Journal Homepage: - www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI: 10.21474/IJAR01/17997
DOI URL: http://dx.doi.org/10.21474/IJAR01/17997

RESEARCH ARTICLE

JUST TRANSITION TO GREEN ENERGY - A CASE STUDY ON INDIA AND DENMARK

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Manuscript Info

Manuscript History
Received: 15 October 2023
Final Accepted: 18 November 2023
Published: December 2023

Key words:-
CO_2 Productivity, Linear Regression Analysis, Green Energy, Green Jobs

Abstract

The transition towards green and decent jobs is a critical imperative for sustainable economic growth and environmental well-being. However, amidst global efforts to combat climate change, India faces the challenge of achieving inclusive economic growth. This paper delves into the juxtaposition of two distinct narratives in the realm of green and decent jobs, exploring the disparities between India and Denmark, an exemplar of sustainable development in Europe. Currently Denmark runs mostly on renewable Energy, around 75% of energy comes from renewable energy sources, with Denmark's trajectory in achieving 100% renewable energy by 2030, it serves as an aspirational benchmark against which we assess India's CO_2productivity. India's coal dependency extends further due to its massive coal reserves, estimated at around 100 billion tons, primarily concentrated in the eastern states of Jharkhand, Chhattisgarh, and Odisha. It was estimated that 74% of India's energy generation came from coal fired plants in 2021. Therefore, it is essential to have a just transition which also ensures upskilling and employing workers in green Jobs. Linear regression models for Denmark and India have been constructed to understand the relationship between CO_2 productivity and various predictor variables. The model for Denmark exhibits a good fit, implying that all predictor variables collectively explain 95% of the variance in CO_2 productivity. The model for India shows a strong fit, indicating that approximately 97.5% of the variance in CO_2 productivity is explained by the predictor variables. This suggests that the model is highly significant in understanding the factors influencing CO_2 productivity in India. In conclusion it has been recommended that India can incorporate Denmark's policy for a smooth transition towards green energy, using the five "R's", these key elements provide a roadmap for policymakers, governments, and local stakeholders to navigate the complex challenges of economic restructuring and environmental sustainability.

Introduction:-

Fossil fuels are the primary cause of human-made climate change. Coal is the most carbon-intensive fossil fuel, and its rapid phasing out is essential to limit global warming to 1.5°C, as set out in the Paris Agreement. Carbon dioxide (CO_2) from the combustion of fossil fuels and biomass accounts for 90% of total greenhouse gas (GHG) emissions

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and is thus a key factor in country's ability to deal with climate change[1]. The stabilization of GHG concentrations in the atmosphere depends on the implementation of coherent national and international policies that aim at structural and technological changes. It depends on country's ability to further decouple CO_2 and other GHG emissions growth from economic growth and reduce the overall level of emissions. Climate change is of global concern for its effects on ecosystems, human settlements, agriculture and the frequency of extreme weather events which could significantly impact human well-being and socio-economic activities.

Production-based CO_2 productivity is calculated as real GDP generated per unit of CO_2 emitted (USD/kg) and included are CO_2 emissions from combustion of coal and other fuels. In 2022, Global energy-related carbon emissions rose by 6% to 36.3 billion tonnes, their highest-ever level as the world rebounded strongly from the covid 19 crisis and relied heavily on coal to power that growth. Notably, coal being a cheap and abundant resource, accounted for 40% of the overall growth in global CO_2 emissions[2]. As the demand for electricity in many emerging and developing economies has been growing rapidly, increase in renewable power sources like solar and wind is still not high enough and hence coal is often called upon to fill the gap. Today, there are around 8500 coal power plants in operation worldwide, producing a fifth of global greenhouse gas emissions - more than any other single source. Most of the world's existing coal-fired power generation is in emerging and developing economies. For example, roughly 60 percent[3] of the electricity generated in China, India and Indonesia is from coal.

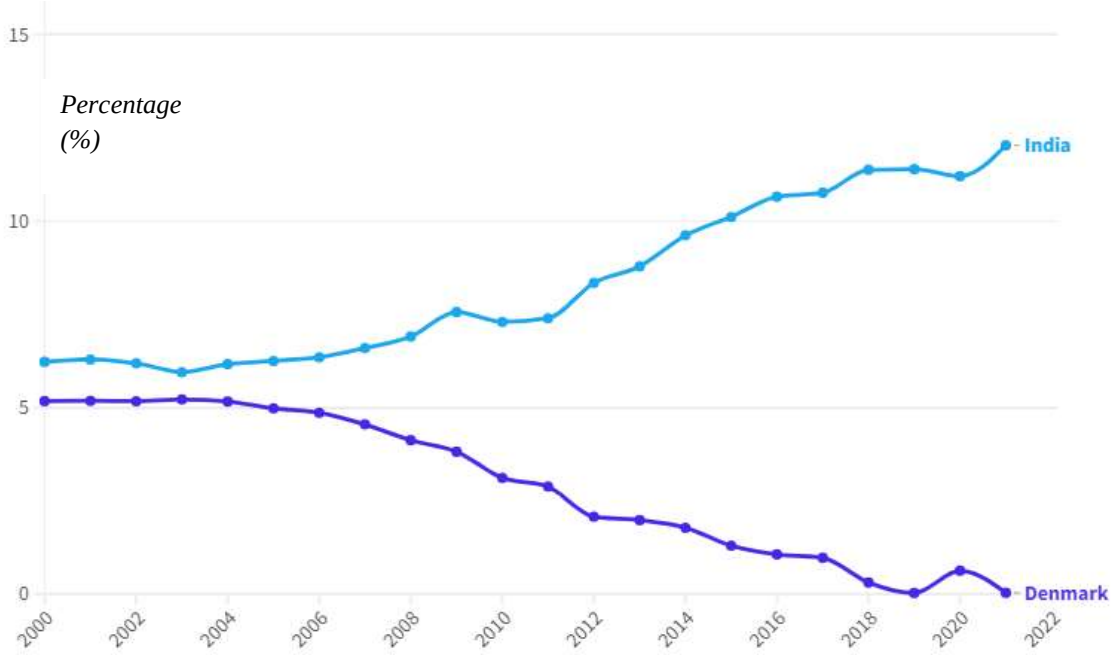

Figure 1:- Percentage share of global annual CO_2 emissions from coal[1]

As transitioning away from coal is crucial to ensuring a clean energy future, a well-managed retirement of coal power plants calls for a "Just Transition for all" initiative that puts people and communities at the center of the transition. Phasing out coal is complex as it not only would displace mine workers but disproportionately impact workers in related sectors and entire communities in surrounding coal regions. A just transition does not imply low economic productivity, in fact, it paves the way for higher economic productivity as demonstrated by countries like Denmark.

[1]https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data
[2] https://www.iea.org/news/global-co2-emissions-rebounded-to-their-highest-level-in-history-in-2021
[3]https://www.iea.org/commentaries/it-s-critical-to-tackle-coal-emissions

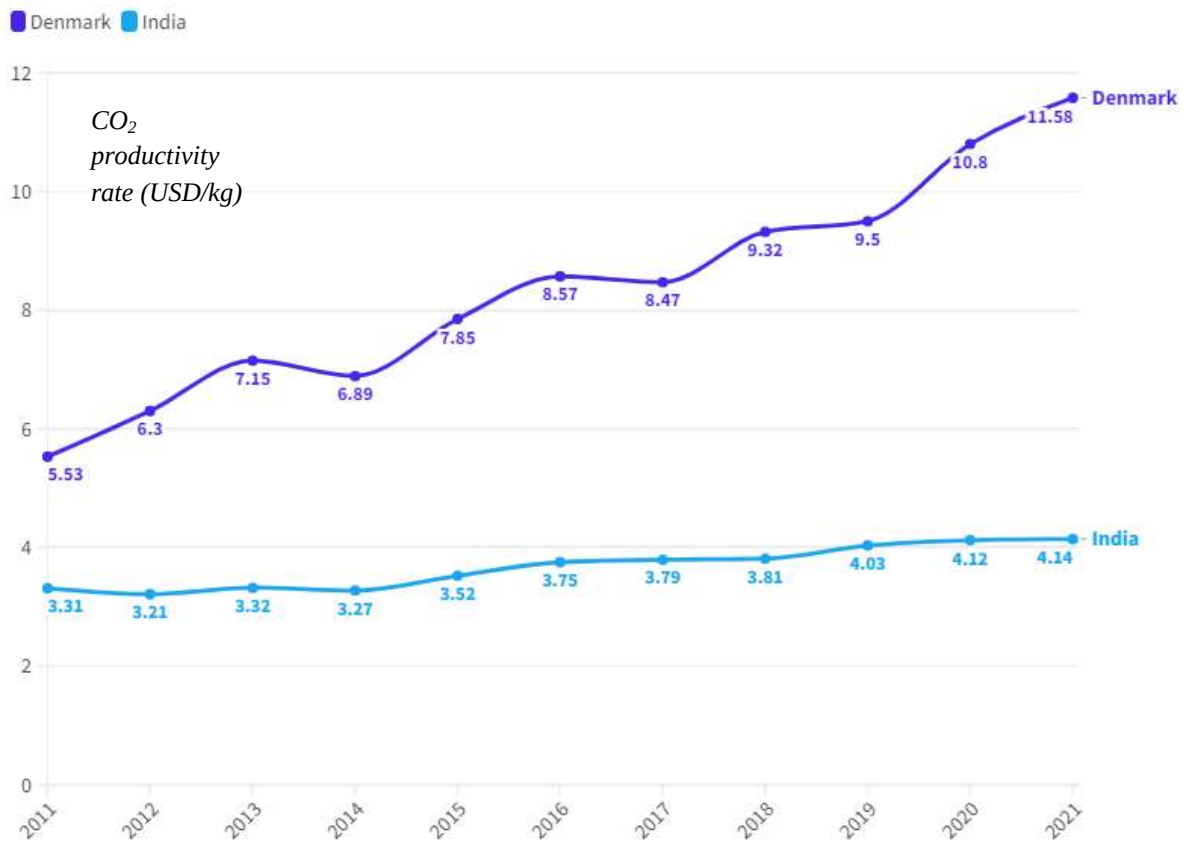

Figure 2:- Energy-Related CO_2 Productivity Rate for Denmark and India[1]

Denmark's remarkable CO_2 productivity rate of 11.58 in 2021 in contrast with India's Carbon productivity rate 4.1 in the same year. Denmark's approach prioritized the well-being of the workers and emphasized social equity and inclusivity. India's heavy dependence on coal, responsible for about 1.238% of its GDP and employing roughly 355,000[4] direct workers and 1.2 million indirect workers underscores the need for a just transition strategy. To strike a balance between economic growth and environmental responsibility, India should prioritize clean energy, retraining coal workers, and creating alternate employment opportunities, taking cues from successful just transition models.

India's Coal Dependence Landscape

India's heavy dependence on coal is a multifaceted challenge that demands focused attention for a just transition. Recent findings reveal that nearly 40 percent of India's 736 districts have some form of coal dependency[5]. Approximately 2 million people are either directly or indirectly employed in coal mining and power sectors across 159 districts, with 80 percent of these jobs tied to coal mining in 51 districts, while the remaining 20 percent are associated with coal power plants[6].

India's coal dependency extends further due to its massive coal reserves, estimated at around 100 billion tons, primarily concentrated in the eastern states of Jharkhand, Chhattisgarh, and Odisha. Coal is deeply ingrained in the local economies of these regions, serving as a lifeline for some of India's poorest communities. Even with global pressure to reduce coal usage, India has continued to ramp up production and imports, potentially reaching 1.18 billion tonnes of national coal consumption by 2024.

[4]https://www.teriin.org/sites/default/files/2021-06/Coal-Dependence-Need-Just-Transition_WP1.pdf
[5]https://ddrn.dk/9307/#:~:text=Research%20by%20Sandeep%20Pai%20at,some%20form%20of%20coal%20dependency.
[6]https://india.mongabay.com/2021/07/about-40-percent-of-indias-districts-have-some-form-of-coal-dependency/

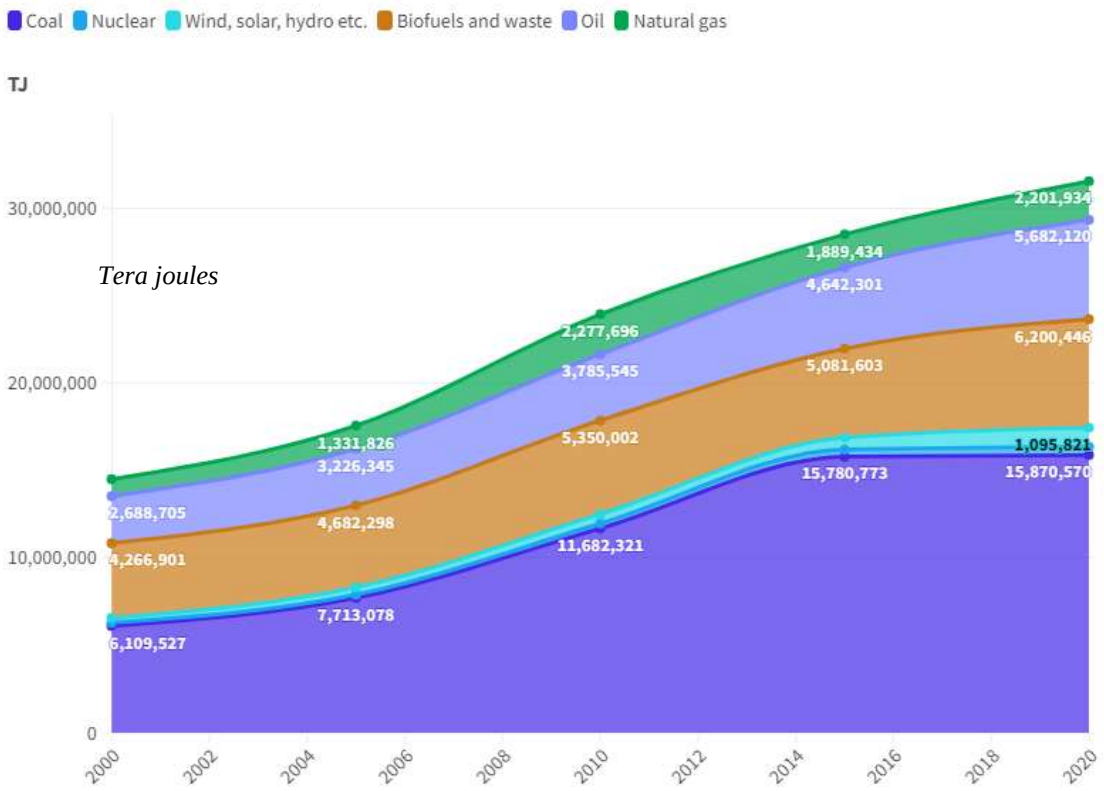

Figure 3:- Total energy supply (TES) by source, India 2000-2020[12]

Despite substantial investments in renewable energy sources like solar and wind, coal remains central to meeting India's rising energy demand and consumption. The nationalization of coal mining and the establishment of Coal India Limited (CIL), the world's largest coal mining organization, have further entrenched India's reliance on coal. In 2021, coal constituted 74 percent of India's power generation, with a forecast suggesting that coal-fired generation will account for 70 percent of the electricity mix in 2024, while renewables will make up 22 percent.[7]

[7]https://ember-climate.org/countries-and-regions/countries/india/

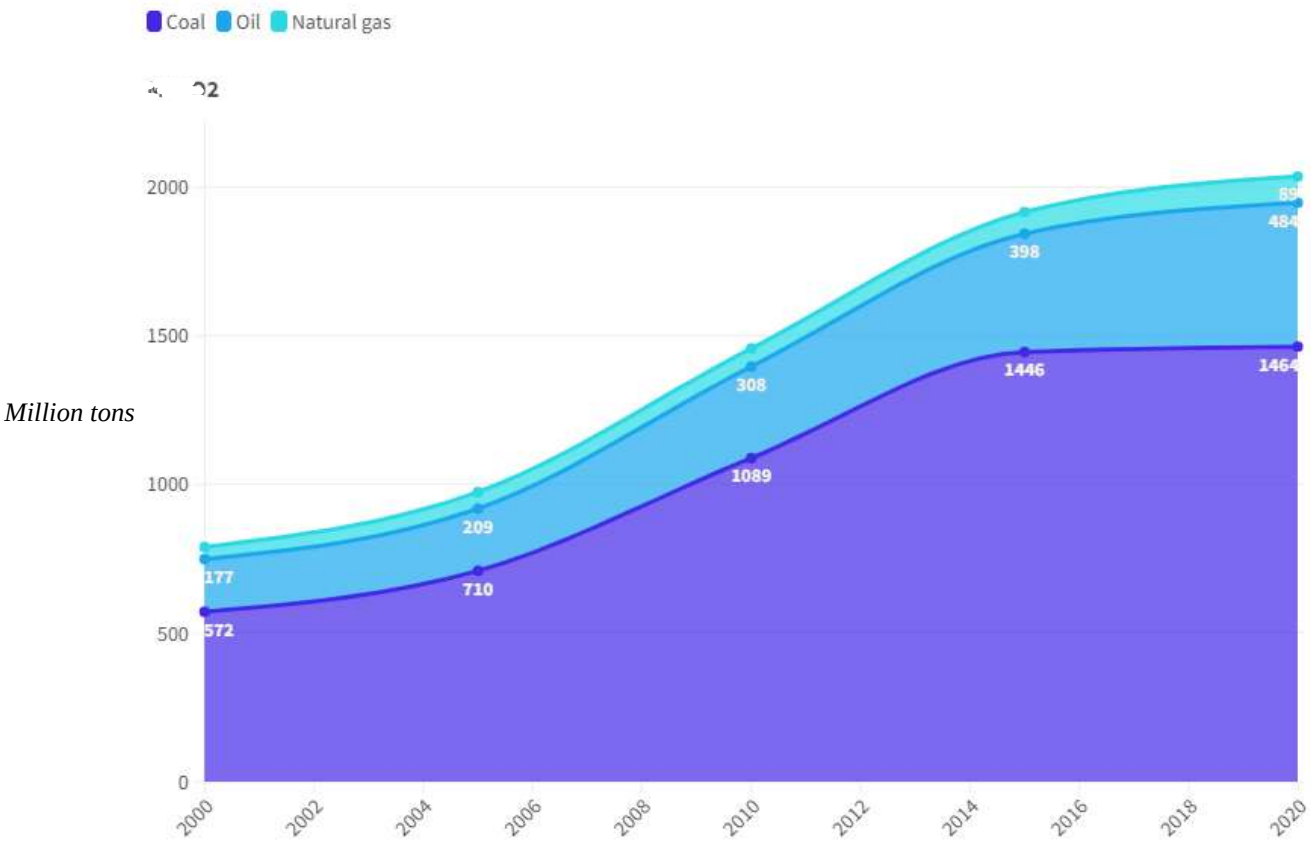

Figure 4:- CO_2 emissions by energy source, India 2000-2020[16]

These statistics highlight the depth of India's coal dependency, underlining the critical need for a well-planned and equitable just transition strategy in line with its climate action goals and pledges. Such a strategy must consider the livelihoods and well-being of the millions of individuals and communities intertwined with the coal sector while navigating the transition toward a more sustainable and greener energy landscape.

Literature Review:-

Energy production is a global issue.India's energy system, which is crucial to the world, is currently facing a double crisis[8]. On one hand, with the arrival of the peak production of coal, natural gas and oil, the world has begun to enter the stage ofexploitation of these resources, resulting in a resource crisis. In addition, in terms of waste, the burning of fossil fuels, coal, and other fuels leads to an increase in greenhouse gas emissions which results in an environmental crisis, thus requiring an unprecedented worldwide energy transition for the sustainable development of human society. At present, the growth of energy consumption in developed countries is slow, as social development is gradually decoupled from energy consumption growth, and the development of distributed energy promotes a change in supply mode.Fossil fuels are the primary cause of human-made climate change. Coal is the most carbon-intensive fossil fuel, and its rapid phasing out is essential to limit global warming to 1.5°C, as set out in the Paris Agreement. In March 2021, the UN Secretary-General urged all theOECD(Organisation for Economic Co-operation and Development) countries to commit to phasing out coal by 2030 and non-OECD countries to do so by 2040 to be able to meet the 1.5°C goal[9]. However, the statusof coal power plants as of 2021 shows that the world is far from reaching this objective unless drastic steps are taken immediately.

[8]https://www.sciencedirect.com/science/article/pii/S2214790X2200003X
[9]https://www.ilo.org/wcmsp5/groups/public/---asia/---ro-bangkok/documents/publication/wcms_845700.pdf

Energy security in an energy transition environment[1]:
This article explains concept of energy security taking into account sovereignty, robustness and resilience. The energy security of 27 countries in the European union has been studied. Two methods are used namely narrow method and composite method. Given all the above, this research verifies that it is possible to present a quantitative representation of the evolution of security of supply. It must nonetheless be borne in mind that the results of the study could change if one assigns different weightings to the indicators used.the study suggests that Russia's blockage of the flow of gas to Ukraine and Europe undermined the EU's security of gas supply, since changes in the level of security of gas supply were clearly observed in the research, and could be connected with the impact of interruptions to gas supply and the policies adopted after the conflicts. In order to improve the EU's problem of energy security, then, given the current scenario of energy transition, the need would be to adopt an EU-wide energy policy emphasising restrictions on the consumption of fossil fuels, the reduction of imports, an increase in the consumption of renewable energies, and leaving part of the reserves of fossil fuels in the ground. In other words, a serious approach to the Paris challenge, as well as reducing global GHG emissions, limiting the burning of fossil fuels and leaving a percentage of reserves of such resources in the ground.

Energy system transformation to meet NDC, 2 °C, and well below 2 °C targets for India[7]:
This paper talks about India's race to achieve national sustainable development (NSD) goals. India's commitment to Paris Climate Change Agreement through its Nationally Determined Contribution (NDC) will require the energy system to gradually move away from fossil fuels. This paper provides a quantitative assessment using optimization models of the parameters required for achieving NSD goals. To achieve net zero carbon emissions the following things have been recommended by the model:

1. 280 GW of renewable energy by 2050
2. All electric vehicles on the road by 2030
3. 32 GW of nuclear energy by 2050
4. Installations of power efficient appliances in the building sector by 2030
5. Approx. $ 8 trillion required to implement the above actions by 2030

Jobs for Just transition[10] **:**
This paper has done a survey in Jharkhand, one of the leading coal producers in India, the study is to identify the characteristics that make alternate jobs attractive as compared to coal jobs. Currently 90000 people are directly employed in the coal industry in Jharkhand, around 140 households were surveyed spanning across 144 villages, it was found that laborer's generally do not prefer coal mining jobs. They would rather do other jobs, but due to the scarcity of other well-paying jobs, they are left with no other option. In areas dominated by the coal industry, alternative employment opportunities are often not readily available, and those that are have often built up as a result of the coal industry's presence, and may be subject to decline as coal production does.

The model specification used is as follows:

$$\mathbf{Jobchoice}_{i.j.k} = \beta_1 \,.\, \mathbf{Pay}_{i,j,k} + \beta_2 \,.\, \mathbf{Distance}_{i.j.k} + \beta_3 \,.\, \mathbf{Safety}_{i,j,k} + \beta_4 \,.\, \mathbf{EmploymentPeriod}_{i,j,k} + \beta_5 \,.\, \mathbf{jobtype}_{i,j,k} + \lambda \mathbf{X}_i + \varepsilon_{i,j,k}$$

Where iindexes respondents, j indexes scenarios and k indexes jobs. Jobchoice is a dummy variable which just captures the respondents answer choice. Pay is a vector containing range of salary options, it varies between 3000 to 10000 rupees a week, distance is a vector of options of how far the job location is from the respondent's home, it can range from 1-50 kms. Safety is a dummy variable capturing whether the job is safe or not.EmploymentPeriod is a vector of options for how many months of employment would be offered by each job, JobType is a vector of dummy variables for what type of work each job entailed, and can be either coal-miner, farmer, street vendor, or solar energy worker.

Coal has always been seen as 'beneficial for the Indian Economy'. Three reasons have been identified that support this hypothesis. Firstly, it is cheap and abundant. Secondly, over 10 million people are directly employedby the coal industry[0],making it an employment-generating sector. Finally, central and eastern states generate royalties from coal mining, and the central government receives dividends from CIL (Coal India Limited). Indian Railwaystoo, generates revenues by transporting coal, which helps offset the loss incurred in their passenger services.[10]

[10]https://link.springer.com/article/10.1007/s10584-019-02616-1

In 2018, coal-fired electricity generation accounted for 30 per cent of global CO_2Emissions[11] and the majority of this generation was found in Asia. In this region, coal consumption has risen by 150 percent over the last 20 years[12] and the share of coal in the electricity generation has increased from 27 percent in 2010 to 43 per cent in 2019. Thus far, a "just energy transition" is vaguely defined as a situation where all groups have access to affordable, safe and sustainable energy and can maintain a decent lifestyle, have the opportunity to participate in the energy decision-making process, and enjoy the right to make changes. Cha and Pastor (2022) suggest that as fossil fuel activities decline, workers dependent on such activities will face negative economic and social consequences; mitigating these impacts and incorporating socioeconomic considerations into the energy transition is often referred to as a "just energy transition."[13]

Research Objective:-

The primary objective of this research paper is to conduct a comprehensive analysis of the factors contributing to India's comparatively lower CO_2 productivity in contrast to Denmark. We aim to achieve this objective by benchmarking India's CO_2 productivity against Denmark, a nation that has achieved exceptional success in terms of CO_2 productivity and sustainable development. This benchmarking exercise will provide critical insights into the specific gaps that India needs to address to enhance both its environmental and economic efficiency.

Additionally, we seek to delve into the in-depth analysis of Denmark's just transition policies, which have played a significant role in driving their high CO_2 productivity and sustainable economic growth. Our aim is to uncover the mechanisms and strategies employed by Denmark in promoting green and sustainable jobs, particularly those focusing on labour-centric approaches. Drawing inspiration from Denmark's successful experience, we intend to formulate India-specific recommendations that can effectively bridge existing policy gaps, stimulate the creation of green employment opportunities, and facilitate a smoother transition towards a sustainable and inclusive economy.

Methodology:-

Data Source:

Data for this study is sourced from reputable institutions, including the World Bank, OECD (Organisation for Economic Green Growth Indicators, and IEA (International Energy Association) reports.

Variables of interest include:

Renewable Energy Supply (% Total Energy Supply):

This variable represents the percentage of renewable energy sources (such as wind, solar, hydro, and biomass) in the country's total energy supply.

Share of Coal in Energy Supply (%):

This variable represents the percentage of coal in the country's total energy supply. It measures the dependency on coal, a major carbon-intensive energy source. Lower percentages suggest a shift towards cleaner energy, while higher percentages indicate a reliance on coal.

Employment in Coal Sector:

This variable signifies the number of people employed in the coal sector in each country.

Environment Transition Score:

The Environmental Transition Score is a crucial metric that gauges a country's progress in shifting towards a more sustainable and eco-conscious economy. It encompasses various aspects, including emissions reduction, increased energy efficiency, biodiversity protection, and reduced material consumption. Additionally, it evaluates labor upskilling policies aimed at aligning the workforce with green industries. This score reflects not only a nation's commitment to environmental responsibility but also its economic resilience and global competitiveness.

[11] https://www.iea.org/reports/global-energy-co2-status-report-2019/emissions

[12]https://www.theenvironment.in/2022/06/21/coal-consumption-in-southeast-asia-rises-to-150-percent-last-20-years-uncc/

[13]https://www.sciencedirect.com/science/article/pii/S2214629622000937?casa_token=f2lIT04SwbcAAAAA:fXSCkJn9l58_6oMYv6pTgQ74uypxovhuRreR7-1NWxq9XrYEeX8iKn2uY2BeKAiLtbtpK3dhN9xr

Real GDP Growth Rate:
This variable indicates the annual percentage change in the country's Gross Domestic Product (GDP).

CO_2 Productivity:
Production-based CO_2 productivity is calculated as real GDP generated per unit of CO_2 emitted (USD/kg) and included are CO_2 emissions from combustion of coal and other fuels.

Model Overview and Objectives
$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{4i} + \beta_5 X_{5i}$

Where,
Y_i: CO_2 productivity
X_1: Renewable energy supply
X_2: Share of coal in energy supply
X_3: Employment in coal sector
X_4: Environment transition scores
X_5:Real GDP growth rates with their corresponding β coefficients.

We employ a multiple linear regression model to analyse the relationship between the above-mentioned key independent variables and our dependent variable, CO_2 productivity. By obtaining coefficients for each variable, we determine the direction of their impact but also quantify the magnitude of their effect on CO_2 productivity. This provides valuable insights into the factors that contribute to a country's CO_2 productivity, thus shedding light on the path toward a more sustainable and environmentally responsible economy.

Data Trends:

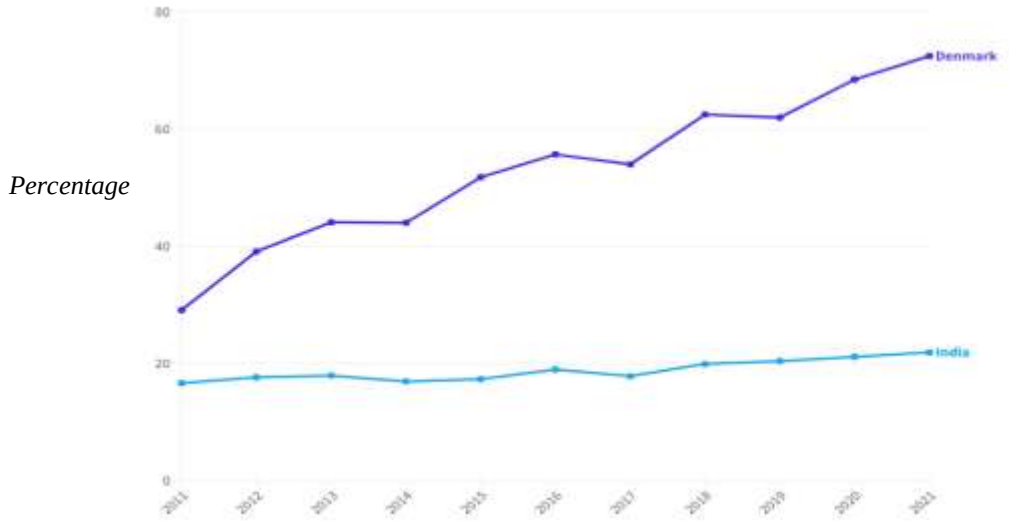

Figure 5:- Share of Renewables in Energy Mix[1]

Denmark's transition towards sustainability is evident in its impressive trends. As shown in fig.2, CO_2 productivity rose steadily from 5.53 in 2011 to 11.58 in 2021, signifying improved economic output per unit of energy-related CO_2 emissions. Notably, renewable energy supply surged from 33.10% to 72.50%, showcasing Denmark's commitment to cleaner energy. Coal's share in energy supply dropped from 33.00% to 8.00%, reflecting reduced coal dependency. Employment in the coal sector decreased from 15,993 jobs to 2,120, indicating a labor-conscious shift. Denmark's Environment Transition Score climbed from 64.1 to 75.3, reflecting its sustainability efforts. Despite fluctuations, real GDP growth remained positive, peaking at 4.9% in 2021. These trends highlight Denmark's exceptional success in merging environmental and economic goals.

In India, the data reveals a mixed picture of progress in the transition towards sustainability. India's CO_2 productivity has modestly increased from 3.31 in 2011 to 4.14 in 2021 (fig.2), albeit remaining considerably lower than Denmark's. The country has made gradual strides in renewable energy supply, rising from 16.61% in 2011 to 21.85% in 2021, indicating a slow but positive shift towards cleaner energy sources.However, India's heavy reliance on coal, which accounted for 53.89% of the energy supply in 2021 (although slightly decreased from 58.32% in 2011), is a cause for concern. Employment in the coal sector has fluctuated, declining from 4,03,000 direct and formal workers in 2011 to 2,68,450 in 2021, indicating a shift in labor dynamics. India's Environment Transition Score increased gradually from 54.6 in 2011 to 60.1 in 2021, reflecting incremental progress in environmental sustainability. Real GDP growth rate experienced fluctuations, with a notable peak of 9.1% in 2021.

Results and Discussion:-

Model Fit and Coefficient Interpretations

The multiple linear regression models for both Denmark and India are constructed to understand the relationship between CO_2 productivity (GDP per unit of energy-related CO_2 emissions) and various predictor variables. In both cases, the models were fitted to the data, and their significance was evaluated.

Denmark's Model:

OLS Regression Results

Dep. Variable:	y	R-squared:	0.959
Model:	OLS	Adj. R-squared:	0.9071
Method:	Least Squares	F-statistic:	110.5
Date:	Mon, 21 Aug 2023	Prob (F-statistic):	0.00899
Time:	10:04:20	Log-Likelihood:	31.013
No. Observations:	8	AIC:	-50.03
Df Residuals:	2	BIC:	-49.55
Df Model:	5		
Covariance Type:	nonrobust	p-value = 0.01	

	coef
const	0.9071
x1	1.50
x2	-0.9071
x3	-0.915
x4	0.825
x5	0.6174

Figure 6:- Regression analysis results for Denmark.

R-squared (R^2) = 0.95: The model for Denmark exhibits a good fit, implying that all predictor variables collectively explain 95% of the variance in CO_2 productivity. This suggests that the model is highly effective in capturing the relationship between CO_2 productivity and the chosen predictors.

Renewable Energy Supply (X_1):
A positive coefficient 1.50 indicates that an increase in the percentage of renewable energy supply is associated with higher CO_2 productivity. Denmark's strong emphasis on renewable energy sources contributes positively to its CO_2 productivity.

Share of Coal in Energy Supply (X_2):
The negative coefficient suggests that a higher share of coal in the energy supply negatively impacts CO_2 productivity. Denmark's lower reliance on coal is beneficial for reducing CO_2 emissions per unit of GDP.

Employment in Coal Sector (X_3):
The negative coefficient indicates that higher employment in the coal sector is associated with a decrease in CO_2 productivity in Denmark.In practical terms, as employment in the coal sector increases, CO_2 productivity, GDP per unit of energy-related CO_2 emissions, tend to decrease.

Environment Transition Scores (X_4):
A positive coefficient implies that higher environment transition scores are associated with increased CO_2 productivity. Denmark's commitment to environmental sustainability positively affects its CO_2 productivity.

Real GDP Growth Rates (X_5):
This positive coefficient indicates that periods of higher real GDP growth rates are linked to increased CO_2 productivity. Economic growth in Denmark is concurrent with improved CO_2 productivity.

India's Model:

OLS Regression Results

Dep. Variable:	y	R-squared:	0.975
Model:	OLS	Adj. R-squared:	0.912
Method:	Least Squares	F-statistic:	15.49
Date:	Mon, 21 Aug 2023	Prob (F-statistic):	0.0618
Time:	19:19:51	Log-Likelihood:	13.151
No. Observations:	8	AIC:	-14.30
Df Residuals:	2	BIC:	-13.83
Df Model:	5		
Covariance Type:	nonrobust	p-value = 0.01	

	coef
const	-19.7956
x1	0.9084
x2	-9.1682
x3	-9.697
x4	0.7183
x5	-0.7559

Figure 7:- Regression analysis result for India.

R-squared (R^2) = 0.975: The model for India shows a strong fit, indicating that approximately 97.5% of the variance in CO_2 productivity is explained by the predictor variables. This suggests that the model is highly significant in understanding the factors influencing CO_2 productivity in India.

Renewable Energy Supply (X_1):
With a positive coefficient, as the percentage of renewable energy supply increases in India, there is a modest increase in CO_2 productivity. However, this effect is considerably weaker compared to Denmark, indicating that India's efforts in renewable energy adoption have a more limited impact on CO_2 productivity.

Share of Coal in Energy Supply (X_2):
The negative coefficient here is substantial and suggests that a significant reduction in the share of coal in India's energy supply is strongly associated with higher CO_2 productivity. This emphasizes that a transition away from coal is a critical factor for improving CO_2 productivity in India.

Employment in Coal Sector (X_3):
The coefficient for employment in the coal sector is large and negative. This means that changes in coal-related employment have a substantial impact on CO_2 productivity in India. A decline in coal employment is positively correlated with higher CO_2 productivity, highlighting the importance of shifting the workforce from coal-dependent industries.

Environment Transition Score (X_4):
With a positive coefficient, a higher Environment Transition Score in India contributes positively to CO_2 productivity. However, the impact is still relatively weaker compared to Denmark, indicating that India's environmental policies have room for improvement to enhance CO_2 productivity further.

Real GDP Growth Rate (X_5):
The negative coefficient for the real GDP growth rate indicates that as India's economy grows, CO_2 productivity decreases. This implies that India is facing challenges in decoupling economic growth from carbon emissions. It highlights that the country needs to focus more on sustainable growth practices to improve CO_2 productivity.

Regression Line

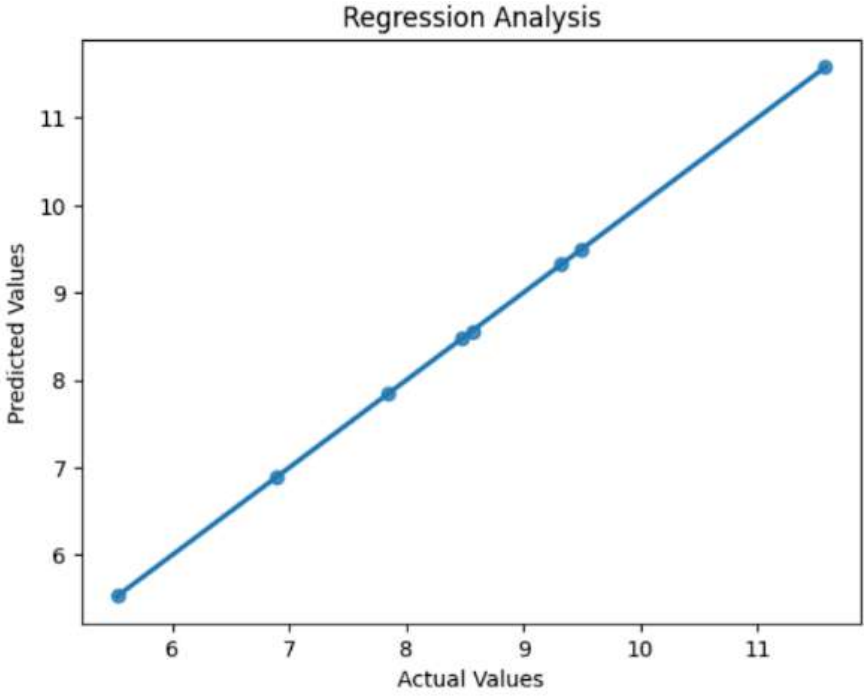

Figure 8:- Denmark's Regression Line.

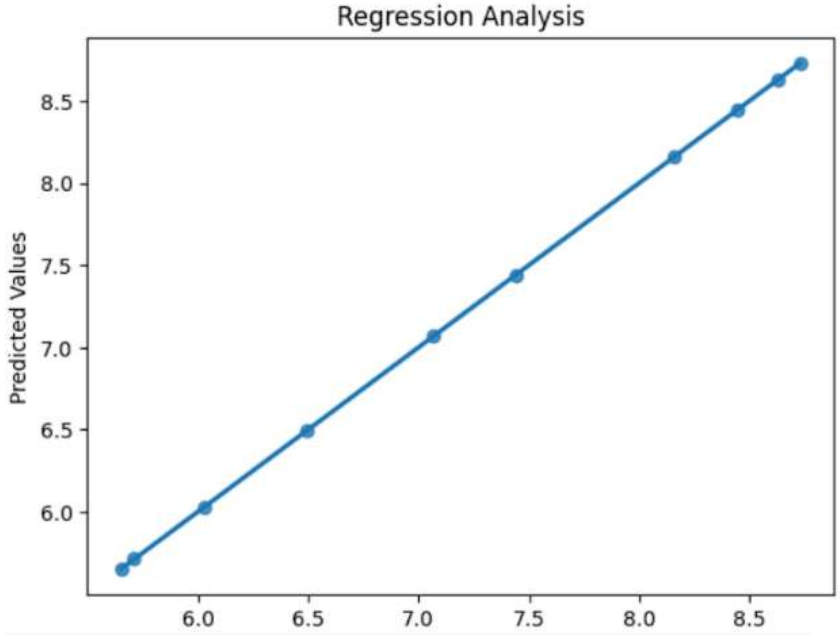

Figure 9:- India's Regression Line.

The results of the regression analysis reveal a striking pattern: all selected independent variables, including Production-based CO_2 productivity, Renewable energy supply, Share of Coal in Energy Supply, Employment in the Coal Sector, and Environment Transition Score, exhibit a remarkable alignment with the regression line. This alignment provides compelling evidence of the robust and linear relationships between these variables and the dependent variable, CO_2 productivity. The convergence of these independent variables with the regression line solidifies our findings. It underscores the fundamental roles played by these variables in explaining variations in CO_2 productivity, providing critical insights into the intricate interplay between economic, environmental, and

energy-related factors. These results highlight the importance of considering these factors in policies aimed at enhancing CO_2 productivity and framing an inclusive Just Transition Policy.

Summary of Model Findings:
Denmark's high CO_2 productivity can be attributed to its substantial use of renewable energy sources, low reliance on coal, and strong environmental commitment. India's lower CO_2 productivity is influenced by its heavy dependence on coal in its energy mix, despite efforts to promote renewable energy and improve environmental scores.Even with fluctuations, the positive trend in the Real GDP Growth Rate of Denmark demonstrates the country's ability to marry economic growth with reduced carbon emissions, a noteworthy achievement.

Both countries exhibit a positive correlation between CO_2 productivity and renewable energy supply, indicating the importance of transitioning to cleaner energy sources for sustainable development.The negative association between CO_2 productivity and the share of coal in the energy supply underscores the necessity of reducing coal dependence to improve CO_2 productivity. India's case highlights the challenge of balancing economic growth with environmental sustainability, as higher GDP growth rates are associated with lower CO_2 productivity.

Lessons From Denmark: A Model for Achieving a High CO_2 Productivity and a Just Labour-Centric Transition
Denmark's exceptional performance in achieving a just transition towards a green economy while significantly increasing its CO_2 productivity serves as a valuable case study. Denmark has become a global leader in renewable energy production and usage, with renewable sources accounting for 75%of its electricity generation in 2022. Moreover, Denmark is on track to achieve 100% national electric power production from renewables by 2030, aligning with its commitment to achieving net-zero emissions by 2050 under the Paris Agreement.

Denmark's remarkable journey begins with a bold energy strategy outlined in the "Energistrategi 2050," published in 2011. This strategy set ambitious goals to eliminate fossil fuels from Denmark's energy mix by 2050. It laid the foundation for the subsequent "Our Energy" agreement, focusing on expanding renewable energy sources, particularly wind, biomass, and biogas. Denmark's commitment to phasing out coal-fired power by 2030 exemplifies its dedication to greener energy sources. The decline of coal from providing 83% of electricity in 1994 to just 25% in 2015 highlights a successful transition. This shift was accompanied by a significant increase in renewable energy, including a world record of 49% of electricity consumption from wind in 2015.

The country’s efforts towards a labour-centric just transition was driven by a combination of factors. The Danish experience demonstrates how climate policies can not only phase out polluting sectors but also generate new jobs and create thriving industries and consequently also achieving a high CO_2 productivity rate. Starting in the 1970s, Denmark's tradition of strong social dialogue brought together labour unions, industry leaders, and policymakers. This collaborative approach facilitated the development of effective industrial and climate policies aimed at transitioning from coal to wind energy. With over two-thirds of Denmark's workers being union members and significant representation on company boards, Danish unions played a pivotal role. They recognized green jobs as a substantial source of new employment opportunities,They established a Green Think Tank and consistently called for greater ambition in climate and energy policies. By actively promoting, proposing, and commenting on new climate initiatives, they contributed to the creation of decent green jobs.

Green employment also became a key policy priority in the late 1990s with the introduction of a law in 1997 regarding a new pool for green employment (Lov om puljetilgrønbeskæftigelse), which aimed to create new and permanent green jobs. From the period 1997–2001, a total of DKK 500 billion (approximately €67 billion) was allocated to stimulate employment growth of green occupation. According to the official evaluation of the green employment pool, this initiative alone contributed significantly to the creation of new jobs, including at least 1,000 new green full-time jobs from 1997 to 2000, of which nearly 73 per cent were created in the private sector (the rest were created in organizations and public institutions). Nearly 80 per cent of the projects continued beyond the end of the financial support from the pool.

What sets Denmark apart is the demonstration that economic growth and a green transition can go hand in hand.
Denmark's experience highlights the potential for high CO_2 productivity while embracing renewable energy.During the transformative period from 2011 to 2021, as Denmark made a pronounced shift from coal to wind energy, it witnessed a decline in coal-related employment, and experienced a surge in renewable energy initiatives, there was

an unexpected trend: its CO_2 production notably increased. The decreasing cost of renewable energy, particularly offshore wind power, has surpassed that of new coal power plants, rendering coal a relic of the past in Denmark's electricity production. Furthermore, Denmark's commitment to a just transition extends beyond environmental objectives. The country's approach recognizes the importance of addressing socioeconomic disparities and inequalities in policy design. In terms of job creation, Denmark's green transition has been nothing short of remarkable as over 75,000 individuals currently hold "green jobs" in Denmark, with the potential to create up to 300,000 more green jobs as the country progresses toward its 2030 climate targets. The wind industry alone employed 31,251 people in 2015, and wind power contributed significantly to Denmark's electricity generation.

In sum, Denmark's experience underscores the importance of a just transition in achieving both environmental and economic goals. Its exceptional performance in transitioning to renewable energy sources while maintaining high CO_2 productivity offers valuable lessons for countries seeking to balance economic growth with sustainability.

Conclusion:-

This research paper has explored the intricate interplay between transitioning from coal to renewable energy sources, employment dynamics, and CO_2 productivity, drawing insights from both India and Denmark. Denmark has been a first-mover in the wind power industry for years and it is one of the world's leading manufacturers of wind energy. In 2004, Denmark accounted for a market share of 40.4% of total world wind turbine production. Denmark's leading position is a result of an active energy policy in the 1990s – a period during which the rest of the world did not focus as strongly on renewable energy. This has been a consequence of a concerted policy to increase the share of wind power in Danish energy production. The policy has only been made possible through substantial subsidies supporting wind turbineowners. This indirect subsidy has in turn generated the demand for wind turbines from the manufacturers.

The findings emphasize the multifaceted nature of the energy transition process and its implications for the labour market, economic growth and environmental sustainability. In the case of India, despite concerted efforts to boost renewable energy capacity, coal continues to maintain its dominance in the energy mix. Employment in the coal sector exhibits a complex relationship with CO_2 productivity, with a negative correlation indicating the need for a just transition strategy that safeguards the livelihoods of those dependent on coal while promoting cleaner energy alternatives. The Indian experience underscores the challenges of aligning environmental goals with economic and employment considerations.

Conversely, Denmark's demonstrates the feasibility of achieving high CO_2 productivity while transitioning to a green economy. The Danish model showcases how an effective labour-centric transition that generates new green jobs, fosters renewable energy industries can boost CO_2 productivity. Both cases underline the importance of context-specific policies and strategies to ensure a just transition. Denmark's success lies in its ability to harmonize environmental and economic objectives, while India grapples with the intricate task of phasing out coal without jeopardizing livelihoods. These lessons underscore the need for comprehensive, inclusive and adaptive approaches to navigate the complexities of energy transition and to address the pressing challenges of our time, from climate change mitigation to inclusive economic growth.

Way Forward

The path to a just transition in regions heavily dependent on fossil fuel industries necessitates a comprehensive strategy encapsulated by the "Five R's." These five key elements provide a roadmap for policymakers, governments, and local stakeholders to navigate the complex challenges of economic restructuring and environmental sustainability.

Restructuring the Economy and Industries:

By transitioning toward low-carbon industries, regions can experience increased CO_2 productivity. These industries are inherently more energy-efficient and environmentally friendly. For example, investments in renewable energy, sustainable agriculture, and eco-tourism can create jobs while reducing carbon emissions. Moreover, economic diversification reduces reliance on a single industry, enhancing resilience against economic downturns.

Repurposing Land and Infrastructure:

The repurposing of former fossil fuel sites can also drive CO_2 productivity. Reclaimed land can be used for renewable energy projects like solar or wind farms, which produce electricity without greenhouse gas emissions.

Additionally, the redevelopment of infrastructure can foster energy-efficient urban planning and transportation systems, further reducing CO_2 emissions.

Reskilling the Workforce:
Reskilling and upskilling the workforce aligns with the growth of green industries. A skilled workforce can drive innovation in renewable energy technologies, leading to increased economic growth. Moreover, providing training and education opportunities for the workforce can result in higher-income levels, stimulating consumer spending and boosting the local economy.

Revenue Substitution and Investments:
Redirecting public revenue from fossil fuels into just transition initiatives stimulates economic growth in multiple ways. Investments in green infrastructure, research and development, and sustainable projects generate economic activity and job creation. For instance, funding for research in clean energy technologies can lead to breakthroughs, making these technologies more competitive in the market.

Responsible Social and Environmental Practices:
Embracing social and environmental responsibility can foster economic growth. Sustainable land-use practices, such as afforestation and reforestation, not only sequester carbon but also provide opportunities for timber and non-timber forest products. Moreover, inclusive development policies can reduce income inequality, ensuring a more equitable distribution of economic benefits, which can stimulate local demand.

Additionally, Solar energy is rapidly expanding its footprint across India and proving to be a pivotal player in the transition away from coal-based energy sources. States like Odisha and Karnataka have already set the stage for this transformative shift by repurposing land for solar parks and industrial clusters.

In Odisha, the establishment of industrial parks has not only boosted sustainable industrial growth but has also contributed significantly to state revenue. These parks are demonstrating the potential for economic diversification and job creation, essential components of a just transition. Furthermore, the use of land previously dominated by coal mines for solar energy projects is a strategic move towards decarbonization. This approach leverages existing infrastructure and resources like land, labour and transportation connectivity to increase clean energy production.

Karnataka's plans to convert unused land in Kolar Gold Fields into a massive industrial park align perfectly with the state's renewable energy vision and sustainable development goals. By focusing on advanced manufacturing and renewable energy, this initiative not only attracts investments but also accelerates the transition from coal. Solar energy has a proven track record of creating jobs, with rooftop solar producing 24.72 jobs per year per MW. It offers a green alternative that can substitute coal-related revenue with long-term benefits and represents a crucial step towards a sustainable, low-carbon future.

Solar parks and renewable energy initiatives can effectively drive economic growth, provide employment opportunities, and reduce coal dependency, aligning perfectly with India's sustainability goals. As solar energy continues to grow and evolve, it holds the potential to revolutionize India's energy landscape while contributing to a cleaner, more resilient, and economically vibrant future.

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