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Economic and Sustainability Analysis of Renewable Energy in India

Swapnil Soni [α] & Varurn Jyothiprakash [σ]

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I. Introduction

Energy is the driver of growth for an economy. For a developing economy, energy plays a vital role to run the gear of structural change and reap the effect of this structural change in the economy. Sen has defined energy as 'capability' for societal development (Rosie et al., 2016). The consistent contribution of energy towards the development of society, economy, and ecology yields a sustainable and overall development of the nation. The definition of consistency in contribution can be well understood in the context of renewable energy resources and technologies. By the definition itself, the renewable energies are everlasting due to its very nature of renewability. The salient features of these energy sources are they everlasting and readily available in nature. The major renewable energy sources are solar, wind, hydro, biomass, tidal, and geothermal energy, etc. However, the utilization of these forms of renewable energy sources mainly depends on the availability of these energies as per geographic location and also the technology required for extracting these energy sources into useful energy sources. The everlasting characteristics of renewable energy sources assure the constancy of their contribution to the growth of the economy. It is with this backdrop that this study has been undertaken to diagnose the role of renewable energies and technologies in the development of the Indian economy.

India has been witnessing a fast pace of economic structural change and economic growth for last three decades with Gross Domestic Product (GDP) growth rate averaging around 6% (World Bank databank).[1] In the process of economic and occupational structural change and growth, India has exhibited significant industrialization especially post-liberalization, 1991. The economic development is majorly driven by the development of industries and infrastructures on one-hand at the macro-level and the uplifting of living standards of individuals on the other at the micro-level by improved access to transportation, cooking fuel, comfort heating or cooling, and access to modern energy services, etc. Both, at macro-and micro-levels, energy and energy services invariably play a governing role.[2]

a) India Energy Scenario

India is the second-largest populated country in the world with a population of 1.3 billion (Worldometer, n.d.). Currently, the country is the third-largest consumer of electricity in the world with the annual consumption of 1,389.21 TWh in 2019-20, where the thermal energy sources contribute to 62.1% of the total electricity generation (Government of India, 2020). The county is the third-largest emitter of CO2 from fuel combustion with 2,222 MtCO2 in 2019 (Enerdata, 2020). India's CO2 emissions grew at a Compound Annual Growth Rate (CAGR) of 5.8% from 1990 to 2019 (Enerdata, 2017). At the national level, the Government of India (GOI) has a voluntary pledge of reducing the emissions intensity of GDP by 20 to 25% over 2005 levels by 2020 and 33 to 35% by 2030. GOI has recently enhanced its target to have 175 GW of power from renewable sources by 2022 and 40% of cumulative installed electric power capacity by 2030. The country has targeted to create a carbon sink of 2.5-3 GtCO2e through additional forest and tree cover by 2030. India is one of the fast-growing economies of the world (Government of India, 2016). The country's rapid increase in overall income has increased the demand for electricity. India has assigned

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[1] World Bank databank <https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?end=2016&locations=IN&start=1987>

[2] Energy refers to energy sources and energy carriers such as fuel, electricity and LPG; whereas, energy services refers to the services or utilities derived out of energy carriers such as transportation, cooking and illumination etc.

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the role of overseeing the implementation of 17 Sustainable Development Goals (SDG) through central ministry, where they have formed a nodal agency NITI Aayog to ensure the functioning and operations of SDG across India.

India is the third-largest producer and consumer of electricity in the world with the annual consumption of 1389.21 TWh and an installed capacity of 372 GW in 2019-20 which is roughly one-third of the World's average consumption (CEA, 2020; IEA, 2016). Figure 1 shows the pictorial representation of India's electricity generation capacity mix. Conventional source (coal, gas, oil) of energy are the major contributors in India's current energy mix with 62.1 % (231,421 MW) followed by Renewable Energy sources 23.8 % (87,027 MW), Large Hydro 12.3 % (45,699 MW) and Nuclear 1.8 % (6,780 MW) (Government of India, 2020). In the Renewable Energy Sources, the wind energy source is predominant with 42.8 % (37999.5 MW) followed by Solar Energy 40.2 % (35,739.3 MW), Bagasse and Cogeneration 10.6 % (9373.8 MW), Small Hydro Power 5.3 % (4739.9 MW), Biomass/Captive Power 0.9 % (772 MW) and Waste to Power 0.2 % (168.6 MW) (Ministry of new and renewable energy, 2019).

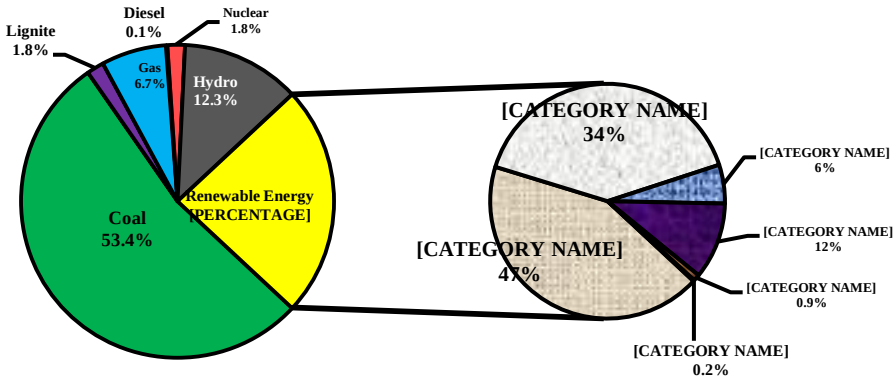


Figure 1: Electricity Generation Mix

As seen from the above figure the coal is a major energy source for India which is a non-renewable. In the criteria of '*accessibility*', '*affordability',* and '*availability*', the fossil fuels (Coal) have made their distinguished place but measurably failed to meet the criterion of '*acceptability'* due to heavy GHG emissions which in turn damages the environment.[3] Currently, India imports 48.8% of coal which adds to the international trade issue and cost to the county (Ministry of Coal, 2020; Ministry of Statistics and Programme Implementation, 2020). Renewable energy comes with a boon to tackle this issue of environmental sustainability but bears the question of availability, reliability, accessibility, and affordability. For instance, solar energy in India is renewable and environmentally acceptable but has the concern of availability round the clock and lack of indigenous manufacturing of solar panels, making the country dependent on neighboring countries that hamper the trade balance.[4]

Also, the development with consumption of conventional energy resources engenders concerns of environment and sustainability challenges. On the cost of environmental concerns and sustainability, India cannot forego the development of an economy that results in the wellbeing of the society at large. Investment in, adoption, and development of renewable energy pave the path to tread the way of development maintaining sustainability in the eco-system.

The promotion of renewable energy leads to sustainable economic development that in turn leads to investment in renewable energy further. This is phrased as a 'feedback relationship'. The literature advocates the positive feedback relationship between the development of renewable energy and the economy in most of the industrial economies (Nicholas, 2014). This present study probes into such a relationship in Indian contexts and provides policy recommendations.

II. Literature Review

The short and long run relationship between renewable energy investment and economic growth have been analyzed in many developing and developed economies. Nicholas' work (2014) established a strong relationship between renewable energy consumption and economic growth using empirical analysis of 80 countries. The study proves that renewable energy is important for economic growth which further encourages the use of more renewable energy sources. The presence of causality provides an avenue to continue the use of government policies that enhance the development of the renewable energy sector. Sari and Soytas (2008) estimate an ARDL (Auto-Regressive Distributed Lag) model with respect to disaggregated

[3] A sustainable energy is defined by the criteria of 'availability' (adequacy of supply), 'accessibility' (accessible to all consumers of society), 'affordability' (cost-effectiveness of energy source) and 'acceptability' (eco-friendly fuel).

[4] India's 87 per cent solar cell is imported from China (neighbor) <http://indianexpress.com/article/india/indias-87-per-cent-solar-cell-imports-from-china-in-april-september-piyush-goyal-4417312/>

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measures of U.S. renewable energy consumption and find that industrial production has a positive impact on renewable energy consumption. In a sectoral analysis of renewable energy consumption, Bowden and Payne (2010) show unidirectional causality from residential renewable energy consumption to the real output, while the absence of a causal relationship between commercial and industrial renewable energy consumption and real output, respectively. Tugcu (2013) investigates the long- and short-run relationships between disaggregate energy consumption and total factor productivity growth in the Turkish economy. His study highlights that disaggregate energy consumption is co-integrated into total factor productivity growth and there exists a bi-directional causal relationship among the variables. Leitao (2014) also investigates the correlation between economic growth, carbon dioxide emissions, renewable energy, and globalization. His results document that there is a strong and positive link between renewable energy and economic growth.

Economic development has a dimension of occupational structure and employment that also seems to have a significant influence on renewable energy technologies. International Renewable Energy Agency (IRENA, 2016) report indicates that the creation of jobs doubles due to solar energy generation with respect to the conventional energy generation. The report underscores the role of renewable energy in making energy cost-effective, reliable, secure and environmentally sustainable that result in economic development. The impact of renewable energy has been predicted to be +0.2% to +4.0% in GDP. The literature also considers the fact that the invasion of new and renewable energy technologies negatively impacts the employment in conventional energy sectors, yet the positive impacts created by this new arena of renewable energy nullify the negative impact and produce overall beneficial outcomes for the economy in long run.

With literature review and analysis, this study further examines the scenario of renewable energy in the context of the Indian economy. The following section 3 and section 4 highlight the economic and sustainability analysis using the qualitative and quantitative framework. Section 5 summarizes the results, policy implications, and suggests the way forward.

III. Economic Analysis

The optimum utilization of resources by the productive sectors generating employment is responsible for economic and occupational structural changes and results in economic growth (Kuznets, 1955). There is always a shift of employment and value-added from low to high productive sectors which are termed as 'structural change'. The bonus of this structural change, if properly and timely reaped, results in economic growth. In the process of development, it becomes vital for a country to shift its reliance on energy from convention to new and renewable energy sources and technology. This shifting process generates employment opportunities with moderate frictional and structural unemployment, in the short run, that are components of the natural rate of unemployment. However, in the long run, the benefits are immense in terms of qualitative and quantitative dimensions of the economy of a developing country.

The energy sector contributes to economic activity in two ways. Firstly, energy is an important economic sector that creates jobs and values by extracting, transforming, and distributing energy goods and services throughout the economy (World Economic Forum, 2012). Secondly, there exists strong linkages between energy sector and other industries that need energy to power their machinery and associated facilities. Energy is input to nearly every product and service in the economy and supoorts the economic activities across each of its productive sectors. Thus, the energy sector's impact ripples through the rest of the economy. Some of the major contributors to such expected growth can be envisaged as increased trade of renewable technologies and equipment, infrastructural investment, employment generation, and opened arena for Foreign Direct Investment (FDI), etc. Whereas, the developing countries like India have the potential to welcome opportunities for investment and development of renewable energy and technologies. India's export basket is currently outweighed by food products, basic consumer goods, and low technology products resulting in a volume-heavy but value-light basket (Bala, 2014). This causes the issues in trade balance and negatively impacts the GDP of India that is constituted by consumption, investment, government expenditure, and net exports. The introduction of high technology products meant for renewable energy technologies such as wind turbines, solar panels, and small hydro turbines, etc. into the export basket will not only enhance the value of the export basket but also contribute to maintaining the desired trade balance resulting in sustainable economic growth. IRENA (2016) quantifies this positive impact of investment in renewable energy to be 2.4% growth in GDP.

To empirically diagnose the relationship between usage of renewable energy in terms of electricity production and other economic factors- GDP and access to electricity and environmental factor- CO_2 emission, the study analyses 33 major countries in the world using last 7 years' data from 2010through 2016.[5]

[5] Data bank of World Bank <http://databank.worldbank.org/data/reports.aspx?Code=IND&id=556d8fa6&report_name=Popular_countries&populartype=country&ispopular=y> Major 33 countries considered for the analysis: Afghanistan, Argentina, Austria, Bangladesh, Bhutan, Brazil, Chile, China, Egypt, Arab Rep., Finland, France, Hungary, India, Iraq, Italy, Japan, Libya, Malaysia, Mexico, Nepal, Norway, Philippines, Portugal, Singapore, South Africa, Sri

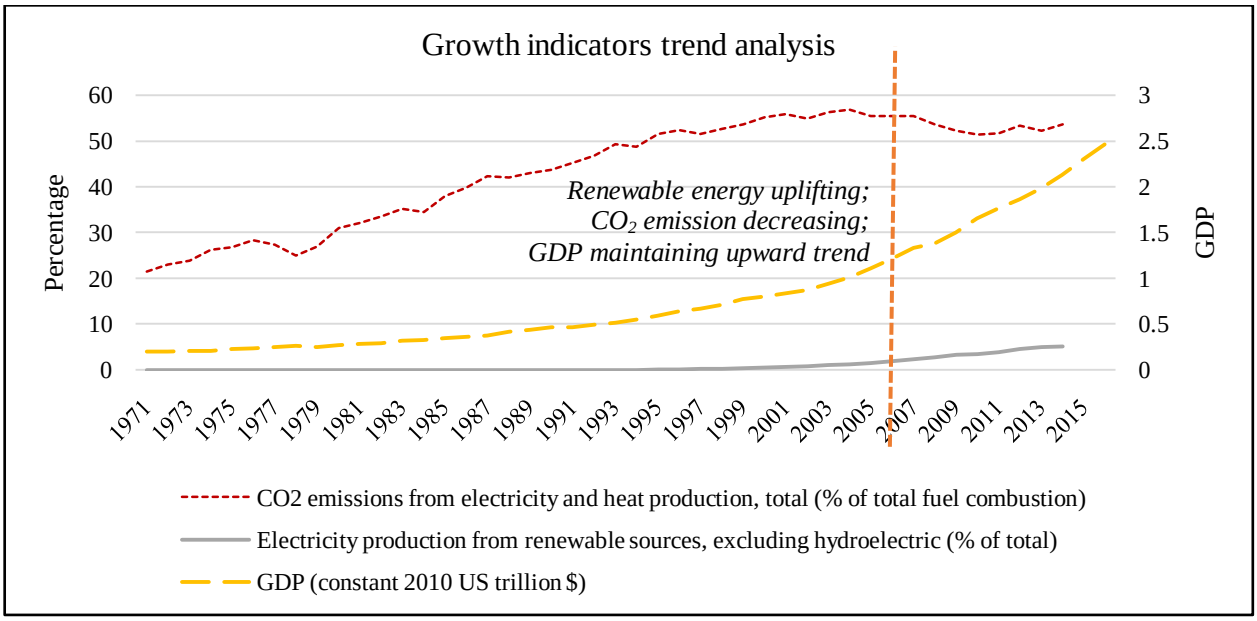
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The data series is extracted from the databank of World Bank. The average of the last 7 years' time-series data has been considered for each country against each data series (indicator) to mitigate the effect of time series and make the data apt for cross-sectional analysis. A simple Pearson correlation technique of assessing the linear association between indicators is deployed.

Table 1: Correlation analysis of growth indicators for the world

Pearson Correlation coefficients	Access to electricity (% of population)	CO_2 emissions (metric tons per capita)	Electric power consumption (kWh per capita)	Electricity from renewable (% of total)	GDP (constant 2010 US$)
Access to electricity (% of population)	1				
CO_2 emissions (metric tons per capita)	0.51	1			
Electric power consumption (kWh per capita)	0.44	0.67	1		
Electricity from renewable (% of total)	0.30	-0.01	0.2	1	
GDP (constant 2010 US$)	0.21	0.45	0.23	0.02	1

Table 1 presents the correlation analysis of growth indicators of 33 major countries (including developing and developed countries).[6] The highlighted correlation values are significant at 5% level. The obvious positive association between electricity access and power consumption (0.44) can be observed along with a positive relationship between electricity from renewable energy and electricity access (0.30). This reveals an important fact that more contribution of renewable energy in electricity production of the nation promotes access to electricity by the nationals. Electricity access is one of the major health indicators of the development of society and the nation. Based on the available data, there is a bleak association between renewable energy electricity output and GDP growth, however, the relationship is positive (0.02). The study further diagnoses the growth indicators for India in particular.



(Source: Author)[7]

Figure 2: Growth indicator trend in India

Lanka, Sudan, Sweden, Switzerland, United Arab Emirates, United Kingdom, United States and Zimbabwe

[6] For this study, electricity access, power consumption, renewable energy contribution to electricity, CO_2 emissions and GDP have been considered as growth indicators.

[7] The plot and data are available in a separate excel file present in following 'Data and Analysis' section.

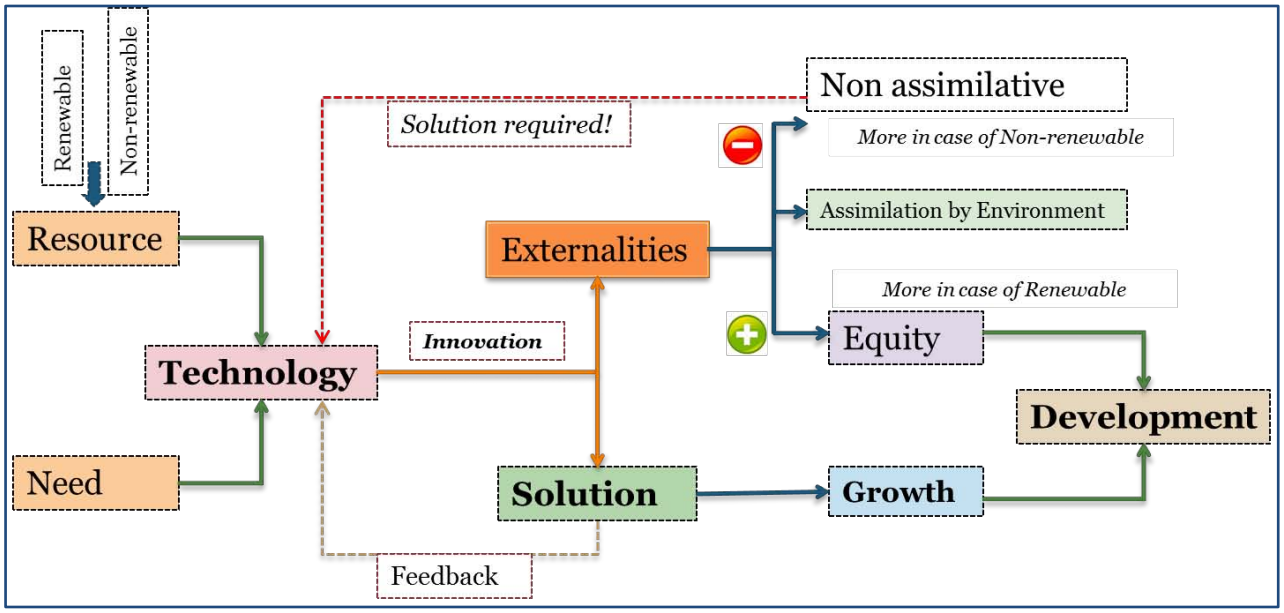
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The time-series data of the major growth indicators concerned (with the relationship between renewable energy and economic growth), from 1971 through 2016, are plotted in the Figure 2. In the process of economic growth, CO_2 emission has also increased substantially until the year 2005 when a significant increase in the contribution of renewable energy to electricity production can be observed. Post 2005, the CO_2emission seems to start declining with the uplifting of renewable source electricity production, maintaining the pace of GDP growth in the Indian economy. This leads to the conclusion that renewable energy enables economic development, preserving the environment, and thus resulting in sustainable economic development.

IV. Sustainability Analysis

The implementation of renewable energy sources and technology to exploit sustainable resources for the development of the nation, falls in line with the definition of sustainability. In a granular framework, the energy can be assessed from major four dimensions of sustainability- (1) Availability, (2) Affordability, (3) Accessibility, and (4) Acceptability. For a century, fossil fuels have been satisfying the criteria of availability, affordability and accessibility, but at present, they measurably fail in the criterion of acceptability due to environmental and global warming concerns. The Paris Agreement signifies years of work in trying to combat climate change. In 1992, countries joined an international treaty, the United Nations Framework Convention on Climate Change (UNFCCC). In 2005, the Kyoto Protocol became a legally binding treaty.

The county is the third-largest emitter of CO2 from fuel combustion with 2,222 MtCO2 in 2019. India's CO2 emissions grew at a Compound Annual Growth Rate (CAGR) of 5.8% from 1990 to 2019 (Enerdata, 2020). At the national level, the Government of India (GOI) has a voluntary pledge of reducing the emissions intensity of GDP by 20 to 25% over 2005 levels by 2020 and 33 to 35% by 2030. GOI has recently enhanced its target to have 175 GW of power from renewable sources by 2022 and 40% of cumulative installed electric power capacity by 2030. The country has targeted to create a carbon sink of 2.5-3 GtCO2e through additional forest and tree cover by 2030. Development with the concern of climate change is the key challenge for India which is leading in the league of developing economies. The study considers the interaction of need, resources (renewable and non-renewable), technology, and externalities (positive and negative) producing environmental destruction and economic development.



(Source: Author)

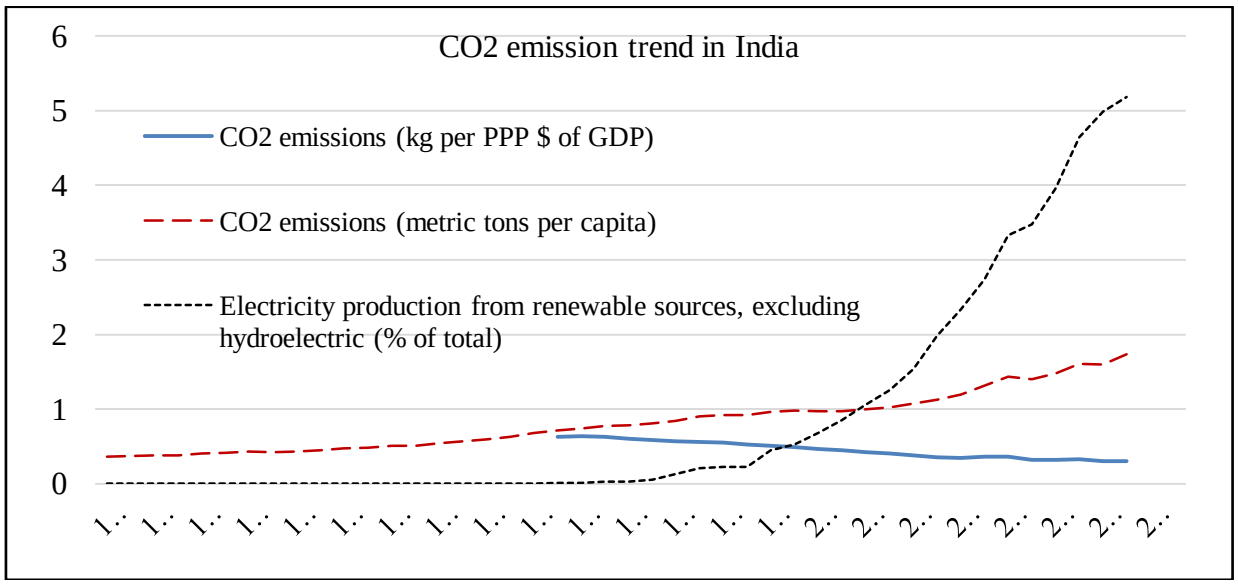
Figure 3: Sustainable development framework with renewable and non-renewable sources

Figure 3 depicts the sustainable development framework incorporating both renewable and non-renewable energy sources as inputs to the system. Need for growth, calls for resources that can be consumed using technology. The energy which is the capacity to do work is the basic need of the hour which defines the driving force for life. The quality of our life is dependent on the continuous and reliable supply of energy sources. There is a continual debate about which is the "best" energy source, with considerations of availability and cost of the resource, efficiency of production, public safety, health, and marketing. Access to modern forms of energy carriers (electricity and cooking fuels) contributes to the economic and societal development of the country. The energy consumption and conversion processes generate the solution

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along with the positive (desirable) and the negative (undesirable) externalities as by-products. Some proportion of negative externalities can be assimilated by the environment or nature (assimilation of CO_2 emission by plants and forests; assimilation of wastages by ground as fertilizers etc.). However, the rest of the negative externalities turns non-assimilative and create environmental concerns for which one has to go back to technology to provide a solution that may again generate externalities and create other concerns. This cycle of growth and concerns continue in perpetuity. At the onset of the cycle, need and resources play the cornerstone role to control the entire cycle of development and generation of negative externalities. Reining the need up to a desired threshold and deployment of renewable energies as input resources mitigate the germination of undesirable externalities maintaining the desirable growth and development of the country.

Usage of solar energy needs manufacturing of solar panels, wind energy needs windmills, geothermal needs drilling technologies. With these facts, the generation of negative externalities cannot be ignored in the case of renewable energies as well. But, at the same time, positive externalities are spinning out of them in the form of employment generation (IRENA, 2016), reduced fossil fuel consumption, and increased acceptability in long run. These positive externalities outweigh all the negative externalities producing a long term and sustainable solution for economic development with moderate harm to the environment. India as a country that has a twin challenge of development and climate change, exhibits the benefit of the implementation of renewable energy for power generation and meeting the development need of the economy.



(Source: Author)[8]

Figure 4: CO_2 emission trend in India with incorporation of renewable energy

Figure 4depicts the trend of CO_2 emission per PPP (Purchasing Power Parity) $ of GDP and per capita along with the trend of renewable energy electricity production from 1971 through 2015 (Data from databank of World Bank). The graph witnesses the fact that India as a developing nation does emit CO_2 per capita with increasing trend resorting to increasing consumption of energy by individuals. However, when CO_2emission is observed from a GDP growth perspective, the trend seems downward sloping. This reveals India's strategic and sustainable development framework. CO_2 emission per capita may increase yearly but it decreases per PPP $ of GDP indicating that value-added in the economy (measured as GDP) has been increasing vis-à-vis CO_2 emission. Precisely phrasing, the rate of CO_2 emission per unit GDP has been decreasing. Eventually, this divergence of CO_2 emission per capita and GDP coincides with the uplifting trend of renewable energy electricity generation. This vindicates that a substantial contribution has been made by renewable energy in terms of mitigating the undesirable emission while maintaining the pace of economic growth.

To quantify the relationship, the study further estimates a linear regression model using the data series of the major 33 countries (considered in the earlier correlation analysis in section 3).CO_2 emissions (metric tons per capita), the dependent variable is regressed on Electric power consumption (kWh per capita), GDP (constant 2010 trillion US$) and Renewable electricity output (% of total electricity output).

[8] The plot and data are available in a separate excel file present in following 'Data and Analysis' section.

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Table 2: Regression result for CO_2 emission using other growth indicators

	Coefficients	Standard Error	t Stat	P-value
Intercept	4.226	0.836	5.052	0.000
Electric power consumption (kWh per capita)	0.001	0.000	6.362	0.000
GDP (constant 2010 trillion US$)	0.300	0.159	1.889	0.069
Renewable electricity output (% of total)	-0.056	0.015	-3.822	0.001

Table 2 presents the multiple linear regression modeling results to predict CO_2 emission. All three independent growth indicators are significant at 10% significance level and follow the expected relationship with the dependent variable. Electric power consumption per unit per capita increases the CO_2 emission by 1 gram (0.001 ton) per capita; 1 trillion-dollar increase in GDP also gives rise to CO_2 emission by 0.3 ton per capita; whereas 1% increase in renewable energy mitigates CO_2 emission by 56 grams per capita. This analysis also vouches for the increase in the contribution of renewable energy in power generation to reduce carbon footprint and develop the national economy.

V. Conclusion

The present study analyses the adoption and promotion of renewable energy in India from an economic and sustainability perspective using qualitative and quantitative frameworks and empirical data. Correlation analysis of growth indicators reveals that the increased contribution of renewable energy in power generation and electricity access tread in tandem. The time series trend of growth indicators supports the argument that renewable energy not only contributes to mitigating the carbon emission but also strengthens the economic growth by inviting the investments, enhancing the trade basket, and generating employment opportunities.

The great energy challenge of the future is to meet demand growth. Decisions made today on energy sector investments and infrastructure have long-lasting implications. Environmental consciousness and energy security concerns have compelled policymakers to explore energy supply options that are cost-effective, reliable, secure, and environmentally sustainable. Renewable energy is a key part of the solution. It can contribute to the long-term resilience of the Indian energy system, which underpins economic development.

Government commitments can take the form of credible, time-bound renewable energy targets, which serve to anchor investor confidence and set out the trajectory for the development of the sector. Importantly, targets must be backed by dedicated policies and regulatory frameworks.

Renewable energy is emerging not only as a solution to meet growing energy demand for economic growth while sharply reducing carbon emissions but also as a potential engine for economic growth and diversification. Renewable energy and technology are fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies Limitations and way forward.

The present study has holistically considered all the renewable energies and technologies in a single framework. However, there exist vast variations in the nature and technologies of access to various renewable energy sources. The economic and sustainability analysis is different for each renewable energy source. Consideration of such heterogeneity within the renewable energy will provide a clear pathway for analysis to the policymakers and government.

The study has been built on the foundation of renewable energy and economic growth from the perspective of the Indian economy. The roadmap may further be explored for the other developing and developed economies with cross-country comparisons. Each economy's occupational and economic structures are unique and the paths of development are different from others. Using the frame of reference of this study, the further avenues can be explored for sustainable development of all the economies and a holistic framework can be worked out for the world as a whole since environment and development are a concern for all and not limited to a country in particular.

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