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Renewable Energy Perspectives of Pakistan and Turkey: Current Analysis and Policy Recommendations

Riaz Uddin [1,2,*], Abdurrahman Javid Shaikh [1,2], Hashim Raza Khan [1,3], Muhammad Ayaz Shirazi [2], Athar Rashid [4] and Saad Ahmed Qazi [1,3]

1 Faculty of Electrical and Computer Engineering, NED University of Engineering & Technology, Karachi 75270, Pakistan; arjs@neduet.edu.pk (A.J.S.); hashim@neduet.edu.pk (H.R.K.); saadqazi@neduet.edu.pk (S.A.Q.)
2 Haptics, Human-Robotics and Condition Monitoring Lab. (National Center of Robotics and Automation), NED University of Engineering & Technology, Karachi 75270, Pakistan; mshirazi@ee.knu.ac.kr
3 Neurocomputation Lab. (National Centre of Artificial Intelligence–NCAI), NED University of Engineering & Technology, Karachi 75270, Pakistan
4 Department of Governance and Public Policy, National University of Modern Languages, Islamabad 44000, Pakistan; atharrashid@numl.edu.pk
* Correspondence: riazuddin@neduet.edu.pk

Abstract: To a great extent, Pakistan and Turkey rely on imported fossil fuels to meet their energy demands. Pakistan is moving in the right direction, placing focus on renewable energy resources in its current infrastructure in order to address the energy shortage. Several projects (e.g., wind power and solar PV (photovoltaic) technologies) are operational or under development; they are intended to reduce energy challenges in Pakistan. The new government in Pakistan aims to increase the share of renewable energy in total power generation to 30% by 2030. On the other hand, Turkey surpasses Pakistan in renewable energy resources; for example, there are 186 operational wind energy power plants across the country. In addition, Turkey utilizes solar energy—mainly for residential usage. Turkey's Vision 2023 energy agenda aims to supply 30% of their power demands from modern renewable energy resources. Turkey has implemented solar PV, solar buildings, wind power plants, geothermal energy resources, and biomass technology for heating, cooling and electricity generation. At present, Turkey's supply to meet energy demands in the country is 56% fossil fuel energy resources and 44% renewable energy, including hydropower. Accessible details reveal that geothermal energy resources have been continuously neglected in Pakistan by the Ministry of Energy (power division); this is in contrast to the Turkish case, in which utilization of geothermal energy resources for heating and cooling purposes is efficient. With all the facts and figures under consideration, in this paper, comparative analyses are performed which reveal that the production of electricity from geothermal energy technologies is lower than the massive potential in both countries. Recommendations are made for important policies to promote renewable energy technologies, which could effectively support energy decentralization by providing electricity to rural areas and the national grid.

Keywords: renewable energy resources; renewable energy technologies; policy recommendation; comparative analysis

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1. Introduction

For energy security and availability, the supply of power is vital for a nation's viability in the contemporary world. Persistent exploitation of conventional fuels is likely to contribute to multiple threats, including: reduction of conventional fuel assets, global warming, ecological issues, geopolitical and armed disputes, sustainability and rising fuel costs. These challenges point out an unsuitable condition. Alternative power technologies offer a resolution for growing power demands in the world—especially in Pakistan and Turkey [1]. Alternative energy technologies (e.g., solar, wind, hydroelectric, biomass, and wave/tidal energy) are limitless and ecofriendly [2]. The Kyoto protocol [3] has dealt with the subject of climatic change since 1990 and aims to sustain CO_2 production at a secure level [4]. This is critical for the world as it faces the challenges of climatic change and rising greenhouse gases.

Figure 1 demonstrates the predicted worldwide alternative power situation by 2040 according to the European Renewable Energy Council (EREC) following the advanced international policies scenario (AIP). The assumptions of AIP include (1) the continuation of efforts for the promotion of renewable energy projects, (2) an expectation of price hikes for traditional energy resources, (3) implementation of the Kyoto protocol and (4) transfer of substantial resources from industrialized to developing countries [5]. About half of the international power contribution will be obtained from alternative energy technologies by 2040 in accordance with the EREC. A noteworthy growth in the manufacturing of alternative power technologies is observed between 2001 and 2040. These include photovoltaic (PV) (from 0.2 to 784 Mtoe (million-ton oil equivalent) and wind power (from 4.7 to 688 Mtoe). In addition, the contribution of biomass energy resources—at its highest in 2001(1080 Mtoe)—will show significant growth leading up to 2040 (reaching an expected 3271 Mtoe). The contribution of alternative energy resources to overall electricity production is 13.6% in 2001; it will reach 47.7% in 2040 [5].

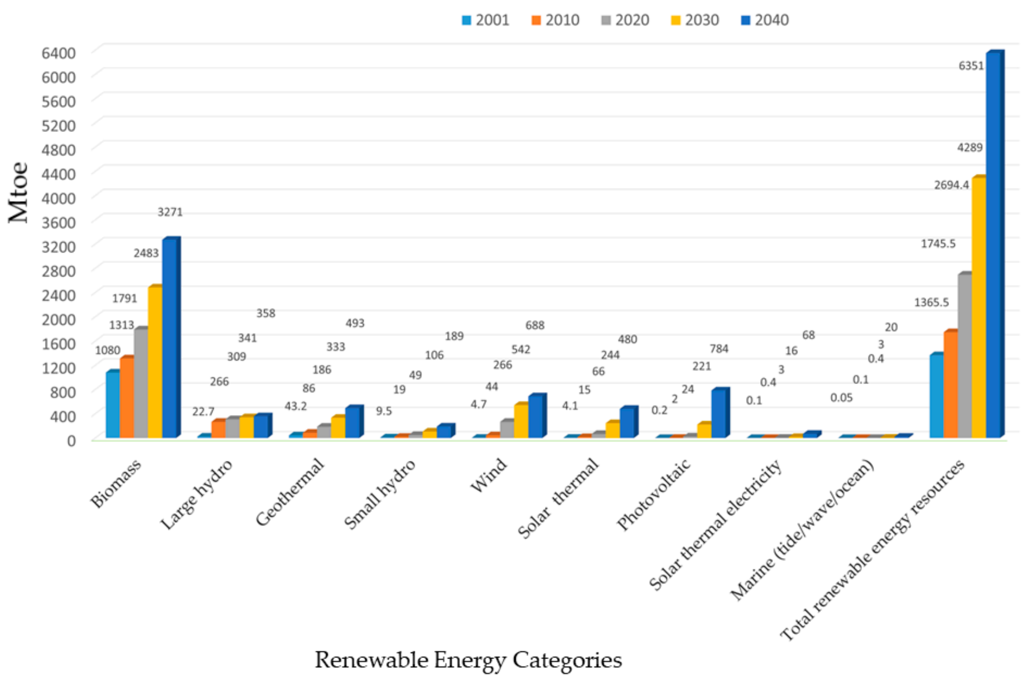


Figure 1. Global Different Alternative Energy Scenario in (Mtoe) 2001–2040 [5].

Both Turkey and Pakistan are actively pursuing the use of renewable energy technologies in their energy policies. The land area of Pakistan is 881,913 km^2 with a population of 211.17 million [6]. Until 2019, electricity generation in Pakistan was 87.3 TWh [6]. Figure 2 shows the rise in installed capacity and energy generation from 2017 to 2019. Figure 2 shows a scenario in which Pakistan is facing a severe energy crisis that has affected all sectors of the economy—especially in terms of the evolving energy mix. In this scenario, to solve these problems, Pakistan is continuously implementing several renewable energy projects to meet its dire power needs [7].

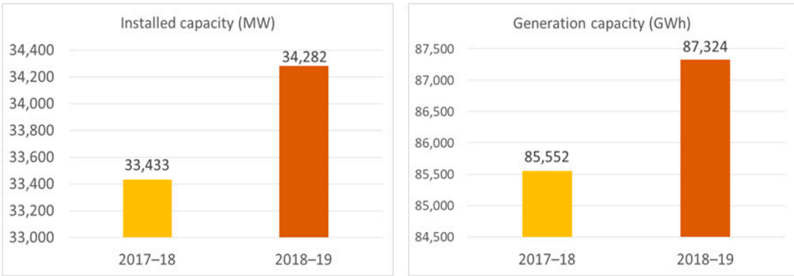
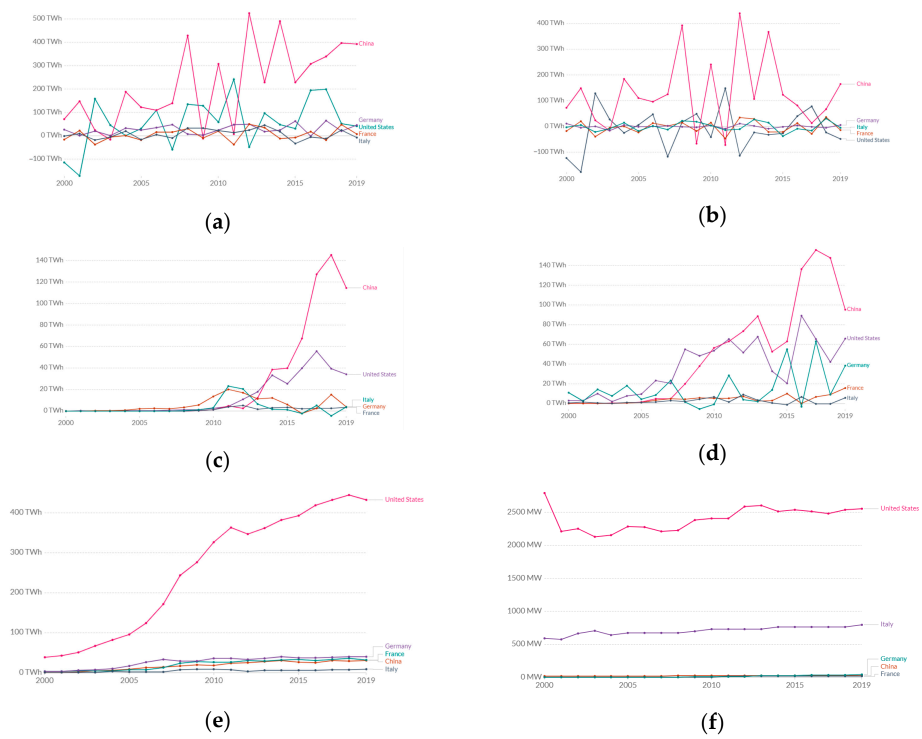


Figure 2. Installed capacity and energy generation (Pakistan) [7].

Turkey has a land area of 783,356 km^2 [8] with a population of 83.1 million people [1]. In terms of total electricity generation, Turkey produced 307 TWh in 2019. Pakistan mainly depends on gas and oil for power generation. The facts [6] reveal that the role of fossil fuels in Pakistan's energy generation remains the largest (i.e., 62.1% resource consumption in order to produce electricity in 2019). Hydro power plants produce 25.8% of Pakistan's energy, while nuclear power plants stand at 8.2% and renewable energy technologies stand at 3.9%. According to observation, Turkey depends on coal (37%), natural gas (19%), hydropower (29%) and renewable energy (15%) [1] to generate electricity. Table 1 shows a comparison between Pakistan and Turkey in the aforementioned statistics. We have also added renewable energy graphs [9] in Figure 3, providing the reader an opportunity to learn about the situation in other countries. Figure 3a–d shows trends from 2000 to 2019 for annual change in renewable energy generation (i.e., hydro, solar and wind power). Figure 3e,f presents trends (2000–2019) for biofuel energy generation and geothermal capacity in specific countries. Figure 3a–d shows China's dominance in terms of annual change in overall renewable energy generation, hydropower, solar and wind power generation. The USA dominates other countries in terms of biofuel energy generation and geothermal capacity (Figure 3e,f).



(a) (b) (c) (d) (e) (f)

Figure 3. Trends (2000–2019) for renewable energy generation in different countries [9]. Annual change in (**a**) global renewable energy generation; (**b**) hydropower generation; (**c**) solar energy generation (**d**) wind energy generation (**e**) biofuel generation and (**f**) geothermal energy capacity.

Table 1. Comparison of Pakistan and Turkey.

S.No.	Country	Land Area (km^2)	Population (Million) (2019)	Electricity Generation (2019) (TWh)	Share of Power Production (2019)
1.	Pakistan	881,913	211.17	87.3	62.1% (oil and gas) 25.8% (hydro power) 8.2% (nuclear power) 3.9% (renewable)
2.	Turkey	783,356	83.1	307	37% (coal) 19% (natural gas) 29% (hydro power) 15% (renewable)

Considering the above discussion of renewable energy potentials for Pakistan, Turkey and other advanced countries, as well as their trends of usage over time, there is a need to discuss and propose suitable policies that can benefit both countries, address future energy challenges and comply with their visions. This paper proposes important policy recommendations—after discussing in detail comparisons of both countries in terms of various factors, e.g., reliance on fossil fuels, population, CO_2 emission per capita, international funding received for clean renewable energy, and annual change in renewable energy generation and associated energy categories. The proposed policy recommendations aim to minimize losses in the energy sector, reduce greenhouse gases and relieve both countries from dependence on imported energy. Moreover, they emphasize the governments' role in providing subsidies to private sector and development partners, and launching innovative, feasible projects. The policy recommendations encourage the governments to accelerate support of research and development, education, and public consciousness—along with global collaboration to encourage foreign direct investment in their energy sectors. In this regard, Section 2 highlights the advantages of renewable energy. Section 3 presents a summary of each country's reliance on fossil fuels. Section 4 highlights the renewable energy development of both countries. Section 5 compares the power setup and renewable energy potential in each country. Section 6 recommends important policies that could be used to counter current energy demands. Section 7 concludes the paper.

2. Advantages of Renewable Energy

Renewable energy has many advantages, but, there are some downsides, as well. Large increases in biomass energy production would probably require crops that are harvested only for that purpose (energy generation). This could change the balance of the agricultural market, leading to an increase in food prices. Research [10] has provided evidence that biofuels worsen food security in developing countries. Renewable energy resources (RERs) pose several challenges linked with their high penetration due to their random nature, and as a result, they cannot provide prompt response to demand variations. That's why, energy storage systems (ESSs) are essential for the successful deployment of renewable energy resources. ESSs assist to control the stochastic nature and correct sudden deficiencies that occur with RERs. They also increase grid stability, reliability, and efficiency due to the provision of services in power quality, e.g., connecting power and providing facilities of energy management. However, ESSs involve huge costs [11]. The problem of energy storage for renewable energy also raises the issue of intermittent power supply [12]. The end user should experience some level of predictability with regard to energy generation from solar and wind resources. There are times when renewable energy resources generate more power than the national grid is able to handle. This creates issues; for a national grid, if the demand is high, the supply needs to be high—and vice versa. Therefore, the national grid should be able to solve intermittency issues. One solution could be to subsidize renewable energy producers in order to prevent grid overloading from intermittent sources (e.g., in cases of excess generation).

There are a lot of benefits to using renewable resources over traditional fuels. Here are some of the advantages of renewable energy [13]:

2.1. Environmental Benefits

The rise in the average annual temperature of the globe due to the greenhouse effect is known as global warming. Through this effect, the earth utilizes some of the sun's energy in order to provide warmth and sustain life. Human actions (such as burning fossil fuels, unnecessary smoke discharge from mills, and deforestation) have resulted in increased levels of greenhouse gases—to which rising global temperatures can be attributed. At the UN Conference on Climate Change conducted in Paris, 195 nations decided on a strategy to decrease greenhouse emissions. They aimed to reduce the global temperature rise to below 2 °C compared to the earth's preindustrial climate—implying a future rise of less than 1.4 °C, as the temperature had already risen by 0.6 °C by the end of 20th century) [14].

Pollution is among the biggest disadvantages of fossil fuels. The largest source of pollution worldwide is fossil fuel burning for electricity generation, primarily in transport, heating and industrial sectors (U.S. EPA 2016). According to WHO, the biggest global health risks are carbon emissions and pollution. Approximately 3.7 million deaths occurred due to ambient air pollution in 2012. A significant number (4.3 million deaths) occurred due to residential air pollution in 2016. The effects of climatic change include increased disease, infection, and death rates from excessive heat, flooding and increased frequency of severe storms. Secondary effects include malnourishment, infectious diseases, diseases caused by air pollution and mental illness due to social and political instability. Burning fossil fuels also emit atmospheric pollution that can cause heart problems. The incidence of these pollutants can be decreased by adopting renewable power, resulting in a safer environment.

Fossil fuel-based energy generation also causes other types of pollution, e.g., land degradation, water pollution, ocean acidification and emissions other than carbon dioxide [15]. Fossil fuel exploration involves unearthing, processing and moving underground deposits, which severely affects landscapes and ecosystems. This exploration also involves the scraping and blasting away of forests and mountainous regions, which may not recover even after operations cease. Furthermore, drilling, fracking and mining operations generate waste water contaminated with heavy metals, radioactive materials, and other pollutants that may mix with water resources—causing water pollution. Due to fossil fuel burning, the acidity of the oceans is rising. This has led to a decrease in levels of calcium carbonate, which are essential for the growth of countless marine organisms. Fossil fuels also emit harmful air pollutants (including benzene and formaldehyde), causing diseases such as childhood leukemia, blood disorders and cancer.

2.2. Economic Benefits

Renewable energy is less expensive and more economical than traditional energy resources. Utilization of renewable sources can offer long-term savings as users can save on maintenance and operational costs. Users do not have to be able to afford to refuel if they use technologies that produce energy from the sun, from wind, from steam, or from other completely natural procedures. Renewable energy systems also involve less maintenance than typical fuel generators. This is due to the fact that renewable generation technology (e.g., solar panels and wind power turbines) often has fewer moving components or does not depend on flammable sources for operation.

According to statistics, renewable energy manufacturing will result in the creation of hundreds of thousands of stable jobs. In the case of European countries such as the UK and Germany, renewable energy measures have already been adopted, resulting in the creation of thousands of jobs. From Figure 4, it can be noted that the number of jobs is increasing annually owing to the use of renewable energy in electricity generation.

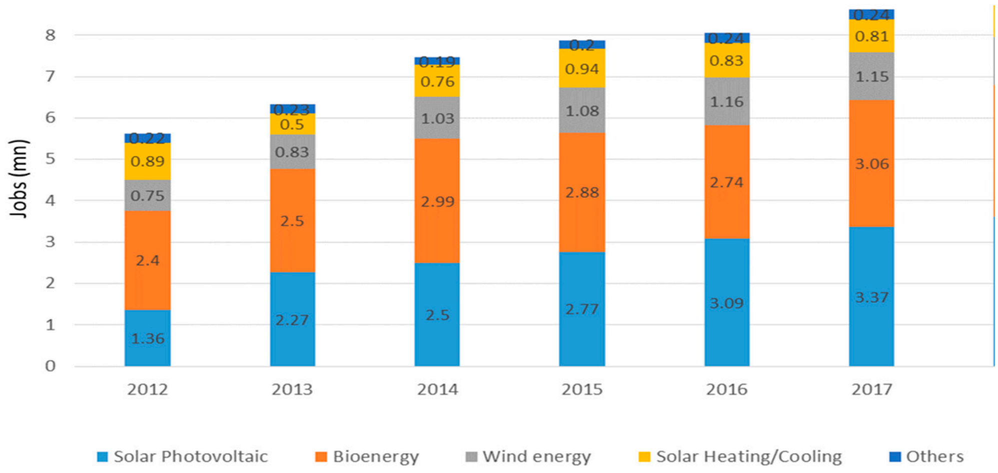


Figure 4. Global renewable employment by technology 2012–2018 [16].

2.3. *Renewable Nature of Renewable Energy*

Nonrenewable resources are characterized by their presence in a finite quantity on earth. These resources do not regenerate after their harvesting and usage [17]. Therefore, these resources are being depleted with the passage of time due to continuous use. These resources can never be exploited in a sustainable fashion.

Renewable energy is considered unlimited—in the sense that these resources are continually regenerated through natural processes [18]. The daily supply of solar energy is theoretically sufficient to fulfill the energy demand of the human race for a whole year. Renewable energy resources are considered limited only in the sense that their availability changes across space and time. Every region of the world possesses particular types of renewable energy resources. Though renewable energy resources replenish after harvesting, their excessive use and inefficient management may degrade them, affecting their renewable nature [17]. That's why the qualified term "potentially renewable resources" was introduced. Renewable energy resources—with appropriate management—may lead to a sustainable future.

2.4. *Reliable Source of Energy*

Pakistan is heavily dependent on fossil fuels for energy generation [19] and our national security is endangered by reliance on fossil fuels. Fossil fuels are unstable energy resources as they are vulnerable to political inconsistency, trade disputes, wars and inflation. This is more crucial than just our national energy policy; weather uncertainties in renewable energy generation can be tackled through the wide distribution of solar and wind power plants over a large geographical area. This would ensure that the power supply to an entire region is not affected by weather disruptions in a specific area.

2.5. *Reduction in the Cost of Renewable Energy Technologies*

According to the IRENA (International Renewable Energy Agency) [20], the installation of renewable energy projects would cost less than even the cheapest fossil fuels. More than 50% of the renewable energy capacity added in 2019 involved lower electricity costs than coal-based power plants. New solar and wind projects are also offering lower costs compared to the cheapest and least sustainable existing coal-fired plants. The generation costs for onshore wind and solar PV have also dropped between 3% and 16% annually since 2010 [20]. The same trend can be observed in wind energy in the USA. Wind technology in the USA is considered the best in the world. Wind energy technology is the least expensive renewable resource—and its cost has also gone down over time, leading to the manufacture of cost-effective wind power plants. Similarly, the cost of solar panels is dropping over time.

3. Reliance on Fossil Fuels

3.1. Turkey's Reliance

Seventy-two percent (72%) of the total primary energy supply (oil, natural gas, coal) is imported by Turkey, which is undoubtedly a huge burden on the Turkish financial system [21]. Due to Turkey's current 8% annual boost in power loads [21], there is a dire need to enhance power production. According to studies, the major contributor to the rise in demand is the industrial sector. Industrial sector power demands are anticipated to reach 97–148 TWh due to the export of industrial goods and agricultural processed goods to the European open market without any customs duty (until 2020) [22]. In order to meet the requisite power supply and demand, Turkey's 2023 vision [23] plans to deploy alternative power technology resources to produce 160,000 GWh of electricity by 2023. After accomplishing this goal, Turkey will be less reliant on conventional fuel and can do away with the carbon tax [21]. The current percentage of fossil fuel used for transport in Turkey is 40%.

3.2. Pakistan's Reliance

Pakistan, on the other hand, is spending 60% of its capital on importing fossil fuels —which is an immense load on its weak economy. Pakistan was heavily dependent on oil to generate electricity until 2013–14—when the energy sector transferred from oil to gas to generate electricity for the industrial, household, commercial and transport sectors. This was due to price hikes on crude oil imports. In spite of this, Pakistan has not been capable of fulfilling the power demand. This state of affairs largely affected the manufacturing sector, resulting in export reduction and causing undesirable consequences on economic growth. The total established capacity—in terms of conventional fuel, hydro power and nuclear power plants—of electricity generation in Pakistan (up to July 2020) was 35,972 MW with a production of 96,382 GWh [6,7]. This included the output from three energy plants to the national grid (Nandipur Furnace Oil (425 MW), Chashnupp-III nuclear (340 MW) and Bhiki gas (760 MW)). The new government in Pakistan aims to increase the share of renewable energy in total power generation to 30% by 2030 [24]. The percentage share of fossil fuel used for transport in Pakistan is 10%. Table 2 shows the reliance of both countries on energy from imported fossil fuels.

Table 2. Comparison of Pakistan and Turkey in fossil fuels and renewable energy.

S.No.	Country	Fossil Fuel Import	Renewable Energy	Expected Increase in Renewable Power Generation	Fossil Fuel Share for Transport System
1.	Pakistan	60% of its capital	3.9% of primary energy	30% share of renewable by 2030	10% of Fossil fuel
2.	Turkey	72% of primary energy	15% of primary energy	30% share of renewable by 2023	40% of Fossil fuel

4. Renewable Energy Development

Geographically, Turkey is positioned in a perfect region, where modern renewable energy technologies can be utilized effectively to cope with upcoming energy demands in the country. Consumption in different sectors of Turkey is shown in Table 3. Turkey can generate 160 TWh of power using renewable energy resources (i.e., wind power, solar power, biomass, and geothermal energy technologies). That is twice the power generation produced in Turkey in 1996 [25]. Additionally, the Ministry of Energy and Natural Resources (MENR) in Turkey aims to identify targets and policies linked to power and natural resources in ways that serve the energy security goals of the country. Other bodies for renewable energy technologies in Turkey include the General Directorate of Renewable Energy (YEGM), which is responsible for policies and activities in renewable energy and energy efficiency. TUBITAK MAM Energy Institute (EI) is another significant body with the Energy Institute in Marmara, and works to contribute to global competitiveness and the sustainable development of Turkey through advanced energy technologies and energy conservation measures [26].

Table 3. Comparison of electricity consumption in different sectors of turkey [1].

Year	Total	Household	Commercial	Government	Industrial	Illumination	Other
	(GWh)			(%)			
2013	198,045	22.7	18.9	4.1	47.1	1.9	5.3
2014	207,375	22.3	19.2	3.9	47.2	1.9	5.5
2015	217,312	22.0	19.1	3.7	47.6	1.9	5.7
2016	231,204	22.2	18.8	3.9	46.9	1.8	6.4

On the other hand, Pakistan suffered from a severe energy crisis (a deficiency of 4000 MW) in 2008 and it was anticipated that power deficiency would rise to 8000 MW by 2010. This power shortage was expected to grow at the usual annual pace of 5.67% [27]. According to observations made in a 2018 review [28], Pakistan confronted a power shortfall of 5201 MW in 2015. There has been load shedding in 14–18 h increments across the country on a daily basis since 2011.

According to a report, Pakistan was generating 553.3 MW of electricity through modern renewable energy technologies in 2015–2016, all of which was added to the national grid [28]. With the purpose of decreasing reliance on conventional fuels, the government of Pakistan (GOP) has set up two subdivisions—Pakistan Council of Renewable Energy Technologies (PCRET) and Alternate Energy Development Board (AEDB)—for the deployment of alternative energy technologies, particularly in the power sector. The PCRET assists in research and development initiatives. AEDB aids in the development of renewable energy policies and provides support for the deployment of renewable energy technologies across Pakistan. AEDB argues that the plans under development will help to cope with the prevailing power shortages across the country [14] by producing 9700 MW of energy through renewable energy technologies and supplying 7874 off-grid rural communities with power in distant areas. The Council of Common Interests (CCI) of the Government of Pakistan, in August 2020, approved an alternative renewable energy policy. This policy unleashed the full renewable energy potential of Pakistan. PCRET implemented small scale projects to display their practicability and effectiveness across the country [29]. Some of the pilot projects of renewable energy technologies which were effectively installed by the PCRET include: wind turbines, solar desalination systems, biomass plants and solar water heater projects. Table 4 summarizes the functions and measures of government bodies to promote renewable energy development in Pakistan and Turkey.

Table 4. The functions and measures of government bodies to promote renewable energy development in Pakistan and Turkey.

S.No.	Government Bodies	Functions	Steps to Promote Renewable Energy Projects
1.	PCRET	▪ Decreasing reliance on conventional fuel energy. ▪ Assisting GOP (government of Pakistan) in the research and development initiatives.	▪ Commenced and implemented small scale projects to display its practicability and effectiveness. ▪ Installation of wind turbines, solar desalination systems, biomass plants and solar water heater projects.
2.	AEDB	▪ Decreasing reliance on the conventional fuel energy. ▪ Development of renewable energy policy providing support for the deployment of renewable energy technologies across Pakistan.	▪ Plans to develop renewable energy project and cope with the prevailing. power shortages across the country by producing 9700 MW of energy.

Table 4. *Cont.*

S.No.	Government Bodies	Functions	Steps to Promote Renewable Energy Projects
3.	MENR [30]	▪ Aims to identify targets and policies linked to power and natural resources to serve the energy security goals of the country.	▪ Striving to improve the whole capacity of renewables to 61,000 MW by 2023.
4.	YEGM	▪ Executes all sustainable energy-related work, including educational activities. ▪ Energy efficiency performance indicators, standards, product performance testing activities.	▪ Implementing, monitoring and coordinating all energy efficiency activities and studies in relevant institutions across the country.
5.	TUBITAK MAM Energy Institute [31]	▪ Aims to be a leading and competent research center conducting applied research and development projects in energy technologies. ▪ Performs research and development activities with two teams: one in Gebze and one in Ankara.	▪ It aims to lead the development of energy technologies domestically in parallel with Turkey's development goals for 2023 and to develop projects for these goals.

According to a report by the government of Pakistan [32], 438 MW of renewable power plants (installed in different regions of the country) provided 802 GWh of electricity during the year 2014–15. Table 5 shows renewable energy projects of Pakistan with capacity and power generation [32].

Table 5. Renewable energy projects with capacity and power generation [32].

S.No. (Serial Number)	Renewable Energy Project	Capacity (MW)	Power Generation (GWh)
1.	FFC Energy Ltd. Sindh	50	139
2.	Zorlu Energy Sindh	56	156
3.	TGF Wind Farm Pvt. Ltd. Sindh	50	80
4.	Foundation Wind Energy–I Sindh	50	56
5.	Foundation Wind Energy-II Sindh	50	26
6.	Bagasse Co-generation, Jamaldin Wali (JDW)-II Punjab	26	163
7.	Jamaldin Wali (JDW)-III Sindh	26	124
8.	Rahim Yar Khan (RYK) Mills Ltd. Punjab	30	32

The new government in Pakistan plans to increase the share of renewable energy in total power generation to 30% by 2030—specifically referring to power from wind, solar, small hydro plants and biomass [24]. The share of coal remained in single digit percentages over the last two decades. However, FY2018 (fiscal year 2018) recorded a high output of 12.7 percent coal consumption in the energy mix. Likewise, the share of renewables was recorded at 0.3 percent in FY2015, which was steadily increased to 1.1 percent in FY2018 [6].

The following section briefly talks about the prospects of renewable energy technology and their existing position in Turkey and Pakistan. It also argues about other developments of renewable energy technologies which are under development.

4.1. Hydro Power Plant in Pakistan

Through hydel (hydro) power plants, the national grid was provided with 24,544 GWh of generated electricity, according to the GOP economic survey [32]. The total established capacity of hydropower plants was 7407 MW, which was connected to the national grid in 2018. Information from the Alternative Energy Development Board in 2012 [14] disclosed that the established power capacity was inadequate compared to the national power demand. A study [33] recommended potential areas of Pakistan with expected potential of 60,000 MW of energy. Figure 5 shows the area-wise operational & identified hydel power resources [34] in Pakistan.

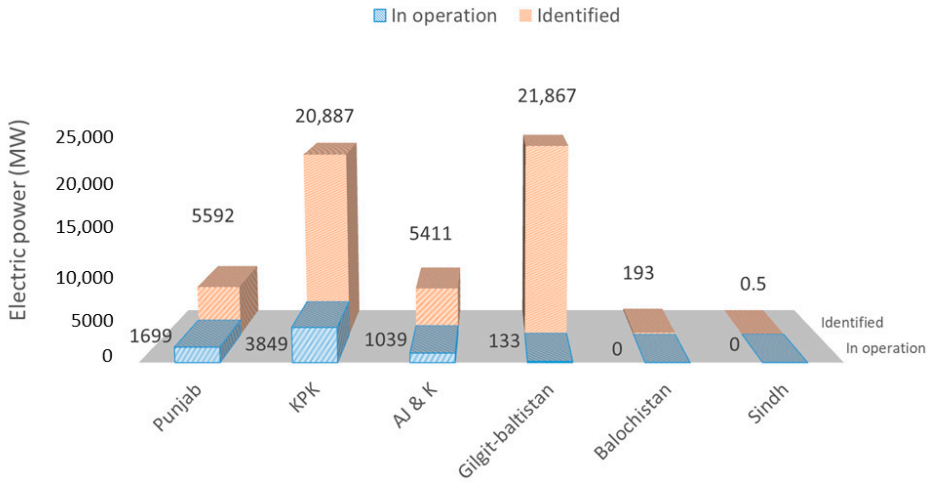


Figure 5. Area-wise operational & identified hydel power resources [34].

Hydropower has the lowest life-cycle cost among power generation technologies. Hydropower is a potential life-saver for Pakistan, yet its development was hampered for decades. Hence, only 15 per cent of Pakistan's over 60,000 MW hydropower potential has been developed over the past 70 years. Water and Power Development Authority (WAPDA) produced the highest ever hydel electricity in 2019–20, with an increase of 20 percent compared to the previous year. The hydro share in total electricity generation increased in FY2020 (27,270 GWh) as compared to FY2019 (24,931 GWh), according to a GOP economic survey performed in 2019–20. This is encouraging—that initiatives were taken by the ministry of planning and development to invest in the hydro power sector. In this regard, the potential increase in massive hydel capacity is taking place with the Kohala Hydropower project and the building of the Dasu, Mohmand and Diamir Bhasha dams. The total established power of hydro plants was 9389 MW, which was connected to the national grid in 2019.

4.2. Small Hydropower Projects

Apart from large hydro, definite prospects to develop small/mini/micro hydro power projects are evident. Small hydropower is counted as one of the most remunerative options to generate electricity. Provincial governments usually manage small hydropower project development. AKRSP (Agha Khan Rural Support Program) has been working in collaboration with AEDB. More than 103 micro-hydro power plants in the northern areas of Pakistan (including the Chitral and Gilgit regions) are under development and 307 projects have been completed in 11 districts of KPK (Khyber Pakhtunkhwa) province [35]. The Pakistan Council of Renewable Energy Technologies (PCRET) installed 228 river-type hydel plants—each generating 3 MW in the northwestern region of Pakistan [31,36,37].

The Ministry of Power reviewed many other mini-hydel power plant projects of 187 MW capacity, and feasibility reports of these projects are under consideration [38]. In addition, the provincial government of KPK is working on six micro-hydel projects with capacities of 118 MW and the provincial government of Punjab is working on four micro-hydro projects of 20 MW capacity. Due to their vast experience in hydropower projects, these projects are expected to be completed in time [28,39].

The Pakistan Council of Renewable Energy Technology (PCRET), Sarhad Rural Support Program (SRSP), Alternative Energy Development Board (AEDB), Pakistan Council for Appropriate Technologies (PCAT) and Pakhtunkhwa Energy Development Organization (PEDO), with the support of the Pakistan Renewable Energy Society (PRES), has installed

1100 SHPPs (small hydropower promotion projects) with a total capacity of 42.507 MW. This fulfills the electrical energy demand of approximately 0.7 million people in Pakistan. PEDO is also working on SHPPs that will provide 2156 MW of electric power by the end of 2020 [40]. Figure 5 shows the amount of electric power produced from hydropower resources in various regions of the country. Pakistan has tremendous hydel potential; however, only 15% of the potential has been utilized to date [34]. The remaining untapped potential, if properly exploited, could effectively meet Pakistan's ever-increasing demand for electricity in a cost-effective way.

4.3. Solar Photovoltaic (PV) Technology

Sunshine remains for 8–9 h each day in Pakistan, especially in the province of Balochistan, which is the most favorable and appropriate place for the deployment of solar energy technology to overcome the current shortage of electricity [41].

Pakistan installed a solar power grid in Islamabad (with the support of Japan International Cooperation Agency) to produce 356.16 KW of power through a photovoltaic solar system. Excess power will be put up for sale to the Islamabad Electric supply company (IESCO) [42]. AEDB-installed solar PV systems in 601 houses in 2004–2005 at multiple localities of the country—exceeding its goal of 400 residences [43]. An additional landmark, in this regard, is the deployment of a photovoltaic system with a capacity of 2 MW on the Pakistan National Assembly building [44]. This system meets the building's own power prerequisites and transmits surplus electricity to the grid [28]. At present, a 1000 MW solar PV power plant is under construction in Bahawalpur, Pakistan by Quaid-e-Azam Solar Power (Pvt.) Ltd. (Lahore, Pakistan) [45].

AEDB is pursuing 22 solar PV power projects with a cumulative capacity of approximately 890.80 MW. Six solar power projects (of 430 MW cumulative capacity) are operational at Quaid-e-Azam Solar Park–Bahawalpur, Pind Dadan Khan and Sahiwal. Twelve solar PV power projects (of 419 MW cumulative capacity) obtained LOI (Letter of Intent) from AEDB and are at different stages of project development [46].

The World Bank, in collaboration with the Alternative Energy Development Board (AEDB) in 2017, established a series of new solar maps for Pakistan to encourage the efforts speeding up the development of renewable energy in Pakistan. As a result, Pakistan became the first country to utilize the validated solar maps under a global initiative on renewable energy resource mapping conducted by the Energy Sector Management Assistance Program (ESMAP), a multi-donor trust fund governed by the World Bank.

4.4. Biomass Plants in Pakistan

62% of people in Pakistan reside in rural areas, which comprise the largest portion of the country's residents with scarce/no energy resources. The study [47] also emphasizes biomass power as a way to address energy deficiencies in Pakistan. The research [48] argues that an average biomass-using household consumes 2325 kg of firewood (or 1480 kg of dung or 1160 kg of crop residues) per annum, which is essential for cooking, heating, and other residential purposes. According to another study [49], Pakistan possesses 62 million animals (with an annual increase rate of 8%). Dung averages approximately 10 kg/animal each day, meaning that as much as 620 million kg of animal dung drop every day. One kg of animal dung at 15 °C produces 0.19 m^3 of biogas. This doubles at 27 °C [48]. This denotes that, at the annual mean temperature of Pakistan (25.8 °C), 1 m^3 gas/day can be produced through 20 Kg wet dung [50]. Approximately 23.25 million m^3/day of biogas production is possible per these calculations. According to research conducted by Meena et al. [51] on the lighting of 100 candle-power lamps, 0.127 m^3 of gas is needed; to power a 1 KW generator, 0.57 m^3/h of gas is required.

Agricultural remains are another major opportunity—to use the agricultural wealth of Pakistan to generate electricity through biomass energy [52] e.g., rice straw, bagasse or sugar cane. While there are about 80 sugar mills in the country (or 3000 MW energy production capacity), only 700 MW of production has been accessed so far. The Director General of

Renewable Energy Resources (DGN-RER) [53] installed 4137 biogas units throughout the country by 1987. These improved with the passage of time. Observation in the report [54] showed that 5357 biogas units were installed all over the country, with the capability to generate 3–15 m^3 of biogas daily.

In Karachi in Sindh province, at Landhi cattle colony, AEDB worked on a 30 MW biogas project. In Punjab province, at Shakarganj mill (Jhang), an 8.25 MW biogas plant production project was developed [55]. Both of the projects were completed successfully [56,57]. AEDB—with the cooperation of M/s Eco-Friendly Fuels Pvt. Ltd.—has inaugurated a pioneer commercial biodiesel plant at Karachi, yielding an annual capacity of 18,000 tons [58,59]. Pakistan Amraas International Pvt. Ltd.—with A-Power Energy Generation System Ltd. and Shenyang Power Group [60]—has worked to build two biomass power plants of 25 MW capacity to meet its own energy needs since 2011.

4.5. Wind Power Plants in Pakistan

AEDB is engaged in the development of 40 wind power projects of cumulative capacity of approximately 2010.2 MW. Twenty-Four (24) wind power projects (of 1235.20 MW cumulative capacity) are operational and currently supplying electricity to the national grid. The government of Pakistan financed twelve wind power projects (of 610 MW cumulative capacity) and their construction is in progress. Research [41] into the monthly average speed of wind in the four provincial capitals of Pakistan has shown that the lowest and highest wind speeds in Karachi (Sindh province) were 2.75 m/s and 6.7 m/s, respectively. In Quetta (Baluchistan province), the measurements were 2.5 m/s to 4.4 m/s, respectively. Thus, these capitals were declared the perfect sites for the establishment of wind energy plants. The first wind power plant (five wind turbines) was established in Jhimpir (Sindh province) to generate 6 MW clean energy with the help of a Turkish company (Zorlu Enerji) in 2008 [14]. Zorlu Enerji was anticipated to provide more wind turbines in order to generate 200 MW by the end of 2018 [61]. As reported in the Pakistan energy year book [43], 100 micro wind turbines have been installed to provide electricity to 467 houses across Pakistan. AEDB has also installed 40 wind turbines in Karachi (Sindh province) with 10 MW power. According to AEDB and various universities in Baluchistan province, research and development is underway on 500 watt wind energy generation turbines, as well. PCRET set up 26 micro-units of 500 watt wind power plants at Gul Muhammad Village of Sindh province [38]. Fauji Fertilizer Company (FFC) Energy Ltd. installed 50 MW wind power plants in 2013 and 2014. Other wind power projects (of 663 MW) in the Jhampir and Gharo regions of Sindh province are also operational [28].

4.6. Geothermal Energy in Pakistan

Pakistan has a great potential and could produce 100,000 MW of energy through geothermal power [62]. The energy derived from the heat of the earth's core is defined as geothermal energy, and is clean, abundant, and reliable [63]. An investigation [64] evaluated the tectonic and geologic facial appearance with outside symptoms of geothermal movement in Pakistan to clarify the potential qualities of the region for study of geothermal force. Likewise, research [65] gave an overview on the potential geothermal areas of Pakistan and argued—by providing details of the Himalayan collision zone—that Murtazabad (Gilgit Baltistan-GB), Karachi and Dadu (Sindh province) were the most suitable ones. According to research conducted in Murtazabad (GB) [66], the surface temperature was noted as 40–94 °C. Moreover, water samples were collected and—after isotopic analysis—it was determined that the origin of the thermal water was meteoric. This serves as proof that the region is most suitable for geothermal power production. Amraas Pvt. Ltd. and Shenyang Power Group (SPG) were reportedly working jointly on a geothermal project in Pakistan to supply power by exploiting this resource [55,60].

4.7. Hydro Power in Turkey

In 2015, 25.6% of hydel renewable energy was used in generating a total of 17,024 GWh of electricity in Turkey [1]. In 2018, electrical energy generated by hydroelectricity plants was 59,900 GWh. By the end of August 2019, electrical energy generated by hydroelectricity plants reached 88,440 GWh.

By the end of 2018, 653 operational hydroelectricity power plants (a total of 28,291 MW) had a 31.9% share in Turkey's total installed capacity. By the end of August 2019, hydroelectricity installed capacity reached 28,437 MW [67]. It was further observed that the total yearly production estimation in these projects was 9933 GWh (as reported in the study) [68,69]. These projects are still under different stages of commission and will significantly reduce Turkish dependence on fossil fuel imports.

4.8. Solar Power in Turkey

The Anatolian region and Mediterranean locations in Turkey are ideal locations to produce electricity through solar technology as the standard solar emission in Turkey is 309.6 cals/cm^2 day with the average sunshine duration estimated at 7.2 h [70–72]. In 2008, Turkey exploited 0.4 Mtoe of solar energy through solar collection for heating purposes in residential and industrial sectors [21]. In 1996, Turkey adopted a unique concept: solar power-enabled houses. These solar power-driven houses were designed to meet electricity requirements, e.g., lighting, heating, cooling, and ventilation. Solar energy has mostly been used for the purpose of heating the water in which solar collectors are placed on rooftops.

4.9. Biomass Power in Turkey

Until 1998, for energy production through biomass technology [73,74], 5512 ktoe (kilotons of oil equivalent) of firewood and 1533 ktoe of plant and animal waste was utilized in Turkey each year. This biomass energy resource met the necessities of 40% of the residential regions of Turkey for heating and cooking. The annual biomass energy potential of Turkey is estimated to be 32 Mtoe and can produce 372,000 GWh of power [75]. On the other hand, two biomass power projects in Ankara and Adana with estimated production rates of 77 and 260 GWh, respectively, have been planned [74]. Biomass energy resources are mainly based on wheat straw, cocoon shell, grain dust, crop residues and fruit tree residues in Turkey [76].

4.10. Wind Power in Turkey

Turkey has an ideal geographical location for wind power; the Black Sea lies in the north, the Aegean region of the Mediterranean Sea lies in the south, and Marmara is located in the west region of the country. To generate 160 KWh of electricity per annum, the coastal line of Turkey can be utilized effectively—as it is 8500 km long [77,78]. In an investigation [79] done, wind speed and potential wind power regions were discussed. The resulting data showed 3–4 m/s wind speed in the northwestern, Eastern Mediterranean Sea, southeastern and northeastern regions of the country. In addition, wind potential areas were recognized and measured in some parts of the country (i.e., 50–200 W/m^2).

Turkey's first wind power plant commenced operation in 1998. It had a capability of 1.5 MW and over time, its total capacity improved to 730 MW by the year 2009 [80]. Presently, 158 wind power plants are operational across Turkey with a total 6484 MW capacity. Several other wind power plants are under development [81].

4.11. Geothermal Power in Turkey

Turkey has plenty of geothermal energy resources, as it lies in the Alpine–Himalayan orogenic belt [74]. In 1960, several studies were conducted in numerous research institutions across Turkey, and work on the exploration of geothermal energy was initiated in the same era. Around 140 geothermal fields were explored (with 40 °C temperatures) across the country, and it was anticipated that, through this geothermal field, 35% of Turkey's urban and rural areas could conveniently and economically be heated [74]. The Kizildere geothermal plant, located in Denizli in western Anatolia, has a capacity of 20.4 MW electricity production. In 2008, Turkey was utilizing 0.9 Mtoe geothermal energy for heating purposes in residential areas, which corresponds to 1509 MW of heat generated through geothermal power. Thus, Turkey emerged as a pioneer in the world for the direct use of geothermal heat [21] and was among one of the five leading countries utilizing geothermal power openly for heating purposes [82,83].

5. Comparative Analyses

5.1. Pakistan's Scenario

5.1.1. Power Sector of Pakistan

Since 1947, Pakistan's energy infrastructure has passed through many phases [84]. The generation capacity in the housing, commercial and industrial sectors has increased massively—but it is still not comparable to the energy demand. T&D (transmission and distribution) has lagged equally behind. Pakistan's energy sector is controlled by either government bodies or private institutions (directly or indirectly). Most power consumption comes from the domestic sector (44.90%), followed by industrial (29.45%), commercial (7.72%), agricultural (8.04%) and others (9.88%) [7]. Furthermore, there has been a 1.4 percent and 7.1 percent reduction in power consumption in the government and agricultural sectors, respectively. Oil, coal, gas, LPG (liquefied petroleum gas), nuclear and hydropower are the main sources of energy. These resources are used to generate electricity, as shown in Figure 6. Thermal electricity has the largest share in power generation [85].

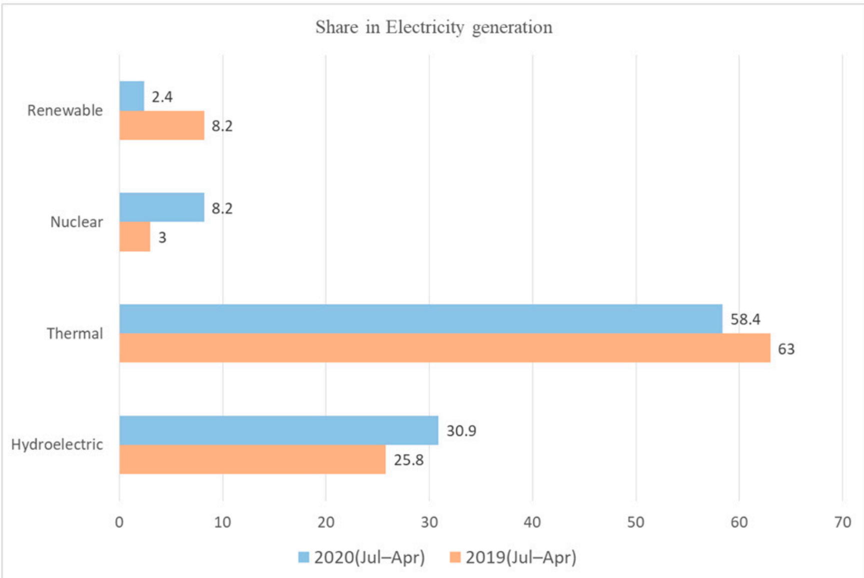


Figure 6. Power sector in Pakistan, with percentage shares in electricity generation [85].

5.1.2. Energy Supply and Demand

Accordingly, the National Transmission and Dispatch Company (NTDC) has estimated that power generation capacity will have to be increased to about 62,000 MW by 2040 [86]. The gap between supply and demand is rapidly growing. As in other developing nations, oil and natural gas resources are rapidly depleting, leaving only 10 and 19 years, respectively. The abundant national reserves of coal have not been fully exploited in the country's power supply matrix. The country's energy deficiency is expanding, negatively affecting economic development. Gross domestic product (GDP) is a monetary indicator of the market rate of all final (quarterly or annually) produced goods in a time span. Calculations of GDP are used to evaluate an entire region's economic performance.

5.1.3. Renewable Energy Scenario in Pakistan

The available renewable power resources in Pakistan are sufficient to meet global energy requirements [38]. Utilization of these resources can ensure a sustainable long term power supply and lessen pollutants. Consequently, measures should be taken to discover and strengthen sustainable power sources, in order to reduce the gap between energy supply and energy demand. Promotion and utilization of renewable sources will produce job opportunities, (e.g., manufacturing components of windmills, tourism) as an outcome of the advancement of solar and wind farms. To some degree, the electrical power shortage can be resolved by using the nation's capacities for wind and solar power. Figure 7 represents Pakistan's technological ability for various renewable energy generation sources (MSW (municipal solid waste) [87], centralized (CNT) and decentralized (DCNT) systems [88]). Pakistan's renewable energy potential is around 167.7 GW—seven times greater than the total national electricity demand of 25 GW [6].

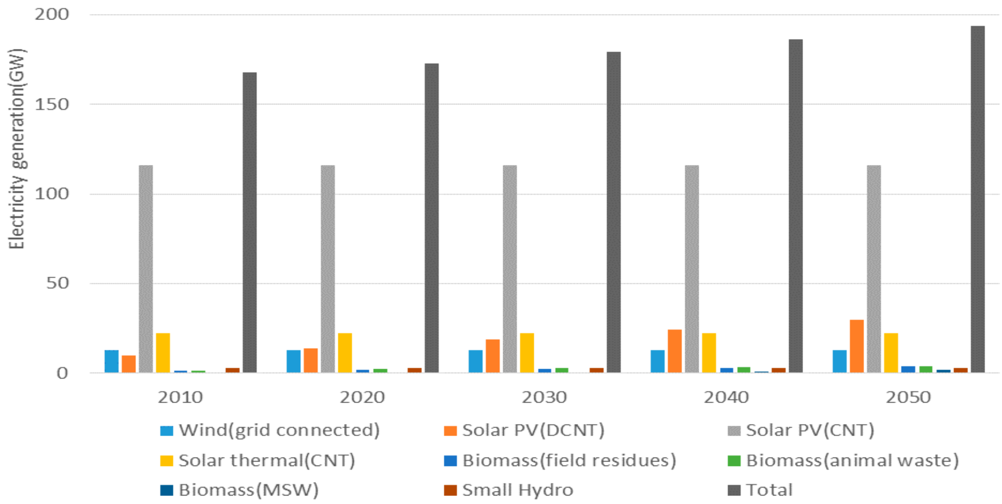


Figure 7. Estimated potential for electricity generation (2010–2050) [88].

Fifty million people in Pakistan do not have electricity [89]. Nearly 6500 MW of electricity deficit in Pakistan was noted in 2015 [90]. Currently, load shedding of up to 8 h per day is a prevalent custom, experienced by people in rural regions with even worse circumstances.

5.1.4. Power Generation Policy

In 2015, the GOP announced a power production policy, providing improved rewards and streamlined handling to shareholders in an attempt to close the demand and supply gap, using renewable assets for the cheap production of electricity for socioeconomic advantages [91]. The goal of the strategy was to produce power at the lowest possible price, using indigenous funds with environmental protection. The strategy offered maximum exploitation of native, inexpensive and clean resources of renewable energy especially raw Site hydropower and run-of-river hydro projects. The GOP promoted the Public Private Partnership (PPP) by providing companies with opportunities to set up PPP energy initiatives in line with relevant legislation. It is essential now to implement fresh energy strategies, in view of previous events, concentrating on the depletion of existing fossil energy assets, and discussing environmental issues and availability.

5.1.5. Energy Potential of Pakistan

Wind Energy

The main advantage of wind power in Pakistan is that it is abundantly accessible, particularly in the southern areas of Sindh and Baluchistan, with an approximate wind speed of 7 m/s at a height of 50 m. Potential sites along the 9700 km^2 coastal storm-prone areas are in Sindh. The wind potential of Pakistan's coastal belt is 43 GW, whereas only 11 GW is exploitable, as a result of land use restrictions [92].

Solar Energy

Pakistan is situated in an area of high solar activity, receiving 5 to 7 kWh/m^2 per day [93]. The barren areas of Sindh, Punjab and Baluchistan have the capacity for solar power growth. According to estimations, the sun shines for around 8.5 h per day in Baluchistan, giving 20 MJ/m^2 daily solar radiation. The National Renewable Energy Laboratory (USA), in collaboration with USAID (United States Agency for International Development), reports complete solar energy potential in Pakistan as 2.9 TW.

Bio Energy

As an agricultural country, Pakistan has an enormous capacity for biomass production. It might be possible to achieve rural electrification and use biogas for cooking equipment—if correctly utilized. Pakistan has 12 to 16 million m3 of daily biogas capacity. The production of approximately 81 million tons per annum of biomass has enormous capacity to generate enough bioenergy using various techniques, e.g., combustion, pyrolysis, and gasification [94].

Hydropower Energy

Enormous hydro power capacity is Pakistan's greatest strength in the renewable energy industry. Pakistan has nearly 100 GW of hydropower potential [95] and only 7.116 GW (28.67% of the complete power mix) has been utilized. The aim of WAPDA is to raise it to 16 GW by 2025.

Geothermal Energy

Pakistan's capacity for geothermal energy is also among the nation's greatest strengths in the renewable energy sector [96]. In Pakistan, geothermal energy—mud volcanoes, geysers and hot springs—is readily accessible. Geothermal power enriches Karachi, Hyderabad and the northern regions.

5.2. Turkey's Scenario

5.2.1. Turkey's Economy

Since 2010, the Turkish economy has expanded quickly, and there has been a corresponding increase in the need for energy. Figure 8 shows the increase in Turkey's GDP between 1990 and 2018. Energy consumption in Turkey rose sharply by an estimated 5.7 percent per year—in comparison to the general decrease in Europe. As a developing nation, Turkey's energy demand has risen quickly, owing to its rapidly expanding population and economy [97]. For instance, the complete primary energy consumption recorded in 1996 was 71 million Mtoe; it increased to 120 Mtoe in 2013, and complete energy production that year was 32 Mtoe. The annual energy generation of Turkey amounts to only 35,374 kilotons of oil (ktoe), while the energy consumption in 2016 was 136,230 ktoe [98]. Turkey's parity of purchasing power to gross domestic product was projected at USD $1576 trillion in 2015.

5.2.2. Turkey Energy Policy

The energy policies of Turkey are focused on energy security, renewable energy assets, use of national energy resources to generate added importance for the economy, energy sector liberalization and power efficiency. It is projected that energy needs will rise by about 4–6 percent per year until 2023. The Turkish state has set a goal—raise the proportional share of alternative energies in the complete operational energy of the country to 30% by 2023 [29].

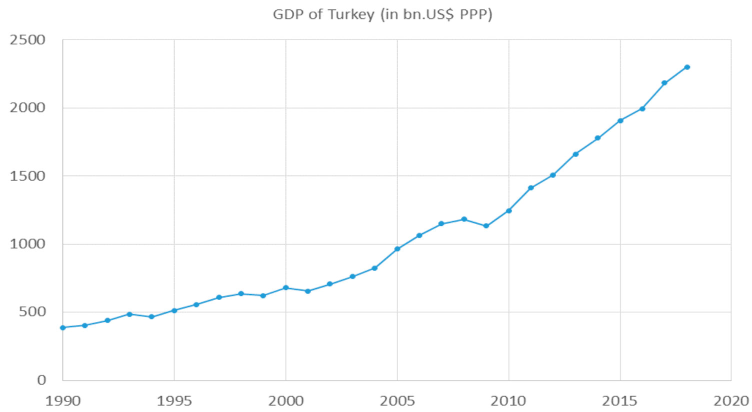


Figure 8. Data about Turkey's GDP between 1990 and 2018 [99].

Hydropower

Turkey has 1% of the world's electricity capacity, and 16% of that of Europe. Turkey has 433 GW of total gross hydroelectric capacity with 125 GW of economically feasible capacity out of gross potential; the technically and economically feasible capacities are 50% and 28%, respectively [100].

Bioenergy

Turkey has a huge capacity for producing bioenergy. Based on the recoverable energy capacity from agrarian and timber handling residues, the complete annual recoverable bioenergy capacity in Turkey was projected at around 32 Mtoe [101]. The possibility for biogas manufacturing in Turkey was projected at approximately 1.5 to 2 Mtoe [102].

Geothermal Energy

Turkey has considerable geothermal energy capacity and there may be around 4500 MW for electricity generation [103].

Solar Energy

Turkey has an estimated insulation period of 7.5 h/day and a solar radiation rate of 1527 kWh/year/m^2 [104]. The only ground region accessible for PV panels is 611 km^2; the energy yield of this region would be 90 billion KWh/yr. Additionally, it has been determined that the total land area in Turkey with an irradiation rate of more than 1650 KWh per m^2 is around 4600 m^2, which means the solar power capacity is equivalent to a 54,300 MW natural gas plant.

Wind Power Energy

Bounded to the north by the Black Sea, to the west by the Sea of Marmara and the Aegean Sea, and to the south by the Mediterranean Sea, Turkey has enormous capacity for generating wind power. Turkey has a theoretical capacity of almost 90,000 MW of wind power [105]. It is projected that, with a destination capability of 20,000 megawatts, Turkey could satisfy 20 percent of its electricity supply from wind power, assuming an 8% average annual increase in power usage [5].

In order to fulfill the energy demand of both countries, Figure 9 draws a comparison between the total electricity generation of Turkey and Pakistan (in GWh) from 2011 to 2020. In Turkey, production of electricity during 2011–12 was 229,395 GWh, which rose considerably to 261,783 GWh in 2015–16. On the other hand, the production of electricity in Pakistan was 95,366 GWh in 2011–12, and reached 108,408 GWh in 2015–16 as an attempt to address the critical energy crisis in the country. It did not generate the total requisite energy, but helped in meeting some of the energy needs.

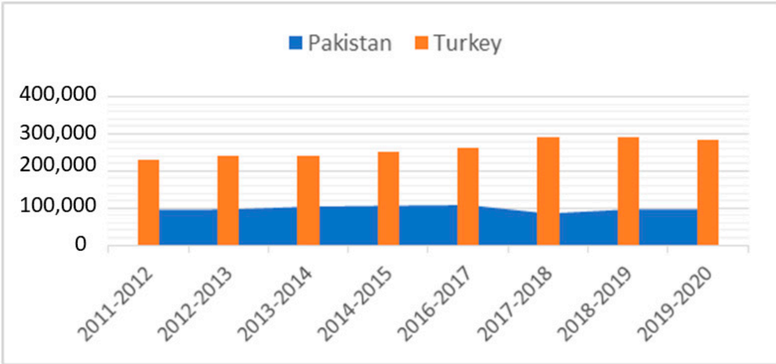


Figure 9. Comparison of total electricity generation (GWh) in Turkey and Pakistan [1,6,106].

Figure 10 points to the facts [1,32] supplying the actual power production scenario in GWh by utilizing modern renewable energy resources. Furthermore, it is observed in the case of Pakistan that there are a variety of projects related to modern renewable energy technologies under implementation—as well as a few that commenced operation in 2018. It is thought that these renewable energy projects will facilitate the country's ability to address its dire power crisis. It is also believed that there will be great benefits to the economy of Pakistan with the gradual implementation of these renewable energy projects. In addition, with the adoption of a rigorous policy of renewable energy technologies, the country is believed to minimize its dependence on imported fossil fuels (already a huge burden on the economy).

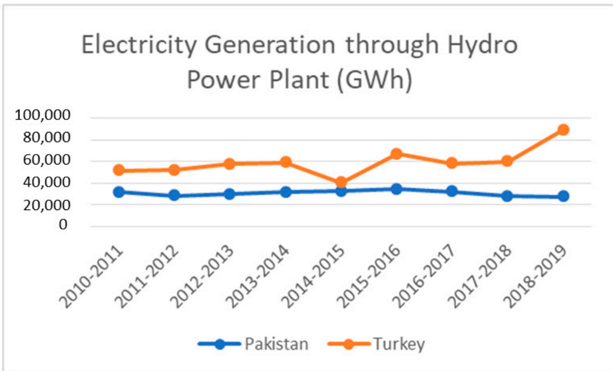
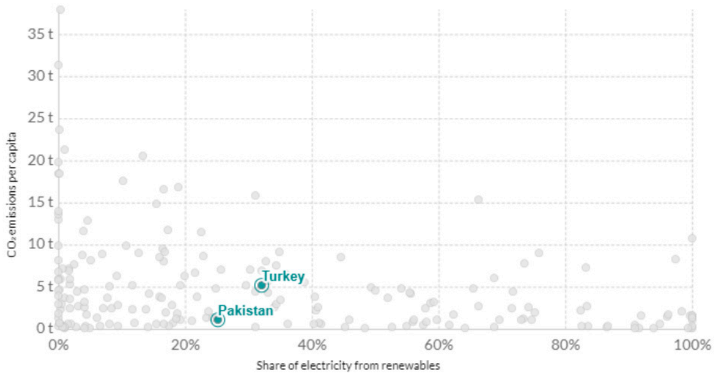
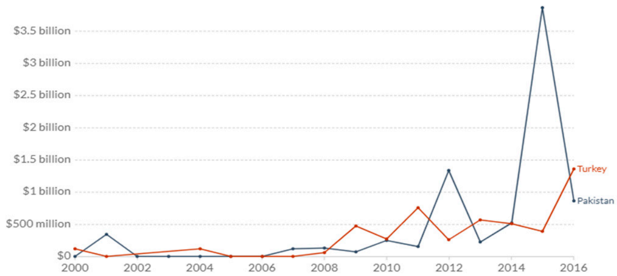


Figure 10. Comparison of total electricity generation through renewable hydro power plants in Turkey and Pakistan (2010–2019) [1,6,106].

Figure 11 shows a comparison between Turkey and Pakistan's CO_2 emissions per capita and international finance received for clean energy. Pakistan has lower CO_2 emissions per capita than Turkey, while Turkey's share of electricity from renewable energy is greater. Figure 11a,b depicts the rise of international funding in Pakistan and Turkey from 2008 to 2016, and compares those data to before 2008. Pakistan and Turkey received the highest amount of clean energy funding in 2015 and 2016, respectively. The comparison of Pakistan and Turkey in terms of annual change in renewable energy generation and associated subcategories is shown in Figure 12. Figure 12a shows fluctuations of the annual change in renewable energy generation. The highest annual changes were observed in 2013 and 2019, respectively, for Pakistan and Turkey. The same behavior was observed for hydropower generation, with the highest annual changes in 2013 and 2019, respectively, for Pakistan and Turkey (Figure 12b). In the case of solar and wind energy generation (Figure 12c,d), Turkey has outperformed Pakistan, with highest annual changes in 2018 and 2016, respectively, for solar and wind energy.



(**a**)

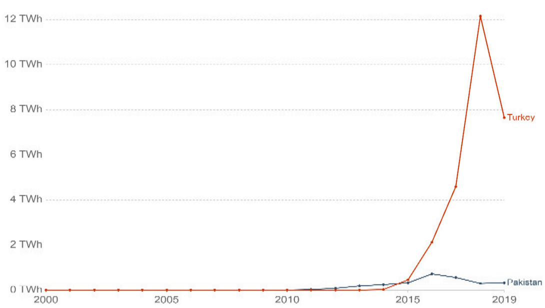


(**b**)

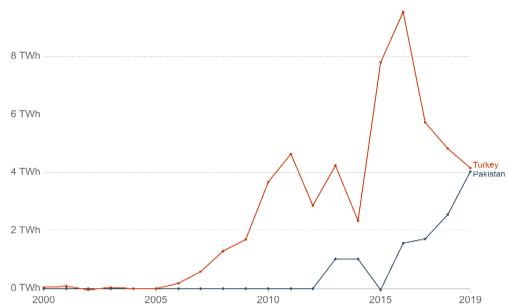
Figure 11. Comparison of the Turkey and Pakistan [9] (**a**) CO_2 emission per capita vs. share of electricity (tons per year) from renewables (**b**) Trend (2000–2016) for international finance received for clean energy.

(**a**)

(**b**)



(**c**)



(**d**)

Figure 12. Trend (2000–2019) for renewable energy generation in Pakistan and Turkey [9]. (**a**) annual change in renewable energy generation (**b**) annual change in hydropower generation (**c**) annual change in solar energy generation and (**d**) annual change in wind energy generation.

Another very interesting observation is that Turkey and Pakistan have great potential for geothermal energy resources, which can effectively be utilized for the generation of electricity. Geothermal energy has unfortunately been neglected for electricity production by both countries. A Kenyan case could prove to be a good example for Turkey and Pakistan in terms of geothermal power utilization. Kenya is considered to be the global leader in using geothermal energy for electricity generation.

From an energy security perspective, conservation of energy is an obligation for the two countries. Both Turkey and Pakistan should diversify their energy supplies by focusing on renewable energy technologies. They should also consider different possible methods of power supply, rather than relying on conventional fuels. In today's competitive social and political environment, energy security holds paramount significance. Dependence on the import of fossil fuels can lead to great threats to the national security and sovereignty of Turkey and Pakistan from an energy security perspective. So, renewable power technologies are demonstrably the best option for the two countries to sustain and protect their social and economic interests.

6. Energy Policy Recommendation

After analyzing the current status of the utilization of renewable energy resources in both countries and comparing their energy generation, we concluded that there are great potential renewable energy resources in both countries. In order to increase reliability and sustainability in renewable energy technologies, energy storage technologies may be integrated into energy production. Moreover, both countries should increase collaborative efforts in research and development with other developed countries. Following are the energy policy recommendations, which should be included in the Pakistani energy policy/2030 energy vision [24] and in the 2023 vision of Turkey [29]. Table 6 summarizes the importance of each point in the energy policy recommendation.

1. Establish a policy to reduce losses in the energy sector by introducing advanced technologies and solutions.
2. Establish a policy to create a bridge among the stakeholders (e.g., government, the private sector and development partners) to advance renewable energy infrastructure in the country.
3. Accelerate support and grants for research & development in education sector and research centers.
4. Pakistan's national interests and security could be at stake because of dependence on fossil fuels, which are vulnerable to political instabilities, trade disputes and wars; thus, renewable energy development becomes more crucial for the country. Therefore, efforts and policy for a systematic shift towards major dependence on renewable energy technologies should be carried out.
5. Policies on the effective use of renewable energy setups need to be furnished in order to reduce greenhouse gases (produced through the energy production processes of fossil fuels, causing climate change and emitting pollutants).
6. Establish a policy to launch new feasible projects for renewable energy generation; for example, speed breaker-based electricity generation, corporate energy generation, E-Plants, biogas plants, oceanic and geothermal energy projects, and other small- and large-scale innovative projects.
7. Establish a policy to provide subsidy to the private sector and development partners for renewable energy plant installation.
8. Establish a policy in order to organize energy conferences/workshops/seminars for encouraging FDI (foreign direct investment) in renewable energy technology (RET).
9. Establish a policy to adopt and manufacture cost effective energy storage technologies in the country to promote renewable energy projects.
10. Establish an incubation center for research & development with global collaboration, especially in the energy sector, to deploy new renewable energy technologies.

Table 6. Summary of policy recommendations along with their significance.

S.No.	Policy Recommendation	Significance
1.	Losses reduction in the energy sector	Line losses in electricity distribution are prevalent, and need to be reduced.
2.	Generation of electricity through speed breaker	Environmentally friendly renewable energy technology.
3.	Corporate energy generation	Building may generate its own electricity, providing relief to the national grid.
4.	E-Plant	Building may generate its own electricity, providing relief to the national grid.
5.	Tidal/ocean wave and geothermal energy	Environmentally friendly renewable energy technology, especially for residential usage
6.	Biogas Plant	Cost-effective, environmentally friendly renewable energy technology.
7.	Subsidy for renewable energy plant installation	To completely eradicate the energy crisis in Pakistan.
8.	Energy conferences for encouraging FDI in RET	Higher the investment in RET, higher the probability to set up RET projects.
9.	Adoption of energy storage technologies	The development of renewable energy is proportional to the enhancement of energy storage technologies.
10.	R&D along with global collaboration	Necessary to march with the growth of RET in developed countries.

6.1. Losses Reduction in the Energy Sector

Currently, the line losses of electricity are due to the poor quality of power distribution transformers, along with the poor health of transmission and distribution feeders. Wrong placement of power capacitors in medium voltage transmission lines can also increase the line losses.

The transmission and distribution losses were: 2010 (16.23%), 2013 (18.9%), 2014 (18.7%), 2016 (18%) and 2017 (16.25%) [107,108]. Karachi Electric took a very impressive step by introducing and installing aerial bundle cables, each of which has its own insulation layer on the conductor (to deter electricity theft) and can lead to reduction in line inductance as shown in Equation (1).

$$L = 2 \times 10^{-7} \ \ln\left(\frac{GMD}{GMR}\right) \tag{1}$$

where L is the line inductance, GMD is geometric mean distance, GMR is geometric mean radius

It is also helpful to increase the maximum power transfer capability as shown in Equation (2).

$$P = \left(\frac{VsVr}{X}\right) Sin\gamma \tag{2}$$

where P is the transmitted power, vs. is the sending end voltage and Vr is the receiving end voltage, X is the reactance and γ is the phase angle.

Capacitance of the line increases as shown in Equation (3).

$$Cn = \frac{2\pi\epsilon_0}{ln\left(\frac{GMD}{GMR}\right)} \tag{3}$$

where Cn is the line capacitance, ϵ_0 is permittivity of free space, GMD is geometric mean distance and GMR is geometric mean radius. Conversely, in Turkey, power distribution in urban areas goes through underground cabling and uses belted cable for 11 KV, screening cable for 32 KV and oil pressure cable for more than 69 KV in the distribution network.

The excitation current losses in the transformer should be minimized by adopting the best material to design the core of the transformer.

6.2. Feasible Projects of Renewable Energy

On moving over a speed breaker, a vehicle produces its kinetic energy. This energy is dependent on its speed, friction between road and its wheels, heat generated in motion and the energy of wind striking the vehicle. This energy is transferred to a roller attached beneath the speed breaker. Then, the roller shifts the energy to a spring and the spring transfers it to a dynamo, which performs the conversion of the mechanical energy into electrical energy. This DC energy requires an inverter for converting it into AC, at which point it can be used to light up the whole road. This technology provides benefits to society. However, wide usage of speed breakers may actually result in a higher usage of car fuel. A large amount of energy is wasted by the vehicles on the speed breakers through friction. This effect can be mitigated by only employing speed breaker technology on the busiest roads of metropolitan cities where traffic density is very high.

The performance of this technology in terms of force, power and torque can be evaluated by Equations (4)–(6).

$$F = av^2 + b \tag{4}$$

where F is the applied force by the vehicle, a is coefficient for a two-wheeled vehicle and b is the reference weight of vehicle in kg.

$$P = T * s \tag{5}$$

where P is the consumed power, T is torque generated by dynamometer and s is the shaft speed.

$$T = F * D \tag{6}$$

where F is friction force due to rotation of shaft and D is the difference of shaft from the pivot.

It is recommended that at the corporate level, for every building, the building should generate its own electricity via the installation of photovoltaic panels in the glass elements of the building and by utilizing the rooftop. The generated electricity can provide for the building automation, lighting and HVAC (heating, ventilation, and air conditioning) systems. In this way, these buildings reduce the line losses of power being supplied through the national grid. National and international corporate entities are also taking keen interest in renewable energy development as Pakistan is a green paradise for investment in its energy sector. According to the government of Pakistan, several companies are willing to relocate their manufacturing facilities (for wind turbine and solar panel production) to Pakistan [109]. Recently, Australian company officials met the Prime Minister of Pakistan and expressed keen interest in investing in the nation's renewable energy sector [110].

Pakistan's energy sector should adopt the e-plant mechanism on the roof top of corporate buildings to generate electricity. This technology [111] was invented and first implemented in Holland, and research is ongoing to efficiently generate electricity by utilizing plants and grass. Basically, plants store chemical energy in their roots in the form of chemical sugar bonds. When electrodes are placed in the roots, the ions move toward the electrodes and this flow of ions produces electricity. The electrodes usually consist of iron (cathode) and copper (anode).

Microbial fuel cells are a bio electrochemical system making use of biocatalysts for converting chemical energy into electrical energy.

Equations (7)–(9) show the chemical reaction required to produce electricity.

$$\text{At anode}: \; 2C_6H_{12}O_6 \rightarrow 2C_6H_{10}O_6 + 4H + 4e \tag{7}$$

$$\text{At Cathode}: \; O_2 + 4H + 4e \rightarrow 2H_2O \tag{8}$$

$$\text{Net reaction}: \; 2C_6H_{12}O_6 + O_2 \rightarrow 2C_6H_{10}O_6 + 2H_2O \tag{9}$$

Through the photosynthesis process, we can obtain 2.427 V and this will increase with the passage of time. Electricity should also be generated on a commercial scale by utilizing the tidal, ocean and geothermal energy resources. Currently, Turkey uses geothermal energy resources for its HVAC systems and for residential usage. Geothermal energy is frequently utilized for heating purposes.

Energy should be generated through trash by means of biogas plants on a commercial level by treating biomass as a raw energy material. Cost effective biogas plants should be developed and installed in areas with high population density in order to utilize waste and produce appropriate gases. This will allow the nations to producing electricity to fulfill the energy demand. In rural areas of Pakistan, the average biomass required for one household is 2325 kg of firewood [48] (or 1480 kg of animal gung, or 1160 kg of crop residues) per annum for heating and cooking purposes.

6.3. Subsidy for Renewable Energy & Energy Storage Technology

The government of Pakistan took a very impressive step by giving tenders to independent power producers (IPPs) to generate electricity through renewable energy technologies in order to eradicate the energy crisis in Pakistan. No doubt, surplus energy will increase the country's economy and establish more industrial zones at different locations of Pakistan. The government should promote renewable energy technologies by giving subsidies to IPPs.

Energy storage policies should be integrated with renewable energy technologies as they increase the reliability of sustainable energy generation. The cost of energy storage technology is decreasing continuously and it is the right time to invest in it for sustainable generation and supply of electricity.

6.4. R&D along with Global Collaboration

An incubation center for research & development (especially in the energy sector) should be established in order to deploy new renewable energy technologies. In this regard, the generation of electricity through cars' wheels to power street lights will be a major contribution, as will the production of electricity through plants.

For investors in renewable energy, Pakistan is a green. To spread awareness of this opportunity for potential investors, more energy-related conferences should be held in Pakistan. Potential investors should be informed about investor-friendly policies in the renewable energy market to encourage more investment.

7. Conclusions

Transforming the energy systems of Turkey and Pakistan is at the core of working toward a resolution for global warming problems in their respective regions. Additionally, air pollution and energy security perspectives are of great significance and will help to define how this transition will take place. This article is an effort to assess the use of renewable energy technologies in both countries. With the utilization of only 10% of modern renewable energy resources as of 2017, Turkey produced 297,278 GWh electricity to meet some of its energy demands. Annual electricity production in Turkey is much higher than in Pakistan, which is dependent on the import of fossil fuels. The power crisis in Pakistan is anticipated to be wiped out in 2021, based on the present government's energy policies of ongoing renewable energy projects. With these projects, the installed electricity generation capacity reached 37,402 MW in 2020. Previously, 1445 MW of electricity was added to the national grid through the implementation of modern renewable power technologies in Pakistan in 2017.

Along with the discussion on the comparative energy perspectives of the two countries and the discussion on the utilization of their renewable energy technologies, this paper also recommends policies for the adaptation of resources like oceanic/tidal, geothermal and biomass energy for electricity production. The policy recommendations aim to minimize losses in the energy sector, reduce greenhouse gases and relieve the country from dependence on imported energy. They encourage the governments of Turkey and Pakistan to provide subsidies to the private sector and development partners, and to launch innovative projects such as speed breaker-based electricity generation, corporate energy generation, E-Plants, biogas plants, oceanic and geothermal energy projects. This article suggests that the governments accelerate support of research and development, education, and public consciousness along with global collaboration, to encourage foreign direct investment in the energy sector. The adaptation of renewable energy technologies in energy policies will ensure energy security, job creation, reduction of global warming, protection of the environment and economic development. We conclude that, with a modified energy security policy, both countries can effectively reduce their dependence on fossil fuels and improve their economies, tackling global climate change and air pollution.

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References

1. Turkish Statistical Institute. Main Statistics. Population & Demography. Environment & Energy. Available online: http://www.turkstat.gov.tr/UstMenu.do?metod=temelist (accessed on 10 January 2020).
2. Asif, M.; Muneer, T. Energy supply, its demand and security issues for developed and emerging economies. *Renew. Sustain. Energy Rev.* **2007**, *11*, 1388–1413. [CrossRef]
3. Grubb, M. The Kyoto Protocol-A guide and assessment. *Nature* **1999**, *402*, 233–234.
4. Protocol, K. United Nations framework convention on climate change. *Kyoto Protoc. Kyoto* **1997**, *19*, 497.
5. European Renewable Energy Council (EREC). Renewable Energy Scenario to 2040. Available online: http://energiasolar.net/erec2040.pdf (accessed on 8 December 2020).
6. Pakistan Economic Survey 2019–20. Available online: http://www.finance.gov.pk/survey_1920.html (accessed on 20 November 2020).
7. Pakistan Economic Survey 2018–19. 2019. Available online: http://www.finance.gov.pk/survey/chapters_19/14-Energy.pdf (accessed on 20 November 2020).
8. *Turkey's Statistical Yearbook 2009*; Turkish Statistical Institute: Ankara, Turkey, 2009. Available online: http://www.tuik.gov.tr/yillik/yillik.pdf (accessed on 10 October 2020).
9. Ritchie, H. Renewable Energy. 2017. Available online: https://ourworldindata.org/renewable-energy (accessed on 26 January 2021).
10. Subramaniam, Y.; Masron, T.A.; Azman, N.H.N. The impact of biofuels on food security. *Int. Econ.* **2019**, *160*, 72–83. [CrossRef]
11. Krishan, O.; Suhag, S. An updated review of energy storage systems: Classification and applications in distributed generation power systems incorporating renewable energy resources. *Int. J. Energy Res.* **2019**, *43*, 6171–6210. [CrossRef]
12. Why is Intermittency a Problem for Renewable Energy? Available online: https://www.thegreenage.co.uk/why-is-intermittency-a-problem-for-renewable-energy/#:~{}:text=Without%20a%20doubt%2C%20the%20biggest,or%20we%20risk%20mass%20blackouts (accessed on 20 January 2021).
13. Osman, A.A.M. Renewable Energy Advantages and Disadvantages. *Sudan Univ. Sci. Technol.* **2016**, *15022*, 7–61. Available online: http://repository.sustech.edu/bitstream/handle/123456789/15022/Resesarch.pdf?sequence=3 (accessed on 20 January 2021).
14. AEDB Alternate Energy Development Board. Available online: http://www.aedb.org/ae-technologies/small-hydro (accessed on 20 December 2020).

15. Fossil Fuels: The Dirty Facts. Available online: https://www.nrdc.org/stories/fossil-fuels-dirty-facts (accessed on 16 February 2021).
16. The Renewable Energy and Jobs Annual Review. 2019. Available online: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Jun/IRENA_RE_Jobs_2019-report.pdf (accessed on 20 January 2020).
17. Freedman, B. Environmental Science: A Canadian Perspective. Available online: https://ecampusontario.pressbooks.pub/environmentalscience/chapter/chapter-12-resources-and-sustainable-development/#navigation (accessed on 18 February 2021).
18. Timmons, D.; Harris, J.M.; Roach, B. The economics of renewable energy. *Glob. Dev. Environ. Inst. Tufts Univ.* **2014**, *52*, 1–52.
19. Irfan, M.; Zhao, Z.Y.; Ahmad, M.; Mukeshimana, M.C. Solar energy development in Pakistan: Barriers and policy recommendations. *Sustainability* **2019**, *11*, 1206. [CrossRef]
20. Renewable Power Generation Costs in 2019. Available online: https://www.irena.org/publications/2020/Jun/Renewable-Power-Costs-in-2019 (accessed on 20 January 2020).
21. Tükenmez, M.; Demireli, E. Renewable energy policy in Turkey with the new legal regulations. *Renew. Energy* **2012**, *39*, 1–9. [CrossRef]
22. Dilaver, Z.; Hunt, L.C. Industrial electricity demand for Turkey: A structural time series analysis. *Energy Econ.* **2011**, *33*, 426–436. [CrossRef]
23. Melikoglu, M. Vision 2023: Feasibility analysis of Turkey's renewable energy projection. *Renew. Energy* **2013**, *50*, 570–575. [CrossRef]
24. Pakistan to Set 30% Plus 30% Renewable Energy Target by 2030. Available online: https://wwindea.org/blog/2019/04/02/pakistan-to-set-30-plus-30-renewable-energy-target-by-2030/ (accessed on 20 January 2020).
25. Wind Energy in Turkey. 2002. Available online: www.bsrec.bg (accessed on 20 October 2019).
26. European Commission. Available online: https://setis.ec.europa.eu/energy-research/country/turkey (accessed on 20 October 2019).
27. EIA (Energy Information Administration). International Energy Outlook Department of Energy USA. 2009. Available online: https://www.nrc.gov/docs/ML0932/ML093280292.pdf (accessed on 20 January 2020).
28. Kamran, M. Current status and future success of renewable energy in Pakistan. *Renew. Sustain. Energy Rev.* **2018**, *82*, 609–617. [CrossRef]
29. PCRET. Pakistan Council of Renewable Energy Technologies. Available online: http://www.pcret.gov.pk/2010 (accessed on 10 January 2019).
30. Erdin, C.; Ozkaya, G. Turkey's 2023 energy strategies and investment opportunities for renewable energy sources: Site selection based on electre. *Sustainability* **2019**, *11*, 2136. [CrossRef]
31. Tubitak Mam Energy Institute. Available online: https://ee.mam.tubitak.gov.tr/en/about-ei/who-we-are (accessed on 19 January 2021).
32. Pakistan Economic Survey 2015–2016. 2016. Available online: http://www.finance.gov.pk/survey/chapters_16/14_Energy.pdf (accessed on 10 January 2020).
33. Ali, A.; Baig, F.S.; Memon, A.H. Designing Hydel Power Generation Capacity using a Mini/Micro Hydro Power Plant at Left Bank Outfall Drain Drainage System, near Goth Ahori, Jhuddo, Sindh. *Mehran Univ. Res. J. Eng. Technol.* **2020**, *39*, 554–563. [CrossRef]
34. Hydel Power Potential of Pakistan—NEPRA. Available online: https://nepra.org.pk/Policies/Hydel%20Potential%20in%20Pakistan.pdf (accessed on 10 January 2020).
35. K-P to Set Up Two Hydro Power Plants. Available online: https://tribune.com.pk/story/2267873/k-p-to-set-up-two-hydro-power-plants (accessed on 10 January 2020).
36. World Energy Council (WEC). *Renewable Energy in South Asia: Status and Prospects*; World Energy Council (WEC): London, UK, 2000.
37. Pakistan Council of Renewable Energy Technologies (PCRET). *Internal Report 2008*; Pakistan Council of Renewable Energy Technologies (PCRET): Islamabad, Pakistan, 2008.
38. Sheikh, M.A. Energy and renewable energy scenario of Pakistan. *Renew. Sustain. Energy Rev.* **2010**, *14*, 354–363. [CrossRef]
39. Shah, S.A.A. Feasibility study of renewable energy sources for developing the hydrogen economy in Pakistan. *Int. J. Hydrog. Energy* **2020**, *45*, 15841–15854. [CrossRef]
40. Uddin, W.; Ayesha; Zeb, K.; Haider, A.; Khan, B.; Islam, S.U.; Ishfaq, M.; Khan, I.; Adil, M.; Kim, H.J. Current and future prospects of small hydro power in Pakistan: A survey. *Energy Strat. Rev.* **2019**, *24*, 166–177. [CrossRef]
41. Nasir, S.; Raza, S. Wind and solar energy in Pakistan. *Energy* **1993**, *18*, 397–399. [CrossRef]
42. Japan's Grant Aid for the Project for Introduction of Clean Energy by Solar Electricity Generation System by the Islamic Republic of Pakistan. Available online: http://www.pec.org.pk/Jica_PROGRESS.aspx (accessed on 8 January 2020).
43. HDIP. *Pakistan Energy Year Book*; Hydrocarbon Development Institute of Pakistan (HDIP): Islamabad, Pakistan, 2005.
44. National Assembly of Pakistan, Pakistan's Parliament Goes Green. Available online: http://www.na.gov.pk (accessed on 10 November 2020).
45. Valasai, G.D.; Uqaili, M.A.; Memon, H.R.; Samoo, S.R.; Mirjat, N.H.; Harijan, K. Overcoming electricity crisis in Pakistan: A review of sustainable electricity options. *Renew. Sustain. Energy Rev.* **2017**, *72*, 734–745. [CrossRef]
46. Current Status of Solar PV Power Projects. Available online: http://www.aedb.org/ae-technologies/solar-power/solar-current-status (accessed on 20 November 2020).

47. Chaudhry, A.M.; Raza, R.; Hayat, A.S. Renewable energy technologies in Pakistan: Prospects and challenges. *Renew. Sustain. Energy Rev.* **2009**, *13*, 1657–1662. [CrossRef]
48. Mirza, U.K.; Ahmad, N.; Majeed, T. An overview of biomass energy utilization in Pakistan. *Renew. Sustain. Energy Rev.* **2008**, *12*, 1988–1996. [CrossRef]
49. GOP. *Annual Report 2006, Livestock Statistics*; Ministry of Food, Agriculture and Livestock, Government of Pakistan, Pakistan Bureau of Statistics, Ministry of Planning, Development & Special Initiatives: Islamabad, Pakistan, 2006.
50. Ghaffar, M.A. The energy supply situation in the rural sector of Pakistan and the potential of renewable energy technologies. *Renew. Energy* **1995**, *6*, 941–976. [CrossRef]
51. Meena, J. Biogas for Rural Applications. In *Renewable Energy Conference—International Progress (Part B)*; Elsevier Publishing Company: Oxford, UK, 1984.
52. Asif, M. Sustainable energy options for Pakistan. *Renew. Sustain. Energy Rev.* **2009**, *13*, 903–909. [CrossRef]
53. ADB. *Promotion of Renewable Energy, Energy Efficiency and Greenhouse Gas Abatement (PREGA)*; Pakistan country report; Asian Development Bank (ADB): Manila, Philippines, 2004.
54. Khan, T.A.; Zaidi, A.K.; WHO. *Indoor Air Pollution and Child Health in Pakistan*; Aga Khan University: Karachi, Pakistan, 2005.
55. Bhutto, A.W.; Bazmi, A.A.; Zahedi, G. Greener energy: Issues and challenges for Pakistan—Biomass energy prospective. *Renew. Sustain. Energy Rev.* **2011**, *15*, 3207–3219. [CrossRef]
56. Wakeel, M.; Chen, B.; Jahangir, S. Overview of Energy Portfolio in Pakistan. *Energy Procedia* **2016**, *88*, 71–75. [CrossRef]
57. Yasar, A.; Ali, A.; Tabinda, A.B.; Tahir, A. Waste to energy analysis of shakarganj sugar mills; biogas production from the spent wash for electricity generation. *Renew. Sustain. Energy Rev.* **2015**, *43*, 126–132. [CrossRef]
58. Alternative Energy Development Board, Ministry of Water & Power, GOP. *National Biodiesel Program—Alternative Energy Development Board, Ministry of Water, and Power, Government of Pakistan*; Alternative Energy Development Board, Ministry of Water & Power, GOP: Islamabad, Pakistan, 2010.
59. Ahmad, M.; Jan, H.A.; Sultana, S.; Zafar, M.; Ashraf, M.A.; Ullah, K. Prospects for the Production of Biodiésel in Pakistan. In *Biofuels-Status and Perspective*; IntechOpen: London, UK, 2015.
60. *A-Power to Build Two Biomass Power Plants in Pakistan. RISI Wood Biomass Markets*; RISI Inc.: Burlington, MA, USA, 2010.
61. Shakir, M.; Haq, I.U.; Khan, M.A.; Malik, S.A.; Khan, S.A. Alternate energy resources for pakistan: Sustainable solutions for fulfilling energy requirements. *World Appl. Sci. J.* **2014**, *31*, 718–723.
62. Tariq, M.I. Solution to Energy Crisis. 2012. Available online: http://www.pakistantoday.com.pk/2012/05/12/comment/editors-mail/solution-to-energy-crisis/ (accessed on 10 November 2020).
63. Zaigham, A.N.; Nayyar, Z.A.; Hisamuddin, N. Review of geothermal energy resources in Pakistan. *Renew. Sustain. Energy Rev.* **2009**, *13*, 223–232. [CrossRef]
64. Shuja, T.A. Geothermal areas in Pakistan. *Geothermics* **1986**, *15*, 719–723. [CrossRef]
65. Bakht, M.S. An overview of geothermal resources of Pakistan. In Proceedings of the World Geothermal Congress, Kyushu-Tohoku, Japan, 28 May–10 June 2000.
66. Ahmad, M.; Akram, W.; Hussain, S.D.; Sajjad, M.I.; Zafar, M.S. Origin and subsurface history of geothermal water of Murtazabad area, Pakistan—Isotopic evidence. *Appl. Radiat. Isot.* **2001**, *55*, 731–736. [CrossRef]
67. Hydraulics. Available online: https://enerji.gov.tr/bilgi-merkezi-enerji-hidrolik-en (accessed on 10 November 2020).
68. DSI (State Hydraulic Works). *Statistical Information*; DSI Report; General Directorate of State Hydraulic Works (DSI): Ankara, Turkey, 1999.
69. Yumurtaci, Z.; Asmaz, E. Electric energy demand of Turkey for the year 2050. *Energy Sources* **2004**, *26*, 1157–1164. [CrossRef]
70. DSI (State Hydraulic Works). *Hydroelectric Development Plans in Turkey, State Hydraulic Works (DSI)*; General Directorate of State Hydraulic Works (DSI): Ankara, Turkey, 2001.
71. Ediger, V.Ş.; Kentel, E. Renewable energy potential as an alternative to fossil fuels in Turkey. *Energy Convers. Manag.* **1999**, *40*, 743–755. [CrossRef]
72. WECTNC. *Seventh Energy Congress of Turkey. Energy Statistics*; Turkish National Committee, World Energy Council Ankara: Ankara, Turkey, 1997.
73. Turkish Scientific and Technologic Research Committee (TUBITAK); Turkish Technology Development Committee (TTGV). *Energy Technologies Policies Study Group Report*; Science-Technology-Industry Discussion Platform: Ankara, Turkey, 1998. (In Turkish)
74. Hepbasli, A.; Ozdamar, A.; Ozalp, N. Present status and potential of renewable energy sources in Turkey. *Energy Sources* **2001**, *23*, 631–648. [CrossRef]
75. Demirbas, A. Electricity from biomass and hydroelectric development projects in Turkey. *Energy Explor. Exploit.* **2002**, *20*, 325–335. [CrossRef]
76. Sürmen, Y. The necessity of biomass energy for the Turkish economy. *Energy Sources* **2003**, *25*, 83–92. [CrossRef]
77. Wind Energy. 2002. Available online: http://egetek.unimedya.net.tr/pages/links/energy/wind.html (accessed on 8 November 2019).
78. A vision for Turkish Energy Issues. 2002. Available online: www.egetek.org (accessed on 10 November 2018).
79. Solar and Wind Energy. 2002. Available online: www.meteor.gov.tr (accessed on 10 November 2018).
80. Celik, A.N. Review of Turkey's current energy status: A case study for wind energy potential of Çanakkale province. *Renew. Sustain. Energy Rev.* **2011**, *15*, 2743–2749. [CrossRef]

81. Turkish Wind Energy Statistics Report. 2017. Available online: http://www.tureb.com.tr/files/tureb_sayfa/duyurular/2017_duyurular/agustos/turkiye_ruzgar_enerjisi_istatistik_rapor_temmuz_2017.pdf (accessed on 25 November 2018).
82. Akpınar, A.; Kömürcü, M.İ.; Önsoy, H.; Kaygusuz, K. Status of geothermal energy amongst Turkey's energy sources. *Renew. Sustain. Energy Rev.* **2008**, *12*, 148–1161. [CrossRef]
83. Hepbasli, A.; Ozgener, L. Development of geothermal energy utilization in Turkey: A review. *Renew. Sustain. Energy Rev.* **2004**, *8*, 433–460. [CrossRef]
84. Ullah, K. Electricity infrastructure in Pakistan: An overview. *Int. J. Energy Inf. Commun.* **2013**, *4*, 11–26.
85. Thermal Has Largest Share in Pakistan's Energy Mix. Available online: https://tribune.com.pk/story/2240789/2-thermal-largest-share-pakistans-energy-mix (accessed on 25 November 2020).
86. Share of Hydropower in Energy Mix Likely to Decline Sharply. DAWN. Available online: https://www.dawn.com/news/1552568 (accessed on 10 November 2020).
87. Cao, Y.; Fu, L.; Mofrad, A. Combined-gasification of biomass and municipal solid waste in a fluidized bed gasifier. *J. Energy Inst.* **2019**, *92*, 1683–1688. [CrossRef]
88. Farooq, M.K.; Kumar, S. An assessment of renewable energy potential for electricity generation in Pakistan. *Renew. Sustain. Energy Rev.* **2013**, *20*, 240–254. [CrossRef]
89. Samad, H.; Zhang, F. *Electrification and Household Welfare: Evidence from Pakistan*; The World Bank: Washington, DC, USA, 2018.
90. Ali, A.; Mahar, R.B.; Sheerazi, S.T.H. Renewable electricity generation from food waste through anaerobic digestion in Pakistan: A mini-review. *Earth Syst. Environ.* **2019**, *3*, 95–100. [CrossRef]
91. Power Generation Policy 2015. Available online: http://pedo.pk/uploads/policies/Federal_Power_Policy_2015.pdf (accessed on 10 November 2020).
92. *Guidelines for Environmental Assessment of Wind Farms in the Gharo Wind Corridor- Pakistan*; Alternative Energy Development Board (AEDB): Islamabad, Pakistan, 2009. Available online: https://www.aedb.org/component/judownload/root/2-wind/15-guidelines-for-environmental-assessment-of-wind-farms-in-the-gharo-wind-corridor-pakistan?Itemid=101 (accessed on 20 November 2020).
93. Ghafoor, A.; ur Rehman, T.; Munir, A.; Ahmad, M.; Iqbal, M. Current status and overview of renewable energy potential in Pakistan for continuous energy sustainability. *Renew. Sustain. Energy Rev.* **2016**, *60*, 1332–1342. [CrossRef]
94. Abdullah, A.; Ahmed, A.; Akhter, P.; Razzaq, A.; Zafar, M.; Hussain, M.; Shahzad, N.; Majeed, K.; Khurrum, S.; Park, Y.K.; et al. Bioenergy potential and thermochemical characterization of lignocellulosic biomass residues available in Pakistan. *Korean J. Chem. Eng.* **2020**, *37*, 1899–1906. [CrossRef]
95. Pakistan Has 100,000 MW Production Potential. Available online: https://tribune.com.pk/story/996382/hydroelectric-power-pakistan-has-100000mw-production-potential (accessed on 15 November 2020).
96. Younas, U.; Khan, B.; Ali, S.M.; Arshad, C.M.; Farid, U.; Zeb, K.; Rehman, F.; Mehmood, Y.; Vaccaro, A. Pakistan geothermal renewable energy potential for electric power generation: A survey. *Renew. Sustain. Energy Rev.* **2016**, *63*, 398–413. [CrossRef]
97. Balat, M. Energy consumption and economic growth in Turkey during the past two decades. *Energy Policy* **2008**, *36*, 118–127. [CrossRef]
98. Kaygusuz, K.; Guney, M.; Kaygusuz, O. Renewable energy for rural development in Turkey. *J. Eng. Res. Appl. Sci.* **2019**, *8*, 1109–1118.
99. Economy of Turkey. Available online: https://en.wikipedia.org/wiki/Economy_of_Turkey#cite_note-80 (accessed on 15 December 2020).
100. Balat, M. Current hydropower potential in Turkey and sustainability of hydropower for Turkey's energy demand. *Energy Explor. Exploit.* **2005**, *23*, 1–18. [CrossRef]
101. Saracoglu, N. The biomass potential of Turkey for energy production: Part I. *Energy Sources Part B Econ. Plan. Policy* **2010**, *5*, 272–278. [CrossRef]
102. Kiliç, A.M. Turkey's main energy sources and importance of usage in energy sector. *Energy Explor. Exploit.* **2006**, *24*, 1–17. [CrossRef]
103. Mertoglu, O.; Simsek, S.; Basarir, N.; Paksoy, H. Geothermal energy use, country update for Turkey. In Proceedings of the European Geothermal Congress 2019, Den Haag, The Netherlands, 11–14 June 2019.
104. Republic of Turkey Ministry of Energy and Natural Resources—Solar. Available online: https://enerji.gov.tr/bilgi-merkezi-enerji-gunes-en (accessed on 25 December 2020).
105. Ozerdem, B.; Ozer, S.; Tosun, M. Feasibility study of wind farms: A case study for Izmir, Turkey. *J. Wind Eng. Ind. Aerodyn.* **2006**, *94*, 725–743. [CrossRef]
106. Pakistan Economic Survey 2017–18. Available online: http://www.finance.gov.pk/survey/chapters_18/14-Energy.pdf (accessed on 25 December 2020).
107. Pakistan Economic Survey 2016–17. 2017. Available online: http://www.finance.gov.pk/survey/chapters_17/14-Energy.pdf (accessed on 25 December 2020).
108. Hussain, Z.; Memon, S.; Dhomeja, L.; Abbasi, S. Analysis of non-technical electrical power losses and their economic impact on Pakistan. *Sindh Univ. Res. J.* **2017**, *49*, 1–6.
109. Pakistan Offers $100 bn Investment Opportunities in Energy Sector: Ayub. Available online: https://www.dawn.com/news/1536503 (accessed on 25 September 2020).

110. Australian Company Keen to Invest in Pakistan's Renewable Energy Sector. Available online: https://profit.pakistantoday.com.pk/2020/09/07/australian-company-keen-to-invest-in-pakistans-renewable-energy-sector/ (accessed on 20 January 2021).
111. Plant-E and Irnas Stand-Alone Plant-Power Device for IoT Solutions. Available online: https://www.plant-e.com/en/plant-e-and-irnas-stand-alone-plant-power-device-for-iot-solutions/ (accessed on 20 January 2021).