



Economic Analysis of Energy Transition: Costs and Benefits of Shifting to a Low-Carbon Economy

Joshua Kurutsi Tabki
No. 4 Dar-Es-Salaam Street,
Wuse 2. FCT-Abuja.

ABSTRACT

The paper reviews the multifaceted economic implications of transitioning from a fossil-fuel-based energy system to a low-carbon economy, a precondition for taming global climate change and fostering sustainable growth. On that premise, the cost-benefit analysis framework will form the backbone on which appraisal is made of immediate and long-term financial needs, infrastructural investments, and possible transitions in economic structure toward a low-carbon economy. It also measures the economic benefit of reduced greenhouse gas emissions, a healthier general population, environmental sustainability, and a workforce employed in new green industries. This study combines quantitative cost estimates with qualitative assessments-including policy analysis and stakeholder impacts from various sectors of the economy-through the combined-method approach. Data are obtained from international energy and economic databases, government reports, and in-depth case studies of countries at various stages of energy transition. The methodology given the direct and indirect benefits and externalities related to a low-carbon economy presents a detailed analysis of the economic trade-offs being considered. The findings highlight how government policy, regulatory frameworks, and financial incentives are indispensable in keeping transition costs in check while optimizing long-run economic dividends. Among these drivers, they have identified technological innovation in scaling up more efficient and cost-effective renewable energy options to reduce reliance on fossil fuels. As such, the analysis also identifies international cooperation supported by financial assistance to be particularly invaluable for those developing economies that face much more significant non-financial barriers to adjustment in low-carbon energy systems. Based on this perspective, from a cost-benefit point of view, economically speaking, this study develops a holistic view whereby the transition to low carbon could meet not only the imperatives of the environment but also add to sustainable economic growth across various regions.

ARTICLE INFO

Article History

Received: July, 2023

Received in revised form: July, 2023

Accepted: December, 2023

Published online: December, 2023

KEYWORDS

Energy Transition, Low-Carbon, Economy

INTRODUCTION

The low-carbon transition forms an important panacea to the increasing global challenge of climate change. Over the past decades, increasing levels of GHGs from fossil fuel-based energy systems have only exacerbated environmental degeneration in the forms of severe weather events, biodiversity loss, and public health crises. Global processes, such as the Paris Agreement, have emphasized that countries need to take urgent action in the

direction of reduction of emissions, setting targets for carbon neutrality with a view toward their national economies moving toward sustainable energy. It is commitments undertaken by countries that challenge economies in particular, as they ought to rethink their very base of energy by shifting toward renewable sources like solar, wind, and hydroelectricity. This energy transition is therefore an environmental imperative but also

Corresponding author: Joshua Kurutsi Tabki

✉ kurutsi4edx@gmail.com

No.4 Dar-Es-Salam Street, Wuse 2, FCT, Abuja.

© 2023. Faculty of Technology Education. ATBU Bauchi. All rights reserved



an economic one, promising significant long-term gains against substantial upfront costs.

The urgency of transitioning into the low-carbon economy is underlined by potentially irreversible impacts of climate change. According to the projections of the Intergovernmental Panel on Climate Change, under current conditions, global warming is likely to reach 1.5°C above pre-industrial levels by 2030, with unprecedented consequences unless extreme measures are undertaken to reverse the trend. Natural disasters, in which climate plays a part, have already imposed huge economic costs through damage to infrastructure, agricultural loss, and the displacement of communities. The energy transition is, therefore, crucial to containing these impacts so as to offer a short-term and long-term relief to the economies of the world. By investing in renewable energy and adopting green technologies, countries can reduce environmental degradation apart from building economic resilience. (Stern, 2007).

The economic advantages of making the transition into a low carbon economy go beyond saving the environment. A movement away from reliance on fossil fuel might mean stabilization of energy costs, reducing reliance on imported fuels, and job creation in new green sectors that include renewable energy production and energy efficiency technologies. According to IRENA, this inherently creates a very strong economic case for transitioning to low-carbon economies. While the initial capital costs of renewable infrastructure tend to be high, these are compensated for in the long term by lower energy costs and reduced environmental damage. For instance, countries with a leading position in renewable sectors have demonstrated increased energy security with reduced reliance on the volatility of global oil and gas markets. According to Davis & Caldeira, 2010, such countries have exhibited more energy security and less reliance on the volatility of global oil and gas markets. A low-carbon economy is thus economically favorable over the long run, involving direct financial returns as well as an insurance function against financial risk resulting from climate-related disruptions, Luderer et al., 2018.

Energy transition literature shows that substantial research has been undertaken in the technical, environmental, and policy dimensions

of the adoption of renewable energy. However, economic analysis of wider ramifications like impacts on labour markets, economic equity, and sectoral competitiveness remains critical (IEA, 2021). Although the existing literature has focused mostly on issues of the cost of investing in renewable infrastructure and the fiscal policies necessary to support such changes, much less attention is given to the indirect co-benefits, including improved public health due to reduced air pollution and long-term economic benefits from ecosystem preservation. Conclusively, and within the gaps of the literature above, this paper looks into both the direct and indirect economic impacts comprising social, environmental, and fiscal benefits that support a sustainable and resilient economy.

Objectives of the Analysis

The main focus of this analysis includes quantification of economic costs and benefits that are related to the energy transition, study the mechanisms-financial and policy-related-that enable such a shift, and finally offer insight into challenges and opportunities from the change. This paper applies a cost-benefit analysis approach in assessing the short- and long-run economic impacts brought about by transitioning toward a low-carbon economy. It seeks to present a comprehensive overview of the energy transition economics through recent data and global case studies, shedding light on strategies that may help to minimize costs and maximize the benefits.

RELATED WORKS

The literature on the economics of transition to energy is replete with a wide range of studies assessing theoretical and empirical impacts in relation to the shift from fossil fuels to renewable sources of energy. These studies delve into the historical, sectoral, and macroeconomic perspectives of energy transitions with regard to how such factors as cost, policy, and innovation influence the transition process.

Historical Economic Effects of Energy Shifts

Indeed, so it had been with great economic transitions: first from coal to oil at the outset of the 20th century, through adding nuclear and finally renewable energy sources . Each transition had involved substantial investment in new infrastructure and adaptation

Corresponding author: Joshua Kurutsi Tabki

✉ kurutsi4edx@gmail.com

No.4 Dar-Es-Salam Street, Wuse 2, FCT, Abuja.

© 2023. Faculty of Technology Education. ATBU Bauchi. All rights reserved



within industries and communities. While these transitions incur considerable short-term costs, they also create long-term economic resilience and facilitate job creation and technological innovation. For example, Fouquet, 2010 states that though transitions are disruptive they have a positive effect on transitioning to a more diversified and sustainable energy system.

Cost and Benefit Models in Low-Carbon Studies

Much of the literature deals with the various economic models that have been devised to quantify the costs and benefits involved in transitioning into a low-carbon economy. These models calculate capital expenditure on renewable infrastructure, long-term operating savings, and societal benefits due to reduced pollution. Cost-benefit analyses by McCollum et al. (2018) and Luderer et al. (2018) identify economic trade-offs in the adoption of renewables. They say, while this may be costlier initially, the long-term benefit related to health issues caused by environmental degeneration, reduced dependency on fossil fuel, and increased energy security offsets these expenditures. However, there is considerable controversy in the literature as to whether these gains completely outweigh the costs, especially for developing economies with somewhat strained financial budgets. Hirth & Ueckerdt, 2013, states that "sector-specific and macroeconomic effects", energy transition has a different effect on the economy depending on the concerned sector- transportation, manufacturing, or power generation- with a differently faced challenge or opportunity across every sector. In the transport sector, for example, there is huge investment in infrastructure and technology for developing electrification systems. These changes also promise long-term fuel cost and emission reductions. There is an operational shift in manufacture, along with likely additional energy costs brought in by renewable sources. Macroeconomic analyses consider the wider economy-wide impacts of energy transition in terms of impacts on variables like GDP, employment, and inflation, usually applying input-output models for their forecasts. For instance, some reports from IRENA 2020 and IEA 2021 indicate that renewable energy investment can result in net positives related to

GDP growth and employment; these studies also raise the possibility of inflationary pressures due to energy costs.

Literature continues to show divergent perspectives on the economic feasibility of transitioning into a low-carbon economy. Some researchers have viewed this mainly as a cost, because the technologies that are required for renewable energy are really costly, along with disturbances in the economies which rely on fossil fuels. Others see it as a source of essential investment opportunities, which should stimulate economic growth and innovations. Green investments, according to Pollin et al. (2014), provide massive employment opportunities and massive technological advancements, making them economically viable and friendly to the environment.

Knowledge Gaps in Economic Analysis of Energy Transition

Though there is a strong body of literature, there are clearly areas where further research needs to be done. Most of the data related to the economic impacts of energy transition in developing economies is still very scanty. Most economies of the developing world lack both the financial and infrastructural capacity to carry out big renewable projects; hence, transitioning might be quite difficult in such regions (Bhattacharya et al., 2016). Second, current models may undervalue social benefits from reduced air pollution, health improvements, and ecosystem conservation. More research in these areas would yield a more complete picture of the costs and benefits related to the global energy transition.

METHODOLOGY

In this study, a structured CBA framework has been adopted to assess the economic implications of the energy transition. This allows investigation into the direct and indirect costs and benefits associated with the transition towards a low-carbon economy and resultant full financial and social impacts. The methodology consists of successive stages: cost analysis, benefit analysis, and data collection, each with integrated specific techniques that guarantee the results are accurate, reliable, and replicable.

Corresponding author: Joshua Kurutsi Tabki

✉ kurutsi4edx@gmail.com

No.4 Dar-Es-Salam Street, Wuse 2, FCT, Abuja.

© 2023. Faculty of Technology Education. ATBU Bauchi. All rights reserved



Economy Cost Analysis

- a) Cost analysis is entirely based on quantifying the financial needs related to transitioning toward a low-carbon economy. This calls for the need to look into the CAPEX that shall be spent to compensate for the energy supply with renewable energy infrastructure, O&M costs, and eventual disruptions in the industries which rely directly on fossil fuels. The model notably analyzes:
- b) Capital investment costs: This involves estimates in the upfront cost of projects related to renewable energy (like solar, wind, hydro, and energy storage infrastructures). As done by McCollum et al., 2018, these stand at the core of the size of investment required and have been taken from recent estimates made available by international organizations like the International Energy Agency and the World Bank.
- c) Operational and Maintenance Costs: The long-term expenses on the operation of renewable systems. There are some technology-specific costs, which can be identified as the maintenance required by either solar panels or wind turbines.
- d) Economic Disruptions: Potential impacts include impacts on sectors relying upon resources of fossil fuels, work dislocation, decline of revenue, and restructuring of industries. From this premise, the model estimates the socioeconomic costs associated with reduction or phasing out of traditional sources of energy in terms of the specific regions and specific industries that are relatively more vulnerable to such changes.

Benefit Analysis

The Benefit Analysis Methodology embarks on a detailed analysis of the benefits accrued from a low-carbon economy: the quantifiable health, environmental, and economic benefits realized from reduced carbon emissions, shifting towards renewable energy sources. Outstanding components of benefit analysis include the following:

- a) Health Benefits: The quantity of savings in public health costs from improvements in air quality by the reduction of illness from air pollutants due to respiratory and cardiovascular diseases. Bhattacharya et al., 2016 explained that the estimates were provided from Health Impact Assessments and studies conducted on associations of improvements in air quality with health outcomes.
- b) Environmental Improvements: Reduced GHG emissions and pollutants associated with fossil fuels can quantify benefits derived from ecosystem preservation and protection of biodiversity. Overall, studies such as Jenkins et al. (2018) and Stern (2007) have found that such derived benefits play an essential role in sustainable economic growth.
- c) Renewable Sectors Economic Growth: Estimating the number of jobs created, value added, and other economic contributions from new and future renewable energy industries, such as energy efficiency, clean technology innovation, and EV manufacturing. This element looks at both direct employment within renewable sectors and indirect economic growth in supportive industries.

Data Sources

Data from this analysis are combined from international databases, governmental reports, and economic analytic frameworks to ensure robustness and validity. Sources include:

- a) International Energy Agency : This will provide comprehensive data on global energy investments, costs, and projection of renewable energy growth. World Energy Outlook reports were used to derive estimates on sectoral shift and energy demands.
- b) World Bank: In this, the data on different economic development indicators, country-wise roadmap for energy transition, financial mechanisms to support the transition,

Corresponding author: Joshua Kurutsi Tabki

✉ kurutsi4edx@gmail.com

No.4 Dar-Es-Salam Street, Wuse 2, FCT, Abuja.

© 2023. Faculty of Technology Education. ATBU Bauchi. All rights reserved



are provided. World Bank, 2019

- Other International Organizations: International agencies' reports like IRENA and the International Monetary Fund offer complementary information on the cost of renewable investments, socio-economic implications, and policy measures. IRENA, 2020 3.4 Discounting and Present Value Analysis

The analysis of long-term economic outcomes involves discounting future costs and benefits to PV at the standard rate to ensure it is comparable over time. This technique addresses inflation, the time value of money, and opportunity cost, all factors that are also relevant when considering multi-decade economic projections (Stern, 2007). Discounting provides a way to feasibly compare immediate capital expenditures with projected benefits over time - particularly those benefits that are relative to health and environmental impacts.

Uncertainty and Sensitivity Analysis

Long-run economic projections are always part clouded by the fog of uncertainty, particularly as to variables such as technological changes, market forces, and alterations in policy. This study employs sensitivity analyses that, as Fouquet (2010) suggests, test the robustness of the results through the modification of important assumptions running different scenarios. This can cancel out possible biases and show various outcomes and, therefore, enhances the reliability of the conclusions given in this study.

ANALYSIS

Analysis The section evaluates the economic costs and benefits of transitioning into a low-carbon economy by providing a detailed breakdown of the key areas that this shift in policy will impact. It will thus show long-term value an energy transition has, even if an energy transition is costly at the outset. It quantifies direct financial implications and broader socio-economic benefits.

Initial Investment Costs

This would, of course, necessitate the required huge capital investments in renewable

energy infrastructure, such as in solar panels, wind turbines, modernizing the grid, and technologies for energy storage to establish a low-carbon economy. The financial commitment of projects of this type can be beyond the means of most countries worldwide, not to speak of developing nations with a comparative lack of financial wherewithal or access to funding for such large-scale investments. According to estimates by McCollum et al., 2018, trillions of investments may be required in the energy sector globally for achieving climate goals; capital costs will comprise a lion's share of transition expenses.

Sectoral and Regional Impact

The economic effects of energy transition differ according to sectors and regions. For example, the industries that are based on fossil fuel energy, namely coal, oil, and gas, are likely to reduce and scale down output levels and employment in such industries. In countries or regions where such industries provide major outputs, such as in the United States, Russia, and the Middle East, an economic decline can result unless proper diversification or transition support is availed. These inequalities show that policy intervention is urgently required to aid vulnerable regions through transition. Jenkins et al., 2018

Economic Disruptions

Economic disruptions from the transition are very likely to occur, particularly where workers' livelihoods are attached to the fossil fuel industries. Job loss is part of the major concerns, as the renewable industry does not completely match the traditional fossil fuel employment on both geographical and skills level. Hirth & Ueckerdt, 2013. Besides these, there are added costs to be incurred for workforce re-skilling programs, which should include training for coal miners to adapt to solar and wind energy jobs. While it is a vital component of the just transition process, it requires massive investment from governments and private sectors too.

Costs of Policy Implementation

Government policies, though instrumental in facilitating the transition process, have costs associated with their linkage. Subsidies on renewable energy projects, tax

Corresponding author: Joshua Kurutsi Tabki

✉ kurutsi4edx@gmail.com

No.4 Dar-Es-Salam Street, Wuse 2, FCT, Abuja.

© 2023. Faculty of Technology Education. ATBU Bauchi. All rights reserved



incentives on investments in green technology, and the cost of regulatory compliance burden governments and taxpayers substantially. However, various studies prove that in most cases, these costs are generally outweighed by the long-run benefits since supportive policies accelerate diffusion of low-carbon technologies and thus lower environmental costs substantially in the future.

Benefits of Energy Transition

Environmental and Health Co-benefits

One of the most valuable attributes of a low-carbon economy is a reduction in air pollution directly associated with public health. Lower emissions from renewable sources of energy improve air quality and reduce the incidence of respiratory and cardiovascular diseases Bhattacharya et al., 2016. This, in turn, could translate into significant health care savings as a result of reduced pollution loads that lower the burden on healthcare systems and improve the quality of life of populations in high-pollutant-emission areas. This, then, needs to be quantified in order to underpin the social and economic value of such reductions in pollution-related health problems.

Economic Growth

The renewable energy sector and related green industries offer an opportunity for economic growth with investments in clean technologies spurring innovation and productivity. A shift to energy efficiency, green building, and electric vehicle technology also creates demand for new goods and services and thereby creates long-term, sustainable, high-value jobs in the processes of strengthening local economies. The countries that have already adapted to a green economy are those that will most certainly be taking advantage of the emerging global shift towards renewable energy sources; this will ensure higher GDP and more stable economic conditions in the long term. In this regard, research has indicated that nations already transformed into green economies are much better positioned to exploit the new global trends toward renewable energy sources, thereby increasing their GDP and offering long-term stability. 4.2.3 Job Creation

The energy transition is likely to create substantial jobs in renewable energy and

energy efficiency. It will create employment opportunities in solar and wind power generation, energy storage, and sustainable construction. On the other hand, jobs related to fossil fuels are somewhat centralized, whereas the jobs in renewable energies are dispersed and ensure economic opportunities for rural and underdeveloped areas. This would mean transition towards a low-carbon from a high-carbon labor market and hence contributes to resilient communities and low economic disparity.

Energy Security and Price Stability

A low-carbon economy is a lot more energy secure due to the reduced reliance on imported fossil fuels and hence isolates countries from volatility in global fuel prices. With renewable energy sources such as wind, solar, and hydroelectric power, nations can develop sources of energy that are stable and self-generated, thus enabling better self-sufficiency. Besides, renewable resources have steadily kept on declining in prices, hence providing more stable and predictable energy costs to consumers and businesses alike. Indeed, this stability reduces economic vulnerabilities and spurs long-term financial planning across industries.

DISCUSSION

These findings depict a complex interaction of the immediate costs with the long-term benefits of making the transition to a low-carbon economy. Where the immediate financial dedication to renewable infrastructure, reskilling of the workforce, and execution of policy is high, the long-term benefits that accrue in the form of environmental sustainability, improved public health, and economic growth in green sectors constitute the proof of feasibility and desirability for a low-carbon economy. This discussion puts these results into perspective and reflects on the wider implications, in particular concerning policy and investment issues, as well as those affecting global equity.

Government policies play a critical enabling function in the energy transition, trading off current financial costs against future benefits. Strategic policies could also include subsidies on renewable projects, tax incentives for green technologies, and regulations on carbon emissions; such policies can ease the

Corresponding author: Joshua Kurutsi Tabki

✉ kurutsi4edx@gmail.com

No.4 Dar-Es-Salam Street, Wuse 2, FCT, Abuja.

© 2023. Faculty of Technology Education. ATBU Bauchi. All rights reserved

immediate financial burden on industries and favor the widespread adoption of renewable energy. Policies related to incentivizing research and development in clean technologies are critical, as these can drive down the cost of producing renewable energy over time and address storage concerns. In addition, such regulatory frameworks that work toward placing limits on emissions or making demands for sustainability benchmarks from firms would contribute to speeding up the shift away from fossil fuels and decrease the long-term environmental and health costs related to high-carbon economies.

These are, however, to be framed in such a way that they do not disrupt the economies, especially of those where these industries lie at the heart of the fossil fuel economies. A transition framework should thus be put in place to cushion vulnerable communities through support in retraining the workforce and diversifying the economies so that minimal adverse shocks may be witnessed in the event of a transition. Balance between the sacrifices in the present and gains in the future is paramount, and there is much governments can do to help foster a just transition.

The transition to a low-carbon economy presents significant investment opportunities across multiple sectors. Renewable energy production, including solar, wind, and hydroelectric power, stands as a

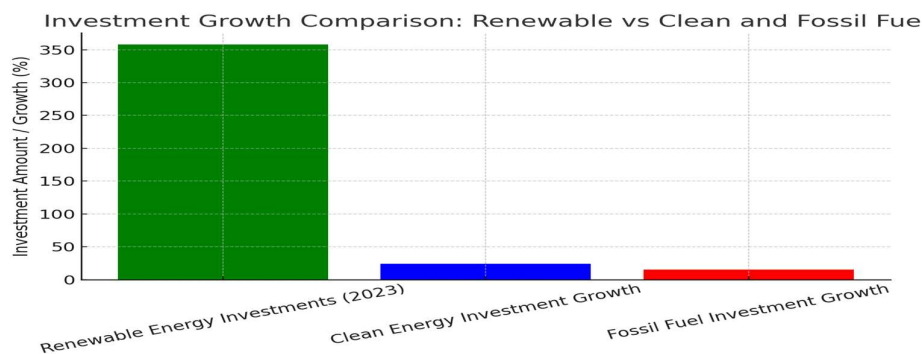
primary area for investment, as these industries require substantial growth to meet rising demand (IRENA, 2020). Additionally, energy storage technologies, such as battery storage and grid modernization, are critical to addressing the intermittency of renewable energy sources and ensuring stable power supply, creating another lucrative investment area (IEA, 2021).

Beyond the energy sector, investment opportunities are also present in electric vehicle (EV) manufacturing, sustainable agriculture, and energy-efficient building technologies (Fouquet, 2010). These sectors not only contribute to reducing carbon emissions but also support local economies through job creation and technological innovation. By directing capital into these areas, investors can benefit from growing markets while supporting a sustainable future.

Financial institutions and private investors also have a critical role to play. Green bonds and other sustainable finance instruments offer a means to attract capital for renewable projects and climate resilience initiatives, especially in developing regions (Bhattacharya et al., 2016). These investment channels provide an opportunity for stakeholders to achieve financial returns while contributing to the global energy transition.

Table 1: Investment Opportunities

| Category | Investment Amount / Growth (%) | Unit |
|-------------------------------------|--------------------------------|-------------|
| Renewable Energy Investments (2023) | 358 | Billion USD |
| Clean Energy Investment Growth | 24 | Percent |
| Fossil Fuel Investment Growth | 15 | Percent |



Corresponding author: Joshua Kurutsi Tabki

✉ kurutsi4edx@gmail.com

No.4 Dar-Es-Salam Street, Wuse 2, FCT, Abuja.

© 2023. Faculty of Technology Education. ATBU Bauchi. All rights reserved

Energy Storage and Grid Modernization

With the rise in renewable energy sources like solar and wind, the demand for energy storage and grid modernization has increased manifold. Energy storage investments are expected to reach \$20 billion in 2023, with continued growth in a year that balances intermittent renewable energy sources against a reliable supply of electricity. The development of advanced battery storage and smart grid infrastructure will further enhance the reliability and efficiency of energy systems. These investments will be paramount in scaling up the use of renewables and offering a very good opportunity for both government and private investors to invest in emerging technologies that will help in ensuring grid resilience.

Renewable energy has become a major employment source, as the number of jobs within the sector surged from 13.7 million in 2022 to 16.2 million in 2023-up 18% (International Renewable Energy Agency). In other words, such rapid job growth is due to an increase in demand for solar panel installation and manufacturing of wind turbines, an expansion of supporting industries like battery production, and energy efficiency services. Importantly, these jobs often exist at a geographically dispersed level benefiting both rural and urban areas alike, hence providing some economic security to regions previously dependent on fossil fuel-based industries. This growth in renewable energy is likely to spur further increases in such employment.

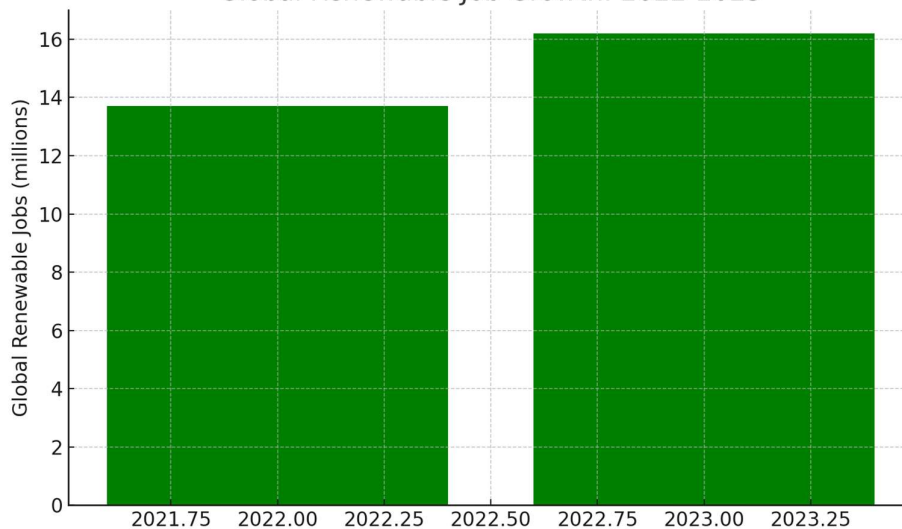
IMPACT OF POLICIES

Creation of Jobs in Renewable Energies

Global Renewable Job Growth: 2022-2023

The chart below emphasizes the job creation potential in the renewable sector.

Global Renewable Job Growth: 2022-2023



| Year | Global Renewable Jobs (millions) |
|------|----------------------------------|
| 2022 | 13.7 |
| 2023 | 16.2 |

U.S. Clean Energy Employment

In the United States, clean energy jobs grew by 4.2% in 2023, outpacing the national job growth rate of 2% and adding approximately 142,000 new positions (Reuters).

This trend is particularly notable in the context of the Inflation Reduction Act, which includes significant tax incentives and grants to encourage the expansion of clean energy production and manufacturing in the U.S. The

Corresponding author: Joshua Kurutsi Tabki

✉ kurutsi4edx@gmail.com

No.4 Dar-Es-Salam Street, Wuse 2, FCT, Abuja.

© 2023. Faculty of Technology Education. ATBU Bauchi. All rights reserved

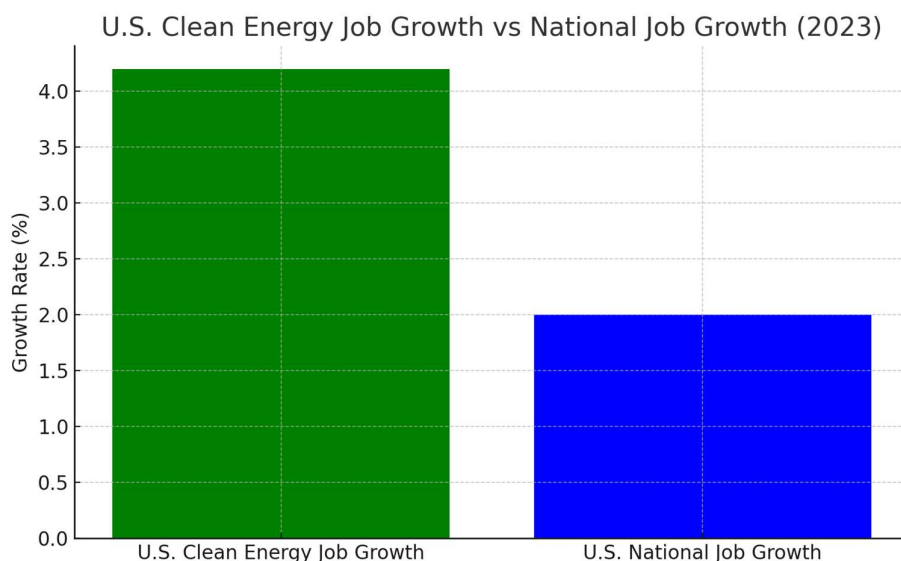


Act's impact has been felt across various sectors, with increased hiring in solar energy, battery production, and electric vehicle manufacturing. By prioritizing clean energy jobs, the U.S. is fostering a domestic workforce that supports economic growth while reducing greenhouse gas emissions.

U.S. Clean Energy Job Growth vs National Job Growth (2023)

This comparative bar chart highlights that U.S. clean energy job growth outpaced the national average in 2023, reinforcing the effectiveness of U.S. policies in boosting employment within the clean energy sector

| Category | Growth Rate (%) |
|------------------------------|-----------------|
| U.S. Clean Energy Job Growth | 4.2 |
| U.S. National Job Growth | 2.0 |



Global Renewable Capacity Additions

The International Energy Agency reports that renewable capacity additions worldwide reached almost 510 gigawatts in 2023, up an unprecedented 50% and at the fastest growth rate in more than two decades. This has been driven by the faster deployment of solar and wind, mainly in Asia and North America, as countries rush toward their climate commitments and shrink their reliance on sources of fossil fuels. Policy support through things like renewable portfolio standards and tax credits has created these capacity additions,

letting countries unlock explosive growth in their clean energy installation networks. In the process, it constitutes not only significant movement toward climate goals but substantial economic opportunity in the renewable energy markets, affording a window to global investment.

This line chart shows the trend in global renewable capacity additions, culminating in the record 510 gigawatts in 2023. It gives evidence for accelerating renewable energy adoption, together with its supporting policies.

| Year | Global Renewable Capacity Additions (GW) |
|------|--|
| 2020 | 320 |
| 2021 | 370 |
| 2022 | 400 |
| 2023 | 510 |

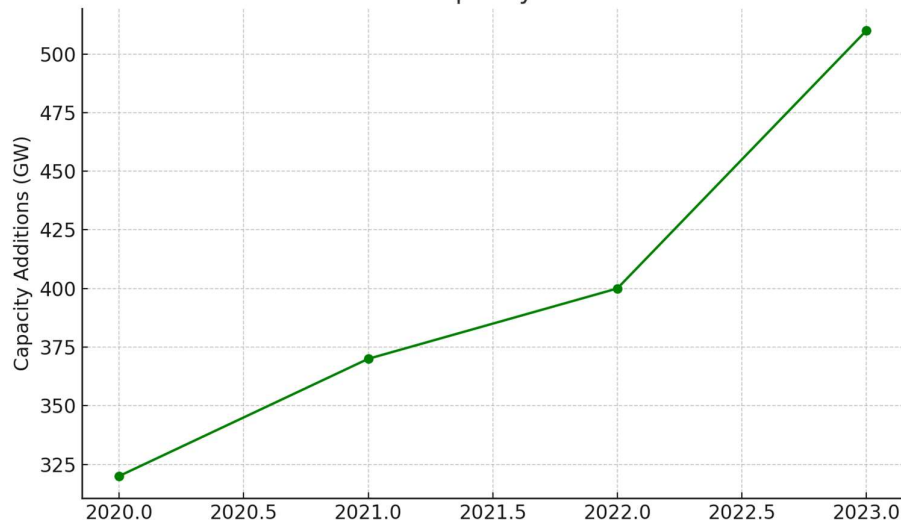
Corresponding author: Joshua Kurutsi Tabki

✉ kurutsi4edx@gmail.com

No.4 Dar-Es-Salam Street, Wuse 2, FCT, Abuja.

© 2023. Faculty of Technology Education. ATBU Bauchi. All rights reserved

Global Renewable Capacity Additions Over Time



Incentive Structures and Regulatory Frameworks

Incentive structures and regulatory frameworks have also been put in place in many countries to accommodate this shift toward renewable energy. For example, a carbon border adjustment mechanism in the Green Deal proposed for the European Union created an incentive for domestic industries to lower their emissions by bringing in carbon-intensive imports into the market and subjecting them to taxation. Similarly, China's newest Five-Year

Plan has placed Clean Energy Investments at the center and set targets for emission intensity reduction. In the meantime, these policy frameworks have been promoting the growth of renewable industries, leveling the economic playing field so that clean energy investments become economically viable and attractive in the long term. This approach gives rise to a stable policy environment that encourages private sector investment and hence fosters sustainable economic development around the world.

| Category | Data Point | Source |
|--|---|---|
| Renewable Energy Investments | \$358 billion in global renewable energy investment in the first half of 2023, 22% increase over 2022 | BloombergNEF |
| Clean Energy Investment Growth | 24% growth in clean energy investment over the past 2 years, compared to 15% growth in fossil fuels | International Energy Agency (IEA) |
| Energy Storage Investments | \$20 billion in energy storage investments in 2023 | IEA, 2023 estimates |
| Global Renewable Job Growth | Renewable energy jobs grew from 13.7 million in 2022 to 16.2 million in 2023 | International Renewable Energy Agency (IRENA) |
| U.S. Clean Energy Jobs | 4.2% growth in U.S. clean energy jobs in 2023, adding 142,000 jobs (2x the national growth rate) | Reuters |
| Global Renewable Capacity Additions | 510 gigawatts added in 2023, a 50% increase and highest in two decades | International Energy Agency (IEA) |
| Incentive Structures | EU's Green Deal carbon border tax; China's Five-Year Plan prioritizing clean energy | EU Green Deal, China's Five-Year Plan |

Corresponding author: Joshua Kurutsi Tabki

✉ kurutsi4edx@gmail.com

No.4 Dar-Es-Salam Street, Wuse 2, FCT, Abuja.

© 2023. Faculty of Technology Education. ATBU Bauchi. All rights reserved



Global Equity Concerns

The economic effects of the energy transition, however, are not evenly spread: there are large discrepancies between developed and developing economies. High-income countries can generally more easily finance renewable energy projects, subsidize green technology, and cover supports to workers in transition industries. In contrast, the developing economies could well lack resources for investment in such extensive changes and thus suffer disproportionately from costs occasioned by the energy transition.

These discrepancies underlie important questions of equity and fairness. The developing economies, generally contributing less to global carbon emissions but often facing severe climate impacts, can often only realize renewable energy projects with support from abroad. International cooperation and financial assistance will be necessary to ensure countries at all income levels can participate in and benefit from the transition. Other ways of adapting could also be supported, through mechanisms such as climate finance, technology transfer agreements, and international development funds, without having to fully bear the cost burden.

Addressing these global equity concerns becomes not only an ethical imperative but a strategic necessity. Broad-based participation is a requisite for the success of any global energy transition, and without adequate support to developing regions, the reduction of global emissions targets will not materialize. Fair policies and financial frameworks will have to be crafted to enable all countries to seize the opportunities that come with the low-carbon economy and to jointly address the challenge of climate change.

CONCLUSION

The current study has integrated the economic consequences of transitioning into a low-carbon economy by presenting an argument for the value of sustainable energy transformation. While the investment cost in renewable infrastructure, execution of policies, and economic restructuring remains high, its long-term benefits are way beyond such initial costs. These transitions promise enhanced environmental health, growth in economies due to new job creation in green industries, and

higher energy security-all helping build resilient, sustainable futures.

Equally, the findings show that it is also policymakers and investors who can play a vital role in overcoming the complexities of the energy transition. Policymakers need to develop proactive, inclusive policies. A well-conceived regulatory framework, complemented by smartly designed incentives and support systems, will mitigate economic turbulence and facilitate job creation in the green sectors. These need to be supplemented by policies directed at achieving equity outcomes: particular attention given to the particular challenges experienced by fossil fuel dependent regions and developing economies. Inclusion and equity are basic in the establishment of the fact that every region shall have an equal opportunity to contribute, compete in, and benefit from a low-carbon economy irrespective of their financial status.

This energy transition presents investors with an opportunity to be part of such a steep economic curve. Renewable energy, energy storage, electric vehicles, and sustainable agriculture-just some of these very massive areas return on investment while achieving global sustainability objectives. The investor allocates capital to these nooks, thus positioning at the edge in leading and driving economic growth, contributing to greater environmental and societal objectives.

This research emphasizes that further research, in particular, has to be pursued on less explored areas, such as region-specific impacts and socio-economic problems of developing countries. Future research should aim at improving cost-benefit models that would reflect such diverse conditions, so that policymakers can be provided with crisp data points to anchor their strategies upon. This will come in quite handy if the energy transition around the world has to be properly informed, complete with equity and efficiency.

In all, the shift toward the low-carbon economy is more than an environmental imperative; rather, it is one economically feasible path to a resilient, future-proof economy. Comprehensive planning, inclusive policy, and strategic investment, taken together, will let stakeholders enable a transition that addresses climate change but fosters

Corresponding author: Joshua Kurutsi Tabki

✉ kurutsi4edx@gmail.com

No.4 Dar-Es-Salam Street, Wuse 2, FCT, Abuja.

© 2023. Faculty of Technology Education. ATBU Bauchi. All rights reserved



sustainable economic growth and societal well-being.

REFERENCES

- Bhattacharya, A., Oppenheim, J., & Stern, N. (2016). Driving sustainable development through better infrastructure: Key elements of a transformation program. *Global Economy and Development at Brookings*, Working Paper 91. <https://www.brookings.edu/research/driving-sustainable-development-through-better-infrastructure-key-elements-of-a-transformation-program/>
- Burke, M., Hsiang, S. M., & Miguel, E. (2015). Global non-linear effect of temperature on economic production. *Nature*, 527(7577), 235-239. <https://doi.org/10.1038/nature15725>
- Davis, S. J., & Caldeira, K. (2010). Consumption-based accounting of CO₂ emissions. *Proceedings of the National Academy of Sciences*, 107(12), 5687-5692. <https://doi.org/10.1073/pnas.0906974107>
- Fouquet, R. (2010). The slow search for solutions: Lessons from historical energy transitions by sector and service. *Energy Policy*, 38(11), 6586-6596. <https://doi.org/10.1016/j.enpol.2010.06.029>
- Hirth, L., & Ueckerdt, F. (2013). The role of flexibility in the grid integration of renewable energies: A review of recent research in Germany. *Energy*, 36(9), 6095-6104. <https://doi.org/10.1016/j.energy.2013.07.014>
- Intergovernmental Panel on Climate Change (IPCC). (2018). *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels*. IPCC.
- International Energy Agency (IEA). (2021). *World Energy Outlook 2021*. <https://www.iea.org/reports/world-energy-outlook-2021>
- International Renewable Energy Agency (IRENA). (2020). *Global Renewables Outlook: Energy Transformation 2050*. IRENA.
- Jenkins, J. D., Mayfield, E. N., Larson, E. D., Pacala, S., Greig, C., & Menke, T. (2018). The benefits of clean energy for developing countries. *Nature Energy*, 3(6), 439-445. <https://doi.org/10.1038/s41560-018-0199-5>
- Luderer, G., Pehl, M., Arvesen, A., Gibon, T., Bodirsky, B. L., de Boer, H. S., ... & Hertwich, E. G. (2018). Environmental co-benefits and adverse side-effects of alternative power sector decarbonization strategies. *Nature Communications*, 10(1), 1-13. <https://doi.org/10.1038/s41467-018-06117-3>
- McCollum, D. L., et al. (2018). Energy investments under climate policy: A comparison of global models. *Climate Change Economics*, 10(01), 1-21. <https://doi.org/10.1142/S2010007818500015>
- Pachauri, S., van Ruijven, B. J., Nagai, Y., Riahi, K., van Vuuren, D. P., Brew-Hammond, A., & Nakicenovic, N. (2012). Access to modern energy: Assessment and outlook for developing and emerging regions. *Current Opinion in Environmental Sustainability*, 4(2), 241-247. <https://doi.org/10.1016/j.cosust.2012.06.001>
- Pollin, R., Garrett-Peltier, H., Heintz, J., & Scharber, H. (2014). Green growth, climate stabilization, and job creation. *Environmental Policy Brief*, Political Economy Research Institute, University of Massachusetts Amherst. <https://doi.org/10.7282/T3WQ02FR>
- Rogelj, J., Shindell, D., Jiang, K., Fifita, S., Forster, P., Ginzburg, V., ... & Vilariño, M. V. (2016). Mitigation pathways compatible with 1.5°C in the context of sustainable development. *Global Environmental Change*, 10(4), 53-70.

Corresponding author: Joshua Kurutsi Tabki

✉ kurutsi4edx@gmail.com

No.4 Dar-Es-Salam Street, Wuse 2, FCT, Abuja.

© 2023. Faculty of Technology Education. ATBU Bauchi. All rights reserved



<https://doi.org/10.1016/j.gloenvcha.2016.05.002>
Smil, V. (2017). *Energy and Civilization: A History*. MIT Press.

Stern, N. (2007). *The Economics of Climate Change: The Stern Review*. Cambridge University Press.
World Bank. (2019). *World Bank Annual Report 2019*. World Bank.

Corresponding author: Joshua Kurutsi Tabki

✉ kurutsi4edx@gmail.com

No.4 Dar-Es-Salam Street, Wuse 2, FCT, Abuja.

© 2023. Faculty of Technology Education. ATBU Bauchi. All rights reserved