Energy and Environmental Security Nexus in Pakistan

Mabroor Hassan, Muhammad Irfan Khan, Muhammad Waseem Mumtaz, and Hamid Mukhtar

Abstract Energy security has evinced a prime role in shaping prospects of economic and social development with its intrinsic relationship with environmental security due to convergence of energy generation and distribution with so many factors like global governance, economic development, affordability, equitable and sustainable energy transitions, environmental protection, environmental politics, water security, air pollution, climate change, conflicts, and environment-induced migrations. Pakistan has energy requirements of more than 75 million tons of oil equivalent (MTOE) in 2019 which is experiencing exponential increase due to growing population and changing lifestyle. The country is currently relying on thermal energy and imported fossil fuels to meet energy requirements. The share of coal in primary energy has been increased in recent years. The construction and operational phase of energy projects have significant threats to environmental security due to soil erosion and compaction, chemical spills and debris disposal, air emissions, noise and wildfire. It also shapes the terrain by damaging vegetation cover, terrestrial ecosystems and wetlands. The impacts further include dislocation of species, disturbance in migratory corridors and changes in breeding areas of wildlife. These projects also affect the water quality and modify drainage patterns causing aesthetic disruption and changes. Archeologically and culturally important sites are also being disturbed on the pretext of improving socio-economic conditions. Furthermore, climate change

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is reshaping the nexus of energy with environmental security in Pakistan. Resultantly, there may be a paradigm shift due to energy insecurity, geopolitical conflicts in the region, consumer's access to affordable energy, environmental injustice and insecurity. Pakistan already lacks renewable energy but inefficient use, line losses, energy-inefficient infrastructure and technologies challenge the government to meet the targets of Sustainable Development Goals (SDG 7), pillar 4 (Water, energy and food security) of the Pakistan Vision 2025. Hence, Pakistan has to establish a good framework of governance for thermal power sector, upgrade its existing energy infrastructure, diversify energy recourses, introduce energy-efficient technologies, develop minimum standards for power generation, explore renewable and competitive energy market, identify low carbon power generation methods, subsidize alternative and renewable energy (ARE) technologies, balance energy mix, improve fuel efficiency, manage energy demand, invest on research and development, aware the people and regulate consumer's behavior and practices to achieve optimum energy security and environmental security.

Keywords Energy · Environment · Human · Security · Systems · Renewables · Climate change · Nexus · Pakistan

1 Introduction to Energy and Environmental Security

1.1 Energy Security

Access to sustainable energy is considered as a fundamental human right and cardinal policy discourse of every government across the world. Meanwhile, the goal 7 of United Nations (UN) agenda of sustainable development for 2030 stresses on member states to provide access to affordable, reliable, sustainable and modern energy for all. However, the requirement of energy is considerably increasing in both developed and developing countries with the growing population, changing lifestyle and rapid economic growth. In this scenario, the procurement of sustainable energy to all is part of the global commitment of every government. At the same time, energy security is among the top priority agendas of political governments. But the definition of energy security varies across the world due to diverse geopolitical and socio-economic circumstances. However, the Asia Pacific Research Center defines energy security as "the ability of an economy to ensure the availability and timely access to energy resource supply in sustainable manners at an affordable cost without adversely affecting the economic performance of the economy [1]. Winzer (2011) describes energy security as the continuous transitions of energy relative to energy demand [2]. According to Sovacool (2011), energy security has multi-dimensions such as availability of energy resources, diversification, dependency, trade, innovation, decentralization, investment, affordability, price stability, produc-

tion, transparency, good governance, literacy of society, efficiency, reliability and environmental factors (adequate land use, resilience against climate change, water use, pollution, and greenhouse gas emissions) [3]. The states have to consider all dimensions to ensure energy security and environmental sustainability.

1.2 Environmental Security

Environmental challenges have threatened the survival of humanity worldwide. The concept of environmental security has emerged as an integral part of both national and foreign policies of the governments in recent years. The prospects of environmental security have been broaden from adequate availability, access and equitable supply of natural resources (water, energy, minerals, oils, food, and use of marine passages, etc.), environmental pollutions, illegal transboundary movement of hazardous waste and transboundary river pollution to human security (environmental refugees and social upheavals caused by natural resource scarcity and environmental disasters), national security and foreign policy discourse. Recent challenges like exploitation and unequal distributions of resources, environmental migrations, energy insecurity, water crises and climate change have disturbed patterns of human, environmental and national security in recent decades. Hence, survival of humanity, inclusive economic growth and stability of the state are entwined with environmental security in the recent time.

2 Energy-Environmental-Human Security Nexus

Sovacool (2013) has established the view, "*if the 20th century was about energy, then the 21st century would be about energy governance and climate change*" [4]. Meanwhile, the UN Sustainable Development Goal (SDG) 7 is set to ensure access to affordable, reliable, sustainable, and modern clean energy for all by 2030. However, the conditions are divesting in developing countries because of increasing demand, overwhelming population growth and intermitting supply. Developing countries are relying on interim sources of power generation like thermal power plants to meet energy requirements which have the potential to endure environmental degradation, air pollution resulting climate change, human ill-health, environmental conflicts and threatened environmental and human security.

The triad of energy-environment-human security nexus have a complex relationship in developing countries as mega projects for energy generation including dams or power plants require land, which is usually acquired from communities. Communities are not only inhabiting that land but also dependent for livelihood on that land for subsistence (food, fuel, and livestock). At the same time, the land may be a habitat for many species in that ecosystem. The distinct topography and landscape

also contribute to supporting ecosystems and biodiversity. However, land requirement, clearance and use for construction of power generation projects need resettlement of communities, impact on livelihood, topographic and landscape changes and disturbed biodiversity. Dislocation and resettlement of communities surrounding the projects have potential to threat human security by social disruption, conflicts, pressure on urban areas, changing means and ways of livelihood, management of livestock, exploitation of natural resources for income and shift in ways to availability and access to food, fuel, education and health. Such conditions may be worse in developing countries because of thick population density and dependence of communities on agriculture and livestock for livelihood. In developing countries like Pakistan, governments or investors usually pay the price of land on acquisition and rarely consider resettlement and subsistence to some extend. But overall dimensions of human security are rarely considered or consulted with communities. Similarly, the land use for construction of energy projects has eminent threats to environmental security. The removal of top soil may cause soil erosion, dust, contamination of soil, loss of nutrients, removal of vegetation cover decreases the ability of carbon sequestration and migration of wildlife species. These energy generation systems require water, materials, chemicals, whereas, machine operations and vehicular transportation during construction phase cause dust, exposure to chemicals, noise, waste and air pollution. Meanwhile, the energy projects may also affect nearby protected forests, national parks, archeological site or environmentally sensitive areas.

Alike construction phase, energy security has a genuine relationship with human and environmental security during the operation phase of the energy project. The human security might be adversely affected by air pollution, noise, poor standards of occupational safety and health as well as occupational accidents. The air pollution from the thermal power plants and noise from the hydropower and wind project can lead to public health issues. Contemporary, the functioning of energy projects have a positive impact on human security. They create employment opportunities for the local communities which improve the income, meliorate livelihood of people, and reduce the poverty. The energy projects are usually planned in remote areas in developing countries like Pakistan which have poor road infrastructure and accessibility. The commencement of energy projects improves the road infrastructure, build schools and health units. They enhance the accessibility to urban markets. Some energy companies are providing education, health facility, skill development training and opportunities for women empowerment under their corporate social responsibility e.g. Engro Energy Pakistan (a subsidiary Engro Corporation Pakistan). Engro Energy Pakistan in collaboration with the Engro Foundation has established 26 schools in Sindh where more than 1300 out of school children were accommodated to peruse education. They have established a clinic at Daharki, trained 7690 farmers in better livestock management and developed the skills in hundreds of women to improve livelihood [5].

The operation of energy systems has significant impacts on environmental security. The functioning of energy systems may affect the land through fossil fuel exploration, material extraction, transportation, processing, refining, manufacturing, use, waste, and disposal. At the same time, energy generation from thermal power plants is

releasing greenhouse gases, toxic air contaminants, and particulate matter. Air pollution from energy generation leads to serious public health concerns. The public health concerns include respiratory inflammation, chronic respiratory infection particularly in children, lung cancer, bronchitis, heart diseases, asthma, adverse health effects on the fetus, reduced life expectancy, and premature mortality. Air pollution can also cause acid rain, damage to buildings and degradation to biodiversity. Moreover, greenhouse gases are contributing to global warming and climate change which are enduring illustrious threats to environmental and human security. The developing counties are facing massive floods, frequent droughts, abrupt rains, an outbreak of infectious diseases, flash flooding, sea-level rise, and glacier melting due to climate change. It has divesting impacts on agriculture, food security, livestock, tourism, livelihood, infrastructure, water security, and economic development. Besides air pollution, energy generation requires water for both hydropower and thermal power (heating and cooling system). Therefore, energy security has a distinct relationship with water security which may affect or affected by the availability, access, and use of water. The mega-dam projects increase the water logging in the surrounding areas and affect the agriculture, livestock, and livelihood of the communities. The energy generation from hydropower, thermal and wind produce the noise which has direct or indirect effects on the communities. The noise has serious public health concerns from temporary hearing loss, poor concentration, stress, reverberation, loss of productivity, sleeping issues, fatigue, cardiovascular diseases, tinnitus, to permanent hearing loss. While, it has also significant impacts on the environment including the loss of biodiversity, migration of birds and wildlife species, behavioral changes in birds and land animal species, and causes the loss of communication among the birds and animal species. The noise from geothermal energy and offshore exploration of oil and gas has posed adverse effects to marine species. These adverse effects include problems in communication, stress, confusion, hearing problems, difficulties in the detection of acoustic information which may cause the problem in migration, hunting, food and detection of threats around them, and physical trauma. The marine species migrate in deep waters which may affect their reproduction and population.

Although, it is a mandatory obligations to conduct environmental assessments like Initial Environmental Examination (IEE) or Environmental Impact Assessment (EIA) or Strategic Environmental Assessment (SEA) before the commencement of energy projects by law in Pakistan and most of developing countries. These assessments must have to identify the issues caused by the pre-construction, construction and operation phases of energy projects which may endure adverse impacts on the environmental and human security as well as propose mitigation measures to reduce their adverse effects. Unfortunately, the proponents of the projects pretermit the environmental management and resettlement plans due to poor monitoring of the Environmental Protection Agencies (EPAs). Perhaps, the EPAs have low human resource capacity, financial constraints, lack of availability of technical resources, low institutional capacity, fragile governance, and weak legal framework which have considerably reduced their effectiveness of monitoring systems. Hence in the context

of energy-environmental-human security nexus, there is a dire need to rationalize this nexus to ensure judicious informed decision making and policies to provide the affordable, reliable, sustainable, and modern clean energy for all, human and environmental security.

3 Current Energy Scenario of Pakistan and the Contribution of Renewables

Pakistan has distinct and immense energy resources. Pakistan has about proven 185 billion tons of coal, 19 trillion cubic feet of gas reserves since 2017, and 350,632 million barrels of oil reserves (Fig. 1). It has also monumental alternative and renewable energy (ARE) resources. According to the Government of Pakistan, it has ARE potential of about identified 45,000 MW from hydropower, estimated 346,000 MW from wind power (60,000–70,000 MW is technically exploitable), about 1000,000 MW from solar power (irradiation of more than 5–6 kWh/m^2/day in most areas of the country), 2,000 MW from geothermal energy, 4,000 MW from solid waste, annual 50 million tons biofuels from 34 million hectares marginal land, and 225,000 tons of crop biomass for bioenergy [6] (Fig. 2).

The Economic Survey of Pakistan 2019 had demonstrated that the energy requirements of Pakistan have been increased from 64.5 million tons of oil equivalent (MTOE) (2010–11) MTOE (2015–16) to more than 75 MTOE in 2019. The energy demand is increasing day by day due to the increasing population and change in lifestyle. It has been projected that the energy demand of Pakistan will be more than 131 MTOE by 2030 [7].

Pakistan has enhanced the electricity installed capacity to 34,282 MW in 2019 at the growth rate of 2.5% as compared to the previous fiscal year. According to the Economic Survey of Pakistan 2019, the contribution of different energy resources in electricity generation was hydropower (25.8%), thermal (62.1), nuclear (8.2), and

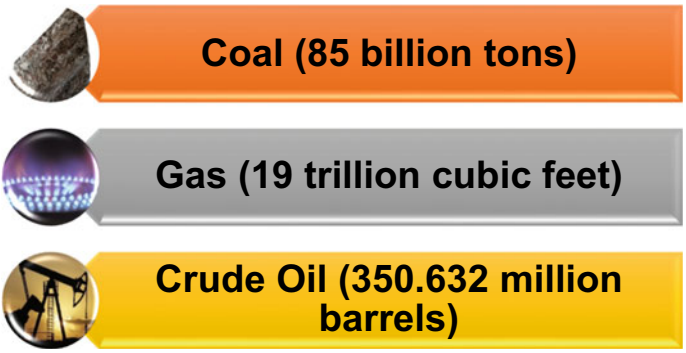

Fig. 1 Non-renewable energy potential of Pakistan

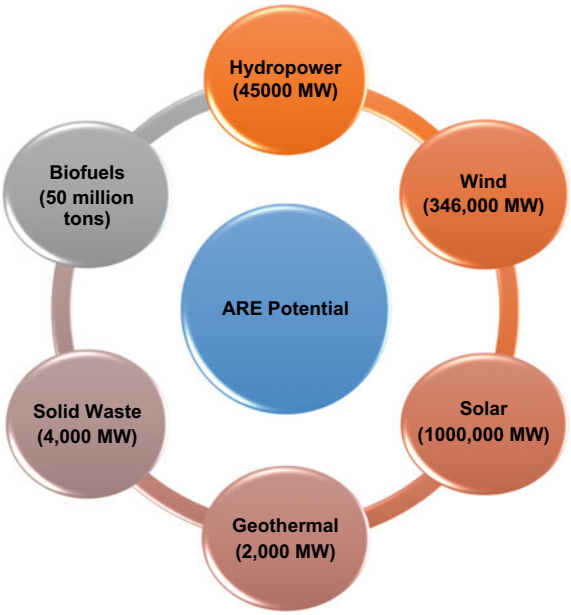

Fig. 2 ARE potential in Pakistan

renewables (3.9%) in 2019. In the context of the primary energy mix, the oil has contributed 32.2% in 2018 as compared to 43.5% in 2001. The gas has contributed a 34.6% share (2018) in the overall energy mix as compared to 50.4% in 2006. The share of coal in the energy mix was increased to the highest of 12.7% (2018) in the history of the country. Similarly, the share of liquefied natural gas was recorded to 8.7% in 2018 with an increase of 0.7% as compared to share in 2015. A steady increase of 2.7% share (2018) of nuclear energy in overall energy has been observed as compared to a 0.2% share in 1997. However, the hydropower and renewables have contributed to the overall energy mix at the share of 8.1% and 1% respectively in 2019 [8] (Fig. 3).

4 Energy Generation and Environmental Security in Pakistan

It is evident from the recent data of the energy of Pakistan that energy security in the country has an established relationship with environmental security in assorted dimensions. The country is intemperately relying on thermal energy or fossil fuels to meet the energy requirement. The contribution of interim energy resources like coal has been increased in the overall energy mix of the country. According to the Private Power and Infrastructure Board (PPIB), 12 projects of power generation having the capacity of 11,000 MW are under construction currently. But the 9 projects of them

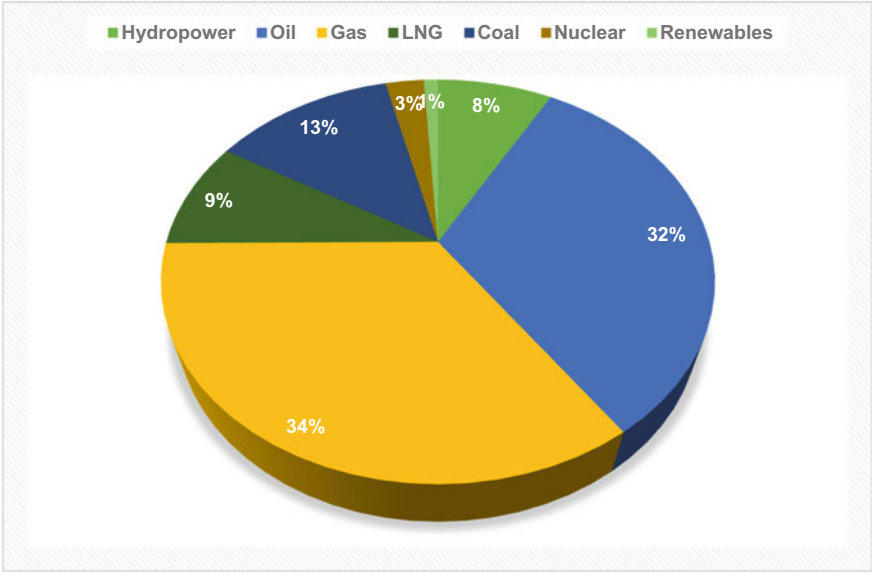

Fig. 3 Overall energy mix of Pakistan in 2018–2019

having the generation capacity of 8,220 MW are coal-powered thermal plants while 3 projects are hydropower (2,714 MW). The PPIB plans both non-renewable and renewable mega independent power projects of more than 100 MW. It seems that the contribution of thermal energy generated by coal power will be increased in the primary energy mix in future years. The construction of coal power plants may threaten environmental security.

Alternative and renewable energy is contributing a 1% share in the overall primary energy mix. The government of Pakistan has set the target of a 5% alternative and renewable energy share in the primary energy mix by 2030. The Alternative Energy Development Board (AEDB) (deal with ARE projects of less than 100 MW) is focusing on alternative and renewable energy in collaboration with independent power producers to reduce the share of non-renewable energy in primary energy mix and combat with the adverse impacts of climate change. The AEDB has completed the 5 wind energy projects of 256 MW capacity and 1 solar power project (Quaid-e-Azam Solar Park) of 100 MW capacity. However, 8 wind projects and 3 solar power projects of energy generating capacity of 450.8 MW and 300 MW respectively are under construction across Pakistan. The AEDB has planned further planned 6 wind power projects of 300 MW capacity and 8 solar power projects of 345 MW across Pakistan.

According to International Union of Conservation for Nature and Natural Resources [9], the soil erosion, compaction, spills of chemicals, disposal of debris, terrain shaping, impacts on water quality, modification in drainage patterns, damage

to vegetation of cover, air emissions, noise, and aesthetic disruption are significant environmental impacts from power plant's construction in Pakistan during pre-construction and construction phase. Alike, impact on terrestrial ecosystems including flora and fauna, habitat loss, wildfire, dislocation of species, disturbance of migratory corridors, changes in breeding area of wildlife, destruction of wetlands and plastics may reduce the number of species and habitats which eventually placed them in the list of endangered or extinct species and endure adverse impacts on environmental security. Additionally, there might be changes in archeological, cultural and socio-economic conditions. However, the operational phase of the energy projects has multifaceted risks to environmental security in Pakistan. The operation of power plants requires a dam for cooling which affect the communities due to the dam failure, and water quality. The cooling system requires water which is likely to affect the water availability and security of communities. The heat discharges from the cooling tower may alter the surrounding temperature, habitat, and biodiversity. At the same time, the use of on-site equipment (turbines, generators, cooling towers, fans or boilers) may generate noise and affect the terrestrial fauna (migration, breeding, spawning, calving areas, and nests). The transportation of coal or oil to power plants also contributes to greenhouse gas emissions. The coal washing and preparation contaminates the soil, releases dust from pulverizes, water pollution from waste residues and affects biodiversity. The solid waste generated by power plants and workers may attract pests or vector diseases, smell, aesthetic pollutions as well as impair water quality by leachate. The fuel and chemical may spill or leak during handling and storage which can contaminate soil and water. Although the construction of thermal power plants will generate employment opportunities for communities and positively affect their livelihood. There are also occupational safety and health concerns at thermal power plants in Pakistan. The burning of fossil fuels has the potential to contaminate soil from ash, sludge, and downwind deposition of air contaminants. The disposal of ash and sludge from combustion towers can cause water pollution. The exhaust and stack emission can deteriorate the air quality surrounding areas. The burning of fossil fuels has adverse impacts on public health and conduces to climate change. According to the World Air Quality Index 2019, the two cities (Lahore and Karachi) are among the polluted cities of the world. It has significant adverse health impacts on public health particularly children. The communities are suffering from respiratory, mental and cardiovascular diseases due to air pollution in Pakistan. The contaminated air may affect the pediatric and early childhood development among children in Pakistan. The urban centers of Pakistan are also suffering from the problem of smog in September and October every year from the last 3 three years. The smog increases the severity of health effects caused by air pollution. Furthermore, Pakistan is already among the most vulnerable counties to the impacts of climate change. The burning of fossil fuels may foster the phenomenon of climate change and environmental insecurity in Pakistan. However, the adverse environmental impacts from thermal power generation can be minimized or avoided by strong policy measures, planning, and environmental management. The PPIB has planned most of the thermal power plants in the remote areas of Sindh like Thar Desert and Baluchistan. Although, non-renewable energy has eminent environmental impacts but the government of

Pakistan has overcome the yawning energy crises, load shedding, and shortfall by utilizing these energy resources. The un-interrupted energy supply may have positive impacts on the growth of agriculture and industry particularly small and medium units which will ultimately improve the livelihood of people and inclusive economic growth. However, the appropriate practices for environmental management, rationale both non-renewable and renewable energy share in the primary energy mix adequate policy measures and good energy governance are still obligatory to ensure environmental security.

5 Renewable Energy and Environmental Security

Wind, solar and hydropower are the sources of renewable energy in Pakistan. Pakistan has added renewable energy in the national grid from solar and wind after 2015. However, Pakistan is generating the cheapest and clean energy from hydropower for the last six decades. But the recent Economic Survey of Pakistan has reported that hydropower contribution in electricity generation has been reduced from 70% in 1970, 37.8% in 2005–06 to 25.8% in 2018–19. Similarly, the share of hydropower has been decreased from about 14% (2006) to 8% (2019) in the overall primary energy mix. The thermal power has replaced the hydropower contribution which has threatened environmental security in Pakistan.

Renewable energy generation has both positive and negative impacts on environmental security in Pakistan. Although, the wind energy requires less land area per kilowatt-hour (kWh) energy generation than any other energy source and no water for cooling systems but it produces noise which may adversely affect the communities and bird biodiversity. The birds may be trapped into the moving and stationary blades of the wind turbine which may affect the distribution lines and crash into the tower. It can stress ecosystems by changing wind speed during large scale generation. These impacts can be avoided or minimized by planning wind projects in remote arrears and modern design. Pakistan has planned to install the wind turbines in remote and least populated coastal zones of Sindh and Baluchistan. Meanwhile, modern designs have significantly reduced the noise level and increased the protection of wind turbines. The modern, least noisy and protected wind turbines have insignificant impacts on communities, environment, and bird biodiversity.

The solar power projects require the land which maybe agriculture. The proposed solar projects in Pakistan are located in the Punjab which may affect the agricultural land. Besides agriculture, the construction of large scale solar power projects may affect topography, landscape, habitats, biodiversity, soil, air quality, vegetation cover, water quality, fragmentation in biodiversity, albedo, ecosystems, and agriculture. Similarly, the operational phase of solar power projects requires water for the cleaning of solar panels. The solar panels may have toxic materials used in their manufacturing. Meanwhile, the disposal of waste solar panels or modules is also a challenge and may affect the environmental conditions. Contemporary, solar power projects have benefits and positive environmental effects. The solar power projects utilize a low

quantity of water which is only for the cleaning of solar panels. They did not emit greenhouse gases and mitigate climate change. The environmental impacts from land can be avoided by using degraded, barren or desert land and use the solar panels as a decentralized energy system. The decentralized solar energy provides the opportunity to electrify the remote areas of Sindh and Baluchistan where the electricity distribution and transmission line costs are very high due to nomadic lifestyle and scattered population. The AEDB has introduced the net metering policy for the individual decentralized consumer which will not only reduce the load on the national grid but an individual consumer can also avail financial benefits by selling extra energy to the government. At the same time, the AEDB has planned to electrify the 7,875 villages through decentralized solar energy in the remote areas of Sindh of Baluchistan. There are no transmission line losses in case of decentralized energy. Additionally, the utilization of solar energy has created many job opportunities and economic activities in Pakistan. Modern solar energy technologies have long life therefore solar power projects have a long life span and more payback as compared to coal power plants. Agriculture is considered as a backbone of the economy of Pakistan. The agriculture land is being irrigated by the thousands of diesel-driven tube wells in the rural areas of Pakistan which are among the largest consumers of diesel and releasing air emissions. The shifting of tube wells from diesel to solar energy has the potential to cut the use and import of diesel, economic benefits, and reduce air emissions. Hence, solar technologies may be preferable renewable energy sources by individual consumers and government in the future due to their distinct economic and environmental benefits.

Hydropower is the largest contributor to renewable energy in the primary energy mix of Pakistan. The utilization of hydropower also offers both positive and negative environmental impacts on Pakistan. The hydropower turbines are installed on the river flow or dams. There are numerous adverse environmental impacts from dam construction. The communities in the project area have to dislocation. The decrease in river flow or environmental flow to low riparian has been recorded particularly in dry seasons to maintain flow which is required to generate hydropower. The construction of the dam also results in the cutting of trees, biodiversity and habitat loss in the dam area, migration of species, air emissions from transportation of material and changes in area terrain. Meanwhile, the changes in the migratory patterns of river animal-like trout have also been observed due to the construction of dams. The dams limit the flow of land fertility-enhancing sediments in the dam area which results in silting of reservoirs, reduces their capacity and reduced the fertility of low riparian. It can affect the downstream temperature of the river, the humidity of the surrounding environment, waterlogging in the vicinity, and salt level of water. The dam may be a source vector disease because it provides an appropriate environment for the breeding and growth of mosquitos and snails. The large water reservoir can cause the fragmentation of the river ecosystem by restricting migration, changes in the breeding areas, flooding of wetlands, change food patterns, loss of local species, and habitat loss. The greenhouse gases may also be released from dams due to different environmental conditions of water columns, flooded soils, and eutrophication. There are also failure hazards due to poor construction, negative environmental impacts,

terrorism, and induced seismicity. Furthermore, there are several issues and conflicts on water allocation, distribution, taxes, and royalty among provinces in Pakistan which is also a distinct barrier in the construction of new dams. Climate change has also affected water availability particularly in dry seasons which is fostering conflict among the provinces, enduring adverse impact on livelihood and leading to water scarcity and environmental insecurity.

Besides adverse impacts, the hydropower generation has diverse positive impacts on the environment, agriculture growth, agriculture expansion, livelihood improvement, poverty alleviation, and economic development in the context of Pakistan. Pakistan has generated clean energy from hydropower at the lowest price for decades. The cost will be further reduced if it will be produced from large dams which are the most practical and environment-friendly solution to energy crises. It has contributed as a major energy source for many decades. The government of Pakistan has procured the sustainable, clean and affordable energy transactions through hydropower. It has neither contributed to greenhouse gas emissions nor in the climate change but fosters environmental security. Meanwhile, Pakistan has built large water reservoirs or dams like the Mangla and Tarbela dam for the installation of hydropower turbines and generation of energy. The dams are supporting the largest canal system of Pakistan, agriculture and terrestrial ecosystem of Indus of the valley. They are contributing to sustaining livelihood support systems of communities, gross domestic products (GDP) and economic development of Pakistan. At the same time, per capita availability of water is drastically decreasing in Pakistan which has endangered the water and environmental security in Pakistan. The large water reservoirs are attuning the floods in rainy seasons, providing the water in dry seasons and contributing to ensuring water security. The ecosystem or environmental services include food, water, shelter, herbal medicines, biodiversity, living environment, soil for agriculture, recreation, aesthetic value, water purification waste management, pollination, pest control, and climatic regulation, etc. Pakistan has faced hottest May recently and heatwaves in many parts of the country due to variations in climatic regulations particularly relative humidity. The relative is directly associated with the evaporation of water. The water reservoirs and surface water have a core role in the evaporation potential, eventually in sustaining the relative humidity, water cycle, and rain. The government of Pakistan has planned to reduce the social and environmental impacts from hydropower and dam by adopting integrated water and environmental resource management. The seldom disputes between communities and government have been observed in recent mega hydropower projects e.g. Diamir Bhasha Dam and Karur Hydropower projects due to adequate consultation with communities, consideration of their views and resettlement plans. Furthermore, the construction of decentralized independent small hydropower units on runoff of streams has been increased in Northern Areas and mountainous Khyber Pakhtunkhwa. The small hydropower units neither require large land areas, dislocation of people, and infrastructure nor restrict the water flow. They have very low adverse impacts on the environment and ecosystems. However, there are numerous further requirements including comprehensive policy for hydropower generation, diverse resettlement policy, modern design, consideration of corridors for migration of aquatic species,

getter governance in dam management, transparency in cost–benefit (economic, social, environmental, technical and technical), use of innovative modern technologies, optimization of operational phase, silt management, resilience against climate change, adequate institutional capacity and good governance standards to transform future hydropower generation into sustainable and eco-friendly energy for Pakistan.

6 Energy-Climate Change and Environmental Security Paradigm for Pakistan

Energy security, climate change, and environmental security have an established paradigm for Pakistan. Climate change has shaped a complex multivariate and diverse paradigm in terms of energy security, regional geopolitical rift, affordability of consumer, energy access for all, energy requirement, ecological impacts, environmental justice and environmental security (Fig. 4). According to Germanwatch Report 2020, Pakistan is 5th most vulnerable country to the impacts of climate change in the Global Climate Change Risk Index. It has eminent threats to environmental and energy security in Pakistan. The recent climate data of Pakistan have demonstrated that the 0.6 °C increase in average temperature has been recorded as compared to the increase in the global average temperature [10]. Additionally, climate change has induced about 150 freak weather incidents including flash floods, glacier melting in the Hindu Kush-Himalaya region, smog, forest fires in summer, landslides, heatwaves, dislocation of people, and severs droughts like a drought in Thar Desert in the last two decades.

Environmental security in Pakistan is at significant risk due to climate change-induced adverse impacts on water availability and ecosystems. The variability in snowfall patterns may reduce the permafrost of the Hindu Kush-Himalaya region and flash floods as the weather turns to hot which will drastically affect the ecosystems and cause biodiversity loss. Similarly, the changes in rainfall patterns have radically affected the recharging of groundwater in Pakistan and water availability. A substantial decrease in water availability per capita, temperature rise, and more frequent and massive floods have observed in recent years which have challenged environmental security in terms habitat loss, damage to agriculture, biodiversity loss, reduction in the food availability, decrease in water availability, adverse impacts on livelihood of communities, infrastructure damage, catastrophe to archeological sites and national parks, destruction of energy system, endemic morbidity and mortality, sea-level rise, loss coastal reefs, marine biodiversity loss, human causalities, and economic loss. According to the Germanwatch report, Pakistan has suffered 3.8 billion dollars economic loss, and 9,989 human deaths due to the 152 extreme weather events during 1998–2018. Additionally, climate change may cause social and environmental injustice through the unequal distribution of natural resources, social inequality, instability, conflict among the communities, and climate change-induced migration.

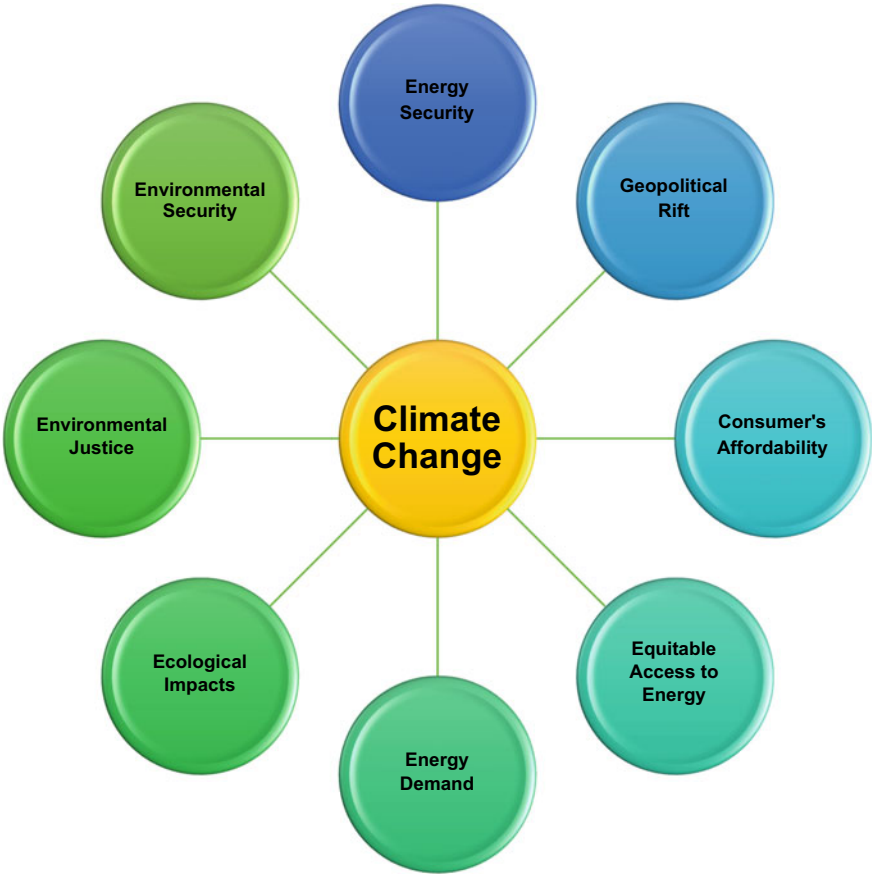

Fig. 4 Energy-climate change and environmental security paradigm for Pakistan

Pakistan is depending on the Transboundary Rivers for water and generation of energy. The country has continuous conflicts on water distribution with neighboring countries particularly India besides geopolitical rift. Climate change has the potential to affect the Hindu Kush-Himalaya glaciers and water availability in the region. It may not only lead the region to water scarcity and insecurity but also volatilizes the geopolitical rift between India and Pakistan which may agitate regional and environmental insecurity.

In the current energy security-climate change-environmental security paradigm, climate change may reshape energy security discourse in Pakistan. The temperature rise, abrupt rains and climatic variation in Pakistan may affect the efficiency of future renewable energy like solar energy by affecting the irradiation. The abrupt rains and floods may also damage the transmission and infrastructure of solar power projects. Similarly, the wind turbines and transmission lines are also at the risk of impacts of change such as frequent storms, temperature rise, abrupt rains, and

floods. The conventional energy systems of Pakistan like hydropower, nuclear, and thermal require the water for cooling or hydropower generation. Climate change is affecting water availability and security through changes in rain patterns, extreme weather events, variability in recharging of groundwater, glacier melting, and adverse impacts on permafrost. The water availability in Pakistan is decreasing due to the huge population, over-abstraction, inefficient use of water, the use of less water and energy-efficient technologies, and climate change. Pakistan is geographically located in the region which is the most vulnerable climate change which is supporting the phenomenon of the water-stressed country to water-scarce country. Therefore, the energy generation is at a noteworthy risk due to climate change in Pakistan. Climate change is threatening energy access, affordability and demand in the context of Pakistan. A decrease in energy generation will increase the demand and supply gap which will lead to the energy shortfall. According to the Economic Survey of Pakistan 2019, the major reason for the decline in hydropower share in electricity generation and the primary energy mix is the decrease in water availability in Pakistan. The government will introduce the load shedding and energy supply management strategy in which some consumer is preferred on others which affects the equitable access to energy for all. Pakistan has preferred the commercial urban centers and industries over the domestic consumers to sustain GDP in recent energy shortfall from 2005 to 2016. Meanwhile, the governments rely on costly, interim and non-renewable energy sources to overcome shortfall which affects the affordability and environmental security. Pakistan has relied upon thermal power generation from oil and coal to overcome the shortfall. It has not only increased the share of thermal energy in the primary energy mix but also enhances both generation and overall energy cost in Pakistan.

Alike generation, climate change endure adverse impacts on the energy infrastructure and distribution in Pakistan. The electricity is distributed across Pakistan through a centralized national energy grid. The national grid comprises of the overhead tower located across Pakistan. The extreme weather events including thunderstorms, abrupt rain, and floods can damage the national grid and interrupt the power supply which can affect the access of consumers to energy. Furthermore, the dams or hydropower turbines are situated on the river runoff and the flash floods can damage or fail the infrastructure of dams or hydropower turbines. The dam failure has divesting impact on ecosystems, agriculture, infrastructure, industries, livelihood, communities, transmission lines, and environmental security due to the massive flood. The Shadi Kaur Dam (Baluchistan) failure had killed more than 100 people and washed away many villages in 2005. Similarly, many thermal power projects in Pakistan are located in the areas which may affect from the floods. The operation of some projects may remain close and face infrastructure damage during the flood. Hence, the damage to infrastructure and interruption in supply may affect the access, demand, payback time of projects, operational cost, affordability of consumers, energy and environmental security in Pakistan.

Overall, Pakistan has limited capacity and financial resources. Therefore, it should have the water-smart energy systems, energy-smart water system, adequate design of power projects, and implementation of Climate Change Policy of Pakistan and

framework, climate change resilient infrastructure of power projects, utilization of renewable energy, human capacity building, stakeholder engagement, decarbonization of economy, enhance energy efficiency, and diversify energy sources to secure energy and environment in the context of climate change.

7 Energy and Environmental Security of Pakistan in the Context of SDGs

The United Nations has introduced the 2030 Agenda for Sustainable Development in 2015 and adopted by member states. It comprises 17 goals and commonly known as Sustainable Development Goals (SDGs). The SDGs offer a shared global framework and policy guidelines for the prosperity of people, peace and sustainable future of the planet. The SDGs require urgent actions by the all member states in global partnership to alleviate poverty and hunger, reduce inequalities, decent economic growth, providing good standards of health and education, access to clean energy for all, access to clean water and sanitation, innovative industrial growth, sustainable consumption, mitigation of climate change, marine and land biodiversity conservation, and peace. Pakistan has not only signed and ratified the SDGs but adopted them as national development goals in the Pakistan Vision 2025 [11]. It is a detailed policy document which visualized an aspiration destination to development, future strategies, planning, reforms, and national goals. Pakistan is attempting to meet its global commitment and the targets of SDGs.

In the context of the energy and environmental security of Pakistan, a strong partnership is required among SDGs to achieve their targets (Table 1). The SDG 6 (Clean water and sanitation), SDG 7 (Access to clean and affordable modern energy for all), SDG 8 (Decent work and economic growth), SDG 9 (Innovation in industry and infrastructure), SDG 11 (Sustainable cities and communities), SDG 12 (Responsible consumption and production), SDG 13 (Actions on climate change), SDG 14 (Life below water), SDG 15 (Life on land), and SDG 16 (Peace, justice and strong institutions) are directly related to energy and environmental security nexus, coalesce, and necessitate understanding and partners to ensure energy and environmental security.

Pakistan is heading towards a water-scarce country from the water-stressed country due to a consistent per capita decrease in water availability due to inefficient use, poor management, transboundary conflicts, and climate change. Meanwhile, water pollution is also increasing which is decreasing the quality of water. The decrease in water availability has adversely affected both energy and environmental security. Therefore, vibrant policy, judicious legal framework, strong institutions, integrated water resource management, water cooperation on Transboundary Rivers, community engagement, efficient use, and water-smart technologies are urgent measures required to meet the targets of SDG 6.

Table 1 SDGs and their target related to energy and environmental security

SDG	Target related to energy and environmental security
Clean water and sanitation (SDG 6)	• Reduce water pollution and improve quality • Enhance water use efficiency among all consumers • Improve water availability to reduce scarcity • Adopt integrated water resource management • Improve water cooperation on transboundary rivers • Engage the local communities
Access to clean and affordable modern energy for all (SDG 7)	• Ensure access to clean and affordable modern energy for all • Improve the share of renewable energy • Improve the energy efficiency at double rate • Support the developing countries in renewable energy production and research • Invest in energy-efficient infrastructure and technology
Decent work and economic growth (SDG 8)	• Diversify technology and innovation to achieve a higher level of economic growth • Improve global resource efficiency (energy and environment) in both consumption and production
Innovation in industry and infrastructure (SDG 9)	• Develop quality, climate change resilient, and sustainable infrastructure • Reduce carbon dioxide per unit of value-added • Improve resource efficiency (energy and environment) • Use sustainable, clean, efficient and environmentally sound technology
Reduce Inequalities (SDG 10)	• Reduce all types of inequalities and inclusion of all without any discrimination • Ensure the representation of all stakeholder in decision-making
Sustainable cities and communities (SDG 11)	• Provide access to affordable, safe and sustainable transport • Improve inclusive and sustainable urbanization • Minimize per capita adverse environmental impacts of cities • Integrate social, economic and environmental benefits Enhance resource efficiency, energy efficiency to mitigate climate change and disasters

(continued)

Table 1 (continued)

SDG	Target related to energy and environmental security
Responsible consumption and production (SDG 12)	• Implement road map sustainable production and consumption • Improve the management and efficient use of natural resources • Achieve sound and sustainable environmental management • Reduce and manage the waste • Support the lifestyle compatible with sustainable development and nature • Cut fossil fuels to reduce environmental impacts • Improve energy efficiency, and use of renewable energy
Actions on climate change (SDG 13)	• Strengthen adaptive capacity and resilience against climate change • Improve awareness, the capacity of institutions, and integration of climate change in national policies • Provide financial support to developing countries
Life below water (SDG 14)	• Prevent and reduce marine pollution • Protection and sustainable management of coastal and marine ecosystems • Regulate overfishing and illegal destruction of marine biodiversity • Improve research, conservation, and sustainable use of oceans
Life on land (SDG 15)	• Ensure restoration, conservation, sustainable use, and management of land and mountain ecosystems • Restore the degraded land and combat desertification • Act to reduce habitat loss and extinction of biodiversity urgently • Stop the trafficking and illegal trade of flora and fauna • Take actions to prevent the impacts of invasive alien species • Integrate the value of biodiversity with national strategies
Peace, justice and strong institutions (SDG 16)	• Develop the transparency and equal representation of all stakeholders at all levels and decision-making • Promote non-discriminatory laws
Partnership for the goals (SDG 17)	• Strengthen and develop a partnership for finance, technology, trade, capacity building and systematic issues to achieve SDGs

According to Pakistan's Implementation of the 2030 Agenda for Sustainable Development Report 2019, the country has improved 8% points access to electricity in the last ten years and 3.9% ARE in the primary energy mix from 2015–19 [12]. Currently, the country is about 93% electrified without any discrimination and relying on non-renewable energy while the contribution is 11% in the total final energy consumption. The prices of electricity and fuels are also increasing. The government has planned to electrify less populated remote areas, schools and public sector buildings with decentralized solar energy. The AEDB is working on the development of domestic ARE technologies. Meanwhile, the National Energy Conservation Authority (NECA) of Pakistan is working on energy efficiency in collaboration with the United Nations but its improvement pace is too draggy. The NECA has replaced the tube lights and energy savers with energy-efficient light-emitting-diode (LED) bulbs in the local market. The NECA has assisted the local fan and air conditioner industry and significantly improved the energy efficiency of fans and air conditioners after a change in design and technology. Despite numerous efforts, Pakistan is still dependent on the non-renewable sources energy sources, lacking renewable energy, bear inefficient use, line losses, energy-inefficient infrastructure, and technologies which hampers evident threats to meet the targets of SDG 7, pillar 4 (Water, energy and food security) of the Pakistan Vision 2025, energy, and environmental security.

The pillar 2 (Achieving sustained, indigenous, and inclusive growth) of Pakistan Vision 2025, SDG 8, and SDG 12 have emphasized on decent economic growth, modern industrializing, sustainable consumption, and production through innovation, diversifying technology, recourse efficiency, and quality and climate change resilient infrastructure to ensure climate change mitigation, energy and environmental security in Pakistan. The economic growth of Pakistan is recorded to be steady in recent years. The most prominent contributors in economic growth were agriculture and manufacturing but both are using non-renewable energy, energy inefficient and traditional technologies. The diesel-driven tube well engine, tractors, and harvesters are being used in the agriculture sector. Similarly, the manufacturing sector is also using traditional and resource inefficient technologies that consume extra raw material and energy and deliver low production at high product cost, pollution, and extra waste. Meanwhile, unskilled labor, traditional working procedures, inadequate practices, and inefficient process worsens the condition. The waste is also promptly increasing due to a huge population and poor management. Meanwhile, the lifestyle of Pakistani people is also energy inefficient, consumes extra resources, and less compatible with the modern norms of environmental sustainability. Besides lifestyle, Pakistan is wretched in cutting fossil fuels. The contribution of fossil fuels is increasing in the primary energy mix. Perhaps, Pakistan has been dispensed low points in SDG 8 and 12 in 2019 due to these reasons. The current scenario, practices, and inefficient use of resources in leading contributors to GDP are lagging behind the targets of SDG 8 and 12 and threatening energy and environmental security.

The SDG 9 (Innovation in industry and infrastructure), SDG 11 (Sustainable cities and communities), and pillar 3 (Modernizing transportation, infrastructure, and greater region connectivity) of Pakistan Vision 2025 have focused on sustainable infrastructure (quality, and climate change resilient), low carbon dioxide, resource

efficiency, eco-friendly urbanization, sustainable transport and use of sustainable, clean, efficient and environmentally sound technology to ensure and environmental security. Although, Pakistan has improved the infrastructure, building design, and included energy efficiency in building codes of Pakistan. But rapid urbanization, horizontal housing and individual construction without prior design are overlooking building codes and parameters for energy efficiency. The horizontal housing requires more land, destruct biodiversity, extra resources, adversely affect food security and energy as compared to vertical construction. Pakistan has significantly improved the transport infrastructure and introduces mass transit projects. However, the transport sector is among the largest consumer of fossil fuels (Compressed Natural Gas, petrol, and diesel) in Pakistan which is releasing greenhouse gases. The hybrid cars are also getting popularity and increasing in Pakistan. The government of Pakistan has recently introduced the electric vehicle policy and intended to cut fossil fuel to improve energy and environmental security.

Pakistan has established climate change governance and integrate the climate change in national policies to meet the targets of SDG 13. However, the country is still striving to develop adaptive capacity and resilience against climate change. The energy sector is the most leading contributor to greenhouse emissions (51%) and followed by agriculture and livestock (39%). Pakistan has planned and started the renewable projects to cut fossil fuels and mitigate climate change. Pakistan is encountering the glacial outburst floods (GLOF) by 37 million dollars funding under Green Climate Fund. The SDG 14 (Life below water) accentuated the prevention of marine pollution, protection, conservation, regulate the fishing, prevent the illegal biodiversity loss, sustainable use, and management of coastal and marine ecosystems. But the marine and coast biodiversity are at the risk of loss due to marine pollution, and industrial and commercial activities in the coastal areas of Pakistan. The SDG 15 (Life on land) marked reduction in habitat loss, prevent extinction, restore degraded land, combat desertification, stop illegal trade of biodiversity, prevent the impacts of invasive alien species, and restoration, conservation, sustainable use, and management of land and mountain ecosystems as the distinct targets. Pakistan has faced a 2.1% increase in deforestation from 2001–2005. However, the Billion Tree Tsunami Project has been completed on 350,000 hectors of land in 2014 to restore the depleted forests. A large number of trees and shrubs are still used as fuel to meet the energy requirement in rural and mountainous areas of Pakistan due to interruption in electricity and gas supply in winter. The development of energy projects may also affect terrestrial ecosystems.

Overall, transparency, justice, representation of all stakeholders in decision-making, and strong institution capacity (SDG16) through productive partnerships for finance, technology, trade, capacity building, and systematic issues are cardinal for mechanisms to achieve SDGs in the context of energy and environmental security of Pakistan.

8 Conclusion and Policy Implications to Ensure Energy and Environmental Security in Pakistan

Energy security has an intrinsic link with human and environmental security in Pakistan due to an established relationship of energy generation and distribution systems with global governance, economic development, affordability, equitable sustainable energy transitions, environmental protection, environmental politics, water security, air pollution, climate change, conflicts, and environmental migrations. The energy policy discourse and decision-making are being perplexed by environmental security and climate change in the recent era. More informed and sensible decision-making is indispensable to ensure sustainable energy transitions, energy security, and environmental sustainability. Access to energy is conceived as a fundamental human right worldwide and the core priority of every government for economic development. Meanwhile, energy sector decisions are crucial for economic development, environmental sustainability, and decision-making of other sectors like industry, production, mining, and residential. It determines the discourse of the economic growth of every country. The informed and sensible decision-making for energy security should reflect practical knowledge, indigenous needs, future expectations, and clear vision. Pakistan is still struggling to meet the unremitting energy demand and ensure energy security. The country anticipates clear energy vision and sensible decision-making to rational energy and environmental security nexus. The vibrant policy implications (Fig. 5) can unriddle the complexity of decision-making for energy security in the context of the environmental security of Pakistan.

8.1 Good Energy Governance

Good energy governance comprises vibrant energy policies, a legal framework (regulating the energy sources, prices, efficiency, infrastructure, climate change, and environmental aspects), strong institutions, and all stakeholder representation and engagement in the decision-making process. Energy policy should be judicious and coherent with indigenous needs, stakeholder expectations, clear vision, policy objectives, energy demands, climate change, agriculture, development, external relations, and environment. Pakistan has established and implemented the ARE Policy 2011, National Power Policy 2013, and Power Generation Policy 2015. Hassan et al. (2019) critically analyzed the energy policies in Pakistan in terms of technical, economic, social and environmental aspects [13]. The study identified that several gaps in ARE Policy including low compatibility with industrial growth, disregard environmental aspects (land use and water security), neglect the integration of ARE technologies, pretermit domestic manufacturing of ARE technologies, omit biofuel portfolio standards, and high interconnection cost. It was observed that the National Power Policy 2013 was lacking the projection of future energy demand, compatibility with industrial growth, employment opportunities, and environmental aspects (Greenhouse gas

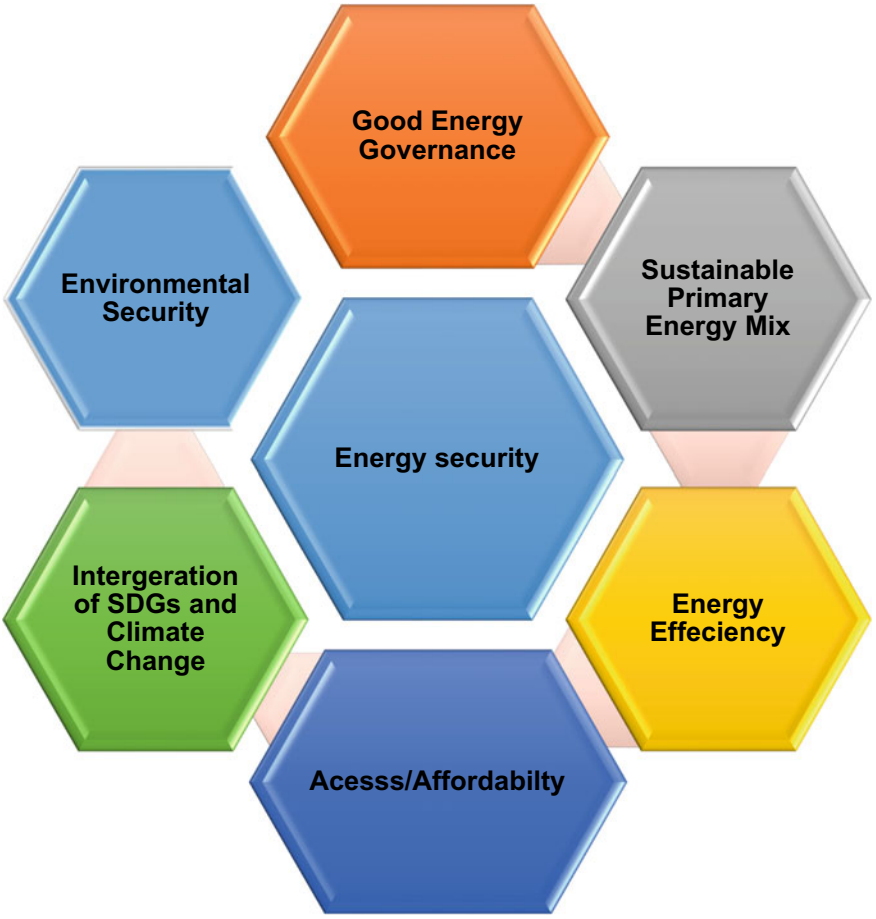

Fig. 5 Policy implications to ensure energy and environmental security in Pakistan

emissions, noise, land use, climate change, and water security). Power Generation Policy 2015 has also snubbed the future energy demand, energy potential, fuel cost, compatibility with industrial growth, and environmental aspects (Greenhouse gas emissions, noise, land use, climate change, and water security). The government of Pakistan should revisit energy policies to ensure energy and environmental security. Although, Pakistan has established a legal and institutional framework in the energy sector. There is a need to implement laws, provide resources, ensure transparency, remove system errors, and mobilize the institutions. However, the stakeholder representation and engagement in the decision-making process is still least considered in Pakistan. There is an urgent need to enhance stakeholder representation and engagement in the decision-making process through participatory approach mechanisms.

8.2 Sustainable Primary Energy Mix

Pakistan is still relying on non-renewable sources for energy generation. The government should identify the exact potential of renewable energy in Pakistan and indigenous needs. It should devise a comprehensive strategy to phase out energy-inefficient technologies, optimum utilization of renewable energy, cut the use of fossil fuels, and balance the energy mix to ensure sustainable energy production, energy, and environmental security.

8.3 Energy Efficiency

The national energy policies in Pakistan reflected energy efficiency in terms of transparency, tariff efficiency, fuel allocation, merit in contracts, optimization of line losses, and procurement of clean efficient ARE technologies. Pakistan has successfully reduced the line loss due to maintenance and replacement of the national grid but it has least prioritized the procurement of clean efficient ARE technologies. Energy efficiency can improve the efficient use of natural resources, and reduce the energy cost. Pakistan has upgraded the electric appliances, introduces LED lights, provide custom duty relaxation on the import of ARE technologies, offered soft loans for ARE, and implemented the Pakistan Energy Conservation and Efficiency Act 2015. However, it should restructure the thermal power plants, upgrade existing energy infrastructure, diversify energy recourses, introduce energy-efficient technologies, develop minimum standards for energy generation, explore renewable and competitive energy market, identify low carbon energy generation methods, subsidize ARE technologies, balance energy mix, improve fuel efficiency, manage energy demand and regulate the people behavior and practices to achieve optimum energy efficiency and environmental security.

8.4 Equitable Access to Affordable Energy

The government of Pakistan considers equitable access to affordable energy for all as a basic human right. Pakistan is about 93% electrified and attempting to ensure equitable access to energy. Pakistan has also introduced a net metering policy to promote centralized solar energy and environmental sustainability. Furthermore, Pakistan has planned to electrify the remaining 7% through decentralized ARE. However, the uninterrupted supply and price are the major concerns of the consumers. The electricity supply interruption increases in summer due to the increase in demand. Meanwhile, both electricity and fuel prices are also increasing in Pakistan due to oil price volatility and dependence on thermal energy. The energy prices affect the socio-economic benefits of energy and the hardships of low-income families. Pakistan can

reduce the price of energy through efficient use, exploration of indigenous resources, increasing the share renewable energy particularly hydropower, use of modern clean and energy-efficient technologies, decentralization of energy supply in remote areas, developing domestic ARE technologies, capacity building, regional energy trade, sustainable infrastructure, energy conservation, demand–supply management and increasing the role of community in energy efficiency and conservation.

8.5 Integration of SDGs and Climate Change with Energy Policies and Generation

The energy generation and security may be affected by climate change in Pakistan. The energy sector should meet the requirement of economic, social, environmental sustainability. It should be efficient, low carbon releasing, and not contribute to the global warming. The climate change should be addressed in goals and integrated with energy policy. Although, Pakistan has an established climate change governance but it is addressed only in ARE policy. Meanwhile, the energy sector of Pakistan is relying on non-renewable sources. Therefore, it is urgent to mediate climate change in energy policies, balance energy mix, cut fossil fuels, utilize indigenous renewable energy resources, foster energy efficiency, and establish effective climate change governance to combat the adverse impacts of climate change. The energy policies in Pakistan were implemented before the SDGs but Pakistan has adopted them as national development goals. But the SDGs should be integrated with energy policies and development of the energy sector in Pakistan.

8.6 Environmental Security

The energy policies in Pakistan have least considered the environmental aspects like land use, emissions, biodiversity, noise, water security, and climate change but Pakistan has established environmental governance to regulate pollution and conduct environmental assessments to assess environmental impacts of projects before commencement. There is a need to comply with the environmental policy, acts, and regulations during the commencement of energy projects and energy generation, reduce greenhouse gas emissions, use of clean technologies, integrate energy governance with environmental governance, and cooperate on transboundary natural resources to ensure environmental security.

8.7 Awareness and Education

The education and awareness are requisite to individual behavior and lifestyle changes to reduce carbon emissions, efficiently use energy, foster sustainable consumption, and wise use of natural resources to ensure energy and environmental security in Pakistan. The government should raise awareness of the consequences of energy and environmental insecurity, include them in the school curriculum, educate the children, and regulate public behavior with effective legislation.

8.8 Research and Development

The research and development are critical to reduce the price of energy, upgrade existing systems, and provide solutions to the future energy problems of Pakistan. Pakistan has experienced low investment in research and development in energy sectors and still imported both non-renewable and renewable technologies. The government of Pakistan should invest on research and development in energy sector to create new knowledge, manage the data (Outlooks, and reports), understand the problems, project future energy demand, set the goals, project the required resources, manage demand–supply, upgrade existing technologies, develop domestic ARE technologies, achieve sustainable consumption and production, informed decision-making, and futuristic planning to ensure energy and environmental security.

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