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Energy Storage for Energy Security and Reliability through Renewable Energy Technologies: A New Paradigm for Energy Policies in Turkey and Pakistan

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Abstract: Forecasting the microeconomics of electricity will turn into a challenging process when electricity is produced through renewable energy technologies (RET). These technologies are mainly sunlight-based photovoltaic (PV), wind power, and tidal resources, which vigorously rely upon ecological conditions. For a reliable and livable energy supply to the electricity grid from renewable means, electrical energy storage technologies can play an important role while considering the weather effects in order to provide immaculate, safe, and continuous energy throughout the generation period. Energy storage technologies (ESTs) charge themselves during the low power demand period and discharge when the demand of electricity increases in such a way that they act as a catalyst to provide energy boost to the power grid. In this paper, we presented and discussed the renewable ESTs for each type with respect to their operational mechanism. In this regard, the renewable energy scenarios of Pakistan and Turkey are first discussed in detail by analyzing the actual potential of each renewable energy resource in both the countries. Then, policy for the EST utilization for both the countries is recommended in order to secure sustainable and reliable energy provision.

Keywords: renewable energy technologies; electricity storage system; sustainable energy; reliable energy; energy policy

1. Introduction

For secure, reliable, and sustainable energy production, electricity storage technologies (ESTs) play a vital role in the implementation of renewable energy technologies [1]. ESTs provide several benefits, services, and smooth reliable operation to off-grid systems [2]. Through the services provided by the ESTs, smooth operations will certainly improve the power quality, reliability, strength, and competitiveness of the deployed renewable energy technologies (RET) [2–4]. Various ESTs [5] provide an overview and the detailed explanation of each energy storage technology by comparing the battery storage system in-terms of technical and economical features. In this regard, the work [6] compares the lead acid battery with lithium ion battery in terms of capacity fading and partial charging of batteries. It describes the procedure of battery testing in off-grid renewable energy applications.

Several approaches were also proposed in the modeling of the battery. The work [7] developed twelve models of lithium ion batteries. The datasets of each models were collected under three different temperatures of two lithium ion cell by utilizing swarm optimization algorithm. The algorithm derived the optimal model parameters of the two types of lithium ion cell. In research [8], the techniques to determine the internal resistance of electro-chemical batteries are defined, such as lead acid, lithium ion, nickel metal-hydride, and electrochemical double layer capacitors-based batteries. The study also compares the ohmic resistance and dynamic internal resistance of the electrochemical batteries. Similarly, the work [9] developed the battery model/energy storage system and derived the parameters through a manufacturer's data sheet by simulating it via the SimPowerSystems (SPS) simulation software tool. The tool integrated the model of battery and performed complete analysis through simulation of hybrid electric vehicles power train. Study [10] reviewed the battery modeling of electric vehicles by changing its dimension from lithium ion battery to lithium sulphur batteries. It also discussed in detail the challenges for the deployment of lithium sulphur batteries on electric vehicle application. Work [11] carried out the modeling and simulation of the battery storage technologies, while deriving the size result of battery energy storage (BES) for residential areas of electricity peak shaving. In addition, the study [12] used the particle swarm optimization algorithm to find the parameter of the lithium-ion battery in order to define the battery model in healthy or degraded state.

Study [13] described each energy storage technology and compared the energy storage technologies in terms of efficiency, energy capacity, energy density, capital cost, response time, self-discharge, and life cycles in order to improve the energy security. Analysis [14] briefly clarifies the storage scheme using batteries and through recreation of the photo-voltaic framework and HOMER (a computer model developed by National Renewable Energy Lab (NREL)), the real price of solar panel, lead acid, nickel-cadmium, NiMH, and Li-ion batteries were inferred. Research [5] explained the battery storage technologies in detail and investigated their application in power systems. Research [15] compared the battery, ultra-capacitors, and fuel cell technologies for hybrid and plug-in hybrid vehicles by composing the hybrid electricity storage system through the utilization of ultra-capacitor, battery, and fuel cell technologies. Another study [16] compared and discussed the energy storage technologies and briefly explained the applications of the energy storage technologies by highlighting its maturity level and potential level to connect the storage technologies, whereas the work [17] did the cost-benefit analysis of electrical storage system by focusing on the capital cost, operation, maintenance, and replacement cost. Similarly, work [18] presents a review on several electricity storage technologies suitable for wind power application.

In the research [19], the literature talks about the life cycle assessment and metrics for calculation of input energy requirement and emission of greenhouse gas. It was developed for energy storage systems and applied to energy storage technologies, such as pump hydro storage (PHS), compressed air energy storage (CAES), and battery storage systems with vanadium and sodium poly sulphide type as electrolytes. The study also revealed that greenhouse gas emission by these storage systems will be lower when coupled with nuclear or renewable resources as compared to fossil fuel resources. Further, PHS gives lower greenhouse gas emission when integrated to nuclear or renewable energy resources, whereas CAES emits lower greenhouse gas emissions when integrated with fossil fuel resources as compared to PHS and battery energy storage (BES).

The world desperately needs to de-carbonize the global energy sector in order to limit the effects of climate change by shifting towards renewable energy resources from fossil fuel [20]. As the contribution of renewable energy technologies in the global power generation increases rapidly, there is a dire need for energy storage systems. For improvement of power quality, proper provision to maintain the voltage level and constant frequency in energy storage technologies is required for the deployment of sustainable renewable energy technologies [1,21]. After reviewing the above-mentioned ESTs, it is necessary to

identify the optimum electricity storage technology to render the cost effective services and benefits to the power grid. Based on this scenario, the energy storage for energy security and reliability through RETs is studied for the case of Turkey and Pakistan. In this connection, we have the following objectives of this research:

- The detailed study and comparison of renewable ESTs for each type with respect to their operational mechanism.
- Discussion of the renewable energy scenarios of Pakistan and Turkey to analyze the actual potential of each renewable energy resource.
- Proposal and recommendation of the policy for the ESTs application suggested for both nations to secure feasible and trusted power supply arrangement.

The remaining part of the paper is organized as: Section 2 describes various ESTs and their deployment in the power sector along with discussion and comparison of different ESTs. Section 3 comprises renewable energy scenarios of Pakistan and Turkey. Section 4 states energy targets and storage policy along with energy storage policy recommendation for both the countries. Section 5 draws conclusions of the conducted study with the focus on policy recommendations.

2. Energy Storage Technologies (EST)

A power repository system is broadly considered and installed in progressive nations of Europe, Asia, and Australia for the arrangement of smooth, reasonable, and low-cost power supply to the particular local distribution frameworks [21]. Power storage technologies are essentially divided into six categories depending on its development and utilization. Therefore, Figure 1 portrays the number of ESTs accessible around the world, which can be utilized for diverse applications of power distribution to the end user depending upon the benefits and draw backs of each technology.

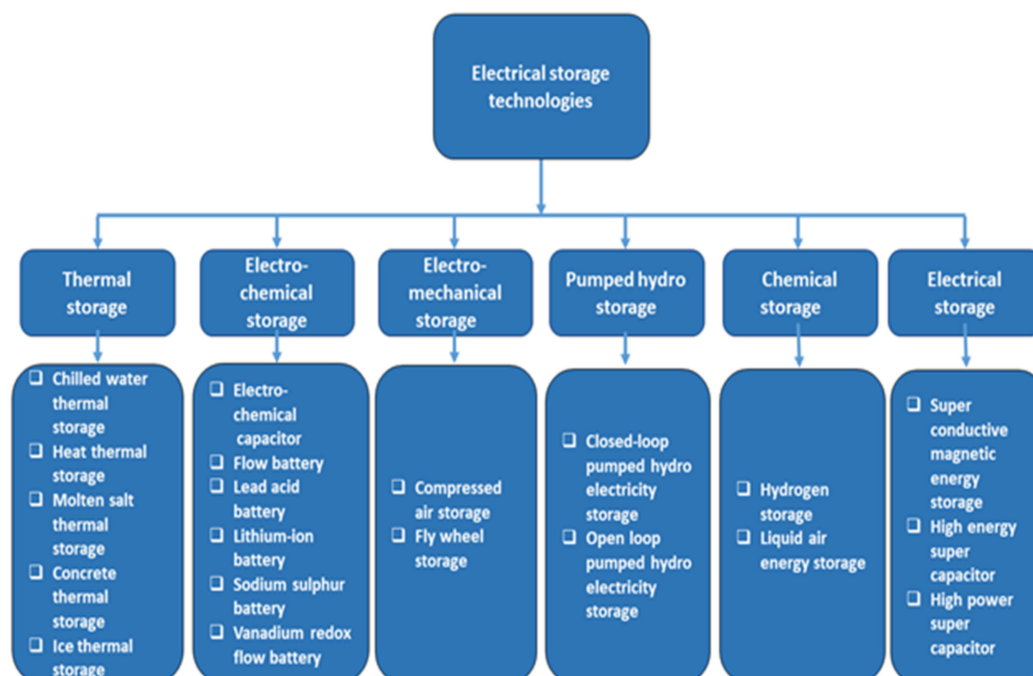


Figure 1. Electricity storage technologies (ESTs) [17].

Considering the latest updates, most the developed nations, which are equipped with energy storage technology, have made the best use of a battery storage scheme, a pumped hydro storage scheme, and a thermal storage scheme in their agenda to supply low cost, maintainable, reasonable, and smooth power supply to end users. Figure 2 shows the cost summary of electrical energy storage technologies as TCC (total capital cost), while the

global capacity share of each storage technology utilized by different countries (i.e., specific storage/total) in terms of capacity and deployment ratio is depicted in Figure 3 [22]. As shown in Figure 2, the lowest cost is recorded for the case of super-capacitors-based energy storage systems. Figure 3 concludes that molten salt thermal storage covers the highest capacity and the deployment ratio, i.e., 2.5 GW and 75%, respectively.

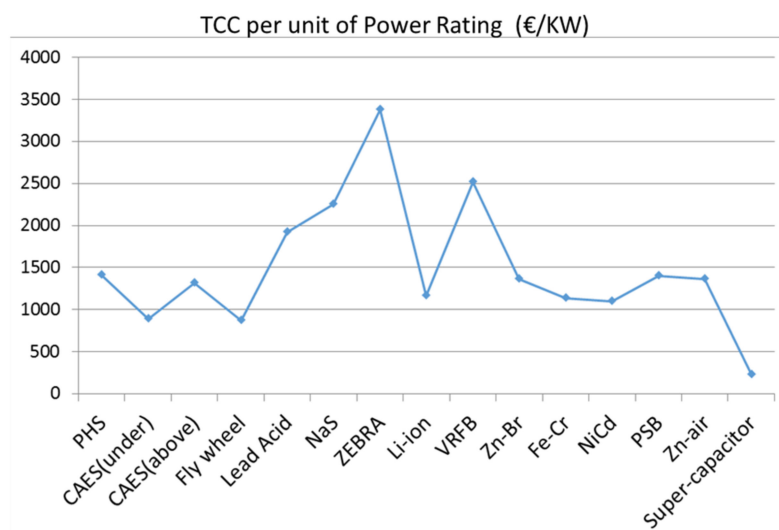


Figure 2. Cost summary of electrical energy storage technologies [17].

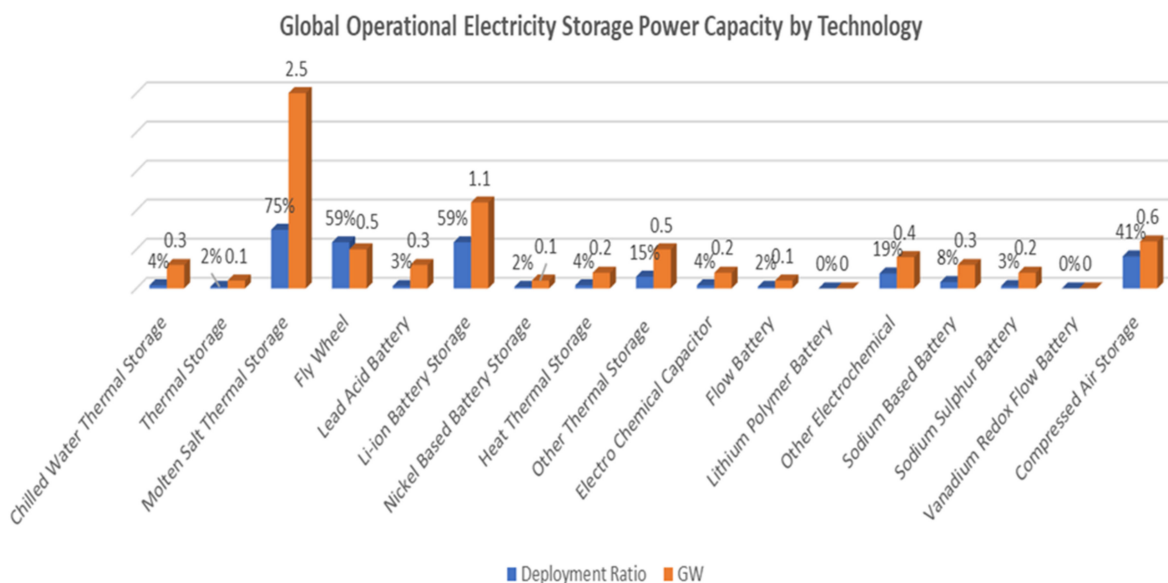


Figure 3. Global operational electricity storage power capacity by technology [22].

2.1. Different ESTs with Implementation in Power Sector

Electricity storage system plays an important role by deploying electricity storage technologies in different locations of power systems in order to provide safe, reliable, and affordable electricity [2]. Charging/discharging of storage technologies plays a significant part in short and long interval of time for energy storage capacity. It also depends on high/low output power to the power grid. ESTs mainly depend upon its charge and discharge time, which takes seconds to hours to charge and discharge completely [23]. Moreover, each EST is best suited for particular application of KW level to GW power of the system requirement. For bulk energy storage, PHS and CAES are most suitable for this application due to its discharge time for tens of hours economically [14,17]. On the

other hand, flywheel energy storage technology discharges (10 KW–900 KW), high power super-capacitor storage discharges (10 KW–1 MW), and superconducting magnetic energy storage discharge (1 MW–10 MW) in a very short period of time, i.e., few seconds, but with rapid high power rating, which makes it suitable for UPS (uninterruptible power supply) application or improves the quality of power [14,17]. Similarly, flow batteries like zinc-chlorine flow battery, zinc air flow battery, zinc bromine flow battery, vanadium redox flow battery, and polysulfide bromine flow battery charges and discharges the power rating from 10 KW–10 MW. It also takes hours to discharge at rated power [5,11,14]. In addition, high temperature battery sodium sulphur (NaS) takes hours to discharge at rated power from 1 MW to 15 MW. On the other hand, lithium-ion battery discharges at (1 KW–1 MW), lead acid batteries (1 KW–12 MW), high energy super-capacitors storage (1 KW–10 KW), advanced lead acid battery (100 KW–10 MW), nickel cadmium battery (1 KW–100 KW), sodium nickel chloride battery (100 KW–5 MW), and nickel-metal hydride battery (1 KW–1MW) mainly take minutes to discharge at rated power in order to provide the services to the grid [5,11,14].

Electricity storage systems can be used in three main segments of the electricity sector named as grid services, behind the meter application, and off-grid applications. Below, we briefly describe different ESTs regarding the suitability of electricity storage technology for different applications in these three main segments of electricity sector:

- Pumped hydro storage technology is suitable for frequency restoration reserve, energy shifting/load leveling and island grid applications [17].
- Compressed air energy storage technology is best suited for frequency restoration reserve, energy shifting/load leveling and island grid application [17].
- Fly wheel storage technology suits for the application to enhance frequency response, frequency containment reserve, increased power quality, peak shaving, and island grid.
- Flooded lead acid storage batteries and valve-regulated lead acid batteries are suitable to enhance frequency response, frequency containment reserve, self-consumption for small residential (community) storage, increased power quality, peak shaving, time of use, nano-off grid, village electrification, and island grid.
- Lithium-ion storage batteries stand ideal for enhancement of frequency response, frequency containment reserve, self-consumption for small residential (community) storage, increased power quality, peak shaving, time of use, nano-off grid, village electrification, and island grid applications [6].
- Sodium nickel chloride storage battery is best suited for enhancing frequency response, frequency containment reserve, community storage, increased power quality, peak shaving, time of use, village electrification, and island grid applications [5,17,24].
- Vanadium redox flow battery is ideal application for frequency restoration reserve, energy shifting/load leveling, self-consumption for small residential (community) storage, peak shaving, time of use, village electrification, and island grid application [17].
- Zinc bromine flow battery is ideal for applications such as self-consumption for small residential areas, community storage, time of use, village electrification, and island grid [6,11].

2.2. Discussion and Comparison on Different ESTs

Pumped hydro storage (PHS) technology is usually used in peak demand of electricity to reduce the power generation cost. Presently, PHS plays an important role in storing the energy worldwide, which constitutes 96% share of world's generation (169 GW capacity). An additional benefit of PHS technology is the low discharging rates at idle scenario and it can also store energy for a longer period of time as compared to electro-mechanical flywheel energy storage technology. The drawback of the flywheel energy storage technology is its high discharge rates at idle scenario. On the other hand, it also provides high power ratings in terms of voltage regulations and frequency within the electricity system [25]. Hydrogen

ammonia storage technology has gained attention in terms of reliable and efficient means available, irrespective of the region, policies, and conditions. This storage technology can be utilized to gain the maximum output for energy storage as well as to store the energy for a longer period of time. In case of bulk power generation, we can store energy by using the hydrogen ammonia technology and utilize it according to demand for a longer period of time. In order to compare ESTs in different common specifications, Table 1 provides a useful analysis of all technical indicators, which details the five different energy storage systems separately according to their features, capacities, and issues [17].

Table 1. Comparison of technical indicators of ESTs [17].

S.No	Technical Indicators	Storage Systems				
		Pumped Hydro Storage (PHS)	Compressed Air Energy Storage (CAES)	Flywheel Energy Storage	Electrochemical Battery Energy Storage (BES)	Hydrogen Based Storage
1	Commercially proven	Yes	Yes	R & D proven	Initial stage	Ready to implement
2	Power Capacity	100–2000 MW	About 3–15MW (with 2–4 h discharge time)	200 KW flywheel EES and store 5 kWh for a few seconds	Capacity of 10 MW with 4 h as the discharging time	Ready to implement
3	Operational Cost	4.6 €/kW-year	No significant reduction of cost	5.2 €/kW-year	Between 3.2 and 13 €/kW-year	Initial stages
4	Construction and Installation costs	Average costs 1406 €/kW	Average costs 893 €/kW	Average costs 867 €/kW	Average costs 2512 €/kW (Li-ion batteries)	The capital costs of electrolysis itself varies in different applications.
5	Efficiency	0.70–0.82	0.70–0.90	0.93–0.95	0.85–0.95 (Li-ion Batteries)	Net electrolysis efficiency up to 83%

Until now, 42 countries have fully utilized the pumped hydro storage technology in energy transition for secure, affordable, and reliable energy provision to their consumers [22,26]. In this regard, China stands as a leading case with a large capacity of PHS technology (32 GW) followed by Japan (28 GW capacity). The data for other countries includes USA (23 GW), Spain (8 GW), Italy (7 GW), and the lowest capacity of energy storage through PHS among 42 countries is reported for Denmark, whereas, non-PHS storage stands at 162 GWh (2017). Thermal storage capacity (TSC) is 3.3 GW (1.9%) in the recent scenario, electro-chemical battery capacity is 1.9 GW (1.1%), and electro-mechanical storage battery capacity is 1.6 GW (0.9%) [26]. The shared capacity of ESTs with respect to top countries are as follows: China (electro-chemical capacity 0.1 GW, TSC 0.1 GW, PHS capacity 32 GW), followed by Japan (electro-chemical capacity 0.3 GW, PHS capacity 28.3 GW), USA (electro-mechanical 0.2 GW, electro-chemical capacity 0.7 GW, TSC 0.8 GW, PHS capacity 22.6 GW), Spain (TSC 1.1 GW, PHS capacity 8.0 GW), Germany (electro-mechanical 0.9 GW, Electro-chemical capacity 0.1 GW, PHS capacity 6.5 GW), Italy (electro-chemical capacity 0.1 GW, PHS capacity 7.1 GW), India (TSC 0.2 GW, PHS capacity 6.8 GW), Switzerland (PHS capacity 6.4 GW), France (PHS capacity 5.8 GW), Republic of Korea (electro-chemical capacity 0.4 GW, PHS capacity 4.7 GW).

It is estimated that the electricity storage demand for stationary [27] and mobile applications will increase rapidly from 4.67 TWh (2017) to 11.89–15.72 TWh (2030) [22] if the contribution of the deployment of renewable energy technologies doubles as compared

to the present scenario. Non-PHS storage is estimated to rise up to 5821–8426 GWh by 2030 depending on the falling cost of the battery. Hydrogen ammonia storage technology is estimated to rise to 1560–2340 GWh of energy storage by 2030. It is estimated that battery deployment capacity in stationary application will increase from 11 GWh to 100–167 GWh by 2030 [17]. In addition, the utility sector utilized the battery energy storage (BES) system of 10 GWh (2017), which will rise to an estimate of 45 GWh to 74 GWh by 2030 [22]. In the renewable energy map analysis [22], it is concluded that by 2030, electricity energy storage will reach 1000 GW, when the installed capacity of solar and wind plant capacity will soar to 5000 GW. The share of storage capacity in 2030, will be 1100 GW, which will constitute 600 GW capacity from electric vehicle storage, 325 GW from PHS, and 175 GW from stationary battery storage [22].

3. Renewable Energy Scenario of Pakistan and Turkey

3.1. Pakistan Scenario

The entire land of Pakistan is 881,913 km² with 211.17 million people [28]. Up until 2019, electricity generation in Pakistan was 87.3 TWh [28]. Pakistan is facing severe energy crises and the facts [29] reveal as follows: (1) the role of fossil fuel remains the highest in form of oil and gas, i.e., 62.1% resource consumption in order to produce electricity in 2019 in Pakistan; (2) the share of power production through hydro power plants is 25.8%, nuclear power plants stand at 8.2%, and renewable energy 3.9%. It is a dire need to make a strategy to overcome the prevailing crisis and formulate a clear goal keeping in view the decreasing levels of fossil fuel in the world simultaneously reducing massive expenditures incurred on its import [30]. Pakistan is spending 60% of its reserves on importing the fossil fuel, which is a great burden on its crumbling economy [31]. From energy security, sustainable energy resource, climate change, and economic considerations, alternative energy resources can prove to be the best option in hand in the present scenario [32]. Pakistan's Ministry of Energy and other responsible departments, such as Pakistan Water and Power Development Authority (WAPDA), Karachi Electric Supply Company (KESC), and Independent Power Plant (IPPS), are planning and executing several renewable energy projects by establishing plants for wind energy, solar power, hydel power, and biogas across the country [31].

In order to provide low-priced electricity, transformation of the existing resources of energy from thermal plant (fossil fuel) to renewable energy resources is taking place for clean energy production. With this shift of renewable energy technologies, there will be less or no reliance on fossil fuels as the main source for energy. Moreover, there will be positive effects on the environment in both the countries. According to study [33], the demand increases up to 5% annually. The difference between demand and supply was 5000 MW in 2013, but it increased to 6000 MW in 2018 [34]. According to the study [35], Pakistan faced an energy deficit of 5201 MW in 2015 and on a daily basis, there was load-shedding of 14–18 h across the country continuing from 2011. According to the Pakistani government, the prediction was that the energy crisis in Pakistan would completely vanish in 2019 and the country would produce surplus energy of 2732 MW [35]. Pakistan is still facing the energy crisis with a shortfall of 3000 MW due to transmission losses [36]. According to this report, Pakistan was generating 553.3 MW of electricity through modern renewable energy technologies in 2015–2016, which was added to the national grid [35]. Still, the Pakistani energy scenario heavily relied on oil to produce electricity, but in 2013–2014, a shift from oil to gas could be witnessed in the power sector to generate electricity for industrial, household, commercial, and transport sector consumption. As compared to 2008, the fossil fuel cost increased in 2009 resulting in 0.6% decrease in the total energy supplies [31], which badly affected the economy of the country. The contribution of fossil fuels remains the highest in the form of oil and gas, i.e., 64% to generate electricity. Despite all these efforts, Pakistan is unable to fulfill the demands of energy requirement. This situation mainly affected the industrial sector resulting in the export minimization and causing adverse effects on the economic growth of the country. The total installed capacity

in terms of fossil fuel, hydro power, and nuclear power plant to generate electricity in Pakistan up to July 2017 was reported to be 25,100 MW with the generation of 108,408 GWh [31].

Pakistan deployed several wind power plants, solar photovoltaic plants, and biomass plants in order to cope with the energy crisis. The summary of power capacity installed and electricity generation through the renewable energy technologies is shown in Figures 4–7 [22]. The share of the hydro power renewable energy technology is far high as compared to other modern renewable energy technologies. The installation capacity and energy production of each renewable energy technologies are summarized in Figures 4 and 5. Similarly, the detailed usage of solar-, wind-, and biomass-based capacity and power generation are shown in Figures 6 and 7, respectively.

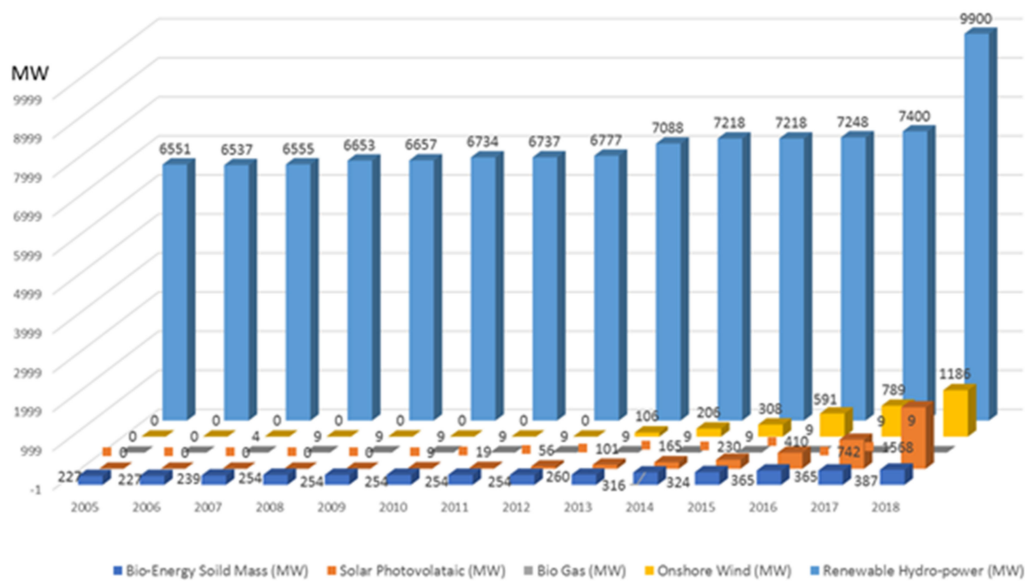


Figure 4. Total installed capacity of renewable energy in Pakistan up until 2018 [22].

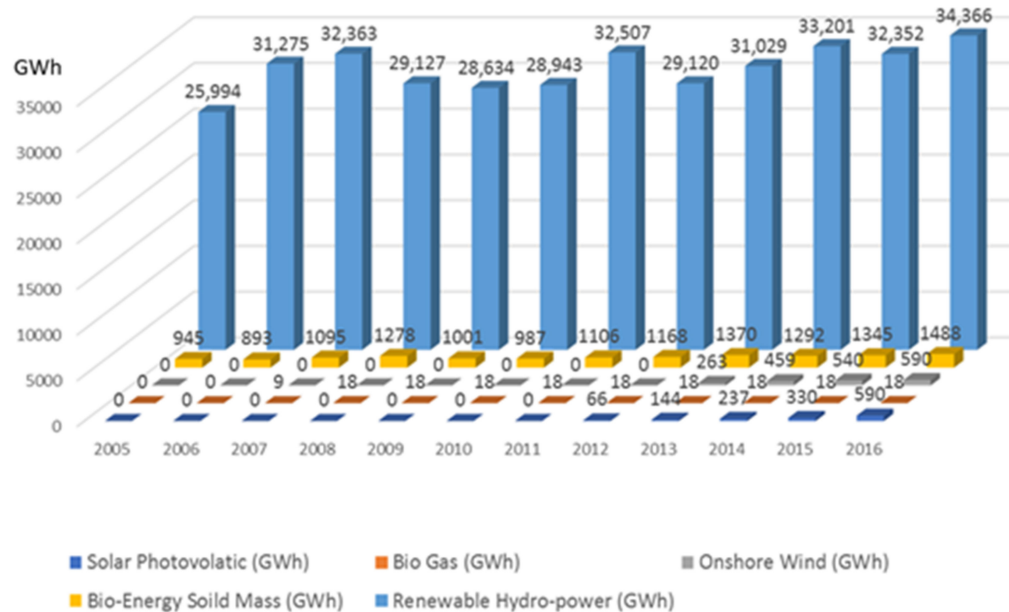


Figure 5. Total electricity generation through renewable energy technologies of Pakistan up until 2016 [22].

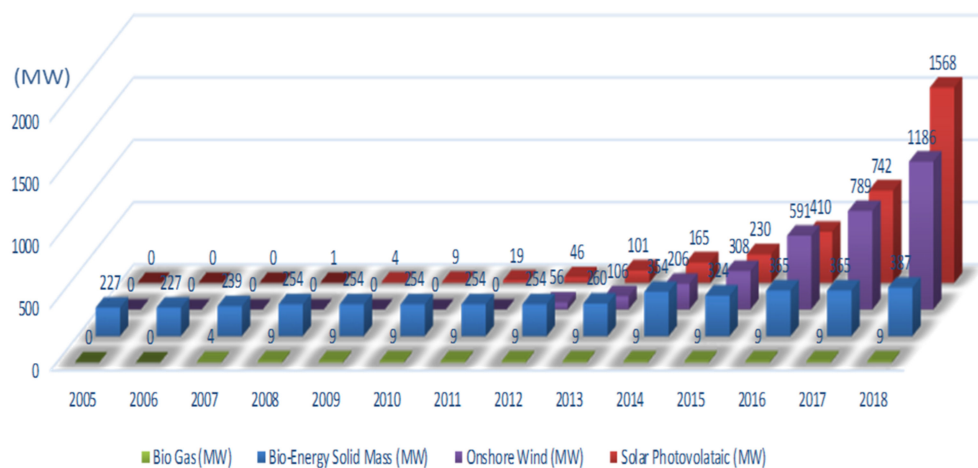


Figure 6. Total capacity of modern renewable energy technologies of Pakistan up until 2018 [22].

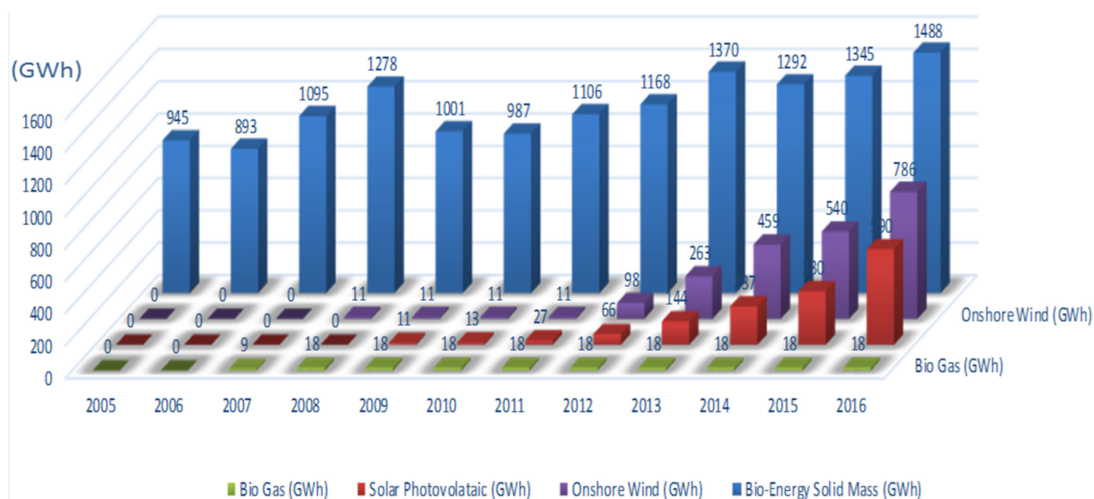


Figure 7. Total electricity generation through modern renewable energy technologies of Pakistan [22].

3.2. Turkey Scenario

Turkey has 783,562 km² territorial area [37] with a population of 83.1 million [38]. Total electricity generation for Turkey was recorded to be 261,783 GWh up until 2015. According to the observation, Turkey depends mainly on coal (37%), natural gas (19%), hydropower (29%), and renewable energy (15%) [38] to generate electricity. Turkey imports 72% of these total primary energy supplies (oil, natural gas, coal), which is certainly an enormous load on the Turkish economy [32,39]. In this regard, the research [40] analyzes the operational performance and investment performance of natural gas-, oil-, and coal-based thermal power plant operated by public and private sectors of Turkey. It also derived some useful efficiency scores based relationships between the thermal power plants in terms of operational and investment cost [41]. With the 8% increase of energy demands in Turkey annually [39], there is a lurking need to increase energy production. According to the observation, the major share in the rise of demand is due to the industrial sector. The industrial sector energy demand was expected to reach 97 to 148 TWh due to the exports of industrial goods and agricultural processed products to the European open market (without custom duty) till 2020 [42]. In order to fulfill the requirement of energy demand and supply, and with a vision [43] to utilize the 30% renewable energy technology resources to generate (160,000 GWh) electricity till 2023, Turkey will be less dependent on fossil fuel and can also get rid of the carbon tax [39].

Turkey lies in a perfect region where it can utilize the maximum resources of modern renewable energy technologies to cope with the upcoming energy demand in the country. By utilizing the renewable energy resources, such as wind power technology, solar power technology, biomass technology, and geothermal energy technology, Turkey has the potential to produce 160 TWh of energy, which is double the energy generation compared to electricity generated in 1996 [44].

Moreover, this renewable energy technology does not emit CO₂ as compared to the utilization of the traditional fossil fuel used for electricity generation, which is not only harmful for the environment, but lays heavy costs on the national economy of Turkey in terms of conventional fuel (coal, gas, oil) import costs. Energy security and sustainable energy supply is paramount for the Turkish state as only dependence on fossil fuels would make the state dependent on the stakeholders causing risk to the national security of the Turkish state. According to the collected facts in the years 2008–2009, 80% of electricity generated in Turkey was thermal-based (gas, coal, oil), where renewable-based electricity generation was only 19.3% (18.5% hydropower, 0.8% others) [45]. Turkey has a great potential of wind power plant as shown in Figures 8–11 and as of now, 158 companies have installed wind power plants across the country.

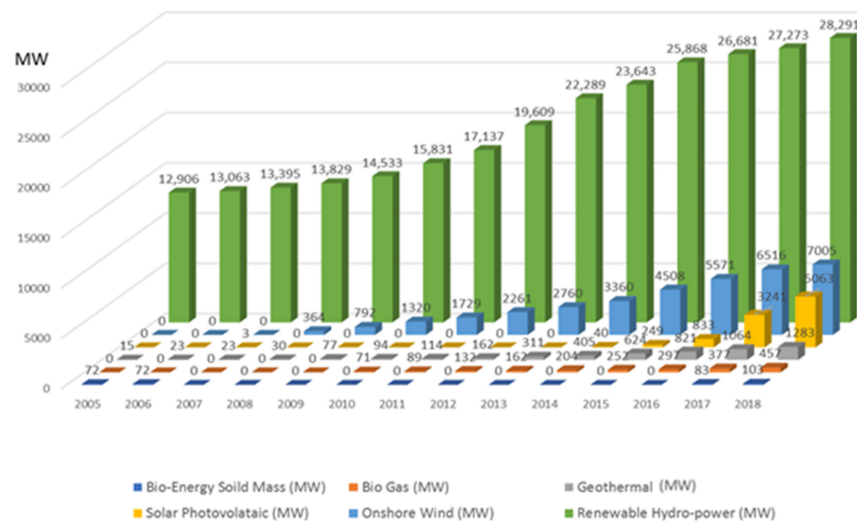


Figure 8. Total capacity of renewable energy technologies of Turkey up until 2018.

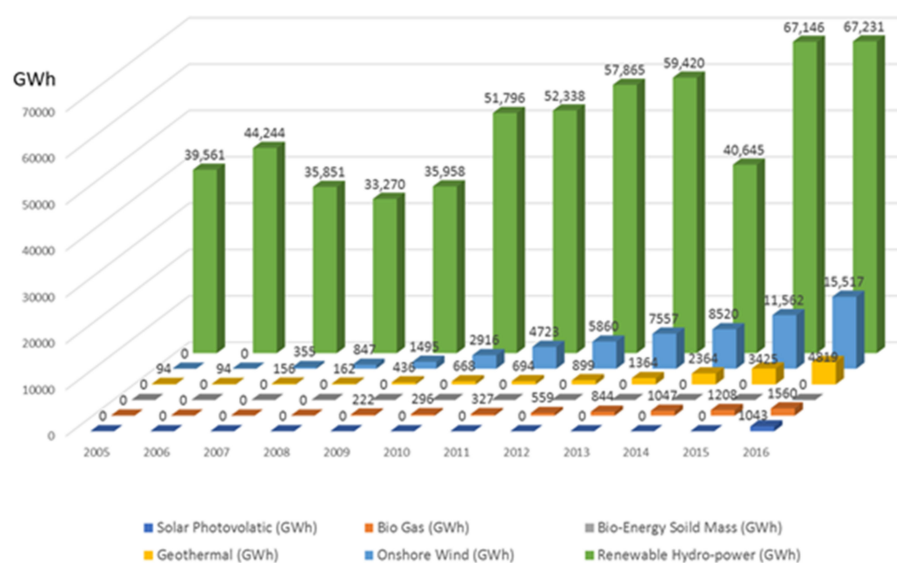


Figure 9. Total generation through renewable energy technology up until 2016.

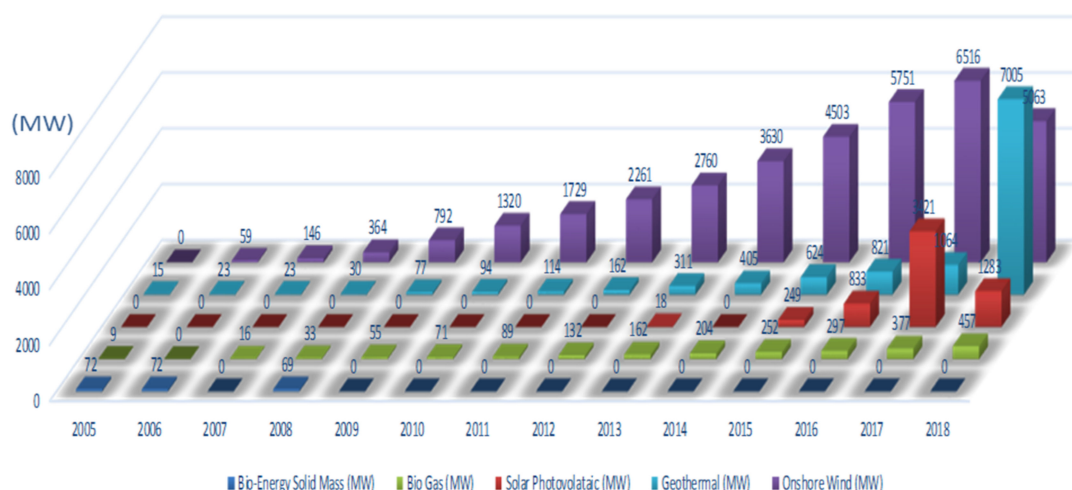


Figure 10. Total capacity of modern renewable energy technologies of Turkey up until 2018.

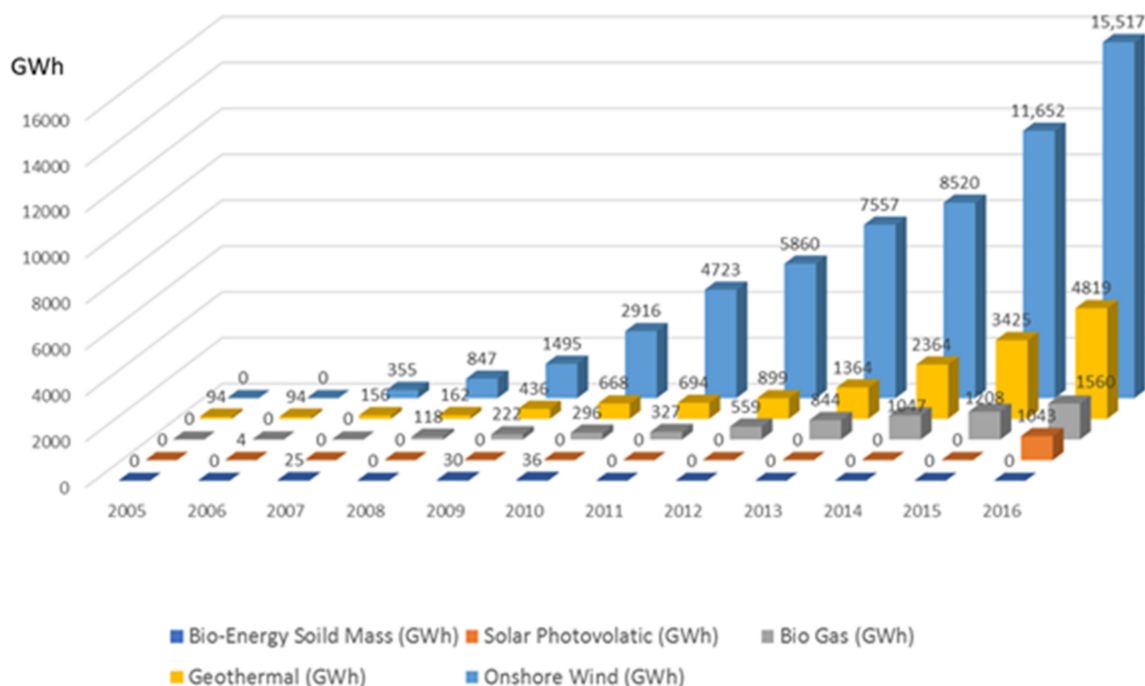


Figure 11. Total generation capacity of modern renewable energy technologies up until 2016.

4. Energy Targets and Storage Policy

Policy targets regarding energy are broadly classified into five different sectors, i.e., primary energy supply, final energy consumption, electricity, transport, and heating/cooling system. In Pakistan’s case, an energy crisis-based scenario sets a target and recommends a strategic policy to overcome the confronting energy challenge through the deployment of modern renewable energy technologies. Several projects of renewable energy technologies are under development to meet the current energy demands and fulfill the requirement by utilizing the available natural resources of energy in power and transport sectors. It is believed that by the middle of June 2021, Pakistan will be in a position to produce surplus energy, which will definitely impact its socio-economic growth. Pakistan should adopt the electricity storage policy in order to produce affordable, safe, secure, and sustainable energy, whereas, in Turkey’s case, the nation aims to fulfill the national energy demands focusing on primary energy supply as well as generating electricity to export it to the other European countries. In this regard, 400 kV Akhaltsikhe-Borcka of transmission line

is under construction with a DC (Direct Current) back to back station at Georgian side. Moreover, Turkey-Romania 400 kV HVDC (High Voltage Direct Current) submarine cable under the Black Sea carrying 600 MW is proposed and feasibility studies are in progress. In addition, Turkey-Iraq 400 kV Cizre-Musul transmission line is in the planning stage and Turkey-Iran transmission line of 400 kV Khoy-Baskale-Van is under construction with DC back to back interconnection.

4.1. Discussion on Energy Storage Policy

Energy storage policy has become a significant issue for both developing and developed countries in terms of reliability, security, sustainability, and affordability. Many countries have a national energy policy entailing the integration of the various renewable energy technologies with effective energy storage systems in order to make the power sector reliable and sustainable. Moreover, this policy will play a significant part in reducing the effect of CO₂ emissions. There is an active global movement going on for the adoption of 100% employment of renewable energy technology in power sectors. Energy storage is directly proportional to deployment of modern renewable energy technologies. On a global scale, every country shows interest in investing money in the power sector for energy storage systems for the implementation of renewable energy technologies. USA, Australia, and China are pioneers in this field, which uses electro-chemical storage, electro-mechanical storage, and thermal storage in its energy infrastructure for reliable operation of the power sector. Hydro pumped storage, which is a mature field, has made its place in the power sector and many countries adopted it in their national policy to store the energy. On the other hand, the prices of battery storage system have fallen down and are expected to move down with the passage of time. The lower the price of the battery storage system, the higher the expectation of the deployment of renewable energy technologies.

For the active implementation of the energy storage technologies along with the renewable energy technologies in the power sector, the support of the public sector stands as paramount. The second step in this regard is a clear framework of promoting the implementation of renewable energy technologies in the current infrastructure to fulfill the demand of energy and phasing out all subsidies on fossil fuel import and nuclear energy production.

In order to achieve the smooth, fast, and cost effective transition to energy storage technologies, government needs to adopt a national legislative act, which ensures to provide the opportunity to private entities to invest money in the deployment of renewable energy technologies as well as energy storage technologies. In this regard, the following are the key recommendations in terms of the deployment of energy storage technology for policy makers for the utilization of the maximum potential of renewable energy resources by integrating it with the latest storage technologies.

4.2. Energy Storage Policy Recommendation

4.2.1. New Channels and Mechanisms to Attract Investors

The German renewable power sources act (EEG) is a good and ideal model of policy guideline in which they establish the permanent feed-in-duty for the deployment of renewable energy systems. This policy guideline gives reduced upfront cost in wind- and solar-based technologies. This policy framework allows preferential award for investment in the renewable energy projects. The German scheme has certain merits and demerits [46], such as the feed-in tariff mechanism posing higher risks on large installations of solar PV with longer project durations as there are higher uncertainties about remuneration levels at project completion time. Feed-in tariffs involve lower costs of equity and cost of debt than tenders.

It has been observed from the data and statistics of different countries that by applying the tenders instead of a feed-in-tariff, this strategy will reduce the investment cost to deploy more renewable energy technologies in the power sector as tender becomes costly for consumers. Tenders are only applicable for capacities above 40 MW and feed-in-tariff

process should be adopted for capacity below 40 MW to promote the renewable energy technologies as well as integration of storage technologies.

Since there are some trade-offs using feed-in tariffs and tenders to remunerate different scales of renewable energy projects [46], hybrid support mechanisms [47] are becoming popular gradually and a new political mechanism also needs to be implemented in order to invest in renewable energy, storage technology, and their integration to achieve the reliable and affordable electricity. Hybrid renewable power plant remuneration (hybrid support mechanism) [47] was introduced and termed as a reformed version of feed-in-tariff and tenders in energy sector.

4.2.2. Phasing out Subsidies on Non-Renewable Resources

It is advised that the governments promote and encourage renewable energy technology by giving subsidies in taxes for the pioneer investors in this sector. It is also recommended to increase taxes on import of fossil fuels discouraging this trend and saving foreign reserves in parallel. This scheme would increase spending of public funding on infrastructure projects and education by the government. The study [48] concludes that the nuclear energy contributes to environmental pollution in Pakistan. This study further suggests certain actions and measures to make nuclear energy a clean source of energy in Pakistan:

- Improvement in the infrastructure for nuclear generation.
- Establishment of independent regulatory body to achieve the threshold level of nuclear share and enhancing nuclear waste management facilities.
- The checks are required for operational performance, efficiency, and monitoring to avoid serious irreversible consequences to humanity and the environment.

4.2.3. Power Storage Sector as Tax-Free Zone

This sector can be categorized as exempted from tax on acquisition of property, procurement of necessary equipment, commercialization, financing, and trading. This will ease the making of relevant business plans by entrepreneurs and they will quickly achieve the break-even point in their financial books. This will minimize the risk of loss and maximize the return on investment in the future. It will also build the trust of businessmen community on the government.

4.2.4. Introducing Carbon and Radioactive Tax

By introducing the carbon and radioactive tax, the trend of power generation from fossil fuel will be declined and most of the countries will switch slowly and gradually to renewable energy and storage technologies. This fact cannot be ignored that fossil fuel reserves will be depleted in the future, so the cost of fossil fuels and imposed taxes will be increased gradually, which will push the world to shift to alternate approaches.

4.2.5. Research and Development for Renewable Energy

Research and development is the key factor for success in a particular field. It is recommended to create awareness in the younger generation of the deployment of renewable energy projects and reducing reliance on fossil fuels by taking the Ministry of Education on board. Universities can play a better role by connecting undergraduates, MS students, PhD scholars, and young entrepreneurs to do research work in this sector. Business and technology incubation centers should encourage business ideas in renewable energy and energy storage sector. Similarly, it is necessary to force local research institutes to apply for collaborative research with international researchers and funding agencies.

4.2.6. Pilot Projects and Their Enhancement

The government should adopt a clear policy to take an initiative after feasible study to deploy the most suitable energy storage technology with the renewable energy technologies and introduce it as a pilot project. The pilot projects can be improved using a learning-by-

doing approach, so that energy storage technologies can be utilized to their maximum in the power sector in order to reduce the emissions of CO₂ and dependence on fossil fuel imports that lay a heavy cost on the national economy.

4.2.7. Safe and Secure Platform to the Competitor

A subsidy and tax reduction policy should be implemented on renewable energy technology deployment along with energy storage technologies. More competitors will show their interest in energy storage systems and ultimately storage technology will be employed for every renewable energy technology installation.

4.2.8. Learning from Positive Case Studies

It is impossible for the user to learn and deploy most suitable storage technologies. User should consider the best-case result in which battery storage or thermal storage technology has played a vital role and replicate the idea if the condition and environment suits the needs and demands.

Table 2 provides a brief summary of the policy recommendations. The right mark indicates the suitability and applicability of the policy recommendation in the respective countries. N/A is the abbreviation of “not applicable”. Table 2 shows the recommendations for the renewable energy and energy storage development of Pakistan and Turkey. These recommendations include the adoption of the mechanisms to attract investments, phasing out subsidies and incentives on non-renewable energy projects, tax exemption from renewable energy projects, creating more competitors for providing relief to consumers and learning from other countries through positive case studies. Table 2 also highlights the other recommendations applicable for Pakistan, such as pilot project initiative, R&D in zero emission, and introduction of radioactive tax to promote renewable energy development. In case of Turkey, the introduction of a carbon tax may prove to be beneficial for renewable energy development.

Table 2. Summary of above policy recommendations.

S.No	Recommended Policies	Pakistan	Turkey
1	Enable the direct investment in renewable energy	✓	✓
2	Phasing out subsidies	✓	✓
3	Tax exemption from RET	✓	✓
4	Introducing carbon tax	N/A	✓
5	Introducing radioactive tax	✓	N/A
6	Research and development in zero emission and RET	✓	N/A
7	Pilot projects initiative	✓	N/A
8	Develop more competition to provide relief to consumers	✓	✓
9	Learn from others through positive case studies	✓	✓

5. Conclusions

In this paper, we have performed comparative analysis of different energy storage technologies with the emphasis on energy security and reliability based on the renewable energy scenario of Pakistan and Turkey. We have compared different energy storage technologies in terms of some technical indicators and suitability of applications useful for the deployment of renewable energy projects. We have also reported the statistics of the deployment of energy storage technologies in the globe and its expected increase until 2030 based on renewable energy scenario. The presented data and analysis prove that Pakistan and Turkey have not fully exploited the renewable energy potential in the respective countries. As Pakistan and Turkey are dependent on the imports of fossil fuels, they may set an example for other developing countries willing to transform their energy sector

towards renewable energy resources by utilizing the maximum potential of renewable energy and its cost effective integration with the energy storage technologies. This change is inevitable due to global environmental and ecological effects pushing the global community to impose certain taxes on the localities releasing CO₂ in the environment.

The mentioned facts and standpoints encourage both the countries to develop, design, and formulate a very strong storage policy, which is easy to implement and should be beneficial in the long run. The policy recommendations include the adoption of the mechanisms to attract direct investments, phasing out subsidies on non-renewable energy resources, tax exemption from renewable energy projects, creating more competitors for providing relief to consumers, imposing carbon tax, and learning from other countries through positive case studies. The policy also suggests cost effective integration of electricity storage technology with the renewable energy technology as the prices of the electricity storage technologies continue to reduce with the passage of time according to IRENA database.

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