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Energy Poverty and Social Well-Being in North Africa: Between Environmental Degradation and Green Investment

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ABSTRACT

This article examines the impact of energy poverty on social well-being in North Africa over the period 2000-2022, incorporating a dual approach: on the one hand, the mediating role of environmental degradation and, on the other, the moderating effect of green investment. Through an empirical analysis based on macroeconomic data, our results show that energy poverty exerts a significant negative influence on social well-being, mainly by exacerbating inequalities in access to essential services. Environmental degradation appears to be a channel aggravating this relationship, illustrating how energy insufficiency contributes to altered living conditions. However, green investment partially mitigates this negative effect, although its effectiveness remains conditional on the implementation of inclusive policies. These results underline the importance of a balanced energy transition, combining a reduction in energy poverty with a sustainable investment strategy to improve social well-being in the region.

Keywords: Energy Poverty, Social Well-being, North Africa, Green Investment, Environmental Degradation, Energy Transition
JEL Classifications: I31, Q5

1. INTRODUCTION

The United Nations Millennium Development Goals (MDGs) did not explicitly include access to energy as a central lever for development, although its role is decisive in achieving many other global priorities, such as improving health and education services (El-Katiri, 2014) However, the gradual recognition of energy poverty by governments and international organizations has led to its inclusion in the Sustainable Development Goals (SDGs), notably in SDG 7, which aims to “ensure universal access to modern, affordable, reliable and sustainable energy by 2030” (Zhang et al., 2021).

This ambitious goal implies not only universal electrification and access to non-polluting cooking methods, but also a doubling of the rate of improvement in energy efficiency and a significant expansion in the share of renewable energies in the global energy mix. Beyond its environmental significance, the energy transition is also a determining factor for the well-being of populations, by reducing exposure to health risks linked to air pollution and facilitating access to quality health and education infrastructures (World Bank, 2024a).

In the context of North Africa, the transition to a green economy could play a decisive role in the fight against energy poverty. The massive adoption of renewable energies would not only reduce dependence on fossil fuels, but also improve environmental sustainability (Eckerberg et al., 2023; Abbasi et al., 2024). The widespread use of clean energy is thus part of a dual dynamic: on the one hand, it promotes economic growth by ensuring a stable and reliable energy supply; on the other, it contributes to reducing greenhouse gas emissions and combating climate change (Soto and Martinez-Cobas, 2025). Access to modern energy is therefore a sine qua non for sustainable development and socio-economic prosperity (IEA, 2017).

The concept of energy poverty is in line with Sen's (2000) capability theory, according to which deprivation of access to energy restricts fundamental freedoms and compromises people's ability to achieve a decent standard of living (Sen, 1983). This is not just a lack of material resources, but also a deficit in opportunities to satisfy basic needs (Pereira et al., 2011). González-Eguino (2015) identifies three fundamental determinants of energy poverty: limited or non-existent access to energy, poor quality of energy resources and infrastructure, and prohibitive cost of energy services. Although these factors are ubiquitous worldwide, they particularly affect vulnerable regions, especially rural areas in developing countries (Barnes, 2014).

Morocco's massive investment in renewable energy infrastructure is a prime example of this commitment to transition. With emblematic projects such as the Noor Ouarzazate solar complex, with a total capacity exceeding 500 MW, the country has positioned itself as a regional leader in clean energy (Benbba et al., 2024). Tunisia has also undertaken similar initiatives, such as the construction of solar photovoltaic power plants in Tozeur, but these infrastructures are still mainly intended to supply national grids and industrial zones, without necessarily meeting the needs of the most precarious populations.

Despite its status as a strategic region for the production and export of hydrocarbons, North Africa continues to face marked inequalities in access to energy. Many households, particularly in remote areas, continue to suffer from energy insecurity, which hampers their social well-being and economic development. This situation exacerbates disparities in health, education and living conditions, underlining the urgent need for a more inclusive approach to the energy transition.

Consequently, this research focuses on a central question: to what extent does multidimensional energy poverty influence the social well-being of North African inhabitants? Several sub-questions follow: (1) does environmental degradation play a mediating role in this relationship? (2) does green investment moderate the effect of energy poverty on social well-being?

This study contributes to the literature in several ways. Firstly, it proposes an integrated, multidimensional framework for measuring energy poverty in North African countries, enabling existing approaches to be refined. Secondly, it develops an innovative analytical model that examines the relationship between energy poverty and social well-being through the prism theory of Sen's capability (2000). Thirdly, by exploring the mediating effect of environmental degradation and the moderating effect of green investment, this study highlights the complex mechanisms by which energy poverty exacerbates negative externalities, weighing on people's quality of life.

Ultimately, this article aims to analyze the direct and indirect impacts of energy poverty on social well-being, taking into account environmental dynamics and green investment strategies. Through a rigorous empirical analysis, this research aims to enlighten decision-makers and investors on the most effective levers of action to reduce energy poverty, promote equal access to energy and strengthen collective well-being in a sustainable perspective.

The remainder of this article is structured as follows. the second section presents literature review and research hypotheses. The third section describes the methodology adopted, detailing the context of the study, the variables used, and the econometric methods employed. The fourth section presents the results obtained, while the fifth section offers an in-depth discussion. Finally, the last section concludes the study and makes strategic recommendations for an inclusive and sustainable energy transition.

2. LITERATURE REVIEW AND RESEARCH HYPOTHESIS

2.1. The Concept of Energy Poverty

The concept of energy poverty was introduced by Boardman (1991), who defines it as a situation where an individual's or household's energy expenditure exceeds 10% of their annual income. However, energy poverty goes far beyond this simple economic dimension. It also encompasses the inability to access modern energy services essential to daily life, such as home heating, lighting, the use of household appliances and mobility (Middlemiss et al., 2019; Okushima, 2016; Thomson et al., 2017). This issue is particularly acute in developing countries, where access to reliable and affordable energy remains a major challenge for vulnerable populations.

In a broader theoretical framework, energy poverty can be analyzed through the capability theory of Sen (2000), who argues that human well-being is multidimensional. For Sen, access to energy represents a vehicle for realizing "essential capabilities" such as health, education and the opportunity for a decent life. Modern energy thus becomes a fundamental technical capability that enables the realization of other social, economic and health capabilities (Acharya and Sadath, 2024). This approach suggests that eradicating energy poverty is not simply a question of access to energy, but an imperative for improving well-being collective, while contributing to the achievement of the Sustainable Development Goals (SDGs).

2.2. Impact of Energy Poverty on Social Well-being: Mediating Effect of Environmental Degradation

A review of the empirical literature leads us to distinguish two main dimensions of the impact of multidimensional energy poverty on social well-being: a direct impact and an indirect impact via the channel of environmental degradation.

On the one hand, the direct impact is manifested through its repercussions on health, education, employment and income, considered to be the pillars of social well-being in North African countries (ElSarawy, 2016; HCP, 2012; Tiliouine, 2015). Energy poverty leads to high exposure to pollutants from burning fossil fuels or traditional cooking stoves, increasing respiratory and cardiovascular diseases (Sovacool, 2012; Kose, 2019). Several studies in Africa and Asia (Ngounou et al., 2025; Iddrisu et al., 2024; Pondie et al., 2024) confirm that lack of access to clean energy leads to increased healthcare expenditure, a trend observed in Ghana, sub-Saharan Africa, China (Wang et al., 2024), Turkey (İpek and İpek, 2024) and India (Faizan and Thakur, 2022). In Nigeria, fuel-poor households are more exposed to catastrophic health expenses, compounded by the absence of social security coverage and social transfer schemes (Okorie and Lin, 2022; Bukari et al., 2021).

On the educational front, energy poverty limits access to modern infrastructure and the Internet, hindering school enrolment, particularly in developing countries (Oum, 2019; Sule et al., 2022). However, education also plays a key role in reducing this precariousness by enabling better adoption of modern energy technologies, especially in rural areas and among women (Nepal et al., 2025; Katoch et al., 2023). However, in contexts where energy insecurity is low, improving education does not systematically translate into gains in health or reduced inequality (Niu et al., 2023).

In terms of employment and income, energy poverty limits productivity and labor market participation, thereby reducing economic opportunities (Li et al., 2021). It particularly affects socio-economically marginalized populations, accentuating inequalities (Koomson and Churchill, 2022). Moreover, the use of polluting energy sources fuels a vicious circle of poverty and environmental precariousness (Apergis and Katsaiti, 2018). Energy poverty also hampers entrepreneurship and industrialization by reducing the capacity for innovation and investment in modern infrastructure (Algül, 2024).

On the other hand, the indirect impact of energy poverty on social well-being is mainly due to environmental degradation (Li et al., 2025). This results from the inefficient use of energy resources, accentuating emissions CO_2 and local pollution (Malla, 2013; Baloch et al., 2020). In the African context, every increase in energy poverty leads to a measurable rise in polluting emissions (Li and Qamruzzaman, 2023). This environmental degradation reduces access to essential resources such as drinking water and food, exacerbating health and nutrition inequalities. On the other hand, the use of renewable energies could mitigate these negative effects and improve public health (Bilgili et al., 2023).

Finally, the environmental consequences of energy poverty have a direct impact on quality of life and social well-being. Exposure to degraded environmental conditions generates stress, health risks and deterioration in living conditions, primarily affecting vulnerable populations (Ferrer-i-Carbonell and Gowdy, 2007). The fight against energy poverty is therefore not just a question of economic development, but also of social and environmental justice.

The aim of this study is to explore the direct and indirect effect of multidimensional energy poverty on the social well-being of people living in North Africa. In order to estimate this effect, the present study seeks to test two main hypotheses that can be formulated as follows:

H_1: Energy poverty has a direct negative effect on social well-being.

H_2: Energy poverty has an indirect negative effect on social well-being through environmental degradation.

2.3. Impact of Energy Poverty on Social Well-being: Moderating Effect of Green Investment

Green investment is increasingly seen as a strategic lever for alleviating energy poverty and accelerating the energy transition while supporting economic growth. From this perspective, green finance can play a crucial role in reducing energy inequalities by promoting access to sustainable energy resources and supporting environmentally friendly economic projects (Hafner et al., 2021). However, some researchers, such as Azhgaliyeva and Liddle (2020), point out that, despite the obvious benefits of renewable energies, investment in fossil fuels remains dominant in many regions, holding back the development of the energy infrastructure needed to guarantee energy security and meet global climate targets.

In the context of South Asia, Amin et al. (2020) highlighted the positive impact of increased investment in renewable energies, helping to reduce energy poverty and stimulate economic growth. However, in Africa, Duppati et al. (2022) observed that, although green investments generate jobs, household incomes remain insufficient to stimulate significant electricity demand. This observation highlights the importance of the size and dimension of investments in ensuring a positive interaction between green finance and energy access. It therefore seems that an investment strategy that combines economic and social objectives could be essential to maximize the benefits of green finance.

Concerning the relationship between green finance and social well-being, Yao et al. (2024) observed that investments in green projects have a direct and positive effect on the well-being of populations, particularly in China, where urbanization and an aging population play a key role in transmitting the benefits of green investments. Similarly, Feng and Zhou (2024) confirmed that green financing policies have a positive impact on public health, helping to reduce the health risks associated with pollution.

These elements suggest that green investment could play a moderating role in the relationship between energy poverty and social well-being, amplifying the positive effects of access to sustainable energy and helping to reduce social inequalities. We therefore formulate the following third research hypothesis:

H_3: Green investment acts as a moderating variable in the relationship between energy poverty and social well-being.

3. RESEARCH MATHODOLOGY

3.1. Country Background and Selection

The study focuses on four North African countries: Morocco, Tunisia, Egypt and Algeria. This choice is based on their exposure to energy challenges, notably the transition to renewable energies, and the persistence of energy poverty despite electrification rates of over 99% (Cantoni and Musso, 2017). Indeed, although these countries display ambitious energy transition policies, their dependence on fossil fuels perpetuates socio-economic imbalances, directly affecting social well-being. Including these states in the analysis makes it possible to examine the impact of energy poverty on key dimensions of social well-being: health, education, employment and income.

Libya and Sudan were excluded for two major reasons. Firstly, their chronic political and economic instability hinders any coherent analytical framework and introduces structural biases compromising the comparability of results (RTBF, 2024). Secondly, the low level of human development in these countries limits their relevance to the study of the link between energy poverty and social well-being. Their inclusion would thus have weakened the robustness of the analyses and diluted the scope of the conclusions.

3.2. Description of Variables and Data Sources

The empirical analysis is based on a set of carefully selected variables to assess the impact of energy poverty on social well-being in North African countries. The dependent variable, the index of social well-being (SWB), is constructed on the basis of fundamental dimensions of human development, namely health, education, employment and income. The variable of interest, energy poverty (EP), is quantified along three complementary dimensions: accessibility, affordability and energy cleanliness. In addition, the study introduces mediating and moderating variables, such as environmental degradation and green investment, to examine the mechanisms by which energy poverty influences social well-being. Finally, control variables, including industrialization, population growth, foreign trade and remittances, help to identify the underlying structural and macroeconomic effects.

The following Table 1 details all the variables used, their definitions and data sources.

In terms of data, this study uses panel data from four countries in the North Africa region for the period 2000-2022. The data used are of a secondary nature and extracted from various databases, namely: the World Bank (WB), the International Energy Agency (IEA) and Our World in Data (OWD).

3.3. Model and Estimation Methodology

3.3.1. Construction of the Multidimensional Energy Poverty Index (MEPI)

The assessment of energy poverty in developing countries is based on multidimensional approaches combining various sub-indices into an overall index (Sy and Mokaddem, 2022). In this study, the Multidimensional Energy Poverty Index is developed according to the methodology of OECD (2008) and Nussbaumer et al. (2012), integrating three fundamental dimensions: energy accessibility, energy affordability and energy cleanliness.

Although equal weighting of indicators is a commonly adopted approach (Bandura, 2008), it has limitations by assuming homogeneous importance of each variable. To overcome this weakness, Principal Component Analysis (PCA) is used to extract weights based on the variance of the data (Greco et al., 2019). In line with the conventional method, the factor loadings of the first principal component are retained as weighting coefficients (Greyling and Tregenna, 2017). The resulting index makes it possible to identify energy disparities between countries and their temporal evolution, in relation to energy poverty.

3.3.2. Analysis of the Mediating Effect of Environmental Degradation

The study examines whether environmental degradation constitutes a transmission channel between energy poverty and social well-being, mobilizing the mediation approach of Baron and Kenny (1986), supplemented by Zhang et al. (2021) and Yao et al. (2024). The methodology is based on a structural equation model inspired by Oubahou and Ouafa (2024), structured in three stages:

Table 1: Variables used in the study

Variable type	Variable name	Definition and source
Dependent variable	Index of social well-being (SWB)	Measured by a composite index integrating health, education, employment and income. Methodology based on OECD (2008), ElSarawy (2016), HCP (2012), and Tilioutine (2015).
Variable of interest	Energy poverty (EP)	According to the work of (El-Katiri, 2014; Rao et al., 2022; Li et al., 2025), energy poverty can be measured in three ways: • Energy accessibility: full access to electricity, urban and rural. • Energy affordability: GDP/capita, cell phone ownership, household consumption expenditure. • Clean energy: access to clean fuels, energy intensity, CO_2 emissions, fossil and renewable energy consumption.
Mediator variable	Environmental degradation (ED)	As defined by the World Bank (2025a), this variable is measured by carbon intensity (quantity of CO_2 produced per unit of energy consumed).
Moderating variable	Green Investment (GI)	Measured by installed solar power capacity and expressed in gigawatts (GW) (Eyraud et al., 2013; Mason and Kumetat, 2011; UNECEA, 2011).
Control variables	Industrialization (LogIND)	Share of GDP from manufacturing and secondary industries (Bagchi, 2016).
	Population growth (LogPG)	As defined by the World Bank (2024c), this variable is measured by the annual population growth rate, based on the de facto population definition.
	Remittances (LogREM)	Current transfers in cash or in kind between host and home countries of migrant workers (World Bank, 2024b).
	Foreign trade (LogTRADE)	Sum of exports and imports as a percentage of GDP (Li et al., 2025; Hill, 2018).

Source (s): Authors' work

- Total effect of energy poverty on social well-being:

$$SWB_{it} = \alpha_1 + \alpha_2 EP_{it} + \sum^{aj} X_{it} + \mu_{it} + \varepsilon_{it} \quad (1)$$

- The effect of energy poverty on environmental degradation:

$$ED_{it} = \beta_1 + \beta_2 EP_{it} + \sum^{\beta_j} X_{it} + \mu_{it} + \varepsilon_{it} \quad (2)$$

- Joint effect of energy poverty and environmental degradation on social well-being:

$$SWB_{it} = \gamma_1 + \gamma_2 EP_{it} + \gamma_3 ED_{it} + \sum^{\gamma_j} X_{it} + \mu_{it} + \varepsilon_{it} \quad (3)$$

If (i) α_2 is significant in the first equation and (ii) β_2 and γ_3 are significant in subsequent equations, then a mediating effect is established. The terms X_{it} represent control variables, while μ_{it} and ε_{it} capture unobserved effects.

3.3.3. Analysis of the Moderating Effect of Green Investment

The study explores whether green investment GI_{it} moderates the relationship between energy poverty and social well-being, in line with the work of Wnuk et al. (2022) and Fairchild and MacKinnon (2009). The estimation is based on a multiple regression with interaction term, where all variables are centered to improve interpretation of the coefficients. The model is written as follows:

$$SWB_{it} = \alpha_1 + \alpha_2 EP_{it} + \alpha_3 (EP_{it} \times GI_{it}) + \sum^{\alpha_j} X_{it} + \mu_{it} + \varepsilon_{it} \quad (4)$$

Here, α_3 captures the differential effect of green investment on the energy poverty - social well-being link. A significant and positive value of α_3 suggests that green investment mitigates the negative effect of energy poverty on social well-being, highlighting its strategic role in North Africa's energy transition.

4. RESULTS

4.1. Descriptive Statistics

Table 2 below presents the descriptive statistics for the main variables included in the model. These statistics enable us to understand the distribution and dispersion of the key variables used in the empirical analysis, namely: the social well-being index (*SWB*), the multidimensional energy poverty index (*EP*), the level of industrialization (*LogIND*), population growth (*LogPG*), remittances *(LogREM*) and trade openness (*LogTRADE*).

Analysis of the results in Table 2 reveals that the social well-being index (SWB) and the energy poverty index (EP) have means close to zero, suggesting a centered distribution. Economic variables, such as industrialization (LogIND), population growth (LogPG), remittances (LogREM) and foreign trade (LogTRADE), show relatively stable means and moderate standard deviations, reflecting controlled dispersion.

Skewness indicates a negatively skewed distribution for SWB (−1.1083) and slightly skewed for EP (−0.3287), while the other variables show less skewness. Kurtosis shows that SWB follows a distribution leptokurtic (6.8802), suggesting a high concentration around the mean, while the other variables remain closer to normal. The normality test Jarque-Bera confirms that SWB deviates significantly from normality (P = 0.0000), while the other variables show distributions more in line with normality assumptions.

These results underline the marked variability for SWB and EP, justifying the adoption of robust econometric methods to improve the reliability of estimates and accurately analyze interactions between model variables.

4.2. Correlation Analysis and Multicollinearity

Table 3 below shows the Pearson correlation matrix, which allows us to examine the linear relationships between the variables in the model. It also includes the assessment of collinearity between independent variables through the Variance Inflation Factor (VIF) test, offering an overall diagnosis of potential multicollinearity.

Analysis of the Pearson correlation matrix and the VIFs reveals several important points. The social well-being index (SWB) is negatively correlated with the energy poverty index (EP) (−0.2787, P < 0.01), indicating that an increase in energy poverty decreases social well-being. The correlations between SWB and other variables such as the level of industrialization (LogIND) (−0.0348) and population growth (LogPG) (0.1213) are low, suggesting that they do not significantly affect social well-being. Remittances (LogREM) show a weak negative correlation with SWB (−0.0217).

The energy poverty index (EP) has a moderate correlation with remittances (LogREM) (0.1422), but a weak correlation with population growth (LogPG) (0.0115), suggesting that remittances may slightly reduce energy poverty.

Table 2: Descriptive analysis of variables

Statistics	SWB	EP	LogIND	LogPG	LogREM	LogTRADE
Mean	−7.59E-16	−1.69E-16	10.4897	0.1524	9.6583	1.8026
Median	−0.0613	−0.0239	10.4770	0.1351	9.5653	1.8054
Max.	2.2517	2.8219	11.1930	0.3627	10.4976	2.0582
Min.	−4.6051	−4.2129	9.7601	−0.2327	8.8976	1.4750
Std. Dev.	1.0030	1.2965	0.3891	0.1350	0.3812	0.1412
Skewness	−1.1083	−0.3287	−0.0280	−0.3541	0.4358	−0.2597
Kurtosis	6.8802	3.5537	1.8583	2.5189	2.6516	2.3636
Jarque-Bera	76.5505	2.8318	5.0086	2.8102	3.3774	2.5870
Probabilit	0.0000	0.2427	0.0817	0.2453	0.1847	0.2743
Obs.	92	92	92	92	92	92

Source (s): Results from Eviews 12

Table 3: Pearson correlation matrix and VIF

Variables	SWB	EP	LogIND	LogPG	LogREM	LogTRADE	VIF
SWB	1.0000						
EP	−0.2787***	1.0000					1.04
LogIND	−0.0348	0.0553	1.0000				3.67
LogPG	0.1213	0.0115	0.7663***	1.0000			4.22
LogREM	−0.0217	0.1422	0.6150***	0.3436***	1.0000		2.34
LogTRADE	−0.0304	0.0049	−0.7193***	−0.7759***	−0.5982***	1.0000	3.72
Mean VIF							3.00

***Coefficient significant at 1%

Source (s): Results from Stata 14

The average VIF is (3.00), indicating moderate but acceptable. No VIF exceeds 5, which is reassuring. However, the VIF of (4.22) for multicollinearity LogPG is the highest, suggesting slight collinearity with other variables, although it remains within an acceptable range. The other VIFs, such as (1.04) for SWB, (2.34) for LogREM, and (3.67) for LogIND, are low and do not pose a problem of multicollinearity.

In summary, the correlations show weak to moderate relationships, and the VIFs confirm that there is no significant multicollinearity, allowing reliable interpretation of the results.

4.3. Impact of Energy Poverty on Social Well-being: Mediating Effect of Environmental Degradation

Table 4 below summarizes the results of the main suitability indices before and after the inclusion of the variable environmental degradation as a mediating variable.

Analysis of the fit indices reveals the impact of the mediator variable on model quality. The RMSEA decreases from (0.077) to (0.065), indicating a better fit to the data, in line with the acceptable threshold of 0.08 (Browne and Cudeck, 1993). Similarly, the SRMR increases from (0.050) to (0.045), reflecting a reduction in residual errors and an improved match between the model and observed data.

However, some indices show a slight decline. The NFI decreases from (0.987) to (0.950), although it remains above the 0.90 threshold (Bentler and Bonett, 1980). A similar trend is observed for the TLI, which falls from (0.975) to (0.910), suggesting an increase in model complexity. The CFI, although down slightly from (0.989) to (0.968), remains in line with the standards of a good fit (Hu and Bentler, 1999).

In short, integrating the mediator variable improves certain adjustments while making the model more complex, without compromising its analytical robustness.

The results in the Table 5 show that before the integration of the mediator variable (regression 1), energy poverty has a negative and significant impact on social well-being, with an estimated coefficient of (−0.232), significant at the 1% level. This suggests that energy poverty (EP) reduces social well-being (SWB) in North Africa. These results confirm the work of Amin et al. (2020), who observed a negative relationship between energy poverty and key factors such as employment, education and per capita income. In addition, studies by Banerjee et al. (2021) indicate that lack of access to clean energy can lead to disease, reducing social well-being. This empirical evidence confirms the first hypothesis of this study.

Table 4: Fit before indices and after integration of the mediator variable

Indices	RMSEA	SRMR	NFI	TLI	CFI
Before inclusion of the mediator variable					
Value	0.077	0.050	0.987	0.975	0.989
After inclusion of the mediator variable					
Value	0.065	0.045	0.950	0.910	0.968

Source (s): Results from Stata 14

Table 5: Estimated results of the mediator effect model

Variables	(1)	(2)	(3)
	SWB	ED	SWB
EP	−0.232***	−0.010**	−0.215***
	(−2.956)	(−1.93)	(−2.683)
ED			1.665
			(1.052)
LogIND	−0.476***	0.085***	−0.618**
	(−2.007)	(5.318)	(−2.266)
LogPG	3.482**	0.321***	2.947*
	(2.349)	(3.204)	(1.881)
LogREM	2.42	−9.13***	3.94
	(1.182)	(−6.600)	(1.573)
LogTRADE	2.383*	−0.104	2.557**
	(1.955)	(−1.264)	(2.079)

***Coefficient significant at 1%; **coefficient significant at 5%; *coefficient significant at 1%

Source (s): Results from Stata 14

Regression (2) shows a significant negative relationship between energy poverty and environmental degradation, with a coefficient of (−0.010), significant at the 5% level. This result suggests that energy poverty contributes to environmental deterioration, creating a vicious circle. Finally, regression (3) shows that energy poverty has a direct and negative effect on social well-being, with a coefficient of (−0.215) significant at the 5% level. This indicates that energy poverty directly affects social well-being, mainly through its impact on environmental degradation.

The results in the Table 6 above are divided into two distinct segments: the first analyzes the direct relationship between energy poverty and social well-being, while the second explores the direct and indirect relationships between these two variables, taking into account the mediating variable "environmental degradation."

Initially, without including the mediator variable, the results show that energy poverty negatively and significantly affects

Table 6: Test results for the relationship between energy poverty and social well-being

Effect	Effect path	Estimate	P-value	Hypothesis
Without the mediator variable				
Direct effect	EP→SWB	−0.2156	0.005***	Accepted
With the mediator variable				
Direct effect	EP→SWB	−0.1981	0.012**	Rejected
Indirect effect	EP→ED	−0.0159	0.045**	
	ED→SWB	1.1025	0.277	

***Coefficient significant at 1%; **coefficient significant at 5%
Source (s): Results from Stata 14

social well-being, with an estimated coefficient of (−0.2156) and a P-value of (0.005), significant at the 1% level. This relationship indicates that lack of access to clean energy can lead to unfavorable living conditions, such as illness, thus limiting social well-being (Banerjee et al., 2021). Thus, the first hypothesis is confirmed, establishing a direct and negative link between energy poverty and social well-being.

When the mediating variable "environmental degradation" is included, the direct effect of energy poverty on social well-being is slightly attenuated, with an estimated coefficient of (−0.1981) and a P-value of (0.012), still significant at the 5% threshold. This shows that the introduction of mediation moderates somewhat the direct effect of energy poverty on social well-being. The estimated coefficients for the relationship between energy poverty and environmental degradation (−0.0159, P = 0.045) and for the relationship between environmental degradation and social well-being (1.1025, P = 0.277) reveal that although environmental degradation has an indirect effect on social well-being, it does not significantly explain the link between energy poverty and social well-being. The lack of statistical significance for the direct effect of environmental degradation on social well-being (P = 0.277) suggests that mediation by this variable is not sufficient to fully explain the relationship between energy poverty and social well-being.

In conclusion, although energy poverty has a significant direct and negative effect on social well-being, environmental degradation does not play a major explanatory role in this relationship, which leads us to reject the hypothesis of strong mediation by this variable.

Table 7 shows that energy poverty has a negative impact on social well-being, both directly and indirectly. The direct impact is estimated at (−0.1981), indicating a significant negative influence of energy poverty on social well-being. The indirect impact, via environmental degradation, is (−0.0175), showing a moderate but also negative effect. Combining these two effects, the total impact of energy poverty on social well-being is (−0.2156), underlining that energy poverty has a significant negative overall effect on social well-being, both directly and through its influence on the environment.

Table 8 analyses the significance of the relationship between energy poverty and social well-being, with and without the mediator variable. Without mediation, the direct effect of energy poverty on social well-being is significant, with a P-value of (0.005), indicating a negative relationship at the 1% threshold. When the mediator variable is introduced, the direct effect remains significant, although the P-value increases to (0.012), signifying a negative relationship at the 5% threshold. By contrast, the indirect effect, via environmental degradation, is insignificant, with a P-value of (0.339). This suggests that, although energy poverty has a direct impact on social well-being, environmental degradation does not mediate this relationship.

Table 7: Overview of the effect energy poverty and social well-being

Causal link	Direct impact	Indirect impact	Total impact
EP→SWB	−0.1981	−0.0175	−0.2156

Source (s): Results from Stata 14

Table 8: Significance of the links established between energy poverty and social well-being

Causal link	Direct effect (without mediator variable)	Direct effect (with mediator variable)	Indirect effect
EP→SWB	0.005***	0.012**	0.339
Importance of links	Significant	Significant	Not significant

***Coefficient significant at 1%; **coefficient significant at 5%
Source (s): Results from Stata 14

4.4. Impact of Energy Poverty on Social Well-being: Effect Moderating of Green Investment

This sub-section analyzes the impact of energy poverty on social well-being, with particular emphasis on moderating role of green investment in this dynamic.

The results in Table 9 illustrate the impact of energy poverty (EP) and green investment (EP×GI) on social well-being, highlighting a few findings major. Firstly, the coefficient of energy poverty (EP) in Model 1 is (−0.2325) ($P < 0.01$), indicating that energy poverty has a significant negative effect on social well-being. This result is consistent with existing research showing that populations affected by energy poverty often face increased difficulties in accessing basic services such as education and health. In Model 2, the inclusion of the interaction between energy poverty and green investment (EP×GI) slightly reduces this negative effect to (−0.1518) ($P < 0.1$), suggesting that green investment could mitigate the impact of energy poverty on social well-being. However, this effect remains statistically significant, implying that although green investment has a mitigating potential, it fails to completely eliminate the deleterious effects of energy poverty in the context analyzed.

The interaction between energy poverty and green investment (EP×GI) shows a coefficient of (–0.4201) ($P < 0.1$), suggesting that green investment, while important for the energy transition, could exacerbate the negative effects of energy poverty on social well-being, not least because of the initial implementation costs of green technologies and the economic stresses some populations may face. These results underline that a green investment policy, without appropriate support for the most vulnerable, could exacerbate social and economic inequalities.

Table 9: Results of the analysis of the moderating effect of green investment

Variables	Model (1)	Model (2)
EP	−0.2325***	−0.1518*
	(−2.96)	(0.093)
EP×GI		−0.4201*
		(0.069)
LogIND	−0.4762**	−0.5170**
	(−2.01)	(0.031)
LogPG	3.4820**	3.6150**
	(2.35)	(0.017)
LogREM	2.42e-11	4.00e-11*
	(1.18)	(0.074)
LogTRADE	2.3831*	2.5520**
	(1.95)	(0.038)
Obs.	92	92

t statistics in brackets; ***coefficient significant at 1%; **coefficient significant at 5%; *coefficient significant at 1%.
Source (s): Results from Eviews 12

As for the control variables, industrial development (LogIND) has a significant negative impact in both models, with respective coefficients of (−0.4762) ($P < 0.05$) and (−0.5170) ($P < 0.05$), highlighting its detrimental effect on social well-being. On the other hand, economic growth (LogPG) shows significant positive coefficients (3.4820) ($P < 0.05$) and (3.6150) ($P < 0.05$), indicating that economic growth helps improve social well-being. Finally, foreign trade (LogTRADE) has positive effects coefficients of (2.3831), ($P < 0.1$) and (2.5520), ($P < 0.05$), suggesting that openness to international trade promotes access to resources and markets beneficial to social well-being.

In conclusion, although green investment plays a key role in the energy transition, it does not fully offset the negative effects of energy poverty, underlining the importance of adopting a balanced approach incorporating support policies for vulnerable populations.

5. DISCUSSION

The absence of a direct environmental effect on social well-being confirms the hypothesis that multidimensional energy poverty substantially impairs the quality of life of North African populations. This form of poverty manifests itself in people's inability to access clean energy sources, forcing them to resort to traditional fossil fuels such as agricultural residues, wood, charcoal or animal dung. These practices not only contribute to environmental degradation through the emission of polluting gases, but also generate serious health impacts through air and water pollution. In 2023, for example, over 2.1 million Moroccans continue to use traditional cooking methods, generating gas emissions and fine particles that are particularly harmful to public health (Rahhou, 2022). In Tunisia, the growing energy deficit, fuelled by dependence on fossil fuels, continues to exacerbate environmental and health problems to an alarming degree (IRENA, 2021).

These results corroborate the findings of Oum (2019), who refers to the precarious conditions of households in energy poverty, often in rural areas and lacking stable access to electricity. This situation is all the more problematic when we consider the impact of energy poverty on children's education and health. Indeed, the duration of the school year is often reduced, and the quality of education is hampered by the lack of electricity in schools and homes, depriving children of optimal learning conditions (Sovacool and Drupady, 2012). A World Bank study (2008) suggests that improving access to electricity would extend study hours and improve the quality of education, particularly in rural areas.

However, this dynamic is not unilateral. Indeed, some studies suggest that better education could also play an important role in reducing energy poverty. This is shown by the research of Nepal et al. (2025), which establishes an inverse link between education and energy poverty. The electrification rate in Morocco, for example, is linked to a significant improvement in educational conditions, with electrified populations believing that electricity has had a positive effect on their children's education (ONEE, 2023).

With regard to environmental degradation, the study shows that the indirect relationship between energy poverty and social well-being, via environmental effects, is marked by a complexity of interactions. Despite low CO_2 emissions in some rural areas where energy poverty is present, local pollution remains a concern due to the burning of traditional fossil fuels. Indeed, CO_2 emissions reports do not always take into account the pollution generated by the use of wood or charcoal, which contributes to an illusion of reduced carbon intensity, while maintaining high local pollution. This reality is confirmed by the African Development Bank (2012) and Baloch et al. (2020), who highlight the harmful effects of traditional burning practices in developing countries.

Public policies on energy subsidies appear to be a key lever in reducing energy poverty, although their effectiveness remains limited. Electricity and fuel subsidies enable households to vulnerable maintain access to energy, despite ongoing environmental degradation. However, they are not enough to curb the phenomenon. For example, almost 14% of Moroccan households remain in a situation of energy poverty, despite the high cost to the state (Kettani and Sanin, 2024). In Tunisia, although subsidies exist for fossil fuels, the beneficial effects of these policies remain limited (IEA, 2024). What's more, subsidies in Algeria and Egypt mainly benefit the middle classes and large companies, while the most vulnerable households are the most exposed to energy poverty.

Finally, although environmental degradation was not directly linked to social well-being in this study, it is important to emphasize that its indirect effects could have longer-term repercussions. Energy poverty and environmental degradation thus form a complex vicious circle, whose impact on social well-being calls for a more comprehensive, cross-functional approach to public policy.

In terms of green investment, the study reveals a significant moderating effect, illustrated by the negative relationship between investment in solar energy and social well-being. The installation of renewable energy systems, while essential for the energy transition, can have immediate negative economic consequences, notably a drop in employment in areas most dependent on fossil fuels. This dynamic is particularly visible in sensitive regions such as Tunis and Sfax, where the price exposure index reveals a 0.5% reduction in employment, with a greater impact among men. This is largely due to the concentration of jobs in high-carbon-emitting sectors, where men are over-represented. At the same time, women's access to the green economy remains a major challenge, the gap in access to the energy transition being partly caused by their low presence in the scientific sectors crucial to this development (World Bank, 2025b).

Despite the long-term benefits of renewable energies, the energy transition, particularly in North African countries, presents significant entry costs, especially for the installation of solar photovoltaic panels. State financial incentives, while significant, do not always mitigate the burden for low-income households, who remain the most likely to suffer from the costs of acquiring installations (Lequotidien23, 2024). This phenomenon is exacerbated by the fact that the manufacture of solar panels involves high consumption of energy and resources, including water, in a global context of water stress. The impact of these installations on local wildlife and ecosystems is also a concern that deserves further attention. The cleaning of solar panels, for example, leads to massive water consumption, exacerbating the water crisis and compromising long-term social well-being (PolyWater, 2021).

Thus, this study highlights the interdependence of energy, environmental and social factors, underlining the importance of well-targeted, integrated strategies to improve both social well-being and the energy transition in the region. Public policies need to go beyond the simple provision of energy and incorporate measures to ensure equitable access to sustainable energy solutions, while minimizing negative impacts on the environment and health.

6. CONCLUSION

This study has enabled us to gain a better understanding of the impact of energy poverty on social well-being in the context of North African countries, while analyzing the moderating role of green investment in this dynamic. Theoretical and empirical analysis reveals that energy poverty exerts a significant negative effect on social well-being. However, the inclusion of green investment in the analysis mitigates this impact to some extent, although it does not fully eliminate the deleterious effects of energy poverty, particularly in a region undergoing an energy transition. This interaction suggests that green investment can, in some cases, exacerbate social inequalities if adequate accompanying measures are not put in place, particularly in terms of support for the most vulnerable populations.

The empirical results make an important contribution to the literature on the energy transition and energy poverty, highlighting that while green investment is an essential strategic lever for the energy transition, it must imperatively be combined with targeted social policies to ensure that poor populations are not excluded from the benefits of this transition. Analysis of control variables, such as industrial development, economic growth and foreign trade, also demonstrates that, while these factors play an important role in improving social well-being, their interaction with energy poverty and green investment must be carefully managed to maximize their positive effects. Inclusivity thus becomes an imperative in development policies, with particular attention paid to fragile populations who are likely to suffer more from energy poverty and the increased costs associated with the energy transition.

This research has major practical implications for policy-makers in North African countries. It highlights the need for energy transition strategies that not only integrate environmental objectives, but also include social initiatives to protect the most vulnerable. The inclusion of subsidies for green technologies, as well as financial support mechanisms for households in energy poverty, could help prevent the worsening of social inequalities. In addition, the implementation of programs to support training and employment in green energy-related sectors would be beneficial to ensure that the populations most affected by energy poverty can benefit from economic opportunities as part of the energy transition.

However, there are a number of limitations to this study that open up prospects for future research. The analysis period, while significant, remains relatively short for assessing the long-term impact of green investment in the region. A more in-depth analysis, covering several decades, would provide a better understanding of the lasting effects of these policies. In addition, a comparison with other regions of the world, notably other emerging countries, could offer further insights into the specificities and challenges of North Africa. Future research could also explore in greater detail the specific effects of national energy transition policies in each country of the region, taking into account local economic, social and geopolitical particularities.

In conclusion, although green investment is a key lever for a successful energy transition, it should not be seen as an isolated solution. It must be integrated into broader strategies, combining economic development, improved social well-being and the fight against energy poverty. Public policies must ensure that the benefits of the energy transition are shared equitably, with particular attention paid to vulnerable populations. In this sense, this study highlights the importance of a balanced and inclusive approach to ensure that the energy transition leaves no one behind and makes a real contribution to improving social well-being in North African countries.

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