	Dist. Thatta
Sachal Energy Development Pvt. Limited.	50	Dist. Thatta
Total	787.2	

and Northern Areas [9]. The Gul Muhammad village in Sindh was the first village in Pakistan electrified through the adoption of wind energy. Initiated by PCRET, 26 small-scale wind turbines of 500 W were installed in the village [10]. Currently, in consultation with PCRET, more than 400 projects relating to the electrification of remote communities are planned. Notwithstanding, under the remote village electrification program, the AEDB has been involved in electrifying 7,874 remote villages in Sindh and Baluchistan provinces through alternative energy technologies [11].

iv. Protection against political risk.
v. Attractive Tariff (Cost plus 17% ROE), indexed to inflation & exchange rate variation (Rupee / Dollar).
vi. Euro / Dollar Parity allowed.
vii. Carbon Credits available.
viii. No Import Duties on Equipment.
ix. Exemption on Income Tax / Withholding Tax and Sales Tax.

Table 3 Future wind power projects (2019) [11]

Name of the Project	Capacity (MW)	Location
Jhampir Wind Power Limited	50	Jhimpir
Hawa Energy Pvt. Limited	50	Jhimpir
Hartford Alternative Energy Pvt. Limited	50	Jhimpir
China Sunec Energy Pvt. Limited	50	Nooriabad
Three Gorges Second Wind Farm Pvt. Limited	50	Jhimpir
Three Gorges Third Wind Farm Pvt. Limited	50	Jhimpir
Tricon Boston Consulting Corporation Pvt. Limited (A)	50	Jhimpir
Tricon Boston Consulting Corporation Pvt. Limited (B)	50	Jhimpir
Tricon Boston Consulting Corporation Pvt. Limited (C)	50	Jhimpir
Western Energy Pvt. Limited	50	Jhimpir
Zephyr Power Pvt. Limited	50	Gharo
Shaheen Foundation PAF	50	Jhimpir
Burj Wind Energy Pvt. Limited	14	Gajju
Total	614	

1.4 Incentives for wind power projects

The Alternative Energy Development Board of Pakistan (AEDB) as mentioned earlier, is aiming to ensure 5% of the total national power generation capacity will be generated using renewable energy resources by 2030. Notably, the Government of Pakistan's "Policy for Development of Renewable Energy for Power Generation" is offering incentives towards setting up Wind IPPs [11].

i. Wind Risk (risk of the variability of wind speed).
ii. Guaranteed Electricity Purchase.
iii. Grid provision is the responsibility of the purchaser
x. Repatriation of Equity along with dividends freely allowed.
xi. Permission to issue corporate registered bonds.

2 Wind energy and sustainability

The Johannesburg Plan of Implementation (JPOI) addresses energy in the context of sustainable development. As per the goal no. 7 of SDGs, access to affordable, reliable, sustainable and modern energy is essential. In developing countries access to the modern renewable and non-renewable energy is closely linked

with sustainable development. Thus, the relationship between adequate energy services and accomplishment of the Millennium Development Goals (MDGs) was emphasized in Johannesburg Plan of Implementation [12].

Sustainability indicators provide a broad vision to policy and decision makers in determining an appropriate sustainable power generation mix. Though, measuring energy sustainability is associated with a huge range of theoretical and technical matters [13] and may require more robust methodologies to deal with issues [14]. A lot of work has been done in last decade towards the development of energy indicators for sustainable development with broad themes of economy, society, and environment [15]. For renewable energy quantitative indicators like the price of electricity, GHG emissions, security of renewable sources, water consumption, efficiency and land requirements are available in the literature [16,17,18]. Accordingly, indicators were selected for three principal areas.

i. Environmental sustainability: GHG emissions, Biodiversity, Water use impact, Air quality, Land use impacts;
ii. Economic sustainability: Cost of energy, Job market, Employment, Industry expansion, Energy imports, Investments; and
iii. Social sustainability: Health impacts, Rural development, Energy access, Energy security, Food security.

3 Economical sustainability

3.1 Cost of Energy

Wind energy is one of the most cost-effective forms of renewable energy in reducing our reliance on fossil fuels. Due to recent technological advancements associated with wind energy, the cost of energy has been significantly reduced. In 2010, the levelised cost of onshore wind energy (LCOE) was 78$/MWh, decreasing to 61$/MWh in 2015, and in 2010, the Levelised cost for offshore wind Energy was 232 $/MWh and 181$/MWh in 2015 [19]. The levelised cost for wind power according to the National Electric Power Regulatory Authority (NEPRA) of Pakistan, is presently US Cents 8.19 per kWh [20].

3.2 Job market

Unemployment is an enormous problem in Pakistan with a persistent unemployment rate of 5.90 [21]. Importantly, wind power projects are contributing to reducing the rate of unemployment both directly and indirectly. In 2016, the wind industry globally, employed 1.2 million people which was a 7% increase from the previous year. China was the leading country, with employment in the wind energy sector of 509,000, close to half the global total [22]. In 2016, Brazil added 2,014 MW of new wind power capacity, installing 947 wind turbines across 81 wind farms, and creating 30,000 new jobs, with multiple benefits for the Brazilian economy [23].

3.3 Employment

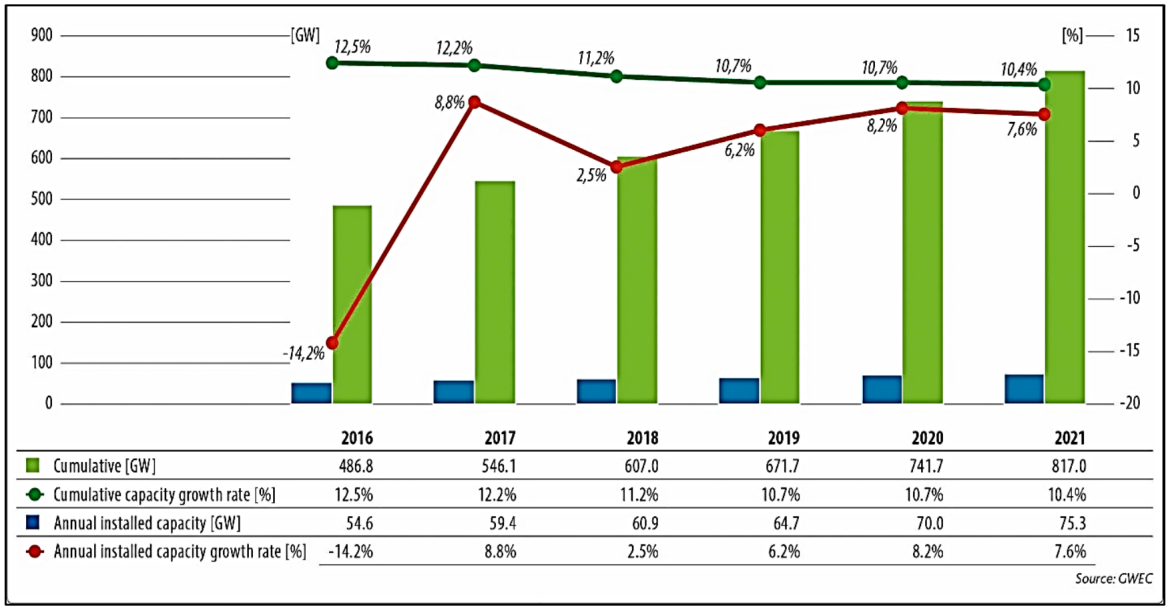
In 2015 employment to population ratio was 50.16% in Pakistan. A major portion of the population is employed in the agriculture sector. It is expected that more people will be employed by wind energy sector in Pakistan. Globally employment within the wind energy sector is likely to rise to around 3 million jobs by 2030, and 4 million by 2050 [24]. The Global Wind Energy Council is projecting that by 2030, employment within this sector could double to 2.4 million under its most promising policy scenario [25].

3.4 Industry Expansion

The potential use of commercial wind power in Pakistan is enormous. Notably, the Industry is vastly expanding with many projects already under construction. Wind power contribution increased from 6 MW in 2011-2012, to 786 MW in 2015-2016. It is expected that 614 MW of electricity generated from wind will be added to the national grid by 2018-2019. Globally, the number of wind energy installations exceeded 50 GW annually for the first time in 2014. Furthermore, in 2016, more than 54 GW of clean, renewable wind power was installed across the global market. The contribution of wind power and its share with other energy sources continues to increase. Furthermore, the markets that generate electricity from wind energy in this market globally include Denmark with 40% as the dominant country, followed by Uruguay, Portugal and Ireland with over 20%, Spain and Cyprus around 20%, and Germany at 16 %. The total capacity in the wind energy market has continued to grow to 2,110 GW and supplying up to 20% of global electricity [23]. By 2020, China is expected to install 200 GW while India aims to install 60 GW of wind power capacity by 2022 [23,26].

3.5 Investment

In 2015, the total investments attributed to the wind energy sector reached a high of USD 124.2 billion. However, in 2016 new investments in wind energy dropped to USD 112.5 billion [27]. Asia-Pacific and China alone accounted for almost 47% of total global investments in clean energy during 2016. Accordingly, by the year 2020, it is anticipated that the industry will realise investments of USD 73 billion per year, and USD 114 billion per year by 2030 [27]. Pakistan and China have signed around $57 billion of energy and infrastructure projects under the China-Pakistan Economic Corridor (CPEC). In recent years the wind power sector has attracted foreign investment and investment by local private investors in wind energy sector.



	2016	2017	2018	2019	2020	2021
Cumulative [GW]	486.8	546.1	607.0	671.7	741.7	817.0
Cumulative capacity growth rate [%]	12.5%	12.2%	11.2%	10.7%	10.7%	10.4%
Annual installed capacity [GW]	54.6	59.4	60.9	64.7	70.0	75.3
Annual installed capacity growth rate [%]	-14.2%	8.8%	2.5%	6.2%	8.2%	7.6%

Figure 5 Market forecast for 2017-2021 by GWEC [23]

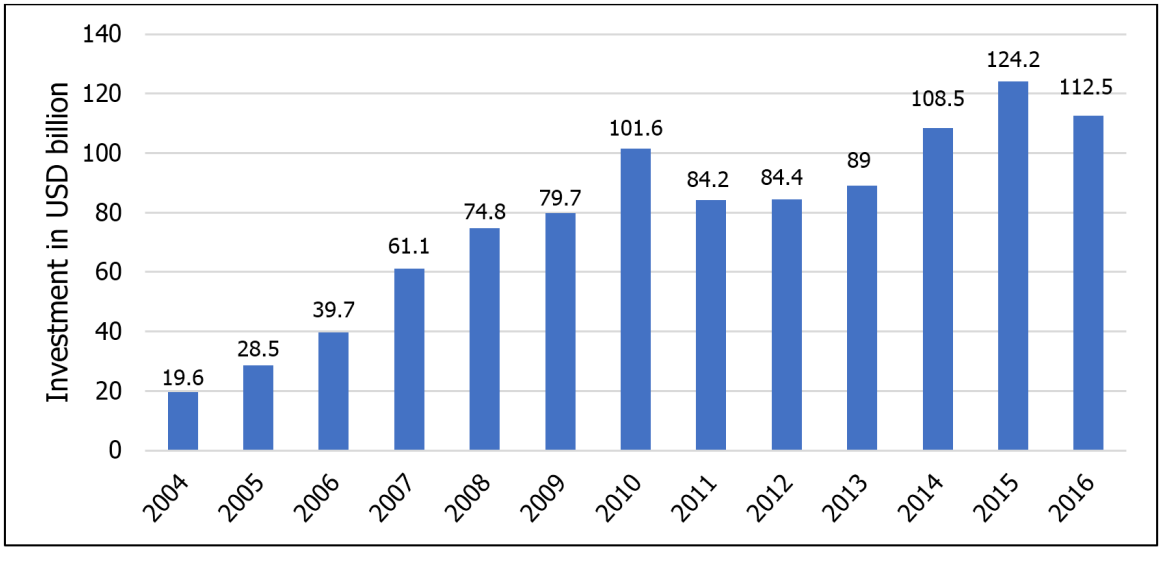


Figure 6 Wind energy global investment in USD billion [28]

3.6 Energy imports

Currently, Pakistan's energy sector depends on local gas fields and expensive oil imports. The dependence on imported oil for thermal power plants has increased the tariff over the last decade. Moreover, Pakistan's electricity generation is highly dependent on imported oil as almost USD 14.5 billion worth of oil is imported each year, the bulk of which is used for electricity generation [29]. Globally, wind energy avoided €9.6 billion of fossil fuel costs in 2012; and is expected that wind energy will avoid between €22 billion and €27 billion of fuel costs annually in 2020, increasing to between €47 billion to €51 billion in 2030 [30].

4 Environmental sustainability

4.1 CO_2 Emission

Pakistan contributes only about 0.8% of total global GHG emissions. In 2008, Pakistan's total GHG emissions amounted to 309 million tons (MT) of Carbon dioxide (CO_2) equivalent, comprising about 54% CO_2, 36 % Methane, 9% Nitrous Oxide and 1% other gases. The most significant contributor is the energy sector having a 50% share, followed by the agriculture sector (39% share), industrial processes (6 % share) and other activities (5% share) [31]. Wind Energy does not need fuel for power generation,

thus resulting in zero emissions. In 2014, wind power avoided 142.5 million tons of CO_2 (Generated Electricity 183,892 GWh) in the USA, 154.6 million tons of CO_2 (Generated Electricity 158,271 GWh) in China, and 0.31 million tons of CO_2 in Pakistan, through the generation of 459 GWh electricity [32]. Indeed, annual reductions in CO_2 from existing wind power plants were about 372 million tons in 2013; Under the IEA New Policies scenario, this is expected to rise to 899 million tons annually by 2020 [33].

4.2 Water Use and Impact

Pakistan is extremely short of freshwater resources. The continual pressure imposed by an increasing population has resulted in becoming a water-stressed country (i.e. having overall per capita water availability less than 1,800 cubic metres per year (m^3/y) and heading towards becoming a water scarce country (per capita availability less than 1,000 m^3/y by 2035 [34]. On average, water-cooled thermoelectric power plants in the United States extracted 60 billion to 170 billion gallons of freshwater from rivers, lakes, streams, and aquifers, consuming 2.8 billion to 5.9 billion gallons each day. Furthermore, in 2012, the electricity generated from wind energy in the U.S. was 140 million megawatt-hours (MWh), which helped to avoid consuming more than 30 billion gallons of water [35].

4.3 Air Quality

Electricity generation from thermal power plants is a leading source of atmospheric (air) pollutants that harm human health, and contributes to global warming and climate change, resulting in 39% of carbon dioxide (CO_2) emissions, 22% of nitrogen oxide (NOx) emissions, 69% of sulphur dioxide (SO_2) emissions, and 40% of mercury emissions in the United States. Other pollutants include volatile organic compounds (e.g., benzene, dioxins) and heavy metals (e.g., arsenic, lead) [36]. The energy sector of Pakistan is responsible for a 50% share in air emissions [31]. The utilisation of Wind Energy for power generation will reduce air emissions thereby enhancing air quality.

4.4 Biodiversity

The primary causes of bird's death within the wind energy sector are attributable to wind turbine collisions, resulting from air pressure changes caused by the spinning turbines, and resultant wildlife fatalities. However, the fatality rates of the wildlife and most bird species, with current estimated numbers are not expected to decline. The use of ultrasonic transmitters may help to deter bats to keep away from rotor swept areas and reduce fatalities [37]. Although, wind power is far less harmful to birds than the fossil fuels it displaces. Incidental losses of individual birds at turbine sites will always be a tiny fraction of all bird deaths caused by human activities. Moreover, wind energy plays a critical role in reducing air pollution and mitigating the impacts associated with climate change, which represents the most significant and lethal threat to wildlife [38].

4.5 Land Use

According to the National Renewable Energy Laboratory (NREL), large wind facilities in the United States found that they use between 30 and 141 acres per megawatt of power output capacity (a typical new utility-scale wind turbine is about 2 megawatts). However, less than 1 acre per megawatt is permanently disturbed, and less than 3.5 acres per megawatt are disturbed temporarily during construction [39]. The remainder of the land can be used for a variety of other productive purposes, including livestock grazing, agriculture, highways, and hiking trails [39].

5 Social sustainability

5.1 Health Impacts

Sound and visual impacts are two primary public health and communal concerns associated with operating wind turbines. There are two types of noises produced by a windmill. The mechanical noise, which is generated by the motor or gearbox, and aerodynamic noise, which is created by the wind passing over the blade of the wind turbine [40]. Wind turbines emit noise, including low-frequency noise, which decreases incrementally with increases in the distance from the wind turbines. Likewise, evidence of a dose-response relationship between wind turbine noise linked to noise annoyance, sleep disturbance, and possibly even psychological distress, was found to be present in the literature. Currently, there is no further existing statistically-significant evidence indicating an association between wind turbine noise exposure and tinnitus, hearing loss, vertigo or a headache [41]. Sub-audible, low-frequency sounds and infrasound from wind turbines do not present a risk to human health [42]. Indeed, when it comes to aesthetics, wind turbines can elicit strong reactions.

5.2 Rural Development

The rural population percentage in Pakistan is 61.1%. [36]. Most remote villages and communities are not as yet electrified, due to the excessive cost of transmission and maintenance. The Alternative Energy Development Board (AEDB) of Pakistan has been involved in electrifying 7,874 remote villages in the Sindh and Baluchistan provinces through utilising renewable energy technologies [11]. Also, the Pakistan Council of Renewable Energy Technologies (PCRET) has so far, installed 155 small-scale wind turbines in Sindh and Baluchistan, electrifying 1,560 houses and nine coast guard check posts [44]. Indeed, the Investment in renewable energy can improve and stabilise rural incomes, contribute towards new product development, new technologies,

and new policy approaches, improve the overall innovation capacity in rural areas, empower local communities, and finally, provide remote rural communities with cheaper energy sources [45].

5.3 Energy Security

Pakistan is one of the most vulnerable countries exposed to the adverse effects of climate change. The average annual temperature in Pakistan has increased by (0.57°C) over the period 1901-2000. The temperature in the Northern part of Pakistan was 02°C higher than that for the remainder of the country [31]. The Hindukush Karakoram Himalaya (HKH) regions are reported to be receding faster than in any other part of the world, and fears have been expressed that if the present rate of the recession continues, the HKH glaciers may disappear by 2035 [46]. Indeed, this type of climatic variation has a notable negative impact on the overall hydrology and hydro-power security. Notwithstanding this fact, the power sector must be resilient towards climate change. Understandably, the wind power sector is expected to benefit from the climatic variation because the change in temperature will cause a change in atmospheric pressure. On the contrary, wind power would lead to total net savings of over 33 million tons of CO_2 each year by 2020, and over 136 million tons by 2030, providing economic and environmental co-benefits while increasing energy security at the same time [33].

5.4 Food security

Renewable Energy has been criticised especially towards growing crops for biofuels. However, wind energy poses no risk to food security as windmills are deployed in those areas which are not suitable for agriculture. Even when the windmills are installed on agricultural land, they do not disrupt plant or vegetation growth. Moreover, wind, hydro and geothermal can be used in agri-food systems as a substitute for fossil fuels to generate heat or electricity for operations [47]. In case of Pakistan, most of the wind energy potential sites are not suitable for agriculture. Wind energy hot spots, especially in Sindh province, are permanently barren due to lack of irrigation system, waterlogging, and salinity.

5.5 Energy access

The rural population percentage in Pakistan is 61.4% [48], with approximately 90% of villages yet to be electrified. These communities are notably separated by vast distances with entirely no connecting roads and would incur excessive costs for power transmission and maintenance. The Pakistan Council of Renewable Energies (PCRET) [44] have Installed 155 small-scale wind turbines (0.5 KW to 10 KW) with an overall capacity of 161 KW in Sindh and Baluchistan, electrifying 1,560 houses and nine coast guard check posts. Also, it is estimated that wind energy can electrify more than 5,000 villages in Sindh, Baluchistan and Northern Areas [9].

6 Conclusion

The potential use of commercial wind power in Pakistan is enormous. In recent years the wind power sector has attracted foreign investment and investment by local private investors. Notably, the Industry is vastly expanding with many projects already under construction. However, despite the enormous potential of renewable energy sources in Pakistan, it has been planned, that of the estimated total potential of 349,315 MW, that a further 7370 MW will be generated by 2030. Thus, policymakers should pay special attention to the opportunities that wind energy can bring to the economy. Due to the advancement of wind energy technology, wind-generated electricity prices are reducing. Wind energy is economically suitable and sustainable for rural areas which cannot be connected to the grid system because of excessive costs of transmission and maintenance. Also, wind energy is clean, efficient and sustainable, helping to alleviate environmental concerns. A wind power plant does not require fuel, so, therefore, there are no fuel costs involved, no pollution and no depletion of resources. From Pakistan's perspective, wind power should be preferred over a coal-based generation of electricity. Moreover, given the passage of time, newer technologies will evolve which will enhance electricity production operations using fossil fuels, thereby releasing less GHGs into the atmosphere. As a result, the future generation of energy will be able to use fossil fuels more efficiently, given that wind can be utilised for power generation, which can enhance the overall resilience towards the climate change. It is expected that this research will reduce the overall gaps to achieve the sustainable electricity generation mix by 2030. Linkages between environment, economy, and society are investigated in the context of wind energy. The present research will help the planning commission of Pakistan, Pakistan Council of Renewable Energies (PCRET), and Alternative and Renewable Energy Board AEDB to formulate plans and policies for the future utilization of the wind energy.

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