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Research Article **Open Access**

THE DEVELOPMENT OF RENEWABLE RESOURCES AND THEIR IMPACT ON ELECTRICITY GENERATION IN PAKISTAN

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Abstract:

The objective of this paper is to analyze relationship between renewable resources and electricity generation in Pakistan. The 20-years'time series data for the period of 1998- 2018 was used. The renewable energy sector was selected as a sample of study. Electricity generation was chosen as a dependent variable while Solar Energy, Nuclear Energy, Biomass & waste and Hydro were selected as independent variables. ADF test, Correlation Analysis and Johansen's co-integration techniques were applied to analyze the data. The findings of this study show that there is a long run positive relationship between renewable energy resources and electricity generation-and Pakistan should focus on their development.

Keywords: Electricity; Energy Crisis; Renewable Resources; Energy demand.
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1 Introduction

1.1 Global energy dynamics

According to World Energy Outlook (2021), the renewable sources of energy such as solar PV and wind are continued to grow rapidly and electric vehicles set new sales records despite the fact that economies are still feeling pressuring of Covid-19 lockdowns. A virtual cycle is revolving due to policy action and technology innovation and its speed is now sustained by lower costs. In most markets, solar PV or wind are assumed to be the cheapest source of new electricity generation. Now clean energy technology is a major area of investment and employment and a dynamic area of global collaboration and completion.

But rapid and uneven recovery from Covid-19 pandemic has put a severe strain on current energy system due to steep rise of in the prices of natural gas, oil, coal and electricity markets. All progress made by renewables and electric mobility in the past few years lost momentum due to a big rebound in coal and oil use. This is the reason that second largest annual increase has been noted in CO_2 emission in the history and only one third of investment could be mobilized for spending on development of sustainable energy sources. The developing countries are specifically facing serious public health crisis due to shortage of funds, affecting progress towards universal energy access in Sub-Saharan Africa and some Asian countries (Durrani, et al. (2021).

The goal of "Net Zero Emission by 2050 scenario" and stabilizing rising global temperature at a 1.5 °C set by International Energy Agency (IEA) appears difficult due to Ukraine-Russia war and US-European sanctions on Russia. The global average temperature rose in 2021 was around 2.1 °C above

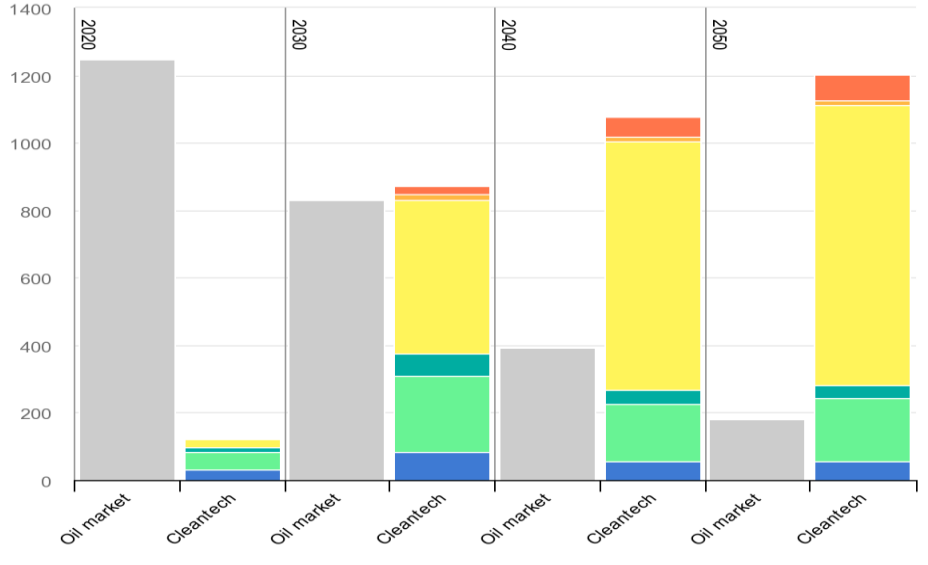
pre-industrial levels. The energy sector is responsible for around three quarters of the emissions so it must be put in the Centre of the solution to climate change. It is estimated that global population will likely to grow two billion people by 2050 and the rising per capita income will definitely push up energy demand. The worrying point it that many developing countries are facing emission-intensive scenario due to rapid urbanization and industrialization. The current energy system is not capable to meet these challenges. However, the future prospectus of renewables is promising because annual additions of solar and wind energy are approaching 500 GW by 2030 and coal consumption is likely to be decreased by 20 percent. The global energy related CO_2 is likely to be fell by 40 percent by 2050. Although global electricity demand will likely to be doubled by 2050 but rapid adoption of renewables by energy sector will reduce level of emission globally.

There is a sharp divergence in the speed of energy transition particularly in the developing countries. There appears to be conflict in the areas of trade and energy-intensive goods as well as international investment and finance. All countries need to align their policies and investment planning and contribute significantly in global transition. The good news is that now all technologies needed to attain emission cuts by 2030 are available and about half of emission reduction by 2050 will come from clean technologies. So the role of clean technologies innovation is significant for emission reduction. There is further need to focus on pollutant industries like iron and steel, cement and transport, deployment of hydrogen based and other low carbon fuels and carbon capture, utilization and storage (CCUS) are imperative for this purpose (Yang, S., Yang, D., Shi, W, (2021).

Electricity's shares in global consumption of energy now stands at 20% and in future it will account for 50 percent by 2050 and this sector delivers useful energy services with better efficiency than other fuels and it can contribute more in reducing emission than other sectors. In global supply chains there is a lot of potential and opportunities for companies and the countries to invest in clean technologies. It is estimated that if the commitment of "Net Zero Emission" by 2050 is seriously taken by all stakeholders there is tremendous opportunity for manufacturers of turbines, solar panels, lithium-ion batteries, electrolysers, fuel cells and biofuels to the tune of $1.2 trillion by 2050. The market of these five items have wide scope more than that of existing oil market industry to generate revenues. The complex process of interaction between electricity, fuels and storage markets, producing new challenges for regulation and market structure in the new energy economy. The major issue is how to manage the potential for increased variability in both demand and supply sides of energy equation. The variability of electricity will be effected by rising shares of wind and solar PV, putting a huge premium on robust girds and other sources of supply flexibility (Ekins and Zengherlis, (2021). The combined size of the market for wind turbines, solar panels, lithium-ion batteries, electrolysers and fuel cells represents a cumulative market opportunity to worth USD 27 trillion by 2025. Out of 60% of the total, batteries account for the lion's share of the estimated market for clean energy technologies by 2050. With over 3 billion electric vehicles (EVs) on the roads and 3 terawatt-hours (TWh) of battery storage deployed in the "Net Zero Emission in 2050", batteries will play a central part in the new energy economy. They also become the single largest source of demand for various critical minerals such as lithium, nickel and cobalt (World Energy Outlook,

(2021). **Fig 1** show the market sizes of Oil and selected clean energy technologies.

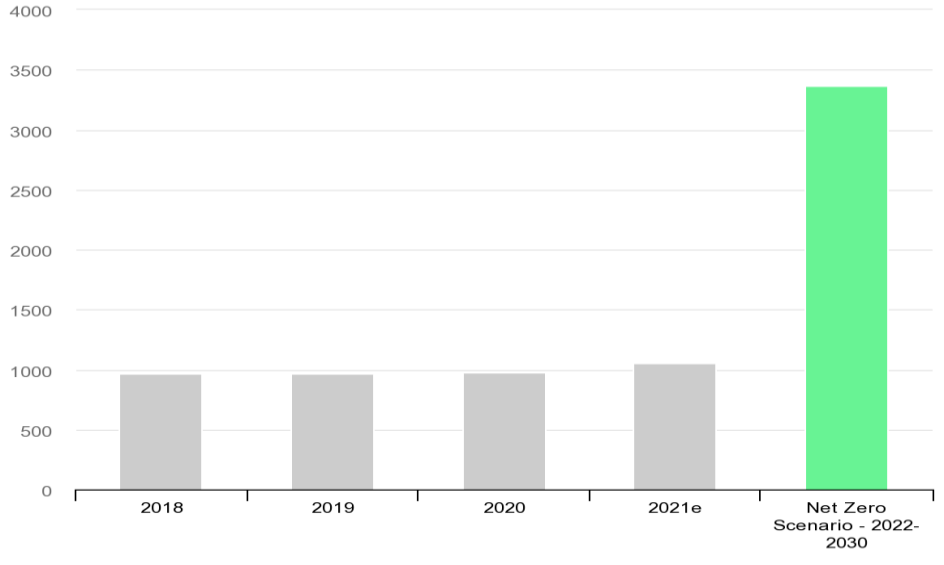
Fig 1: **Market sizes of oil and selected clean energy technologies in the Net Zero Scenario, 2020-2050**



The variability of demand will be shaped by enhancing deployment of heat pumps and air conditioners particularly in the developing economies. The daily variation of the energy demand could increase on the basis of announced pledges to 270 gigawatts (GW) in the European Union (from 120 GW today) and over 170 GW in India (from 40 GW) by mid-century. It is estimated that annual investment in clean energy will likely to be increased by US$4 trillion by 2030 to secure energy transition. The equity raised by the start-up companies is USD4 trillion in 2019 and half of the capital raised from the United States but the Europe still has to increase their level of investment while

China's shares of the clean energy market has risen from 5 percent in 2014 to 35 percent in 2018**.** **Fig 2** shows projected level of investment in renewables during 2018 and 2030.

Fig 2: **Clean energy and infrastructure investment, 2018-2030**

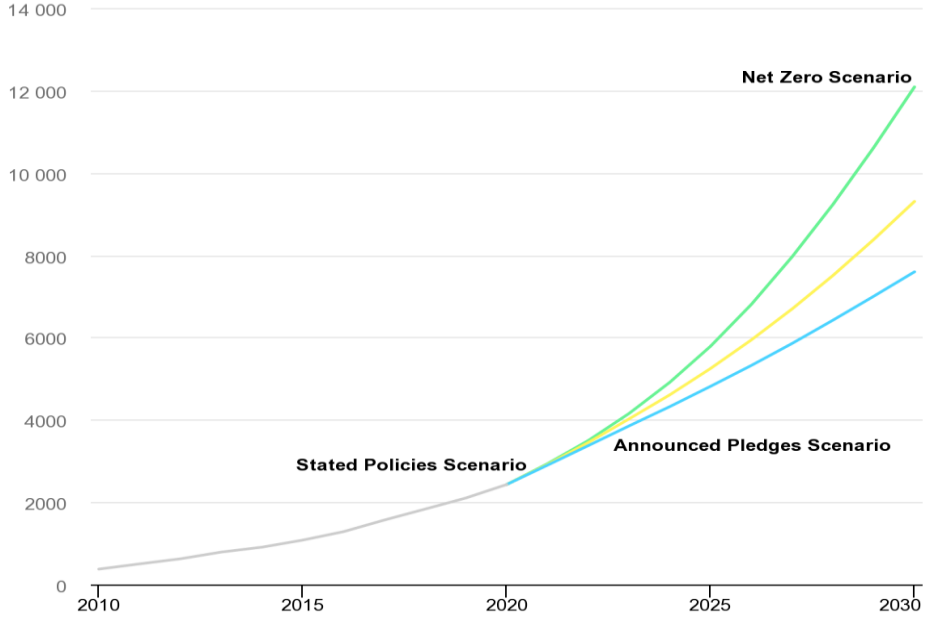


Source: World Energy outlook, IEA,2021.

China, Japan and the United States have shown high level of commitment to energy R&D and innovation while European Battery Alliance are actively working to create new value chains. India and Singapore have taken initiative in public sector to support global clean energy entrepreneurs. India has set a target of solar PV in pursuit of its 450 GW target for renewables by 2030. China has pledged to cancel up to 190 GW of coal projects, which would save 20 GW in cumulative CO_2 emissions, which will be equal to total commitment of the whole European Union. Across the world, the share of variable

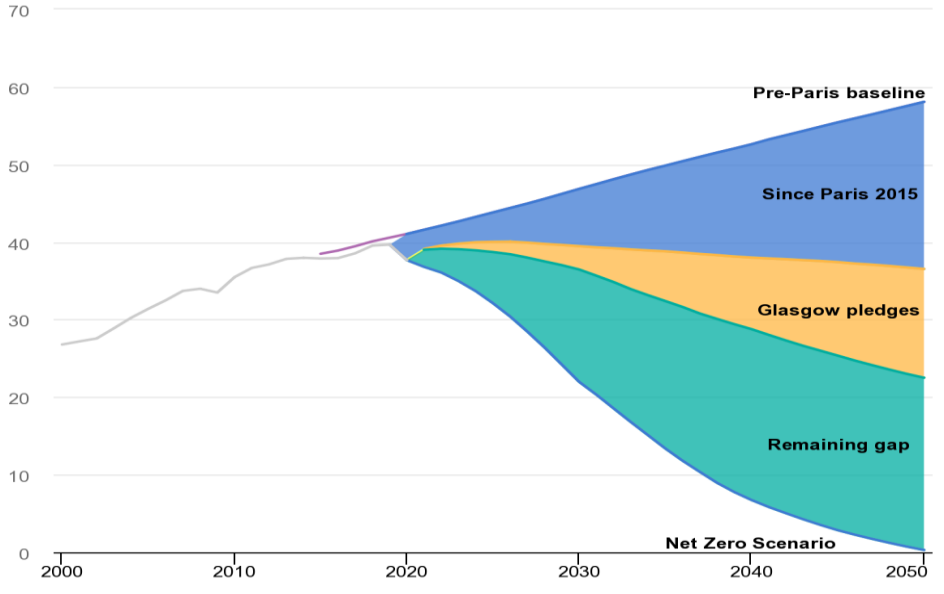
renewables in electricity generation will likely to reach 40-70% by 2050 (and even higher in some regions) as compared to below 10% today. Under "Net Zero Emission" new energy economy there are some 240 million rooftop solar PV systems and 1.6 billion electric cars on roads by 2050. **Fig 3 and Fig 4** show the growth of Solar PV and wind energy generation during 2010 and 2030 and emission scenario during 2000 and 2050, indicating high level of growth of renewables and substantial reduction in the level of emission.

Fig 3: Solar PV and wind generation by scenario, 2010-2030



Source: World Economic outlook, IEA, 2021

Fig 4: Global emissions by scenario, 2000-2050



Source: World Energy Outlook,2021.

However, the International Energy Authority (IEA) has warned that a failure to accelerate clean energy transitions would continue to leave people exposed to air pollution. Today, 90% of the world's population breathes polluted air, leading to over 5 million premature deaths a year. It is expected to see rising numbers of premature deaths from air pollution during the next decade. In the NZE, there are 2.2 million fewer premature deaths per year by 2030, a 40% reduction from today (Word Energy Outlook, (2021)

1.2 Pakistan's Energy Scenario

According to the National Institute of Population Studies (NIPS) estimated population of Pakistan is 215.25 million with population growth rate of 1.80 percent in 2020 and population density is 270 per Km. The country has limited

natural resources and its increasing population is putting more pressure on these resources. More than 11.43 million Pakistanis are working in different 50 countries since 1980s because of high unemployment. The level of poverty can be assessed from the fact that proportion of population living below national poverty line is 29,5 percent of which 18.2 percent lived in urban areas and 35.6 percent lived in the rural areas in 2021. This ratio was 12.5 percent (Urban) and 45 percent (Rural) in 2014. It reveals how demographic transition is being taken place in Pakistan and how rapid urbanization is creating multi-dimensional socio-economic problems. Another issue is high population growth rate. In 2013 Pakistan's total population was around 140.0 million, which has now reached 215.25 million, an increase of 75.25 million just in eight years (Pakistan Economic Surveys, (2020-2021).

Pakistan's energy dynamics have not seen any major shift since long due to heavy dependence on non-renewables and it has been using traditional fuel sources since 1970. Two major dams were constructed in 1960s with the financial assistance of World Bank for hydropower generation. Since then no major dam has so far been constructed due to lack of political consensus (Bhutto A.W, Bazmi AH, Zahedi G, (2012). Oil is the major source of electricity generation and transportation for which Pakistan is dependent upon the Gulf States for its import. The increase in oil prices in international market always jolted Pakistan's economy and disrupted its trade balance. Under 1994 power policy the private sector investment was invited and about 40 power plants based on oil and gas were installed over the years. These plants have above 20-year age and they are likely to be completed their physical life between 2024 and 2030. According to the National Transmission Dispatch

Company almost 6.5 GW of thermal power generation will be retired in 2022 of which 5.9 GW are furnace oil based (Isaad, (2021)

1.3 Gap between Energy demand and supply

Pakistan is ranked among those countries which have highest share of energy consumption (55%) in buildings as compared to the USA (39%), Canada (27%), and China (20%). In 2018, the residential buildings consumed 41.45 TWh (46%) of electricity, whereas the commercial buildings consumed 6.51 TWh (8%) of electricity during the same period. Electricity is mainly generated through the fossil fuels-based thermal power plants that have the highest share (59%) in the electricity generation, whereas the shares of hydroelectric power is 26%. Pakistan's electricity consumption in buildings today has increased by 26.46% since 2006 with an annual increase rate of +2.9%. A typical house in Pakistan consumes 24 Kwh/m2/year of electricity. (Amber et al. (2021). About 59 percent electricity generation in Pakistan is from thermal and out of which 19 percent is from furnace oil. Thermal power plants total installed capacity is around 6,507 MW and its contribution into total installed capacity is 13 percent while coal contribution in power generation is 12.80 percent. It highlights how Pakistan is locked up in high carbon scenario (Isaad, (2021). There is a chance to replace retiring furnace oil run plants by renewables in order to reduce the costs.

The detail of power generation through different nine sources are given in Table 1:

Table 1: **Fuel-wise installed Electricity Generation Capacity**

S.No.	Sources of fuel	Installed generation capacity (MW)	Share (in %)
		April,2021	April, 2021
1.	Hydel	9,874.0	26.00
2.	RLNG	7,325.0	19.66
3.	RFO	6,274.0	16.84
4.	COAL	4,770.0	12.80
5.	Gas	4,529.0	12.15
6.	Nuclear	2,490.0	6.68
7.	Wind	1,235.0	3.31
8.	Solar	400.0	1.07
9.	Bagasse	364.0	0.98
	Total	37,261.0	100.00

Source: Ministry of Energy, (Power Division), Government of Pakistan

If we study statistical data of 2019 and 2021 the share of thermal has increased in total electricity generation due to low water level in Mangla and Tarbela hydro power reservoirs. The significant increase (19%) of RLNG usage in energy mix has significantly contributed to run power plants and supply electricity. RLNG is being widely used in Fertilizer, industrial and transport sectors as well as for domestic heating.

There are three main sectors of Pakistan's economy which consume most of the electricity. Among them, the household is the major one that consumes 49.10 percent electricity and the second major sector is industry which consumes 26.3 percent electricity while agriculture and commercial sector

consume 8.9 and 7.4 percent electricity respectively. The electricity is supplied to household and agriculture sector on subsidized rates. Even the export segment of industrial sector has also been provided electricity at subsidized fixed rate since 2019 in order to encourage the exports. When we compare the consumption of all major sectors of the economy we find that there is a minor change except industrial sector of which consumption was increased from 25.5 percent in 2019 to 26.3 percent in 2021. While the consumption of commercial and other sectors was reduced on small scale. We can observe consumption of pattern of different sector from the data given in Table 2:

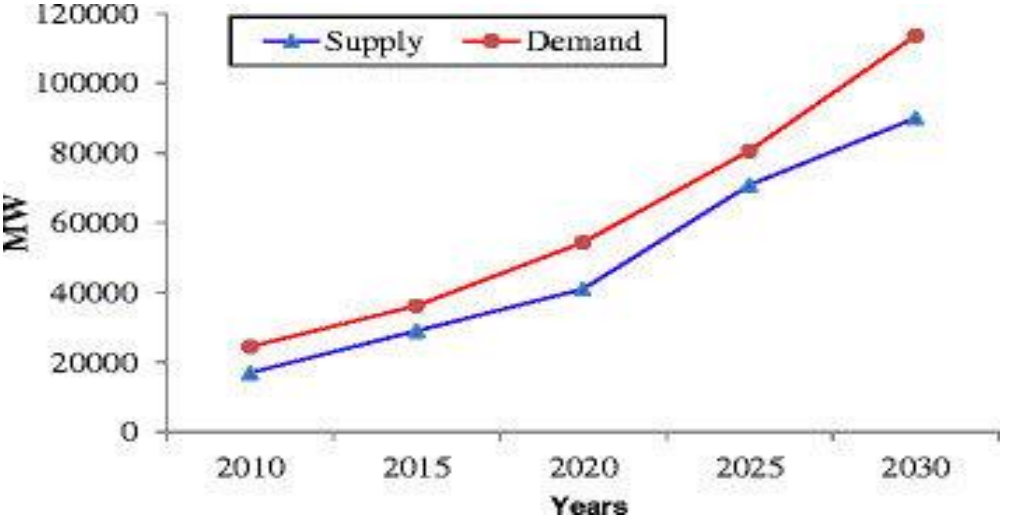
Table 2: Sectoral consumption of electricity in Pakistan during 2020-21

Sector	Units sold (GWh)		Share (in %)	
	March, 2020	March, 2021	March,2020	March, 2021
Household	39,461	41,508	49.2	49.1
Commercial	6,313	6,246	7.9	7.4
Industry	20,461	22,280	25.5	26.3
Agriculture	7,127	7,558	8.9	8.9
Others	6,825	7,008	8.5	8.3
Grand Total	80,187	84,600	100.0	100.0

Source: Hydrocarbon Development Index of Pakistan

Fig 5 shows that gap between supply and demand of electricity is rising since 2015 and it will further increase after 2025 due to high population growth and urbanization and rising income level.

Fig 5. Gap between demand and supply



Source: (Amber et al.2021)

The existing energy system in Pakistan is very inefficient due to high transmission losses, electricity theft and corruption in power sector. Now about 40 independent power producers (IPPs) are operating in Pakistan and most of them are furnace oil and gas-based. Pakistan has provided sovereign guarantee for purchase and payment of the volume of electricity supplied by them. Their production cost and capacity payments are so much high that it has created circular debt problem, leading Pakistan to the edge of sovereign default. Now Pakistan is borrowing loans from different international donors to make payments to these IPPs. Under IMF pressure Pakistan has also passed on high

cost of IPPs; power generation to the consumers. Moreover, four to eight-hour load shedding is being carried out in urban and rural areas to manage load and high cost of power generation.

Now Pakistan is facing twin problem of paying accumulated circular debt and rapid environmental degradation. Another problem is depletion of non-renewable resources such as coal, Oil, Gas etc. as well as level of water reservoirs for drinking and cultivation of crops. Pakistan used total 68.9 million barrels in July-March 2020-2021 to meet its energy needs out of which it imported 48.2 million barrels while the consumption of petroleum products has risen to `4.7 million tons from 12.5 million tons in the same period (Pakistan Economic Survey, (2021).

1.4. Climatic Change

Pakistan has been facing severe problem of climate change due to rapid industrialization, expansion of transport sector, depletion of clean water resources and contamination of agriculture soil, reduction in crop yield and excessive use of non-renewables. As per German Watch, (2019) Pakistan is among those top ten countries which have been affected mostly by climate change during last 20 years on account of devastating floods since 2010, worst episodes of drought during 1998-2022), earthquake in Islamabad and Azad Kashmir in June 2016, severe heatwaves in Karachi and Southern part of Pakistan in 2015-17, increase incidences of landslides and Glacial Lake Outburst Flood in Northern areas of Pakistan. In order to overcome climate change Pakistan has launched “Ten billion tree Tsunami program” in 2019 under which 350 million plants were regenerated and 100,000 persons were employed on daily wages for this drive. (Pakistan Economic Survey).

Similarly, the number of vehicles on roads have been have jumped many fold during last one decade. It has put great pressure on the roads and contributed into the level of emission substantially. In order to reduce the impact of automobiles' emission the Government has offered generous fiscal incentives to shift more than 30 percent to electric vehicles production. But this policy has so far not produced any desired results.

Pakistani policy makers are following short-term policy initiatives to manage energy crisis and currently many highly polluted coal-fired power plants have been installed in different parts of the country. The repayment of foreign debt of $10 billion every years has constrained the option of policy makers to opt the path of clean energy to obtain sustainable economic development. They are reluctance to opt renewables because it involved heavy investment and clean technologies. The policy makers perceived that renewables are not dependable because the experience of different countries has mixed results.

In this scenario the authors have intended to make quantitative analysis whether renewables resources can play any significant role in low cost generation of electricity and can be used as alternatives to non-renewables to solve Pakistan's energy crisis. These two questions are the focus of this research study (World Bank, (2020).

1.4 Objectives of study

The objective of the study is to analyze relationship between renewable resources and electricity generation, low cost production and long term solution of energy crisis. Other objectives of study are stated as under: -

- To analyze the energy sources being used for electricity generation in Pakistan.
- To determine the impact of the use of non-renewable on Pakistan's economy.
- To carry out cost and benefits analysis of renewables and non-renewables in the existing scenario of energy crisis and future demand and supply of electricity in Pakistan.

1.5. Formulation of the Hypothesis

The hypotheses of this research study are given below: -

H_0: Renewable resources don't increase electricity generation sufficiently and have not capability to reduce cost and improve environmental quality in Pakistan.

H_1: Renewable sources can increase electricity generation sufficiently and have capability to replace non-renewables to reduce cost and improve environmental quality in Pakistan.

1.6 Rationale of Study

The rationale of this study is that Pakistan's policy makers are struggling hard to reduce energy cost and improve environmental quality and for this purpose they have under taken many policy initiatives. But even than the energy crisis is still existing and is leading the country to the edge of bankruptcy. The seriousness of the issue can be assessed from the fact that in 2018 the circular debt of energy sector was Rs.1.14 trillion ($9.5 billion) which was jumped to Rs.2.5 trillion ($14 billion) in March,2022. If it continues to grow at the current rate it will likely to reach Rs.4 trillion in 2025. The

Government under IMF's pressure has raised electricity bills by 100 percent during 2018-2022 to cover transmission and distribution losses (Saleem,2022). Pakistan is facing a significant power surplus due to heavy investment in new coal and gas-run power projects in recent past. The projected demand is weaker due to Covid-19 pandemic and people's reluctance to use costly energy. No major new power project is undertaken during 2021-2022. It means the future demand will be higher to increase in population and industrialization. In this scenario Pakistan needs to abandon past policy the "Boom and bust cycle" of underestimating during surplus period and overinvestment in energy shortage period. The development of energy capacity on emergency basis as was seen in the last decade is not sustainable. This study is intended to explore whether variable renewable energy (VRE) is a sustainable model to replace inefficient thermal plants to reduce supply risks associated with imported costly oil and gas or delaying major hydropower projects. The authors have intended to focus that VER model is feasible to reduce import bill of $10 billion annually or Pakistan can afford to change its existing energy dynamics and can move from short-term policy option to long term energy sustainability. The author will focus on this point in this research study.

1.7 Scope of the study

The scope of this study is very high because Pakistan is facing electricity crisis for many decades. Pakistan has been producing electricity through non-renewable energy sources such as Oil, Coal, Wastes, etc. and paying its high cost. The amount of debt is increasing exponentially due to high cost of electricity generation and its distribution at subsidized rates. The only viable solution of this complex problem is the exploitation of renewables to reduce

the cost, obtain energy security, improve quality of environment and ensure sustainable economic development. Although the findings of this study is restricted to Pakistan yet other developing countries, which are facing energy shortage, paying high cost of production and low environmental quality, can take benefit from the results of this study and follow its recommendations. The author believe that the adoption of renewable energy will not only reduce costs, environmental degradation but also improve their trade balance and will enable them to allocate saved financial resources to other development projects.

1.8 Potential of Renewables in Pakistan

Pakistan has been striving hard to develop renewables in order to improve environmental quality, level of emission and reduce cost of energy production. The World Bank study conducted in 2020 disclosed that Pakistan has tremendous potential to generate solar and wind power. by using only 0.071 percent of the country's area for solar PV (Solar photovoltaic) power generation would meet Pakistan's current electricity demand. The study confirms Pakistan's target to increase VRE to 20 percent of its electricity mix by 2025, 30 percent by 2030, which is equivalent to 24,000 MW. The study suggest that Pakistan can save $5 billion in next 20 years if it expand renewable energy It will also make electricity cheaper, achieve greater energy security and expedite the process of decarburization in Pakistan. Keeping. in view of the World Bank (2020) study, the authors have intended to glance at renewables being used in Pakistan currently in order to understand the potential of renewables in Pakistan in future.

1.8 1 Solar Energy

Energy is produced by storing sunlight and converting it to electricity by using solar panels (solar plats). Solar energy can be produced in those areas which are warm and where the sun shine is strong. Pakistan is situated in a zone of solar radiance. It is country which is generally having warm climate. National Renewable Energy Laboratories (NREL) in collaboration with Alternative Energy Development Board (AEDB) conducted an assessment to measure the solar energy potential in Pakistan. It was a joint venture between National Renewable Energy Laboratory of United States and Alternative Energy Development Board of Pakistan. Findings of that study were that Pakistan is located in that part of the world where mostly days are long with full of sun shine. Solar radiations per year having 8-10 hours' sunlight in a day in most of the areas. The assessment of potential electricity generation through solar panels is 16GW annually which is more than 40 times than that of the current power generation capacity. Solar source contribution into total power generation is only 1.1 percent currently.

1.8.2 Wind power

Wind is a clean source of energy. It creates no pollution in the air and the water. Wind turbines have been used to generate electricity from breeze. Normally, Wind turbines are 100 meters tall with three long blades. The wind helps spins the blades, which convert the power into electricity. In 1887 Scotland built first windmill for the generation of electricity. In the past few decades' wind turbine has increased about 30% all around the world but the share of electricity is significant. Due to continuous hike in the prices of fossil fuel, Pakistan is developing sources of wind energy. Five wind projects have

been installed with total capacity of 255.4 MW which are operational. Wind power contribution in the production of electricity is only 3.31% at the moment.

1.8.3 Nuclear Power

Using nuclear source, electricity can be generated by converting water into steam. This steam spins the turbines into Nuclear power plant. Uranium fuel consists of some ceramic pellets for electricity generation. The method of electricity generation by using nuclear power plants is called fission. In 1954 First nuclear power plant started generation electricity in Soviet Union (Russia) in the name of Obninsk Nuclear Power Plant. Now Thirty-five countries are operating nuclear reactors with total capacity of 4000,000 MW. Pakistan is also included in the list of those countries which are producing electricity through nuclear power. Pakistan Atomic Energy Commission (PAEC) is responsible for it. This source could not have exploited at large scale due to International Atomic Energy Agency pressure, which do not want developing countries to use this technology due to nuclear proliferation and for its military use. China is the only country which provides technical assistance to Pakistan in this field. Pakistan's first nuclear power reactor was established at KANUPP Karachi in 1971 with technical collaboration of Canada and its installed capacity was 137MW. Pakistan has also built nuclear reactors at Chashma with technical assistance of China. At the moment, Pakistan has four nuclear power plants with the total power generation capacity of 787MW, which is only 6.68% of total electricity generation capacity of the country.

1.8.4 Hydro

Extracted energy by moving power, called Hydro power or hydroelectricity. It is the best and more reliable source of electricity. More than 150 countries are using Hydro power. In 1879 first hydro power plant was built in Canada at the site of Niagara Falls. Hydro power plants work on a simple technique. Water falls from the dam and spins the blades of turbine which generates electricity. Hydro projects are the basic method to generate electricity all around the world. It's a cheap source of electricity. Pakistan has a high potential for hydropower generation. Estimated generation of electricity through hydro is about 60,000 MW but unfortunately in Pakistan the share of hydroelectricity is 26% only. This is not enough; Pakistan is an agricultural country and is facing water shortage due to lack of water reservoirs. Pakistan could not build any the dams during last three decades. But in 2019 initiatives were taken to develop and construct more hydro power plants at different sites such as: (1) Tarbela Dam with the capacity of 4888 MW (2) Ghazi-Barotha Hydropower Project 1450 MW (3) Mangla Dam 1150 MW (4) Neelum–Jhelum Hydropower Plant 969 MW (5) Warsak Dam 243 MW (6) Chashma Barrage 184 MW.

1.8.5 Biomass

Biomass has been used as source of energy since long, but it was not in a uniform shape. With the passage of time there were new techniques and methods developed to generate electricity through Biomass. It includes Wood, Garbage, Crops, Landfill gas and Alcohol fuels. It is estimated that the share of biomass energy will be increased about to 3000 TW in the world by 2050. Pakistan is an agricultural country and 60% population is living in rural areas. All of them directly and indirectly linked with agriculture. Pakistan holds 180

million animals and on average they drop 10 kg dung every day. PCRET installed 5357 bio gas plants in Pakistan with electricity generation capacity of 12–16 million m3 /day on the basis of private –public partnership Amjid, et al. (2011). According to an estimate Pakistan has potential of producing electricity of 1800 MW through biomass and 500 MW from the waste. This is the cheap and dependable source of energy and Pakistan should exploit it on maximum scale. (IRENA, (2016),

2. Literature Review

Ekins and Zengherlis, (2021) analyzed possible economic implication of existing trends mentioned in The *sixth UN Global Environment Outlook (GEO-6)* and transformation of global economy to resource efficient with low carbon by 2050. They made cost-benefit analysis of decarburization and natural resource management trajectory which mainly depends upon decisions to be made now regarding changing behavior and making innovations. They contended that conventional models are inadequate for measuring the risks unmitigated climate change and overstating the costs of low carbon transition totally ignoring the role of innovations. They stated that the policy makers are puzzled how to reduce volume of growing emissions and are waiting for development of new cost-effective technologies. They argued that delaying decarburization through policy initiatives is increasing its costs and effects. They emphasized that policy makers should understand the importance of innovation, change in social norms and behaviors and need of taking effective measures to control deteriorating condition of natural resources and environment. They urged to start efforts for decarburization without caring its costs, keeping in view the warning of natural scientists about depletion of

natural resources and degradation of environment. Khan, et al. (2021) studies the problem of environmental degradation challenges in the developing countries because these countries are using fossil fuels to increase their economic growth. They stated that use of renewable resources is the only solution to control environmental degradation. However, they disclosed that the sampling 21 developing countries were unable to achieve desired level of renewable energy due to lack of financial resources and clean technologies. They specifically focused on the use of coal energy as a sample of study and compared it with natural gas. They concluded that energy produced from natural gas is less pollutant than coal energy. They suggested that the policy makers of developing countries should focus on the development of renewable energy by phasing out nonrenewable energy use to protect environmental quality. Their results show that financial investment in renewable resources development projects would also reduce environmental degradation and environmental quality. They recommended that policy makers should devise environmentally-friendly policies and machinery to protect environmental quality and attaining sustainable economic development. Raza, Wasim and Sarwar (2019) explored relationship between electricity generation and renewable resources. As the renewable resources increase the electricity generation will also increase and the cost of electricity generation will also fall. They argued that renewables would benefit to manufacturers who are producing costly goods as well as consumers who are buying unhygienic products. Raheem (2016) emphasized that he development of renewable resources are essential for economic development. He argued that Pakistan does not have enough financial resources to bear the high cost of electricity generation by using traditional energy sources like Oil and Gas. He proposed

that energy crisis can be solved through renewables only and sustainable development can be achieved by abandoning traditional sources of electricity generation. IRENA Report (2016) has highlighted the importance of renewable resources by stating that they double the contribution of renewables in the global energy mix, enhances global GDP in 2030 by up to 1.1%, equivalent to USD 1.3 trillion as well as has a positive impact on global welfare, which increases by 2.7 % as compared to a 0.6% GDP improvement. If renewables are used in the electricity generation and transportation it would further enhance global welfare by 3.7 percent. It emphasized that employment would increase directly or indirectly by 24.4 million by 2030 globally due to labour-intensives nature of renewable energy and investment to be made in this sector. It argued that the adoption of the Sustainable Development Goals and the Paris Agreement gave a clear direction to the policy makers to design strategies to attain the objectives of clean climate and safe energy because renewables can offer solutions for the dual objective of achieving economic growth decarburization of the globe. Vezamar, et al (2014) analyzed positive and negative impact of renewable resources for electricity generation in Croatia. They discussed eight positive aspects or benefits of renewable resources. They pleaded that electricity generation through renewable sources will reduce emissions of Hg, Cd and other toxic elements many hundred times and emissions of particles would be very low. These sources also reduce CO2 emissions from Acid rains– SO, NO about 25 times while reduction in greenhouse gases would reduce the volume of global warming. They claimed that renewable source of energy would eliminate total or partial oil spills as most of petroleum products are spilled and create environmental pollution. They further argued that there is nominal use of water in the process of electricity generation through renewables and as such water quality would

improve and pollution of water would stop. Similarly, the erosion of soil will be very small as compared to traditional energy sources which go deep into the soil and contaminate it. They concluded that there is good potential in Croatia in renewables, especially in solar power, wind power, small hydropower and biomass but their development is very slow due to lack of financial resources and the quotas that limit power supply connection to only 5 MW per year. Chaudhry, Raza and Hayat (2009) suggested that renewable resources are the only solution of energy crisis of Pakistan. Energy crisis cannot be solved without exploitation of renewable resources. They further stated that Pakistan should learn from the experience of developed countries which are using different sources of renewables for electricity generation and transportation. They said that Pakistan has a lot of potential to produce electricity through renewables and it should not waste money on import of costly oil and gas, which are polluting environment and creating environmental hazards. Shah, Qureshi and Bhutoo (2008) contended that renewable resources have positive and significant effects on economic growth in Pakistan. Main problem of Pakistan now a day is electricity shortage. If Pakistan use renewable resources not only it will meet all electricity needs but also increase economic growth. Zafar, Azhar, Abbas and Khalil (2008) pleaded that renewable resources have positive and long run relationship with electricity generation. These resources are cost effective and better alternate to traditional source of electricity generation. They also emphasized that Pakistan should carry out long term planning to exploit renewable resources. Mirza (2007) argued that Pakistan is facing the problem of deficit financing. Electricity generation in Pakistan is a big problem because it required a lot of investment and people are using

expensive electricity which is neither affordable for industry nor for domestic consumers. It's a huge burden on Pakistan's Economy.

Although theoretical literature considers that renewable energy is beneficial for environmental quality and it reduces carbon emission (Bilgili, Koçak, and. Bulut, (2016)., but some other studies reveal that renewable energy enhances the level of emission and claim that there is no effect or insignificant impact of renewable energy on carbon emission (Al-Mulali, Ozturk, and Lean, (2015). Similarly, Jebli and Yossef (2017) also suspected the role of renewable energy in environment protection and claim that waste and combustible renewables are not clean energy and the use of combustible renewables and wastes increases emission. However, the majority of researchers have consensus on the exploitation of renewables for energy generation to reduce the cost and enhance environmental quality due to reduction in the level of emission.

3 Data and Methodology

3.1 Area of study

The area of this study is Pakistan and we have intended to investigate the potential of renewables for mitigating environmental degradation and solving existing energy crisis and circular debt problem in energy sector. For this purpose, we selected five variables such as Solar Energy, Hydro, Nuclear, Biomass and wastes as a sample of study. This study will explore the question whether renewables have capability to replace non-renewables and how much it will bring change in cost, environmental quality and level of emission in Pakistan.

3.2 Type of data sources

We have used secondary data relating to selected variable and this data is spread over a period from 1998 and 2018. The data was collected from the World Bank, IMF, Asian Development, State Bank of Pakistan, Pakistan Atomic Energy Commission and different issues of Pakistan Economic Survey.

3.3 Sample of Study

The population of this study is the energy sector of Pakistan out of which five renewables were selected as a sample of study through convenience sampling method. The specific period of the study, e.g. 1998 to 2018 was selected to determine the demand and supply of electricity, use of non-renewables and renewable energy sources, cost of electricity generation and huge circular debt created as a result of the use of non-renewables during this period. This period was crucial because Pakistan faced severe energy crisis and took short term policy option to solve energy crisis on emergency basis. Twenty years are a long time but the policy makers took short-term strategy to attain energy sufficiency, ignoring its cost and impact on environment and health of people.

3.4 Selected Variables

The author selected five variables for measuring the potential of renewable resources in Pakistan. The electricity generation is dependent variable while independent variables include Hydro, Nuclear, Solar, Biomass and wastes. These variables, their expected signs and sources are described in Table 3.

Table 3: Variables and their expected signs

Variables	**Name of variables**	**Symbols**	**Expected relationship**	**Sources**
Dependent Variable	Electricity generation	EG	Negative_	World Bank
Independent Variable	Hydro	HD	Positive(+)	World Bank
Independent Variable	Nuclear	NC	Positive(+)	World Bank
Independent Variable	Solar	SL	Positive(+)	World Bank
Independent Variable	Biomass and wastes	BAW	Positive(+)	World Bank

3.4 Model Specification

The model of the study is given below: -

$$EG=\dot{}\alpha 0 + \beta 1(HD) + \beta 2(NC) + \beta 3(SL) + \beta 4(BAW) + \epsilon$$

Where

EG= Electricity generation with the help of traditional means

HD= Hydro Power

NC= Nuclear Power

SL= Solar Power

BAW= BIOMASS_AND_WASTE

€ = Error term

3.5 Analytical Techniques

The authors used different analytical techniques to determine the impact of renewables and their relationship with sustainable economic development in Pakistan. ADF test was used to check stationarity among variables and Correlation analysis was applied to check degree of relationship between variables. The Johansen's co-integration technique was used to ascertain long run relationship between dependent and independent variables.

4 Results and discussion

The authors carried out empirical analysis of the importance of renewables in solving energy crisis in Pakistan. For this analysis different analytical techniques were used to analyze the data. The results obtained through these quantitative techniques are stated one by one in the following: - -

4.1 Correlation Analysis

Correlation matrix shows the strength of relationship between variables and the correlation coefficient show this relationship numerically. The range of correlation coefficient is between -1 and +1. Perfect positive correlation means that correlation coefficient is exactly 1. A perfect negative correlation means there is no liner relationship between the variables. In this study, there are one dependent and four independent variables. The calculated results of correlation matrix are shown in Table 4.

Table 4: **Results of Correlation Analysis**

	Biomass & waste	Hydro	Nuclear	Solar	EG
Biomass & wastes	1.000000	0.727046	0.900157	0.750569	0.861589
Hydro	0.727046	1.000000	0.779287	0.523790	0.748455
Nuclear	0.900157	0.779287	1.000000	0.842979	0.827868
Solar	0.750569	0.523790	0.842979	1.000000	0.676109
EG	0.861589	0.748455	0.827868	0.676109	1.000000

The results in table 4 show correlation matrix which shows correlation coefficient value of BAW and HD is 0.727046, which is close to 1. It means that there is strong positive correlation between Biomass Wastes and electricity generation. The correlation coefficient value of HD. BAW and NC Value is 0.900157 which is also close to 1. Correlation Value between BAW and SL is 0.750569. Similarly, the correlation coefficient value of BAW and TEG is 0.861589. The value between HD and BAW is 0.727046 and the value of HD and NC is 0.779287. These values show strong positive correlation between variables. The correlation value of HD and SL is 0.523790, which is moderate while the correlation value between HD and TEG is 0.748455, which shows strong positive correlation between variables. The correlation coefficient value of NC and BAW is 0.900157. It shows strong correlation between two variables. The Value between NC and HD is 0.779287. The correlation coefficient value of NC and SL is 0.842979. The coefficient value of NC and EG is 0. 827868. The coefficient value of SL and BAW is 0. 750569.The correlation coefficient value of SL and HD is 0.523790 while the coefficient value of SL and NC is 0.842979. The correlation coefficient value of SL and

TEG is 0.676109, which is moderate while the coefficient value EG and BAW is 0.861589, which shows strong correlation. The coefficient value of EG and HD is 0.748455. The correlation between EG and NC is 0.827868 whereas the coefficient value of EG and SL is 0.676109. The correlation matrix shows positive and significant correlation between variables of the study.

4.2 ADF Unit Root Test

Augmented Dickey Fuller Test (ADF Test) is a common statistical technique. Through this technique, one can check whether the variables are stationary or non-stationary in time series data. There are two ways to check stationarity. One is Null hypothesis testing and the second is to compare the T-Value with Critical Value. This study has opted second approach to check stationarity among variables such as EG, (HD), (NC), (SL), (BAW). The results of ADF's Unit Root Test are shown in Table 5.

Table 5: Result of Unit Root Test

Null Hypothesis: D (ELECTRICITY_GENRATION) has a unit root			
Exogenous: Constant			
Lag Length: 0 (Automatic - based on SIC, maxlag=1)			
		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	c	-3.842694	0.0067
Test critical values:	1% level	-3.679322	
5% level		-2.967767	
10% level		-2.622989	

*MacKinnon (1996) one-sided p-values.		

The results in Table 5 show that there is low t-value from the critical value and negative sign show that there is no stationarity among variables, so the null hypothesis is rejected and alternate hypothesis is accepted and we can use Johansen co-integration technique to determine long run relationship between variables.

4.3 Selection of lag length

For conducting co-integration analysis, the selection of lag length is said to be pre requisite. There are many tests to find good lag length like Schwarz information Criteria, Final prediction Log Likelihood (LL) and The Akaike information criteria etc. For the best lag length, this study has used Schwarz information criteria. It measures the efficiency of the model to predict the large data. Approximately it is equal to least description length criterion but with negative sign. Closely related to other penalized criteria such as Akaike information criterion and RIC. Here one can clearly see a value with star in column 4. Lag one is appropriate for this research study. This method shows goodness of fit of the study model. The calculated results of Schwarz information criteria are depicted in Table 6.

Table 6: **Results of Schwarz Information Criteria**

Date: 03/18/21 Time: 08:27

Sample: 1998 2018

Included observations: 29

Variables: Electricity generation, Hydro, Nuclear, Solar, Biomass and waste

Lags interval: 1 to 1

Schwarz Criteria by Rank(rows) and Model (columns)

0	12.05926	12.05926	12.35577	12.35577	12.64438
1	12.23134	12.31044	12.49087	12.04668*	12.33107
2	12.77820	12.95851	13.06689	12.71035	12.88841
3	13.60920	13.68692	13.81657	13.51918	13.61929
4	14.56379	14.63881	14.74792	14.47448	14.49294
5	15.72277	15.80627	15.80627	15.63654	15.63654

4.4 Johansen Co-Integration Test-

In unit root test we have seen all the variables are not stationary at level that's why we conducted a test at first difference. Every variable has different value form other variable. So we can use Johansen co-integration test to determine long run relationship between variables. The results can be obtained through either testing hypotheses or comparing trace value with critical value. This study has opted first approach for this study and tested following two hypotheses through Johansen co-integration test: -

H_0: There is no co-integration (no long run relationship between variables)

H_1: There is co-integration (long run relationship exists between variables).

The calculated results of Johansen co-integration test are shown in Table 7.

Table 7: Johansen Co-Integration Test

Date: 03/18/21 Time: 08:51
Sample (adjusted): 1988 2018
Included observations: 29 after adjustments
Trend assumption: Linear deterministic trend (restricted)
Series: Electricity generation, Hydro, Nuclear, Solar, Biomass and waste.
Lags interval (in first differences): 1 to 1
Unrestricted Co-Integration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.795327	90.05900	88.80380	0.0405
At most	10.458591	44.05513	63.87610	0.6900
At most	20.374010	26.26132	42.91525	0.7230
At most	30.275266	12.67713	25.87211	0.7630
At most	40.108805	3.340575	12.51798	0.8338

Trace indicates 1 co-integrating (eqn)(s) at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level
**MacKinnonHaug-Michelis (1999) p-values

Unrestricted Co-Integration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE (s)	Eigenvalue	Statistic	Max-Eigen Critical Value	0.05 Prob.**
None *	0.795327	46.00387	38.33101	0.0055
At most	10.458591	17.79381	32.11832	0.8138
At most	20.374010	13.58418	25.82321	0.7574
At most	30.275266	9.336560	19.38704	0.6894
At most	40.108805	3.340575	12.51798	0.8338

Table 7 shows that calculated statistic value at ne is greater than 5% critical value and it proves that there is long run relationship between electricity generation (dependent variable) and independent variables such as Hydro, Nuclear, Biomass & waste and solar energy. So the null hypothesis (Ho) is rejected and alternate hypothesis (A_1) is accepted. These results are consistent with the findings of Vezamar, et al (2014) who stated that the use of renewables will reduce environmental degradation, improve environmental quality, reduce water contamination as well as reduce the level of emission (CO), produced as a results of the use of fissile fuels, chemicals and solid wastes. The results of this study also support the findings of Khan, et al (2021) who suggested that the policy makers of developing countries should focus on renewable energy by phasing out nonrenewable energy use to protect environmental quality. They also suggested that foreign investors should be invited by developing countries to invest in clean energy and this investment will not only help developing clean energy projects and but also generate employment in this sector. The results of this study are also consistent with the projection of IRENA (2016) that states that the use of renewables in energy and transport sectors would enhance the level of GDP, employment and welfare of the people in the long run, The results of this study also support the findings of World Bank (2020) study which concludes that Pakistan has a tremendous potential of renewables and by expanding them into energy sector will not only save $5 billion by 2030, reduce level of emission, enhance generation capacity and improve environmental quality. Thus, the findings of this study proves that existing model of energy development cannot secure Pakistan's energy security and solve problem of circular debt of energy sector.

5 Conclusions and Policy implications

The objectives of this study were to analyze the use of nonrenewable in electricity generation and their impact on Pakistan economy. Another objective of this study was to analyze the potential of the use of energy renewables and their possible positive benefits in the long run. The sample of study was renewable sources of Pakistan. For this purpose, the authors used convenience sampling method. Electricity generation was taken as dependent variable while solar, Nuclear, Hydro and Biomass & wastes were selected as independent variables. The stationarity among variables was check through ADF Test. The Johansen co-integration technique was applied to determine long run relationship between variables. The results show that renewables such as Solar, Hydro. Nuclear and Biomass & wastes have strong positive association with electricity generation in Pakistan in the long run. So the null hypothesis (o) was rejected and alternate hypothesis (A_1) was accepted. So it is empirically proved that renewables have long term positive effect on environmental quality, cost of energy generation and level of emission. Thus, it is concluded that the policy makers should abandon their emergency development of energy projects to resolve energy crisis and to avoid repeat of "boom and bust cycle" by adopting long term renewable sustainable energy model. It will help Pakistan to save $500 per year if current ratio of 6.8 percent contribution of renewables is enhanced to around 13 percent by 2030. It will also improve level of environmental quality, health of population, expenditures on sickness and volume of emission in Pakistan. The policy makers should also prepare a long term plan to phase out retiring furnace oil run power plants and ban on such installation of such plants in future. The retiring furnace oil-run power plants

by 2025 should be replaced by renewable energy to lessen Pakistan's dependence on costly imported oil and gas sources for energy generation. It will ensure country energy security and solve mounting circular debt problem and will lead it to sustainable economic development in the long run

Pakistan is an energy deficit country and has been spending $10 to $12 billion annually on the import of oil and gas to meet energy needs. It is also paying billions of rupees annually to independent power producers (IPPs). This policy is not sustainable in the long run. As population is growing as well as fleet of transport is increasing year after year due to high population growth and per capita income. Pakistani society is moving from low energy consumption to high energy consumption due to excessive use of electric appliance and passenger cars, buses, trucks and two wheelers. Now the cost of fuel is assumed to be higher than food cost. So it is imperative to shift energy use strategy from non-renewable to renewable energy sources. Otherwise it will be extremely difficult for policy makers to control repeated boom and bust energy cycle in Pakistan when its indigenous resources only meeting 25 percent of local energy demand while 75 percent of non-renewables are being imported. In the high global energy price scenario, the policy options are constrained to use imported non-renewables for a long time. It will threaten country future energy security and lead it to the edge of default. Pakistani policy makers should think how many times IMF, World Bank and other international donors can save it from sovereign default. So it is right time to shift the country's energy strategy from short term gain to long term gains. When neighboring countries like China and India could develop renewables and use them for energy generation on large scale why Pakistan could not adopt the same path for the development of renewables.

6.Contribution of the study

This study contributes into existing literature in many ways because most of the developing countries are facing energy crisis. The results of this study can be generalize and applicable to energy-deficit countries. Currently, about all countries are trying to reduce the use of non-renewables in order to reduce the cost of electricity generation and to keep their environment clean. There is a world-wide campaign to reduce emission and environmental degradation. The results of this study also highlighted this fact and recommend to shift existing Pakistan's energy strategy. During this study the authors have noted that non-renewable resources are in limited quantity and are being depleted rapidly. The depletion of natural gas reservoirs is its best example. Now Pakistan is spending billions of dollars on the import of costly oil and gas. Now there is one option either to discover traditional resources on large scale which appears not possible. Other option is that to move on the trajectory of the developed countries which are rapidly shifting from non-renewables to renewable energy sources under "Net Zero Emission" goal by 2050. In the previous decade, Pakistan developed coal run energy plants through borrowed money. Now it has created dual issue of rising emission in Pakistan and payment of costly foreign loans. This study suggest that Pakistan should replace its retiring furnace-oil run power plants by renewable energy plants in order to get rid of circular debt in energy sector and generate low cost electricity for domestic and industrial use. This is the only solution to Pakistan's energy crisis. This study also draws the attention of Pakistani and energy-deficit other countries' policy makers to the consequences of Russia-

Ukraine war that has disrupted supply chain of world commodities and sky-rocketed their prices. If this war is prolonged and relations between US, European Union and Russian Federation are strained it will have disastrous effect on countries like Pakistan. So the policy makers should learn lesson from Russia-Ukraine conflict and prepare a long term plan to ensure their future energy security.

7. Limitations and future direction of study

Although this study is specific to Pakistan yet its results may be generalized and all developing countries which are facing energy crisis can apply them in the perspective of their local conditions. We have selected four independent variables like Hydro, Nuclear, Solar, Biomass and wastes to measure their impact on dependent variable, electricity generation. These variables belong to renewable category. More variables like wind energy and tidal energy can be included into future studies. Similarly, other researchers can also broaden their study more than 20 years' data to measures long term effect of renewable resources on electricity generation. We have applied Johansen's co-integration technique to determine long run relationship between variables. Other researchers can use Regression analysis, ARDL approach and other econometric techniques for the same purpose in order to widen the scope of their research. There is a large scope of further research on this topic.

Data availability statement

The data that support the findings of this study are available on the request.

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Both authors jointly carried out this research study and collaborated each other. The author 1 collected data, conducted its statistical analysis. He prepared initial draft of manuscript. The Author 2 helped Author 1 in selected of title of research, guided in statistical analysis and formatted final draft of manuscript. Both authors carefully read final draft of manuscript and find it fit for publishing. Both authors fully followed ethical values during the course of this research work.

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