RENEWABLE ENERGY CONSUMPTION AND HUMAN DEVELOPMENT IN AFRICA: A Disaggregated Analysis

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ABSTRACT

This study examined the effect of total renewable energy (RENG) consumption and specific forms of RENG, mainly renewable electricity and access to clean fuels and cooking technologies, on the human development index (HDI) in Africa over the period 2011-2023. The results are shown using the System Generalised Method of Moments (SGMM) to account for endogeneity concerns and the Prais-Winsten Panel corrected standard error for a robustness check of the estimates. Findings show a negative effect of total RENG consumption on HDI. Renewable electricity had no significant effect on HDI. The results reveal a significant positive effect of access to clean fuels and technology (ACFT) on HDI. Based on the findings of the study, efforts that promote ACFT will induce significant progress in reaching higher HDI values in Africa and this should be a key focus of policy initiatives in the region.

Keywords: RENG, Human Development Index, system GMM, Prais-Winsten regression.

JEL classification: O15, Q43

1. Introduction

Human development is central to attaining economic growth and social progress (Nguyen et al. 2023; Olopade et al. 2020). Estimates for human development are generally lower in Africa than global figures (Lekana & Ikiemi, 2021; UNDP, 2015). For instance, HDI estimates for the sub-Saharan African region were 0.549 in 2020, dropped slightly to 0.547 in 2021, and as of 2022 increased marginally to 0.549. This statistic is low compared to the global average of 0.735 in 2020, 0.732 in 2021, and 0.739 in 2022 (United Nations, 2025).

Energy poverty is considered a major constraint to reaching human development targets. Improving energy access and usage, especially from renewable sources, is vital for sustainable development. The deprivation in renewable energy (RENG) energy consumption and usage is identified as a major obstacle to achieving the SDGs, primarily human development by 2030 (United Nations, 2025). Interestingly, Africa is known for low energy demand, particularly RENG. The region is identified with the world's lowest levels of per capita use of modern energy (IEA, 2022). The statistics for energy poverty show that as at 2022, approximately 43% of the global population lacked access to electricity, and the majority of these persons lived in sub-Saharan Africa. In addition, about 970 million Africans lack access to clean cooking technologies (IEA, 2022). These figures indicate disproportional use of energy, especially RENG, in Africa relative to other parts of the globe (IEA, 2022).

There are further arguments for low levels of human development in Africa. One of these is that Africa accounts for less than 3% of the world's energy-related carbon dioxide (CO_2) emissions and yet experiences disproportionate negative effects of climate change, such as increased extreme weather conditions, as well as reduced water supply and food production (IEA, 2022). This in turn drags down the existing low level of human development and economic performance in the region. Another position follows from the high fertility rate in the region, leading to an increase in population growth, requiring a higher level of energy use. In the bid to harness the benefits of high population growth and reach sustainable development targets, the use of modern or otherwise RENG comes to the fore. This is because RENG has the potential to dampen the negative effects of carbon and other environmental pollutants by reducing energy use from fossil fuel consumption. The after-effects are improved public health, learning opportunities, labour income, and all components of wellbeing that are captured in the HDI (Lekana & Ikiemi, 2021; Chiroleu-Assouline, 2001).

Empirical studies of the effect of RENG on HDI exist, though with inconclusive outcomes (Wang et al. 2018; Akbar et al. 2020; Wang et al. 2021; Hashemizadeh et al. 2022; Azam et al. 2023; Kaewnern et al. 2023; Lorente et al. 2024; Pham et al. 2024). While some studies have shown a unidirectional relationship between RE and HDI (Akbar et al. 2020; Kaewnern et al. 2023; Lorente et al. 2024), others found a bidirectional relationship (Wang et al. 2018; Hashemizadeh et al. 2022; Sasmaz et al. 2020; Wang et al. 2021; Azam et al. 2023; Pham et al. 2024), and for some studies, no significant effect of RENG on HDI was observed (Zheng & Wang, 2022). Furthermore, studies on this subject often focus on one form of RENG leaving a gap for exploring the effect of several types of RENG on HDI (Musakwa & Odhiambo, 2022; Ray et al. 2016; Wang et al. 2018). Finding out the effects of different forms of RENG on HDI is important, to determine which has a stronger or more desirable effect on HDI. The evidence in this regard is imperative, especially in Africa, where there is high energy poverty and the need for sustainable fiscal support to provide the most beneficial energy sources (IEF, 2024). This paper fills the identified gap in the literature by providing empirical evidence of the effect of RENG on human development in Africa, using specific forms of RENG and econometric techniques that ensure reliability and consistency of the estimates.

The paper adds to the literature on RENG use and human development in Africa in three ways. First, it provides further evidence on the role of RENG on human development for which there are inconclusive findings in the extant literature. Second, the study provides evidence of the effects of different forms of RENG on human development in Africa. This is necessary given the fiscal constraints to the provision of modern energy along with low human development statistics in the region (UNDP, 2024a; UNDP, 2024b). Third is that the study makes use of rigorous econometric techniques that are not commonly applied in studies of this type, especially using data from developing economies, to obtain consistent and reliable estimates. The results are shown using the System Generalized Method of Moments (SGMM) to account for endogeneity concerns between RENG and HDI. Findings are further shown using the Prais-Winsten regression, with panel-corrected standard errors (PCSE-PW) for a robustness check of the estimates. The PCSE-PW provides consistent and reliable estimates by accounting for cross-sectional dependence and heterogeneous slopes that often characterize panel data.

2. Review of Literature

The literature reveals mixed findings on the association between RENG consumption (RECONS) and human development in both developed and developing economies. In developed countries, the general trend links improvements in human development with RENG consumption. However, evidence from developing economies is inconclusive.

In a study conducted by Wang et al. (2018), the relationship between RENG consumption, economic growth, and the human development index (HDI) in Pakistan was examined over the period 1990 to 2014. The results, analysed using the two-stage least squares (2SLS) method, indicated a negative effect of RENG consumption on human development in Pakistan.

In another study, Musakwa and Odhiambo (2022) analysed data from South Africa for the years 1990 to 2019 to explore the impact of energy consumption on human development using both aggregate and disaggregated energy measures. The Auto Regressive Distributed Lag (ARDL) model was employed for estimation. The findings revealed a significant positive effect of RENG on human development, but only in the short run. When oil products, natural gas, and total energy were used as proxies for energy, a negative impact on HDI was observed, again only in the short run. These results suggest that the positive impact of RENG on human development is not substantial enough to offset the negative effects of other energy sources.

Ergun et al. (2019), using data from 21 African countries and a random effect generalized least squares regression, found that higher HDI and GDP per capita were associated with a lower share of RENG in the national energy grid. This indicates that even small amounts of RENG use can have a significant effect on human development and economic output.

Maji (2019), examined the role of RENG consumption on economic growth in 15 West African countries between 1995 and 2014, using the panel dynamic ordinary least squares (DOLS) method. The results showed that RENG consumption slowed down economic growth in these countries. This was attributed to the predominant use of wood biomass as an RENG source, which is often unclean and highly polluting when burned. Consequently, the use of inefficient RENG sources can reduce productivity and negatively affect human development.

Amer (2020) explored the relationship between energy consumption and human development in countries with varying income groups from 1990 to 2015. The results, based on panel vector autoregressive analysis and SGMM, reveal an insignificant effect of RENG on HDI, except in lower-middle-income countries, where a significant negative effect was observed. The negative impact of RENG on human development was explained by the high installation costs and the time lag before positive effects materialize.

Lekana and Ikiemi (2021) examined the effect of energy consumption on human development in countries of the Economic and Monetary Community of Central Africa (EMCCA), specifically using data from Cameroon, Congo, and Gabon over the period 1990 to 2019, employing the Driscoll-Kraay technique. Their results show that RENG consumption had a positive but insignificant effect on human development.

In another study, Azam et al. (2021) analysed the effects of ICT, RENG, and economic growth on HDI in 30 developing economies from 1990 to 2017, using a panel vector autoregressive model. The findings show a significant effect of RENG on HDI, as well as a bidirectional relationship between these variables.

Zheng and Wang (2022), using data from 26 countries between 2000 and 2018, adopted a different approach by examining both the direct effect of RENG consumption on human development and its interaction with ICT. The results show an insignificant effect of RENG on HDI, except when it interacts with ICT.

Acheampong et al. (2023) investigated the effects of access to electricity and clean energy on human development in 79 energy-poor countries from South Asia, sub-Saharan Africa, and the Caribbean-Latin America over the period 1990–2018, using the Lewbel two-stage least squares method. Their findings indicate that while access to electricity and clean energy improved human development in the Caribbean-Latin America, and sub-Saharan Africa, it worsened human development in South Asia.

Adekoya et al. (2021) examined the impact of RENG consumption and carbon emissions on human development in 126 countries between 2000 and 2014, divided by region. The results, based on fixed effects models, revealed heterogeneous effects of RENG across regions. A negative effect was observed in the Middle East and North Africa (MENA), Central America, and the Caribbean, while a significant positive effect was seen in European countries. In sub-Saharan Africa, the effect was insignificant.

Nguyen et al. (2023) examined the role of RENG on human development using data from 77 countries, grouped into high and middle-income categories, from 2000 to 2019. The evidence, provided using the PCSE model, revealed a positive association between RENG and human development across all countries. However, the effect varied between high- and middle-income countries.

Hmida and Rey (2023) explored the impact of RENG on human development using data from 44 countries representing energy-poor regions between 1990 and 2018. The results, obtained using the ARDL model, showed a positive and significant relationship between electricity access and human development in countries with low and medium HDI, as well as a positive effect of modern RENG on the level of human development in countries with higher HDI. However, the use of conventional RENG was associated with a significant negative effect on human development in the overall sample.

Azam et al. (2023) examined the effects of RENG consumption on human development in eight Asian countries using data from 1995 to 2018. The results, based on the fully modified ordinary least squares and fixed-effects estimators, show that RENG had substantial positive impacts on human development in Asia.

Pham et al. (2024) investigated the heterogeneous effects of renewable and non-RENG consumption on human development in seven countries, from 1991 to 2015. The findings, based on the method of moments panel quantile regression, showed heterogeneous effects of renewable and non-RENG on human development across all income quintiles, with a bidirectional causal relationship between energy consumption, both renewable and non-renewable, and HDI.

A recent study by Djoudji and Nguea (2025) examined the effects of energy vulnerability on HDI, infant and under-five mortality, life expectancy, and human capital in 27 African countries over the period 2000–2019. The study used the Driscoll-Kraay standard errors, the GMM, and panel quantile regression methods. The findings indicate a negative effect of energy vulnerability, including RENG, on HDI.

In developed economies, the evidence generally indicates a positive effect of RENG consumption on human development. For instance, Wang et al. (2021) studied the role of RENG on human development in BRICS countries from 1990 to 2016, using the Westerlund panel cointegration test, Driscoll-Kraay robust standard errors, and Dumitrescu-Hurlin causality tests. The results show a significant positive effect of RENG on human development, although this effect turned negative when RENG interacted with public debt. The study also established bidirectional causality between RENG and human development.

In a related study, Sasmaz et al. (2020) explored the relationship between RENG and human development in 28 OECD countries from 1990 to 2017, using the Westerlund and Edgerton panel cointegration test with structural breaks and the Dumitrescu and Hurlin causality test. The results revealed positive effects of RENG on human development, with bidirectional causality between the variables.

Bilgili and Baglitas (2022) investigated the role of RENG sources in the economic, environmental, and social dimensions of sustainable development in OECD countries between 1995 and 2015. Their findings, obtained using the GMM estimators, linked improvements in human development to RENG consumption. The study also showed that RENG sources improve environmental quality by reducing carbon emissions.

Hashemizadeh et al. (2022) examined the effects of RENG and non-RENG consumption on human development in G-7 countries from 1990 to 2015. The results, based on cointegration tests, Dumitrescu-Hurlin causality tests, and continuously updated fully-modified estimators, revealed that both RENG and non-RENG contribute to human development, with the effect of RENG being more significant than that of non-RENG.

Kaewnern et al. (2023) studied the impact of economic growth, RENG consumption, research and development expenditure, and natural resource rents on HDI in the top ten human development countries from 1996 to 2007. The study used the Driscoll-Kraay, feasible generalized least squares (FGLS), and the GMM techniques. Their findings indicate a positive effect of RENG consumption on HDI and identify a unidirectional causality between HDI and RENG consumption.

Alavijeh et al. (2024) examined the asymmetric roles of RENG, carbon emissions, output growth, and urbanization on HDI in European countries from 2000 to 2019. The results suggest that RENG consumption generally improved HDI, except at the highest quantiles.

Overall, studies provide mixed conclusions regarding the role of RENG consumption on HDI, particularly in developing economies. There is also limited research on the effects of various forms of RENG on HDI. These findings are particularly important for Africa, where HDI values are low, along with high poverty rates and low fiscal capacity that limit access to RENG.

3. Method

3.1 Empirical model specification

The theoretical framework of this study is based on Sen's capability approach (Sen, 1993; Sen, 2001; Sen, 2002; Sen, 2004), which emphasizes the drivers of human development beyond traditional measures. These drivers include investments in social services, infrastructure, and improvements in institutional frameworks. The study uses the human development index (HDI) as a measure of human development. Based on data availability, the forms of RENG examined include RENG consumption (RECONS) as a percentage of total final energy consumption, renewable electricity output as a percentage of total electricity output, and access to clean fuels and technologies (ACFT) for cooking as a percentage of the population. In line with existing literature, the control variables considered in this study include real gross domestic product (RGDP), population growth, greenhouse gas emissions, fertility rate, labour force participation, and inflation rate (Musakwa & Odhiambo, 2022; UNDP, 2015). The empirical model for this study is thus formulated as:

$$HDI_{it} = \alpha + \theta REN_{it} + \rho X_{it} + \varepsilon_{it}, \qquad (1)$$

where i = 1, 2, . . . , N represents country cross-sections, and t = 1, 2, . . . , T symbolizes the time-series index. HDI captures the human development index, REN is a vector of RENG forms, X represents a vector of the control variables and the error term is represented by ε.

3.2 Estimation technique

Some studies indicate a bi-directional relationship between RENG consumption and the human development index (HDI), suggesting the existence of endogeneity between the variables (Wang et al. 2018; Hashemizadeh et al. 2022; Sasmaz et al. 2020; Wang et al. 2021; Azam et al. 2023; Pham et al. 2024). To obtain unbiased estimates, therefore, we employed the SGMM estimation technique to address endogeneity concerns between RENG and HDI. A similar approach was used by Bilgili and Baglitas (2022) to examine the relationship between energy use and HDI. The SGMM developed by Arellano and Bover (1995) provides consistent solutions for endogeneity, particularly in studies with a large number of countries relative to the time period. The method provides efficient estimates under the problems of endogeneity, omitted-variable bias, measurement errors, and heteroscedastic residuals (Bilgili & Baglitas, 2022). To ensure the robustness of our findings, we also made use of the PCSE-PW. This approach addresses the limitations of SGMM and provides robust estimates in the presence of multicollinearity, unobserved country fixed effects, and endogeneity. Not many studies have made use of the PCSE-PW to examine the effect of RENG on HDI.

3.3 Data sources

Data for the study was obtained from the World Development Indicators provided by the World Bank and the UN Human Development Report 23/24.

Data was obtained for the period 2011 to 2023, and across 54 African countries (World Bank, 2024a; UNDP, 2024c).

4. Results and Discussion

Table 1 presents the summary statistics for the variables used in this study. The average human development index (HDI) is 0.55, which places it at the lower end of the medium human development category (UNDP, 2024d). The average RENG consumption as a percentage of total energy consumption is approximately 56%, indicating that more than half of the energy use in the region comes from renewable sources. However, renewable electricity production accounts for about 39% of total electricity output, suggesting that over half of electricity production relies on non-renewable sources. This suggests that the African region still depends heavily on non-RENG for electricity generation.

Access to clean fuels and technologies (ACFT) for cooking is approximately 28% of the total population, indicating that many households in the region still rely on non-clean energy sources for cooking. The real gross domestic product (GDP) during the study period is approximately $12,500 billion, with a population growth rate of about 3%. This growth rate is significantly higher than the global annual population growth rate of 0.8% in 2022 (World Bank, 2024b).

The average total greenhouse gas emissions are around 54,412 kilo tonnes of CO2 equivalent. The fertility rate averages about 4 births per woman, which is notably high compared to the global average of 2 births per woman in 2022 (World Bank, 2024c). Labour force participation for the population aged 15 and older is approximately 61%, suggesting that more than half of the population is part of the labour force. However, most employment in the region is informal, often associated with low earnings (ILO, 2022). The average inflation rate is approximately 11%, indicating a decline in the value of local currencies in the region. Finally, the index for the control of corruption averaged around -0.66, reflecting poor governance in terms of corruption control, as indicated by the negative value of the index (Kaufmann et al. 1999).

Table 1: Summary Statistics

Variable	Obs	Mean	Std. dev.	Min	Max
HDI	637	0.547713	0.104472	0.344	0.808
Ren_Total	563	57.75584	27.0006	0.06	97.03
Ren_Elec	270	38.48895	23.12391	0	100
Cleanfuel_	583	27.98859	30.8015	0	100
RGDP	626	1.25E+13	2.67E+13	2.92E+09	1.67E+14
Pop_growth	648	2.263708	0.987604	-5.28008	5.298815
TotGreengas	540	54412.12	83130.14	126.2041	555409.3
FR	594	4.358874	1.173062	1.36	7.449
LFP	636	61.19286	12.01979	30.751	86.449
Inflation	587	10.61367	32.88863	-6.68732	557.2018
CC	594	-0.65442	0.603754	-1.91646	1.633352

Source: Authors' computation from World Bank (2024a) and the United Nations (2024c)

Table 2 presents the pairwise correlation analysis to assess the existence of multicollinearity among the variables. While some correlation coefficients are statistically significant at the 5% level, none of the variables show high levels of correlation. This suggests that there is no perfect linear relationship among them, as all correlation statistics are below 80%, which would be a cause for concern.

Before estimating the Prais-Winsten regression with panel-corrected standard errors (PCSE-PW) for the robustness check, we first conducted tests for cross-sectional dependence (CSD), stationarity, and cointegration (Baltagi & Pesaran, 2007). The result of the CSD test is shown in Table 3. Findings indicate the presence of CSD, as the null hypothesis is rejected at the 1%, 5%, and 10% significance levels for all variables except for the control of corruption. This suggests that countries in the region experience transmission of shocks for all variables, except for the control of corruption.

The panel unit root test result is also shown in Table 3. The findings are shown using a second-generation unit root test and reveal that most of the variables are stationary at either level or first difference, except for the human development index (HDI) and labour force participation (LFP), which did not demonstrate any form of stationarity at the considered levels. Regarding cointegration, the Westerlund cointegration test shows the existence of a cointegrating relationship among the variables across certain panels, leading to the rejection of the null hypothesis of no cointegration at the 5% level.

Table 2: Correlation Matrix

	HDI	Ren_energt	Ren_Elec	Cleanfuel_~g	LnRGDP	Pop_grwth	TotGreengas	FR	LFP	Infation	CC
HDI											
Ren_Total	-0.6394*	1.000									
Ren_Elec	-0.1639*	0.3282*	1.000								
Cleanfuel_	0.7754*	-0.6960*	-0.1871*	1.000							
LnRGDP	-0.1698*	0.2707*	0.044	-0.1783*	1.000						
Pop_growth	-0.4168*	0.4345*	0.1004*	-0.4093*	0.3215*	1.000					
LnTotgreen	0.0559*	-0.0050*	0.0931*	0.1451*	0.4650*	0.1412	1.0000				
FR	-0.7113*	0.6590*	0.1434*	-0.7198*	0.3406*	0.6458*	-0.1486*	1.000			
LFP	-0.4151*	0.4427*	0.2715*	-0.3977*	0.1416*	0.2257*	-0.1099*	0.3078*	1.000		
Inflation	-0.069	0.023	0.023	-0.021	-0.0802*	-0.1125*	0.019	0.007	0.026	1.0000	
CC	0.4045*	-0.4038*	-0.0818*	0.4580*	-0.2922*	-0.3083*	-0.042	-0.5652*	-0.0802*	-0.1649*	1.0000

Source: Authors' computation, (2024)

Note: * indicates statistical significance at 5%

Table 3: Pre-estimation check

Variable	CSD Statistics	PESCADF		Westerlund
		Level	1st Diff.	
HDI	32.586***	12.811	5.0273	
Ren_Total	3.37***	7.757	-10.641***	-9.185***
Ren_Elec	-1.755*	-0.336	-10.596***	-4.345***
Cleanfuel	12.651***	7.317	-9.660***	-3.500***
RGDP	53.063***	-1.516*	8.000	-4.183***
Pop_growth	16.371***	1.881	-2.093**	-7.395***
LnTotgreen	33.486 ***	7.302	-10.003***	-9.908***
FR	39.857***	9.020	-9.788***	-3.886***
LFP	2.352**	5.924	5.971	-18.407***
Inflation	35.537***	-4.268***	-9.057***	-4.494 ***
CC	-1.413	3.238	-9.936***	-33.231***

Source: Authors Computation, (2024)

Notes: ***, **,* indicate statistical significance at the 1%, 5% and 10% level CSD-Cross sectional dependence; PESCADF = Pesaran cross-sectional augmented Dickey-Fuller CSD Statistics under the null hypothesis of cross-section independence, CD ~ N(0,1) P values close to zero indicate data are correlated across panel groups.

The SGMM estimates for the disaggregated effects of RENG use on HDI are presented in Table 4. Among the categories of RENG considered in the study, only total RECONS and ACFT for cooking showed significant effects on HDI. Notably, total RECONS as a percentage of total final energy consumption had a significant negative impact on HDI. The results indicate that a 1% increase in the percentage of RECONS in total final energy use in the region leads to a 0.001 decrease in HDI. This finding is unexpected, as RENG use generally promotes well-being by reducing environmental pollution. The results, however, suggest that RENG use can be detrimental to HDI. The evidence provided by IRENA (2021) shows that Africa accounts for only about 3% of the world's installed renewable-based electricity generation capacity despite the large resource potential in the region. The results are also in line with findings by Musakwa and Odhiambo (2022) and Osakede et al. (2025), showing that RENG use in Africa is not sufficient to dampen the negative effects of other energy sources on human development. In addition, previous studies have highlighted the negative effects of RENG use on well-being, such as eyesight hazards from solar energy reflectors, population displacement due to dam construction for hydropower, ecological disruptions, flooding of natural environments, and the migration of aquatic animals that are vital for livelihoods and food supplies (Patel & Shrivastava, 2009; Haines et al. 2007; Owusu & Asumadu-Sarkodie, 2016; Capellán-Pérez et al. 2017). These factors underscore the potential adverse impacts of RENG on well-being, and mitigating these harmful effects should be a priority in the region. Similar results were found by Wang et al. (2018) in Pakistan and Adekoya et al. (2021) in the MENA, Central America, and Caribbean regions.

The results also indicate that ACFT for cooking, as a percentage of the population, has an expected positive effect on the HDI. Specifically, a 1% increase in ACFT for cooking leads to a 0.001% rise in the HDI, highlighting the critical role that cooking energy sources play in well-being. The UNDP (2024b) reports that air pollution is responsible for one in five deaths globally. Transitioning from fossil fuels and biomass cooking to clean energy sources can therefore reduce mortality rates and prevent illnesses caused by environmental pollution (UNDP, 2024b). Moreover, clean energy transition enhances well-being by lowering energy demand and freeing up resources for other investments, such as health and education. Thus, ACFT for cooking emerges as a key driver of environmental quality improvement, which in turn positively impacts the HDI.

Additionally, the findings reveal that the fertility rate and inflation rate have significant negative effects on the HDI. Specifically, an increase in the birth rate by one child results in a 0.032 reduction in the HDI. This is expected, as larger families typically have fewer resources across members for essential components of well-being, such as health, education, and consumption, which ultimately hinders HDI improvement. A similar finding was reported by Osakede et al. (2023) using data from African economies disaggregated into country income groups. Furthermore, the results indicate that a 1% increase in the inflation rate decreases the HDI by 0.0001. A steady rise in prices reduces effective demand for goods and services, which negatively affects well-being.

Table 4: SGMM Regression Estimates

Dependent variable: HDI

Variables	SGMM Estimates
L.HDI	0.427
	(0.279)
Ren_Total	-0.001**
	(0.000)
Ren_Elec	-0.001
	(0.001)
Cleanfuel	0.001***
	(0.000)
LnRGDP	0.001
	(0.003)
Pop_growth	-0.042
	(0.026)
LnTotgreen	-0.000
	(0.001)
FR	-0.032*
	(0.017)
LFP	-0.001
	(0.001)
Inflation	-0.0001**
	(0.000)
CC	0.011
	(0.013)
Constant	0.344*
	(0.185)
Model Summary	
Observations	648
Number of ID	54
Hansen_test	31.55
Hansen Prob	0.002
Sargan_test	64.24
Sargan Prob	3.77e-09

Variables	SGMM Estimates
AR(1)_test	-3.476
AR(1)_P-value	0.0005
AR(2)_test	-1.054
AR(2)_P-value	0.292
No. of Instruments	23

Note: ***, **, * indicate statistical significance at the 1%, 5% and 10% levels.
Source: Authors' computation (2024).

The findings for the PCSE-PW model are presented in Table 5. Column 1 displays the results for the panel-level heteroscedastic regression with correlated errors across panels (Panel-specific AR(1)), while column 2 shows the results for a panel-level heteroscedastic regression with independent errors across panels (AR(1)). Column 3 presents the results for a panel-level heteroscedastic regression with correlated errors across panels but without autocorrelation. These results are reported to examine the estimates under varying levels of heteroscedasticity and correlation across panels, allowing us to assess the consistency of the findings.

As noted in the SGMM model, only RECONS and ACFT significantly impact the HDI. In columns 2 and 3 of the PCSE-PW results, a 1% increase in RENG use results in a 0.0003 approximate decline in the HDI. This outcome can be linked to the potential negative effects of RENG use on well-being, particularly concerning health and the quality of agricultural products (Patel & Shrivastava, 2009; Haines et al. 2007; Owusu & Asumadu-Sarkodie, 2016; Capellán-Pérez et al. 2017).

As observed in the SGMM model, ACFT for cooking positively influences the HDI. Across columns 1-3, findings indicate that a 1% increase in ACFT for cooking raises the HDI by approximately 0.001, reinforcing the importance of cooking energy sources on air quality and well-being (UNDP, 2024c).

The results also reveal that population growth negatively affects the HDI in the region. In columns 1-3, a 1% increase in annual population is associated with a 0.02 approximate reduction in the HDI. This suggests that rising population sizes hinder well-being by limiting access to resources and straining fiscal capacities in health and education (UNDP, 2015; Osakede & Adeleke, 2022).

Table 5: PCSE-PW Regression Results

Dependent variable: HDI

Variables	(1)	(2)	(3)
Ren_Total	-0.0001	-0.0003**	-0.0003**
	(0.0002)	(0.0001)	(0.0001)
Ren_Elec	-4.46e-05	-2.48e-05	9.90e-05
	(9.47e-05)	(0.0001)	(0.0001)
Cleanfuel	0.0012***	0.0009***	0.0016***
	(0.0002)	(0.0002)	(0.0001)
LnRGDP	-8.57e-05	-0.0018	0.0016
	(0.0013)	(0.0011)	(0.0010)
Pop_growth	-0.0181***	-0.0168***	0.0020
	(0.0057)	(0.0027)	(0.0031)
LnTotgreen	0.0022	0.0034*	0.0001
	(0.0014)	(0.0020)	(0.0019)
FR	-0.0183***	-0.0100**	-0.0299***
	(0.0053)	(0.0042)	(0.0037)
LFP	-0.0024***	-0.0019***	-0.0010***
	(0.0003)	(0.0003)	(0.0002)
Inflation	-3.82e-05	-5.01e-05	-0.0002**
	(4.20e-05)	(4.84e-05)	(7.17e-05)
CC	-0.0010	-0.0027	-0.0039
	(0.0052)	(0.0059)	(0.0050)
Constant	0.780***	0.754***	0.649***
	(0.0472)	(0.0370)	(0.0290)
Model Summary			
Observations	702	702	702
R-squared	0.971	0.756	0.670
Number of ID	54	54	54

Note: ***, **, * indicate statistical significance at the 1%, 5% and 10% level

Source: Authors' computation (2024).

Total greenhouse gas emissions are shown to improve the HDI, with significant effects observed only in column 2. Specifically, an increase of 1 kiloton in greenhouse gas emissions raises the HDI by 0.003. This finding is unexpected as poor air quality is typically linked to negative health outcomes and cognitive impairments (Hu et al. 2022). However, it may reflect the notion that increased energy use drives industrialization and income growth, even when fossil fuels that emit greenhouse gases are involved.

Additionally, findings across columns 1-3 indicate that an increase in the labour force participation rate negatively affects the HDI. This result is unexpected and may be related to the high levels of informal sector employment in Africa, which are associated with low and irregular incomes and limited access to social insurance, typically available to those in the formal labour market (UNDP, 2021).

In column 3, a negative effect of the inflation rate on the HDI is also reported. Specifically, a 1% increase in the inflation rate leads to a 0.0002 reduction in the HDI. This finding aligns with expectations as rising living costs diminish real income and access to basic necessities. A similar result was noted by Tripathi (2019) in a cross-country study examining the role of urbanization on the HDI.

5. Conclusion

This study investigates the effect of disaggregated forms of RENG use on the HDI in Africa, where energy poverty and low fiscal capacity are prevalent. The aim is to identify the RENG form that is most beneficial to the region.

The analysis includes total RENG as a percentage of total final energy consumption, renewable electricity as a percentage of total electricity output, and access to clean fuels and technologies (ACFT) for cooking as a percentage of the population. Data for the study covers all 54 African countries over the period 2011 to 2023. Findings are shown using the SGMM and the PCSE-PW.

The results indicate that only total RENG consumption and ACFT for cooking significantly affect the HDI. Specifically, ACFT for cooking has a significant positive effect on the HDI, while total RENG use shows a nonpositive effect. These results are consistent across both the SGMM and PCSE-PW models.

Findings for the control variables show negative effects of fertility and inflation rates on the HDI, with population growth also negatively impacting the HDI.

Based on the study's findings, policy efforts should focus on promoting modern energy use while mitigating harmful side effects such as eyesight hazards, ecological disruptions, flooding, and the migration of aquatic animals that are vital for livelihoods and food security. Additionally, increasing ACFT for cooking is crucial, as it enhances the HDI by improving ambient air quality, which translates into better health, cognitive function, increased labour income and consumption, that are key components of the HDI.

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