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Path towards sustainable energy development: Status of renewable energy in Indian subcontinent

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ABSTRACT

Many countries are mitigating the shortfall of electricity through the renewable energy system. Research is still continued in this direction to find other alternatives or reduce the consumption of electricity. This paper presents the status of the renewable energy system in the Indian subcontinent which includes India, Bangladesh, Pakistan, Sri Lanka, Nepal, Bhutan, and the Maldives. This paper presents, a comparative assessment of the capacity of all the renewable energy systems is done. The effects of renewable energy on the economic growth, foreign direct investment, domestic investment, electricity sustainability, and environmental sustainability of the Indian subcontinent is presented along with SWOT analysis. According to the SWOT analysis it is find out, the main threats in different countries are such as inefficiency in risk analysis technology and mitigation mechanism in India, Inadequate infrastructure, Terrorism, Unbalance political issues in Pakistan, Sri Lanka and Bangladesh and opportunity to increase the electricity generation through the wind, geothermal and ocean energy in the Nepal, Bhutan and Maldives.

1. Introduction

A naturally replenished sources of energy like solar, wind, and biomass; hydro; tidal, wave, and geothermal energy; are about to capture future electricity market and is symbol for socioeconomic advancement. South Asian countries hold very good place in harnessing renewable energy with variety of climatic conditions, including tropical and humid which makes it possible to use variety of renewable energy sources (Khare et al., 2016a, 2016b). Hybrid renewable energy systems (HRES), offers a solution to the major issue fluctuations, intermittency, and poor energy density of renewable energy. This paper presents a comprehensive assessment of the status of the renewable energy system in the Indian subcontinent (Khare et al., 2016a, 2016b, 2022, Pillai, 2009, Kumar, 2010).

Khare and Nema (2013) examined the current state of India's solar wind renewable energy system. The primary restrictions to the growth of renewable energy in India is described in a logical and comprehensive manner. New insights and structural deconstruction of the Indian renewable energy sector are described by Wang (2021). Using a multi-regional input-output model (MRIO) and structural decomposition analysis, this study assessed India's renewable energy consumption patterns and transition determinants. The current state and potential scope of renewable energy in Pakistan are described by Kamran (2020) including operational and under construction RE projects such as solar, wind, biomass, biogas, and hydro power. It is mentioned that 100 MW solar, 308 MW wind, 145 MW bagasse, and 98 MW micro hydro projects are now operating, while 856 MW solar, 1140 MW wind, 297 MW bagasse, and 2638 MW micro hydro projects are in various phases of construction. Ullah (2022) investigated Pakistan's renewable energy policies and CO2 emissions. Contrary to policymakers' expectations, the reference scenario does not assist Pakistan in meeting its CO2 emissions reduction target by the compliance year 2030, nor does it give any assistance to power customers. Uddin (2019) presented the current state and potential of renewable energy in Bangladesh. The Bangladeshi government aims to reduce global pollution through the use of biomass, solar, hydro, wind, and tidal power. Bangladesh's current national energy scenario is also presented in this report. Surendra (2011) studied gave an overview of Nepal's renewable energy resources like micro-hydro, solar power, wind energy, biofuel/bioenergy, better cook stoves, and enhanced water mills. Advantages and disadvantages of developing Renewable Energy Technology (RETs) is also discussed and some suggestions are given for promotion, development, and implementation of RETs.

The paper presents a comprehensive study about the status of renewable energy in the Indian subcontinent Comprising of India, Bangladesh, Bhutan, Maldives, Nepal, Pakistan, and Sri Lanka. Renewable energy power plants, its status, government policy and challenges; incentives;

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Table 1
Research summary on status of renewable energy in India.

Author/Ref	Objective	Method	Predictors	Keywords	Outcome	Journal Name	Citation of Paper
Pillai (2009)	Status and potential	Observation through resources	Economic viability, Greenhouse gas saving	Renewable Energy, Diffusion, Potential	Tidal, OTEC, Solar thermal power plant, geothermal power plant at the demonstration stage	Energy	120
Kumar (2010)	Current status and future potentials	Observation through resources	Current status, Future potential, major achievement	Solar, wind, biomass, geothermal	Analyze policy interventions for overcoming the barriers and deployment of renewables	Renewable and sustainable review	277
Khare and Nema (2013)	Status of Solar Wind	Observation through resources	State wise approach, Grid parity	Solar energy, Wind energy	India will achieve solar energy grid parity in 2017 and wind energy grid parity in 2022.	Renewable and sustainable review	338
Ghosh and Yadav (2015)	Indian's energy sustainability approach	Observation through resources	Policy, Planning, Regulation, Renewable Energy Efficiency	Energy Policy, Energy Sustainability	Renewable energy sources accounted for 13.3% of India's total installed power capacity as of July 2015.	IFAC-Papers On Line	9
Sisodiya (2016)	Status of renewable energy research	Observation through Indian academic literature on renewable energy from 1998-2014	Consumer behavior, literature review, empirical studies, Qualitative studies	India solar research, Solar energy consumerism	Since 1998, there has been a gradual increase, but since 2008, there has been a significant change.	Energy Procedia	10
Manju (2017)	Prospectus of solar photo-voltaic system	Observation through resources	Economic progress, Environment sustainability, India's energy security	Solar energy policy, Sustainable energy, Application and prospectus	To advance high-potential innovations in the solar sector, the Government of India should invest in PV research and development.	Renewable and sustainable energy review	74
Das (2020)	Wind-solar hybrid energy policies	Observation through resources	Policy barriers, Policy recommendation		The policy support for both onshore and offshore wind system should be identical	Renewable energy focus	5
Shekhar (2021)	Reduced renewable energy stability	Gaussian process, Machine Learning	Investment subsidies, Operational subsidies, Energy consumption, Policy measure	Renewable energy, COVID-19, Gaussian process, Climate change	The epidemic may have created unanticipated logistical and financial challenges, but the government of India has provided sufficient support through stimulus programmed.	Renewable and sustainable energy review	2
Wang (2021)	New insights of India's renewable energy	Multi-regional input output model, Structural decomposition analysis	Per capita final demand, India's renewable energy consumption	Renewable energy, Multi-regional input output model, Structural decomposition analysis	India should pay greater attention to developing-country cooperation in the field of renewable energy.	Journal of Cleaner production	13
Deshwal (2021)	COVID-19 Impact on renewable energy	Observation through resources	Comparison between before and after covid-19	COVID-19, Renewable energy	In 2020-21, India's renewable energy sector will see a significant drop.	Energy research and social science	2
Pathak (2022)	Barriers to development of RE technologies	Integrated modified Delphi, AHP Method	Social and Economic barriers, Policy and political barrier, Technical barrier, Administrative and market barrier, geographical and environmental barrier	Renewables energy, Sensitivity analysis	The policy and political barrier ranks among the main category barriers.	Sustainable energy technologies and assessment	0

Table 2
Month-wise average solar radiation data set of different state of India.

	Andhra Pradesh	Arunachal Pradesh	Assam	Bihar	Chhattisgarh	Delhi	Goa	Gujarat	Haryana	Himachal Pradesh	Karnataka	Kerala	Madhya Pradesh	Maharashtra	Manipur	Meghalaya	Mizoram	Nagaland	Odisha	Punjab
0.05	6.05	3.95	4.65	5.06	5.35	4.65	6.05	5.70	4.83	2.44	4.88	5.81	5.47	6.05	3.89	3.43	4.36	3.26	5.58	4.13
0.50	6.40	4.54	5.70	6.05	6.17	6.17	6.28	6.51	6.17	3.37	5.24	5.93	6.05	6.28	4.89	4.42	5.12	4.19	6.17	6.05
0.75	6.92	5.47	6.11	6.69	6.74	6.63	6.51	6.74	6.86	4.25	5.53	6.05	6.74	6.51	5.41	5.18	5.41	4.94	6.69	6.63
count	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
max	7.91	6.05	6.51	7.67	8.14	7.67	6.74	7.67	7.91	5.12	6.28	6.28	8.37	6.98	5.58	5.35	5.81	5.12	7.67	7.91
mean	6.55	4.69	5.45	5.91	6.20	5.70	6.26	6.32	5.78	3.29	5.33	5.95	6.20	6.28	4.65	4.28	4.88	4.09	6.24	5.50
min	5.58	3.49	4.19	3.72	4.65	3.02	5.81	4.65	3.02	1.16	4.65	5.81	4.19	5.81	3.26	2.79	3.72	2.79	5.12	2.79
std	0.74	0.92	0.83	1.21	1.12	1.57	0.32	0.95	1.62	1.29	0.53	0.16	1.18	0.36	0.89	0.96	0.71	0.91	0.81	1.69

and effects of the Renewable Energy System (RES) on the country's growth is discussed and SWOT theory is used.

The objectives of this paper are to discuss:

- Status of RES and its effect in India
- Renewable energy prospective in the Bangladesh and Sri Lanka
- Role of renewable energy system in the growth of the Pakistan
- Present status and future perspectives of renewable energy system in Nepal, Maldives and Bhutan.

2. Renewable energy: perspective of India

Like other emerging nations India's key energy challenges include an energy deficit, risks to energy security, and low energy efficiency, only solution to cater these issues is to increase the supply of electricity through the non-conventional energy sources. In 2020, renewable energy accounted for 38 % (136 GW out of 373 GW) of total installed energy capacity in India, making it the world's third largest power user and third largest renewable energy producer. After the United States and China, India was ranked third in Ernst & Young's (EY) 2021 Renewable Energy Country Attractiveness Index (RECAI). As part of the Paris Agreement's Intended Nationally Determined Contributions goals in 2016, India pledged to generate 50% of its total electricity from non-fossil fuel sources by 2030. By 2030, India's Central Power Authority has set a goal of producing 50% of total power from non-fossil fuel sources. India also plans to generate 175 GW of renewable energy by 2022 and 500 GW by 2030. Solar energy was operational on 89.22 GW by September 2020, with 48.21 GW of projects in various stages of execution and another 25.64 GW of projects in various stages of bidding. By 2020, India hosted three of the world's top five largest solar parks, including the 2255 MW Bhadla Solar Park in Rajasthan; the 2000 MW Pavgada Solar Park Tumkur in Karnataka; and the 100 MW Kurnool in Andhra Pradesh. Wind power in India has a strong manufacturing base, with 20 companies producing 53 different international-quality wind turbine models with capacities ranging from 3 to 30 MW, while exporting it to Europe, the United States, and other countries. The knowledge of the development and drivers of renewable energy consumption in India is dependent on good energy policies (Khare et al., 2016a, 2016b, 2022).

A brief work done by researchers in India is compared for different attributes and is shown in Table 1. The main predictors for assessment of RE are economic viability, greenhouse gas saving, future potential, grid parity, policy, planning, regulation, renewable energy efficiency, consumer behaviour and environmental sustainability.

Solar energy system is one of the prominent renewable energy sources in India. Fig. 1 shows the month-wise average solar radiation data set of different state of India. Table 2 shows the descriptive statistics of month-wise average solar radiation of different state of India. From the given data set it is found to have maximum solar radiation in the state of Madhya Pradesh, Chhattisgarh, Haryana, Punjab and Rajasthan. The state, where average solar radiation is more than 6kwh/m2/day, is suitable for electricity generation through the solar energy system.

Tables 3 and 4 show the data set and descriptive statistics of India's renewable energy capacity for different states of India. Statistics shows that, India is found to have the mean capacity of solar, wind, biomass, hydro and ocean energy systems is 1613.07 MW, 1425.75 MW, 375.96 MW, 5399.64 MW, and 1919.82 MW, respectively. Rajasthan have maximum solar energy capacity is 7738 MW in Rajasthan, whereas maximum wind energy capacity is 9231.77 MW owned by Tamilnadu, the maximum biomass energy capacity is 2632 MW in Maharashtra the maximum hydro energy capacity is 52128 MW in Arunachal Pradesh and the maximum ocean energy capacity is 14525 MW in Gujrat. Table 5 shows the attractive score and rank of India for the different RES. Tables 6 and 7 show the top 10 solar and wind power plants and their capacity in MW in India. Fig. 2 shows the percentage growth of renewable energy in India. Table 8 shows the investment/development and government initiatives for RES in 2021.

Table 3
State-wise renewable energy capacity (MW) in India (Das, 2020, Shekhar, 2021).

	Solar	Wind	Biomass	Hydro	Ocean Tidal + Wave
Andhra Pradesh	4380	4077	536	2751	100 + 6900
Arunachal Pradesh	11	0	1	52128	0
Assam	68	0	2	852	0
Bihar	190	0	126	567	0
Chhattisgarh	501	0	270	3300	0
Goa	11	0	1	60	0
Gujarat	5709	7203	100	792	10425 + 4100
Haryana	661	0	218	172	0
Himachal Pradesh	61	0	10	22000	0
Jharkhand	80	0	04	809	0
Karnataka	7469	4753.40	1902	10185	100 + 6100
Kerala	312	62.5	3	4025	100 + 4900
Madhya Pradesh	2634	2519.89	128	2790	0
Maharashtra	2445	4794.13	2632	4100	200 + 8100
Manipur	12	0	1	1861	0
Meghalaya	4	0	14	2528	0
Mizoram	8	0	1	2300	0
Nagaland	3	0	1	1634	0
Odisha	428	0	59	3267	400 + 600
Punjab	1022	0	492	1549	0
Rajasthan	7738	4299.73	125	534	0
Sikkim	2	0	1	4514	0
Tamilnadu	4675	9231.77	1040	2297	230 + 10600
Telangana	3992	128	219	2121	0
Tripura	15	0	1	47	0
Uttar Pradesh	2020	0	2180	1124	0
Uttarakhand	552	0	139	19662	0
West Bengal	163	0	321	3221	900

Table 4
Descriptive statistics of state wise renewable energy capacity.

INDEX	Solar	Wind	Biomass	Hydro	Ocean
COUNT	28.00	26.00	28.00	28.00	28.00
MEAN	1613.07	1425.75	375.96	5399.64	1919.82
STD	2370.87	2617.75	701.93	10558.24	3888.28
MIN	2.00	0.00	1.00	47.00	0.00
25 Percentile	14.25	0.00	1.75	841.25	0.00
50 Percentile	370.00	0.00	112.50	2298.50	0.00
75 Percentile	2492.25	1921.92	282.75	3481.25	925.00
MAX	7738.00	9231.77	2632.00	52128.00	14525.00
	Rajasthan	**Tamilnadu**	**Maharashtra**	**Arunachal Pradesh**	**Gujrat**

Table 5
Attractiveness Score and Rank of India (Das, 2020, Shekhar, 2021).

Renewable Energy	RECAI Score	Rank
Solar PV	62.7	1
Solar CSP Power Plant	9.2	4
Hydro-Electricity	46.4	3
Biofuels	47.4	10
Onshore Wind Power	54.2	6
Offshore Wind Power	28.6	29
Geothermal Power	23.2	16

2.1. Effect of renewable energy in India

In the present scenario, renewable energy sector not only affects the electricity generation, but also different aspects of the country, such as economic growth, foreign investment, domestic investment, suboptimal quality of life, policy stabilization, environment sustainability and job prospectus. Equation shows the relationship between renewable energy and other sector, which is directly or indirectly effected by the renewable energy sector in Equation (Khare et al., 2016)

$$In(RE) = \beta_0 + \beta_1(EG) + \beta_2(ES) + \beta_3(FI) + \beta_4(JP) + \beta_5(SQL) \quad (1)$$

Where β is constant at different stage, RE is the renewable energy consumption, EG is the economic growth, ES is the environment sustainability, FI is the foreign investment, JP is the job prospectus and SQL is the sub optimal quality of life.

According to the solar energy data set of India, the relationship between per megawatt capacity of solar energy system, area required to per megawatt in acres and cost of solar energy in million dollars is given by the Equation (Khare et al., 2016)

$$1\ \boldsymbol{MW\ capacity\ of\ solar\ energy\ system\ in\ India} = 0.06616 \times \boldsymbol{Area\ in\ Acres} + 1.01925 \times \boldsymbol{Price\ in\ \$\ Million} - 229.02585 \quad (2)$$

In a few basic sectors such as renewable energy, waste management, green transportation, and urban farming, the Indian Institute for Human Settlements forecasted the amount of green jobs that may be produced in a year in towns and cities of various sizes. The percentage of people who are likely to embrace sustainable practices in each of the main sectors was estimated using the town's population and a proportion of people who are likely to adopt sustainable practices in each of the important industries. The Table 9 displays the factors that are influenced by generation of electricity using renewable energy system.

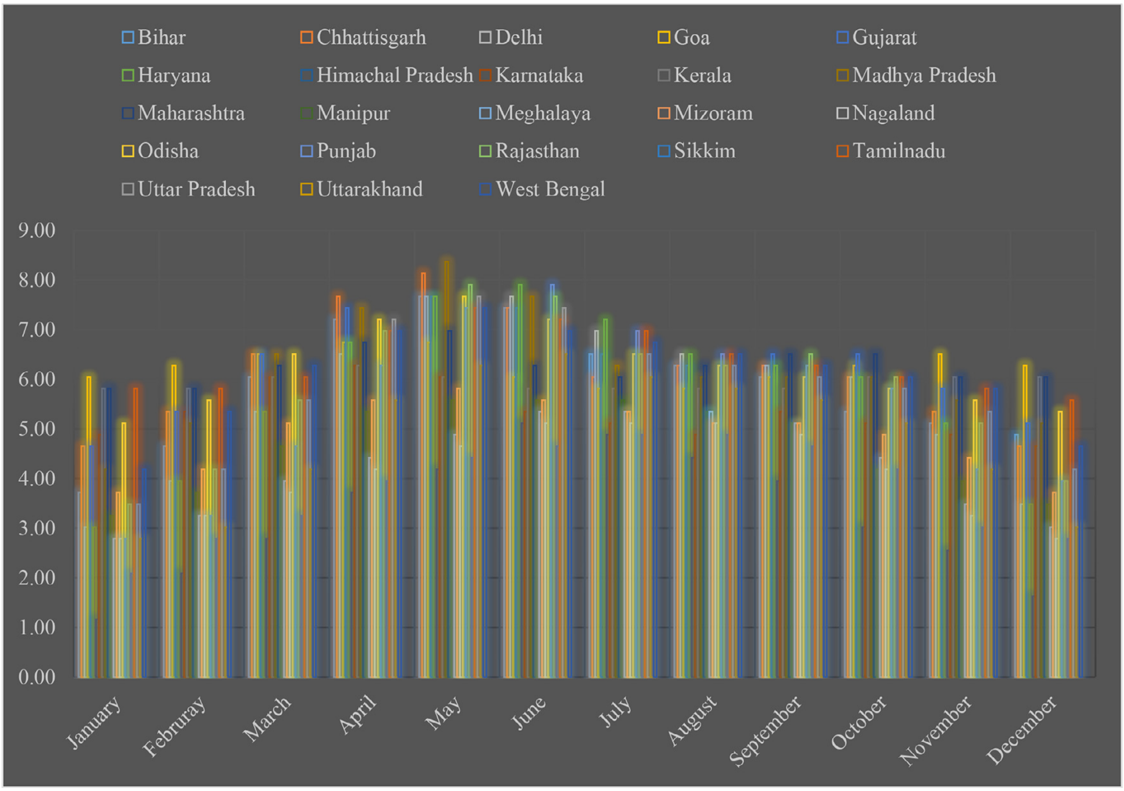

Fig. 1. Month-wise average solar radiation data set of different state of India (Das, 2020).

Table 6
Top 10 solar power plant in India and their capacity (MW) (Das, 2020, Shekhar, 2021).

S.N.	Solar Plant	Capacity (MW)	Area (Acres)	Capital Cost
1	Bhadla Solar Park, Rajasthan	2245	14000	1428.57 $Million
2	Pavagada Solar Park, Karnataka	2050	13000	1285.71 $Million
3	Kurnool Ultra Mega Solar Park, Andhra Pradesh	1000	5932.32	1000.00 $Million
4	NP Kunta, Andhra Pradesh	750	7924.76	600.00 $Million
5	Rewa Ultra Mega Solar, Madhya Pradesh	750	1590	642.86 $Million
6	Charanka Solar Park, Gujarat	615	4900	766.43 $Million
7	Kamuthi Solar Power Project, Tamil Nadu	648	2500	650.00 $Million
8	Ananthapuramu – II, Andhra Pradesh	400	5927.76	206.86 $Million
9	Galiveedu solar park, Andhra Pradesh	500	2999.85	500.00 $Million
10	Mandsaur Solar Farm, Madhya Pradesh	250MW	2636	214.29 $Million

Table 7
Top 10 wind power plant in India (Deshwal, 2021, Pathak, 2022).

S.N.	Wind Power Plant	Capacity (MW)
1	Muppandal Wind Farm, Tamil Nadu	**1500**
2	Jaisalmer Wind Park, Rajasthan	**1064**
3	Brahmanvel Wind Farm	**528**
4	Kayathar Tamilnadu	**300**
5	Dhalgaon Wind Farm, Maharashtra	**278**
6	Vankusawade Wind Farm, Maharashtra	**259**
7	Vaspet, Maharashtra	**144**
8	Tuljapur, Maharashtra	**126**
9	Beluguppa Wind Park, Andhra Pradesh	**100.8**
10	Mamatkheda Wind Park	**100.5**

The green industry in these 12 cities might create up to 650 jobs in town municipal councils, 1875 jobs in city municipal councils, and 9085 jobs in municipal corporations, according to the authors. Depending on the size of a municipality, 150–2500 jobs in renewable energy, 300–2000 jobs in waste management, 20–125 jobs in green mobility, and 80–1700 jobs in urban farming might be produced depending on the size of a municipality (Deshwal, 2021, Pathak, 2022).

According to the International Labour Organization, India's shift to a green economy might result in the creation of 3 million jobs in the renewable energy sector alone by 2030. As per July 2018 India Spend report, this industry has generated 47,000 new jobs in India in 2017, employing 432,000 people. In just one year, employment in India's green energy business surged by 12%, excluding mas-

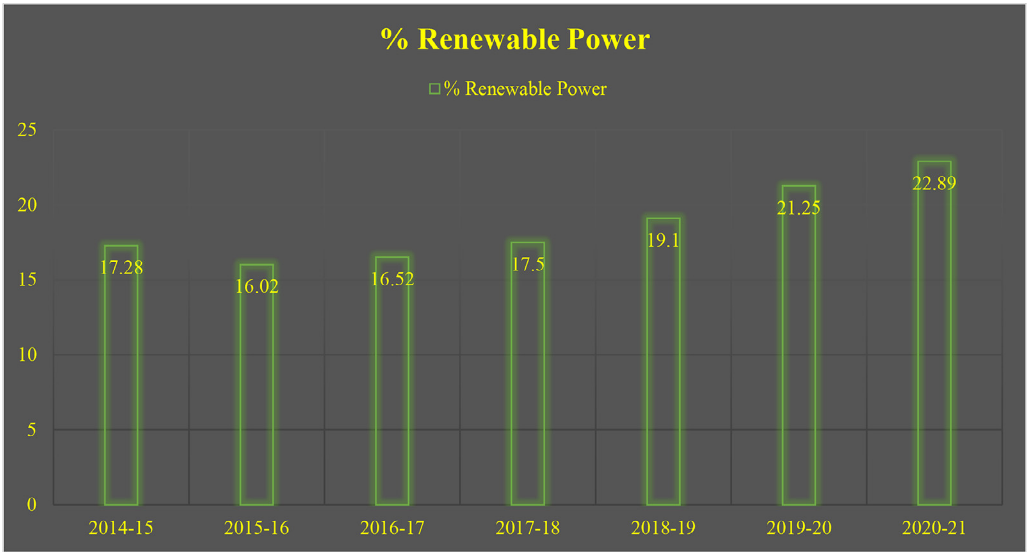

Fig. 2. Year wise % renewable power in India.

Table 8
Investment/development and government initiatives regarding renewable energy in 2021 (Deshwal, 2021, Pathak, 2022).

Months	Investment/Development	Government Initiative
March-2021	1. Strategic energy partnership between India and USA on cleaner energy. 2. Japan International cooperation agency provides loans to companies in India for renewable energy production. 3. Adani green energy announced plan to acquire a 250MW solar power project in Rajasthan.	The Union Cabinet has approved a Memorandum of Understanding between India and the French Republic in the field of renewable energy cooperation.
April-2021	1. Central electricity authority approved the uprating of 1000MW capacity hydro power plant.	The Indian renewables dashboard was established jointly by the national power authority and the center for energy financing.
May-2021	1.Singapore based Sindicatum renewable energy company Pvt. Ltd. Acquired 76% of India's solar asset portfolio	Under the national government's Rs. 4,500 crore (US$ 616.76 million) Production Linked Incentive (PLI) plan, the Indian Renewable Energy Development Agency Ltd. (IREDA) has requested proposals from solar module manufacturers for the establishment of solar manufacturing units.
June-2021	Tata power solar secure investment of US$ 93.58 million on 210MW solar project and suzlon secured investment in 252MW wind power plant Reliance industry announced investment of US$ 10.07 billion to the green energy segments.	
July-2021	NTPC-REL to invest in first green hydrogen fueling station in Leh- Ladakh	The Ministry of New and Renewable Energy (MNRE) has approved the construction of a 4,750 MW renewable energy park near the Rann of Kutch in Khavada, Gujarat, by NTPC Renewable Energy Ltd., a 100% subsidiary of NTPC.
August-2021	Copenhagen infrastructure partners have agreed to spend $200 million in renewable energy projects in India.	New laws for the acquisition and use of green energy have been recommended by the Indian government.
October-2021	Adani Green Energy is investing $3.5 billion in India's renewable energy sector to boost its position.	The Ministry of Power has released a new set of guidelines aimed at lowering financial stress for stakeholders and ensuring prompt cost recovery in the power producing industry.

Table 9
Factor that effected through renewable energy system in India.

Country	Factor That Effected Through Renewable Energy System Positive Effect = ↑, Negative Effect = ↓				
INDIA	Economic Growth ↑	Greenhouse gas emission reduction ↑	Foreign Direct Investment ↑	Domestic Investment ↑	Urbanization ↓
	Policy Stabilization ↑		Suboptimal quality of Life ↑		Environmental Sustainability ↑

sive hydropower projects. More than 721,000 Indians were employed in the green sector in 2017, accounting for over 20% of the more than 500,000 new green jobs created globally. As a result, for a country with a huge demographic dividend, a high unemployment rate, and a deteriorating environment, green jobs appear to be the way forward.

According to the 2011 Census, around 55% of Karnataka's population is aged between 20 to 59 year. An estimated 8.47 million skilled employees would be needed by 2022. 18.8 million people are anticipated to seek vocational training between 2017 to 2030. 7.5 million people will be drawn from current employees, while 11.3 million will be drawn from a new pool. This group is made up of casual labourers in the agricultural and non-agricultural industries, school dropouts, people who have finished secondary and higher secondary education, and young ladies looking for work.

- **Positive impact on the gross domestic product (GDP) by infusing investments:**

Renewable energy deployment is likely to boost country's GDP by attracting international and domestic investment. In the first half of 2018, new investments in the non-conventional energy industry totaled $7.4 billion, as India seeks to fulfill its own energy needs. In addition, the industry has attracted $7.83 billion in FDI equity inflows during the previous 10 years.

- **Renewable energy also promotes human welfare:**

The benefits of renewable energy can go well beyond traditional and restrictive metrics of economic success, and are not limited to monetary gains in terms of GDP. Harnessing of renewable energy is promoted nicely in rural parts of the nation and is serving like a catalyst for the growth. Aside from that, renewable resources help to achieve environmental benefits including reducing climate change.

3. Renewable energy: perspective of Pakistan

Exponential rise in energy demand and reduced environmental pollutants, made renewable energy sources to catch the attention of policymakers in Pakistan. According to the Pakistan's energy report, the gap between power demand and supply in 2019 was at 2000MW. Pakistan's energy business has several issues, including a demand-generation mismatch, frequent power outages, expensive electricity tariffs, and significant pollution. Many academics in Pakistan work on renewable energy systems, however owing to political instability and ineffective policymakers, their efforts do not result in a lucrative project. According to the World Bank's meteorological information, there is a lot of solar potential in Sindh, Baluchistan, and the desolate parts of Punjab. In 2010, Pakistan saw the introduction of a solar-powered electric power plant with a capacity of 178 KW. According to the experts, wind speeds of 4–9 m/s at a 10 m anemometer height and 12.5 m/s at a 50 m height are adequate for wind power plants in Baluchistan and Sindh. Fauji Fertilizers Company Energy Limited constructed Pakistan's first 50 MW wind plant in 2013. To tap into the country's potential, the Pakistan Council of Renewable Energy Technologies (PCRET), the Pakistan Council of Appropriate Technology (PCAT), the Alternative Energy Development Board (AEDB), and the Pakistan Renewable Energy Society (PRES) are working on development of new biogas technologies and biogas plants (ABC, 2022a, 2022b).

Renewable energy is a relatively underdeveloped sector in Pakistan; nonetheless, there has been an increasing interest in exploring renewable energy resources for energy generation in recent years. Renewables account for around 7% of Pakistan's total installed electricity production capacity. Hydroelectricity accounts for the majority of Pakistan's renewable energy. According to the Prime Minister's vision, the goal is to "incorporate 20% renewable energy by 2025 and 30% renewable energy by 2030." Currently, 60 million Pakistanis remain without power, and this figure is expected to rise fast as the country's population grows. Companies offering proven, innovative renewable energy solutions in Switzerland are urged to learn more about current prospects and consider visiting the market. Lots of research already to be done in the field of status of renewable energy in Pakistan, which is shown in Table 10. The important predictor of this research is tariff rate, economic growth, substitution of conventional energy source, electricity to everyone and reduction of greenhouse gas emission. Table 11 shows the renewable energy capacity and their contribution. It shows hydro power plant play significant role in the renewable energy scenario of Pakistan (ABC 2022c, 2022d).

Renewable energy, which is still in its infancy in Pakistan, has enormous growth potential due to its low cost and low environmental impact. Pakistan's Alternative Renewable Energy Policy seeks to expand renewable energy's contribution of the national power grid from 5 to 20% in 2025 and 30% in 2030. Pakistan has a diverse variety of prospects for Swiss renewable energy solutions, as well as avenues for commercial partnerships and collaboration.

By 2030, Pakistan wants to generate 5-6% of its total on-grid electricity from renewables (excluding major hydropower). Renewable energy accounted for 4.2% of total installed power capacity at the end of 2016, which was 26 GW. Pakistan has a lot of renewable energy resources, but so far only huge hydropower projects and a few wind and solar projects have used them. Renewable energy capacity is now implemented in the form of solar PV, wind, and biomass-based power plants, totaling 1136 MW. There are further chances to encourage the use of renewable energy sources such as wind, solar, and biomass. Feed-in tariffs/upfront tariffs, tax incentives, net metering, long-term refinancing facility, and micro-financing programmers were among the policies and enabling environments established by the Government of Pakistan (GOP) to encourage corporate sector participation in the RE industry. The GOP decided to open up the market and encourage more competition among private sector players for delivering electricity from renewable energy sources (i.e. wind/solar) at the best possible rates, taking into account market growth, technological advancements, recent cost reductions, and new financial mechanisms. As a result, the GOP has issued bids for competitive/reverse bidding for renewable energy projects, with the first phase of bidding for wind power projects now underway (ABC, 2022a, 2022b). Following are the sector wise details of renewable energy in the Pakistan.

- **Solar:** In Pakistan, where individuals have begun to put solar panels on the rooftops of their homes, stores, and industrial units, it is the most appealing alternative energy choice for the general public. Pakistan has a solar irradiation of 5.3 $kWh/m^2/day$. The agriculture industry, which employs 45% of the workforce and generates 20% of the country's GDP, is also benefiting greatly from this technology for irrigating areas and other associated tasks. Table 12 shows the solar power plant in the Pakistan.
- **Wind:** With a covering area of 9700 km^2, this sub-sector has the capacity to generate 43,000 MW. In 10% of Pakistan's windiest places, average wind speeds are 7.87 m/s. Pakistan plans to add 24,000 megawatts (MW) to the national system by 2030. Table 13 shows the wind power plant in the Pakistan.
- **Bioenergy:** In the country, biomass is anticipated to create 50,000 GWh per year. Pakistan's metropolitan regions create 64000 tons of municipal solid waste (MSW) every day. MSW is expected to produce 13,900 GWh of electricity. Pakistan's rural areas have vast biomass reserves and can generate 12 million m^3 of biogas each day. Pakistan's large sugar sector also uses biomass energy to create electricity for use in sugar mills. Bagasse energy output is predicted to be 5700 GWh per year, or around 6% of Pakistan's existing power producing capacity. During the current electricity crisis, the government has enabled sugar mills to sell surplus power to the national grid up to 700 MW. Sugarcane bagasse is thought to have the ability to create 2000 MW of electricity. However, most sugar mills

Table 10
Research summary on status of renewable energy in Pakistan.

Author, Journal Name, Citation of Paper/ Ref.	Objective	Method	Predictors, Keywords	Outcome
Sadiqa, [2018], Energy, 71 (Sadiqa, 2018)	Energy transition roadmap towards 100% renewable energy		Electricity price, Significance of installed technology, Desalination demand, Power to gas	The levelised cost of electricity from renewable energy declines from 106.6€/MWh in 2015 to 46.2€/MWh in 2050 in power scenario.
Kamran M. [2018], Renewable and sustainable energy review, 94 (Kamran, 2020)	Current status and future success			Renewable energy's success is crucial to Pakistan's future, and it will entice both local and foreign investors to participate in the country's energy industry.
Kamran M. [2020], Renewable Energy, 0 (Kamran, 2018)	Empowerment of renewable energy sector	SWOT analysis	Socio, Economic and Environment impact Renewable energy, SWOT analysis	Authentic policy based strategies are ensure to the retain ability of renewable energy sector towards secure and sustainable Pakistan
Wang Y.[2020], Sustainable cities and society, 91 (Wang, 2020)	Strategic renewable energy resource selection	SWOT Fuzzy AHP approach	Economic, Environmental, Technical, Socio-political	In order to develop the RE power plant, an appropriate policy plan and package should be created in the country for both the commercial and governmental sectors.
Shahid M. [2020], Journal of cleaner production, 16 (Shahid, 2020)	Electricity supply pathways based on renewable energy		Electricity demand analysis, Scenario based analysis, emission assessment, Electricity modelling, Sustainability	The study finding that the electricity generation through non-conventional energy source is five times more than the solar, wind and hydro scenario
Irfan M.[2021], Sustainable production and consumption, 39 (Irfan, 2021)	Public acceptance and Utilization of renewable energy	Theory of planned behavior, Structural equation modeling	Perception of self-effectiveness, Awareness, Renewable energy, Consumers	The outcomes of this study can assist policy maker, experts and consumers in understanding renewable energy consumption and gaining awareness about environmental problems
Ullah H.Q. [2022], Energy, 0 (Ullah, 2022)	Renewable energy policy and CO_2 emission	Observation through resources	CO2 emission, electricity price, Paris agreement, Indigenous energy resources	Pakistan can achieve their electricity bill saving 23% per annum due to the renewable energy sources

Table 11
Renewable energy capacity and contribution (%) (ABC 2022a).

Renewable Energy System	Capacity (MW)	Contribution %
Hydro	10002	25
Solar	737	2
Wind	1236	3
Bioenergy	432	1
Geothermal	0	0

are located in distant rural regions that are not even linked to the national grid, it is currently impossible to receive additional power from them owing to system limits. The integration of power generated by biomass energy into the national grid can help to alleviate the country's electricity crisis. Forests provide livelihood, fuelwood, and shelter to a vast number of people in Pakistan's rural areas. Many people take use of the woodlands in non-sustainable methods to meet their home energy demands. As a result, forest loss and degradation pose a significant threat (ABC 2022c).

Table 12
Solar power plant in Pakistan (ABC, 2022a, 2022b, 2022c).

S.N.	Name of Project	Capacity (MW)	Land area	Cost
1	M/s QA Solar Pvt. Ltd.	400	6500acres	700 $Million
2	M/s Appolo Solar Pakistan Ltd.	100	1800	200 $Million
3	M/s Crest Energy Pakistan Ltd.	100	1600	225 $Million
4	M/s Best Green Energy Pakistan Ltd.	100	2000	230 $Million
5	Harappa Solar Pvt. Ltd	18	500	75$Million
6	AJ Power Pvt. Ltd.	12	350	60$Million

Table 13
Wind Power Plant in Pakistan (ABC, 2022a, 2022b, 2022c).

Name of Wind Power Plant	Capacity (MW)	Place
Jhimpir Wind Power Plant	50	Jhimpir, Sindh
Fauji Foundation Wind Energy I & II	50	Gharo, Thatta
Artistic Energy Pvt. Ltd	49.3	Jhimpir, Sindh
Tricon Boston Consulting Corporation Wind Power Plant	50*3 = 150	Jhimpir, Sindh

- **Hydropower:** Pakistan's hydropower sector has a potential of 60 GW, according to the International Renewable Energy Agency (IRENA). The government, on the other hand, is unable to pursue it actively since vast sums of foreign cash are required as capital expenditure. Nonetheless, it remains the cheapest source of energy in the country's energy mix. Smaller installations may be found all around the nation. The micro-hydropower industry is still in its early stages of development. Micro-hydro power plants have been supplying energy to 40,000 rural homes since the mid-1980s. The majority of the plants are located in the Northern Areas and Chitral and is community-based. Small hydropower is another interesting alternative for generating electricity off the grid. The country has 128 MW operational capacity, 877 MW capacity plants are under construction, and roughly 1500 MW of capacity available for future expansion.
- **Energy Efficiency and Conservation:** Pakistan has set a goal of saving 3 million tons of oil equivalents (MTOE) by 2023 as part of its Strategic Plan (2020–2023). Through energy efficiency and conservation, the country has the ability to conserve up to 10–15% (10-12 MTOE) of its primary energy supply. Spinning and processing textiles have the potential to save 3.5% and 18.4% of energy, respectively.

According to the solar energy data set of Pakistan the relationship between per megawatt capacity of solar energy system, area required to per megawatt in acres and cost of solar energy in million dollars is given in Eq. (3).

$$1\ \boldsymbol{MW\ capacity\ of\ solar\ energy\ system\ in\ Pakistan} = 0.02704 \times \boldsymbol{Area\ in\ Acres} + 0.34969 \times \boldsymbol{Price\ in\ \$\ Million} - 22.64032 \tag{3}$$

3.1. Effect of renewable energy system in Pakistan

There are many ways to overcome the challenges that RETs face. Pakistan's government must take strong measures to overhaul its energy strategy to increase energy security and should make a move towards a sustainable energy future. Subsidies, feed-in tariffs, and accounting for negative and positive externalities should all be used to decrease the competitive gap between RETs and fossil fuels. Issues like infrastructure, financing, and technological availability must also be addressed. Market penetration will naturally develop when the issues confronting RETs are addressed, and support for tackling additional RETs challenges will follow.

Although there will be bidirectional causal links between renewable energy and fossil energy in the near future, the research shows that for short term, there are unidirectional causalities flowing from terrorism and fossil energy to GDP, GDP to renewable energy, and income inequality to fossil energy (ABC 2022a, 2022b). Pakistan should also continue to encourage renewable and fossil energy consumption by (or through) growing diplomatic efforts to address political and military conflicts throughout the world, particularly in the Middle East. Improving the quality of Pakistan's power supply and strengthening the system's security requires investment and operational changes. But it is necessary to identify the answer of following question, how much variable renewable energy can the country's power system absorb? What level is economically optimal?

4. Status of renewable energy in Bangladesh

There is enough space for expansion of Renewable energy in Bangladesh. According to the World Bank, Bangladesh is among the top six world economies in terms of yearly GDP growth as of 2019. To achieve its energy needs, the country today mostly relies on natural gas and biofuels. The administration announced to install rooftop solar systems on all educational institutions to provide additional solar power to the grid. Bangladesh plans to replace its fossil-fuel fleet with solar-powered vessels as well. In addition, this year, the government will adopt the Electric Vehicle Registration and Operation Guidelines, which were proposed in 2018, and commence construction of solar charging stations for EVs with an average capacity of 20 kilowatts. For the time being, the future seems bright, even if it is still far away. According to the REN21 research, Bangladesh, along with China, India, and Japan, leads the area in renewable energy development. Bangladesh has one of the most effective off-grid renewable energy systems in the world, according to the World Bank economist Dandan Chen (ABC 2022f, Baky, 2017). According to a report published in 2019 (ABC 2022f), coastal land and riverbanks are constantly eroding and flooding. Bangladesh must overcome a slew of extra hurdles in order to create a speedy turnaround in the national electricity grid. Lack of incentives for private investors such as a lack of cooperation between ministries, procedural obstacles, restricted budget allocation to RES based projects, poor technical uptake, a lack of understanding and execution of green construction rules, and more are just a few examples of hurdles in the growth of RES. Literature is already available for status of renewable energy in Bangladesh, which is shown in Table 14. The important predictor of this research is tariff rate, economic growth, substitution of conventional energy source, electricity to everyone and reduction of greenhouse gas emission. Table 15 shows the year-wise renewable energy capacity in Bangladesh. Table 16 shows the solar energy project in Bangladesh.

Main challenges to biomass in Bangladesh are the high cost and difficulty in gathering significant volumes, making it costly. Due to its geographical location wind has always been a difficult resource to assess in Bangladesh. According to a panel of specialists, Bangladesh's wind potential, particularly onshore, is limited. Even if there are unproven claims of enormous potential, the offshore potential is unclear. In terms of finance, it's difficult to remark because there aren't any extensive environmental and technical investment-grade studies on offshore wind potential (ABC 2022f, Baky, 2017).

5. Status of renewable energy in Sri Lanka

Sri Lanka's government hopes to achieve energy independence by 2030. The objective is to enhance the country's power generation capacity from 4,043 megawatts to 6,900 megawatts by 2025, including a significant increase in renewable energy. By South Asian standards, Sri Lanka has already achieved a 98% grid connection rate. Thermal power, hydropower, and other non-conventional renewable energy sources are the three primary sources of electricity in Sri Lanka. Between 2018 to 2037, Sri Lanka plans to increase its energy generating capacity by 842 megawatts of major hydro, 215 megawatts of small hydro, 1389 megawatts of solar, 1205 megawatts of wind, 85 megawatts of biomass, 425 megawatts of oil-based power, 1500 megawatts of natural gas, and 2700 megawatts of coal power. The total yearly power consumption is expected to be roughly 14,150 GWh. Annual electricity consumption is expected to climb by 4.9% over the next 20 years, a rate capped by high prices (ABC 2022i, Jeyatharshini, 2002).

Sri Lanka will need to build a capacity to meet current and future electricity demand, which is estimated to grow at a pace of about 5% per year. Sri Lanka has a total energy production capacity of 40 GWH,

Table 14
Research summary on status of renewable energy in Bangladesh.

Author, Journal Name, Citation/Ref	Objective	Method	Predictor	Keywords	Outcomes
Baky [2018], Renewable and Sustainable Reviews, 68 (Baky, 2017)	Development of renewable energy	Based on the data set	Electricity generation capacity, greenhouse gas emission	Renewable energy, Electricity generation	The government of Bangladesh has set up a plan to generate 5% of the country's total electricity from renewable sources within 2015 and 10% within 2020
Uddin et al. [2019], Energy Procedia, 28 (Uddin, 2019)	Status of renewable energy	Based on the observation	Installed capacity, Capital investment, Energy consumption	Sustainable energy, Solar PV, Wind energy	To meet the near future demand Bangladesh needs more sophisticated research facilities and skilled manpower for exploration activities both inland and offshore areas.
Gulagi et. Al. [2020], Renewable Energy, 0 (Gulagi, 2020)	Renewable energy policy and transition scenarios	Case study	Greenhouse gas emission, Carbon credit	Energy transition, Energy economics	Bangladesh will reach 94% electricity generation through renewable energy system by 2050
Bhuiyan et al. [2021], Clean Engineering and Technology, 3 (Bhuiyan, 2021)	Renewable and sustainable energy resources	Based on the data set	Socio-economic infrastructure, Electricity generation	Solar energy, Wind energy, Hydro energy	The government supported for capacity build up to renewable energy resources and imported the renewable and sustainable energy related machinery should be tax free
Hasan [2022], Renewable and Sustainable Reviews, 0 (Hasan, 2022)	Sustainable energy sources present and future prospect	Based on the observation	Power grid disruptions, Global warming	Energy sources, Sustainability	

Table 15
Year wise renewable energy capacity (MW) of Bangladesh (ABC, 2022f, Baky, 2017).

Year	Solar	Wind	Hydro	Biomass	Biogas	Others (Tidal, Wave)	Total
Until 2018	350	2.9	230	0	1.08	0	583.98
2019	84	0	0	0	1	0	85
2020	100	38	0	0	2	0	140
2021	120	80	0	15	3	0	218
2022	150	120	0	15	4	0	289
2023	165	170	0	15	4	0	354
2024	165	170	0	15	4	0	354
2025	165	170	0	15	4	2	356

Table 16
Solar energy project in Bangladesh (ABC, 2022f, Baky, 2017).

Implemented Solar Projects (Fiscal Year 2018-2019)	
Name of the Project	**Location**
7.4 MW Grid Connected Solar PV Power Plant	Kaptai, Rangamati
Solar Street Lighting Program in 8 City Corporations	City Corporations of Bangladesh
28 MW (20 MW AC) Solar Park	Cox's Bazar
8 MW (AC) Solar Park	Tetulia, Panchagarh
Ongoing Solar Projects	
Name of the Project	**Location**
32 MW (AC) Solar Park	Dharmapasha, Sunamganj
50 MW (AC) Solar Park	Gouripur, Mymensingh
200 MW (AC) Solar Park	Teknaf, Cox's Bazar
200 MW (AC) Grid Tied Solar PV Power Project	Sundarganj, Gaibandha
30MW (AC) Solar Park	Gangachara, Rangpur
100 MW (AC) Solar Park	Mongla, Bagerhat
Future Solar Projects:	
Name of the Project	**Location**
0.813 kW Grid Tied Rooftop Solar PV Project	Jamalpur
50 MW Grid Tied Solar Power Plant	Bariahaat
50 MW Grid Tied Solar Power Plant	Chuadanga
50 MW Grid Tied Solar Power Plant	Netrokona
100 MW Solar Photovoltaic Power Plant	Feni

Table 17
Research summary on status of renewable energy in Sri Lanka.

Author/ Journal/ Citation/Ref.	Objective	Method	Predictor	Keywords	Outcomes
Jeyatharshini [2002], Energy for Sustainable Development, 0 (Jeyatharshini, 2002)	Renewable energy market	Based on observation	Economic growth	Renewable energy, GDP,	
McEachern [2008], Energy Policy, 58 (McEachern, 2008)	Socio-geographic perception in solar energy technology	Diffusion theory	Government policy	Solar innovation and diffusion	The findings add to the idea of innovation diffusion and provide policy recommendations for organizations working to promote solar energy in poor countries.
Priyantha [2014], Renewable Energy, 0 (Priyantha, 2014)	Regulation for renewable energy	Data analysis based on policy framework	Tariffs rate, Renewable energy portfolio	Renewable energy, Regulation, Avoided cost	Renewable energy has benefited from the installation of net-metering for renewable energy-based distributed generation, as well as limited green-tariff interventions.
Kolhe [2015], Sustainable energy technologies and assessment, 101 (Kolhe, 2015)	Techno-economic sizing of renewable energy system	Modelling and assessment	Net present cost, Hybrid system capacity	Renewable energy fraction, Rural electrification	The hybrid system has been proved to be economically viable whether operated off-grid or linked to the grid.
Gunaratne [2021], Journal of cleaner production, 3 (Gunarathne, 2021)	Diffusion of cleaner production	Diffusion Theory	Demand pull and supply push factor	Efficient choice, Managerial technologies	Due to a number of factors such as efficient choices, forced selection, and fashion, cleaner production is trickling down from highly polluting industries and export-oriented sectors to other peripheral sectors in Sri Lanka.
Dasanayaka et. al. [2022], Cleaner engineering and technology, 0 (Dasanayaka, 2022)	Renewable energy utilization towards economic growth	Structural equation modelling	Economic growth, Trade balance	Renewable energy, Sustainable development	While renewable energy consumption has yet to have a significant direct impact on Sri Lanka's GDP, it does have an indirect positive impact through capital formation and an indirect negative impact through trade balance, according to the research.

Table 18
Electricity generation capacity (MW) 2015–21 (ABC 2022i, Jeyatharshini, 2002).

Year	Wind	Small Hydro	Solar	Biomass
2016	124	313	16	34
2017	144	338	31	49
2018	244	363	46	74
2019	442	388	219	99
2020	690	413	392	124
2021	887	438	563	129
Plant Load Factor	30	39	17	70

which includes a Chinese-built coal power plant that generates 45% of the country's electricity. Insufficient rainfall has hampered hydropower production, causing the government to impose power cutbacks in early 2019 owing to a generation capacity constraint (McEachern, 2008). The literature available so far regarding status of renewable energy in Sri Lanka, is shown in the Table 17. The important predictor of this research is tariff rate, economic growth, demand pull and supply push factor, electricity to everyone, net present cost and reduction of greenhouse gas emission.

According to data collected before to a project's launch, Sri Lanka's total primary energy supply has expanded significantly, whereas recorded power consumption is increasing at a rate of 6% each year. It has revealed a significant local effect in terms of energy supply security, air pollution, environmental degradation, water shortages, harm to national heritage, and a direct impact on human life. Table 18 shows the electricity generation capacity (MW) of Sri Lanka from 2015 to 21. Table 19 shows the descriptive statistics of renewable energy system in Sri Lanka. Tables 20 and 21 shows the details of solar power and wind power plant of Sri Lanka.

6. Maldives: towards renewable energy system

In 2008, the Maldives became the first country in the world to have universal access to electricity. Due to import of diesel, which is delivered in small quantities by boat to islands, Maldives one of the highest power generating costs in South Asia. Electricity was first brought to the Maldives in 1949, with a 1014 MW diesel engine serving 50 residences. By the end of 2008 almost seven regional utility companies formed. Currently they provide electricity to 9 islands. Primary energy source in Maldives depends on imported fossil fuel for electricity generation. Large amount of imported diesel is used for electricity generation and transportation (ABC 2022l, Keiner, 2022, Liu, 2018). Around 83% of diesel oil is used in electricity production at resorts. Status of renewable energy in Maldives, is shown in the Table 22 as per the literature available so far. The important predictor of this research is relative cost of energy, transportation cost and carbon emission, institutional, financial and political factor and reduction of greenhouse gas emission.

Government of Maldives continuously provides affordable energy while doing privatization of power sector. They encourage energy efficiency in production, distribution and usage. Maldives is located on the equator and therefore receives abundant solar energy around 400 million MW per annum. Daily average irradiation is 4.5 to 6 kwh/m^2/day approximately.

Presently they utilize:

- Solar PV power generation for resorts, telecommunication and navigation lights etc.
- Solar thermal system for water heating in resorts and hotels.
- Wind power generation for pilot system.

Table 19
Descriptive statistics of renewable energy system in Sri Lanka (ABC 2022i, Jeyatharshini, 2002).

	Wind	Small_Hydro	Solar	Biomass
Count	6	6	6	6
Mean	421.8333	375.5	211.1667	84.83334
Standard Deviation	311.84	46.77072	225.5566	39.16844
Standard Error	127.3081	19.09406	92.08308	15.99045
Lower 95% CL Mean	94.57735	326.4171	-25.54044	43.72858
Upper 95% CL Mean	749.0893	424.5829	447.8738	125.9381
Minimum	124	313	16	34
Maximum	887	438	563	129
Skewness	0.4801327	0	0.6048054	-0.1077584
Kurtosis	1.695841	1.731429	1.821198	1.482462

Table 20
Solar power plant in Sri Lanka (McEachern, 2008).

Solar farm	Location	Capacity (MW)
Hambantota	06°13′34″N 81°04′35″E	1.2
Laugfs	06°13′47″N 81°04′48″E	20.0
Maduru Oya	07°38′53″N 81°12′25″E	100.0
Sagasolar	06°13′54″N 81°05′08″E	10.0
Solar One Ceylon	07°58′30″N 81°14′10″E	12.6

- They also used biomass, Landfill, wave, tidal energy, current energy etc.

To encourage energy efficient technology a number of RE based projects are developed in last few years which are tabulated as in Table 23:

Maldives does not have any proven reserves of fossil fuels. However, it has abundant renewable energy resources, including solar, wind, and ocean, and the possibility to produce green hydrogen fuel with the surplus of renewable energy produced in the islands. electricity capacity and generation for the year 2020 is shown in Table 24. Fig. 3 shows the Net capacity change (%) in MW.

7. Insights of renewable energy in Bhutan

Bhutan has long sought to grow in a sustainable manner, and the country's "Gross National Happiness" (GNH) system demonstrates that it now prioritizes both its inhabitants' well-being and environmental conservation. Environmental protection, preservation, socioeconomic growth, and cultural promotion, as well as excellent governance, are all priorities. It is an ecological leader and a net-carbon-negative nation as a result of its carbon sequestration. Thanks to significant hydropower capacity, it absorbs far more carbon than it emits.70% of the nation is covered with forests.

In 2016, hydropower contributed one-fifth of domestic revenue and one-third of export revenues, making it an important part of the national economy. The country's overall energy usage has been rapidly increasing. In terms of energy consumption, industry and transportation are the fastest increasing industries. In the period 2005–2014, demand is increased by more than double. Converting biomass (mostly fuel-wood) to electricity, which serves around one-third of the world's population hydropower accounts for around one third of total energy demand.

Bhutan can meet its energy needs while simultaneously creating economic possibilities and presenting itself as a global key to sustainable growth and well-being by shifting to sustainable energy in all energy sector applications. The Renewables Readiness Assessment (RRA) was established in partnership with the International Renewable Energy Agency (IRENA) by the Ministry of Economic Affairs' Department of Renewable Energy (DRE) with the objective of aiding the country's efforts to expand the usage of various renewable energy technologies. The Bhutan RRA has benefited the Department of Renewable Energy's and other relevant governmental and private sector institutions. In December 2018, IRENA and the DRE co-hosted an initial "expert consultation workshop" that was crucial in building the groundwork for the RRA's findings and recommendations (ABC 2022o, 2022p).

In Bhutan, hydropower is the primary source of renewable energy. The dzongkhags (districts) of Lhuntse, Mongar, and Wangdue are thought to have excellent hydropower potential. The hydropower potential is predicted to be greater than 41 GW, while the DRE–MOEA 2016b estimates the constrained technical potential as 26.6 GW. Despite its rugged geography, the country has a pleasant climate. Several

Table 21
Wind power plant in Sri Lanka (Priyantha, 2014).

Farm	Location	Capacity (MW)
Ambewela Aitken Spence	06°50′36″N 80°48′47″E	3
Hambantota	06°08′46″N 81°06′47″E	3
Madurankuliya	08°00′46″N 79°43′37″E	12
Mampuri-I	08°00′37″N 79°43′24″E	10
Mampuri-II	07°58′35″N 79°43′53″E	10.5
Mampuri-III	08°00′35″N 79°43′44″E	10.5
Thambapavani Wind Farm	09°03′01″N 79°47′13″E	103.5
Nala Danavi	08°05′23″N 79°42′33″E	4.8
Nirmalapura	07°57′53″N 79°44′07″E	10.5
Pawan Danavi	08°02′56″N 79°43′08″E	10.2
Pollupalai	09°34′40″N 80°19′12″E	12
Seguwantivu	08°02′48″N 79°48′54″E	9.6
Uppudaluwa	07°58′52″N 79°46′33″E	10.5
Vallimunai	09°33′54″N 80°20′12″E	12
Vidatamunai	08°04′00″N 79°47′38″E	10.4
Willwind	06°36′40″N 80°44′44″E	0.85

Table 22
Research summary on status of renewable energy in Maldives.

Author, Journal Name, No. of Citation/ Ref.	Objective	Method	Predictor, Keywords	Outcomes
Keiner et al. (2022), Applied energy, 0 (Keiner, 2022)	Limited land area complicates renewable energy deployment in archipelagos	Floating offshore technologies	Relative cost per final energy, Energy transition, solar PV, wave energy converter, floating PV	In 2030, a fully renewable energy system with a relative cost per final energy of 120.3$/Kwh will be theoretically achievable, and floating solar PV and wave energy converters will be used to defossilize islands with limited land area.
Liu (2017), Applied Energy, 30 (Liu, 2018)	Feasible analysis of renewable energy-driven island	Mutual adaptability	Transportation cost and carbon emissions, Water resource, energy supply system, water supply system, Mutual Adaptability	With lower renewable energy costs, the Maldives can implement a zero input energy and water (ZIEW) system.
Alphen et al. (2008), Renewable and sustainable energy reviews, 25 (Alphen, 2008)	Evaluates different policy options to develop domestic market for RET	Stack holder analysis	Nature of market and finance, Market barriers, Stakeholder analysis, policy evaluation, SIDS	Sustainable renewable energy projects are being developed to boost renewable capacity while lowering costs.
Alphen et al. (2008), Renewable and sustainable energy reviews, 40 (Alphen, 2008)	Enhance the current fossil foil based lock in situation and increase the chances of a successful transfer and diffusion of RETs	Technology transfer	Institutional and political factors, Innovation System, technology transfer, project evaluation, developing states	RE program strengthen to processes necessary in an innovation system
Alphen et al. (2007), Renewable and sustainable energy reviews, 71 (Alphen, 2007)	Promote sustainable energy	HOMER, Multi-criteria analysis	Financial aspects, Resource assessment, RE technology, adoption multi-criteria	Fully RE system configuration is not financially viable in the Maldives
Fulhu (2019), Energy for sustainable development (Fulhu, 2019)	Adjusting end use to fit supply constraint is essential for energy security	Voluntary demand participation (VDP)	Micro-grid, Demand side management, energy transition, micro-grids, demand response	Completely RE cant reasonably substitute for fossil fuel to supply demand

Table 23
Renewable energy project in Maldives (ABC 2022l, Keiner, 2022, Liu, 2018).

Type	Capacity	connectivity	Grant by
Solar-diesel hybrid system	12.8 kWp PV panels + 108 kWh battery + 2 x 32 kW gen sets	Now grid connected and contributes to 50%	EU,ADEME,UNDP
Solar-wind-diesel hybrid system	PV(2.64 kW) + Wind (24 × 1.8 kW Skystream) + Diesel Gen (48 kW) + Battery (96 kWh)	standalone	Maldive Gas (Loan)
Solar-wind-diesel hybrid system	PV (2.64 kW) + Wind (18 × 1.8 kW Skystream) + Diesel Gen (32 kW) + Battery (96 kWh)	standalone	Maldive Gas (Loan)
Solar-wind-diesel hybrid system	PV(5.28 kW) + Wind (6 × 1.8 kW Skystream) + Diesel Gen (18 kW) + Battery (96 kWh)	standalone	Maldives Gas (Loan)
Wind-solar system	3.5 kW wind + 5 kW solar	standalone	Powering community centre (UNIDO grant)
Rooftop solar system (total 5 sites)	395 kW Solar	Grid connected feeding	Govt. owned, operated by STELCO And Grant Aid by Japan

Table 24
Electricity capacity and generation in 2020 (Data from IRENA) (ABC 2022l, Keiner, 2022).

Capacity	MW	%
Non Renewable	272	94
Renewable	17	6
Hydro/Marin	0	0
solar	15	5
wind	1	0
Total	289	100

areas have good solar resources. Because of the country's high altitude and rugged terrain, satellite readings aren't as accurate as they are in other parts of the world. The theoretical solar potential is 6 terawatts (TW) while the restricted technical potential is 12 GW, according to the DRE–MOEA (ABC 2022p, 2022q).

Bhutan's overall wind pattern is governed mostly by the seasonal monsoon, which means that wind speeds are strongest from November to April and lowest during rest of the year. This corresponds to seasons when hydro resources are sparse, and it allows for the diversification of energy supply by taking advantage of the seasonal complementarity availability of wind and hydro resources.

The 11th FYP (five-year plan) 2013–2018 sought to promote hydropower and other renewable energy technologies by developing institutional capacities, people capabilities, and actual sectorial plans, including a renewable energy master plan. The 12th FYP 2018–2023 emphasizes the deployment of pilot renewable energy projects while continuing to develop key legislative and institutional frameworks. Thermal energy accounts for 72% of Bhutan's energy requirement, with electric-

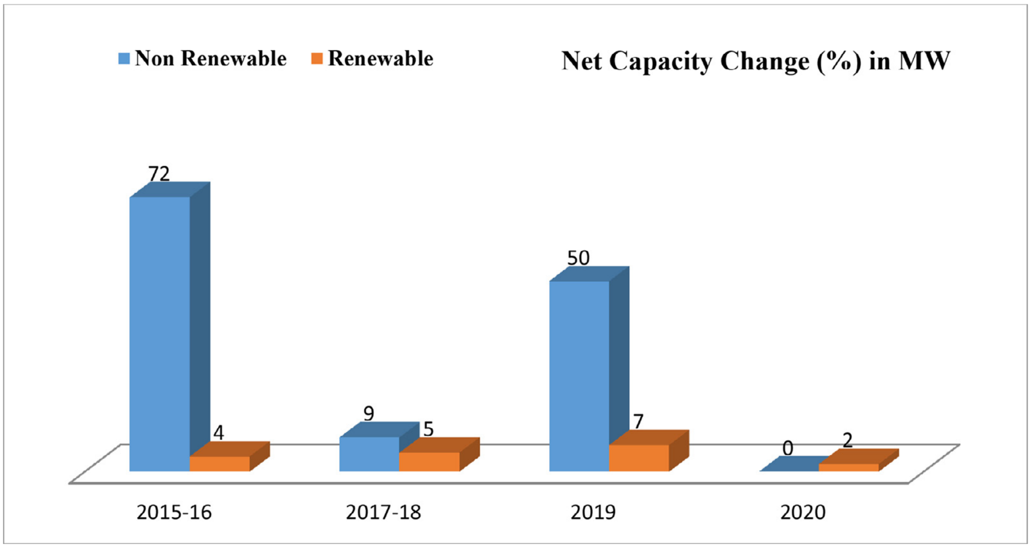

Fig. 3. Net capacity change (%) in MW (Liu, 2018).

Table 25
Renewable energy capacity in Bhutan (ABC 2022q).

Small hydro power plant	Capacity by 2025 (MW)	
	Base Case 67.5	High Case 110
Wind	5.1	7.8
Solar	6.1	11.9
Biomass	1	8.1
Total	79.7	137.8

ity accounting for only 28%. Biomass is the most frequent source of thermal energy, accounting for 36% of total demand in the form of fuelwood, biogas, and briquettes. Diesel, coal, and other petroleum products (petrol, kerosene, and LPG) are in second, third, and fourth place, respectively, with 16%, 15%, and 5% of demand met.

Bhutan's installed capacity is dominated by hydropower generating plants, which account for 1614 MW of the country's total capacity of 1 623 MW in 2018. Medium, large, and mega hydropower plants account for 98% of total hydropower capacity, with the Tala Hydropower Plant alone accounting for more than 1 GW. The remaining capacity is provided by diesel generators, wind turbines, and small solar plants. Diesel generators provide a total of 8 MW, with wind energy providing another 0.6 MW. Solar PV has been employed in small-scale on-grid and off-grid applications. Around 2400 solar PV systems were scheduled to be active in 2014, providing around 143 MWh of power. Table 25 shows the renewable energy capacity in Bhutan.

Due to significant cost reductions in solar PV and onshore wind in recent years, current costs are already lower than the estimates utilized for these LCOE calculations when compared to IRENA's worldwide costing database. According to IRENA data, project costs for solar PV is varied from 4 BTN/kWh to 16 BTN/kWh in 2018. Onshore projects are being developed at rates ranging from 3 BTN/kWh to 7 BTN/kWh, according to IRENA's wind prices database, making small scale solar PV is a viable alternative to replace or complement off-grid diesel and petrol gen-sets with typical generating costs of around 17.4 BTN/kWh. Wind LCOEs are projected to be higher in Bhutan due to the scarcity of accessible sites and lower wind speeds. The dzongkhags of Thimphu, Paro, Haa, Wangdue Phodrang, Punakha, and Phuentsholing are having charging stations. Electric taxis have the potential to revolutionize the transportation industry (ABC 2022o, 2022p).

8. Insights of renewable energy in Nepal

Nepal's primary source of energy is biomass combustion, solar and wind power are viewed as crucial supplements to help the country overcome its energy issue. Hydroelectricity is Nepal's most established renewable energy source. The majority of Nepal's electricity comes from hydropower, but the country is trying to enhance solar power's position in its energy mix. In Nepal, average global solar radiation ranges from 3.6 to 6.2 kWh/m2/day, the sun shines for about 300 days a year, the number of sunlight hours totals over 2100 hours per year, with an average of 6.8 hours of sunshine per day and an average insolation intensity of around 4.7 kWhm2/day, and the sun shines for about 300 days a year. The commercial potential of a solar power system is around 2100MW. In December 2017, Nepal launched its largest wind-solar power system to serve rural houses in Hariharpurgadi village, Sindhuli district, as part of the South Asia Sub Regional Economic Cooperation Power Plant Expansion Project. Every day, the system may create 110 kilowatt-hours of electricity (ABC 2022r, Suman, 2021, Gurung, 2011). The country also has a mini-grid wind-solar system in the rural village of Dhaubadi in the Nawalparasi district, which delivers 43.6 kilowatt-hours of electricity each day. Table 26 shows the research summary on status of renewable energy in Nepal. Table 27 shows the capacity change (%) in renewable energy in Nepal.

9. Outcomes

As per the above discussion in Indian subcontinent, India dominates other countries in the tremendous way. The India's renewable energy capacity is in GW and other countries have capacity in MW. Table 28 shows the comparative analysis between renewable energy capacities in each of the country of Indian subcontinent.

In Indian subcontinent, renewable energy systems are contributing for the economic growth. Other positive effects are foreign direct investment, domestic investment, policy stabilization, shared ownership models, human development and service growth. The significant effect of renewable energy sector in the Pakistan is reduction of terrorism activity. Table 29 shows the comparative analysis of factor that effects the renewable energy generation in different countries of Indian subcontinent.

In India, major contribution of electricity generation through the solar, hydro and biomass power plant. In the Bangladesh biomass energy system play critical role in the renewable energy sector and on the other hand in the Pakistan major contribution in the renewable energy sector

Table 26
Research summary on status of renewable energy in Nepal (ABC 2022r).

Author, Journal Name, Citation/Ref	Objective	Method	Predictor, Keywords	Outcomes
Surendra [2011], Renewable and Sustainable energy review, 92 (Surendra, 2011)	Opportunity and challenges in renewable energy	Based on the data	Socio-economic, Political, Hydro power, Developing country	Given the diversity of available resources as well as socioeconomic and geophysical conditions, energy policy should concentrate on the proper hybridization of various energy solutions to meet both the affordability and acceptability of the local community.
Gurung [2011], Renewable Energy , 36 (Gurung, 2011)	Renewable energy for rural electrification	Data Analysis	Economic, Environment, Rural electrification Micro-hydropower	To provide micro-hydro-based energy to Nepal's most rural and impoverished villages, a more systematic and complete study supported by research and development is required.
Gurung [2012], Energy Policy, 39 (Gurung, 2012)	Renewable energy for rural electrification	Data Analysis	Environment, Political	This paper provides a comprehensive analysis of Nepal's energy situation, as well as current regulations and incentives targeted at increasing the usage of renewable energy resources in rural areas that are distant and underprivileged.
Gurung [2013], Energy Policy, 14 (Gurung, 2013)	Gaps and opportunity in renewable energy		Percentage energy mix, Primary energy demand	If the existing renewable resources are efficiently utilised, RETs may provide significant chance to enhance Nepal's vulnerable rural energy infrastructure.
Poudyal [2019], Renewable and Sustainable energy review, 57 (Poudyal, 2019)	Mitigating energy crises with renewable energy	Data Analysis	Ongoing energy crisis, Demand Forecast	Our findings show that renewable resources are essential not just for alleviating the current energy crisis, but also for assuring Nepal's long-term energy independence by generating reliable and sustainable energy supply.
Suman [2021], Renewable and Sustainable energy review, 2 (Suman, 2021)	Climate change adaptation and mitigation	Based on the data	Social, economic, and environmental benefits	According to this research, Nepal's government should focus its efforts on energy policy reviews in order to address local energy demand and climate change concerns by utilising renewable energy resources at the local level, which has global implications.

Table 27
Capacity change (%) in renewable energy in Nepal (ABC 2022r, Suman, 2021).

Renewable Energy Source	2015-20	2019-20
Hydro/Marine	+65	+10.6
Solar	+60	+10.2
Wind	+352	+19.2
Bioenergy	+188	0
Geothermal	0	0

through the hydro power plant. Nepal, Bhutan and Maldives are the new player in the field of renewable energy system. In the terms of limitation, after the whole assessment, it is also find out, none of the country doesn't use the electricity generation through the tidal energy system. In India, there are lots of possibility of electricity generation through the tidal energy system at the location of Gulf of Kutch and Gulf of Khambhat. Table 30 shows the possible location for tidal power plant in Indian subcontinent. Bangladesh is also one of the country, where number of location such as Sandwip, Cox's bazar, Hiron Points, Golachippa, which have sufficient number of tidal range to generate the electricity through the tidal power plant. In the Maldives also there are number of location for the electricity generation from the tidal power plant. Cocoa Island, Veligandu Island, Thulusdhoo island, Hulhumale Island and Fulhadhoo Island are the possible location for the electricity generation through the tidal power plant, where the tidal range is more than 6–7 m.

SWOT analysis is a strategic planning and strategic management technique for identifying strengths, weaknesses, opportunities, and threats in corporate competitiveness or project planning. It's also known as scenario analysis or situational evaluation. Table 31 shows the outcome of renewable energy system in different country according to the SWOT theory.

The result of electricity generation through renewable energy system, CO_2 reduction. In India, according to the, accelerated renewable energy technology scenario, 23% of electricity is generated by renewables only, and 74% of CO_2 reduction is possible by 2050. The renewables share in electricity supply rises to 36% as compared to the reference scenario, while the CO_2 emission reduction in this case remains at 74%. Pakistan's GHG emissions include 158.10 Mt of CO_2 (54%), 111.60 Mt of CH4 (36%), 27.90 Mt of N2O (9%), 2.17 Mt of CO (0.75), and 0.93 Mt of volatile organic carbon (VOC) (0.3%). Pakistan's accumulative CO_2 emissions are likely to reach 250 Mt by 2020, which may grow to 650 Mt if subsidies continue on fossil fuels. To decrease the CO_2 emission, it is necessary to increase the electricity generation through the renewable energy system. In the Bangladesh forecasted results sug-

Table 28
Comparative analysis of renewable energy capacity in Indian subcontinent.

Country	Solar	Wind	Hydro	Biomass
India	48.55 GW	40.03 GW	51.34 GW	10.62 GW
Sri Lanka	563 MW	887 MW	438 MW	129 MW
Pakistan	737 MW	1236 MW	10002 MW	432 MW
Bangladesh	120 MW	80 MW	0 MW	15 MW
Nepal	5 MW	3 MW	1142 MW	-
Bhutan	6.1 MW	5.1 MW	0 MW	1 MW
Maldives	15 MW	1 MW	0 MW	0 MW

Table 29
Factor that effected through renewable energy system.

Country	Factor That Effected Through Renewable Energy System Positive Effect = ↑, Negative Effect = ↓				
Bangladesh	Economic Growth ↑	C02 Emission ↓	Foreign Direct Investment ↑	Domestic Investment ↑	Urbanization
Nepal	Economic Growth ↑			Electricity Sustainability ↑	
Sri Lanka	Economic Growth ↑		Attraction of Foreign Capital ↑		Policy Stabilization ↑
Maldives	Economic Growth ↑			Shared Ownership Models ↑	
Pakistan	Economic Growth ↑		Human Development ↑		Terrorism Reduction ↑
Bhutan	Economic Growth ↑		Environmental Quality ↑		Service Growth ↑
India	Economic Growth ↑	Green Job ↑	Environmental Sustainability ↑	Energy Management↑	Research and Development Sector↑

Table 30
Possible location for tidal power plant in Indian subcontinent.

India	Bangladesh	Pakistan	Sri Lanka	Maldives
Gulf of Kutch	Sandwip	Sonmiani, Baluchistan	Pearl of the Indian Ocean	Cocoa Island
Gulf of Khambhat	Cox's Bazar	Kalamat,Balochistan		Veligandu Island
Palk Bay- Mannar Channel in Tamil Nadu	Hiron Points			Thulusdhoo Island
Hoogly River	Golachippa			Hulhumale Island
Sunderbans in West Bengal	Patuakhali			Fulhadhoo Island
	Barishal			
	Sundorikota			
	Mongla			
	Char Changa			

Table 31
Outcome of renewable energy system of Indian subcontinent through SWOT theory.

India	
Strength	• India is the world's third largest power user and third largest renewable energy producer, with renewable energy accounting for 38%. • India was placed third in Ernst & Young's (EY) 2021 Renewable Energy Country Attractiveness Index (RECAI), after the United States and China • Increased environment sustainability • Economic growth • Greenhouse gas emission reduction • Suboptimal quality of life • Inception of indigenous manufacturers and developers
Weakness	• Intermittent weather condition of environment, temperature is vary from 0 degree centigrade to 48 degree centigrade • There are different tariff rates and policy framework for different states • normal people avoid due to the higher capital cost • Lack of existence of adequately skilled and technical man power • Lack of infrastructure for implementation
Opportunity	• Opportunity to increase the RECAI score of wind power and geothermal power • Opportunity to increase the potential of ocean energy system
Threats	• Inefficiency in risk analysis technology and mitigation mechanism
Pakistan	
Strength	• Pakistan government encourages the adoption of small-scale, deregulated and standalone systems which are especially important in the context of remote and rural areas. • An important financial incentive is income tax exemption, as well as equipment sales and customs tax exemption.
Weakness	• Lack of Competition with Conventional Power Generation • Market, Institutional and Financial Barriers • Poor Infrastructure • Poor Information & Technology Access • Lack of Social Awareness & Acceptance
Opportunity	• Energy Subsidy Transfers • The implementation of feed-in tariffs (FITs) is another important policy tool that can be used to increase the deployment of RETs and improve competitiveness. • To bridge the competitive gap between renewable energy and fossil fuels is to account for the negative and positive externalities associated with each other. • Public Sector Involvement and Institutional Cooperation
Threats	• Inadequate infrastructure, Terrorism, Unbalance political issues
Bangladesh and Sri Lanka	
Strength	• Bangladesh and Sri Lanka government encourages the adoption of small-scale, deregulated and standalone systems which are especially important in the context of remote and rural areas.
Weakness	• High initial cost and lack of awareness
Opportunity	• Lots of possibility in Tidal energy system
Threats	• Inadequate infrastructure, Unbalance political issues
Nepal, Bhutan and Maldives	
Strength	• Increased environment sustainability • Economic growth
Weakness	• Minimum
Opportunity	• Opportunity to increase wind power and geothermal power • Opportunity to increase the potential of ocean energy system
Threats	• Inefficiency in risk analysis technology and mitigation mechanism

gest that CO_2 emissions will peak at 58.97 MTOE by 2040, which can be reduced by renewable (i.e. solar, wind, biomass) and energy technologies.

10. Conclusion

In the present scenario, renewable energy sector not only for the electricity generation, but other aspects also like economic growth, foreign investment, domestic investment, suboptimal quality of life, policy stabilization, environment sustainability and job prospectus in country. India's shift to a green economy might result in the creation of 3 million jobs in the renewable energy sector alone by 2030. Renewable energy, which is still in its infancy in Pakistan, has enormous growth potential due to its low cost and low environmental impact. Pakistan's Alternative Renewable Energy Policy seeks to expand renewable energy's contribution of the national power grid from 5% to 20% in 2025 and 30% in 2030. But it is necessary to identify the answer of following question in Pakistan, how much variable renewable energy can the country's power system absorb? What level is economically optimal? while assessing renewable energy sector of Bangladesh, it is found, that the main challenges to biomass in Bangladesh are the high cost and difficulty in gathering significant volumes, which makes it costly., Bangladesh's wind potential, particularly onshore, is limited. There are lots of possibility, in Maldives to generate the electricity from tidal energy system. SWOT analysis made shows that, some of the the main threats in different countries are inefficiency in risk analysis technology and mitigation mechanism in India, Inadequate infrastructure, Terrorism, Unbalance political issues in Pakistan, Sri Lanka and Bangladesh and lack of opportunity to increase the electricity generation through the wind, geothermal and ocean energy in the Nepal, Bhutan and Maldives.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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