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Abridgement of Renewables: It's Potential and Contribution to India's GDP

Aarti Dangwal[1], Sanjay Taneja[2], Ercan Özen[3], Igor Todorovic[4], Simon Grima[5*]

[1] University School of Business – Commerce, Chandigarh University, Mohali (Punjab) 140413, India
[2] University School of Business – BBA, Chandigarh University, Mohali (Punjab) 140413, India
[3] Faculty of Applied Sciences, University of Uşak, Uşak 64200, Turkey
[4] Faculty of Business, Management and Economics, University of Latvia, Riga LV-1586, Latvia
[5] Faculty of Economics, Management and Accountancy, Department of Insurance and Risk Management, University of Malta, Msida MSD2080, Malta

Corresponding Author Email: simon.grima@um.edu.mt

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ABSTRACT

In today's world, one cannot deny the magnitude of energy use. It is a necessity in every field and can be categorized as renewable and non-renewable energy. The importance of renewables cannot be overstated since the non-renewable resources will not last forever. Once they are used, we must remember to consider their effect on the environment. This paper highlights how deploying renewable energy sources instead of non-renewables improves the Indian Economy. To do this, we gathered time series data and applied the statistical test for analysis of variance (ANOVA) to measure the strength of the impact of selected variables. Findings show that renewable energy sources have become progressively critical in terms of the fossil fuel recession. Energy-efficient technologies and sustainable energy applications and their impact on the Indian Gross Domestic Product (GDP) demonstrate that renewables significantly impact the Nation's growth prospects.

1. INTRODUCTION

Regenerative power is energy that tends to come from a non-exhaustive source. There is much discussion about how to utilize energy resources in the best way possible [1]. Because of this, it is necessary to ascertain what fuel source will be used and for what reason. A significant proportion of aspects, including hygiene, expense, cohesion, quality, and ecological impacts, must be considered [2]. Admittedly, countless industries worldwide still rely on burning coal to generate electricity. These fuels are efficacious in producing power quality, although they are not cost-effective in the long term. Since biofuels are running out, we need to initiate using alternative fuels as soon as possible [3]. They are also a big threat to climate change and responsible for numerous eco hazards.

The capacity factor for green resources in India is 151.4 GW. As of the latest figures given in Figure 1 during the end of December 2021, the split of installed capacity for Renewables was 40.08 Giga Watts (GW) of wind power, 49.34 GW Solar Power, 10.61 BioPower, 4.83 GW Small Hydro Power and 46.51 GW of Large Hydro [4]. India ranks 3rd in renewable energy country attractive index but is the 3rd largest energy consuming country in the world. Moreover, the India Government aims for the world's largest expansion plan in renewable energy, with an ambitious target of 175GW w worth of renewable energy by the end of 2022, which expands to 500 GW by 2030 [4].

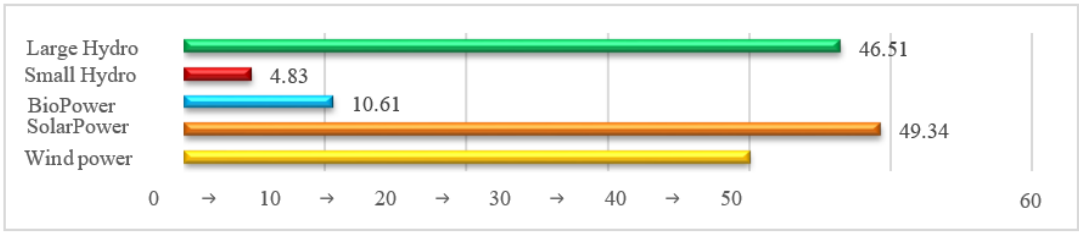
To reduce the carbon intensity of the Nation's Economy by less than 45 percent by the end of the decade, attain climate impact by 2070, and boost India's embedded renewables by 2030 the government aims to carry out forty-five solar electricity projects with a combined strength of 37 Mega tones. These include amongst others a solar park in Pavagada providing 2 GW, Kurnool providing 1 GW, Bhadla -11 supplying 648 mega watts (MW) and Gujarat already under construction, which is the Nation's biggest power generation hybrid power plant with a 30 GW capacity.

India is managing to achieve the set target capacity of 175 (GW) by the end of this financial year [5]. Undoubtedly, with this consistency, the expansion would score 500 GW in the next 10 years. Indian non-fossil-based net solar potential has reached 158.17 GW, contributing 40.2 percent of the Nation's annual installed power, effectively attaining its Nationally Determined Contribution (NDC) benchmark (a climate action plan to cut emissions and adapt to climate impacts).

1.1 Fossil fuel dilemma

Biofuels are hydrogen compounds, including petroleum, natural gas, and diesel [6]. Emissions of CO_2 cannot be retained in the coming decades [7] since they can inevitably be depleted. When they are oxidized, they radiate a large harmful gas, the far more noticeable of which is carbon dioxide. This gas is by far the most harmful in terms of global warming. This is unceasingly detrimental to the planet's temperature and the endangering of its species.

Further to that, as a result of the high temperatures, ice has been continuously melting in the Arctic and Antarctica, elevating sea levels above normal [8]. This can cause flooding and critically affect crops and fishery activities.



Source: Authors' Compilation adapted from Invest India Report [9]

Figure 1. Break up of total installed capacity for renewables as of Dec. 31 2021 (in GW)

Algeria, Angola, Ecuador, Libya, Nigeria, Venezuela, and Middle Eastern countries such as Iran, Iraq, Kuwait, Qatar, Saudi Arabia, and the United Arab Emirates (UAE) are members of the Organization of Petroleum Exporting Countries (OPEC) [10], as shown in Table 1. According to the Energy Information Administration (EIA), many such countries make up nearly 40% of the total crude oil production and hold the large bulk of global petroleum resources [11]. Several other nations rely on this supply as an energy source [12]. Because of this dominance, the spot price of fossil fuels varies tremendously. Figure 1 shows the break up of total installed capacity for renewables as of Dec. 31 2021 (in GW).

Table 1. Member states of OPEC

No	Nations
1	Algeria
2	Angola
3	Ecuador
4	Libya
5	Nigeria
6	Venezuela
7	Iran
8	Iraq
9	Kuwait
10	Qatar
11	Saudi Arabia
12	United Arab Emirates

Source: Authors' Compilation adapted from organizations of the Petroleum Exporting Countries [13]

The burning of fossil fuels creates nitrogen monoxide, nitrogen dioxide, sulphur dioxide, and carbon monoxide gases. Indirectly, these fumes are responsible for polluting the air. It makes it hard to remain fit and grow healthy crops. The resultant acid rain, mostly caused by sulphur dioxide, is bad for marble monuments and crops [14]. Coal mining has taken away the land's liveliness and turned it into a desert. There are areas of land where crops cannot be grown because of the negative side effects of these fossil fuel.

There have been many lost lives in the past decades as a result of coal mining. In 1942, a blast at the Benxihu Colliery in China killed 1549 miners in one day. Oil splattering has wiped out ecologies. Most of the time, fossil fuel leaks when it is moved by water.

The largest oil spill so far, Ixtoc I, resulted in about a metric ton of raw petroleum spilled into the Gulf of Mexico. This increased the pollution to around 162 miles of the US coastlines. Five people died, and more than two hundred were hurt when the blaze broke out at an oil store in Jaipur, India, a few years ago. Natural gas, on the other hand, has foul odours and is found to cause traffic issues. When the Sinopec pipeline exploded in the Shandong Province in 2013, it killed 55 people and caused extensive damage to the zone. Companies that make fuel, oil, coal and gas know that such threats are devastating. It will be hard for them to do anything until renewable energies become more common as main power sources.

1.2 Importance

Bioenergy is a current need; it is clean and long-lasting. The idea is that if trees harvested as biomass are replanted as fast as the wood is burned, new trees take up the carbon produced by the combustion, and the carbon cycle remains in balance—so biomass is arguably "carbon neutral". Therefore, Research by scientists and engineers in this field is continuous with an aim to improve its usage. It is still very dangerous even though coal, oil, and natural gas are all combustible energy sources.

More work has to be done on the use of cleaner and environment friendly sources of energy such as wind and water and lessen the use of dirty and polluting sources such as Fossil fuels. The former sources do not contribute to the build-up of noxious gases. In addition, biofuels are scarce. They will certainly end someday. Experts in the solar industry should think positive about this and try their best to switch from fossil renewables as the main power source as soon as possible. Clean energy is available and could be very cheap when this new tech and its infrastructure are better. Sunlight, air, compost, hydropower and tidal energy are some of the main sources of Bioenergy, but there are many more [15]. Non-renewable sources of energy, like coal, natural gas, and oil, require costly explorations and risky mining and drilling, which will cost more as supplies run out and energy demand rises [16]. Renewable energy emits only tiny amounts of CO_2 into the air, which helps fight climate change induced by carbon fuel use [17].

The daily fuel price is influenced by various factors including in the main geopolitical stability. Civil unrest has earlier led to severe scarcity. In relation, renewables are not impacted by secluded politics. Clean energy does not suffer from similar security concerns as carbon fuels, which is impacted by unfortunate events such as oil rig explosions, wars and coal collapses.

Deposits of ore, gas and diesel are obscured, usually buried beneath the earth or subsea. In addition to becoming more complex and expensive, locating reserves will also become more unsafe as more are threshed. A tiny level of natural gas is required to process non-oil reserves like oilfields. The British Petroleum Oil Leak in 2010 illustrated drilling rigs gone wrong. Toxins from coal mining and exploration include heavy metals like mercury and cyanide. Petrol and crude oil are similar pollutants. These chemicals cause respiratory illnesses that erase constructions and sensitive species. On the other hand wind and sunlight are both easily available renewable resources.

2. APPLICATION OF RENEWABLE SOURCES OF ENERGY

The first "On-grid" and "off-grid" renewable energy applications can be categorized. A grid is a series of connected power generation, transmission, and power grids used to supply power to many people. Renewables such as wind farms and solar panels fall under the category of on-grid. 0ff-grid systems are designed to serve a single load, e.g. a small house or a shack in a rural area. E.g. photovoltaic (PV) modules for individual village homes, unified windmills to power a surface & water pump, or commercial battery charging facilities are all examples of off-grid uses that can improve flexibility. Remote & rural areas tend to make massive use of these off-grid alternatives. Generating electricity on the grid is a significant utilization case [18]. Air turbine is an essential feature of wind energy. In order to generate hydroelectric power, a power station uses mechanical motion caused by wind power [19]. In order to charge batteries, this excess energy can be used to draw water. Evs powered by wind can also harness the energy it provides plenty of fuel can be preservation & the vehicle's performance and efficiency can be improved as a result. It is ideal for remote areas because of its low impact and high reliability. Glass photovoltaic devices are used in offices to keep a steady electric current. Renewable sources, solar calculators, and solar lights are just a few devices that use solar. In order to use sunlight energy, users must sell it during the day & store it at dawn. Farmers are most inclined to use geothermal. In order to build a variety of foods all year, they use this power to heat greenhouses [20]. This power is also used in some countries to keep streets & bicycle lanes from freezing during extreme winters. Combustion of biomass heats up that can be used to make steam, which can then be used to make power. The use of Bioenergy like ethyl acetate can also be created from organic matter. Hydropower is frequently used in compressors. Furthermore, you can fine-tune the turbine blade and governor valve orientation using a compressor designed to work. They can also be used to remove the load during initiating by blasting out the water.

3. MATERIALS AND METHODS

The objectives of the paper are;

i-To examines the current state of usage of renewables.

ii-To measure the impact of the use of renewable resources on countries' economies.

iii-To conduct the trend analysis of the use of renewable energy in India.

To meet the research objectives, time series data were collected from the World Bank's official website from 1993 to 2020. Renewable energy consumption is an independent variable in the research, and GDP is a dependent variable. In the research, GDP acts as an index of growth of the Nation and consumption of renewable energy acts as an indicator for sustainable development. To conclude linear regression technique has been used to assure the predictability of GDP by increasing the use of renewable energy. Also, the statistical test ANOVA is used to measure the strength of the impact of selected (independent and dependent) variables.

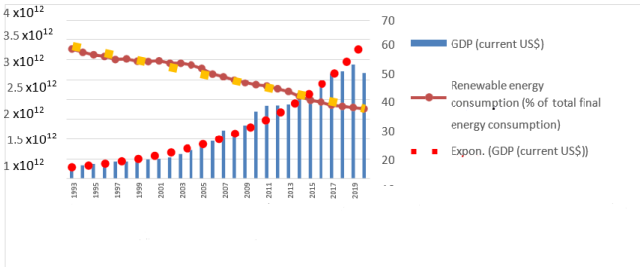
$$GDP = \alpha + \beta 1Rc$$

where,

- Rc represents renewable energy consumption.
- GDP represents the gross domestic product that will act as an index of the growth prospects of India.

4. RESULTS

Figure 2 shows the values and trends in the change in GDP & renewables consumption as a percentage of total energy from 1993 to 2020. The analysis that can be made from this projection data is that renewable energy percentage as of total Energy consumption is declining with time. The dotted golden colour trend line shows the declining nature of green energy consumption, which is a concern for policymakers. However, fortunately, GDP shows an upward trend post-economic reforms of 1993. This projection of data raises the concern for promoting sustainable development techniques in the development of India. However, India's effort to increase the usage of renewable energy is constantly increasing.



Source adapted from World Bank [21].

Figure 2. Time series projection of data of GDP and renewable energy consumption

These efforts are even showing results. Such an advancement in renewables has been the result of certain growth drivers. INR 1810.56 Cr for 210 Megawatts The Luhri Stage-I Hydroelectric Project on the Sutlej River was authorized by PM Sh. Narendra Modi & this facility will produce 758.20 million units of energy annually, resulting in direct and indirect employment for around two thousand people, boosting the socio-economic growth of India, which has garnered $ 64 billion in foreign investment, making it the fourth biggest and fastest expanding Economy. By the end of 2022, the proportion of renewables will accomplish the 220 Gigawatt target. PM-KUSUM is a scheme to increase the use and production of solar energy in the agricultural sector. In re-Invest 2020, it is announced by the Prime minister that India now has a renewable energy capacity of hundred and thirty-six Giga Watts.

Eight hydroelectric projects in the Indus basin have been launched, seven of which are in Union territories (including Ladakh, Jammu, and Kashmir). The Nation will have 37 large hydropower projects in the past year. Renukaji Dam in Himachal Luhri Stage 1 Hydro Power Project, Dhaulasidh along with Sawra-Kuddu Hydro Power Project are among the projects inaugurated in Mandi, HP worth eleven thousand crores even fifty solar parks with a combined capacity of 37.92 GW have been allotted in 14 states. The Raksha Mantri launched a 100 KW grid-connected solar power plant as part of the Ministry of Renewables initiative to promote solar rooftop plants on public buildings. The Union Minister of Power and the Ministry of New and Renewable Energy have authorized 23 new interstate transmission system (ISTS)

projects with an estimated 15,893 crores. By creating Siot Substation in Jammu, the new transmission projects would permit the evacuation of 14 GW of renewable energy projects in Rajasthan, 4.5 GW of renewable energy projects in Gujarat, and 1 GW of renewable energy projects in Madhya Pradesh, and feeding regions surrounding Akhnoor and Jammu. The Intra-State Transmission System – Green Energy Corridor Phase-II is expected to cost 12,031 crore and seeks to attain 450 GigaWatt of installed renewable energy capacity by 2030.

BHEL has begun work on power plant flexibility and Industry 4.0 implementation to improve power generation, emphasizing carbon reduction. Under the latest Tariff Policy of 2016, Distribution Licensee(s) must acquire 100% electricity generated by all waste-to-energy facilities in the state. The government, via the National Institute of Wind Energy, published 'Guidelines for Offshore Wind Power Assessment Studies and Surveys' to assist private investors in assessing offshore wind resources. The equity investment of INR 1500 crs in the Indian Renewable Energy Development Agency Limited, which is expected, would contribute to roughly 10200 jobs per year and the reduction of approximately 7.49 million tonnes of CO_2 equivalent emissions per year. Indian Renewable Energy Development Agency Ltd. inked a memorandum of understanding with Brahmaputra Valley Fertilizer Corporation Limited to provide technical and financial skills to build renewable energy projects and obtain funds. By 2070, GOI intends to achieve Net Zero Emissions, whereas IREDA and Goa Shipyard Limited have signed an agreement to establish a rooftop solar energy project at the organization's headquarters in Vasco da Gama, Goa will also provide GSL with technical and commercial expertise to conduct Environmental and Social due diligence on projects following internationally accepted E&S standards to reduce the company's electricity costs and carbon footprint. The Indian Renewable Energy Development Agency Ltd has signed a memorandum of understanding with THDC India Ltd to offer technical and financial expertise in developing renewable energy projects. A Letter of Intent between India and Australia on New and Renewable Energy Technologies was signed to open the path for collaboration to lower the cost of new and renewable energy technologies and scale up deployment to accelerate global emissions reductions. PM inaugurated National Hydrogen Mission to assist the government in attaining its climate goals and transforming India into a green hydrogen centre. This will aid in achieving the aim of 5 million tonnes of green hydrogen generation by 2030 and the associated growth of renewable energy capacity. The Hindustan Petroleum Corporation Limited & the Solar Energy Corporation of India Limited have signed a memorandum of understanding to advance green energy goals and the Government of India's efforts toward a carbon-neutral economy.

Table 2 shows the results of various regression analysis indicators by running linear regression analysis on the framed data set. Multiple R is the first element that shows correlation, and the second element of the R square is the regression coefficient, which has a value of 0.98 and 0.97, respectively. However, the adjusted R square with a value of 0.97 for conducting data analysis will be preferred as it gives a more reliable reckoning of the result.

Table 2. Elements of regression analysis

Regression Stats	
Multiple R	0.989468256
R Square	0.979047429
Adjusted R Square	0.978241561
Standard Error	$0.1x10^{12}$
Observations	28

Table 3. F-value Calculation of framed data

	df	*SS*	*MS*	*F*	*Sig F*
Regression	1	$2x10^{25}$	$2x10^{25}$	1214.898	$2.35x10^{-23}$
Residual	26	$4.27x10^{23}$	$1.64x10^{22}$		
Total	27	$2.04x10^{25}$			

The values of the Regression coefficient interpret that the prediction rate of GDP through Renewable energy consumption is high. It means with the increase in consumption of renewable energy with result in economic development of India. Moreover, such development is good for economy and ecology both. This high relation of renewable energy on Indian GDP is a proof that economic development can be triggered even without harming environment.

Table 3 shows the F value calculation of the frame data set. The F value is calculated based on the degree of freedom sum of squares and the mean square. The result shows the consequential impact of the independent variable as the significance of the value is less than 0.05. Hence, it can be deciphered that renewable energy consumption also pushes the Nation's GDP as other related factors.

The P values of Table 4 are less than 0.05, signifying the statistical impact of bioenergy consumption on India's GDP. In coefficients column of the table represents the constants of the regression equation crafted which gives the following values to the equation formulated in the research methodology: GDP = $5.76202\ x10^{12} + 0.100958\ x10^{12}$ (Rc).

Figure 3 shows the residual plot of renewable energy consumption. A residual plot is a graph in which the vertical axis depicts the residuals & the horizontal one represents the independent variable. A linear regression model is adequate if the dots are randomly distributed down the horizontal axis; otherwise, a non-linear model is appropriate.

A normally distributed plot as a graphical aid is used to depict significant deviations from normality visually. Outliers, skewness, kurtosis, the necessity for transformations, and mixes are all examples of outliers. Normal probability charts are constructed using raw data, model fit residuals, and estimated parameters. Figure 4 shows our research's normal probability plot of the dependent variable GDP. In the figure's sample, the percentile is aligned in a linear line when plotted along with the GDP. This alignment is a good sign for the data fit for the analysis and drawing conclusion.

Table 4. F-value calculation of framed data

	Coefficient	**Standard Error**	**t Stat**	**P-value**	**Lower 95%**	**Upper 95%**
Intercept	$5.76202x10^{12}$	$1.31x10^{11}$	43.90763	$6.4x10^{-26}$	$5.49x10^{12}$	$6.03x10^{12}$
Renewable energy consumption (% of total final energy consumption)	$-1.00958x10^{11}$	$2.9x10^{9}$	-34.8554	$2.35x10^{-23}$	$-1.1Ex10^{11}$	$-9.5x10^{10}$

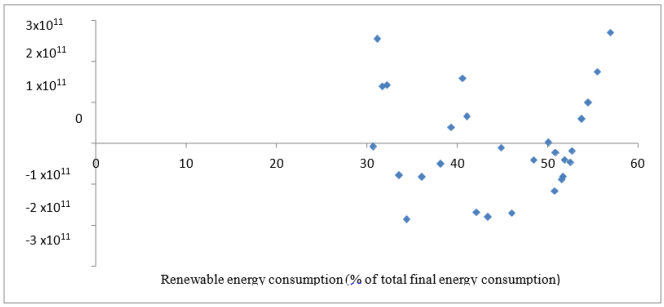


Figure 3. Renewable energy consumption (% of total final energy consumption) residual plot

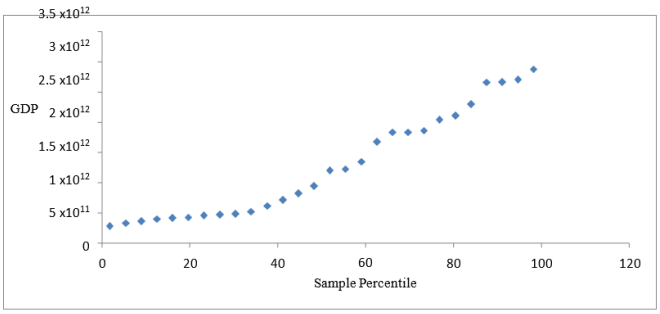


Figure 4. Normal probability plot

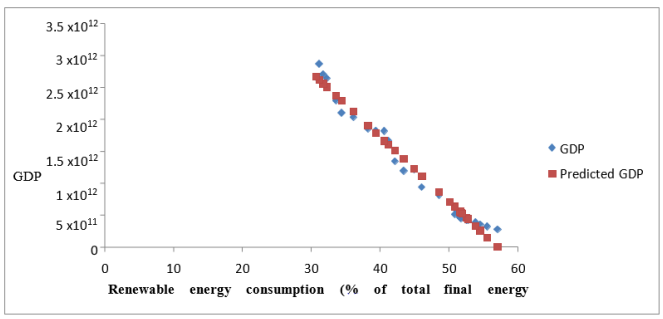


Figure 5. Renewable energy consumption (% of total final energy consumption) line fit plot

Figure 5 shows a line fit plot comparing actual and predicted GDP. The predicted GDP is calculated based on green energy consumption, which is the independent variable in the article. As in the diagram, it can be observed that the predicted and actual GDP is dense; hence the prediction is quite near to the actual values of the variable.

Table 5 displays descriptive statistics for GDP and the proportion of entire energy utilization, respectively. Regarding average data, there is a positive & increasing trend in the percentage of power usage and Economy. This also present the regression coefficients for the factors under consideration. The highest standard deviation is found in GDP, followed by the net total of final energy consumption. Variables are skewed positively, while energy usage is biased negatively. The kurtosis value of the factors is also less than the normal distribution.

The CAGR tool helps measure the jump of a variable over some time. Figure 6 shows the compound annual growth rate of GDP and renewable energy consumption. Since it is clear from the figure that renewable energy consumption shows a negative growth rate of -2.27%, it is not conducive to the sustainable development of the Economy. This is a matter of concern for the government, and the administration must take specific steps to increase this percentage in the upcoming years. This percentage must be increased by changing the policies and creating specific awareness campaigns.

Moreover, as far as the other variable, GDP, is concerned for a country like India, this compounded rate of 8.71% is remarkable. As in today's time, it is necessary because of the change in the climatic condition, the development of the Economy is not done at the development of ecology.

Nevertheless, with a collective effort of the government and people of India, if the role of renewable energy in this growth can be increased, it will be good for both the Economy and ecology.

Table 5. Descriptive statistics

Particulars	*GDP (current US$)*	*(% of total final energy consumption)*
Mean	1.27 x10^12	44.5281
Standard Error	1.64 x10^11	1.609689
Median	1.07 x10^12	45.4833
Standard Deviation	8.69 x10^11	8.517673
Sample Variance	7.55 x10^23	72.55076
Kurtosis	-1.21592	-1.35217
Skewness	0.501841	-0.29531
Range	2.59 x10^12	26.33997
Minimum	2.79 x10^11	30.6434
Maximum	2.87 x10^12	56.98336
Sum	3.55 x10^13	1246.787
Count	28	28
Largest (1)	2.87 x10^12	56.98336
Smallest (1)	2.79 x10^11	30.6434
Confidence Level (95.0%)	3.37 x10^11	3.302809

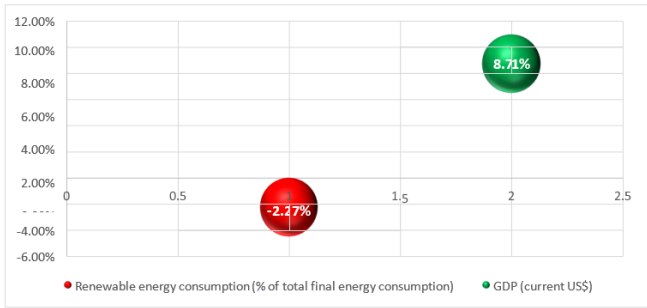


Figure 6. CAGR of the variables used in research

5. CONCLUSION

The findings of different regression analysis indicators are shown in Table 1 after performing linear regression analysis on the framed data set. The first element of the R square is the correlation coefficient, and the second element of the R square is the regression coefficient, both of which have values of 0.98 and 0.97. However, the adjusted square, or 0.97, will be preferable while doing data analysis since it provides a more dependable calculation of the outcome. The F value computation for the frame data set is shown in Table 2. The F value is determined using the sum of squares of the degree of freedom and the mean square. The result demonstrates the independent variable's consequential effect since the significance level is smaller than 0.05. As a result, it may be deduced that renewable energy use, like other variables, contributes to the Nation's GDP. The P values in Table 3 are less than 0.05, indicating that renewable energy usage

statistically influences India's GDP. The coefficients column of the table contains the constants used to construct the regression equation, which results in the following values for the equation established in the study methodology: GDP = 5.76202E+12 + 1.00958E+11(RC).

The use of renewable energy is essential in growing India sustainably without harming the natural resources. Hence, it can be interpreted that renewable energy consumption is significantly impacting the Nation's growth prospects. So, the government must focus on sustainable growth by encouraging green energy as a big section of India's energy usage.

6. FUTURE DIRECTION

Appropriate energy reuse is required to meet the energy demand. Experts from all over the globe agree that renewables are used to make power. Diesel prices are no longer limited, as fuels are no longer the primary energy source for businesses. The solar power effect of wind, hydro energy, solar thermal, solar, and biomass urges energy supply organizations to use them. Besides, people could configure tiny PV arrays on their rooftops to meet their load. Saving energy or using renewables is the ultimate goal as many cars run on gas which will eventually run out, forcing the auto industry to transform to alternate fuels like hybrids. There are many ways to save energy; for example, we often leave the lights on when no one is present. This habit will save much money on electricity. Compact Fluorescent Lamps can be substituted for Incandescent Lamps. They need little power and generate more light with the same flow of electricity. This reduces costs and saves the resources required to achieve a nation's tremendous economic success.

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