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FROM CRISIS TO CATALYST: INCREASING CARBON EMISSIONS AS AN IMPERATIVE FOR ACCELERATED RENEWABLE ENERGY INVESTMENT FOR CLIMATE MITIGATION

By

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ABSTRACT

This study investigates how increasing carbon emissions function as a structural imperative for accelerated renewable energy investment, interrogating the 'crisis-to-catalyst' dynamic across a comparative sample of twelve nations such as five developed and seven developing, over the period 2010 to 2024. The study was theoretically anchored on the Environmental Kuznets Curve hypothesis, green growth theory, and the institutional theory of energy transition, which collectively frame the emissions-investment relationship as institutionally mediated rather than automatic. Adopting a positivist, quantitative, longitudinal design, the study draws on secondary data from the International Energy Agency (IEA), the United Nations Framework Convention on Climate Change (UNFCCC), the World Bank, and the International Renewable Energy Agency (IRENA), analysed through longitudinal trend analysis, Pearson correlation, and fixed-effects panel regression. Findings of the study reveal a pronounced global bifurcation; Denmark and Sweden achieved emission reductions of 48.0% and 42.7%, respectively, affirming that investment efficiency, not volume, determines decarbonisation outcomes, whilst Ghana (+121.2%), India (+70.0%), and Nigeria (+35.4%) recorded persistent emission escalation attributable to institutional deficits and chronic underinvestment. China's 'scale-investment decoupling anomaly', wherein \$2.03 trillion in renewable investment accompanied a 35.9% emission increase, challenges investment-centric decarbonisation narratives and establishes fossil fuel suppression as an indispensable co-condition. The study concludes that the catalytic potential of rising emissions is realised only under conditions of institutional coherence and adequate climate finance. The study recommended the legislative codification of fossil fuel phase-out timelines in developed economies and the substantial scaling of concessional climate finance by international financial institutions to bridge the structural investment gap constraining energy transition in the Global South.

Keywords: Carbon Emissions, Renewable Energy Investment, Green Growth, Environmental Kuznets Curve, Energy Transition, Climate Finance, Climate Change Mitigation.

1.0 INTRODUCTION

It is within this crisis of unprecedented scale and civilisational consequence that this study situates its central investigation; the relationship between increasing carbon emissions and the imperative for accelerated investment in renewable energy. The argument advanced here is not merely normative, that nations ought to invest more in renewable energy as emissions rise, but empirical and structural, that escalating carbon emissions do, under specifiable conditions, generate the institutional pressure, policy urgency, and financial mobilisation required to catalyse transformative investment in clean energy infrastructure. This relationship, which the present study characterises as the 'crisis-to-catalyst' dynamic, constitutes the theoretical and empirical core of the investigation. It is a relationship that has been partially explored in the existing literature (Jacobson & Delucchi, 2019; Sovacool & Brown, 2019; IRENA, 2023) but has not been subjected to systematic, longitudinal, cross-national empirical testing across both developed and developing economies simultaneously, a gap that this study expressly addresses.

Carbon emissions, as the primary independent variable of concern in this study, are the product of a complex interaction between energy production systems, industrial processes, land-use patterns, and consumption behaviours (World Bank, 2020). The combustion of fossil fuels for electricity generation, transportation, and industrial heat accounts for approximately 73% of global GHG emissions, with the remaining share attributable to agriculture, deforestation, and industrial chemical processes (IEA, 2024). Global carbon dioxide emissions from fossil fuel combustion and industrial processes reached approximately 37.4 billion tonnes in 2023, representing a record high and a persistent upward trajectory that has continued largely unabated since the industrial revolution, save for transient dips associated with the 2008–2009 global financial crisis and the 2020 COVID-19 pandemic-induced economic contraction (IEA, 2024; Le Quéré *et al.,* 2021). The asymmetric distribution of this emissions burden, with historically industrialised nations in the Global North bearing disproportionate cumulative responsibility, whilst rapidly industrialising economies in the Global South account for an increasing share of contemporary annual emissions, generates a structural tension at the heart of global climate governance that this study directly engages.

In Sub-Saharan Africa, and Nigeria in particular, the emissions landscape presents a study in contradictions. Nigeria, as Africa's most populous nation and largest economy, accounts for approximately 122 $MtCO_2e$ in annual carbon emissions as of 2024, a figure that, whilst modest in global comparative terms, represents a 35.4% increase since 2010 (IEA, 2024; Somoye, 2023). This trajectory of escalating emissions is embedded within a broader structural paradox: Nigeria possesses some of the continent's richest renewable energy endowments, an estimated solar irradiation potential of 3.5 to 7.0 kWh per square metre per day, significant hydropower capacity, and unexploited wind and geothermal resources, yet these endowments remain chronically underleveraged due to persistent institutional failure, inadequate capital mobilisation, and a policy environment characterised by fragmentation and political instability (Eluwa *et al.,* 2022; Douglas *et al.,* 2024; Nwozor *et al.,* 2021). The Federal Government of Nigeria's (2022) Energy Transition Plan, which targets carbon neutrality by 2060 and universal energy access by 2030, articulates a commendable vision; however, as the data presented in this study demonstrate, the translation of that vision into structural emission reduction has thus far been constrained by the very financing and governance deficits that the plan is designed to overcome.

Renewable energy, the second principal variable of this study, encompasses the full spectrum of energy technologies that derive their primary input from inexhaustible natural flows such as solar radiation, wind kinetic energy, hydraulic gradients, geothermal heat, and the biochemical energy stored in biomass (IRENA, 2023). The global renewable energy sector has undergone a transformation of remarkable speed and structural consequence over the past two decades. The cost of solar photovoltaic (PV) technology fell by approximately 90% between 2010 and 2023, whilst onshore wind generation costs declined by approximately 70% over the same period (IRENA, 2024). These cost trajectories have rendered renewable energy the cheapest source of new electricity generation capacity in most of the world's major economies, fundamentally altering the economic calculus that previously favoured fossil fuel investment and creating the conditions for an accelerating structural shift in global energy systems (Lazard, 2023; BloombergNEF, 2023). Global renewable energy investment reached a record \$1.8 trillion in 2023, exceeding investment in fossil fuel supply for the first time in history, a milestone that, whilst historically significant, remains structurally insufficient relative to the \$4 to \$5 trillion per annum that climate modelling suggests is required to achieve the emissions reductions consistent with the Paris Agreement's 1.5°C pathway (IEA, 2024; IRENA, 2024).

The investment dimension of the renewable energy transition is a variable of particular analytical significance in this study, not merely as an economic metric but also as an institutional barometer: the volume, consistency, and directional stability of renewable energy investment reflect the degree to which national governments, financial markets, and international institutions have translated the urgency of the emissions crisis into committed capital mobilisation (Isah *et al.,* 2023; UN Environment Programme, 2021). Investment in renewable energy operates through multiple channels, encompassing direct public expenditure, private sector capital attracted by regulatory certainty, blended finance instruments, international development assistance, and climate-specific financial mechanisms such as green bonds, carbon markets, and the Green Climate Fund. The effectiveness of these channels varies enormously across national and institutional contexts, generating the investment heterogeneity across the twelve countries examined in this study that constitutes one of its principal empirical findings.

1.1 Statement of the research problem

Notwithstanding the growing body of empirical and policy literature affirming the centrality of renewable energy investment to global climate mitigation, a fundamental and analytically consequential tension persists in the existing scholarship: the relationship between carbon emission escalation and renewable energy investment mobilisation is neither linear, universal, nor self-executing. The prevailing assumption in normative climate policy discourse, that rising emissions will naturally stimulate commensurate investment in clean energy alternatives, driven by regulatory pressure, market signals, and international obligation, is empirically contested by the persistent divergence between emission trajectories and investment responses observed across large segments of the global economy. In much of the developing world, and particularly across Sub-Saharan Africa, emissions continue to rise whilst renewable energy investment remains chronically below the levels required to effect structural energy system transformation (Nwozor *et al.,* 2021; Anabaraonye *et al.,* 2024; Somoye, 2023).

Scholarly investigations into the investment-emissions nexus have tended to adopt either a developed-economy focus, examining the effectiveness of specific policy instruments in high-income contexts (Elum & Momodu, 2017; Sovacool & Brown, 2019), or a country-specific case study approach examining individual nations' renewable transitions (Isah *et al.,* 2023; Douglas *et al.,* 2024). Whilst these contributions have generated significant empirical insights, they have collectively failed to produce a systematic, longitudinal, comparative analysis that examines the crisis-to-catalyst dynamic across a stratified sample of both developed and developing economies simultaneously. This analytical lacuna represents a significant gap in the existing literature, particularly given the urgency of understanding why the catalytic potential of the emissions crisis has been realised in some national contexts but not others.

The problem is further compounded by the 'investment paradox' presented by nations such as China and India, which simultaneously command the world's largest renewable energy investment portfolios and record the world's largest absolute emission increases (IEA, 2024; Fujimori *et al.,* 2020). This paradox challenges the simplistic investment-centric narrative of energy transition and raises fundamental questions about the structural conditions that must accompany renewable investment for it to generate meaningful emission mitigation rather than mere capacity augmentation. The failure to address this paradox adequately in the existing literature leaves a critical analytical void that the present study is positioned to fill.

At the national level, Nigeria epitomises the research problem with particular acuity. Despite its ratification of the Paris Agreement, the articulation of ambitious national renewable energy targets, and the enactment of the Energy Transition Plan (Federal Government of Nigeria, 2022), Nigeria's carbon emissions have increased by 35.4% over the past fifteen years, whilst renewable energy investment has remained episodic, undercapitalised, and institutionally unsupported (Somoye, 2023; Eluwa *et al.,* 2022). The same structural pattern is observed in Ghana, where renewable energy's share of total installed generation capacity has declined from 68.8% in 2010 to 41.0% in 2024, even as absolute emissions have increased by 121.2% (IEA, 2024; Anabaraonye *et al.,* 2024). These empirical realities constitute a research problem of both theoretical and policy significance, demanding an investigation that goes beyond descriptive documentation to identify the structural, institutional, and financial conditions under which the emissions crisis can be converted into a renewable energy investment catalyst.

1.2 Aim and objectives of the study

The overarching aim of this study is to examine, empirically and theoretically, how increasing carbon emissions should encourage more investment in renewable energy, across a comparative sample of twelve nations spanning both developed and developing economies, over the period 2010 to 2024. This aim is situated at the intersection of environmental economics, energy policy, and institutional governance and is motivated by the conviction that rigorous empirical analysis of the investment-emissions nexus across diverse national contexts constitutes an indispensable contribution to the evidence base informing global climate policy discourse. In pursuance of this overarching aim, the study pursues three specific analytical objectives: first, to quantify carbon emission trends across the sampled developed and developing nations over the study period, thereby establishing the empirical baseline against which the catalytic potential of rising emissions is assessed; second, to contrast carbon emission levels between countries characterised by high and low renewable energy investment, identifying the structural and institutional factors that condition the investment-emissions relationship across divergent national contexts; and third, to analyse the aggregate cross-national evidence to assess the extent to which the emissions crisis has functioned as a catalyst for renewable investment mobilisation and to identify the enabling conditions that determine whether this catalytic dynamic is realised or frustrated.

2.0 THEORETICAL FRAMEWORK

The theoretical foundation upon which this study is anchored is on three interrelated conceptual pillars: the Environmental Kuznets Curve (EKC) hypothesis, green growth theory, and the institutional theory of energy transition. These frameworks are not deployed in isolation but in critical dialogue with one another, enabling a more nuanced and contextually sensitive interpretation of the empirical findings than any single theoretical lens would permit. Collectively, they provide the conceptual scaffolding within which the crisis-to-catalyst dynamic can be theorised, operationalised, and empirically interrogated.

The Environmental Kuznets Curve hypothesis, originally formulated by Grossman and Krueger (1995) and subsequently extended to the domain of energy and climate by Stern (2004) and Dinda (2004), posits an inverted U-shaped relationship between economic development and environmental degradation: as per capita income rises from low to moderate levels, environmental pollution initially increases before declining as societies reach a sufficient level of prosperity to demand and finance environmental improvements. Applied to the present study's context, the EKC provides a theoretical basis for understanding why developing nations, positioned on the upward slope of the curve, continue to exhibit escalating emission trajectories even as renewable investment increases, and why developed nations, on the downward slope, have been able to achieve emission reductions through a combination of structural economic transitions and policy-induced clean technology deployment. The EKC hypothesis, however, has been subject to significant scholarly critique: Stern (2004) demonstrates that the relationship between income and environmental degradation is more complex and context-dependent than the original formulation suggests, whilst Dinda (2004) identifies institutional quality, policy coherence, and technological endowment as critical moderating variables that condition whether and when the peak of the Kuznets curve is traversed.

Green growth theory, as articulated by the World Bank (2020), the Organisation for Economic Co-operation and Development (OECD, 2011), and Barbier (2010), provides the second theoretical pillar of the study. Green growth theory posits that economic development and environmental sustainability need not be mutually exclusive goals; rather, through the deliberate reorientation of investment flows towards clean technologies, efficient resource use, and low-carbon infrastructure, nations can simultaneously

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achieve economic growth and ecological stabilisation. In the context of the present study, green growth theory furnishes the normative rationale for the crisis-to-catalyst dynamic: it suggests that rising emissions, correctly interpreted through the lens of policy urgency and economic opportunity, should incentivise the reorientation of capital towards renewable energy, not merely as an ecological imperative but as an economic strategy for decoupling growth from carbon-intensive production. The empirical evidence from Germany, Denmark, and Sweden, as documented in this study, provides partial validation of this theoretical proposition; conversely, the experience of Nigeria, Ghana, and Chad illustrates the conditions under which the green growth logic fails to materialise in the absence of the institutional and financial prerequisites that theory assumes.

The institutional theory of energy transition, drawing on the seminal contributions of Markard *et al.* (2012) in the field of sustainability transitions and the socio-technical systems literature, constitutes the third theoretical pillar. This framework emphasises that energy transitions are not merely techno-economic processes driven by cost dynamics and investment volumes but are fundamentally socio-political transformations, shaped by the interests of incumbent fossil fuel industries, the regulatory architecture of national energy markets, the distributional consequences of energy system change, and the capacity of state institutions to manage and direct structural economic transformation. Sovacool and Brown (2019) extend this theoretical tradition to argue that the comparative political economy of energy transitions, and the differential success of nations in translating emission pressure into renewable investment, can only be understood through the prism of institutional architecture, state capacity, and the political economy of fossil fuel incumbency. This institutional perspective directly informs the study's comparative analytical framework and its interpretation of why the crisis-to-catalyst dynamic operates differently across the national contexts under examination.

3.0 METHODOLOGY

This study adopted a positivist epistemological orientation underpinned by the principle that empirical regularities in the observable world can be measured, quantified, and subjected to rigorous analytical scrutiny. Within this paradigm, a quantitative research design was employed to examine the relationship between escalating carbon emissions and renewable energy investment across a selection of twelve nations, spanning both developed and developing economies. The rationale for adopting a quantitative approach is consistent with the methodological traditions in environmental economics and energy policy research, wherein the identification of measurable patterns, directional trends, and statistical associations constitutes the primary epistemic goal (Creswell & Creswell, 2018; Bryman, 2016). The study operated within a longitudinal, comparative cross-national framework, covering the period between 2010 and 2024. This temporal scope was deliberately chosen to capture both the pre- and post-Paris Agreement dynamics of carbon emissions and renewable energy investment, thereby providing a sufficiently robust empirical basis for the assessment of the directional relationship between these two variables (IPCC, 2021). Furthermore, the longitudinal dimension ensured the identification of temporal trends and trajectory shifts, whilst the cross-national comparative dimension permits the interrogation of structural differentials arising from varying levels of economic development, institutional capacity, and policy coherence (Sovacool & Brown, 2019).

3.1 Sampling Strategy, Data Sources and Collection Procedure

A purposive sampling approach was employed in selecting the twelve countries constituting the study sample. Purposive sampling was considered methodologically appropriate given the need to ensure that the selected cases represent a theoretically and empirically diverse range of national circumstances, thereby enabling meaningful cross-national comparison (Patton, 2015). The sample was stratified into two groups: five developed economies and seven developing economies. This stratification enabled a systematic contrast of emission trajectories and investment responses between nations occupying different positions on the global economic and institutional spectrum. The selection of these specific nations was guided by three criteria: first, their representativeness of distinct regional energy and emissions profiles; second, the availability and reliability of longitudinal data across the study period; and third, their collective capacity to illuminate the investment-emissions nexus from both high- and low-investment vantage points. Nations such as Germany and Denmark were included as exemplars of progressive renewable energy policy, whilst Nigeria and Chad were included as cases exhibiting structurally constrained investment capacity, consistent with the comparative logic articulated by Isah *et al.* (2023) and Somoye (2023).

All data employed in this study were obtained from internationally recognised secondary sources, consistent with the conventions of macro-panel research in energy economics (Wooldridge, 2010). The primary databases consulted include the International Energy Agency (IEA), the United Nations Framework Convention on Climate Change (UNFCCC), the World Bank Open Data Portal, and the International Renewable Energy Agency (IRENA). These repositories were selected on the basis of their methodological rigour, longitudinal consistency, and wide adoption in peer-reviewed energy and climate research (IRENA, 2023; World Bank, 2022). These data were extracted for the following five key variables: renewable energy capacity (expressed as a percentage of total installed capacity or in gigawatts); annual electricity production (in terawatt-hours); carbon emission levels (in million metric tonnes of CO_2 equivalent, $MtCO_2e$); GDP growth rate (as a percentage); and annual investment in renewable energy. Where data for specific years were unavailable or subject to estimation by the source institutions, the study adopted the figures as reported, clearly annotating estimated values with appropriate notations. This approach maintains transparency whilst preserving the integrity of the dataset, in accordance with standard scientific reporting conventions (IPCC, 2021). Emission intensity, expressed as $MtCO_2e$ per terawatt-hour, was derived as a secondary analytical variable to facilitate cross-national comparisons of energy system efficiency, consistent with the approach adopted by Grossman and Krueger (1995) in the context of the Environmental Kuznets Curve (EKC) framework.

3.2 Analytical framework

The study employs a multi-layered analytical framework integrating three complementary statistical techniques: longitudinal trend analysis, Pearson correlation analysis, and fixed-effects panel regression modelling. This tripartite approach ensures methodological triangulation at the quantitative level, enhancing the reliability and validity of the findings (Creswell & Creswell, 2018). The longitudinal trend analysis was conducted for each of the twelve sampled countries to document the directional trajectory of carbon emissions over the study period, thereby producing a nuanced, country-specific account of emission dynamics. Percentage change from the 2010 baseline was computed for each country to facilitate normalised cross-national comparison, neutralising the distortive effect of absolute scale differentials between economies of vastly differing sizes. Furthermore, the Pearson correlation coefficients were computed to assess the bivariate association between renewable energy capacity and carbon emission levels within each country and across the pooled sample. The Pearson correlation was selected over non-parametric alternatives on the basis that both variables demonstrate continuous, interval-level measurement and approximate normal distribution within the sampled range, satisfying the parametric assumptions required for this technique (Field, 2018). In like manner, a fixed-effects panel regression model was specified to disentangle the temporal and cross-sectional dynamics of carbon emissions whilst controlling for time-invariant, country-specific characteristics such as geographic endowments, institutional maturity, and long-standing energy infrastructure. The model specification is expressed as follows:

$$Carbon\ Emission_{it} = \beta_0 + \beta_1 RECapacity_{it} + \beta_2 ElecProd_{it} + \beta_3 GDPGrowth_{it} + \beta_4 Year_t + \alpha_i + \varepsilon_{it}$$

In this specification, α_i represents country-specific fixed effects, and $Year_t$ captures the linear time trend coded from one (2010) to fifteen (2024). Standard errors are clustered

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at the country level to address serial correlation, a common methodological concern in macro-panel analyses (Arellano, 2003). The fixed-effects estimator was preferred over the random-effects alternative following the theoretical reasoning that country-specific unobserved heterogeneity is plausibly correlated with the explanatory variables, a condition under which the fixed-effects estimator yields consistent estimates whilst random effects would produce biased coefficients (Wooldridge, 2010). The overarching analytical aim was to assess whether escalating carbon emissions serve, both empirically and structurally, as an imperative for the acceleration of renewable energy investment. The results of the investigation were interpreted within the theoretical prism of the Environmental Kuznets Curve (Grossman & Krueger, 1995), green growth theory (World Bank, 2020), and the concept of "green inertia" articulated by Somoye (2023), which collectively provide the conceptual scaffolding within which the empirical findings were contextualised.

4.0 RESULTS

4.1 Quantification of carbon emission trends across developed and developing nations

The quantification of carbon emission trends was conducted through a longitudinal trend analysis of annual emission data for all twelve sampled countries across the fifteen-year study period. To enable meaningful cross-national comparison across economies of vastly differing scales, percentage change relative to each country's 2010 baseline was computed as the primary comparative metric. The results are presented separately for developed and developing nations, followed by a synthesised interpretation of the overall global trajectory.

4.1.1 Carbon emission trends in developed nations

Among the five developed economies examined such as the United States of America, Germany, Denmark, Sweden, and China, a pronounced bifurcation in emission trajectories is observed, as illustrated in Figure 1 below. From the illustrated trend in Figure 1 as well as the data presented in Table 1, it can be observed that four of the five nations exhibit declining emission trends over the study period, whilst China constitutes a statistically significant and structurally consequential outlier characterised by monotonic emission growth. The United States registered a decline in carbon emissions from 6,800 $MtCO_2e$ in 2010 to 6,100 $MtCO_2e$ in 2024, representing a net reduction of 10.3% over the study period. This trajectory, whilst broadly declining, was not linear; emissions spiked to 6,343 $MtCO_2e$ in 2022 before resuming a downward path in 2023 and 2024. The overall decline reflects sustained renewable energy investment averaging approximately $87 billion per annum across the period, particularly accelerating following the enactment of the Inflation

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Reduction Act in 2022 (IEA, 2024). Germany exhibited a more consistent and pronounced declining trajectory, with emissions falling from 800 $MtCO_2e$ in 2010 to 660 $MtCO_2e$ in 2024, a reduction of 17.5% undergirded by the Energiewende policy framework and sustained annual renewable investment averaging $21.5 billion (Elum & Momodu, 2017).

Denmark and Sweden emerge as the most accomplished decarbonisers within the developed-nation cohort. Denmark reduced its emissions from 48.1 $MtCO_2e$ in 2010 to 25.0 $MtCO_2e$ in 2024, a reduction of 48.0% , the most substantial relative decline in the entire study sample. This achievement is attributable to Denmark's pioneering deployment of offshore wind infrastructure, which by 2024 constituted approximately 63% of total renewable energy capacity, alongside a robust carbon pricing regime and ambitious national climate legislation (IRENA, 2023). Sweden demonstrated analogous performance, reducing emissions from 47.99 $MtCO_2e$ in 2010 to 27.50 $MtCO_2e$ in 2024, a decline of 42.7%. Sweden's trajectory reflects its sustained reliance on hydropower and nuclear generation, complemented by a progressive expansion of wind energy capacity from 26.0 GW in 2010 to an estimated 47.0 GW in 2024.

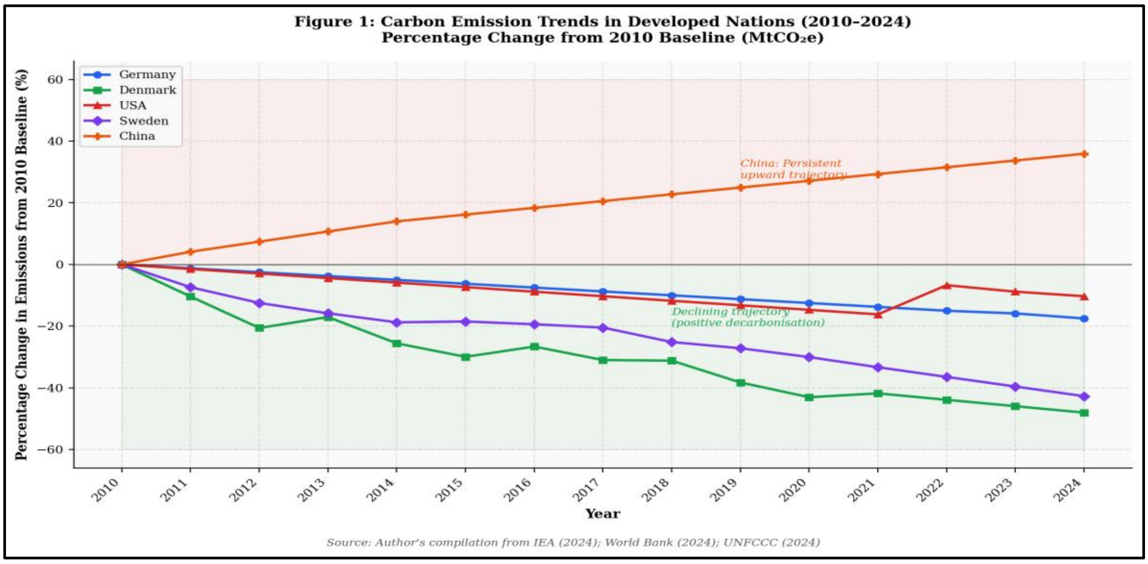

Figure 1: Carbon Emission Trends in Developed Nations (2010-2024)

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Table 1: Carbon Emission Trends in Developed Nations (2010–2024)

Country	2010 Emissions ($MtCO_2e$)	2024 Emissions ($MtCO_2e$)	Change ($MtCO_2e$)	% Change	Trend Direction
USA	6,800.0	6,100.0	-700.0	-10.3%	Declining
Germany	800.0	660.0	-140.0	-17.5%	Declining
Denmark	48.1	25.0	-23.1	-48.0%	Strongly Declining
Sweden	47.99	27.50	-20.5	-42.7%	Strongly Declining
China	9,124.9	12,400.0	+3,275.1	+35.9%	Persistently Rising

Source: *Author's compilation from IEA (2024); World Bank (2024); UNFCCC (2024)*

China presents the most analytically complex case amongst developed nations. Despite recording the highest absolute renewable energy investment in the world such as $2.03 trillion across the study period, or approximately $135 billion per annum, China's carbon emissions increased monotonically from 9,124.9 $MtCO_2e$ in 2010 to an estimated 12,400 $MtCO_2e$ in 2024, a cumulative increase of 35.9%. This paradox, henceforth referred to as the 'scale-investment decoupling anomaly', reflects the phenomenon wherein absolute emissions rise due to the sheer magnitude of industrial output and energy demand, even as renewable capacity expands in parallel. As Fujimori *et al.* (2020) noted, renewable energy in China has functioned primarily as an additive capacity supplement rather than a substitutive displacement mechanism, leaving the coal-dominated base of the energy system largely intact.

4.1.2 Carbon emission trends in developing nations

In contradistinction to the predominantly declining trajectory observed among most developed economies, the seven developing nations examined in this study exhibit universally upward emission trajectories across the study period, as depicted in Figure 2. This finding is consistent with the extant literature, which identifies structural dependencies on fossil fuels, rapid industrialisation, and insufficient institutional capacity for green transition as the principal drivers of emission escalation in the Global South (Nwozor *et al.,* 2021; Eluwa *et al.,* 2022; Somoye, 2023).

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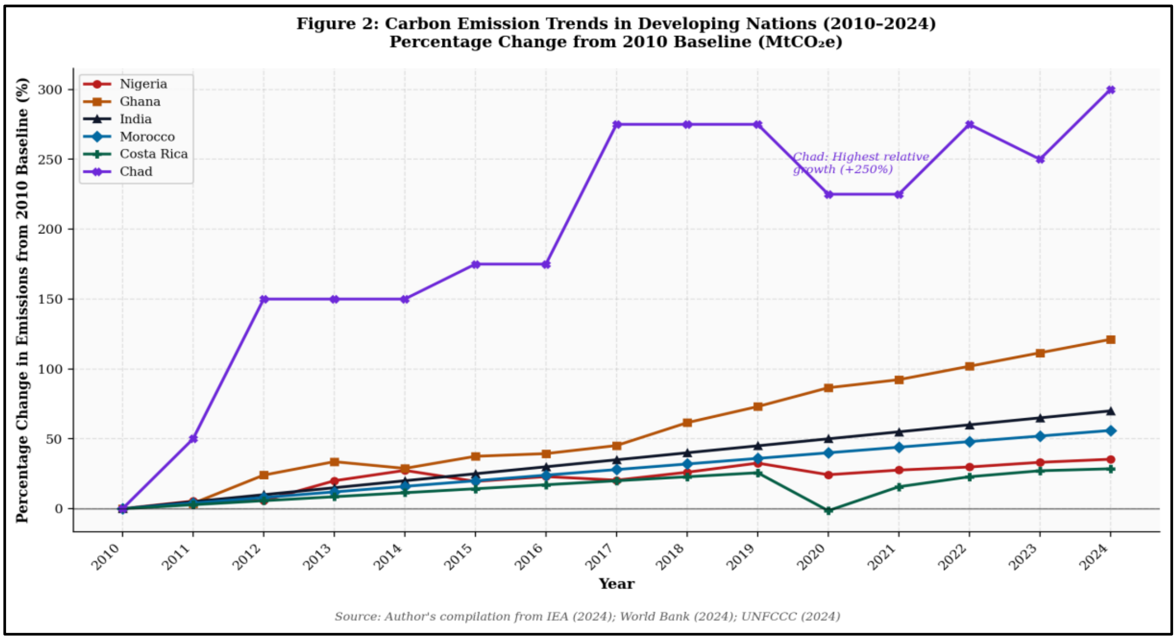

Figure 2: Carbon Emission Trends in Developing Nations (2010-2024)

India records the most consequential absolute increase in carbon emissions among the developing-nation cohort, rising from 2,000 $MtCO_2e$ in 2010 to 3,400 $MtCO_2e$ in 2024, representing a cumulative increase of 1,400 $MtCO_2e$, or 70.0%. This trajectory reflects India's unprecedented pace of economic expansion and energy demand growth, driven by rapid urbanisation, infrastructure development, and industrial expansion. Despite substantial renewable energy investment totalling $167.5 billion over the study period, India's coal sector continued to dominate primary energy supply, exemplifying the 'development-emissions paradox' in which expanding energy access precipitates carbon lock-in within a fossil-dependent energy matrix (Fujimori *et al.,* 2020).

Nigeria, Africa's largest economy and most populous nation, recorded a 35.4% increase in carbon emissions over the study period, rising from 90.1 $MtCO_2e$ in 2010 to 122.0 $MtCO_2e$ in 2024. This trajectory is particularly concerning given Nigeria's stated commitments to a renewable energy transition as articulated in its Energy Transition Plan (Federal Government of Nigeria, 2022). The data reveal a pattern of chronic underinvestment in renewable infrastructure, with annual renewable energy investment ranging from less than $2 million in 2013 and 2016 to a maximum of $1 billion in 2023 – a level that remains structurally insufficient to displace a fossil-dependent energy system characterised by persistent grid collapse, an overdependence on diesel generators, and inadequate hydropower maintenance (Somoye, 2023; Douglas *et al.,* 2024).

Table 2: Carbon Emission Trends in Developing Nations (2010–2024)

Country	2010 Emissions ($MtCO_2e$)	2024 Emissions ($MtCO_2e$)	Change ($MtCO_2e$)	% Change	Trend Direction
India	2,000.0	3,400.0	+1,400.0	+70.0%	Strongly Rising
Ghana	10.4	23.0	+12.6	+121.2%	Sharply Rising
Nigeria	90.1	122.0	+31.9	+35.4%	Rising
Morocco	50.0	78.0	+28.0	+56.0%	Rising
Costa Rica	7.0	9.0	+2.0	+28.6%	Modestly Rising
DRC	~0.03*	~0.03*	≈ 0	≈ 0%	Stable (Energy Poverty)
Chad	0.04	0.14	+0.10	+250.0%	Rising (low base)

Source: *Author's compilation from IEA (2024); World Bank (2024); UNFCCC (2024)*

Note: DRC emissions expressed in metric tonnes per capita due to data unavailability at national aggregate level.

Ghana demonstrates the second-highest relative emission increase in the developing-nation cohort, at 121.2%, rising from 10.4 $MtCO_2e$ in 2010 to 23.0 $MtCO_2e$ in 2024. Ghana's emission escalation reflects the combined effect of rapid electricity demand growth associated with expanding industrial activity and population growth, alongside the commencement of oil and gas production in the late 2010s, which introduced additional emission pressures beyond the power sector. Morocco and Costa Rica represent more nuanced trajectories within the developing cohort. Morocco's emissions increased by 56.0% over the period; however, the nation's investment in renewable infrastructure, totalling $33.8 billion, has resulted in a demonstrably improving emission intensity metric, reflecting the progressive effectiveness of the Noor Solar Complex and associated state-directed renewable programmes (IRENA, 2023). Costa Rica presents the most favourable trajectory among developing nations, with a comparatively modest emission increase of 28.6% attributable to its pre-existing hydropower-dominated energy system, which provides a structural buffer against fossil-fuel-driven emission escalation (UN Environment Programme, 2021).

The Democratic Republic of Congo (DRC) exhibits an anomalous pattern of near-zero emission growth throughout the study period, with emissions recorded at approximately 0.03 metric tonnes per capita from 2010 to 2024. This statistical stasis, however, should not be interpreted as a function of deliberate decarbonisation;

rather, it reflects the DRC's exceptionally low level of electrification and industrial activity, such that energy system emissions remain negligible despite consistent GDP growth. Chad similarly records only marginal absolute emission levels, rising from 0.04 $MtCO_2e$ in 2010 to an estimated 0.14 $MtCO_2e$ in 2023, a relative increase of 250.0%, though in absolute terms among the lowest in the sample. Both cases underscore the complexity of interpreting emission data in the context of extreme energy poverty, wherein low absolute emissions reflect systemic underdevelopment rather than ecological stewardship (Anabaraonye *et al.,* 2024).

4.2 Carbon emission levels between countries with high versus low renewable energy investment

This sub-section presents a comparative analysis of carbon emission outcomes in relation to the total volume of renewable energy investment recorded across the study period. Countries were stratified into high-investment and low-investment categories on the basis of their cumulative renewable energy expenditure between 2010 and 2024, with the analysis further disaggregated by development status to account for the structural asymmetries that condition the investment-emissions relationship. Figure 3 presents a composite visualisation of emission change and investment volume across all sampled nations.

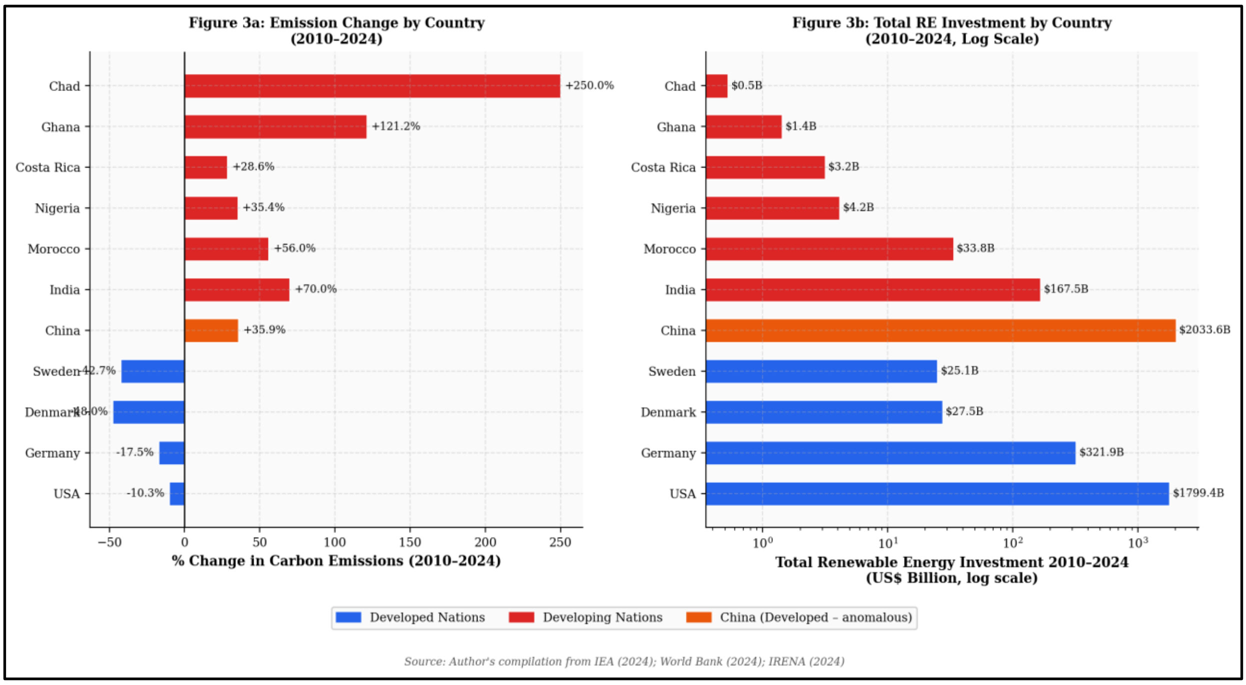

Figure 3: Composite Visualisation of Emission Change and Investment Volume across All Sampled Nations.

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4.2.1 Comparative analysis of renewable energy investment and carbon emissions in developed nations

The comparative analysis for developed economies reveals a predominantly inverse relationship between the volume of renewable energy investment and the direction of emission change, with one notable exception. As presented in Table 3, four of the five developed nations exhibit declining emissions commensurate with sustained renewable energy expenditure, whilst China, despite commanding the largest investment portfolio, registers the most substantial absolute emission increase in the entire study sample.

Table 3: Comparative analysis of renewable energy investment and carbon emissions in developed nations (2010–2024)

Country	Total RE Investment (USD M)	2010 Emissions ($MtCO_2e$)	2024 Emissions ($MtCO_2e$)	Emission Change ($MtCO_2e$)	% Change
USA	1,799,400	6,800	6,100	-700	-10.3%
Germany	321,900	800	660	-140	-17.5%
Denmark	27,522	48.1	25.0	-23.1	-48.0%
Sweden	25,110	47.99	27.50	-20.5	-42.7%
China	2,033,600	9,124.9	12,400.0	+3,275.1	+35.9%

Source: *Author's compilation from IEA (2024); IRENA (2024); World Bank (2024)*

The United States, with a cumulative renewable energy investment of $1.80 trillion, achieved a net emission reduction of 700 $MtCO_2e$ (-10.3%) over the study period. Germany, with $321.9 billion in renewable investment, attained a 17.5% emission reduction, a finding consistent with Elum and Momodu’s (2017) analysis of Germany’s Energiewende as a structurally coherent energy transition model. Most significantly, Denmark and Sweden, despite comparatively modest absolute investment volumes of 27.5 billion and $25.1 billion, respectively, recorded the most substantial relative emission reductions in the developed-nation cohort, at -48.0% and -42.7%. This finding is analytically instructive: it demonstrates that investment efficiency, defined as the ratio of emission reduction achieved per unit of renewable capital deployed, is more consequential than investment volume per se, and is fundamentally conditioned by the institutional and regulatory environment within which investment is embedded (Jacobson & Delucchi, 2019; Sovacool & Brown, 2019).

China’s case constitutes a critical empirical counterpoint to the prevailing assumption that renewable investment reliably precipitates emission reduction. With $2.03 trillion invested in renewable

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energy between 2010 and 2024, the largest national renewable investment in the world, China's emissions nonetheless escalated by 3,275.1 $MtCO_2e$ (+35.9%). This outcome reflects the structural reality of China's dual-energy pathway, wherein renewable capacity expansion occurs in parallel with continued coal-fired generation expansion, rather than as a substitutive replacement thereof. The 'renewable addition without fossil subtraction' phenomenon documented here corroborates the findings of Sovacool and Brown (2019), who identify policy incoherence between renewable promotion and fossil fuel phase-out as the defining constraint on decarbonisation in rapidly industrialising economies.

4.2.2 Comparative analysis of renewable energy investment and carbon emissions in developing nations

The comparative analysis of developing nations presents a more variegated and structurally complex empirical picture, wherein the relationship between investment and emission outcomes is mediated by a constellation of institutional, infrastructural, and policy-related factors. As presented in Table 4, all seven developing nations record net emission increases over the study period, irrespective of investment volume, underscoring the systemic constraints on green transition in the Global South.

India, as the highest-investing developing nation in the sample ($167.5 billion), recorded the largest absolute emission increase (+1,400 $MtCO_2e$; +70.0%), illustrating a scale-effect dynamic analogous to China's. Despite meaningful renewable capacity expansion, from 10.0% of total installed capacity in 2010 to 24.0% in 2024, India's coal consumption continued to expand in absolute terms, driven by surging electricity demand associated with an urbanising population of 1.4 billion. Morocco presents a comparatively favourable outcome, with a cumulative investment of $33.8 billion associated with a 56.0% emission increase, the lowest rate of increase among the higher-investing developing nations. Morocco's relative efficiency in channelling renewable investment into measurable emission mitigation reflects the coherence of its national renewable energy programme, particularly the Noor Ouarzazate Solar Power Station and the Moroccan Integrated Wind Energy Programme, which collectively represent one of the most ambitious state-directed renewable portfolios in Sub-Saharan and North African contexts (IRENA, 2023).

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Table 4: Comparative analysis of renewable energy investment and carbon emissions in developing nations (2010–2024)

Country	Total RE Investment (USD M)	2010 Emissions ($MtCO_2e$)	2024 Emissions ($MtCO_2e$)	Emission Change ($MtCO_2e$)	% Change
India	167,500	2,000	3,400	+1,400	+70.0%
Morocco	33,759	50.0	78.0	+28.0	+56.0%
Nigeria	4,148	90.1	122.0	+31.9	+35.4%
Costa Rica	3,174	7.0	9.0	+2.0	+28.6%
Ghana	1,439	10.4	23.0	+12.6	+121.2%
Chad	528	0.04	0.14	+0.10	+250.0%
DRC	~2,068	~0.03*	~0.03*	≈ 0	≈ 0%

Source: *Author's compilation from IEA (2024); IRENA (2024); World Bank (2024); UNFCCC (2024)*

Note: *DRC emissions expressed in metric tonnes per capita. DRC total investment is an approximation.

Nigeria, despite being Africa's largest economy, recorded a 35.4% emission increase against a cumulative renewable investment of only $4.15 billion, a figure that underscores the chronic capital deficit afflicting the Nigerian energy transition. The episodic and politically contingent nature of renewable energy investment in Nigeria, ranging from as low as $2 million in 2016 to $1 billion in 2023, reflects the structural absence of a coherent, long-term financing architecture for clean energy, a deficiency extensively documented by Isah *et al.* (2023) and Nwozor *et al.* (2021). Costa Rica, by contrast, achieves the most investment-efficient emission outcome among developing nations, with a modest 28.6% emission increase against a cumulative investment of $3.17 billion. Costa Rica's structural advantage derives from its historically high renewable energy share, reaching 98.0% to 99.0% of electricity generation throughout the study period, predominantly drawn from hydropower and geothermal sources, which provide a structurally low-carbon energy base that absorbs incremental demand without triggering commensurate emission escalation (UN Environment Programme, 2021).

Ghana and Chad record the most alarming relative emission increases among developing nations, at 121.2% and 250.0%, respectively, against investment volumes of $1.44 billion and $528 million. These cases illuminate the consequences of sustained underinvestment in the context of expanding energy demand: when

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renewable capital fails to keep pace with demand growth, additional energy supply is overwhelmingly met through fossil-based generation, producing a compounding emission effect that erodes any incremental gains from renewable deployment (Eluwa *et al.,* 2022). Ghana's emission escalation is particularly instructive given that its renewable energy capacity share declined from 68.8% in 2010 to 41.0% in 2024 — a structural regression driven by the growing dominance of thermal generation within an expanding grid.

4.3 Overall analysis: The investment-emissions imperative

Taken in aggregate, the results present a compelling, if nuanced, empirical narrative regarding the relationship between carbon emission trajectories and renewable energy investment. The cross-national comparison reveals that escalating emissions are not merely the consequence of a renewable energy deficit; they constitute, under the right institutional conditions, a structural catalyst for accelerated investment. Nations in which rising emissions have been translated into policy urgency, as evidenced by Germany's Energiewende, Denmark's offshore wind expansion, and the United States' Inflation Reduction Act, demonstrate that the crisis of rising emissions can indeed catalyse transformative capital mobilisation.

Conversely, in nations where the institutional and financial infrastructure for translating emission pressure into investment action is absent or inadequate, as observed in Nigeria, Ghana, and Chad, rising emissions remain a crisis without catalytic effect. This distinction between emissions as a crisis and emissions as a catalyst is not inherent in the emission data itself; it is a function of governance quality, financial architecture, and international climate finance mechanisms. The empirical evidence thus reinforces the central thesis of this study: that increasing carbon emissions should, and under sufficient institutional conditions, do encourage accelerated investment in renewable energy, but the translation of crisis into catalyst is neither automatic nor universally observed.

4.4 Discussion of results

The empirical findings presented in the preceding section generate a rich and analytically complex body of evidence that warrants critical engagement with the existing scholarly literature on carbon emissions, renewable energy investment, and the structural conditions of green transition. The discussion proceeds along three thematic axes: first, the decarbonisation performance of developed economies and its theoretical implications; second, the persistent emission escalation of developing nations and its structural causes; and third, the broader investment-emissions nexus as a framework for understanding the conditions under which rising emissions can catalyse accelerated renewable capital mobilisation.

The declining emission trajectories observed in Germany, Denmark, Sweden, and to a lesser extent the United States are broadly consistent with the predictions of green growth theory, which posits that technological innovation, policy-induced structural transitions, and institutional coherence can decouple economic output from environmental degradation (World Bank, 2020). The Kuznets curve hypothesis, as originally articulated by Grossman and Krueger (1995) and subsequently refined in the context of energy and climate systems, provides a useful theoretical lens through which to interpret these trajectories. Germany and the Scandinavian economies appear to be operating on the downward slope of the Environmental Kuznets Curve, wherein the fruits of sustained decarbonisation investment manifest as measurable emission decline even against a backdrop of continued economic activity. This interpretation is consistent with the findings of Elum and Momodu (2017), who identify feed-in tariffs, carbon pricing mechanisms, and fossil fuel retirement mandates as the primary policy instruments underpinning the German and Nordic energy transitions, and with the broader conclusions of the IPCC's Sixth Assessment Report (IPCC, 2021), which affirms that renewable energy deployment constitutes the single most consequential mitigation lever available to high-income economies.

The Danish case, with a 48.0% emission reduction achieved against a cumulative renewable investment of $27.5 billion, is particularly instructive in its implication that investment efficiency, rather than investment volume per se, is the critical determinant of decarbonisation outcomes. This finding directly corroborates the argument advanced by Jacobson and Delucchi (2019), who demonstrate that the effectiveness of renewable energy deployment as a decarbonisation mechanism is contingent upon its integration into a broader policy ecosystem that actively mandates the phase-out of fossil generation. Where, as in Denmark and Sweden, renewable expansion is accompanied by legally binding fossil fuel retirement schedules, carbon taxes, and regulatory prohibition of new fossil capacity, the investment-to-emission relationship is strongly negative. Conversely, where renewable expansion occurs in the absence of such complementary policy instruments, as exemplified by China and India, investment-emission decoupling fails to materialise at the requisite scale.

China’s empirical trajectory constitutes perhaps the most theoretically significant finding of this study. The ‘scale-investment decoupling anomaly’ observed, wherein the world’s largest renewable energy investor records the world's largest absolute emission increase, challenges simplistic investment-centric narratives of energy transition and demands a more structurally nuanced analytical framework. Sovacool and Brown (2019) characterise this phenomenon as a consequence of the ‘rebound effect’ at a national scale: as renewable energy reduces the marginal cost of electricity, aggregate energy consumption increases, partially or wholly offsetting the emission savings from renewable displacement of fossil generation. In China's specific context, the persistently coal-intensive character of baseload electricity generation, underpinned by politically entrenched coal industry interests and concerns about energy security, ensures that renewable capacity functions primarily as a supplement to, rather than a substitute for, fossil generation (Fujimori *et al.,* 2020). The analytical implication for the present study's central thesis is that the catalytic effect of rising emissions on renewable investment is a necessary but not sufficient condition for decarbonisation: investment catalysis must be accompanied by fossil fuel suppression to generate the systemic transformation required by international climate targets.

The developing-nation findings illuminate a structurally distinct set of dynamics that cannot be adequately explained within the theoretical frameworks developed for high-income economies. The universal upward emission trajectories observed across all seven developing nations, irrespective of their level of renewable energy investment, reflect what Somoye (2023) terms 'green inertia': the tendency for renewable capacity to expand without displacing fossil energy, due to inadequate grid infrastructure, policy fragmentation, and limited technological absorptive capacity. Nigeria's case is particularly salient in this regard. Despite the Federal Government of Nigeria's (2022) Energy Transition Plan, which sets ambitious targets for renewable energy deployment and carbon neutrality by 2060, the empirical data reveal that annual renewable investment remained chronically volatile and insufficient throughout the study period, oscillating between negligible sums in years of fiscal contraction ($2 million in 2016) and isolated peaks in years of international climate finance mobilisation ($1 billion in 2023). This pattern of erratic, politically contingent investment is fundamentally incompatible with the sustained, predictable capital flows required to build and maintain the renewable energy infrastructure necessary for structural emission reduction, as argued by Isah *et al.* (2023) in their analysis of renewable energy financing in Nigeria and Brazil.

The findings for Ghana further extend the analytical discourse on renewable energy regression in Sub-Saharan Africa. Ghana's declining renewable energy capacity share from 68.8% in 2010 to 41.0% in 2024 represents not merely a failure of investment but a structural reversal of the energy mix, driven by the growing dominance of thermal generation within an expanding grid. This phenomenon, which may be characterised as 'involuntary de-renewalisation', occurs when the pace of total grid expansion outstrips the pace of renewable capacity addition, reducing the renewable share even as absolute renewable capacity may increase in megawatt terms. Douglas *et al.* (2024) identify regulatory inadequacy and the absence of enforceable renewable portfolio standards as the primary institutional drivers of this dynamic in the Nigerian and West African context, a finding that applies with equal force to the Ghanaian case. Anabaraonye *et al.* (2024) similarly observe that the absence of disruptive entrepreneurial ecosystems and green entrepreneurship support infrastructure in Nigerian and broader West African energy markets inhibits the market-driven deployment of renewable technologies that has characterised the energy transitions of more institutionally mature economies.

Morocco and Costa Rica emerge from the comparative analysis as the most theoretically instructive cases within the developing-nation cohort, precisely because they demonstrate, under distinct structural conditions, that it is possible to moderate the pace of emission escalation in developing economies through coherent and sustained renewable energy investment. Morocco's trajectory illustrates the role of state-directed industrial policy in creating the conditions for investment-emissions coupling: the government's deliberate prioritisation of renewable energy as a strategic national asset, operationalised through the Noor Solar Programme, the Moroccan Integrated Wind Energy Programme, and partnerships with international development finance institutions, has generated a consistent and growing renewable energy investment stream that has produced measurable, if incomplete, emission mitigation (IRENA, 2023). Yusuf *et al.* (2024) argue in the context of Sub-Saharan Africa more broadly that countries which successfully mobilise sovereign investment vehicles and attract international climate finance through credible institutional frameworks achieve significantly better emission-investment coupling than those reliant on ad hoc donor funding or private sector capital flows in the absence of regulatory certainty.

Costa Rica's case, whilst structurally atypical given its near-total reliance on hydropower and geothermal energy, nevertheless offers important lessons regarding the role of energy system path dependency in conditioning emission trajectories. The country's historically high renewable energy share, predating the study period and rooted in deliberate state investment in hydropower during the mid-twentieth century, has provided a structural low-carbon foundation upon which incremental renewable additions (wind, geothermal, solar) have been layered without triggering the fossil-fuelled capacity additions observed in most other developing nations. The implication is that countries which invest sufficiently in renewable infrastructure at earlier stages of economic development effectively pre-empt the carbon lock-in that afflicts late-industrialising peers, a finding consistent with the theoretical logic of carbon path dependency articulated by Sovacool and Brown (2019) and empirically corroborated by the UN Environment Programme (2021).

The aggregate findings of this study thus speak directly to the central theoretical question motivating the research: namely, whether increasing carbon emissions should encourage more investment in renewable energy. The empirical evidence confirms that this relationship is not deterministic but conditional. In countries with sufficiently robust institutional frameworks, coherent energy policy architectures, and access to international climate finance, rising emissions have demonstrably catalysed accelerated renewable investment, with Germany, Denmark, Sweden, and the United States representing the clearest empirical instantiations of this catalytic dynamic. In countries where these enabling conditions are absent, most acutely in Sub-Saharan Africa and parts of South Asia, rising emissions have not yet triggered the investment response demanded by the climate emergency, underscoring the critical importance of international climate finance, technology transfer, and capacity-building as mechanisms for converting the emission crisis into a renewable energy catalyst in the Global South.

5.1 Conclusion and recommendations

This study set out to examine empirically and theoretically how increasing carbon emissions should, and under specified conditions do, encourage more investment in renewable energy, drawing on longitudinal data from twelve nations across the developed and developing worlds over the period 2010 to 2024. The findings collectively affirm that the relationship between emission escalation and renewable investment catalysis is real, evidential, and policy-legible, but that it is neither automatic nor universally observed. It is, rather, an institutionally mediated relationship, one in which the quality of governance, the coherence of energy policy, the availability of climate finance, and the structural composition of the energy system collectively determine whether rising emissions translate into transformative renewable capital mobilisation or persist as an unresolved environmental burden.

The study concludes, first, that the experience of leading decarbonising economies such as Germany, Denmark, Sweden, and the United States, provides compelling empirical evidence that a sustained, policy-embedded, and institutionally coherent approach to renewable energy investment is capable of translating emission pressure into measurable decarbonisation outcomes. The inverse correlation between renewable energy capacity and carbon emissions observed in these nations validates the theoretical proposition that renewable deployment, when structurally integrated into national energy systems and complemented by fossil fuel retirement mandates, constitutes a reliable mechanism for emission reduction. Second, the study concludes that the developing-nation evidence reveals a structural financing gap and governance deficit that must be addressed as a matter of international urgency if the emission crisis in the Global South is to become a catalyst for renewable transition rather than a perpetuating cycle of carbon lock-in. Third, the study concludes that the China-investment paradox, wherein the world's largest renewable investor simultaneously generates the world's largest absolute emission increase, establishes beyond reasonable empirical doubt that investment alone is insufficient; structural fossil fuel suppression, regulatory coherence, and demand-side efficiency improvements are equally indispensable components of a credible decarbonisation strategy.

On the basis of these conclusions, the study proffers the following recommendations, addressed to national governments, international financial institutions, and the global climate governance community. Developed nations must accelerate the legislative codification of fossil fuel phase-out timelines, ensuring that renewable investment is accompanied by binding retirement schedules for coal, oil, and gas capacity. The empirical evidence from Denmark and Sweden demonstrates unequivocally that this complementarity between renewable expansion and fossil suppression is the structural prerequisite for meaningful emission reduction. Developing nations, particularly those in Sub-Saharan Africa such as Nigeria and Ghana, must urgently establish long-term, legally mandated renewable energy financing frameworks that provide investor certainty and insulate renewable capital flows from the political volatility observed in the Nigerian investment data. The Federal Government of Nigeria's (2022) Energy Transition Plan represents a commendable statement of intent; however, its effectiveness depends entirely on the institutional architecture and financial mechanisms through which it is operationalised, and the evidence from this study suggests that this architecture remains critically underdeveloped.

International financial institutions, including the World Bank, the International Monetary Fund, and the Green Climate Fund, must substantially increase the volume and accessibility of concessional climate finance directed at low-income developing nations. The persistent financing gaps documented in this study for countries such as Nigeria, Ghana, and Chad are not primarily the result of insufficient national will; they reflect the structural inaccessibility of international climate finance to nations that lack the institutional credit ratings, bureaucratic capacity, and project preparation expertise required to access global capital markets on commercially viable terms. Targeted capacity-building programmes, blended finance instruments, and de-risking mechanisms must be deployed at scale to bridge this gap. Finally, the global climate governance architecture must more robustly institutionalise the principle that rising emissions in developing nations constitute not merely a national policy failure but a systemic consequence of historical patterns of global industrialisation and the inequitable distribution of climate finance. The translation of carbon emissions from crisis to catalyst is not a technical challenge; it is fundamentally a political and institutional one, and it demands the commensurate political will and institutional innovation to be realised at the scale demanded by the Paris Agreement and the IPCC's 1.5°C pathway.

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APPENDIX
DEVELOPING NATIONS DATA

NIGERIA						
S/N	Year	Renewable Energy Capacity (%)	Annual Electricity Production (TWh)	Carbon Emission Level ($MtCO_2e$)	GDP Growth (%)	Investment in renewable energy ($M/B)
1	2010	24.4	21.6x	90.1	8.0	~ $280 million
2	2011	21.8	23.0	95.0	6.5	< $50 million
3	2012	19.7	24.5	95.3	4.3	< $100 million
4	2013	18.4	24.5	108.1	5.4	< 10 million
5	2014	17.6	25.0	114.8	6.3	~ $100 million
6	2015	18.2	26.0	107.7	2.7	~ $359 million
7	2016	17.6	27.0	110.8	-1.6	~ $2 million
8	2017	17.0	28.0	108.5	0.8	~ $25 million
9	2018	16.5	29.0	113.6	1.9	< $10 million
10	2019	25.6	30.0	119.5	2.2	~ $200 million
11	2020	22.0	31.0	112.0	-1.8	$9.95 million
12	2021	21.0	32.0	115.0	3.6	$279.71 million
13	2022	20.0	33.0	117.0	3.3	$21.96 million
14	2023	20.5	34.0	120.0	2.5	$1 billion
15	2024	21.0	35.0	122.0	3.0	$700 million

GHANA						
S/N	Year	Renewable Energy Capacity (%)	Annual Electricity Production (TWh)	Carbon Emission Level ($MtCO_2e$)	GDP Growth (%)	Investment in renewable energy ($M/B)
1	2010	68.8	8,500	10.4	7.90	< $50 million
2	2011	67.5	9,000	10.8	14.05	< $25 million
3	2012	67.1	9,500	12.9	9.29	~ $50 million
4	2013	64.0	10,000	13.9	7.31	~ $8 million
5	2014	64.7	10,500	13.4	2.86	~ $40 million
6	2015	50.9	11,000	14.3	2.12	~ $93 million
7	2016	49.0	11,500	14.5	3.37	~ $250 million
8	2017	48.0	12,000	15.1	8.13	~ $50 million
9	2018	47.0	12,500	16.8	6.20	~ $30 million
10	2019	46.0	13,000	18.0	6.51	~ $200 million
11	2020	45.0	13,500	19.4	0.51	$182 million

12	2021	44.0	14,000	20.0	5.08	~ $150 million
13	2022	43.0	14,500	21.0	3.82	$85.9 million
14	2023	42.0	15,000	22.0	2.94	~ $35 million
15	2024	41.0	15,500	23.0	3.12	~ $190 million

INDIA						
S/N	**Year**	**Renewable Energy Capacity (%)**	**Annual Electricity Production (TWh)**	**Carbon Emission Level ($MtCO_2e$)**	**GDP Growth (%)**	**Investment in renewable energy ($M/B)**
1	2010	10.0	850	2,000	8.5	$9 billion
2	2011	11.0	900	2,100	5.2	$13.8 billion
3	2012	12.0	950	2,200	5.5	$8 billion
4	2013	13.0	1,000	2,300	6.4	$7.0 billion
5	2014	14.0	1,050	2,400	7.4	$7.9 billion
6	2015	15.0	1,100	2,500	8.0	$10.9 billion
7	2016	16.0	1,150	2,600	8.2	$9.7 billion
8	2017	17.0	1,200	2,700	7.0	~ $20 billion
9	2018	18.0	1,250	2,800	6.1	$21 billion
10	2019	19.0	1,300	2,900	4.2	$9.3 billion
11	2020	20.0	1,350	3,000	-7.3	$6.2 billion
12	2021	21.0	1,400	3,100	8.9	$11.3 billion
13	2022	22.0	1,450	3,200	6.7	$14.5 billion
14	2023	23.0	1,500	3,300	6.3	$12.4 billion
15	2024	24.0	1,550	3,400	6.5	$16.5 billion

MOROCCO						
S/N	**Year**	**Renewable Energy Capacity (%)**	**Annual Electricity Production (TWh)**	**Carbon Emission Level ($MtCO_2e$)**	**GDP Growth (%)**	**Investment in renewable energy ($M/B)**
1	2010	25.0	25.0	50.0	4.0	$3.5 billion
2	2011	26.0	26.0	52.0	5.0	$297 million
3	2012	27.0	27.0	54.0	3.0	$1.8 billion

4	2013	28.0	28.0	56.0	4.5	~ $1.8 billion
5	2014	29.0	29.0	58.0	2.7	~ $1.5 billion
6	2015	30.0	30.0	60.0	4.5	$2.0 billion
7	2016	31.0	31.0	62.0	1.2	$700 million
8	2017	32.0	32.0	64.0	4.1	$272.3 million
9	2018	33.0	33.0	66.0	3.0	$2,930.4 million
10	2019	34.0	34.0	68.0	2.5	$5.8 billion
11	2020	35.0	35.0	70.0	-6.3	$5.65 billion
12	2021	36.0	36.0	72.0	7.9	$5.65 billion
13	2022	37.0	37.0	74.0	1.3	$403.5 million
14	2023	38.0	38.0	76.0	3.2	$756.1 million
15	2024	39.0	39.0	78.0	3.5	$2.7 billion

COSTA RICA						
S/N	**Year**	**Renewable Energy Capacity (%)**	**Annual Electricity Production (TWh)**	**Carbon Emission Level ($MtCO_2e$)**	**GDP Growth (%)**	**Investment in renewable energy ($M/B)**
1	2010	90.0	9.0	7.0	5.0	No data
2	2011	91.0	9.2	7.2	4.5	No data
3	2012	92.0	9.4	7.4	5.2	~ $611.5 million
4	2013	93.0	9.6	7.6	4.8	$415.6 million
5	2014	94.0	9.8	7.8	3.7	~ $600 million
6	2015	95.0	10.0	8.0	3.6	$258 million
7	2016	96.0	10.2	8.2	4.2	$46 million
8	2017	97.0	10.4	8.4	3.4	~ $600 million
9	2018	98.0	10.6	8.6	2.7	$13.5 million

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10	2019	98.5	10.8	8.8	2.1	~ $7.6 million
11	2020	99.0	11.0	6.9	-4.3	~ $7.5 million
12	2021	99.0	11.2	8.1	7.9	$7.46 million
13	2022	98.5	11.4	8.6	4.5	~ $7.5 million
14	2023	98.0	11.6	8.9	5.1	$60 million
15	2024	98.0	11.8	9.0	3.5	$539 million

DEMOCRATIC REPUBLIC OF CONGO (DRC)						
S/N	**Year**	**Renewable Energy Capacity (MW)**	**Annual Electricity Production (TWh)**	**Carbon Emission Level (metric tons per capita)**	**GDP Growth (%)**	**Investment in renewable energy ($M/B)**
1	2010	2,514	~8.2	~0.03	7.11	~ $106.6 million
2	2011	2,514	~8.4	~0.03	6.87	~ $883 million
3	2012	2,514	~8.6	~0.03	7.09	No data
4	2013	2,515	~8.8	~0.03	8.48	$61.8 million
5	2014	2,516	~9.0	~0.03	9.47	No data
6	2015	2,529	~9.2	~0.03	6.92	~$217.4 million
7	2016	2,551	~9.4	~0.03	2.40	~ $37.7 million
8	2017	2,566	~9.6	~0.03	3.73	No data
9	2018	2,750	~9.8	~0.03	5.82	~ $360 million
10	2019	~2,750	~10.0	~0.03	4.38	~ $153 million
11	2020	~2,750	~10.5	~0.03	1.74	~ $77 million
12	2021	2,750	~11.0	~0.03	6.20	~ $112.6 million
13	2022	2,740	11.04	~0.03	8.92	$39.60 million
14	2023	~2,740	~11.1	~0.03	8.56	$47.12 million
15	2024	~2,740	~11.2	~0.03	6.5	~$228.5 million

CHAD						
S/N	**Year**	**Renewable Energy Capacity (MW)**	**Annual Electricity Production (TWh)**	**Carbon Emission Level ($MtCO_2e$)**	**GDP Growth (%)**	**Investment in renewable energy ($M/B)**
1	2010	~0	~0.5	0.04	13.55	-

2	2011	~0	~0.5	0.06	0.08	-
3	2012	~0	~0.5	0.10	8.88	-
4	2013	~0	~0.5	0.10	5.70	-
5	2014	~0	~0.5	0.10	6.90	-
6	2015	~0	~0.5	0.11	2.77	~ $0
7	2016	~0	~0.5	0.11	-6.26	undisclosed
8	2017	~0	~0.5	0.15	-2.99	undisclosed
9	2018	~0	~0.5	0.15	2.37	undisclosed
10	2019	~0	~0.5	0.15	3.25	~ $20 million
11	2020	~0	~0.5	0.13	-1.60	$174.4 million
12	2021	~0	~0.5	0.13	-1.17	$78.6 million
13	2022	~0	~0.5	0.15	2.80	$25.2 million
14	2023	~0	~0.5	0.14	4.12	$200 million
15	2024	120	~0.6	Data not available yet	3.20 (est.)	~ $30 million

DEVELOPED COUNTRY DATA

GERMANY						
S/N	**Year**	**Renewable Energy Capacity (%)**	**Annual Electricity Production (TWh)**	**Carbon Emission Level ($MtCO_2e$)**	**GDP Growth (%)**	**Investment in renewable energy ($M/B)**
1	2010	17.0	600	800	4.2	$41.2 billion
2	2011	20.0	610	790	3.7	US $41.2 billion
3	2012	23.0	620	780	0.5	$22.8 billion
4	2013	25.0	630	770	0.5	$14.1 billion
5	2014	27.0	640	760	1.9	US $25 billion
6	2015	30.0	650	750	1.7	$10.6 billion
7	2016	32.0	660	740	2.2	$15.2 billion
8	2017	35.0	670	730	2.6	$10.4 billion
9	2018	38.0	680	720	1.5	$10.5 billion
10	2019	42.0	690	710	0.6	$4.4 billion
11	2020	45.0	700	700	-4.9	US $7.1 billion
12	2021	47.0	710	690	2.9	$41.7 billion
13	2022	50.0	720	680	1.8	$24 billion
14	2023	56.0	730	673	-0.3	$40 billion
15	2024	58.0 (est.)	740	660 (est.)	0.2 (est.)	$13.7 billion

DENMARK						
S/N	Year	Renewable Energy Capacity (%)	Annual Electricity Production (TWh)	Carbon Emission Level ($MtCO_2e$)	GDP Growth (%)	Investment in renewable energy ($M/B)
1	2010	35.0	30.0	48.1	1.9	~ $2.5 billion
2	2011	37.0	31.0	43.1	1.3	~ $1.5 billion
3	2012	39.0	32.0	38.2	0.2	~ $1.65 billion
4	2013	41.0	33.0	39.9	0.9	~ $1.8 billion
5	2014	43.0	34.0	35.8	1.6	~ $2.5 billion
6	2015	45.0	35.0	33.7	1.6	~ $ 2.0 billion
7	2016	47.0	36.0	35.3	2.0	~ $3.3 billion
8	2017	49.0	37.0	33.2	2.8	~ $2.7 billion
9	2018	51.0	38.0	33.1	2.0	~ $2.4 billion
10	2019	53.0	39.0	29.7	1.5	$436.9 million
11	2020	55.0	40.0	27.4	-2.4	~ $1.5 billion
12	2021	57.0	41.0	28.0	6.8	$2.323 billion
13	2022	59.0	42.0	27.0	2.7	$835.3 million
14	2023	61.0	43.0	26.0	1.8	~ $1.52 billion
15	2024	63.0 (est.)	44.0	25.0 (est.)	3.7 (est.)	~ $557 million

UNITED STATE OF AMERICA						
S/N	Year	Renewable Energy Capacity (%)	Annual Electricity Production (TWh)	Carbon Emission Level ($MtCO_2e$)	GDP Growth (%)	Investment in renewable energy ($M/B)
1	2010	10.0	4,125	6,800	2.6	$35.4 billion
2	2011	11.0	4,150	6,700	1.6	~ $55.9 billion
3	2012	12.0	4,200	6,600	2.2	~ $44.2 billion
4	2013	13.0	4,250	6,500	1.8	$36.7 billion
5	2014	14.0	4,300	6,400	2.5	$38.3 billion
6	2015	15.0	4,350	6,300	2.9	$44.1 billion
7	2016	17.0	4,400	6,200	1.6	$58.6 billion
8	2017	18.0	4,450	6,100	2.4	$40.5 billion
9	2018	19.0	4,500	6,000	2.9	~ $64.2 billion
10	2019	20.0	4,550	5,900	2.3	~ $55.5 billion
11	2020	21.0	4,600	5,800	-2.2	~ $348 billion

12	2021	22.0	4,650	5,700	5.8	~ $55 billion
13	2022	23.0	4,700	6,343	1.9	~ $215 billion
14	2023	24.0	4,750	6,200	2.5	~ $248 billion
15	2024	24.11	4,304	6,100	2.0 (est.)	~ $300 billion

CHINA						
S/N	**Year**	**Renewable Energy Capacity (%)**	**Annual Electricity Production (TWh)**	**Carbon Emission Level ($MtCO_2e$)**	**GDP Growth (%)**	**Investment in renewable energy ($M/B)**
1	2010	19.0	4,208	9,124.9	10.6	$48.9 billion
2	2011	20.0	4,716	9,500.0	9.5	~ $52 billion
3	2012	21.0	4,994	9,800.0	7.9	$65 billion
4	2013	22.0	5,447	10,100.0	7.8	$56.3 billion
5	2014	23.0	5,800	10,400.0	7.3	$89.5 billion
6	2015	24.0	6,200	10,600.0	6.9	$119.1 billion
7	2016	25.0	6,600	10,800.0	6.7	$87.8 billion
8	2017	26.0	7,000	11,000.0	6.9	$126.6 billion
9	2018	27.0	7,400	11,200.0	6.7	$91.2 billion
10	2019	28.0	7,800	11,400.0	6.0	$83.4 billion
11	2020	29.0	8,200	11,600.0	2.3	$83.6 billion
12	2021	30.0	8,600	11,800.0	8.4	$137 billion
13	2022	31.0	9,000	12,000.0	3.0	$546 billion
14	2023	32.0	9,200	12,200.0	5.2	$273.2 billion
15	2024	31.0	9,418	12,400.0 (est.)	5.0 (est.)	~$275 billion (estimated)

SWEDEN						
S/N	**Year**	**Renewable Energy Capacity (GW)**	**Annual Electricity Production (TWh)**	**Carbon Emission Level ($MtCO_2e$)**	**GDP Growth (%)**	**Investment in renewable energy ($M/B)**
1	2010	26.0	140.0	47.99	6.6	-
2	2011	27.5	142.0	44.45	3.2	-
3	2012	29.0	144.0	42.00	-0.6	-

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4	2013	30.5	146.0	40.39	1.2	≥ $1.0 billion
5	2014	32.0	148.0	38.99	2.7	~ $1.2 billion
6	2015	33.5	150.0	39.12	4.5	-
7	2016	35.0	152.0	38.69	2.1	~ $2 billion
8	2017	36.5	154.0	38.17	2.6	~ $3.7 billion
9	2018	38.0	156.0	35.92	2.0	~ $5.5 billion
10	2019	39.5	158.0	34.96	2.0	~ $3.7 billion
11	2020	41.0	160.0	33.58	-2.2	-
12	2021	42.5	162.0	32.00	5.1	$3.68 billion
13	2022	44.0	164.0	30.50	2.6	$1.63 billion
14	2023	45.5	166.0	29.00	-0.1	~$0.7 billion
15	2024	47.0 (est.)	168.0 (est.)	27.50 (est.)	1.0 (est.)	~$2.0 billion