An Overview of Global Renewable Energy Trends and Current Practices in Pakistan—A Perspective of Policy Implications

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Abstract

Sustainable, efficient and affordable energy supply embraces a strong relationship with socio-economic development, especially in developing countries. Pakistan has been facing an energy crisis in the form of expensive electricity generation, by largely depending upon fossil fuels and experiencing power shortages. This paper offers a thorough analysis of Pakistan's renewable energy (hereinafter RE) potential and current practices, in trying to meet its energy demands. There is a limited academic discussion available concerning the utilisation of RE resources of Pakistan to produce cost-effective and cost-competitive energy, including the formulation of pertinent laws and policies. This study adopts qualitative means, to investigate global trends and current practices in renewables, followed by concrete observations and recommendations to improve the situation in Pakistan. The objective of the study is, therefore, to establish the significance of renewables and to examine possible solutions available to the government of Pakistan, in addressing its energy crisis. The study concludes by suggesting that, there is an urgent need to follow the global trend in replacing conventional energy methods with the country's extensive RE resources, in order to ensure sustainable economic security and growth.

Keywords: Total energy mix in Pakistan; Current renewable energy; Renewable energy potential; Global trends; Policy implications

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1. Introduction

Energy is one of the necessities of any country, which is essential in promoting socioeconomic prosperity. Nowadays, with climate change concerns, it is also vital to switch from conventional energy source, to renewable alternatives. Every economic and social sector has specific energy demands, whether in the developed or underdeveloped countries of the world [1]. It is, thus, important to maintain efficiency in terms of supply and demand, while also considering efficient, environmental-friendly, cost-effective and renewable sustainable energy sources. Many of the developed countries worldwide have prioritised switching to utilising their RE resources, in meeting their energy demands more efficiently. Nonetheless, despite facing energy inefficiency and crisis, Pakistan has not yet balanced its energy mix with an appropriate contribution from renewables and is still dependent on traditional energy-producing sources, i.e., fossil fuels and coal-based power plants. There are various reasons for this situation; non-utilisation of indigenous resources due to the country's unstable economic situation, lack of planning and above all, less than ideal policy implications towards sustainable and RE sources [2]. Statistics indicate 147 GW currently installed capacity is being derived from renewable sources worldwide [3-4], [5]. Unfortunately, Pakistan still depends mainly on non-renewables to meet its energy demands [2], which signifies unsustainable, expensive and limited policy implications for the country's stakeholders, which suggests the necessity for a rapid shift toward the sustainable exploitation of RE resources. In addition to the poor policy implications, increased energy demand, coupled with an increasing population and lack of innovation as well as technological advancement, have added considerably to the energy crisis in the country [6].

Independent Power Producers (IPPs) contribute about 50% of overall electricity generation in Pakistan [7], this primarily deriving from traditional energy resources, i.e., coal-fired plants, oil and gas and thus, producing relatively expensive electricity [8]. The power sector in Pakistan significantly relies on thermal energy production. There are almost 20% distribution and transmission losses recorded, which represents an inefficient production and distribution system in the country [9]. The point of concern is why energy prices are continuously increasing and the likelihood that, supply will fail to meet demand, withing approximately two years. This situation exists because despite following the global trends in utilising the country's renewables,

succeeding governments have still been considering short-term solutions, since the 1980s [10]–[11]. In the meantime, many energy-related policies have been introduced in the country. National policy has encouraged participation from the private sector, by providing attractive incentives and assurances but most of these mainly are still invested in thermal energy production [10], [12]–[15], confirming a shift in Pakistan's energy mix from the hydel in 1971 to thermal energy production, as of this moment [16]. Statistical data reveals that, more than 55% of the local natural gas and three-quarters of oil reserves, have already been consumed [17].

Although, the government of Pakistan has initiated a move to decrease its over-dependence on fossil fuels, replacing them with the renewables to overcome its power deficiency, the transition is slow and further progress is required [1]. The demand and supply gap and expensive energy production, have affected not only the livelihood of the population but has also slowed down economic growth in Pakistan [18]. The per capita energy demand consumption in Pakistan has increased during the last decade from 445.3 kgoe to 481.62 kgoe [19]. The modern world is heading toward more efficient, sustainable and cost-effective energy production, imperative that Pakistan exploits its RE, i.e., solar, wind, and biomass, as rapidly as possible.

Pakistan possesses significant RE resources, which would be more than enough to meet its energy demand [20]. In 2006, Pakistan's government announced a RE policy for the first time, aimed at shifting its energy dependency from traditional to modern RE resources, through exploiting its indigenous resources, such as wind and solar [21]. Pakistan has designed an institutional framework to administer and promote energy production from the renewables [22]. To date, however, it has faced many challenges in achieving its objectives [1], which needs to be addressed by the appropriate government policies, in order to bring a sustainable and environment-friendly future in renewable-based power generation.

China is investing a significant amount, (62 billion dollars) in Pakistan, under the China Pakistan Economic Corridor (CPEC), which is almost equal to 2/3rds of Pakistan's total foreign debt [23]. There is limited literature available regarding the potential, current practices, and prospects of growth in the RE sector of Pakistan. Few studies have been conducted, either by the government of Pakistan or in coordination with international organisations, such as the International Resource Group (IRG) (2007) [24], the World Bank (2014) [25], Japan's

International Cooperation Company (2015) [26], the energy component of Pakistan's Planning Commission (2017) [27], the Atomic Energy Commission of Pakistan (2017) [28] and the Water and Power Development Authority (WAPDA) of Pakistan (2019) [29]. Similarly, only a few academic studies can be found, which specifically focus on the RE situation in Pakistan, such as Shah (2014) [30], Rauf (2015) [31], Mirza (2017) [32], and Hussain (2017) [33]. Such studies as there are, however, have concentrated on either criticising the current energy situation or comparing it with that of the past, without learning lessons from the developed countries and suggesting appropriate policy measures to the government and other stakeholders. This situation is the justification of this study.

Pakistan offers a unique case of a country which experiences energy shortages and even crisis, meanwhile spending much on the country's other development sectors, such as various projects under CPEC, including energy generation through coal power plants, yet ignoring the RE sector, despite having abundant potential and RE strength. There are around 22 energy projects comprising about 14,000 MW according to the present plan with an estimated cost of US$ 27 billion. These projects mainly include coal, but also include solar, wind, hydel, imported fuel and transmission lines as well. The result of the aforementioned is that, the objectives of this study include highlighting the significance of producing energy from renewable sources, examining global trends and current practices or priorities of the government or the relevant departments in Pakistan, in addressing finding the optimal solution of the energy crisis on the one hand and advocating a need to produce cost-effective, sustainable and environment-friendly energy by exploiting country's renewable resources, on the other hand. The study also provides guidelines about how various policies may be devised to replace current arrangements, the later having to be relatively ineffective. The findings of the study offer forward thinking and engage the attention of policymakers and various stakeholders through concrete observations and recommendations. The statistical data relating to the energy sector in Pakistan is not up to date [34], which inhibits accurately measuring the origins of slow progress in institutional and policy reforms in this domain.

2. Overview of Global Energy Mix

2.1. Energy Mix in Pakistan

Pakistan has extended its installed energy capacity to 34,282 MW by 2019 [35], however, the country has been facing energy shortfall of around 3000-6000 MW in recent years. The total energy mix in Pakistan represents around 37% of the energy produced through fossil fuels, which represents expensive energy and unstable pricing, due to the instability in oil prices. The primary energy sources of the country include oil, gas, hydropower, coal, and nuclear energy [36], which represent non-renewables. Its power usage increased from an approximate value of 58.06 million tonnes of oil equivalent (Mtoe) to 70.27 Mtoe, from 2006 to 2015, respectively [37]. From the sources cited above, oil and natural gas contribute most to energy production, i.e., 43% and 36% respectively, of the total energy production. The national natural gas reserves have been extensively exploited and decreased from 31 trillion standard cubic feet (Tscf) to 23.64 Tscf, from 2009 to 2014 [38], which indicates an increased share in the country's overall energy mix. Furthermore, in 2016, Pakistan signed an agreement with Qatar to import 3.75 million tonnes of Liquefied Natural Gas (LNG) per annum, for a period of 15 years [36].

Oil's contribution in overall primary energy supply (OPES) has continuously increased from 28.27% of OPES in 2006 to 32.04% in 2011 and then 34.42% in 2015, which represents around a 4.5% increase in annual oil consumption by the country [39]. Oil, coal, natural gas, hydro, nuclear, renewables, and imported electricity, also add to Pakistan's energy mix. Energy from biomass contributes significantly to the energy mix; a report by the International Energy Agency (IEA) mentioned that, around 105 million people in Pakistan rely on conventional biomass energy, which is equal to a sum of 8.2 Mtoe of imported electricity (mainly imported from Iran) and LPG [40]. It is also noteworthy that, a nuclear energy project of 2880 MW is under construction in Pakistan [28], which will significantly promote 'clean energy' in the country. Presently, the energy mix in Pakistan comprises mainly (as shown in Figure 1) gas or RLNG, oil, hydro, nuclear and coal-based power plants, with gas/RLNG accounting for 3865 MW, oil (8571), coal (2367), hydro (8845), nuclear (1320), and renewables add 1337 MW, in the national energy mix.

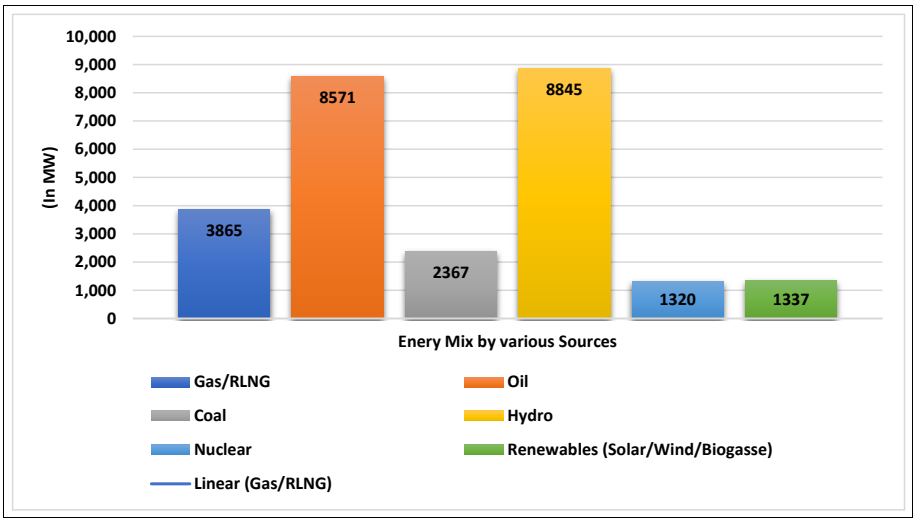

Figure 1. The share of Installed Capacity Mix by Source (as of March 2019) [41].

2.2. Energy Mix in Other Countries of the World

Most of the countries across the globe are shifting their reliance from traditional energy sources to renewables, which is not only sustainable but also environmentally-friendly [42]. A significant contribution in the aggregate energy mix, however, as shown in Figure 2, still represents energy production from non-renewable sources, i.e., 73.50%. A report by the US energy information administration demonstrated that, total renewable power capacity worldwide has more than doubled in the last ten years, with an estimated power generation capacity of 2,195 GW and around 17 countries have produced more or less 90% of their electricity by utilising their RE sources [43], [44]. The report also mentioned that, the net addition in global energy production in recent years, includes 70% from renewables.

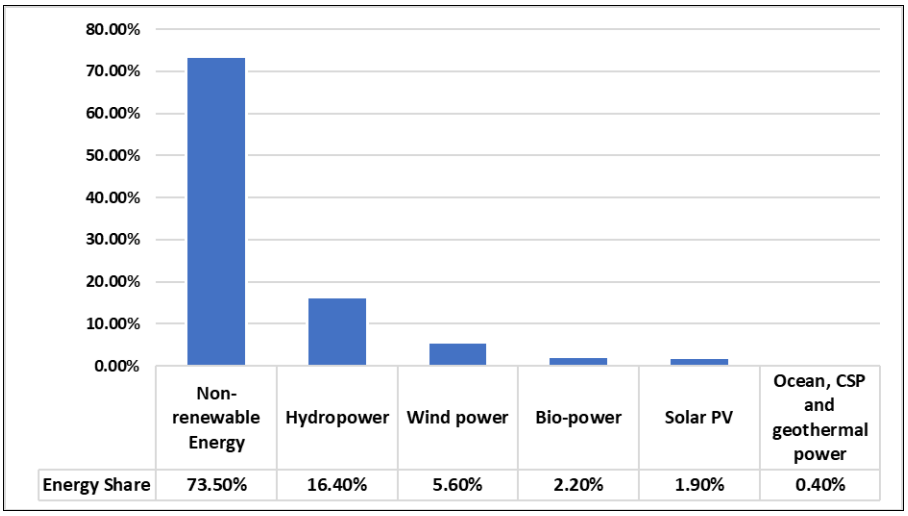

Figure 2. Share of RE in Global Electricity Production [44]**.**

3. Global Trends Toward RE and Situation in Pakistan

An increase in electricity generation by renewables in recent years signals a strong commitment to reducing carbon emissions and addressing climate change. The number of installed new solar power projects is more than the net additions by gas, coal and nuclear plants combined. China alone, has contributed around 45% of the world's total investment in RE in recent years, which includes 13 off-shore wind projects. This demonstrates the huge potential of the RE sources to produce energy, not in massive quantities but also being cost-effective and environment-friendly, which helps the world in its fight against climate change.

Figure 3 shows the global trends of investing in RE production from 218 billion USD in 2007, to 393.8 billion USD in 2017. These cheap and efficient energy generation sources have also attracted oil-rich countries such as the United Arab Emirates (UAE), to invest and produce more clean energy from renewables [45]. The various stakeholders, especially relevant government departments in the world, should continue to endorse this global momentum, by offering more financial, technological and administrative support to the private sector, to encourage investing in RE generation.

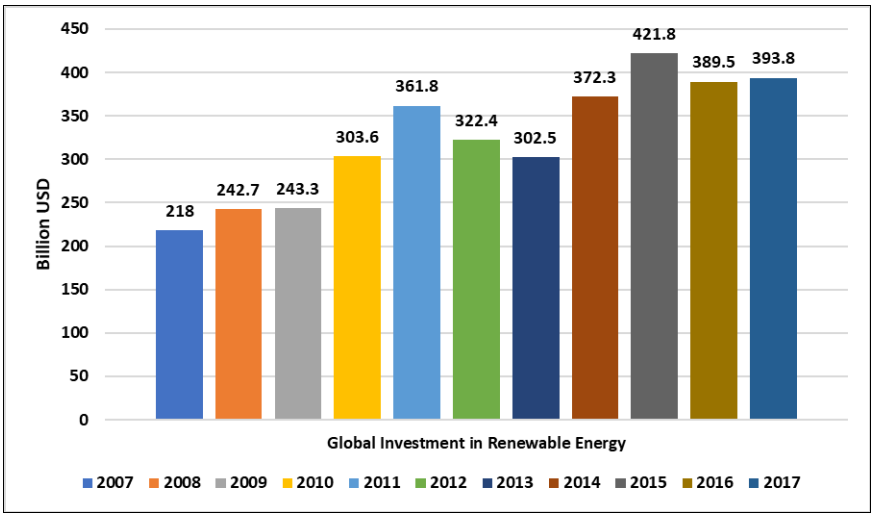

Figure 3. Global Trends in RE Investment in the Recent Years [46]**.**

3.1. Energy Shift from Traditional to RE Sources Worldwide

The RE generation technology is cost-effective and cost-competitive, which explains is growing appeal. For example, since 2009, there has been a significant decrease in the solar PV module costs, by as much as 80%, with almost three-quarters being achieved from 2010 to 2017. Onshore wind energy costs fell almost a quarter, being as low as four cents of USD cents (USD 0.04)/kWh currently, and is projected to decline to three cents (USD 0.03)/kWh shortly [37]. In 2007, the average global weighted cost of energy produced by hydropower was recorded as five US cents (0.05 USD)/kWh and ten cents (0.10 USD)/kWh, from electricity produced by utility-scale solar PV projects [37]. The number of cities in the world which are powered by at least 70% of the RE has also been doubled, during the last decade [44].

In recent years, China played a leading role in shifting its focus from coal-based plants to RE sources, which showed a strong commitment to clean energy production and the achieving of the sustainable development goals under the Paris Agreement 2015 [47]. To this end, China has enacted a coal-ban over 28 cities. In addition, China's 13th Five-Year Plan also comprises numerous renewable heating-related targets, in fulfilling its commitment to building an

environmentally-friendly world [48]–[52]. China has also recently added the largest solar system to supplying its industrial needs [53]–[56].

3.2. RE Potentials in Pakistan

Solar energy is regarded as the most widely spread and most plentiful source of all the all RE sources. The estimated potential of solar PV power is around 1600 GW, about 80 times greater than the present energy produced by non-renewable sources in Pakistan; the currently installed capacity is only 400 MW [36]. Some solar energy plants are under consideration by the CPEC, that may be useful in exploiting the country's solar potentials, to produce cheap and clean energy. In addition, wind, biomass, and hydropower (60000 MW) also offer massive potential for energy production in the country [2]. Table 1 presents a summary of the existing RE sources in Pakistan.

Table 1. Potential of RE Resources in Pakistan [30], [36], [57]**.**

Energy Resources	Energy Potential in Pakistan
Hydroelectric	The estimated total hydroelectric potential in Pakistan is 40000 MW, whereas, the installed capacity as at June 2017, was only 7,116 MW, which included the functioning of the river plants on canals and rivers on the southern plains, as well as high-head and storage-based schemes on mountainous streams in the north and low-head.
Wind	Pakistan possesses a wind power generation capacity of around 63000 MW but unfortunately, the present contribution towards the energy mix is quite nominal. Coastal Baluchistan and the southern areas of Sindh, have huge exploitable wind energy potential, with monthly average wind speeds above 7-8 m/s
Solar and Thermal	Pakistan is blessed with extensive solar (1600 GW) and thermal energy sources; southern Punjab, Sindh and Baluchistan provinces receive plentiful solar irradiation of more than 2 MWh/m2, as well as 3000 hours of sunshine annually.
Biomass	In Pakistan, the scope for generating energy from biomass is vital; the agricultural and livestock sector produces bagasse, animal waste, dung, and rice husk. In addition, the municipal solid waste management system produces an ample amount of usable methane gas or potential electricity, by utilising or disposing of dumps produced by the urban population in the country.

3.3. Applications of RE Resources in Pakistan

The availability of abundant RE resources in Pakistan is now more fully appreciated. These resources can be utilised for producing energy, in excess of energy demands. The plains and desert lands in the centre and glaciers and high mountains ranges in the northern region of Pakistan, provide great potential for installing solar and hydropower projects, respectively. In addition, southern Punjab, Baluchistan and Sindh provinces are rich in the wind power potential and the well-established sugar-refining industry and agricultural sector add to the RE capacity of the country.

The RE resources need to be explored, mapped and then exploited by the concerned departments of the country. To this end, the World Bank, under a project funded by the Energy Sector Management Assessment Programme (ESMAP), is closely collaborating with the Alternative Energy Development Board (AEDB) of Pakistan for assessment of the country's RE resources including wind, solar, biomass, geothermal and hydropower energy [58].

3.4. Present Contribution by Renewables in Pakistan

The potential for energy generation through renewables is acknowledged in Pakistan. The US National RE Laboratory (NREL) has conducted a research study which elaborates and classifies countries by solar radiation and wind power potential. According to the report, the areas of Baluchistan, Khyber Pakhtunkhwa and Sindh provinces, have more potential for producing energy from wind power. In contrast, many other parts are considered appropriate for power generation through the installation of solar PVs across the country [59], [60].

In Pakistan, many of the RE projects in recent years, including wind power projects, have been in the areas of Thatta, Jhimpir, and Gharo. Among these projects, 12 have been completed, connected to the national grid and are providing 590.5 MW. In addition, 36 wind projects, having a capacity of 1842.6 MW and 24 biogas plants, with 817.5 MW potential, are at different development stages but will eventually contribute to commercial production and grid system. In addition to these, four solar energy projects are also operational, which potentially add to the national grid, these being Quaid-E-Azam 1000 MW Solar Park (Bahawalpur), currently adding 400 MW [61], the other three adding only 100 MW to the national grid of the country [7]. It is a

matter of the fact that, Pakistan is still producing a considerable amount of electricity by thermal sources (62.1%), while the total share from the renewables is relatively nominal [62]. Figure 4 explains and presents the current contribution to energy generation by RE sources in Pakistan, together with a contrast of the situation in 2012-13, with that in 2018-19. It can be observed from Figure 4 that, even after six years have passed, the contribution from thermal energy remains almost unaltered, i.e. from 64% to 62.1%, and there is minimal improvement in the contribution from other renewables, which is inadequate when compared to the RE-growth in other countries. This six-year comparison also illustrates the government's priority, in posing questions as regards progress in the sphere of RE in the country.

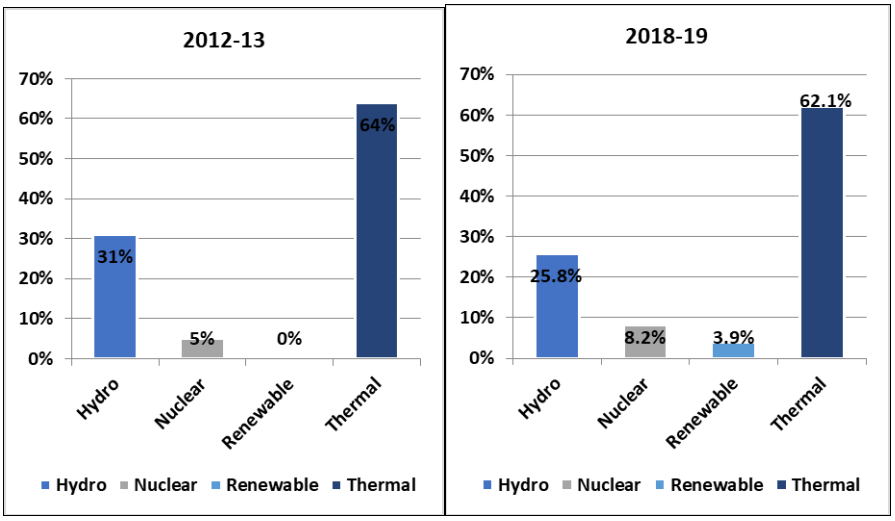

Figure 4. Renewable's Share in Electricity Generation in Pakistan [36], [63], [41]**.**

4. Policy Implications for RE

4.1. Policies Implemented by Various Countries, in Adopting RE

By the end of 2018, more than 150 countries in the world had set targets for generating electricity from RE sources, and around 145 countries had officially enacted, 'energy efficiency

236 policies.' Table 2 presents a thorough overview of such policy developments in various countries
237 across the world.

238 **Table 2. Policies implemented by Various countries to adopt RE**

Name of the Country	Description of the pertinent RE Polices
Canada	Awarded feed-in tariff (FIT) support to landfill gas, biogas, and solar PV projects in Ontario [44], [64].
China	Decreased FIT rates for utility-scale solar PV in some of its regions [45].
Taiwan	Decreased FIT rates for wind and solar PV and increased geothermal energy production by 5% [65].
India	Decreased FIT rates for producing wind energy in the southwest state of 'Karnataka' [65]. India has also established higher capacities to promote the rooftop PV system in 'Gujrat' state [66].
Cyprus	Expanded its capacity within its prevailing schemes concerning biogas and biomass energy plants [67].
Lithuania	Set a target to install 200 MWs of additional solar PVs by the end of 2020 and amended its net metering scheme to achieve this goal [68], [69].
Mauritius	Launched the second phase of its net metering scheme to install up to 2 MW of additional solar PV in the national grid [70].
Pakistan	Amended its net metering programme to expand its scope for selected cities across the country [71].
Other Countries (Bahrain, Argentina, Albania, Namibia, Moldova, and Tanzania)	Expanding their current net metering programmes and also formally enacted net metering policies [44].
United States	There has been a long debate and progress on net meting policies, in recent years [72].
Nevada	The Public Utilities Commission of Nevada implemented a net metering policy, which had been ceased in 2015 [73].
Arizona	Regulators decreased FIT rates for net metering to promote new rooftop solar PV in Arizona [74].

Policy formation and incorporation require an eclectic variety of methodical concepts [75], including synthetic inertia and fast frequency response, to enable grid service provision from distributed energy resources and demand-side management [66], [76]–[78]. For instance, China released a policy document as a guide to promoting the energy storage-related industry, which also comprises non-pumped storage projects, to reduce 'variable RE' curtailment and to promote energy generation from renewables [79]. Furthermore, China's 13th Five-Year Plan envisaged an increase in pumped storage capacity to 40 GWs by the year 2020 [80].

4.2. Renewable Policy Mechanisms in Pakistan

The energy crisis continues unabated in Pakistan and despite facing energy crisis and inefficiency, the country has not yet balanced its energy mix with an appropriate contribution from renewables and is still more dependent on the traditional energy-producing sources, i.e., fossil fuels and coal-based power plants; among the main reasons being non-utilisation of indigenous resources due to the country's unstable economic situation and a lack of appropriate planning, coupled with lacking a comprehensive energy policy [2]. A Pakistan launched its RE policy in 2006, for the first time [21]. Its formulation and implantation are managed and divided among the federal, provincial and local level, pertinent institutions. These institutional entities are responsible for addressing the various relevant issues, including energy generation, distribution and consumption, i.e., measuring petroleum standards and gas mileage [81]. The comparative tabulated form (see Table 3) presents a short brief about the RE situation in South Asian countries, which shows that, Pakistan demonstrates the highest per capita electricity consumption in South Asia after India but still, it lacks an adequate RE contribution in the country's total energy mix.

Table 3. Comparison of the Per Capita Electricity Consumption of Some Countries in South Asia [82].

South Asian Countries	Per capita electricity consumption in kWh
India	644
Sri Lanka	636.3
Pakistan	457

Bangladesh	278.1
Nepal	454.1
Afghanistan	119.8

To formulate national energy policy, requires appropriate legislation, understanding or ratifying pertinent international treaties, granting incentives and subsidies to private sector's investors, government-specific special energy efficiency and incentive schemes, as well as providing comprehensive guidelines for energy conservation, ample taxation, and various other public policy practices or strategies. In Pakistan, NEPRA regulates the energy sources and determines the relevant energy prices, on the recommendations of the Water Ministry (policy enforcer) and AEDB [83].

4.2.1. Policy Implications

Pakistan needs to design short, medium, and long-run policies, in order to move on from the crisis of power shortage, as well as expensive power production, by formulation, implementation and bringing structural enhancement through sustained institutional development, as well as political commitment [16]. Although, some wind and solar power projects have been launched and are contributing (a little) to the national grid, the power division of the Energy Ministry in Pakistan does not provide a robust policy concerning the induction of renewables into the country's existing energy mix. For example, small hydropower plants cannot be built because of the unavailability of a clear, relevant policy regarding induction of the renewables.

NEPRA, in an effort to achieve consistency with international trends, announced some upfront tariff rounds, to allow the development of projects in a relatively short period, coupled with lower tariffs; notified several tariffs plans through the NEPRA Upfront Tariff Regulations 2011 (Approval and Procedure) for small hydropower and bagasse generation plants, to provide an incentivised regime. It has also recommended adopting and following a competitive bidding system, having more attractive tariffs [36]. To this end, AEDB is playing a significant role, as it is the relevant agency to the subject matter. The central concept conveyed through the Amendment Act, 2018 refers to the National Electricity Policy and the National Electricity Plan

(NEP&NEP), which prescribes the authorities and functions of NEPRA Act to be exercised under NEP&NEP.

Pakistan has massive potential to produce electricity from RE resources such as wind and solar. There is a requirement for government priorities and firm commitments, in order to effectively sufficiently and sustainably utilise or exploit these resources, through proper institutionalisation. Such action will not only overcome the power shortfall but also offer clean and environmentally-friendly energy to the country, at cheaper and more competitive rates.

4.2.2. The Legislation, Regulation, and Relevant Departments

The primary energy policy in Pakistan was announced in 2006, however, there have been subsequent legislation and regulations concerning the administration and governing the RE sector. Major relevant departments in Pakistan include the National Transmission and Despatch Company, the National Electric Power Regulatory Authority, the Alternative Energy Development Board, the Sindh Energy Department and the Punjab Energy Department and the pertinent regulations are tabulated in Table 4, which explains the formation and the operation of the RE-related laws and regulation.

Table 4. The RE-related Regulations in Pakistan [84]**.**

Name of the Law or Policy	**Description**
NEPRA (Tariff Standards and Procedures) Rules 1998	According to Section 31, read with section 46 of the Act, NEPRA developed the Tariff Standards and Procedure Rules, 1998, which provides a tariff setting process and the broad principle of tariff setting.
NEPRA (Alternative and RE) Distributed Generation and Net – Metering Regulations, 2015	It provides the policy implications concerning the development and tariff plans, to promote and encourage RE in Pakistan. The authority decided to look into the possibility of introducing net metering at the consumer level. Accordingly, an initial draft document of NEPRA (Alternative & Renewable Energy) Distributed Generation and Net Metering Regulations was prepared.
Policy for Development of RE Generation, 2006	The Government of Pakistan introduced a policy for the development of RE for electricity generation in 2006 and also introduced a phased programme for the development and execution of Alternative and RE

	based projects in the country.
Review of environmental impact assessment (EIA) and initial environmental examination (IEE) Regulations 2000	These Regulations provide the list of projects that require an IEE and projects that require an EIA. It also provides the guiding principle concerning the various activities of IEE and EIA.
NEPRA Licensing (Modification and Application Procedure) Regulations, 1999	In exercise of the powers conferred by section 47 of the Regulation of Generation, Transmission and Distribution of Electric Power Act, 1997 (XL of 1997), NEPRA notifies such regulations, which include consideration of the application, admission of the application, application procedure, application for licence and modification to the licence.

4.2.3. Policies and Initiatives Concerning RE in Pakistan

Pakistan is among those developing countries which have developed a systematic framework to invite the private sector to participate in energy production. The private sector was allowed to invest in the development of solar, wind, and biomass energy sectors, under the Power Policy of 1994, however, the economic viability of the country and technological barriers restricted its anticipated growth at that time. The 2006 Alternative and RE Policy of Pakistan, consist of a comprehensive regulatory framework for exploiting the country's renewable resources and devising RE technologies. It attracts investors by offering numerous incentives for the private-sector, however, its success and effectiveness will depend on the successful implementation of NEPRA directives on competitive bidding concerning wind and solar energy generation.

Several initiatives launched under the Alternative and RE Policy 2006 guidelines have brought slow progress towards the development of RE in Pakistan. AEDB, being the key authorised department, has led in the initiatives concerning promoting RE in the country. Barriers in attracting investment from the private sector have been removed and handled through independent resources and also with the support of bilateral as well as multilateral development partners. Some of the foremost, initiatives include: upfront tariffs for RE technologies; standardised templates; net-metering; grid study for integration of intermittent RE sources; grid integration code for solar and wind power projects; grid infrastructure development for RE projects; quality standards for imported solar equipment; finance scheme by the state bank of

Pakistan for RE; NEPRA guidelines for competitive bidding (auctions); and various provincial government initiatives, including provincial governments, can also issue intent-letters for developing RE projects [37].

4.2.4. Revised Financing Scheme for RE by the State Bank of Pakistan (SBP)

In 2009, the SBP launched a financing scheme, to promote RE generation in the country. This scheme was solely designed for those power plants which were using RE sources such as wind, solar, biogas, bagasse cogeneration, biofuels, hydro and geothermal as fuel. The SBP promoted, 'green and sustainable banking', to meet the challenges in this domain, such as granting finance and special incentives for utilising indigenous (renewable) energy resources. These programmes will cover both small-scale RE solutions and large RE projects [85].

4.2.5. Pakistan's Council of RE Technologies (PCRET)

PCRET is the primary government institution that coordinates and administers research and development (R&D) and other promotional activities, concerning various RE-related technologies. The Council was created through merging the National Institute of Silicon Technology (NIST) and the Pakistan Council for Appropriate Technologies (PCAT), on May 8, 2001. The objectives and salient features of the institution include to: conduct RE training workshops for the general public; enhancement of PCRET facilities for advanced R&D; enhancement in the existing solar PV research facilities; produce devices, applications, and materials in the sphere of RE; create expertise, facilities and carry out research; develop appropriate required technologies; determine policies and devise short as well as long-term plans; promote and encourage RE technologies through R&D; organise various workshops, seminars and conferences, for promoting the RE-related technologies; create liaison in this domain at national and international levels; and assist and advise the government, pertinent departments and industry sector in the country [86].

There is significant scope covered by the work in the areas, that affects the PCRET mandate. Many of the existing PCRET programmes have suffered irretrievable harm because

R&D funding was extremely scarce and there was also an acute shortage of qualified technical labour. It would be desirable to carry out more advanced R&D for testing and designing already developed products, develop new concepts and train or introduce the general public in adopting these technologies in everyday life.

4.2.6. Energy Security Action Plan (2005–2030)

Pakistan announced its Energy Security Action Plan of 2005–2030 in 2005, as demonstrated in its 2030-vision to ensure secure energy supplies [87]. Under this plan, the country's capacity for electricity generation will increase from 19,540 to 162,590 MWs by 2030. To achieve this target, it was proposed to have an energy mix including hydropower, nuclear and other RE sources, to produce around 143,050 MWs in additional capacity, under a phased programme [88]. This was estimated based on past trends of energy consumption, as well as projected future load growth; the plan was devised to promote the stability of supplies and pricing in the country. Despite the aforementioned, after passing of more than a decade, there has been very little progress towards the development, exploitation and exploration of RE resources in the country. So far, Pakistan has only added a negligible amount of modern RE sources to the national energy mix [89], which questions the government's progress and priorities, over the last ten to fifteen years.

4.3. Comparison of RE Policy in Pakistan's and Four Other Countries

Table 5 shows the situation in Pakistan, as well as in four other countries (Spain, Germany, Sweden, and the United Kingdom) concerning national RE targets, installed capacity of wind, solar and various schemes or policies regarding producing electricity through utilising RE resources. According to the figures provided in Table 5, Pakistan is lagging far behind, not only in achieving the specific objectives but also in setting rational targets for generating energy from the RE sources. For example, as regards installed capacities to date, national RE targets and the formulation of relevant schemes and policies, all are significantly weaker, as compared to the other four countries (see Table 5). Additionally, the assessment of the RE contribution to the national grid (as provided in Figure 4; comparison of the country's situation from 2012-13 to 2018-19), would seem to indicate that, the government should revise its policies and energise its

efforts in RE sector, to achieve its specific targets. To this end, the recommendations concerning policy measures provided in this study (see Section 6), should be considered for future development in the RE sector.

Table 5. A Comparison of Pakistan's RE Policy and other Four Other Countries [57], [90]–[93]**.**

Components	Pakistan	Spain	Germany	Sweden	United Kingdom
National targets for RE	RE's minimum installed capacity is projected to be 9700 MW up till 2030	22.7% RE forecasted by 2020	35% RE till 2020, and 80% by 2050	50% RE till 2020	15% RE till 2020
Solar power installed capacity	200 MWs	7.13 GWs	39.6 GWs	85 MWs	9.08 GWs
Wind power installed capacity	308.2 MWs	23 GWs	44.9 GWs FITs,	6.03 GWs	13.9 GWs
Schemes or Policies	FITs, tax incentives	FITs	FITs, comprehensive RE law tax, and investment incentives	Exemption from energy taxes, Quota obligation, FITs,	FITs, renewables obligation, renewable heat incentive

5. Strengths and Barriers in the Development of RE in Pakistan

5.1. Strengths of RE

The world has shifted its focus over integrating RE and energy efficiency [94]. International organisations have started various global campaigns, to increase awareness regarding the significance of alternative or RE worldwide, as well as encouraging policymakers and other stakeholders to consider this issue as a priority [44]. Thus far, pertinent policy-making has brought favourable results in promoting RE and energy efficiency. For example, gross domestic product (GDP) rose by 3%, together with an increase in energy demand by only 1.1%, in 2016 [95]. By applying energy efficient techniques and policies, the world has maintained a positive trend for global GDP, in comparison to 'energy use', over the last two decades [96]. It would be reasonable to comment that, global energy demand has reduced, when compared to the per unit of economic output, which is a result of making structural changes in industries, a combination of focused demand and supply-side mechanisms and policies through utilising

renewable resources such as the extension, consolidation and lifelong impact of energy efficiency canons for its various usages and applications; enhanced fuel efficiency standards; shifting from fossil fuels to relatively less carbon-concentrated substitutes, such as renewables; and structural changes in industries, including a shift toward more service-oriented and less energy-intensive industries.

Pakistan urgently needs a comprehensive energy plan that adequately addresses the issues, including energy inefficiency, poor utilisation of natural energy resources and a lack of awareness and attention to prioritising by the government and other stakeholders of a switch to renewables. Pakistan's Nationally Determined Contribution, under the 2015 Paris Agreement, has set a target to decrease its greenhouse gas emissions by 20%, by 2030 [37]. To this end, the use of oil and gas, together with the electricity sector being dealt with under one energy ministry since 2017, would seem to offer the opportunity for the country to develop a better-co-ordinated energy plan, which may reduce institutional obstacles and create a unified position on the RE planning process and implementation for environmentally-friendly, as well as clean energy mechanisms. It is also worth mentioning here that, Pakistan's Energy Security Action Plan (2005–2030) reveals that, the country's anticipated capacity for electricity generation will increase from 19,540 to 162,590 MWs, by 2030 [87]. To achieve this target, it was proposed to have an energy mix including hydropower, nuclear and other RE sources producing around 143,050 MWs, as additional capacity under a phased programme [88]."

5.2. Barriers to the Development of RE Sector of Pakistan

5.2.1. Poor Infrastructure and Market Access, along with Financial Barriers

Grid reinforcement, suitable grid codes and relevant infrastructure are required for the extraction of energy from RE sources, which will require further significant investment in the power infrastructure, in order to allow RE sources to contribute to the national grid. The inadequate funds and lack of financial support or incentive schemes from the government for RE sources, represents one of the main barriers to encouraging a meaningful contribution from the country's RE sector and of course, the current situation does not offer investor appeal.

5.2.2. *Policy Challenges*

Presently, there would appear to be no or only nominal focus and concern about the current situation, as indicated by the various policies of the government concerning efficient utilisation of RE resources, despite the apparent lack of success of existing policies and legislation. It is fairly evident that, there is a lack of competition between conventional and RE resources and various economic incentives, such as the exclusion of external costs on non-RE sources, lengthy licensing procedures and feed-in-tariff are also provided to the conventional means of energy production, which inhibit the possible benefits from RE enhancing sources to the national grid [97].

5.2.3. *Information-Based Technical Capacity*

The deficiency concerning technical information (i.e. sunshine and wind speed data) is among the critical barriers to harvesting RE technologies in Pakistan, which encourages extracting benefits from such sources. In addition, the shortage of relevant service corporations (contractors, consultants and equipment suppliers) and lack of essential professional expertise, are inhibiting any meaningful progress [97].

5.2.4. *Institutional Barrier*

It is an unfortunate reality that, the relevant institutions in Pakistan have been exhibiting a lack of unanimity and cohesive action, concerning the improvement, development, and enhancement of investments in the RE sector [31]. This level of poor or lack of organisation between relevant government agencies and other stakeholders in the country, hinders the development and proper utilisation of these RE sources.

5.2.5. *Absence of Social Awareness*

Besides the factors mentioned earlier, one significant barrier to the progress of RE sector of Pakistan is the absence of much-needed awareness schemes addressed to the general public concerning compensation, benefits and importance of using modern technologies concerning RE sources. This omission discourages public participation in the national development process.

5.3. Lesson-learning and Moving Towards the Way Out

Climate change has caused a number of incidences of environmental harm and apparently contributed to an increase in global temperatures, thus meriting implementing urgent action to stabilise global the climate. Shifting energy production from the traditional sources to perceived clean RE sources, could offer the way forward, to a more sustainable world. To this end, China may assist Pakistan both financially as well as through technology transfer, in exploiting the country's RE resources, since China is investing considerably in Pakistan's energy sector, under CPEC. It may base as regards regional development, where China sees its involvement, including investing significantly in various projects under CPEC (an extended part of Chinese Belt and Road Initiative) [98]. Since China has strategic interests and is already assisting Pakistan in many ways, including combating the energy crisis, i.e., installation of a coal-based power plant in Pakistan, it is, therefore, suggested that it would be beneficial, as well as environmentally friendly, if China might also assist Pakistan in the development of RE technologies. This would make Pak-China collaboration more feasible in this regard, than might calling for assistance from others, such as ASEAN and the EU. Such an action would, however, bring some potential national risks, including the issue of the repayment of foreign debt, since Pakistan is already facing various economic problems, as regards the servicing of foreign debt [99].

The above situation, including the global trends and comparative presentation of Pakistan's RE with some other countries, offers some lessons for Pakistan about how it may learn from their practices and improve the environmental situation in the country. The government, thus, with the help of private local or international organisations, must pay heed to not only exploiting the existing RE resources but also exploring new options, in the face of potentially an overwhelming power demand and supply gap. To this end, several foreign organisations might be consulted and might also be a part of the various energy negotiations under CPEC. In addition, it is imperative to encourage the private sector, semi-government and local organisations to promote RE-related technologies, i.e. solar cells, hydel turbine, micro-wind and wind farms, since Pakistan possess ample potential for harnessing these RE sources.

6. Conclusion and Recommendations

The significance of installing alternatives or renewables in energy production is vital in the contemporary industrial and technology regime. Most of the developed countries in the world have recognised, adopted, and set targets to shift their energy generation from conventional sources to RE sources. Unfortunately, despite having an energy crisis in the form of electricity shortfall and expensive production, Pakistan still depends too much on conventional energy sources. Pakistan has had its RE policy for more than a decade (in 2006), however, there is still a minimal contribution from renewables to the energy mix and indeed, fossil fuel developments are still ongoing. The coal-based and other conventional energy sources may be the short-term solution to the country's power crisis, but will have a substantial environmental impact in the long-run, rebalancing with renewables is not accelerated. A degree of urgency is required from the government and various other stakeholders, to revolutionise the energy sector of Pakistan, and create a link between energy production and efficiency, in order to achieve economic development by utilising the country's natural resources to meet its energy demands more efficiently and at affordable prices, as well as making the world safer, more sustainable and environmentally-friendly.

This study offers proposals for devising a sustainable clean energy system in Pakistan and other developing countries, which are striving to establish or enhance their RE sector, while facing similar barriers and it recommends (below) comprehensive as well as rational policy measures to keep such endeavours live and to integrate future adjustments:

i. Develop, coordinate and then ensure implementation of integrated energy policy across the country;

ii. Binding targets encourage investors, since they are not so vulnerable to variations in the political climate. Therefore, it is recommended to set short, medium and long-term targets, especially for RE;

iii. Encourage RE zoning, and competitive procurement; new RE zoning should be considered and synchronised with current national grid development plans, to lessen

concerns that RE projects make grid operations more problematical. The 'Quaid-e-Azam Solar Park' is an appropriate illustration of RE zoning.

iv. Involve the private sector in transmission development, create an enabling environment for private-sector involvement and develop a comprehensive distributed power generation plan, in order to improve overall energy efficiency;

v. Lack of experience and technical challenges in power generation and distribution are valid concerns, which should be addressed through capacity building in the relevant departments;

vi. Some long-run plans are required, comprising clear policies as well as an appreciation of the supply and demand situation, in order to maintain continued reliability in the system; to this end, small hydropower plants should be encouraged, for the long-term sustainability of this sector;

vii. New induction and exploration of indigenous (renewable) energy resources should be stimulated, to diminish dependence on imported fuel;

viii. The Power Division of the Ministry of Energy should be urged to resolve the technical issues as well as policy level ambiguities, in promoting the renewable technologies, since wind and solar provide clean energy, without using fuel;

ix. Ministry of Energy (Power Division) being tasked with responsibility for power generation, distribution and transmission, is required to take extraordinary steps to ensure the readiness of stable distribution and transmission infrastructure, for ultimately providing a more reliable electricity supply;

x. It is suggested that, the NEPRA and other concerned departments should adopt all these measures, which may help in tracking the flow of electricity from high voltage grids to end-consumers. To this end, centralised monitoring systems, remote metering devices, and automatic metering systems should be installed across the country, as soon as possible;

xi. The provincial bodies which are responsible for power generation as well as distribution, require to enhance their capacities and skills improvement in human resources;

xii. It is also suggested, the 'Net-Metering regime' should continue to reduce the burden on constrained networks; and

xiii. It is recommended to encourage and initiate local manufacturing units to produce energy from RE sources, in order to decrease the capital cost of key equipment in transmission, generation, and distribution sectors.

Data Availability Statement

Availability of Data	Temple for Data Availability Statement
No scientific data is included	The current table is being prepared as a requirement of the journal. However, the current study does not use any specific scientific data sets, instead, it is based on the qualitative means of analytical studies. Nonetheless, any information, fact or figures used in the paper are duly cited and appropriately added in the reference part of the paper.

References

[1] U. Zafar, T. U. Rashid, A. A. Khosa, M. S. Khalil, and M. Rashid, "An overview of implemented renewable energy policy of Pakistan," *Renew. Sustain. Energy Rev.*, vol. 82, no. September 2017, pp. 654–665, 2018, doi: 10.1016/j.rser.2017.09.034.

[2] S. Gul, "Renewable Energy," *Pakistan Observer*, 2017. https://pakobserver.net/renewable-energy-2/ (accessed Dec. 21, 2018).

[3] M. I. Khan and Y. C. Chang, "Environmental challenges and current practices in China-A

548 thorough analysis," *Sustain.*, vol. 10, no. 7, pp. 1–20, 2018, doi: 10.3390/su10072547.

549 [4] A. Neslen, "Renewable energy smashes global records in 2015, report shows," *The*
550 *Guardian*, 2016.
551 https://www.theguardian.com/environment/2016/jun/01/renewable-energy-smashes-global
552 -records-in-2015-report-shows (accessed Dec. 24, 2018).

553 [5] P. D. Lund, "Effects of energy policies on industry expansion in renewable energy,"
554 *Renew. Energy*, vol. 34, pp. 53–64, 2009, doi: 10.1016/j.renene.2008.03.018.

555 [6] M. A. Aman, S. Ahmad, M.-Munir, and M. Ali, "Solutions of current energy crisis for
556 Pakistan," *Int. J. Comput. Sci. Inf. Secur.*, vol. 15, no. 5, pp. 145–149, 2017.

557 [7] MoF, "Pakistan Economic Survey 2016-17," *Ministry of Finance, Government of*
558 *Pakistan.*, 2017. http://www.finance.gov.pk/survey_1617.html (accessed Dec. 21, 2018).

559 [8] Pakistan Today, "Circular debt soars to Rs1.3tr, minister tells NA," *Pakistan Today*, 2018.
560 https://www.pakistantoday.com.pk/2018/09/28/power-division-circular-debt-soars-to-rs13
561 00bn/ (accessed Dec. 21, 2018).

562 [9] M. Q. and K. Kotani, "Causes of energy shortage in Pakistan: An empirical evidence,"
563 *Asia-Pacific Dev. J.*, vol. 21, no. 1, pp. 137–166, 2014.

564 [10] M. I. and S. Rana, "Reforming the Energy Sector of Pakistan: The Case of Punjab,"
565 *Centre for Public Policy and Governance, Forman Christian College*, 2014.
566 http://cppg.fccollege.edu.pk/wp-content/uploads/2014/04/Reforming-the-Energy-Sector-o
567 f-Pakistan.pdf.

568 [11] S. Chavan and M. Chavan, *Recent Trends in ICT-Enabled Renewable Energy Systems*.
569 Springer Singapore, 2019.

570 [12] F. Ali and F. Beg, "The History of Private Power in Pakistan," Islamabad, Pakistan, 106,
571 2007.

572 [13] GoP, "Policy Framework and Package of Incentives for Private Sector Power Generation
573 Projects in Pakistan," *Government of Pakistan (GoP)*, 1994. www.ppib.gov.pk/Pow er

574 Policy 1994.pdf (accessed Dec. 21, 2018).

575 [14] A. Malik, "Effectiveness of Regulatory Structure in the Power Sector of Pakistan,"
576 Islamabad, Pakistan, 25, 2007. [Online]. Available: http://www.pide.org.pk/pdf/Working
577 Paper/WorkingPaper-25.pdf.

578 [15] A. Malik, "Power Crisis in Pakistan: A Crisis in Governance?," Islamabad, Pakistan,
579 2012. [Online]. Available: http://www.pide.org.pk/pdf/
580 publications/Monograph/Monograph-4-Afia%25 20Malik.pdf.

581 [16] M. Imran and N. Amir, "A short-run solution to the power crisis of Pakistan," *Energy*
582 *Policy*, vol. 87, pp. 382–391, 2015, doi: 10.1016/j.enpol.2015.09.028.

583 [17] IPP NUL, "The State of the Economy: Emerging from the Crises," *Institute of Public*
584 *Policy (IPP) of Beaconhouse National University, Lahore*, 2009. http://ippbnu.org/AR/
585 2AR.pdf (accessed Dec. 22, 2018).

586 [18] J. A. Lesser and X. Su, "Design of an economically efficient feed-in tariff structure for
587 renewable energy development," *Energy Policy*, vol. 36, no. 3, pp. 981–990, 2008, doi:
588 10.1016/j.enpol.2007.11.007.

589 [19] K. Lo, "A critical review of China's rapidly developing renewable energy and energy
590 efficiency policies," *Renew. Sustain. Energy Rev.*, vol. 29, pp. 508–516, 2014, doi:
591 10.1016/j.rser.2013.09.006.

592 [20] B. Tenenbaum, C. Greacen, T. Siyambalapitiya, and J. Knuckles, *From the Bottom Up:*
593 *How Small Power Producers and Mini-Grids Can Deliver Electrification and Renewable*
594 *Energy in Africa*. Washington, DC, USA: The World Bank, 2014.

595 [21] N. Nazar, "Projects based on renewable energy resources: government decides to end
596 upfront tariff," *Business Recorder*, Islamabad, Pakistan, Dec. 2017.

597 [22] AEDB, "Organogram of AEDB," *Alternative Energy Development Board (AEDB),*
598 *Ministry of Power, Government of Pakistan*, 2018. http://www.aedb.org/ (accessed Dec.
599 24, 2018).

[23] S. Afzal, Naseem, and Anum, "www.ssoar.info China Pakistan Economic Corridor (CPEC): Challenges and Prospects," *Pakistan Adm. Rev.*, vol. 2, no. 1, pp. 209–222, 2018.

[24] M. Latif, P. Delaquil, G. Goldstein, S. Pye, and Gargiulo Maurizio, "Addressing the Critical Need for Longer Term Energy Planning in Pakistan," *International Resource Group (IRG)*, 2007. https://www.decisionwaregroup.com/assets/pak-iem-development-and-training.pdf (accessed Jun. 30, 2019).

[25] "Electricity production from renewable sources, excluding hydroelectric (% of total)," *The World Bank*, 2014. https://data.worldbank.org/indicator/EG.ELC.RNWX.ZS?locations=PK (accessed Jun. 30, 2019).

[26] "Japan's Official Development Assistance," *Japan International Cooperation company*, 2015. https://www.mofa.go.jp/files/000118826.pdf (accessed Jul. 01, 2019).

[27] "Functions & Working of Planning Commission," *Energy Wing of Planning Commission of Government of Pakistan*, 2017. http://www.npo.gov.pk/downloads/PQI_Presentations/MoPDR.pdf (accessed Jun. 30, 2019).

[28] PAEC, "Nuclear Power: A Viable Option For Electricity Generation," *Pakistan Atomic Energy Commission*, 2017. www.paec.gov.pk/NuclearPower/ (accessed Jun. 30, 2018).

[29] "WAPDA Projects (Highly Essential)," *water and power development authority (WAPDA)*, 2019. http://www.wapda.gov.pk/ (accessed Jun. 30, 2019).

[30] A. A. Shah, A. Bhutto, S. M. Qureshi, A. Shah, and W. Shah, *Renewable Energy Scenario of Pakistan for Sustainable Development*. IGI Global, 2014.

[31] O. Rauf, S. Wang, P. Yuan, and J. Tan, "An overview of energy status and development in Pakistan," *Renew. Sustain. Energy Rev.*, vol. 48, pp. 892–931, 2015, doi: 10.1016/j.rser.2015.04.012.

[32] F. M. Mirza and A. Kanwal, "Energy consumption, carbon emissions and economic

growth in Pakistan: Dynamic causality analysis," *Renew. Sustain. Energy Rev.*, vol. 72, no. October 2016, pp. 1233–1240, 2017, doi: 10.1016/j.rser.2016.10.081.

[33] N. H. Mirjat, M. A. Uqaili, K. Harijan, G. Das Valasai, F. Shaikh, and M. Waris, "A review of energy and power planning and policies of Pakistan," *Renew. Sustain. Energy Rev.*, vol. 79, no. June 2016, pp. 110–127, 2017, doi: 10.1016/j.rser.2017.05.040.

[34] K. Ullah, M. J. Arentsen, and J. C. Lovett, "Institutional determinants of power sector reform in Pakistan," *Energy Policy*, vol. 102, no. December 2016, pp. 332–339, 2017, doi: 10.1016/j.enpol.2016.12.019.

[35] F. Yousafzai, "Installed capacity of electricity rises," *The Nation*, Islamabad, Pakistan, Jun. 11, 2019.

[36] NEPRA, "State of industry Report 2017," *National Electric and Power Regulatory Authority (NEPRA), Government of Pakistan*, 2017. https://www.nepra.org.pk/Publications/State of Industry Reports/State of industry report 2017.pdf (accessed Dec. 23, 2018).

[37] A. Yasir, I. Yousuf, G. Gonul, and S. Malik, "Renewables Readiness Assessment: Pakistan," *International Renewable Energy Agency (IRENA)*, p. 68, Apr. 2018.

[38] NEPRA, "State of Industry Report 2015," *National Electric Power Regulatory Authority*, 2015. https://www.nepra.org.pk/Publications/State of Industry Reports/State of Industry Report 2015.pdf (accessed Dec. 24, 2018).

[39] SBP, "Annual Report of the Country-2015-16," *State Back of Pakistan*, 2016. http://www.sbp.org.pk/reports/annual/ (accessed Dec. 25, 2018).

[40] U.S. IEA, "International Energy Outlook 2016," *U.S. Energy Information Administration (EIA)*, 2016. https://www.eia.gov/outlooks/ieo/pdf/0484(2016).pdf (accessed Dec. 25, 2018).

[41] Pak-MoF, "Economic Survey of Pakistan 2018-19," *Ministry of Finance, Government of Pakistan.*, 2019. http://www.finance.gov.pk/survey/chapters_19/14-Energy.pdf (accessed Jun. 07, 2020).

654 [42] M. Wróbel, M. Jewiarz, and A. Szlęk, Eds., *Renewable Energy Sources: Engineering,*
655 *Technology, Innovation*. Cham, Switzerland: Springer Nature Switzerland, 2020.

656

657 [43] U.S. EIA, "International Energy Statistics-2017," *U.S. Eergy Information Administration*
658 *(EIA)*, 2018. https://www.eia.gov/beta/international/ (accessed Dec. 25, 2018).

659 [44] REN21, "Renewables 2018: Global Status Report--A comprehensive annual overview of
660 the state of renewable energy," *Renewable Energy Network for the 21st Century*, Paris,
661 France, p. 325, 2018.

662 [45] Frankfurt School-UNEP, "Global Trends in Renewable Energy Investment 2018,"
663 *Frankfurt School-UNEP Collaborating Centre for Climate & Sustainable Energy Finance*
664 *and BNEF (FS-UNEP Centre and BNEF)*, 2018. http://fs-unep-centre.org/sites/
665 default/files/publications/gtr2018v2.pdf (accessed Dec. 23, 2018).

666 [46] United Nations Environment Programme, *Global Status Report 2017 - Towards a*
667 *zero-emission, efficient, and resilient buildings and construction sector*. 2017.

668 [47] Y.-C. Chang, C. Wang, M. I. Khan, and N. Wang, "Legal practices and challenges in
669 addressing climate change and its impact on the oceans—A Chinese perspective," *Mar.*
670 *Policy*, no. November, pp. 0–1, 2018, doi: 10.1016/j.marpol.2018.11.018.

671 [48] P. Maloney, "Utilities see benefits in energy storage, even without mandates," *Utility*
672 *Dive*, 2017.
673 https://www.utilitydive.com/news/utilities-see-benefits-in-energy-storage-even-without-m
674 andates/504587/ (accessed Dec. 22, 2018).

675 [49] T. Creamer, "Grid operators turning to batteries as costs fall and need for flexibility rises,"
676 *Engineering News*, 2017.
677 http://www.engineeringnews.co.za/article/grid-operators-turning-to-batteries-as-costs-fall-
678 and-need-for-flexibility-rises-2017-11-28/rep_id:4136 (accessed Dec. 23, 2018).

679 [50] REW, "Enel Signs 85 MW of Energy Storage Supply Agreements with PG&E,"
680 *Renewable Energy World*, 2017.

681 https://www.renewableenergyworld.com/articles/2017/12/enel-signs-85-mw-of-energy-sto
682 rage-supply-agreements-with-pg-e.html (accessed Dec. 23, 2018).

683 [51] Bloomberg NEF, "Utilities See Value in Storage Alongside PV, and Will Pay,"
684 *Bloomberg New Energy Finance*, 2017.
685 https://about.bnef.com/blog/utilities-see-value-storage-alongside-pv-will-pay/ (accessed
686 Dec. 23, 2018).

687 [52] SEPA, "2017 Utility Energy Storage Market Snapshot," *Smart Electric Power Alliance*,
688 2017. https://sepapower.org/resource/2017-utility-energy-storage-market-snapshot/
689 (accessed Dec. 23, 2018).

690 [53] C. John Vernacchia, "A Brief History of Utility-Scale Energy Storage," *Renewable*
691 *Energy World*, 2017.
692 https://www.renewableenergyworld.com/articles/print/volume-20/issue-5/features/energy-
693 storage/a-brief-history-of-utility-scale-energy-storage.html (accessed Dec. 23, 2018).

694 [54] Navigant Research, "Country forecasts for utility-scale energy storage," *Navigant*
695 *Research*, 2017. https://www.navigantresearch.com/
696 research/country-forecasts-for-utility-scale-energy-storage (accessed Dec. 23, 2018).

697 [55] J. Spector, "Tesla Fulfilled Its 100-Day Australia Battery Bet. What's That Mean for the
698 Industry?," *Green Tech Media*, 2017.
699 https://www.greentechmedia.com/articles/read/tesla-fulfills-australia-battery-bet-whats-th
700 at-mean-industry (accessed Dec. 23, 2018).

701 [56] Ecogeneration, "Fluence to supply world's largest Li-ion battery," *Ecogeneration*, 2018.
702 http://www.ecogeneration.com.au/fluence-to-supply-worlds-largest-li-ion-battery/
703 (accessed Dec. 23, 2018).

704 [57] GoP, "Policy for Development of Renewable Energy for Power Generation: Employing
705 Small Hydro, Wind, and Solar Technologies," *Ministry of Water and Power, Government*
706 *of Pakistan*, p. 44, Dec. 2006.

707 [58] The World Bank, "Renewable Energy Resource Mapping in Pakistan," *Energy Sector*

Management Assessment Program (ESMAP) of the World Bank, 2018. https://www.esmap.org/node/3058 (accessed Dec. 25, 2018).

[59] NREL, "Pakistan Direct Normal Solar Radiation," *National Renewable Energy Laboratory (NREL)*, 2007. https://www.nrel.gov/international/images/pak_10km_dni_ann.jpg (accessed Dec. 23, 2018).

[60] NREL, "Pakistan 50m Wind Power," *National Renewable Energy Laboratory (NREL)*, 2007. https://www.nrel.gov/international/pdfs/pak_wind.pdf (accessed Dec. 23, 2018).

[61] Pak-MoP, "Quaid-E-Azam 1000MW Solar Park (Bahawalpur)," *Ministry of Planning, Development & Reform, Islamabad, Pakistan*, 2020. http://cpec.gov.pk/project-details/10 (accessed Jun. 06, 2020).

[62] MoF, "Pakistan Economic Survey 2016-17," *Ministry of Finance, Government of Pakistan.*, 2018. http://www.finance.gov.pk/survey/chapters_17/overview_2016-17.pdf (accessed Dec. 23, 2018).

[63] N. U. R. Anwar, W. A. Mahar, and J. F. Khan, "Renewable energy technologies in Balochistan: Practice, prospects and challenges," in *5th International Conference on Energy, Environment & Sustainable Development (EESD) 2018*, 2018, pp. 1–9.

[64] ESE, "DOE Global Energy Storage Database," *Energy Storage Exchange (ESE)*, 2018. http://www.energystorageexchange.org/ (accessed Dec. 23, 2018).

[65] IRENA, "Electricity Storage and Renewables: Costs and Markets to 2030," *International Renewable Energy Agency (IRENA)*, 2017. https://www.irena.org/DocumentDownloads/Publications/IRENA_Electricity_Storage_Costs_2017.pdf (accessed Dec. 23, 2018).

[66] S. Prateek, "GERC Amends Rooftop Solar Net Metering Regulations in Gujarat," *Mercom India*, 2017. https://mercomindia.com/gerc-rooftop-solar-net-metering-regulations-gujarat/ (accessed Dec. 23, 2018).

[67] G. Maroulis, "Net-Metering (for households, public administration buildings and

commercial industrial units)," *Legal Sources on Renewable Energy*, 2017. http://www.res-legal.eu/search-by-country/cyprus/single/s/res-e/t/promotion/aid/net-metering-for-households-local-administration-buildings-and-commercial-industrial-units/lastp/115/ (accessed Dec. 23, 2018).

[68] E. Bellini, "Lithuanian government improves net metering scheme for solar," *PV Magazine*, 2017. https://www.pv-magazine.com/2017/03/31/lithuanian-government-improves-net-metering-scheme-for-solar/ (accessed Dec. 23, 2018).

[69] E. Bellini, "Lithuania raises net metering size limit for businesses and farmers," *PV Magazine*, 2017. https://www.pv-magazine.com/2017/12/05/lithuania-raises-net-metering-size-limit-for-businesses-and-farmers/ (accessed Dec. 23, 2018).

[70] MSEI, "Mauritius CEB launches phase two net metering scheme," *Metering and Smart Energy International*, 2017. .

[71] W. Mustafa, "Pakistan's solar homeowners get green light to sell power to national grid," *Thomson Reuters Foundation News*, 2017. http://news.trust.org/item/20171124082528-bs8p5/ (accessed Dec. 23, 2018).

[72] DSIRE, "Net Metering Policies," *U.S. Department of Energy*, 2017. http://www.dsireusa.org/resources/detailed-summary-maps/net-metering-policies-2/ (accessed Dec. 23, 2018).

[73] NPUC, "Order granting in part and denying in part joint application by NV Energy on Assembly Bill 405," *Nevada Public Utilities Commission*, 2017. http://pucweb1.state.nv.us/PDF/AxImages/DOCKETS_2015_THRU_PRESENT/2017-7/23611.pdf (accessed Dec. 23, 2018).

[74] B. Christie, "Arizona Regulators OK Utility Rate Hike, Solar Payment Cuts," *US News &World Report*, 2017. https://www.usnews.com/news/best-states/arizona/articles/2017-08-15/arizona-regulators-

to-ponder-rate-boost-for-aps (accessed Dec. 23, 2018).

[75] R. L. Rana, M. Lombardi, P. Giungato, and C. Tricase, "Trends in Scientific Literature on Energy Return Ratio of Renewable Energy Sources for Supporting Policymakers," *Adm. Sci.*, vol. 10, no. 2, p. 21, 2020, doi: 10.3390/admsci10020021.

[76] Mass DoER, "Baker-Polito Administration Announces Over $4.6 Million in Grants for Peak Demand Reduction Projects," *Massachusetts Department of Energy resources*, 2017. https://www.mass.gov/news/baker-polito-administration-announces-over-46-million-in-grants-for-peak-demand-reduction (accessed Dec. 23, 2018).

[77] AER, "Demand management incentive scheme and innovation allowance mechanism," *Australian Energy Regulator*, 2017. https://www.aer.gov.au/networks-pipelines/guidelines-schemes-models-reviews/demand-management-incentive-scheme-and-innovation-allowance-mechanism (accessed Dec. 23, 2018).

[78] AER, "AER incentive scheme to drive potential $1bn in demand management action," *Australian Energy Regulator*, 2017. https://www.aer.gov.au/news-release/aer-incentive-scheme-to-drive-potential-1bn-in-demand-management-action (accessed Dec. 23, 2018).

[79] CNESA, "China Releases First National-Level Policy Document Guiding Storage Industry Development," *China Energy Storage Alliance (CNESA)*, 2017. http://en.cnesa.org/featured-stories/2017/10/24/china-releases-first-national-level-policy-document-guiding-storage-industry-development (accessed Dec. 23, 2018).

[80] C. Vest, "China turns to energy storage to push renewables," *China Dialogue*, 2017. https://chinadialogue.net/article/show/single/en/9635-China-turns-to-energy-storage-to-push-renewabl (accessed Dec. 23, 2018).

[81] T. Hussain, "CCI approves National Energy Policy," *Pakistan Today*, 2013. https://www.pakistantoday.com.pk/2013/08/01/cci-approves-national-energy-policy/ (accessed Dec. 23, 2018).

789 [82] S. Ahmed, A. Mahmood, A. Hasan, G. A. S. Sidhu, and M. F. U. Butt, "A comparative
790 review of China, India and Pakistan renewable energy sectors and sharing opportunities,"
791 *Renew. Sustain. Energy Rev.*, vol. 57, pp. 216–225, 2016, doi: 10.1016/j.rser.2015.12.191.

792 [83] S. I. Bhatti, "'Ambitious' national energy policy formulated," *The Dawn*, 2013.
793 https://www.dawn.com/news/1031108/ambitious-national-energy-policy-formulated
794 (accessed Dec. 23, 2018).

795 [84] IFC, "A Solar Developer's Guide to Pakistan," *International Finance Cooperation-World*
796 *Bank Group*, p. 84, 2018.

797 [85] SPB, "Revised SBP Financing Scheme for Renewable Energy," *State Back of Pakistan*,
798 2016. http://www.sbp.org.pk/smefd/circulars/2016/C3.htm (accessed Dec. 23, 2018).

799 [86] PCRET, "Overview of PCRET," *Pakistan Council of Renewable Energy Technologies*
800 *(PCRET)*, 2015. http://www.pcret.gov.pk/Services.html (accessed Dec. 23, 2018).

801 [87] Government of Pakistan, "Pakistan in the 21st Century: Vision 2030," *Planning*
802 *Commission Government of Pakistan*, 2007. http://115.186.133.3/pcportal/vision2030.htm
803 (accessed Apr. 22, 2019).

804 [88] "Energy security," *Ministry of Planning Development & Reform of Pakistan*, 2005.
805 http://www.pc.gov.pk/annual plans/2006-07/Chapter_6/Energy.pdf (accessed Jun. 30,
806 2019).

807 [89] M. Wakeel, B. Chen, and S. Jahangir, "Overview of energy portfolio in Pakistan," *Energy*
808 *Procedia*, vol. 88, pp. 71–75, 2016, doi: 10.1016/j.egypro.2016.06.024.

809 [90] WEC, "Energy Resources," *World Energy Council*, 2016.
810 https://www.worldenergy.org/data/resources/ (accessed Dec. 23, 2018).

811 [91] IEA-UK, "National Renewable Energy Action Plan (NREAP)," *International Energy*
812 *Agency (IEA)*, 2010.
813 https://www.iea.org/policiesandmeasures/pams/unitedkingdom/name-39191-en.php?s=dH
814 lwZT1yZSZzdGF0dXM9T2s,%09&%09return=PG5hdiBpZD0iYnJlYWRjcnVtYiI-PGEg
815 aHJlZj0iLyI-SG9tZTwvYT4gJnJhcXVvOyA8YSBocmVmPSIvcG9saWNpZXNhbmRtZ

816 WFzdXJlcy8iPlBvbGljaWVzIGFuZCBNZWFzdXJlcz (accessed Dec. 23, 2018).

817 [92] IEA-Sweden, "National Renewable Energy Action Plan (NREAP)," *International Energy*
818 *Agency (IEA)*, 2010.
819 https://www.iea.org/policiesandmeasures/pams/sweden/name-40146-en.php (accessed
820 Dec. 23, 2018).

821 [93] IEA-Spain, "National Renewable Energy Action Plan 2011-2020," *International Energy*
822 *Agency (IEA)*, 2010.
823 https://www.iea.org/policiesandmeasures/pams/spain/name-24876-en.php?S=dHlwZT1yZ
824 SZzdGF0dXM9T2s,&return=PGRpdiBjbGFzcz0ic3ViTWVudSI-PGRpdiBjbGFzcz0iYnJ
825 lYWRjcnVtYnMiPjxhIGhyZWY9Ii8iPkludGVybmF0aW9uYWwgRW5lcmd5IEFnZW5j
826 eSZ6d25qOzwvYT4mbmJzcDsmZ3Q7Jm5ic3A7PGEg (accessed Dec. 23, 2018).

827 [94] R. R. Choudhury and R. B. Karanam, "Future Trends in Renewable Energy Sector and
828 need for Digital Transformation," *Stud. Indian Place Names (UGC Care Journal)*, vol. 40,
829 no. 74, pp. 1909–1918, 2020.

830 [95] REN21, "Chapter 7 of Global Status Report--A comprehensive annual overview of the
831 state of renewable energy," *Renewable Energy Network for the 21st Century*, p. 27, 2018.

832 [96] IEA, "Energy Efficiency 2018: Analysis and outlooks to 2040," *International Energy*
833 *Agency (IEA)*, 2018. https://www.iea.org/efficiency2018/ (accessed Dec. 28, 2018).

834 [97] B. Meyhoefer, "Renewable Energy Application in Pakistan Potential and Barriers,"
835 *GIZ-Renewable Energy and EnergyEfficiency (REEE) Programme*.
836 https://www.scribd.com/document/52752279/Bernhard-Meyhofer-Potential-Barriers
837 (accessed Jun. 30, 2019).

838 [98] Y.-C. Chang and M. I. Khan, "China–Pakistan economic corridor and maritime security
839 collaboration: A growing bilateral interests," *Marit. Bus. Rev.*, vol. 4, no. 2, pp. 217–235,
840 2019, doi: 10.1108/MABR-01-2019-0004.

841 [99] H. Ullah, "China Pakistan Economic Corridor (CPEC): benefits for Pakistan and
842 comparison with Suez and Panama Canals," p. 116, 2017.

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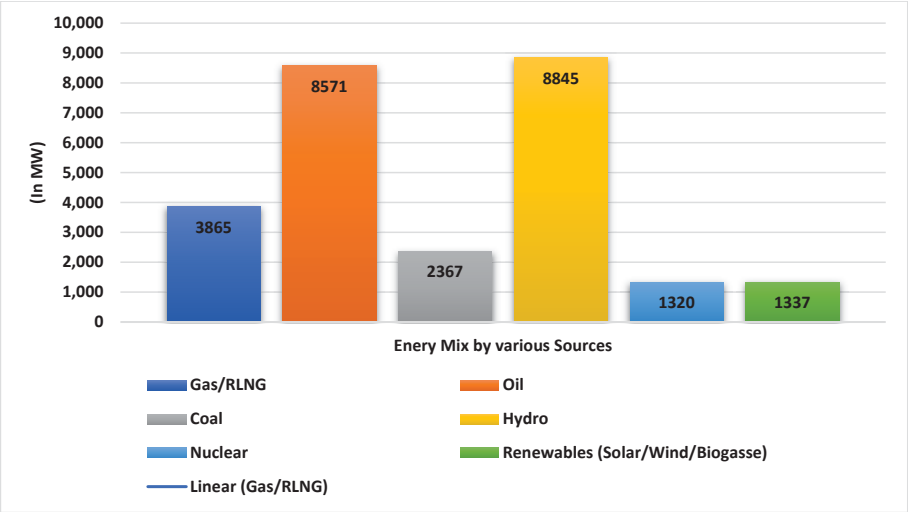

Figure 1. The share of Installed Capacity Mix by Source (as of March 2019) [40].

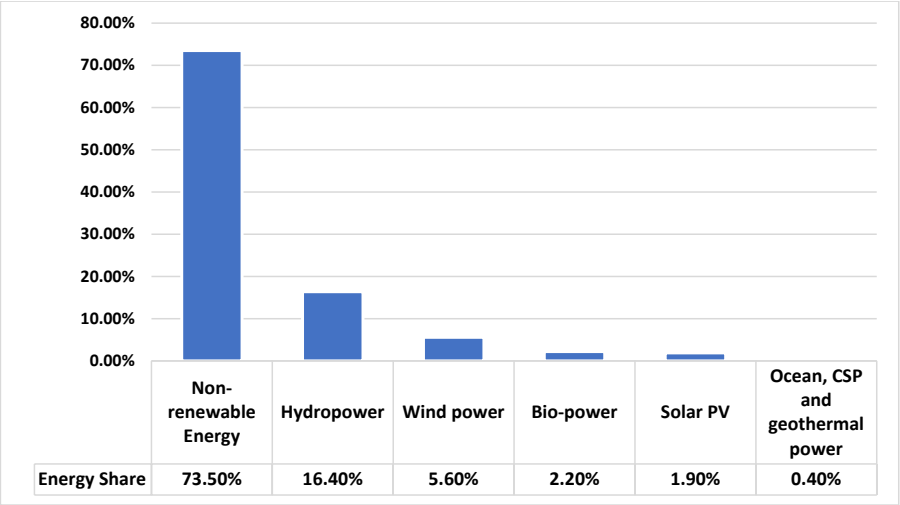

Figure 2. Share of RE in Global Electricity Production [42].

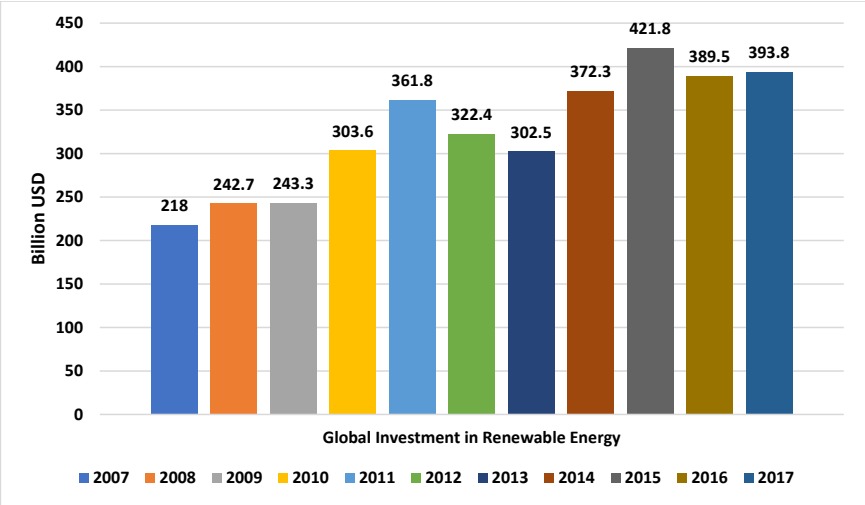

Figure 3. Global Trends in RE Investment in the Recent Years [44].

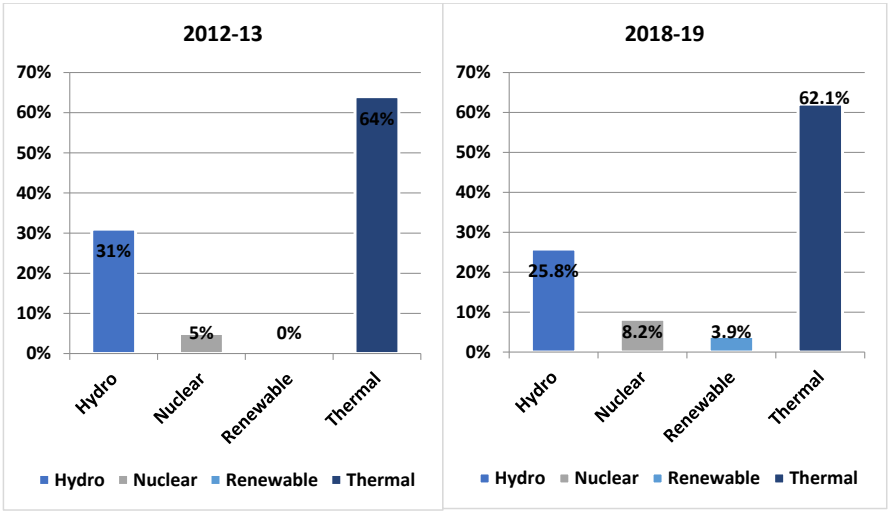

Figure 4. Renewable's Share in Electricity Generation in Pakistan [35], [61], [40].