United Nations Climate Change
Katowice Commitee on Impacts

Understanding the Implications of the Energy Transition on African Economies: Economy and Jobs

Table of Contents

Mandate description

This work is an output implemented in accordance with activity 12 of the workplan of the forum on the impact of the implementation of response measures and its Katowice Committee of Experts on the Impacts of the Implementation of Response Measures.[1]

Activity 12: Develop a case study in each of the five United Nations regions in accordance with activity 7 of the workplan

[1] This output is part of the activities arising from the outcomes of the midterm review of the workplan of the forum on the impact of the implementation of response measures and its Katowice Committee of Experts on the Impacts of the Implementation of Response Measures, contained in annex II of decisions 4/CP.25, 4/CP.15 and 4/CMA.2.

Abbreviations and Acronyms

A
ACF - African Climate Foundation

AfCFTA - African Continental Free Trade Agreement

C
CMA - Conference of Parties serving as the meeting of Parties to the Paris Agreement

COP - Conference of Parties

D
DRC - Democratic Republic of Congo

F
FTE - Full-Time Equivalent

G
GDP - Gross Domestic Product

GHG - Greenhouse Gas

I
IEA - International Energy Agency

IO - Input-Output

IRP - Integrated Resource Plan

J
JEDI - Jobs and Economic Development Impact

K
KCI - Katowice Committee of Experts on the Impacts of the Implementation of Response Measures

L
LCR - Local Content Requirement

N
NDC - Nationally Determined Contributions

NREL - National Renewable Energy Laboratory, now called the National Laboratory of the Rockies

O
O&M - Operations and Maintenance

P
PV - Photovoltaic

S
SAPP - Southern African Power Pool

SDG - Sustainable Development Goals

T
TWh - Terawatt Hours

U
UNECA - United Nations Economic Commission for Africa

UNFCCC - United Nations Framework Convention on Climate Change

USD - United States Dollar

W
WTO - World Trade Organization

WACC – Weighted Average Cost of Capital

Z
ZAR - South African Rand

Chapter 1: Introduction

1.1 Background and Motivation

The Conference of the Parties serving as the meeting of the Parties to the Paris Agreement established the KCI through decision 7/CMA.1 to assist the forum in implementing its work programme (UNFCCC, 2018). Building on this foundation, the Conference of the Parties at its twenty-eighth session adopted updated functions, work programme, and modalities for the forum and its KCI through decisions 13/CP.28, 4/CMP.18 and 19/CMA.5 (UNFCCC, 2023).

Annex 1, paragraph 1(a) of these decisions mandates the KCI to "provide a platform allowing Parties to share, in an interactive manner, information, experience, case studies, best practices and views, and to facilitate assessment and analysis of the impacts of the implementation of response measures, including the use and development of modelling tools and methodologies, with a view to recommending specific actions" (UNFCCC, 2023). This case study is further undertaken in fulfilment of activities identified following the midterm review, where the KCI is mandated to develop case studies in all five of the UN regions before the sixty-third sessions of the subsidiary bodies (UNFCCC, 2023).

1.2 African Context and Development Imperatives

The Paris Agreement serves as a key instrument driving the transition to low greenhouse gas emissions and climate-resilient development pathways globally (UNFCCC, 2015). For African countries, this transition presents both opportunities and challenges that must be carefully analysed to ensure just and equitable outcomes, particularly regarding measures African countries must take, and measures taken by other countries that impact African economies.

As of 2023, 54 African countries have submitted NDCs, with 40 including quantified targets for emission reductions or avoided emissions (UNFCCC, 2023). However, the comprehensive socioeconomic implications of these transition commitments on African economies remain inadequately understood, particularly regarding employment generation, GDP impacts and the role of LCRs in maximizing domestic benefits. This case study not only provides information on such dynamics for African countries, but also showcases a tool that could inform policy decisions for reducing greenhouse gas emissions.

The analysis builds upon previous research by the United Nations Economic Commission for Africa (UNECA), the African Climate Foundation (ACF), and 4SightEngage, which examined the implications of the energy transition on African economies from multiple perspectives including trade, economic development, employment creation, emission reductions and finance mobilization (Ngwadla et al., 2024). This case study extends this work by providing detailed quantitative analysis of specific energy technologies contained in selected African country's NDCs or their Integrated Resource Plans, and their potential for local value creation, with some key policy considerations.

The imperative for this research stems from Africa's unique development context. The continent lags significantly in key development metrics, including GDP per capita, faces substantial unemployment challenges, particularly among youth, and has limited manufacturing capacity owing to colonial legacy and structural impediments within the global economic architecture that confine African economies primarily to raw material export roles (African Development Bank, 2022). Additionally, limited access to modern electricity services, crucial for industrial development and broader socioeconomic advancement, constrains progress towards achieving the Sustainable Development Goals.

Chapter 2: Approach to the Study

2.1 Economic and Energy Context

Africa's electricity demand is projected to increase by approximately 75%, from 680 TWh in 2020 to 1,180 TWh by 2030, driven by population growth and economic development aspirations (IEA, 2022). This growing domestic energy demand presents an opportunity to transition away from the excessive exportation of raw materials and importation of value-added products and to build domestic capacity and employment through strategic energy sector investments. Africa, as an integral part of the global economy, must carefully assess both the opportunities and constraints associated with the energy transition. A comprehensive understanding of these dynamics is essential for informed decision-making and benefiting from sustainable development.

The imperative for a just energy transition in Africa must be understood within the context of historical responsibility and contemporary global inequities. It is important for the international community to recognize the historical and structural factors within the global economic system that have influenced African economic development and contributed to the continent's focus on primary commodity exports. Given Africa's minimal contribution to historical greenhouse gas emissions while bearing disproportionate climate impacts, the energy transition should not impose additional costs on African countries but rather represent an opportunity for supported development and economic transformation.

African NDCs are predominantly focused on avoided emissions rather than absolute reductions from current levels, reflecting the continent's low historical contribution to global emissions while highlighting the potential for substantial socioeconomic co-benefits that can be enabled through appropriate global climate policy support and international cooperation (Climate Action Tracker, 2023). This approach recognizes that Africa's development trajectory should not be constrained by emission limitations designed for countries with vastly different development histories and socioeconomic profiles.

2.2 Country Selection and Representativeness

Five African countries[2] were selected to ensure representation of predominant energy technologies and the former comprehensively demonstrate renewable energy potential across the continent. The technologies modelled for each country are shown in **table 1**, including the policies based on which the analysis was undertaken. With the exception of Botswana, for which the analysis is based on the country's 2021 IRP, the analysis for the countries is based on their NDC with a 2030 target.

Table 1: Technologies Modelled for Each Country

	Botswana	DRC	Eswatini	Ghana
Utility- Scale Solar PV	X	X	X	X
Distributed Solar PV				X
Wind	X	X		X
Hydropower		X	X	X
Natural Gas	X			
Bioenergy			X	X
Coal	X			
Geothermal		X		
Policy	IRP of 2021	NDC by 2030	NDC by 2030	NDC by 2030

Botswana: This upper-middle-income country with a population of approximately 2.5 million and a GDP per capita of $7,695 (2024) (World Bank, 2024a) represents mineral-dependent African economies. The economy is heavily reliant on diamond mining, which accounts for over 90% of exports, while agriculture contributes less than 2% to GDP (World Bank, 2024a). Botswana's energy mix is characterized by 48% domestic electricity generation, primarily from coal-fired power plants, with 52% imported from the Southern African Power Pool, resulting in an overall electricity access rate of 60% nationally (77% of urban population and 37% of rural population) (Africa Energy Portal, 2024). The country aims to generate 15% of its energy from renewable resources by 2030, presenting opportunities for coal-to-renewable transition pathways.

DRC: As one of Africa's largest countries by land area with a population of approximately 108 million and a GDP per capita of $731 (World Bank,2024b), the DRC represents mineral-rich African economies with critical transition minerals including copper, cobalt and lithium (World Bank, 2024b; African Development Bank, 2024). Despite the country possessing an estimated 100,000 MW of hydroelectric potential, only 19% of the population has access to electricity (41% in urban areas and 1% in rural areas), with 96% of current generation from hydropower primarily via the Inga I and II dams (United States Department of Commerce, 2024). The economy is dominated by mining and agriculture, with significant potential for

[2] Equatorial Guinea, albeit part of the initial analysis, is not part of the final analysis owing to data and scale limitations.

large-scale renewable energy development to support both domestic electrification and regional power exportation.

Eswatini: This small, landlocked kingdom with a population of 1.2 million and a GDP per capita of $4,089 (2024) represents smaller African economies with mixed agricultural and manufacturing bases (World Bank, 2024c). Services account for over 50% of GDP, while manufacturing contributes approximately 38%, with agriculture providing livelihoods for most of the rural population. The country has achieved 86% electricity access but imports up to 90% of its electricity from South Africa, highlighting energy security vulnerabilities (World Bank, 2024c). Eswatini's energy profile offers insights into biomass utilization, energy import dependence and opportunities for small-scale renewable deployment.

Ghana: As West Africa's second-largest economy with a population of 34.4 million and a GDP per capita of $2,406 (2024), Ghana represents more diversified middle-income African countries (World Bank, 2024d). The economy shows balanced contributions from services, industry and agriculture, with ongoing industrialization efforts. Ghana's energy mix comprises 69% conventional sources (primarily natural gas), 29% hydropower and 2% other renewables, with an 84% electricity access rate (Energy Commission of Ghana, 2023; IEA, 2024). The country has a renewable energy target of 10% by 2030 and demonstrates a more complex energy transition pathway involving gas as a transition fuel, renewable integration and regional power trade.

2.3 Scenario Development and LCRs

This study applies the JEDI model to reflect LCR scenarios where assumptions are made on local project spending, which are adjusted to reflect the portion of total spending that is captured locally in electricity generation investments. The parameters considered in the localization include costs, expenditures, financing parameters and local shares of spending. The analysis considers two primary LCR scenarios:

1. **Base Case (30% LCR):** Assumes moderate LCRs reflecting current typical implementation levels across African energy projects;
2. **Enhanced Scenario (60% LCR):** Simulates ambitious but achievable local content targets for most technologies, with specific adaptations for hydropower and geothermal projects reflecting their unique supply chain characteristics.

Energy technology deployment projections are based on targets specified in national energy plans and NDC commitments, ensuring policy relevance and realistic scale assumptions. For each scenario, for which the impacts from the modelling outputs are presented, it is important to note that the impacts are 'potential' rather than 'realized' owing to the dynamic nature of the real-world economy and the countries' ability to realize the LCRs. The lifespan of the various technologies is important for interpreting O&M impacts, with the typical lifespan durations presented in **table 2**.

Table 2: Typical Lifespan of Different Energy Technologies

Technology	Typical Lifespan	Notes
Hydropower	65–100 years	Longest-lived technology: civil infrastructure can last indefinitely with maintenance
Coal	50 years (historical)	May be reduced to 20–35 years under climate constraints
Natural Gas	30–40+ years	Well-maintained plants can exceed 40 years
Solar PV	30 years	Standard design life
Wind	25 years	Turbine design life
Bioenergy	20–30 years	Varies by technology and feedstock

Chapter 3: Methodology

3.1 The JEDI Modelling Framework

The analysis employs the JEDI model developed by NREL[3]. According to Goldberg and Milligan (2004), the JEDI model is a user-friendly tool that evaluates the economic impacts of constructing and operating power generation facilities. The model can analyse impacts across multiple energy technologies, including wind, solar PV, biofuels, concentrating solar power, geothermal, marine and hydrokinetic power, coal and natural gas.

The JEDI model operates as an IO model based on simultaneous equations measuring sectoral linkages within an economy, producing the Leontief inverse matrix that captures economic multiplier effects (Allan et al., 2020). The model utilizes national and regional economic IO data to provide a comprehensive view of economic transactions within a defined geographical area over a specified time frame, typically one year.

The JEDI model generates cumulative outputs across four primary dimensions: employment (jobs), earnings (wages and salaries), economic output (value of production) and GDP impacts. These are disaggregated across three impact categories as shown in **table 3**Table 3.

Table 3: Model Outputs

Construction				Operations			
Direct jobs	Direct earnings	Direct economic output	Direct GDP	Direct jobs	Direct earnings	Direct economic output	Direct GDP
Indirect jobs	Indirect earnings	Indirect economic output	Indirect GDP	Indirect jobs	Indirect earnings	Indirect economic output	Indirect GDP

[3] See NREL web page on the JEDI Model https://www.nrel.gov/analysis/jedi/ now reffered to as the National Laboratory of the Rockies

Induced Jobs	Induced earnings	Induced economic output	Induced GDP	Induced Jobs	Induced earnings	Induced economic output	Induced GDP
Total one-off contribution				**Annual ongoing contribution**			

The model outputs include **direct impacts** (employment and economic activity directly associated with project construction and operation), **indirect impacts** (economic activity in supporting industries and supply chains) and **induced impacts** (economic activity generated through spending wages earned from direct and indirect employment). Additionally, impacts are separated into the **construction phase** (typically 1–3 years) and the **operations and maintenance phase** (spanning the project lifetime of 20–30 years), providing insights into short-term economic stimuli and long-term sustainable employment creation.

3.2 Model Application and Validation

Since its launch in 2004, the JEDI model has been deployed by numerous scholars to quantify the impact of renewable energy deployment on employment and the economy (Barbose et al., 2016; Brown et al., 2020; Faturay et al., 2020; Füllemann et al., 2019; Jacobson et al., 2020; Jenniches, 2018; Milani et al., 2020; Woo et al., 2020), establishing its credibility as a robust analytical tool for assessing the impact of the energy transition.

The model has been implemented across a range of countries, including those classified as least developed, developing and developed (Loomis et al., 2016; Semelane et al., 2021a). This wide application underscores the model's suitability for diverse contexts, such as those found in Africa (Loomis et al., 2016; Semelane et al., 2021). Notably, the JEDI model has been employed to evaluate the economic impacts of electricity investments in countries such as the United States of America, the Republic of Korea, India and South Africa's renewable energy procurement, illustrating that renewable initiatives have the potential to match the direct and indirect jobs provided by the coal sector, while also advancing local content development (Kumar, 2015; Loomis et al., 2016; Semelane et al., 2021; Woo et al., 2020).

3.3 Model Limitations

As with all IO models, the JEDI model has several inherent limitations that must be acknowledged. The model assumes static relationships between economic sectors despite ongoing technological advancement and changing demand patterns (Miller and Blair, 2009). It also assumes fixed production technologies where doubling production requires doubling inputs and operates on demand-driven assumptions that may not fully account for supply constraints such as skilled labour shortages (Lenzen, 2001).

Data limitations present additional challenges, as IO data collection is labour-intensive and expensive, with model monetary parameters potentially influenced by price changes affecting temporal and cross-country comparisons. The model assumes consumption patterns are not subject to budget constraints- an assumption that may not reflect real-world conditions (NREL, 2020).

Importantly, the JEDI model results represent gross rather than net economic impacts, and do not account for potential displacement effects in other sectors. The model also cannot capture various real-world economic dynamics such as automation in component manufacturing through artificial intelligence and robotics, nor does it account for exchange rate volatility or electricity cost fluctuations over project lifetimes.

Beyond individual technology assessments, the analysis conducts comparative impact evaluation across different energy technologies to inform strategic policy decisions. This comparative approach examines the relative employment generation potential, economic multiplier effects and local value creation capabilities of solar PV, wind, hydropower, geothermal and natural gas technologies under varying local content scenarios. Such cross-technology comparison enables policymakers to identify which energy pathways offer optimal socioeconomic benefits for specific country contexts and development priorities. The quantification of impact on employment follows established methodologies normalizing jobs created by calculating the ratio of jobs to technology installed capacity, providing standardized metrics for cross-technology and cross-country comparison (Aldieri et al., 2020).

Detailed assumptions for the analysis, including technology-specific parameters, cost structures and local content potential assessments, are provided in **annex A**, and the analysis results in **annexes B-E**. Following the initial impact analysis submitted to KCI - 13, an additional modelling study analysing the Weighted Average Costs of Capital (WACC) for the selected African countries was undertaken to mitigate monetary parameters limitation of the model, and is attached as **annex F**.

Chapter 4: Study Results

This chapter presents the JEDI model results for employment generation potential and GDP contributions to demonstrate broader economic impacts across the four selected African countries under different Local Content Requirementss (LCR) scenarios. The analysis examines the impacts on employment and GDP of various energy technologies during both the construction phase and Operation and Maintanance (O&M) phase, providing insights into jobs generated per technology and the quality of the jobs where the earnings are used as a proxy for job quality. The analysis further examines the economic contributions of various energy technologies during both the construction phase and O&M phase, providing insights into economic multiplier effects, value-addition potential and macroeconomic implications for sustainable development.

4.1 Botswana

I. Jobs Analysis

Botswana's labour market context provides important background for interpreting the impact of the energy technologies on employment. According to the World Bank (2024a), the country has a labor force participation rate of 73.8% and an unemployment rate of 19.1% among adults aged 25 or over. These figures indicate considerable employment challenges that could be alleviated through investments in the energy transition. As a mining-based economy, the nation possesses substantial potential for such a transition. The envisaged energy mix as contained in the country's IRP 2021 is attached as **annex B 1**,Error! Reference source not found. and the results of the analysis are presented inError! Reference source not found., with the analysis based on the implementation of the IRP.

The normalized figures per MW for Botswana are presented in **table 4** to enable the results to be compared across the technologies irrespective of the size of the planned construction work contained in the IRP.

Table 4: Normalized Metrics per MW

Botswana - 30% Local Content				
	PVu	Wind	Coal	Gas
MW	1 300	200	1 500	60
FTE- Construction	17 694	3 369	7 715	3 359
FTE/MW - Construction	14	17	5	56
FTE/Year - O&M	531	242	242	24
FTE/MW/Year - O&M	0	1	0	0
Earnings - Construction	97 688 997	1 020 087 000	273 772 720	569 494 477
Earnings - $/MW - Construction	75 145	5 100 435	182 515	9 491 575
Earnings - O&M	5 558 050	78 650 066	78 650 066	15 730 013
Earnings - $/MW - O&M	4 275	393 250	52 433	262 167

Utility-Scale Solar PV: The IRP provides for utility-scale solar PV of 1,300 MW by 2030. In the 30% LCR scenario, the construction phase has the potential to create a total of 17,694 FTEs, of which 6,885 are direct jobs generating $97.7 million in earnings, whereas in the 60% LCR scenario, it has the potential to create a total of 29,066 FTEs, of which 10,750 are direct jobs generating $1.8 billion. The O&M phase at a 30% LCR, however, has the potential to create 531 FTEs annually, of which 98 are direct jobs generating $5.6 million in annual earnings.

Coal-Fired Power: The IRP provides for the retirement of one coal-fired power station and investment in a new 1,500 MW coal-fired power plant by 2030. In the 30% LCR scenario, the construction phase has the potential to create a total of 7,715 FTEs, of which 2,391 are direct jobs generating $273.8 million in earnings, whereas in the 60% LCR scenario, it has the potential to create a total of 9,731 FTEs, of which 3,026 are direct jobs generating $337.6 million in earnings. The O&M phase at a 30% LCR, however, has the potential to create 242 FTEs annually, of which 74 are direct jobs generating $24 million in annual earnings.

Natural Gas: The IRP provides for the installation of 60 MW of utility-scale natural gas facilities between 2025 and 2030. In the 30% LCR scenario, the construction phase has the potential to create a total of 3,359 FTEs, of which 182 are direct jobs generating $160 million in earnings, whereas in the 60% LCR scenario, it has the potential to create a total of 3,975 FTEs, of which 237 are direct jobs generating $200 million in earnings. The O&M phase at a 30% LCR, however, has the potential to create 24 FTEs annually, of which 3 are direct jobs generating $4.8 million in annual earnings.

Wind Power: The IRP provides for the installation of 200 MW of wind power over a four-year period from 2027 to 2030. In the 30% LCR scenario, the construction phase has the potential to create a total of 3,369 FTEs, of which 1,017 are direct jobs generating $274 million in earnings. Whereas in the 60% LCR scenario, it has the potential to create a total of 4,453 FTEs, of which 1,369 are direct jobs generating $379 million in earnings. The O&M phase at a 30% LCR, however, has the potential to create 242 FTEs annually, of which 74 are direct jobs generating $24 million in annual earnings.

Key Findings for Botswana: Utility-scale solar PV has the potential to create the highest number of construction jobs per MW, but with the lowest earnings per MW, indicative of lower job quality. Natural gas and wind technologies show superior earnings potential, suggesting higher-skilled employment opportunities that warrant focused policy attention on technical capacity development and technology transfer, particularly for O&M phases.

Utility-scale solar PV leads the way in job creation in absolute terms during the construction phase, creating a total of 17,694 jobs at a 30% LCR, followed by coal at 7,715. However, when normalized per MW, natural gas has the potential for most jobs at 56FTE/MW with wind doing marginaly better than utility-scale solar PV at 17 FTE/MW and 14 FTE/MW. Coal perfoms the worst at 5 FTE/MW. Despite smaller deployment scales, natural gas show the highest per-MW employment generation rates.

A critical divergence emerges in job quality metrics. While PVu creates the highest number of construction jobs, it only generates $222,159 in earnings per MW, which is significantly lower than natural gas at $9.5 million and wind power at $5.1 million. This disparity suggests that utility-scale solar PV creates lower-skilled, lower-wage positions, whereas natural gas and wind power create higher-value employment opportunities.

The O&M phase reveals wind power as the superior long-term employer, generating 1FTE per MW annually compared with all other technologies with a neglible contribution per MW. Wind power also provides the highest annual earnings per MW ($393,250), followed by natural gas ($262,167) with utility-scale solar PV providing the lowest earnings per MW. This suggests that for Botswana’s transition from dependency on coal, utility-scale solar PV could serve as an effective technology in providing immediate employment benefits, whilst wind and natural gas provide sustained long-term job creation and earnings.

Given Botswana's mining-dependent economy and high unemployment rates, the results suggest a diversified approach combining utility-scale solar PV for immediate large-scale job creation during construction, natural gas for sustained high-quality employment and wind for balanced medium-term benefits.

II. GDP Analysis

Botswana's economic baseline provides important context for interpreting the impact of the energy technologies on GDP. With a total GDP of $19.4 billion and GDP per capita of $7,695, the country represents an upper-middle-income economy with significant potential for benefitting from the diversification of the energy sector. The country's major export earnings are from diamonds, constituting over 90% (World Bank, 2024a).

Utility-Scale Solar PV: During the construction phase, the planned installation of 1,300 MW of utility-scale solar PV by 2030 has the potential to contribute a total of $1.6 billion to GDP in the 30% LCR scenario and a total of $29.9 billion to GDP in the 60% LCR scenario. During the O&M phase, there is the potential to add $33.4 million to GDP annually at a 30% LCR. In the 30% LCR scenario, the potential total local value added to GDP during the construction phase is $551 million, while the O&M phase has the potential to create $11.3 million of local value added annually in the same scenario.

Coal-Fired Power: During the construction phase, the planned investment in a 1,500 MW coal-fired power plant by 2030 has the potential to contribute a total of $5.8 billion to GDP in the 30% LCR scenario and a total of $7.2 billion to GDP in the 60% LCR scenario. During the O&M phase, there is the potential to add $446.1 million to GDP annually at a 30% LCR. In the 30% LCR scenario, the potential total local value added during the construction phase is almost $478.1 million, while the O&M phase has the potential to create $157.4 million of local value added annually in the same scenario.

Natural Gas: During the construction phase, the planned investment in 60 MW of natural gas power generation has the potential to contribute a total of $3.2 billion to GDP in the 30% LCR scenario and a total of $4.0 billion to GDP in the 60% LCR scenario. During the O&M phase, there is the potential to add $89.2 million to GDP annually at a 30% LCR. In the 30% LCR scenario, the potential total local value added during the construction phase is $1.1 billion, while the O&M phase has the potential to create $31.5 million of local value added annually in the same scenario.

Wind Power: During the construction phase, the deployment of 200 MW of wind power planned for 2027 - 2030 has the potential to contribute a total of $5.8 billion to GDP in the 30% LCR scenario and a total of $7.7 billion to GDP in the 60% LCR scenario. During the O&M phase, there is the potential to add $446.1 million to GDP annually at a 30% LCR. In the 30% LCR scenario, the potential total local value added during the construction phase is almost $2 billion, while the O&M phase has the potential to create $157.4 million of local value added annually in the same scenario.

Key Findings for Botswana: In terms of the efficiency of the contributions to GDP during construction, gas is the dominant contributor to GDP, generating $53,3 million per MW at a 30% LCR followed by wind ($29.2 million per MW), coal ($3.9 million per MW) and last being PVu ($1.2 million per MW). The substantially higher contribution from natural gas reflects its capital-intensive nature and use of more complex technology. Natural gas demonstrate exceptional potential for local value addition during construction, generating $17.8 million in local value added per MW at 30% LCR, significantly higher than wind ($9.9 million per MW) coal ($1,3 million per MW), lastly PVu ($8,696 per MW). This suggests that natural gas followed by wind would be more effective at retaining economic benefits within the domestic economy, provided that LCRs are met.

The combined implementation of the IRP could contribute $16.4 billion (30% LCR) to almost $49 billion (60% LCR) to Botswana's GDP over the 10-year IRP build period from 2021 to 2030. At a 60% LCR, this represents approximately 250% the GDP of Botswana's GDP of $19.4 billion as of 2024 (World Bank, 2024a) during the construction phase and translates to an average 25% annual growth in GDP over a 10-year period. This would constitute a transformational economic impact, whilst providing necessary energy to support industrial development, as such further benefits for the economy.

A combination of natural gas and wind power could prove an essesntial energy mix where natural gas serves a strategic role in grid stability and industrial development, whilst utility-scale solar PV can deliver immediate impact on job creation.

4.2 Democratic Republic of the Congo

I. Jobs Analysis

With an 82.9% labour force participation rate and a 3.6% unemployment rate for adults aged 25 or over(WorldBank, 2024b), the DRC presents substantial opportunities for large-scale employment generation through the development of energy infrastructure. The huge potential of hydropower and other renewable energy technologies can unlock economic opportunities, not only in the DRC but across Africa. The country's 2021 NDC, which forms the basis of this analysis, is attached as Error! Reference source not found.**Error! Reference source not found.** and the results of the analysis are presented in**Error! Reference source not found.**. The normalized figures per MW for the DRC are presented in **table 5** to enable the results to be compared across the technologies irrespective of the size of the planned construction work.

Table 5: Normalized Metrics per MW

DRC 30% Local Content				
	PVu	Wind	Geo	Hydro
MW	10 000	10 000	18 900	1 000
FTE- Construction	697 117	256 677	218 832	23 949
FTE/MW - Construction	70	26	12	24
FTE/Year - O&M	4 922	17 480	167	515
FTE/MW/Year - O&M	0	2	0	1
Earnings - Construction	220 428 905 510	77 717 522 590	4 284 342 123	1 472 680 000
Earnings - $/MW - Construction	22 042 891	7 771 752	226 685	1 472 680
Earnings - O&M	2 021 376 783	5 608 731 611	4 049 124	32 940 000
Earnings - $/MW - O&M	202 138	560 873	214	32 940

Hydropower: The NDC provides for the installation of 1,000 MW of hydropower by 2030 despite there being a potential to install up to 100,000 MW. The construction phase has the potential to create a total of 23,949 FTEs, of which 14,668 are direct jobs generating $934 million in earnings. The O&M phase has the potential to create 515 FTEs annually, of which 116 are direct jobs generating almost $8.2 million in annual earnings. It is important to note that no LCR scenarios are applied for this technology.

Wind Power: The NDC envisages the addition of 10,000 MW of wind power by 2030. In the 30% LCR scenario, the construction phase has the potential to create a total of 256,677 FTEs, of which 77,446 are direct jobs generating $20.9 billion in earnings, whereas in the 60% LCR scenario, it has the potential to create a total of 339,294 FTEs, of which 104,331 are direct jobs generating $28.9 billion in earnings. The O&M phase in the 30% LCR scenario has the potential to create 17,480 FTEs, of which 5,378 are direct jobs generating $1.7 billion in annual earnings.

Utility-Scale Solar PV: The NDC provides for the installation of 10,000 MW of utility-scale solar PV by 2030. In the 30% LCR scenario, the construction phase has the potential to create a total of 697,117 FTEs, of which 210,429 are direct jobs generating $64.3 billion in earnings, whereas in the 60% LCR scenario, it has the potential to create a total of 823,550 FTEs, of which 252,463 are direct jobs generating $76.4 billion in earnings. The O&M phase at a 30% LCR has the potential to create 4,922 FTEs annually, of which 1,952 are direct jobs, generating $461.9 million in annual earnings.

Geothermal: The NDC provides for the installation of 18,900 MW of geothermal energy by 2030. The construction phase has the potential to create a total of 218,832 FTEs, of which 66,821 are direct jobs generating approximately $1.6 billion. The O&M phase has the potential to create 167 FTEs annually, of which 65 are direct jobs generating $2.1 million in earnings. It is important to note that no LCR scenarios are applied for this technology.

Key Findings for the DRC: The massive scale of planned technology deployment in the DRC creates unprecedented employment opportunities. While wind and hydropower show the highest job creation potential per MW during the construction phase, utility-scale solar PV delivers beter job opportunities by almost a factor of 3 at 70FTE/MW, and utility-scale PV superior job quality where the earnings per MW are more than $22.0 million/MW. Wind technology provides the greatest benefits in terms of earnings potential during the O&M

phase at $560,873/MW, while geothermal has the lowest contribution to long-term employment rates during the O&M phase despite having a significant impact on employment during the construction phase.

The analysis for the DRC demonstrates the transformative employment potential of the large-scale deployment of renewable energy. The addition of 10,000 MW of wind power generates a total of 256,677 construction jobs at a 30% LCR, while the installation of the same amount of utility-scale solar PV creates 697,117 construction jobs at a 30% LCR. The installation of 1,000 MW of hydropower and 18,900 MW of geothermal energy generates 23,949 and 218,832 construction jobs respectively. When normalized per MW, utility -scale solar PV leads with 70 jobs per MW whereas wind is comparable to hydropower at 26 and 24 construction jobs per MW respectively. Geothermal potential contributes the least at 12FTE/WM.

Significant disparities emerge in job quality metrics across the technologies. Utility-scale solar PV generates $22.0 million in earnings per MW during the construction phase, followed by wind at $7.8 million per MW, while hydropower generates only $1.5 million per MW and with geothermal energy having the lowest at $226,685 per MW. This substantial difference suggests that modern renewable technologies requires higher-skilled, and create better-compensated employment opportunities compared with traditional hydropower.

The O&M phase reveals wind power as the clear leader in terms of sustained employment generation, creating 2 jobs per MW annually with exceptional earnings potential of $560,873 per MW. Hydropower is the next best contributor to employment (1 jobs per MW) but generates weaker annual earnings at $32,940 per MW. Geothermal performs the weakest during the O&M phase, generating less than 1 job MW and the lowest earnings $214 per MW.

There is a huge potential for generating renewable energy in the DRC, which could create employment opportunities that substantially impact national unemployment levels. The modelling results suggest that a diversified approach combining the large-scale deployment of wind and utility-scale solar could create more than a million construction jobs and hundreds of thousands of permanent O&M positions.

Given the development needs in the DRC and the huge potential of renewables in the country, the results of the analysis support prioritizing wind and utility-scale solar PV for large-scale deployment, supplemented by the strategic development of hydropower. While geothermal offers immediate employment during the construction phase comparable to wind power, wind and utility-scale solar PV provide superior long-term job quality and earnings potential. The country’s abundant critical mineral resources backed by reliable energy supplies could further open up opportuntiies for renewable energy technology manufacturing, which could further enhance GDP contribution and employment multiplier effects across the technology value chain.

II. GDP Analysis

With a total GDP of $70.75 billion and GDP per capita of only $647, the DRC is a low-income country where the large-scale development of the energy infrastructure has a huge potential to transform the economy. The country is well endowed in critical minerals such as cobalt and copper, with a huge potential for hydropower (Worlbank, 2024b)

Hydropower: The addition of 1,000 MW of hydropower between 2021 and 2030 provided for by the NDC has the potential to contribute a total of aboutt $3.4 billion to GDP during the construction phase and almost $91 million to GDP annually during the O&M phase. The construction phase has the potential to create $2.1 billion of local value added, while the O&M phase has the potential to create $53.4 million of local value added annually. It is important to note that no LCR scenarios are applied for this technology.

Wind Power: During the construction phase, the addition of 10,000 MW of wind power by 20230 provided for by the NDC has the potential to contribute a total of $444.7 billion to GDP in the 30% LCR scenario and a total of $586.7 billion to GDP in the 60% LCR scenario. During the O&M phase, there is the potential to add $31.8 billion to GDP annually at a 30% LCR. In the 30% LCR scenario, the potential total local value added during the construction phase is $150.1 billion, while the O&M phase has the potential to create $11.0 billion of local value added annually in the same LCR scenario.

Utility-Scale Solar PV: During the construction phase, the installation of 10,000 MW of utility-scale solar PV by 2030 provided for by the NDC has the potential to contribute a total of $1.3 trillion to GDP in the 30% LCR scenario and a total of $1.5 trillion to GDP in the 60% LCR scenario. During the O&M phase, there is the potential to add $12.1 billion to GDP annually at a 30% LCR. In the 30% LCR scenario, the potential total local value added during the construction phase is almost $458.9 billion, while the O&M phase has the potential to create $4.1 billion of local value added annually in the same LCR scenario.

Key findings for the DRC: Utility-scale solar PV demonstrates superior efficiency in terms of its contribution to GDP during construction, generating $127.0 million per MW at a 30% LCR, compared wind energy ($44.5 million per MW) and hydropower ($3.4 million per MW) and lastly geothermal at $1.2 million per MW. The huge scale of the deployment scenarios creates unprecedented economic opportunities, with utility-scale solar PV contributing about $1.3 trillion to GDP in the DRC during the construction phase at 30% LCR, whereas the next best perfomer in wind enery at $444.7 billion. with both amounts exceeding 40% of the country's GDP of $70.75 billion as of 2024 (World Bank, 2024b).

Utility-scale solar PV generates the highest local value added at 30% LCR during construction ($45.9 million per MW), substantially exceeding the next best, wind energy ($15.0 million per MW). Hydropower and geothermal have the potential of $2.1 million and $473,499 respectively. This indicates that modern renewable technologies effectiveness - subject to local content requirements - at creating domestic economic value than traditional, large-scale hydropower facilities, despite hydropower's historically dominant role in energy planning by the DRC.

The O&M phase reveals wind power's exceptional potential long-term economic contribution, contributing $3.2 million per MW to GDP annually compared to the $1.2 million per MW generated by utility-scale solar PV, and the minimal $90,960 per MW generated by hydropower and $1,718 from geothermal. Wind power's superior contribution during the O&M phase suggests that it provides more sustainable long-term economic benefits for national development.

The overall implementation of the NDC could contribute $1.7 trillion per annum (30% LCR) to $2.1 trillion (60% LCR) to GDP in the DRC during the construction period, representing almost 2,500% of the country's GDP of $70.75 billion as of 2024 (World Bank, 2024b) and translating to an average 250% annual GDP growth. This represents a revolutionary economic development potential that could fundamentally alter the economic trajectory and development status of the DRC. Questions can hpwever be raised on the feasibility of deployment at the level of scale in the DRC's NDC.

The results of the analysis strongly support prioritizing the large-scale deployment of wind power and utility-scale solar PV over traditional hydropower for economic development purposes. While hydropower offers lower-cost electricity generation, wind power and utility-scale solar PV provide superior economic multiplier effects, local value creation and sustained operational benefits that align better with broader development objectives and poverty reduction goals.

4.3 Eswatini

I. Jobs Analysis

Eswatini's challenging labour market conditions, with a labour force participation rate of 62.5% and an unemployment rate of 35.8% for adults aged 25 or over, highlights the critical importance of generating employment from energy investments (World Bank, 2024c). With the country highly dependent on energy imports, it is imperative that the energy transition go hand in hand with achieving energy sovereignty. The country's NDC, which forms the basis of this analysis, is attached as **annex D 1** and the results of the analysis are presented in **annex D 2**.

The normalized figures per MW for Eswatini are presented in **table 6** to enable the results to be compared across the technologies irrespective of the size of the planned construction work.

Table 6: Normalized Metrics per MW

eSwatini - 30% Local Content			
	PVu	Bio - Ut	Hydro
MW	56	95	80
FTE- Construction	909	6 194	3 128
FTE/MW - Construction	16	65	39
FTE/Year - O&M	324	161	41
FTE/MW/Year - O&M	6	2	1
Earnings - Construction	274 869 968	1 981 341 957	195 000 000
Earnings - $/MW - Construction	4 908 392	20 856 231	2 437 500
Earnings - O&M	11 289 389	59 038 072	3 000 000
Earnings - $/MW - O&M	201 596	621 453	37 500

Utility-Scale Solar PV: The NDC provides for the installation of 56 MW of utility-scale solar PV by 2030. In the 30% LCR scenario, the construction phase has the potential to create a total of 909 FTEs, of which 338 are direct jobs generating $90.2 million in earnings, whereas in the 60% LCR scenario, the potential is for a total of 1,408 FTEs, of which 507 are direct jobs generating $138.7 million in earnings. The O&M at a 30% LCR scenario has the potential to create 324 FTEs annually, of which 11 are direct jobs generating $2.6 million in annual earnings.

Utility-Scale Bioenergy: The NDC envisages the installation of 95 MW of utility-scale bioenergy by 2030. In the 30% LCR scenario, the construction phase has the potential to create a total of 6,194 FTEs, of which 2,340 are direct jobs generating $701.1 million in earnings, whereas in the 60% LCR scenario, it has the potential to create a total of 7,685 FTEs, of which 2,994 are direct jobs generating $888.4 million in earnings. The O&M phase at a 30% LCR has the potential to create 161 FTEs annually, of which 42 are direct jobs generating $19.8 million in annual earnings.

Hydropower: The NDC further provides for the installation of 80 MW of hydropower by 2030, for which the construction phase has the potential to create a total of 3,128 FTEs, of which 1,189 are direct jobs generating $76 million in earnings. The O&M phase has the potential to create 41 FTEs annually, of which 22 are direct jobs generating $1 million in annual earnings. It is important to note that no LCR scenarios are applied for this technology.

Key Findings for Eswatini: Utility-scale bioenergy emerges as the optimal technology for Eswatini, showing the highest potential in terms of both the creation of construction jobs and the generation of earnings, particularly during the long-term O&M phase. The technology's integration with the existing sugar cane industry would provide a sustainable supply of feedstock and industrial links that enhance overall economic benefits.

Despite Eswatini's small-scale deployment scenarios, significant differences emerge between the various technologies. The planned installation of 95 MW of bioenergy creates 6,194 construction jobs (65 jobs per MW), substantially exceeding the values for the 80 MW of hydropower at 3,128 jobs (39 jobs per MW) and the 56 MW of utility-scale solar PV at 1,640 jobs (16 jobs per MW). Bioenergy's leading position is a reflection of its labour-intensive construction requirements and integration with agricultural processing infrastructure.

Bioenergy demonstrates superior earnings potential during the construction phase, generating $20.9 million per MW compared with the $4.9 million per MW generated by PVu and the $2.4 million per MW generated from hydropower PV. This dramatic difference in earnings per MW suggests that bioenergy creates significantly higher-value employment opportunities, therefore more specialised skills for the integration of the energy - agriculture systems.

The O&M phase reveals utility-scale solar PV exceptional performance in creating sustained employment opportunities. PVu generates approximately 6 jobs per MW annually with earnings of $201,596 per MW, compared with 2 jobs per MW at $621,453 per MW generated by bioenergy and 1 job per MW generated by hydropower with earnings of $37,500 per MW/annum.

Bioenergy's integration with Eswatini's established sugar cane industry creates unique opportunity in terms of existing agricultural infrastructure, processing capabilities and farmer networks. This synergy enables the achievement of higher LCRs and reduces technology risk compared with other technologies.

Given Eswatini's high unemployment rate (35.8%) and small economy, bioenergy emerges as the optimal technology for maximizing employment impact per dollar invested. The technology's ability to provide both immediate construction jobs and sustained O&M jobs makes it particularly suitable for addressing structural unemployment challenges. The integration with existing areas of the agriculture sector also supports broader rural development objectives and economic diversification beyond the energy sector.

II. GDP Analysis

With a total GDP of $4.89 billion and GDP per capita of $3,936, Eswatini represents a small middle-income economy where energy investments can generate proportionally significant economic impacts within a manageable scale. The economy is dominated by services, with industry, particulalrly manufacturing contributing a third of the output (World Bank, 2024c).

Utility-Scale Solar PV: During the construction phase, the installation of 56 MW of utility-scale solar PV by 2030 envisaged by the NDC has the potential to contribute a total of $1.5 billion to GDP in the 30% LCR scenario and a total of $2.4 billion to GDP in the 60% LCR scenario. During the O&M phase, there is the potential to add $67.8 million to GDP annually at a 30% LCR. In the 30% LCR scenario, the potential total local value added during the construction phase is $534.6 million, while the O&M phase has the potential to create almost $23 million of local value added annually in the same scenario.

Hydropower: The addition of 80 MW of hydropower by 2030 provided for in the NDC has the potential to contribute a total of $274 million to GDP during the construction phase and to contribute $7 million to GDP annually during the O&M phase. The potential total local value added during the construction phase is $167 million, while the O&M phase has the potential to create $4 million of local value added annually. It is important to note that no LCR scenarios are applied for this technology.

Utility-Scale Bioenergy: During the construction phase, the addition of 95 MW of utility-scale bioenergy by 2030 provided for in the NDC has the potential to contribute a total of $11.9 billion to GDP in the 30% LCR scenario and a total of $14.6 billion to GDP in the 60% LCR scenario. During the O&M phase, there is the potential to add $348.6 million to GDP annually at a 30% LCR scenario. In the 30% LCR scenario, the potential total local value added during the construction phase is $5.1 billion, while the O&M phase has the potential to create $141.4 million of local value added annually in the same scenario.

Key Findings for Eswatini: Utility-scale bioenergy demonstrates exceptional efficiency in terms of its contribution to GDP during the construction phase, generating $125.2 million per MW at a 30% LCR, substantially exceeding utility-scale solar PV ($27.0 million per MW) and hydropower ($3.4 million per MW). This dramatic difference reflects bioenergy's labour-intensive nature, agricultural integration requirements and higher local economic multiplier effects through feedstock supply chains.

Bioenergy leads the way significantly in terms of local value added per MW during the construction phase ($53.7 million/MW) compared with utility-scale solar PV ($9.5 million/MW) and hydropower ($2.1 million/MW). This superior performance indicates bioenergy's effectiveness at retaining economic benefits within the domestic economy through integrated agricultural–energy value chains and local processing requirements.

The O&M phase reveals bioenergy's exceptional performance in making a sustained economic contribution of $141.4 million to GDP annually, compared with almost $23 million per annum, and the modest $4,0 million contributed by hydropower. Bioenergy's superior contribution to the economy during the O&M phase reflects its requirements for continuous feedstock processing, equipment maintenance and coordination with the agricultural sector.

The overall implementation of Eswatini's NDC could contribute $13.7 billion (30% LCR) to $17.3 billion (60% LCR) to GDP over the period going to 2030. At a 60% LCR, this represents approximately 350% of the country's GDP of 4.89 billion as of 2024 (World Bank, 2024c) during the construction phase, translating to 35% annual growth in GDP. This equates to a significant but manageable economic boost for sustainable development.

Given Eswatini's small-scale economy and existing agricultural infrastructure, bioenergy clearly emerges as the optimal technology for maximizing economic impact per dollar invested. The technology's integration with sugar cane production creates synergistic benefits that enhance the performance of both the energy and agriculture sectors while generating superior economic multiplier effects compared with stand-alone renewable energy projects.

4.4 Ghana

I. Jobs Analysis

Ghana's strong labour market fundamentals, with a labour force participation rate of 80.5% and an unemployment rate of only 2.6% for adults aged 25 or over, provide a favourable context for employment absorption by the energy sector World Bank, 2024d). Noting that the JEDI model presents potential rather than realizable impacts, the human capital could therefore put the country in a better position to realize this potential. The country's NDC, which forms the basis of this analysis, is attached as Error! Reference source not found. **annex E 1** and the results of the analysis are presented in **annex E 2**Error! Reference source not found..

The normalized figures per MW for Ghana are presented in **table 5** to enable the results to be compared across the technologies irrespective of the size of the planned construction work.

Table 5: Normalized Metrics per MW

Ghana - 30% Local Content					
	PVu	PVd	Wind	Bio - Ut	Hydro
MW	448	294	327	122	200
FTE- Construction	11 483	2 536	13 038	7 954	23 949
FTE/MW - Construction	26	9	40	65	120
FTE/Year - O&M	506	138	855	419	515
FTE/MW/Year - O&M	1	0	3	3	3
Earnings - Construction	2 190 333 194	254 004 034	3 947 583 842	2 544 460 197	1 472 680 000
Earnings - $/MW - Construction	4 889 137	863 959	12 072 122	20 856 231	7 363 400
Earnings - O&M	55 918 130	40 427 536	271 644 656	152 669 227	32 940 000
Earnings - $/MW - O&M	124 817	137 509	830 718	1 251 387	164 700

Utility-Scale Solar PV: The NDC provides for the installation of 448 MW of utility-scale solar PV by 2030. At the 30% LCR scenario, the construction phase has the potential to create a total of 11,483 FTEs, of which 3,884 are direct jobs generating $680million in earnings. In the 60% LCR scenario, the construction phase has the potential to create a total of 15,776 FTEs, of which 5,344 are direct jobs generating $ 1.1 billion in earnings. The O&M phase in the 30% LCR has the potential to create 506 FTEs annually, of which 88 are direct jobs generating $55.9 million in annual earnings.

Distributed/Stand-Alone Solar PV: The NDC further provides for the installation of 294 MW of distributed/stand-alone solar PV by 2030. In the 30% LCR scenario, the construction phase has the potential to create a total of 2,536 FTEs, of which 915 are direct jobs generating $254 million in earnings, whereas in the 60% LCR scenario, it has the potential to create a total of 3,819 FTEs, of which 1,348 are direct jobs generating $607.4 million in earnings. The O&M phase in the 30% LCR has the potential to create 138 FTEs annually, of which 39 are direct jobs generating $1.2 million in annual earnings.

Wind Power: The NDC envisages the installation of 327 MW of wind power by 2030. In the 30% LCR scenario, the construction phase has the potential to create a total of 13,038 FTEs, of which 3,934 are direct jobs generating $1.1 billion in earnings, whereas in the 60% LCR scenario, it has the potential to create a total of 17,234 FTEs, of which 5,299 are direct jobs generating $1.5 billion in earnings. The O&M phase at a 30% LCR scenario has the potential to create 855 FTEs annually, of which 265 are direct jobs generating $80.7 million in annual earnings.

Bioenergy: The NDC provides for the installation of 122 MW of bioenergy facilities by 2030. In the 30% LCR scenario, the construction phase has the potential to create a total of 7,954 FTEs, of which 3,005 are direct jobs generating $900.3 million in earnings, whereas in the 60% LCR scenario, it has the potential to create a total of 9,870 FTEs, of which 3,845 are direct jobs generating $1.1 billion in earnings. The O&M phase at a 30% LCR scenario has the potential to create 419 FTEs annually, of which 110 are direct jobs generating almost $51 million in annual earnings.

Hydropower: The NDC provides for the installation of 200 MW of hydropower by 2030, for which the construction phase has the potential to create a total of 4,690 FTEs, of which 2,874 are direct jobs generating $183 million in earnings. The O&M phase has the potential to create 100 FTEs annually, of which 23 are direct jobs generating $2 million in annual earnings. It is important to note that no LCR scenarios are applied for this technology.

Key Findings for Ghana: Hydropower the highest potential during the construction phase, with bioenergy showing superior performance in both the construction and O&M phases. Distrubted soal PV offers the highest job quality, followed by bioenergy.

In terms of employment dynamics during the construction phase, hydropower emerges as the most employment-intensive technology, generating 120 jobs per MW at a 30% LCR compared to bioenergy (65 jobs per MW), followed by distributed PV (42 jobs per MW) and wind at 40 jobs/MW, and last is PVu at 26jobs/MW.

Significant variations exist in earnings potential across the technologies. Distributed solar PV leads with $165.8 million in earnings per MW, followed by bioenergy ($20.9 million per MW), wind ($12.1 million per MW), utility-scale solar PV ($7.9 million per MW) and hydropower ($7.4 million per MW) during the construction phase. This ranking suggests that bioenergy and distributed solar PV create higher-value employment opportunities, likely requiring more specialized skills and offering better compensation or a higher number of people necessary to run the technology.

The O&M phase reveals bioenergy, wind, hydro as leading in long-term employment potential, generating approximately 3 jobs per MW annually, annual earnings however differ where bioenergy has $1.3 million per MW, wind is $830,718, and hydropower at $164,700. Distributed solar PV provides 2 jobs per MW with the highest annual earnings across all technologies at $8.6 million per MW. Utility-scale solar PV show a limited O&M employment potential, only doing better than hydropower in earnings per MW.

Ghana's diversified economy and strong labour market fundamentals support a technology mix prioritizing bioenergy for sustained high-quality employment, distributed solar PV for widespread job creation and rural development, and wind for medium-term balanced benefits. The results suggest that Ghana is well-positioned to leverage renewable energy deployment for significant employment generation, while building domestic technical capacity across multiple technology platforms.

II. GDP Analysis

With a total GDP of $82.83 billion and GDP per capita of $2,405, Ghana is a lower-middle-income country with established economic diversification that has the potential to absorb and multiply energy sector investments effectively (World Bank, 2024d).

Utility-Scale Solar PV: During the construction phase, the installation of 448 MW of utility-scale solar PV by 2030 envisaged by the NDC has the potential to contribute a total of over $12 billion to GDP in the 30% LCR scenario and a total of almost $ 30 billion to GDP in the 60% LCR scenario. During the O&M phase, there is the potential to add $336.0 million to GDP annually at a 30% LCR. The potential total local value added during the construction phase is $4.4 billion in the 30% LCR scenario and $7 billion in the 60% LCR scenario. In the 30% LCR scenario, the O&M phase has the potential to create $113.7 million of local value addition annually.

Distributed/Stand-Alone Solar PV: During the construction phase, the installation of 294 MW of distributed/stand-alone solar PV by 2030 envisaged by the NDC has the potential to contribute a total of almost $12.3 billion to GDP in the 30% LCR scenario and a total of $19.7 billion to GDP in the 60% LCR scenario. During the O&M phase, there is the potential to add $243 million to GDP annually at a 30% LCR. In the 30% LCR scenario, the potential total local value added during the construction phase is $4.4 billion, while the O&M phase has the potential to create $113.7 million of local value added annually in the same LCR scenario.

Wind Power: During the construction phase, the installation of 327 MW of wind power by 2030 envisaged by the NDC has the potential to contribute a total of $22.6 billion to GDP in the 30% LCR scenario and a total of $29.8 billion to GDP in the 60% LCR scenario. During the O&M phase, there is the potential to add $1.5 billion to GDP annually at a 30% LCR. In the 30% LCR scenario, the potential total local value added during the construction phase is $7.6 billion, while the O&M phase has the potential to create $528.2 million of local value added annually in the same LCR scenario.

Bioenergy: During the construction phase, the addition of 122 MW of bioenergy by 2030 provided for in the NDC has the potential to contribute a total of $15.3 billion to GDP in the 30% LCR scenario and a total of $18.8 billion to GDP in the 60% LCR scenario. During the O&M phase, there is the potential to add $905.5 million to GDP annually at a 30% LCR. In the 30% LCR scenario, the potential total local value added during the construction phase is $6.5 billion, while the O&M phase has the potential to create $367.5 million of local value added annually in the same LCR scenario.

Hydropower: The addition of 200 MW of hydropower by 2030 provided for in the NDC has the potential to contribute a total of $664 million to GDP during the construction phase and to contribute $18 million to GDP annually during the O&M phase. The potential total local value added during the construction phase is $404 million, while the O&M phase has the potential to create $10 million of local value added annually. It is important to note that no LCR scenarios are applied for this technology.

Key Findings for Ghana: Distributed solar PV demonstrates exceptional efficiency in terms of its contribution to GDP, generating $912.3 million per MW at a 30% LCR, followed by bioenergy ($125.2 million per MW), wind ($69.1 million per MW), utility-scale solar PV ($44.6 million per MW) and hydropower ($3.2 million per MW).

Distributed solar PV also leads in terms of local value added per MW at 30% LCR ($324.1 million), followed by bioenergy ($53.7 million per MW), wind ($23.3 million per MW), utility-scale solar PV ($15.9 million per MW) and hydropower ($2.0 per MW). The strong performance of distributed technologies suggests they are more effective at retaining economic benefits within local communities and supply chains.

Distributed solar PV makes the greatest contribution to GDP during the O&M phase ($51.8 million per MW annually), followed by bioenergy ($7.4 million per MW), wind ($4.7 million per MW), utility-scale solar PV ($1.2 million per MW) and hydropower ($90,000 per MW). These sustained annual contributions indicate long-term economic benefits beyond construction phases.

The implementation of Ghana's NDC could contribute $326.7 billion (30% LCR) to $484.0 billion (60% LCR) to the country's GDP over the period going to 2030. At the 60% LCR, this represents approximately 584% of Ghana's GDP of $82.83 as of 2024 (World Bank, 2024d) during the construction phase and translating to just under 60% annual growth in GDP.

4.5 Summary of the Analysis across All Countries

Noting the importance of long-term benefits and sustainability, technology performance metrics across the continent, particularly in respect to the O&M employment metric (FTEs per MW at a 30% LCR), it is evident that utility-scale solar PV delivers up to 6 FTEs per MW but with a lot of variability, whereas wind energy delivers a stable 2 - 3 FTE/MW, whilst hydropower delivers 1 - 3 FTE/MW, distributed solar PV delivers approximately 2 FTE/MW so as utlity-scale bioenergy. Coal and geothermal demonstrate the lowest contribution to long-term job creation.

In terms of the job quality indicator (annual O&M earnings per MW), distributed solar PV delivers approximately $8.6 milliom per MW - only one country in the sample-, whereas wind energy potentially deliver $936,420 in earnings per MW, followed by wind at $594,947, and utility scale solar PV at $152,537. As much as hydropower and coal are comparable at $78,380 and $52,433 respectively, geothermal shows the lowest quality of jobs.

Some key policy insights include:

- Impact of LCRs: Enhanced LCR scenarios (60% versus 30%) consistently deliver superior employment outcomes across all technologies and countries, validating their importance for maximizing how Africa benefits from investments in the energy transition;

- Construction versus O&M trade-offs: While construction phases generate the highest absolute job numbers, these are temporary benefits. O&M jobs, although smaller in scale, provide sustained long-term employment, with the exception of gas and coal, all other technologies show a good potential for generating O&M;

- Technology selection considerations: Renewable and transitional energy technologies demonstrate superior job quality and earnings potential compared with traditional coal. The primary policy consideration is ensuring adequate domestic technical capacity and effective technology transfer mechanisms to capture these benefits;

- Scale and context sensitivity: The results of the analysis demonstrate that the optimal technology choices vary significantly by country context, resource endowments and development priorities, supporting the need for differentiated rather than uniform policy approaches across African countries.

In a comparative assessment of the GDP contribution efficiency metrics for the various technologies included in the analysis, the technologies most efficient at generating contributions to GDP (per MW at a 30% LCR) during the construction phase are distributed solar ($912 million per MW in Ghana), utility-scale solar PV (27 - 127 million per MW), bioenerfy ($125 million per MW), wind power ($29 - 69 million per MW), natural gas ($53 million per MW), hydropower ($4 million per MW), and the lowest being geothermal at about $1million/MW.

In terms of the efficiency of local value added, high levels of efficiency are recorded for coal ($2 billion per MW in Botswana), distributed solar PV ($324 million per MW in Ghana), bioenergy ($54 million per MW in Ghana and eSwatini), utility-scale PV ($46 million per MW in DRC), wind energy ($23 million per MW in Ghana), natural gas ($18m in Botswana), hydropower (around $2m in three countries), and lastly geothermal ($473,00 per MW in DRC).

The macroeconomic transformation potential of implementing the NDCs can be gleaned from the relative impact on GDP during the construction phase at 30% LCR. The contribution to GDP during the construction phase represents over 2000% of the DRC's GDP as of 2024 (transformational impact), 390% of Ghana's GDP as of 2024 (substantial impact), 280% of Eswatini's GDP as of 2024 (relatively substantial impact) and 83% of Botswana's GDP as of 2024 (relatively moderate impact). The annual growth rates are significantly higher that average GDP growth rates in 2024 starting from at least 10 times, which in the bigger picture is transformational across all the economies.

Bioenergy and natural gas technologies demonstrate superior efficiency in relation to the generation of contributions to GDP and the creation of local value added, particularly in countries with existing agricultural or extractive industry infrastructure. The large-scale deployment of renewables (wind and solar PV) shows exceptional economic transformation potential in countries with substantial renewable resources and development needs. Enhanced LCR scenarios (60% versus 30%) consistently deliver improvements in GDP contributions and local value added of 25–40% across all technologies and countries, validating their critical importance for maximizing domestic economic benefits from investments in the energy transition.

Countries with larger deployment scales (DRC and Botswana) show potential for transformational economic impacts that could fundamentally alter development trajectories, while countries with smaller deployment scales (Eswatini and Ghana) demonstrate more moderate but sustainable opportunities for economic enhancement. Technologies that integrate with existing economic sectors (bioenergy with agriculture, natural gas with extractive industries) consistently outperform stand-alone renewable technologies in terms of economic multiplier effects, suggesting that, for economic development purposes, it is important to choose technologies that can be integrated into value chains.

The results of the analysis indicate that investments in the energy transition have the potential to generate substantial economic benefits while maintaining macroeconomic stability, with contributions to GDP growth ranging from relatively moderate impact (less than 10% annual growth) to transformational development (more than 100% annual growth) depending on the country context and deployment scale.

Chapter 5: Key Policy Considerations by African Countries

The employment and GDP impact analysis across five African countries reveals critical barriers that could constrain the realization of the benefits of the energy transition and the pursuit of sustainable development. These are issues that require not only domestic policy response, but also the UNFCCC to leverage the international cooperation ecosystem as an enabler for action. The results of the analysis bring to light four priority policy areas, viz. - technology innovation, local content requirements, international trade rules, financing the transition - where structural impediments may limit the extent to which local value can be captured from energy investments.

Firstly, Africa is behind in the renewable **technology innovation curve**, suggesting that the energy transition will primarily follow a pattern involving the importation of transition technologies with an impact on the trade balance, demand on foreign exchange reserves and borrowing that impacts each country's sovereign debt profile, among other considerations. The superior quality of jobs in advanced technologies potentially exposes critical gaps in technology transfer and capacity-building which would be necessary to achive the potential opportunities. In most cases, African countries lack the technical ecosystems required to absorb, adapt and domestically produce sophisticated energy technologies, making them dependent on imported expertise and components, even under ambitious LCR scenarios.

In respect of **LCRs**, gaps in industrial capacity pose a significant risk to local value capture. While it may be common cause that LCR policies deliver improvements in local impact, there may be a misalignment between LCR policy ambitions and existing industrial capacity, despite some African economies being rich in critical minerals for the energy transition. Beyond the industrial capacity challenges, even optimal technologies for adding local value may operate at insufficient scales to justify sustained local manufacturing investments when looking at individual country programmes. In turn, this undermines the development of industrial capacity.

Some **international trade rules** could act as barriers to the pursuit of generating local value added. The rules at the World Trade Organization do not prohibit countries from mandating transfer of technology as a condition for allowing investment. African economies may wish to provide preferential treatment to domestic manufacturing; however, this flexibility is circumscribed by the requirement that the services purchased should be for governmental purposes and not with a view to commercial resale or with a view to use in the supply of services for commercial sale (Article XIII:1 of the General Agreement on Trade in Services of the World Trade Organization).

As much as African economies can impose technology transfer requirements as a condition for investment and/or import taxes on renewable energy technologies, power asymmetries in global trade limit their agency. New generation trade agreements are actually moving in the opposite direction, where zero tariffs are imposed on green technologies, which unfortunately which unfortunately favours incumbent manufacturing countries. Other challenges include export market access limitations for countries that produce surplus energy, and the barrier of inconsistent standards and certification across African countries due to a nascent regional integration under the African Continental Free Trade Agreement.

The **financing of the energy transition** remains a major barrier for African countries owing to significant capital requirements that exceed domestic financing capacity. This leaves debt-creating instruments from international financing with associated currency and conditionality risks. The debt risk is compounded by risk perception premiums, where despite demonstrated economic returns, international financiers impose substantial risk premiums on African renewable energy projects. This increases capital costs, reduces project viability and limits the scale of deployments that could generate employment and economic benefits.

Although the analysis shows substantial local economic benefits, projects typically require hard currency financing that creates exchange rate risks and debt sustainability concerns. The complexity of structuring blended finance mechanisms that capture public benefits while satisfying private investor requirements creates implementation barriers that delay project development. This requires the UNFCCC to coordinate the international financial architecture so as to address these barriers, as they lead to a widening gap between ambition and implementation.

The superior job quality offered by advanced technologies exposes **critical skills** gaps across most African countries. This issue is particularly applicable to the O&M phase, which – despite creating fewer jobs in absolute terms than the construction phase – provides sustained long-term employment benefits. Vocational training infrastructure is therefore required to prepare workers for these ongoing technical roles, particularly in rural areas where many renewable energy projects are located. Traditional energy workers may not be located in these rural areas, creating geographic barriers to workforce transition that are not addressed by current policies.

Workers face transition risks during technology changeovers and the switchover from the construction to the O&M phase. Generally, African countries lack adequate social protection systems to support workers during transition periods, creating resistance to change and limiting the speed of energy sector transformation. The differential impacts on women and marginalized groups should form part of the policy considerations, which should take into account how traditional energy sectors often exclude these groups from higher-paying technical roles. Without targeted interventions, the deployment of renewable energy risks perpetuating these exclusions, limiting the potential for inclusivity demonstrated in the overall employment results.

Chapter 6: Lessons Learned

The comprehensive analysis of the impacts of the energy transition across the five African countries using the JEDI modelling framework has yielded critical insights into the development process. The application of the JEDI model to African energy transition scenarios demonstrates the indispensable role of quantitative economic impact assessment tools in informing evidence-based policy decisions. Critically, the modelling reveals that economic impact assessments must be context-specific rather than technology-generic, as generic technology recommendations without economic impact modelling risk misallocating resources and missing opportunities for maximizing development benefits.

The study encountered significant **data limitations** that constrain both modelling accuracy and policy relevance, highlighting critical gaps in African energy sector information systems. These limitations span facility-level technical data, national economic accounts and cross-border economic links essential for understanding regional integration opportunities. At the facility level, the analysis relied heavily on international cost and performance assumptions adapted for African contexts owing to limited local project data.

While the JEDI model provides robust default values derived from global industry experience, country-specific variations in labour costs, material availability, logistics requirements and regulatory environments can significantly alter economic impact calculations. The study's assumption of uniform technology costs across countries – with adjustments only for LCR scenarios – may overestimate economic impacts in countries with challenging logistics or underestimate impacts in countries with advantageous conditions.

National economic data limitations proved particularly challenging for IO modelling requirements. Several countries lacked recent IO tables essential for calculating economic multiplier effects, forcing reliance on older data or regional proxies that may not reflect current economic structures. Countries with rapidly evolving economic sectors represent dynamic contexts where outdated IO relationships could significantly misrepresent actual economic impacts.

Moreover, the analysis could not adequately capture the informal economic activities that dominate many African economies. The JEDI model's focus on formal employment and documented economic transactions potentially understates actual employment creation and economic benefits, particularly for distributed technologies that integrate with informal agricultural and commercial activities.

Cross-border economic links represent another critical data gap. The analysis treated each country as an isolated economic system and was unable to model regional value chains that could significantly enhance economic benefits. A country's potential to supply critical minerals for regional renewable energy manufacturing, to serve as a regional renewable energy hub or to function as an industrial centre represents integration opportunities, the analysis of which requires regional IO modelling capabilities currently unavailable.

Conducting a comprehensive energy transition impact assessment across four diverse African countries exposed fundamental challenges in **stakeholder engagement** that constrain both research quality and policy relevance. The study's reliance on continental experts and regional institutions, while necessary given resource and time constraints, highlighted gaps in direct country-level stakeholder participation that limit the ability for the findings to be grounded in local contexts and policy realities.

The absence of systematic engagement with national energy planning institutions, local government agencies and private sector stakeholders in each country included in the case study created information asymmetries that may affect the accuracy of assumptions about the potential of LCRs, workforce capabilities and implementation feasibility. While continental experts provided valuable regional perspectives and comparative insights, their reflections necessarily lack the granular understanding of country-specific political economy factors, regulatory environments and institutional capabilities that shape actual energy transition outcomes.

This stakeholder engagement deficit is particularly problematic for LCR analysis, where the understanding of domestic industrial capacity, supplier networks, skills availability and regulatory frameworks requires deep engagement with national and subnational actors. The study's assumption that the potential of LCRs is uniform across countries, while necessary for comparative analysis, may not reflect the substantial variations in industrial readiness and policy implementation capacity that determine the actual achievement of LCRs.

Furthermore, the multi-country scope created coordination challenges that constrained the depth of country-specific engagement possible within the available resources. The trade-off between the breadth of country coverage and depth of stakeholder engagement in each country represents a fundamental tension in comparative policy research that has implications for both research design and resource allocation in future studies.

The experience demonstrates that effective multi-country energy transition analysis requires innovative stakeholder engagement approaches that can balance comparative consistency with country-specific depth. This might include regional stakeholder platforms that bring together national experts, structured consultation processes that ensure systematic input from key stakeholder categories across countries and partnerships with national institutions that can provide ongoing local perspectives throughout the research process.

The study's application of the JEDI modelling framework revealed substantial **capacity-building opportunities across African institutions** for conducting rigorous economic impact assessments of options for the energy transition. While the analysis demonstrates the value of quantitative modelling for policy development, the limited availability of such analytical capabilities within African governments, research institutions and civil society organizations constrains the widespread adoption of evidence-based energy transition planning.

Current capacity limitations span multiple dimensions, including technical skills for economic modelling, access to appropriate software and analytical tools, availability of quality data for model implementation, and institutional frameworks for incorporating analytical findings into policy development processes. These capacity constraints mean that even where analytical tools like the JEDI model are available, many African countries lack the institutional capabilities needed to effectively utilize them for national energy transition planning.

Dealing with the complexity of the JEDI model, while manageable for experienced practitioners, requires substantial technical training and ongoing support for effective implementation. The model's reliance on IO economic data, the need to understand energy technology cost structures and the ability to interpret complex economic impact results all represent capacity requirements that exceed current capabilities in many African energy planning institutions.

However, the demonstrated value of the JEDI framework for revealing technology-specific economic impacts, optimizing local content strategies and gaining an understanding of employment implications creates strong justification for continental capacity-building initiatives. The substantial differences in economic outcomes across technologies and countries identified in this study would be impossible to understand without systematic modelling capability, indicating that such analytical capacity represents essential infrastructure for effective energy transition policy development.

A potential UNECA-led JEDI training programme could address multiple capacity-building needs simultaneously. Such a programme could provide technical training on model implementation, support the development of country-specific economic databases required for modelling, facilitate knowledge sharing across African Union Member States on best practices in energy transition analysis and create ongoing technical assistance mechanisms for countries implementing energy transition policies.

These lessons underscore the need for more sophisticated, context-specific and integrated approaches to energy transition policy development in African contexts. The JEDI modelling framework provides a valuable foundation for evidence-based policy development, but its application reveals broader challenges in data availability, regional coordination and policy integration that must be addressed to fully realize the transformational potential of Africa's energy transition. Future policy development must therefore invest in improved data systems, enhanced modelling capabilities and integrated assessment frameworks that can capture the full complexity of the impacts and opportunities of the energy transition in developing country contexts.

References

Africa Energy Portal. (2024). Botswana Country Profile. Retrieved from https://africa-energy-portal.org/aep/country/botswana.

African Development Bank. (2022). African Economic Outlook 2022: Supporting Climate Resilience and a Just Energy Transition in Africa. Abidjan: African Development Bank.

African Development Bank. (2024). Democratic Republic of Congo Economic Outlook. Retrieved from https://www.afdb.org/en/countries-central-africa-democratic-republic-congo/democratic-republic-congo-economic-outlook.

Aldieri, L., Carlucci, F., Cirà, A., Ioppolo, G. & Vinci, C. P. (2020). Is green job creation a realistic opportunity for the renewable energy sector? Journal of Cleaner Production, 269, 122284.

Allan, G., McGregor, P. & Swales, K. (2020). Greening regional development: employment in low-carbon and renewable energy activities. Regional Studies, 54(11), pp 1607–1618.

Barbose, G., Darghouth, N., Millstein, D., LaCommare, K., DiSanti, N. & Widiss, R. (2016). Tracking the Sun IX: The Installed Price of Residential and Non-Residential Photovoltaic Systems in the United States. Lawrence Berkeley National Laboratory.

Brown, J., Pender, M., Wiser, R., Lantz, E. & Hoen, B. (2020). Determining the economic impacts of utility-scale solar: A guide for practitioners. Renewable and Sustainable Energy Reviews, 119, 109588.

Climate Action Tracker. (2023). Africa Climate Summit Special Report: African NDCs and Climate Action. Climate Analytics and New Climate Institute.

Cui, R.Y., Hultman, N., Edwards, M.R. et al. (2019). Quantifying operational lifetimes for coal power plants under the Paris goals. Nat Commun, 10, 4759. Retrieved from https://doi.org/10.1038/s41467-019-12618-3.

Energy Commission of Ghana. (2023). 2023 Energy Statistics. Accra: Energy Commission of Ghana.

Faturay, F., Lenzen, M., Nugroho, A. & Baynes, T. (2020). Using virtual laboratories to disseminate best practice in input–output analysis for carbon footprints. Journal of Cleaner Production, 266, 121886.

Füllemann, Y., Moreau, V., Vielle, M. & Vuille, F. (2019). The economic impact of the energy transition. Environmental Innovation and Societal Transitions, 33, pp 160 - 178.

Goldberg, M. & Milligan, M. (2004). User's Manual for JEDI: Jobs and Economic Development Impact Model for Use with IMPLAN Professional Software. National Renewable Energy Laboratory.

IEA. (2022). Africa Energy Outlook 2022. IEA. Available at https://www.iea.org/reports/africa-energy-outlook-2022

IEA. (2024). Ghana Energy Outlook. IEA. Available at https://www.iea.org/countries/ghana

Jacobson, M. Z., von Krauland, A. K., Coughlin, S. J., Dukas, E., Nelson, A. J., Palmer, F. C. & Rasmussen, K. R. (2020). Low-cost solutions to global warming, air pollution, and energy insecurity for 145 countries. Energy & Environmental Science, 13(6), pp 1893 - 1910.

Jenniches, S. (2018). Assessing the regional economic impacts of renewable energy sources – A literature review. Renewable and Sustainable Energy Reviews, 93, pp 35 - 51.

Kumar, D. (2015). Economic Assessment of Photovoltaic Energy Production Prospects in India. Procedia Earth and Planetary Science, 11, pp 425 - 436. Retrieved from https://doi.org/10.1016/j.proeps.2015.06.042.

Lenzen, M. (2001). Errors in conventional and input-output-based life-cycle inventories. Journal of Industrial Ecology, 4(4), pp 127 - 148.

Loomis, D. G., Jo, J. H. & Aldeman, M. R. (2016). Economic impact potential of solar photovoltaics in Illinois. Renewable Energy, 87, 253–258. Retrieved from https://doi.org/10.1016/j.renene.2015.10.021.

Milani, R., Montoya, F. G., Alcayde, A. & Baños, R. (2020). Economic impact of renewable energy technologies in Europe. Renewable and Sustainable Energy Reviews, 124, 109782.

Miller, R. E. & Blair, P. D. (2009). Input-output analysis: foundations and extensions. Cambridge University Press.

Fathi, N.Y., Ali, A.K., Abdulsalam, I.M, Mohmoud, A.S. (2016). Economical and Environmental Assessment of Electrical Generators: A Case Study of Southern Region of Libya. International Journal of Energy Policy and Management, Vol. 1, No. 4, pp.64–71.

NREL. (2020). JEDI Model User Manual. NREL.

Organization of the Petroleum Exporting Countries (OPEC). (2024). Equatorial Guinea Country Profile. Organization of the Petroleum Exporting Countries.

Semelane, S. (2020). Crunching the job numbers in a just transition from coal to renewables. Daily Maverick. Retrieved from https://www.dailymaverick.co.za/article/2020-10-15-crunching-the-job-numbers-in-a-just-transition-from-coal-to-renewables/.

Semelane, S., Nwulu, N., Kambule, N. & Tazvinga, H. (2021). Evaluating economic impacts of utility scale solar photovoltaic localisation in South Africa. Energy Sources, Part B: Economics, Planning, and Policy, 00(00), pp 1 - 21. Retrieved from https://doi.org/10.1080/15567249.2021.1894513.

Semelane, S., Nwulu, N., Kambule, N. & Tazvinga, H. (2021a). Economic feasibility assessment of manufacturing solar panels in South Africa – A case study of Steve Tshwete Local Municipality. Sustainable Energy Technologies and Assessments, 43, 100945.

United Nations Framework Convention on Climate Change (UNFCCC). (2015). Paris Agreement. United Nations Framework Convention on Climate Change.

United Nations Framework Convention on Climate Change (UNFCCC). (2018). Decision 7/CMA.1.

United Nations Framework Convention on Climate Change (UNFCCC). (2023). Decision 19/CMA.5.

United States Department of Commerce. (2024). Democratic Republic of the Congo – Energy. Retrieved from https://www.trade.gov/country-commercial-guides/democratic-republic-congo-energy.

Woo, H., Moroni, M., Park, J., Taskhiri, M. S. & Turner, P. (2020). Residues and bio-energy generation: A case study modelling value chain optimisation in Tasmania. Energy, 196, 117007. Retrieved from https://doi.org/10.1016/j.energy.2020.117007.

World Bank. (2024a). Botswana Overview: Development news, research, data. Retrieved from https://www.worldbank.org/ext/en/country/botswana.

World Bank. (2024b). Democratic Republic of Congo Overview: Development news, research, data. Retrieved from https://www.worldbank.org/en/country/drc/overview.

World Bank. (2024c). Eswatini Overview: Development news, research, data. Retrieved from https://www.worldbank.org/en/country/eswatini/overview.

World Bank. (2024d). Ghana Overview: Development news, research, data. Retrieved from https://www.worldbank.org/en/country/ghana/overview.

Xolisa Ngwadla, Abhijit Das, Anton, Cartwright, Chantal Naidoo, Lungile Manzini, Sachin Sharma, Stanley Semelane, Thapelo Letete. 2024. Energy Transition Considerations by African Economies towards a Just Transition: Summary for Policy Makers. Project by the African Climate Policy Centre of UNECA, funded by the African Climate Foundation.

Annex A: Assumptions Used in the Analysis

Solar PV LCR Factor

Jobs Created by the Solar PV Sector	**LCR 30%**	**LCR 60%**
Modules	**30%**	**60%**
Inverters	**30%**	**60%**
Construction		
Design and civils	50%	50%
Installation	100%	100%
Other (public relations, legal, environmental studies)	90%	90%
Electrical site infrastructure	85%	85%
Transportation	100%	100%
Other		
Professional services (PM, engineering, etc.)	90%	90%
Site improvements (i.e. road construction)	100%	100%
O&M		
Maintenance	100%	100%
Repairs and parts	100%	100%

Coal-Fired Power

Jobs Created by the Coal Sector	**LCR 30%**	**LCR 60%**
Power generation (boilers, turbines, generators, controls)	**30%**	**60%**
Feedstock handling equipment and ash disposal	**30%**	**60%**
General facilities (buildings, cooling systems)	**30%**	**60%**
Non-electrical equipment	**30%**	**60%**
Construction		
Electrical balance of plant	60%	60%
Construction (excluding site improvements)	100%	100%
Other		
Professional services (PM, engineering, etc.)	60%	60%
Site improvements (i.e. road construction)	100%	100%
O&M		
Coal (incl. ash disposal) and water	100%	100%
Plant operations (staff, equipment such as trucks)	100%	100%
Civil works (access road maintenance, etc.)	100%	100%

Natural Gas

Jobs Created by the Natural Gas Sector	**LCR 30%**	**LCR 60%**

Power generation (boilers, turbines, generators, controls)	**30%**	**60%**
Feedstock handling equipment and ash disposal	**30%**	**60%**
General facilities (buildings, cooling systems)	**30%**	**60%**
Non-electrical equipment	**30%**	**60%**
Construction		
Electrical balance of plant	60%	60%
Construction (excluding site improvements)	100%	100%
Other		
Professional services (PM, engineering, etc.)	90%	90%
Site improvements (i.e. road construction)	100%	100%
O&M		
Coal (incl. ash disposal) and water	100%	100%
Plant operations (staff, equipment such as trucks)	100%	100%
Civil works (access road maintenance, etc.)	100%	100%

Wind Power

Jobs Created by the Wind Sector	LCR 30%	LCR 60%
Wind turbines, generators, control	**30%**	**60%**
Blades	**30%**	**60%**
Towers	**30%**	**60%**
Equipment for shipping/transportation	**30%**	**60%**
Construction		
Electrical balance of plant	60%	60%
Construction (excluding site improvements)	100%	100%
Other		
Professional services (PM, engineering, etc.)	90%	90%
Site improvements (i.e. road construction)	100%	100%
O&M		
Rotors	15%	15%
Drivetrains/nacelles	33%	33%
Towers	12%	12%
Development	3%	3%
Engineering	2%	2%
Electrical	15%	15%
Assembly/installation	6%	6%
Road/civil works	8%	8%
Foundations	6%	6%

Bioenergy

Jobs Created by the Bioenergy Sector	LCR 30%	LCR 60%
Equipment and feedstock handling	**30%**	**60%**
Turbines, boilers and air quality control equipment	**30%**	**60%**

Construction		
Professional services (legal, engineering, development, public relations, etc.)	90%	90%
Contractors and balance of plant	100%	100%
O&M		
Feedstock/chemicals	100%	100%
Water	100%	100%
Solids and ash	100%	100%

Hydropower

Jobs Created by Hydropower	**LCR 30%**
Land and water rights	100%
Transmission line rights of way	100%
Construction materials and equipment	75%
Civil works and structures	75%
Dams and reservoirs	75%
Water conveyance	75%
Powerhouse structures	75%
Navigation locks	75%
Equipment	
Turbines	0%
Generators	0%
Balance of plant – electrical	25%
Balance of plant – mechanical	25%
Main power transformers	0%
Switchyard and interconnection	0%
Transmission lines	0%
Installation/labour	
Civil works and structures	50%
Turbines	50%
Generators	50%
Balance of plant – electrical	50%
Balance of plant – mechanical	50%
Main power transformers	50%
Switchyard and interconnections	50%
Transmission lines	50%

Geothermal

Jobs Created by Geothermal	**LCR 30%**
Construction	
Site preparation	100%
Rig operator and drilling services	100%
Cement and cement additives	90%
Petroleum	5%
Bits and stabilizers	90%

Mud and detergents	80%
Casing and well head	80%
Worker housing	100%
Professional services (engineers, geologists, supervisors, etc.)	90%
Other	
Engineering and design	60%
Mechanical equipment (turbines, generators, pumps, condensers, heat exchangers)	0%
Permission and environmental assessment	100%
Additional civil works (i.e. roads)	100%
O&M	
Plant operations, excluding equipment and field operations	100%
Civil works maintenance	100%
Equipment	0%
Field operations, including well equipment	89%

Annex B: Botswana

B.1 Electricity Deployment from IRP 2021

Year	**Wind (MW)**	**Solar PV (MW)**	**Natural Gas (MW)**	**Coal (MW)**
2021				
2022		100		
2023		100		
2024		100		
2025		100	10	
2026		100	10	300
2027	50	200	10	300
2028	50	200	10	300
2029	50	200	10	300
2030	50	200	10	300
Total	**200**	**1,300**	**60**	**1,500**

B.2 Impact Analysis Results

Utility Scale Solar PV

Economic Impact Estimates

30% LCR

Construction Phase

	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**6 885**	**4 805**	**6 004**	**17 694**
Earnings	$97 688 997	$82 558 733	$108 558 940	$288 806 671
Output	$487 436 864	$372 587 754	$709 381 672	$1 569 406 291
Value-added	$166 081 746	$180 625 980	$204 332 685	$551 040 411

O&M

	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**98**	**134**	**299**	**531**
Earnings	$1 269 939	$2 198 907	$2 089 204	$5 558 050
Output	$9 456 812	$10 291 474	$13 651 966	$33 400 252
Value-added	$2 815 772	$4 557 067	$3 932 358	$11 305 197

Economic Impact Estimates

60% LCR

Construction Phase

	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**10 750**	**8 298**	**10 018**	**29 066**
Earnings	$1 787 184 960	$1 611 358 864	$2 046 862 474	$5 445 406 298
Output	$9 346 494 406	$7 198 956 559	$13 375 284 607	$29 920 735 572
Value-added	$2 852 078 318	$3 513 433 365	$3 852 662 003	$10 218 173 686

Coal

Economic Impact Estimates

30% LCR

Construction Phase

	On-Site	Supply Chain	Worker Expenses	
Jobs	**2 391**	**2 600**	**2 725**	**7 716**
Earnings	$273 772 720	$362 875 895	$383 438 386	$1 020 087 000
Output	$1 661 313 218	$1 669 685 921	$2 505 589 704	$5 836 588 843
Value-added	$478 127 610	$770 749 722	$721 718 493	$1 970 595 825

O&M

	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**74**	**79**	**89**	**242**
Earnings	$24 060 666	$25 025 790	$29 563 610	$78 650 066
Output	$139 950 366	$112 941 317	$193 184 304	$446 075 986
Value-added	$45 113 167	$56 673 133	$55 645 457	$157 431 757

Economic Impact Estimates

60% LCR

Construction Phase

	On-Site	Supply Chain	Worker Expenses	
Jobs	**3 026**	**3 272**	**3 433**	**9 731**
Earnings	$337 561 763	$447 425 978	$472 779 530	$1 257 767 272
Output	$2 048 399 198	$2 058 722 740	$3 089 392 105	$7 196 514 044
Value-added	$589 531 344	$950 334 407	$889 878 902	$2 429 744 652

Natural Gas

Economic Impact Estimates

30% LCR

Construction Phase

	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**182**	**878**	**2 299**	**3 359**
Earnings	$160 098 820	$195 329 560	$214 066 097	$569 494 477
Output	$912 898 025	$888 951 946	$1 398 821 372	$3 200 671 343
Value-added	$246 380 036	$418 350 926	$402 921 217	$1 067 652 178

O&M

	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**3**	**7**	**13**	**24**
Earnings	$4 812 133	$5 005 158	$5 912 723	$15 730 014
Output	$27 990 073	$22 588 263	$38 636 861	$89 215 197
Value-added	$9 022 633	$11 334 627	$11 129 091	$31 486 351

Economic Impact Estimates

60% LCR

Construction Phase

	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**237**	**1 119**	**2 619**	**3 975**
Earnings	$200 123 525	$244 161 950	$267 582 621	$711 868 096
Output	$1 141 122 531	$1 111 189 933	$1 748 526 715	$4 000 839 178
Value-added	$307 975 045	$522 938 657	$503 651 521	$1 334 565 223

Wind Power

Economic Impact Estimates

30% LCR

Construction Phase	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**1 017**	**1 194**	**1 159**	**3 369**
Eamings	$273 772 720	$362 875 895	$383 438 386	$1 020 087 000
Output	$1 661 313 218	$1 669 685 921	$2 505 589 704	$5 836 588 843
Value-added	$478 127 610	$770 749 722	$721 718 493	$1 970 595 825

O&M	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**74**	**79**	**89**	**242**
Eamings	$24 060 666	$25 025 790	$29 563 610	$78 650 066
Output	$139 950 366	$112 941 317	$193 184 304	$446 075 986
Value-added	$45 113 167	$56 673 133	$55 645 457	$157 431 757

Economic Impact Estimates

60% LCR

Construction Phase	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**1 369**	**1 538**	**1 546**	**4 453**
Eamings	$379 099 312	$470 122 494	$511 466 186	$1 360 687 993
Output	$2 205 249 966	$2 153 816 222	$3 342 191 228	$7 701 257 416
Value-added	$632 973 762	$1 007 711 405	$962 696 012	$2 603 381 179

Annex C: Democratic Republic of Congo

C.1 Electricity Deployment from NDC

- Increase the 3GW of hydropower to 4GW by 2030;
- For wind, solar and geothermal increase from 2 900 MW to 42 700 MW by 2030.

We model the commitments made on the updated NDC report where wind and solar PV are estimated to generate 10 000 MW respectively. We assume the remaining 18 900 MW would be for geothermal

C.2 Impact Analysis Results

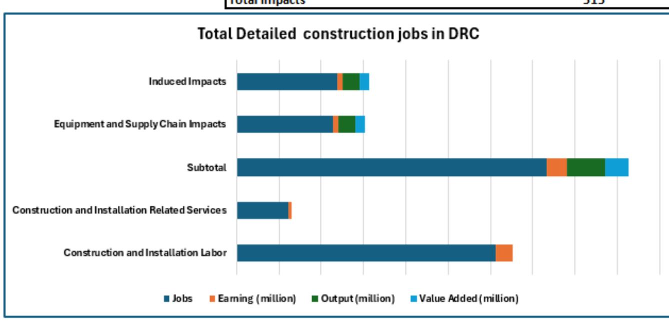
Hydropower

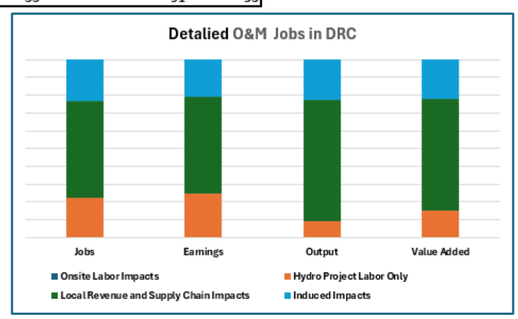
Detailed impacts construction

During construction and installation period	Jobs	Earning (million)	Output (million)	ed (million)
Project Development and Onsite Labor Impacts				
Construction and Installation Labor	$12 232	$798	0	0
Construction and Installation Related Service	$2 436	$136		
Subtotal	**$14 669**	**$934**	**1798**	**1150**
Equipment and Supply Chain Impacts	$4 542	$269	$804	$455
Induced Impacts	$4 739	$270	$794	$458
Total Impacts	**$23 949**	**$1 473**	**$3 396**	**$2 064**

Detailed impacts O&M

During operating years	Jobs	Earnings	Output	alue Added
Onsite Labor Impacts				
Hydro Project Labor Only	116	8	8	8
Local Revenue and Supply Chain Impacts	279	18	62	33
Induced Impacts	119	7	20	12
Total Impacts	**515**	**33**	**91**	**53**





Wind power

Economic Impact Estimates

30% LCR

Construction Phase

	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**77 446**	**90 943**	**88 288**	**256 677**
Earnings	$20 857 963 601	$27 646 480 690	$29 213 078 300	$77 717 522 590
Output	$126 570 721 423	$127 208 613 797	$190 893 741 766	$444 673 076 986
Value-added	$36 427 180 565	$58 721 225 644	$54 985 675 977	$150 134 082 187

O&M

	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**5 378**	**5 730**	**6 372**	**17 480**
Earnings	$1 688 121 229	$1 812 355 895	$2 108 254 487	$5 608 731 611
Output	$9 846 349 055	$8 160 863 761	$13 776 452 569	$31 783 665 384
Value-added	$2 993 324 368	$4 082 917 045	$3 968 215 773	$11 044 457 186

Economic Impact Estimates

60% LCR

Construction Phase

	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**104 331**	**117 196**	**117 767**	**339 294**
Earnings	$28 882 496 636	$35 817 293 587	$38 967 151 679	$103 666 941 903
Output	$168 011 712 678	$164 093 122 260	$254 632 028 631	$586 736 863 569
Value-added	$48 224 467 752	$76 774 661 205	$73 345 066 686	$198 344 195 643

Utility Scale Solar PV

Economic Impact Estimates

30% LCR

Construction·Phase¶

	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**210 429**	**236 278**	**250 410**	**697 117**
Earnings	$64 324 944 554	$73 247 397 062	$82 856 563 894	$220 428 905 510
Output	$388 866 112 457	$339 819 648 249	$541 428 717 282	$1 270 114 477 987
Value-added	$144 136 231 619	$158 824 629 301	$155 954 950 319	$458 915 811 239

O&M

	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**1 952**	**2 671**	**299**	**4 922**
Earnings	$461 857 239	$799 708 419	$759 811 125	$2 021 376 783
Output	$3 439 296 212	$3 742 849 521	$4 965 008 724	$12 147 154 456
Value-added	$1 024 052 688	$1 657 334 562	$1 430 137 826	$4 111 525 075

Economic Impact Estimates

60% LCR

Construction Phase

	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**252 463**	**276 106**	**294 980**	**823 550**
Earnings	$76 361 547 663	$85 697 157 902	$97 604 121 108	$259 662 826 674
Output	$455 048 303 356	$394 679 743 918	$637 797 074 964	$1 487 525 122 238
Value-added	$159 741 169 702	$185 696 938 696	$183 713 216 467	$529 151 324 866

Geothermal

Economic Impact Estimates			
30% LCR			
Construction Phase	**$ Earnings**	**$ Output**	**$ GDP (Value Added)**
	1 565 946 742,73	6 918 336 131,54	3 354 820 404,61
Indirect	1 107 962 910,30	5 125 036 571,09	2 563 117 146,84
Induced	1 610 432 470,73	10 523 419 581,00	3 031 201 200,74
O&M	**$ Earnings**	**$ tput**	**$ GDP**
	2 144 476,77	12 021 450,77	6 554 892,24
Indirect	750 862,21	6 541 360,97	3 453 175,55
Induced	1 153 786,01	13 913 175,48	4 007 597,90

Economic Impact Estimates			
60% LCR			
Construction Phase	**$ Earnings**	**$ Output**	**$ GDP (Value Added)**
	118 230 342		175 305 078
Indirect	185 501 077	1 363 508 491	319 881 423
Induced	7	127 465	104 237

Annex D: Eswatini

D.1 Elecritcity Deployment from NDC

The (NDC Partnership, 2024) shows that the Kingdom of eSwatini has committed to installing 55.85 MW of solar PV, 80 MW of hydropower and 95 MW of bioenergy. As such, for the Kingdom of eSwatini.

D.2 Impact Analysis Results

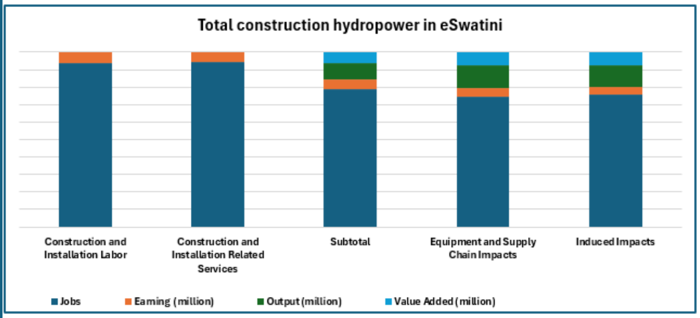
Utility Scale Solar PV

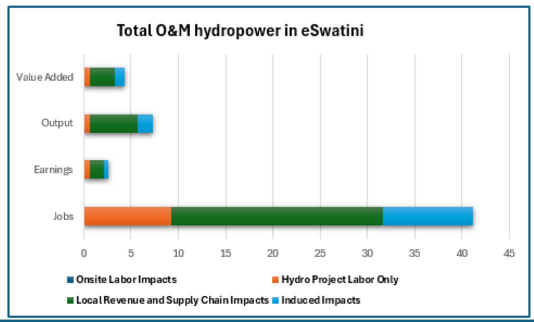
Economic Impact Estimates				
30% LCR				
Construction Phase Total Impacts				
	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**338**	**259**	**312**	**909**
Earnings	$90 252 814	$81 296 852	$103 320 302	$274 869 968
Output	$468 392 238	$369 353 997	$675 149 630	$1 512 895 865
Value-added	$162 688 450	$177 484 979	$194 472 372	$534 645 802
O&M Annual Impacts				
	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**11**	**15**	**299**	**324**
Earnings	$2 579 473	$4 466 372	$4 243 545	$11 289 389
Output	$19 208 469	$20 903 815	$27 729 574	$67 841 858
Value-added	$5 719 334	$9 256 214	$7 987 320	$22 962 868

Economic Impact Estimates				
60% LCR				
Construction Phase Total Impacts				
	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**507**	**413**	**488**	**1 408**
Earnings	$138 730 612	$129 562 888	$161 586 822	$429 880 323
Output	$740 336 642	$581 981 775	$1 055 893 968	$2 378 212 384
Value-added	$231 467 363	$282 192 931	$304 143 253	$817 803 547

Hydropower

Detailed impacts construction				
During construction and installation period	Jobs	Earning (million)	Output (million)	lded (million)
Project Development and Onsite Labor Impacts				
Construction and Installation Labor	$994	$65		
Construction and Installation Related Services	$195	$11		
Subtotal	**$1 189**	**$76**	**$145**	**$93**
Equipment and Supply Chain Impacts	$366	$22	$65	$37
Induced Impacts	$383	$22	$64	$37
Total Impacts	**$3 128**	**$195**	**$274**	**$167**
Detailed impacts O&M				
During operating years	**Jobs**	**Earnings**	**Output**	**Value Added**
Onsite Labor Impacts				
Hydro Project Labor Only	9	1	1	1
Local Revenue and Supply Chain Impacts	22	1	5	3
Induced Impacts	10	1	2	1
Total Impacts	**41**	**3**	**7**	**4**





Bioenergy

Economic Impact Estimates

30% LCR

Construction Phase Total Impacts

	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**2 340**	**1 526**	**2 328**	**6 194**
Earnings	$701 065 909	$475 871 015	$804 405 033	$1 981 341 957
Output	$3 274 974 104	$3 144 508 269	$5 477 774 863	$11 897 257 237
Value-added	$1 034 491 683	$2 000 348 386	$2 062 745 334	$5 097 585 402

O&M Annual Impacts

	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**42**	**52**	**67**	**161**
Earnings	$19 820 026	$17 026 347	$22 191 698	$59 038 072
Output	$122 123 249	$81 474 988	$145 012 322	$348 610 559
Value-added	$59 584 536	$40 060 435	$41 769 837	$141 414 808

Economic Impact Estimates

60% LCR

Construction Phase Total Impacts

	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**2 994**	**1 807**	**2 884**	**7 685**
Earnings	$888 380 016	$564 099 889	$996 768 431	$2 449 248 336
Output	$4 044 837 420	$3 796 378 180	$6 787 716 177	$14 628 931 777
Value-added	$1 268 447 091	$2 416 808 719	$2 556 025 069	$6 241 280 879

Annex E: Ghana

E.1 Electricity Deployment in the NDC 2019 - 2030

RENEWABLE ENERGY MASTER PLAN – RE TARGETS UP TO 2030										
Renewable Energy Technologies	Reference 2015		Cycle I (2018-2020)		Cycle II (2021-2025)		Cycle III (2026-2030)		Cumulative in 2030	
	No. of units	MWp	No. of Units	MWp	No. of Units	MWp	No. of Units	MWp	No. of Units	MWp
Solar Energy										
Solar Utility Scale	-	23	-	270	-	202	-	378	-	873
Distributed Solar PV (Net Metering)		2	20000	18	100000	100	80000	80	200000	200
Solar Home Systems	-	3	-	1.5	-	3.5	-	6	-	14
Solar Street/Community lighting	-	3	-	4	-	4	-	14	-	25
Solar Traffic signals (% of total traffic signals installed in the country)	14	3	11	-	15	-	20	-	60	-
Solar Lanterns	72,000	-	128000	-	300000	-	500000	-	1000000	-
Solar irrigation	150	2	4250	6.8	22000	44	22400	44.8	48800	97.6
Solar Crop Dryers	70	-	80	-	250	-	300	-	700	-
Solar Water Heaters	4,700	-	15300	-	50000	-	65000	-	135000	-
Wind Energy										
Wind Utility Scale	-	0	-	125	-	275	-	250	-	650
Standalone Wind Systems	-	0	-	0.1	-	0.9	-	1	-	2
Wind Irrigation/Water Pumping	10	0	25	-	30	-	35	-	100	-
Biomass / Waste-to-Energy										
Biomass Utility-Scale/ standalone	-	10	-	58.5	-	106.5	-	125	-	300
Waste-to-Energy Utility Scale	-	0.1	-	1	-	3	-	5.9	-	10
Landfill Gas to Energy (LFGTE)	-	0	-	1.5	-	8.5	-	10	-	20
Biogas (Agricultural/Industrial Organic Waste)	10	-	20	-	70	-	100	-	200	-
Biogas (Institutional)	100	-	80	-	140	-	180	-	500	-
Biogas (Domestic)	50	-	30	-	50	-	70	-	200	-
Woodlot Cultivation (ha)	190,000	-	60000	-	100000	-	78000	-	428000	-
Charcoal (Local Demand)	1,551,282	-	94017	-	93947	-	100877	-	1840123	-
Charcoal (Export)	190,450	-	59550	-	100000	-	78000	-	428000	-
Briquetting/Pelleting	19,700	-	20300	-	25000	-	35000	-	100000	-
Biofuel (tonnes)	0	-	100	-	4900	-	15000	-	20000	-
Hydro / Wave Power										
Small/Medium Hydro Plants	-	4.00[1]	-	2.03	-	108	-	232	-	346.03
Wave Power	-	0	-	10	-	15	-	90	-	115
Hybrid Mini-Grids										
Mini/Micro-grids	7	-	73	-	120	4.8	100	4	300	-
End User Technologies										
Improved Biomass Cookstove (Domestic)	800,000	-	500000	-	500000	-	1200000	-	3000000	-
Improved Biomass Cookstove (Institutional/Commercial)	1,800	-	1200	-	7000	-	8000	-	18000	-
Total Installed RE Electricity Capacity		***46.1***		***503.53***		***875.2***		***1239.8***	0	***2664.63***

E.2 Impact Analysis Results

Utility Scale Solar PV

Economic Impact Estimates

30% LCR

Construction phase

Total Impacts

	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**3 884**	**3 569**	**4 030**	**11 483**
Earnings	$680 208 109	$686 805 285	$823 319 799	$2 190 333 194
Output	$3 796 554 140	$3 154 410 195	$5 380 008 074	$12 330 972 409
Value-added	$1 362 579 718	$1 494 151 494	$1 549 675 636	$4 406 406 849

O&M

Annual Impacts

	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**87**	**120**	**299**	**506**
Earnings	$12 776 536	$22 122 644	$21 018 950	$55 918 130
Output	$95 142 585	$103 539 898	$137 348 963	$336 031 447
Value-added	$28 328 767	$45 847 489	$39 562 458	$113 738 713

Economic Impact Estimates

60% LCR

Construction phase

Total Impacts

	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**5 334**	**4 897**	**5 544**	**15 775**
Earnings	$1 088 332 975	$1 098 888 456	$1 317 311 679	$3 504 533 110
Output	$6 074 486 625	$5 047 056 311	$8 608 012 919	$19 729 555 855
Value-added	$2 180 127 549	$2 390 642 391	$2 479 481 018	$7 050 250 958

Distributed Solar PV

Economic Impact Estimates (ZAR R 2024)				
30% LCR				
Construction Phase				
Total Impacts				
	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**915**	**738**	**883**	**2 536**
Earnings	$254 004 034	$231 212 225	$292 234 264	$777 450 523
Output	$1 316 383 941	$1 052 042 826	$1 909 613 617	$4 278 040 385
Value-added	$464 378 689	$505 394 218	$550 051 535	$1 519 824 442
O&M				
Annual Impacts				
	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**39**	**53**	**46**	**138**
Earnings	$9 237 145	$15 994 168	$15 196 222	$40 427 536
Output	$68 785 924	$74 856 990	$99 300 174	$242 943 089
Value-added	$20 481 054	$33 146 691	$28 602 757	$82 230 502

Economic Impact Estimates (ZAR R 2024)				
60% LCR				
Construction Phase				
Total Impacts				
	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**1 348**	**1 135**	**1 336**	**3 819**
Earnings	$604 746 267	$569 421 052	$707 173 174	$1 881 340 492
Output	$3 213 061 035	$2 562 113 975	$4 621 044 445	$10 396 219 454
Value-added	$1 018 056 986	$1 240 797 479	$1 331 061 198	$3 589 915 662

Wind power

Economic Impact Estimates

30% LCR

Construction Phase
Total Impacts

	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**3 934**	**4 619**	**4 485**	**13 038**
Earnings	$1 059 459 403	$1 404 275 340	$1 483 849 099	$3 947 583 842
Output	$6 429 033 224	$6 461 434 329	$9 696 256 719	$22 586 724 272
Value-added	$1 850 282 210	$2 982 685 935	$2 792 942 426	$7 625 910 571

O & M
Annual Impacts

	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**265**	**282**	**309**	**855**
Earnings	$80 737 308	$88 799 402	$102 107 946	$271 644 656
Output	$471 942 273	$399 190 280	$667 227 455	$1 538 360 009
Value-added	$136 713 536	$199 274 300	$192 190 442	$528 178 279

Economic Impact Estimates

60% LCR

Construction Phase
Total Impacts

	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**5 299**	**5 953**	**5 982**	**17 234**
Earnings	$1 467 057 534	$1 819 303 610	$1 979 297 502	$5 265 658 647
Output	$8 533 986 934	$8 334 946 052	$12 933 779 262	$29 802 712 248
Value-added	$2 449 513 615	$3 899 692 141	$3 725 489 317	$10 074 695 073

Bioenergy

Economic Impact Estimates

30% LCR				
Construction Phase				
Total Impacts				
	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**3 005**	**1 960**	**2 989**	**7 954**
Earnings	$900 316 220	$611 118 567	$1 033 025 411	$2 544 460 197
Output	$4 205 756 218	$4 038 210 619	$7 034 616 140	$15 278 582 977
Value-added	$1 328 505 108	$2 568 868 453	$2 648 999 270	$6 546 372 831

O&M				
Annual Impacts				
	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**110**	**135**	**173**	**419**
Earnings	$50 981 964	$44 300 744	$57 386 519	$152 669 227
Output	$317 744 637	$212 772 754	$374 993 940	$905 511 331
Value-added	$155 292 296	$104 154 033	$108 014 517	$367 460 846

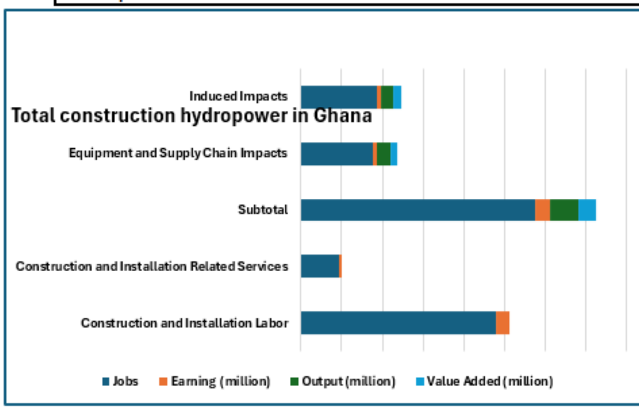
Economic Impact Estimates

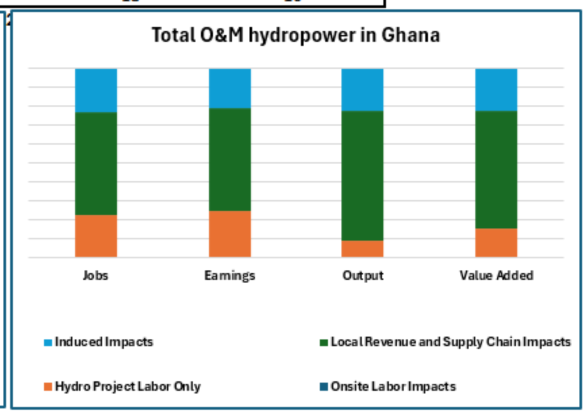
60% LCR				
Construction Phase				
Total Impacts				
	On-Site	Supply Chain	Worker Expenses	Total
Jobs	**3 845**	**2 321**	**3 704**	**9 870**
Earnings	$1 140 866 968	$724 423 015	$1 280 060 511	$3 145 350 495
Output	$5 194 422 792	$4 875 348 820	$8 716 856 565	$18 786 628 177
Value-added	$1 628 953 106	$3 103 691 197	$3 282 474 299	$8 015 118 602

Hydropower

Detailed impacts construction				
During construction and installation period	**Jobs**	**Earning (million)**	**Output (million)**	**Value Added (million)**
Project Development and Onsite Labor Impacts				
Construction and Installation Labor	$2 399	$157	$0	$0
Construction and Installation Related Services	$475	$27	$0	$0
Subtotal	$2 874	$183	$352	$225
Equipment and Supply Chain Impacts	$888	$53	$157	$89
Induced Impacts	$928	$53	$155	$90
Total Impacts	**$4 690**	**$289**	**$664**	**$404**

Detailed impacts O&M				
During operating years	**Jobs**	**Earnings**	**Output**	**Value Added**
Onsite Labor Impacts				
Hydro Project Labor Only	23	2	2	2
Local Revenue and Supply Chain Impacts	54	3	12	7
Induced Impacts	23	1	4	2
Total Impacts	**100**	**6**	**18**	**10**





Annex F: Modelling Study for Weighted Average Cost of Capital

Executive summary
This modelling work integrates country-specific Weighted Average Cost of Capital (WACC) into the International Jobs and Economic Development (I-JEDI) Impact of energy project implementation in Africa through the case studies of Botswana, Ghana, the Democratic Republic of Congo (DRC), and Eswatini. Employing the International I-JEDI model as an analytical framework, we assessed the impact of financing assumptions on capital expenditure (CAPEX), operating expenditure (OPEX), and 60evelized cost of energy (LCOE). Drawing on project data and recent market benchmarks, the evaluations elucidate the differentiated economic implications of energy investments across diverse African contexts. The findings reveal substantial variability in project costs and financing environments, with WACC emerging as a critical determinant of investment viability and local economic benefits. Furthermore, increased Local Content Requirements (LCRs) illustrate that leveraging a greater proportion of local resources and investment sources can yield enhanced benefits in the African energy transition.

1. Introduction
The transition towards renewable energy in African markets is shaped by a complex interplay of technical, economic, and financial factors. Central to project valuation and viability is the Weighted Average Cost of Capital (WACC), which encapsulates the cost of financing and risk premiums inherent to each national context. Accurate modelling of renewable energy impacts, particularly in input-output economic tools such as the I-JEDI model, necessitates the incorporation of country-specific WACC into project cost assumptions. This paper explores methodological approaches for embedding WACC into renewable energy modelling and presents a comparative analysis of project costs and financing structures in Botswana, Ghana, DRC, and Eswatini.

2. Methodological approach
The I-JEDI model serves as the primary analytical instrument for estimating the employment, earnings, and GDP effects of renewable energy projects. While the model itself does not explicitly account for WACC, it relies on project expenditure data that should reflect underlying financing assumptions. Country-specific WACC values are determined using financial methodologies such as the Capital Asset Pricing Model (CAPM) for equity, prevailing debt yields, and local tax rates, augmented by country risk premiums (CRP). Project cost data, including CAPEX and OPEX, are sourced from recent market reports, industry benchmarks, and publicly available project documentation. The integration of WACC into project cost inputs ensures that model outputs accurately represent the financial realities of each country studied (SolarTech, 2025).

3. Country-Specific Analysis

3.1 Botswana

Botswana's renewable energy sector is characterised by elevated financing costs, with WACC estimates for utility-scale photovoltaic (PV) projects likely ranging from 10–15%, reflecting significant country risk, sovereign debt issues, and policy uncertainty. Capital expenditure for distributed solar systems is estimated below USD 1.30/W, with commercial and utility-scale projects potentially as low as USD 0.80–1.20/W. For onshore wind, turbine costs are approximately USD 1–1.25 million/MW, with total project costs between USD 1.2–1.8 million/MW. OPEX for a 100 MW solar project is reported at EUR 20/kW annually, representing roughly 1.5% of initial CAPEX. Coal and natural gas power plants display higher overnight costs, with coal projects ranging from USD 1,833–4,667/kW and gas combined-cycle plants from USD 1,100–1,300/kW. Retail electricity prices for businesses stand at USD 0.114/kWh, and solar PV LCOE is anticipated at USD 0.08–0.10/kWh (SolarTech, 2025; PVKnowhow, 2025)

3.2 Ghana

Ghana's energy market demonstrates a downward trend in utility-scale solar PV CAPEX, with recent projects averaging USD 990/kW. Wind power investments are projected at USD 2.33 million/MW, exceeding global benchmarks due to infrastructure and risk factors. Bioenergy projects, particularly those employing stoker boilers, exhibit significant capital intensity, with installed costs ranging from USD 1,400–2,800/kW. Circulating fluidised bed (CFB) biomass boilers fall within USD 1,000–2,500/kW, with overall bioenergy plant costs reaching USD 3,000–5,000/kW. Natural gas combined-cycle plants show overnight costs between USD 900–1,300/kW, with specific projects such as the Kpone power plant costing USD 2,330/kW. Coal power has not been operationalised, reflecting a policy shift towards renewables and gas (Taishan Group, 2025; Mawusi et., al.; Adu & Lohmueller, 2012; Power Technology, n.d.; Global Climate Scope, 2025; Agarwal,2024; Akpahou, 2025).

3.3 Democratic Republic of Congo (DRC)

Renewable energy in the DRC faces pronounced cost challenges due to high financing rates and infrastructural constraints. Utility-scale wind projects have estimated costs of USD 1.2–1.8 million/MW, while offshore wind is considerably higher at USD 3.5–4.0 million/MW. Utility-scale solar PV CAPEX likely exceeds global averages, ranging from USD 0.90–1.20/W, with a reference project cost of USD 1.05 million/MW used in this analysis. Distributed solar PV systems in the DRC are particularly costly, with estimates above USD 2.00–4.00/W for residential and commercial installations, attributed to logistical, regulatory, and market risks. The prevalence of soft costs and the need for battery storage further increase total investment requirements (SolarTech, 2025; PV Knowhow, 2025).

3.4 Eswatini

Eswatini's renewable energy landscape is dominated by seasonal biomass generation and a growing solar PV sector. Utility-scale bioenergy stoker boiler systems have installed costs of USD 1,400–2,800/kW, while CFB boilers range from USD 1,300–2,200/kW. Biomass gasifiers, both fixed and fluidised bed, exhibit capital costs in the hundreds of millions to billions of USD for large plants, with substantial variability based on feedstock logistics and technology choice. Utility-scale solar PV projects are competitive, with CAPEX between USD 0.90–

1.10/W, as evidenced by recent developments and alignment with regional trends in South Africa (UNDP 2024; Biomass Electricity Prospects in eSwatini; 2022; Dabonn, 2025; Modern Intelligence, 2025)

4. Results

Comparative analysis reveals significant disparities in renewable energy project costs and financing environments across the four countries. Botswana and DRC display higher WACC and CAPEX values, reflecting risk premiums and infrastructural limitations. Ghana benefits from declining solar PV costs and diversified investment in wind and bioenergy, though project scale and technology selection remain critical. Eswatini's seasonal biomass generation and competitive solar PV costs highlight the importance of resource availability and policy support. Across all countries, integration of country-specific WACC into project cost modelling is essential for accurate assessment of local economic impacts, particularly in input-output frameworks such as I-JEDI.

5. Discussion

The findings underscore the pivotal role of financing costs in shaping the economics of renewable energy investments in African markets. Elevated WACC values in Botswana and DRC serve as barriers to cost reduction and market expansion, necessitating interventions such as concessional finance, policy stabilisation, and robust power purchase agreements (PPAs). Ghana and Eswatini illustrate the benefits of targeted development support and infrastructure upgrades, which can lower investment risk and attract private capital. The methodology of integrating WACC into project cost inputs enhances the fidelity of economic modelling and supports more informed policy and investment decisions. Future research should focus on dynamic modelling of WACC in response to evolving market and policy conditions, as well as granular analysis of soft costs and local content requirements.

6. Conclusion

This research demonstrates the necessity of systematically embedding country-specific WACC into renewable energy project cost modelling for African energy markets. Variations in CAPEX, OPEX, and LCOE across Botswana, Ghana, DRC, and Eswatini reflect the heterogeneity of financial environments and infrastructural contexts. Accurate representation of financing costs in input-output models such as I-JEDI is imperative for evaluating local economic benefits and guiding effective policy and investment strategies. The study recommends continued refinement of WACC estimation methodologies and expanded data collection to support robust economic analysis of renewable energy investments in emerging markets.

7. References

UNDP (2024). ESWATINI JUST ENERGY TRANSITION | A PEOPLE CENTRED APPROACH. [ONLINE] UNDP. AVAILABLE AT: HTTPS://WWW.UNDP.ORG/SITES/G/FILES/ZSKGKE326/FILES/2024-12/A_PEOPLE-CENTRED_APPROACH.PDF [ACCESSED 24 DEC. 24AD].

BIOMASS ELECTRICITY PROSPECTS IN ESWATINI AND PRELIMINARY RESULTS OF LULUCF GHG INVENTORY UPDATE FOR ESWATINI: WORKSHOP REPORT (7-8 APRIL 2022). (N.D.). AVAILABLE AT: HTTPS://CLIMATEACTIONTRANSPARENCY.ORG/WP-CONTENT/UPLOADS/2022/05/ESWATINI_OUTPUT-R.PDF [ACCESSED 24 DEC. 2025].

DABONN.COM. (2025). HOW MUCH DOES A BIOMASS BOILER COST? BIOMASS BOILER PRICE 2025 - DABONN. [ONLINE] AVAILABLE AT: HTTPS://WWW.DABONN.COM/NEWS/BLOG/25.HTML [ACCESSED 24 DEC. 2025]

MORDORINTELLIGENCE (2025). MALTA RENEWABLE ENERGY: NEW SCHEME FOR SOLAR & WIND GRANTS. [ONLINE] AVAILABLE AT: HTTPS://WWW.PVKNOWHOW.COM/SOLAR-REPORT/ESWATINI/HTTPS://WWW.MORDORINTELLIGENCE.COM/INDUSTRY-REPORTS/BOTSWANA-RENEWABLE-ENERGY-MARKET. [ACCESSED 24 DEC. 2025].

SOLARTECH. (2025). WIND TURBINE COST GUIDE 2025: COMPLETE PRICING BREAKDOWN ($700-$20M+). [ONLINE] AVAILABLE AT: HTTPS://SOLARTECHONLINE.COM/BLOG/WIND-TURBINE-COST-GUIDE-2025/.

PVKNOWHOW. (2025). CEC'S $500M DRC SOLAR PROJECT TO BOOST REGIONAL ENERGY. [ONLINE] AVAILABLE AT: HTTPS://WWW.PVKNOWHOW.COM/NEWS/DRC-SOLAR-INVESTMENT-500-MILLION-EXPANSION/ [ACCESSED 24 DEC. 2025].

TAISHAN GROUP. (2025). HOW MUCH DOES A CIRCULATING FLUIDIZED BED (CFB) BOILER COST? [ONLINE] AVAILABLE AT: HTTPS://COALBIOMASSBOILER.COM/CIRCULATING-FLUIDIZED-BED-BOILER-COST/ [ACCESSED 24 DEC. 2025].

SYLVESTER KOSI MAWUSI, SHRESTHA, P., CHEN, X. AND LIU, G. (2023). A COMPREHENSIVE REVIEW OF THE PRODUCTION, ADOPTION AND SUSTAINED USE OF BIOMASS PELLETS IN GHANA. HELIYON, 9(6), PP.E16416–E16416. DOI:HTTPS://DOI.ORG/10.1016/J.HELIYON.2023.E16416.

OHENE ADU, R. AND LOHMUELLER, R. (2012). THE USE OF ORGANIC WASTE AS AN ECO-EFFICIENT ENERGY SOURCE IN GHANA. JOURNAL OF ENVIRONMENTAL PROTECTION, 03(07), PP.553–562. DOI:HTTPS://DOI.ORG/10.4236/JEP.2012.37066.

POWER TECHNOLOGY. (N.D.). AYITEPA WIND FARM. [ONLINE] AVAILABLE AT: HTTPS://WWW.POWER-TECHNOLOGY.COM/PROJECTS/AYITEPA-WIND-FARM/.

GLOBAL-CLIMATESCOPE.ORG. (2025). CLIMATESCOPE 2025 | GHANA. [ONLINE] AVAILABLE AT: HTTPS://WWW.GLOBAL-CLIMATESCOPE.ORG/MARKETS/GHANA.

AGARWAL, A. (2024). GHANA. [ONLINE] PVKNOWHOW. AVAILABLE AT: HTTPS://WWW.PVKNOWHOW.COM/SOLAR-REPORT/GHANA/.

ROMAIN AKPAHOU, FLAVIO ODOI-YORKE AND LOUIS KWASI OSEI (2023). TECHNO-ECONOMIC ANALYSIS OF A UTILITY-SCALE GRID-TIED SOLAR PHOTOVOLTAIC SYSTEM IN BENIN REPUBLIC. CLEANER ENGINEERING AND TECHNOLOGY, 13, PP.100633–100633. DOI:HTTPS://DOI.ORG/10.1016/J.CLET.2023.100633.