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Geopolitical crisis & energy Security: Resilience to a green economy

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Abstract

The sustainable development of any country depends on energy. Some countries are energy proficient and suppliers to other countries, whereas some countries are energy deficient, hence ,importers of energy. The trade of energy in the present world condition has the constraint of geopolitical risk. Geopolitical risk arises due to prolonged tension between two or more countries due to war or other disagreement that leads to disruption of peace in the region. In the recent past, the war of West Asia has disrupted the peace and tranquility as well as the energy trade of many nations. The weaponizing of energy has drawn the attention of the entire world on this war. The energy security of many nations has been challenged. The sustainability measures particularly Sustainable Development Goals (SDG) are at stake. India depends on this part of the world for its crude oil imports. Crippling of this trade corridor will have far reaching impact on Indian economy. This present study tries to show the impact of the renewable energy on sustainable development. More use of renewable energy will make India self- reliant in the long run, so trigger the pace of movement of India towards Atmanirbhar Bharat.

Introduction:

The Atmanirbhar Bharat Abhiyan, that aims to make India Self-Reliant maybe triggered off, in the light of the present Geopolitical crisis of energy trade. As per the Oil Market Report (OMR) of the International Energy Agency(IEA), the war of the West Asia would lead to the largest supply disruption in the world history in the global oil market. The strait of Hormuz which serves as the lever for the energy trade through the sea has been blocked as a result the shipping in and around Hormuz has been at a near standstill for days.

Amid direct damage to the energy infrastructure in the gulf countries and near halt movement in the cargo around the Hormuz, there will be steep escalation in the disruption of flow in the fossil fuel energy. The war of the middle East has immediate effect on India as the country heavily depends upon the fossil fuel energy import from this part of the geography. The fuel and energy crisis is forecasted to affect Indian economy directly as the industries like the aviation, logistics, agriculture and manufacturing have been already deeply affected by this fuel and energy crisis. The rises in the domestic LPG prices have triggered off the closure of Indian restaurants and commercial kitchens as well.

Indian trade and energy supply chains traverse the geography of the gulf. Unrest in one of India's most important trade corridors that support the major energy imports, merchandise, trade and maritime connectivity has evolved in primary disruption in energy supplies as well as exposed the country to great geopolitical risks.

The present Geopolitical crisis pertaining to the war in the West Asia has created a crisis in the energy trade. In order to ensure energy security India has to increase dependence on renewable energy sources. This requires promotion in technological innovation and domestic manufacturing of equipments. India has already launched schemes like National Solar Mission, National Green Hydrogen Mission, PM Suryaghar: Muft Bijli Yojana; these schemes aim

* to reduce India's dependence on imported fossil fuel energy

* to enhance energy security of the country. Reliance on renewable energy on the other hand, will support the climate action commitments and generate employment.

Literature Review:

There exist a number of studies in the area of geopolitics. There is a wide availability of studies in the field of energy trade too. A number of studies have been conducted in combination of the two issues. Some have been enumerated below for ready reference.

Soto (2020), has highlighted on the Peer-to-Peer energy trading model where consumers and producers can exchange energy without the need for an intermediary.

Li, Yang and Failler (2021), have analyzed whether geopolitics have an impact on energy trade. They have concluded that geopolitics have a negative impact on the import and export of the energy trade.

Ahmed (2021), has highlighted upon the role of green innovation, trade and energy to promote green economic growth in South Asian Nations.

Bonsu and Wag(2022), have examined the triangular relationship that exists between energy consumption, trade openness and economic growth. The authors have suggested that energy measures that aim to lessen energy usage in an economy will hinder economic growth.

Bointe (2022) has opined about the weaponizing of energy, trade and investment Law in the new geopolitical reality. The author has also opined that with energy being used as a weapon, reform of the liberal energy regime is needed in order to protect the countries energy security in the new geopolitical reality.

Kuzomko et al (2024), has laid emphasis on rethinking about energy geopolitics.

Akadiri and Ozkan (2025), have conducted a study to examine the intricate relationship that exists between energy market swings and geopolitical risks.

Koirala(2025), has attempted to study the geopolitical risks and energy market dynamics.

Miglani (2025), has studied how Blockchain technology influences energy trade.

On an analysis of the available literature, it is seen that very few empirical studies exist in this context.

Objectives:

The main objective of the study is to highlight on the trend of impact of the main energy indicators on sustainable development. From this broad objective the other objectives that follow are:

i) To study the effect of energy used per capita on sustainable development.
ii) To study the effect of energy used per unit of GDP on sustainable development.
iii) To study the effect of supply efficiency on the sustainable development.
iv) To study the effect of productivity on sustainable development.
v) To study the effect of all the seven indicators on CO2 emissions.

Research Methodology:

In our study, we have used quantitative variables to find out the impact of those on sustainable development in India. *"Energy indicators for Sustainable Development: Guidelines and Methodology,2005" by the International Atomic Energy Agency , United Nations Department of Economic and Social Affairs , International Energy Agency , Eurostat and European Environment Agency,* has identified a core set of energy indicators , that are called as Energy indicators for Sustainable Development. These indicators are as follows:

- ***Energy use per capita*** *(it measures the level of energy use on per capita basis and reflects the energy use patterns and aggregated energy intensity of a society)=* ***(Use of energy/ Mid-year population)***

- ***Energy use per unit of GDP****(it reflects the trends in overall energy use relative to GDP, indicating general relationship of energy use to economic development) =* ***(Total supply of energy/GDP at constant price)***
- ***Supply Inefficiency****(it measure the efficiency of energy conversion and distribution systems in various energy supply chain including losses occurring during electricity transmission)=* ***(Losses in transmission of electricity/ Gross generation of electricity)***
- ***Productivity****(it measures the sum of availability of national energy reserves and resources with respect to corresponding fuel production , where reserves are defined as identified resources that are economically recoverable at the point of assessment. But, total resources includes reserves, hypothetical and speculative undiscovered resources)*

a) Reserve to production ratio= (Proven energy resources of a commodity at the end of a year/ Total production of that commodity in that year)

b) Resource to production ratio = (Proven energy reserves of a commodity at the end of a year/ Total production of that commodity in that year)

Productivity= (Reserve to production ratio + Resource to production ratio)

- ***Sectoral energy intensities*** *(it measures the sectoral energy intensity of major energy consuming sectors. How efficiently the technologies are being used in different sectors to improve the efficiency of energy generation)=* ***(Amount of energy consumed against sector/ GVA of that sector)***
- ***Share of Renewable Energy****(it reflects the share of RE in total generation of electricity, depicts the dependency of a nation over fossil fuel, what is the trend of use of RE source in generation of electricity in India)*
- ***Net energy import dependency****(it measures the extent to which a country relies on imports to meet it's energy requirements) =* ***(Net import of energy commodity/ Total supply of that energy commodity)***

All of these 5 indicators are represented as energy indicators for sustainable development and these are independent variable in our paper. For sustainable environment indicator, we consider Co_2 emissions (in million metric tons) is dependent variable and we find out the impact of all these 5 indicators on CO_2 emissions. Reduction in the level of increase in Co_2 emissions is the necessary condition for improvement of clean and sustainable environment. Earlier, we introduced 7 indicators, but entire analysis has done by using 5 indicators. As Electricity use per capita GDP, productivity, Electricity uses, Electricity uses within sector are linked with each other, so to avoid muticollinearity problem we consider only one factor i.e, electricity uses per unit GDP i.e, GDP intensity instead of 4 indicators.

First of all we use descriptive and quantitative research methodology to show the trend of all these factors during 2014-2024 in India. After that, we empirically analyze these time series data by checking Unit root test(ADF test) to check variables are stationary or not, Cointegration test (ADRL Bounds test) that determine long run relationship among variables, VIF test for muticollinearity , Brush- Pagan test for checking heteroskedasticity, Bruesh – Godfrey test for serial correlation & Shaprio-Wilk test for checking residuals are normally distributed or not. In this regression model we also find out statistically significant impact of these entire independent factor on our dependent variable, i.e, CO_2 emissions, that indicate sustainable environment indicator, by checking coefficients of ß's , p value, & the value of R^2. In this analysis, we use t statistic & F test statistic for multi regression analysis. In this model, there arises some level of cointegration, so we introduce ECM (Error Correction Model) & check the short run and long run impact of that variables on CO_2 emissions as well as speed of adjustability if there any shock or crisis in short run.

We used secondary data for our study and collected data from annual report of Energy Statistics India 2024, Annual report of Energy Statistics India 2025, Ministry of Statistics and Programme Implementation, National Statistical Office (NSO) etc.

Data Analysis & Interpretation:

In this section, entire analysis was divided into two sections, first one, we show trend of all these indicators that have been mentioned in earlier section, and second is, we empirically analyse the significant impact of them on CO_2 emissions, and also check short and long run impact of them respectively.

A. Descriptive and Quantitative analysis

i) Trend in Energy use per capita, Productivity, Energy use per unit of GDP, & Supply Efficiency:

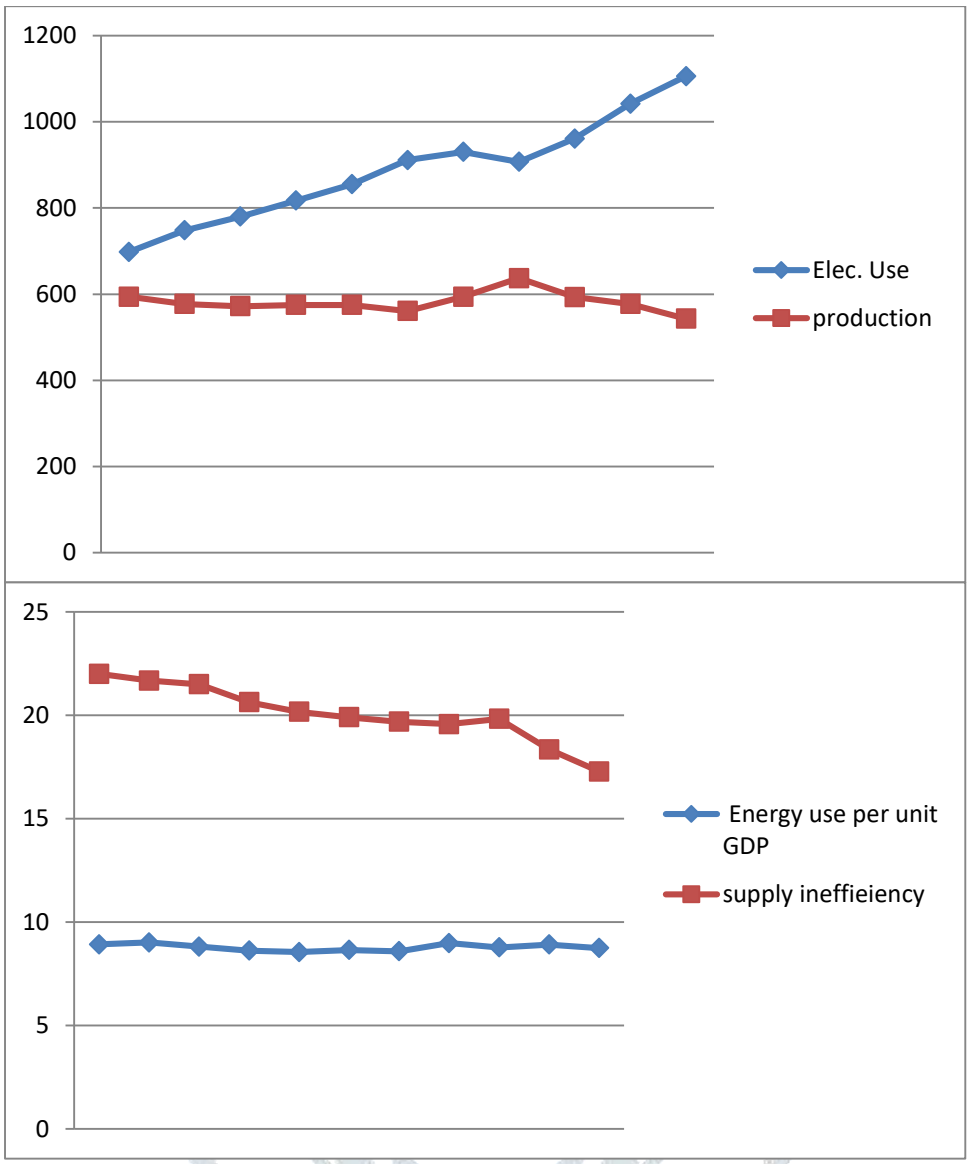
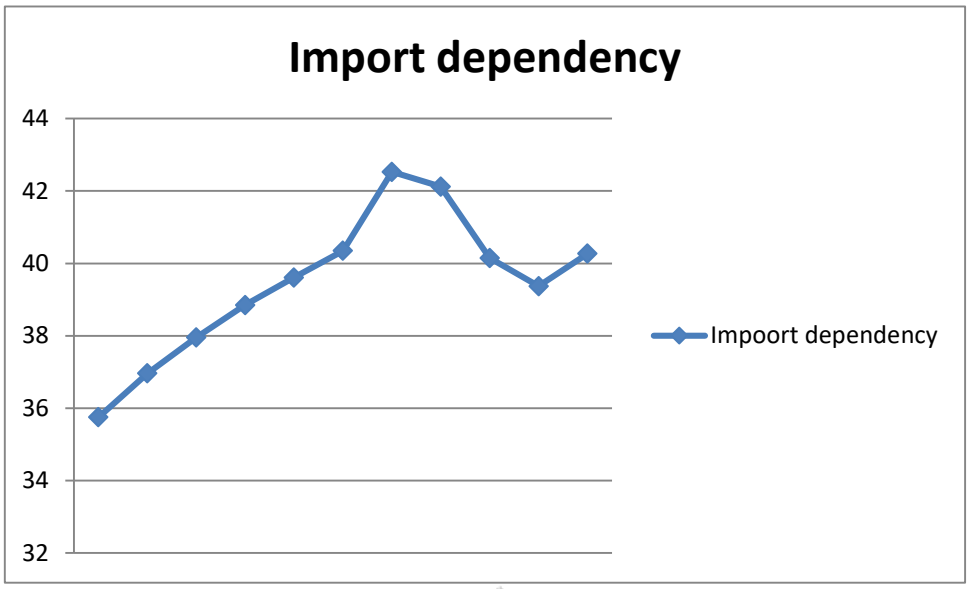


Fig-1A(trends in Energy use per capita& Productivity)

Fig-1B (trends in Energy use per unit of GDP& Supply Efficiency)

From above figure-1A, we find that electricity use per capita increases rapidly from 2014 to 2020 , but it slightly drecreases in 2021,after that it increases in present years. On other hand, productivity i.e,sum of ratio of reserve to prduction and ratio of resource to production rises from 2014 to 2018, after that itreduces in 2019, then it rises upto 2021, then it decreases for the years under study.

Similarly, fig-1B shows energy used per capita in GDP falls from 2014 to now-a-days , whereas, Supply efficiency decreases throughout this period.



ii)Trends in Sectoral energy intensities & Share of Renewable Energy:

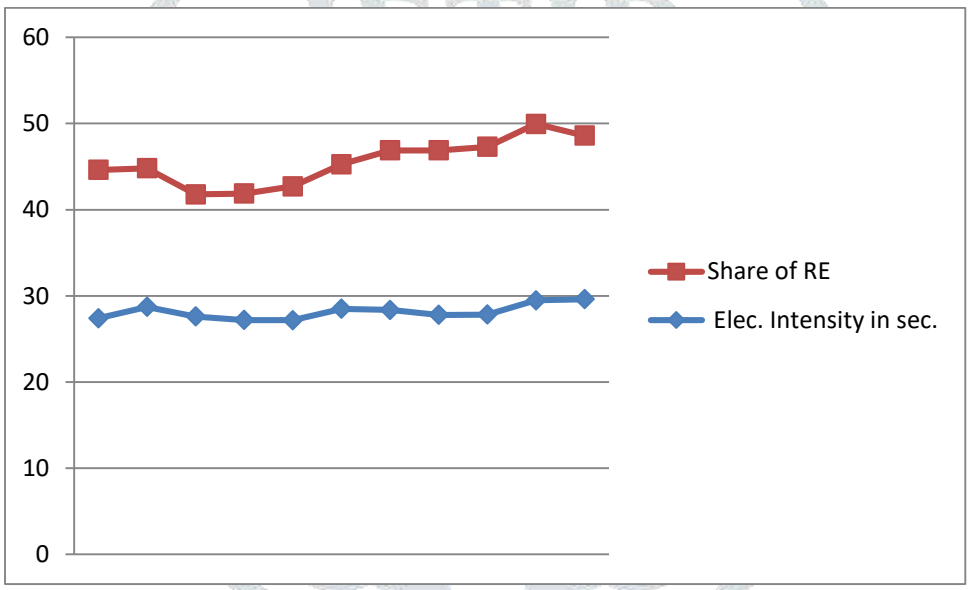


Fig-2A (Trends in Sectoral energy intensities& Share of Renewable Energy)

This graph indicates that, electricity intensities within sector reduces from 2015 to 2018, after that it rises, but share of RE decreases in 2016, then rapidly increases upwards.

iii) Trends in Net energy import dependency & C6arbon-di-oxide (CO_2):

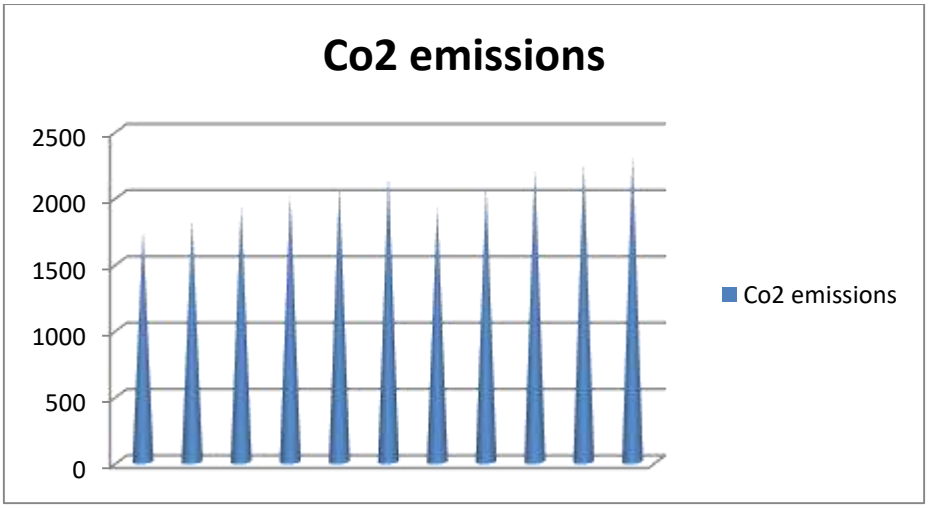


Fig-3A(Trends in Net energy import dependency)

Fig-3B(Trends in CO_2 emissions)

In this figure-3A, import dependency on energy rises from 2014 to 2020, after that it drastically reduces up to 2023 , then slightly increase upwards, but CO_2 emissions decreases in 2020 , due to pandemic of Covid-19, after that it rises.

B. Empirical Analysis

In this section, we have found out whether this earlier diagrammatic relationship between all indicators and CO_2 emissions are statistically significant or not.

i) Unit root test (ADF- Augmented Dickey-Fuller test)

Table-1: ADF test

R Variable	Level I(0) t test	p value	First diff I(1) t test	p value	Results
CO_2 emission	-1.245	0.654	-4.892***	0.001	I(1)
GDP Intensity	-2.102	0.243	-5.110***	0.000	I(1)
Supply inefficiency / Grid losses	-0.890	0.789	-	-	I(0)
Share of RE	-3.984 **	0.012	-3.856**	0.015	I(1)
Import dependency	-1.567	0.498	-4.223***	0.004	I(1)

*Note: *** & ** denotes statistical significance at 1% and 5% level of significance respectively.*

This stationary property of time series data are evaluated using Augmented Dickey- Fuller test. From the table, results indicates share of RE is stationary at level, ie, I(0), but the rest of the variables like- CO_2emissions, and GDP Intensity , Grid losses , and Import dependency contain a unit root at level but become stationary after first difference , i.e, I(1). Therefore, crucially, this tests confirm that no variable is integrated of order I(2),which is mandatory prerequisite for the application of ARDL bounds testing approach. This result confirms that ADRL is the most efficient and unbiased estimator for this specific data set.

ii) ADRL Bunds Test for Cointegration (Bounds test)

Table-2: For cointegrating equation in long run

Test statistic	Value	Significance level	Lower bound I(0)	Upper bound I(1)
F statistic	5.12	1%	3.41	4.68
K	4	5%	2.62	3.79
		10%	2.26	3.35

Note: Critical values are obtained from Peseran et al. (2001), for case III (Unrestricted intercept and no trend)

In order to verify the existence of a long run equilibrium relationship among variables, this ADRL bounds testing procedure was conducted. In this case, calculated F- statistic (5.12) is significantly higher than upper bound critical value (3.79) at 5% level of significance (los).Therefore, we reject the null hypothesis of no cointegration. This indicates a stable long term relationship exists between CO_2 emissions and all these independent variables. This result provides statistical necessity to proceed with the estimation of long run coefficients and short run Error Correction Model (ECM).

iii) Long run coefficients (Dependent variable- CO_2 emissions)

Table-3

Variable	Coefficient	Std. error	t- statistic	Prob.
GDP Intensity	0.852***	0.124	6.870	0.000
Grid losses	18.560**	7.120	2.606	0.021
Share of RE	-0.315**	0.142	-2.218	0.038
Import dependency	0.442*	0.231	1913	0.065
Constant	4.110***	0.980	4.193	0.002

*Note: *** & ** denotes statistical significance at 1%, 5% and 10% level of significance respectively.*

This above mentioned table shows the actual results, i.e, how much each factor impacts CO_2 emissions and how quickly this economy recovers from a geopolitical shock. It indicates that, GDP Intensity, Grid losses has significant positive impact on CO_2 emissions whereas Share of RE has negative significant impact on it. But, Import dependency has positive significant impact on CO_2 emissions at 10% los.

iv) Short run Dynamics and Error Correction Model (ECM):

ECM is the short run component of ADRL analysis, and it indicates some self correcting mechanisms through which variables are correct to solve the problem. Therefore, equation of ECM is as follows: $\Delta In\ (CO_2) = a_0 + \Sigma\ b_i\ \Delta\ In\ (CO_2)_{t-I} + \Sigma\ y_i\ \Delta\ Indicators_{t-j} + n\ ECT_{t-1} + \varepsilon_t$, where, Δ= first difference operator, that represents short term change, n= coefficient of $ECT_{t-1,}$ it is the speed of adjustment, which must be negative and statistically significant at 5% los.

Table-4

Variable	Coefficient	Std. error	t- statistic	Prob.
Δ GDP Intensity	0.210**	0.095	2.210	0.041
Δ Grid losses	5.230**	2.110	2.478	0.024
Δ Share of RE	-0.052	0.061	-0.852	0.402
Δ Import dependency	0.115	0.088	1.306	0.205
ECT (-1)	-0.625*	0.150	-4.166	0.002

*Note: *** & ** denotes statistical significance at 1%, and 5% level of significance respectively.*

This table shows how a short term shocks or sudden geopolitical crisis are solved or absorbed by this system. Here, results indicates that ECT is -0.625 and it is statistically significant at 1% los and negative significant of ECT i.e, Error Correction Term confirms there is an existence of stable long run relationship between energy security and CO_2 emissions. This coefficient of ECT suggests a relatively high speed of adjustment approximately 62.5% of any deviation from long run equilibrium due to external shocks that is corrected within a year. This also confirms that India moves toward a green economy that possesses a higher degree of structural resilience against short term geopolitical volatility. From this table, another important things we found that, grid losses have a positive significant impact in the short run (p=0.024) but RE share takes a longer way to show it's impact as p=0.402. Therefore, it explains green economy transition is the longest way and it is sufficient but grid efficiency is the immediate way to solve crisis, so it is necessary.

Table-5: Comparison between Short and Long run impact

Variables	SR impact	p value in SR	LR impact	p value in LR
CO_2 emission				
GDP Intensity	↑ 1% GDP intensity =>↑ 0.21% CO_2	0.041	↑ 1% GDP intensity =>↑0.85 % CO_2	0.000
Grid losses	↑ 1% Grid losses=>↑ 5.2% CO_2	0.024	↑ 1% Grid losses=>↑ 18.56% CO_2	0.021
Share of RE	↑ 1% share of RE=> ↓0.05% CO_2	0.402	↑ 1% share of RE=> ↓0.31% CO_2	0.038
Import dependency	↑ 1% import dependency =>↑ 0.11% CO_2	0.205	↑ 1% import dependency =>↑ 0.44% CO_2	0.065
ECT	relatively high speed of adjustment approximately 62.5% of any deviation	0.002	Constant	0.002

In long run renewable energy and grid efficiency are the drivers of reducing carbon emissions but in short run dynamics highlights addressing grid losses indicates immediate impact on resilience. On the other hand, import dependency and improving supply efficiency India will achieve self reliant and self sufficient in the next future.

v) Bruesh- Pagan test, Bruesh-Godfrey test , Shaprio-Wilk test & VIF test

Table-6

Test	Test statistic	Value	Remarks
Bruesh- Pagan test	0.450	0.502	*No severe heteroskedasticity ($p<0.05$)*
Bruesh-Godfrey test	1.104	0.385	*No serial correlation*
Shaprio -Wilk test	0.942	0.512	*Residuals are normally distributed ($DW<2$)*
VIF	2.15	-	*No muticollinearity*

In this case, residuals are normally distributed and error variance is equal to a particular constant. At the same time, there is no serial correlation and no multi-co linearity problems associated with these indicators. As Elec. use, Elec use per capita GDP,i.e, GDP intensity , productivity and Elec. use within sector are indicators are linked with each another. So, we dropped these 3 indicators and use only one indicator, i.e, GDP intensity rather than all these three factors.

vi) Multiple Regression Analysis:

In our study, we consider multiple regression model with 7 indicators, where all these indicators are independent variables, and CO_2 emission is considered to be the dependent variable. Here, we want to find out the impact of these seven indicators on CO_2 emission. Therefore, the multiple regression model is as follows:

Model: $\ln(CO_2 \text{ emission}) = ß_0 + ß_1$ (GDP intensity) $+ ß_2$ (Grid losses) $+ ß_3$ (Share of RE) $+ ß_4$ (Import dependency) $+ ß_7$ (Import dependency)$+ Ɛ$, where $ß_0$= intercept term, $ß_i$= the coefficients of each factors, i= 1(1)4, $Ɛ$= error term

Table-7: Multi-regression analysis

Variables	Coefficients(*ß*)	Std. error	t statistic	p value	Significant impact	Interpretation
Intercept ($ß_0$)	3.850	0.820	4.695	0.001		
GDP Intensity	0.785***	0.112	7.008	0.000	Positive impact	*↑ in elec. use per unit GDP by 1 unit, results in CO_2 emissions by ↑ 0.78. It means efficient process reduces emissions.*
Grid losses	16.210***	6.850	2.366	0.028	Positive impact	*↑ in supply efficiency by 1unit, causes CO_2 emissions ↑ by 16.21, indicating efficiency linked with higher production scales.*
Share of RE	-0.294**	0.130	-2.261	0.035	Negative impact	*↓ in CO_2 emissions by 0.29, when share of RE ↑ by 1 unit, reflects clear environment and decarbonization in nation as a whole.*
Import dependency	0.398*	0.210	1.895	0.072	Positive impact	*↑ in import dependency by 1 unit causes ↑ in CO_2 emissions by 0.39. It possibly occurs due to transport services.*
F statistic	28.45			0.000		*All null hypotheses are*

						rejected, and alternative hypothesis are accepted here except in case of productivity.
R^2	0.92= 92%					*92% of CO_2 emissions variation is explained by the independent factors in this model. It indicates good fit.*
Adjusted R^2	0.89= 89%					*Indicates good fit*

*Note: *** & ** denotes statistical significance at 1%, and 5% level of significance respectively.*

Conclusion & Suggestions:

In present geopolitical crisis, all of us realize that energy is important for development and should be procured through direct resource mobilization of one's country. Hence, India's dependency on renewable energy sources rises. One of the important goals of SDGs is Goal-7 that aim to ensure access to affordable ,reliable, sustainable and modern energy, also it stresses more focused attention to improved access to clean and safe fuels, technologies, improve energy efficiency, increase use of renewable sources, and promotes sustainable and modern energy for all purposes.

Descriptive analysis shows during 11 years, level of CO_2 emissions increases along with increase in electricity use per capita, electricity intensity within sector, supply inefficiency, import dependency, productivity, and share of RE decreases with increase in CO_2 emissions. But, GDP intensity remains stagnant. It means effect of increase in GDP Intensity, grid losses dominates the effect of share of RE in the short run, as In our study, we also find that long run impact was more powerful compared to short run impact, in concept of stability of clean environment and green energy in the next future by improving share of renewable energy.

In our study, we found that GDP Intensity, Grid losses and import dependency has statistically positive impact on CO_2 emissions. But, electricity use per unit GDP, but, share of RE has statistically negative impact on CO_2 emissions; it indicates that these 3 indicators have effects immediately on the reduction of CO_2 emissions. In case of cointegration we also found that, grid losses have a positive significant impact in the short run ($p=0.024$) but RE share takes a longer way to show it's impact as $p=0.402$. Therefore, it explains green economy transition is the longest way and it is sufficient but grid efficiency is the immediate way to solve crisis, so it is necessary.

As reduction in CO_2 emissions is the indicator for clean and sustainable energy, so to achieve target of Goal-7 SDGs 2030 agenda, we ought to follow these policy suggestions in prospect of sustainable energy in India so as to make India self reliant i.e., Atmanirbhar Bharat@2047:

- Increase share of RE , that reduces CO_2 emissions
- Improve electricity intensity within sector so that it causes fall in the amount of CO_2 emissions
- Electricity use per unit of GDP or GDP Intensity will be improved by using modern & efficient technology , that harm less and indicates clean and sustainable environment by reducing CO_2 emissions
- Reduction in electricity use per capita results in improvement in the level of reduction in CO_2 emissions, but it 's lengthy process
- Reduction in import dependency will be possible by boosting domestic renewable energy in case of import transmission , as a result it reduces the level of CO_2 emissions
- Improvement in supply efficiency for electricity conversion and distribution in various energy supply chain, so that CO_2 emissions will be reduced.

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