# THE RELATIONSHIP BETWEEN RENEWABLE ENERGY CONSUMPTION AND HUMAN DEVELOPMENT

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# SUMMARY

This article examines the relationship between renewable energy consumption and human development indicators in Moldova. The analysis, spanning from 1995 to 2021, employs econometric techniques, including Ordinary Least Squares (OLS) and Two-Stage Least Squares (2SLS) regression, to investigate the impact of renewable energy on the Human Development Index (HDI). The findings reveal a positive correlation between renewable energy consumption and HDI, indicating that increased adoption of renewable energy is associated with improvements in human development. Specifically, the study finds that a one-percentage-point increase in renewable energy consumption leads to approximately a 1.6% increase in HDI. Moreover, the article discusses Moldova's energy policy landscape, highlighting initiatives and policies aimed at promoting renewable energy development and achieving sustainability goals. The conclusions drawn from this study emphasize the critical importance of prioritizing renewable energy solutions. Such prioritization is deemed essential for driving sustainable development, fostering economic growth, bolstering energy security, and mitigating the adverse impacts of climate change. The study underscores that Moldova's experience and policy initiatives could serve as a valuable model for other nations aiming to enhance their human development through sustainable energy practices. This research argues for a continued and intensified focus on the integration of renewable energy, highlighting its fundamental importance within national and international strategies aimed at achieving ambitious human development and sustainability goals. This involves a reassessment and expansion of current commitments, considering not only the ecological benefits, but also the long-term economic and social impact, thereby strengthening a sustainable future for future generations.


*Keywords: sustainable development, renewable economy, HDI, renewable energy promotion policies, Moldova*

# INTRODUCTION

A remarkable trend in the global economy in recent decades has been the rapid growth of renewable energy (RE). This development was catalyzed by the oil shocks of the 1970s, when global oil prices experienced a spectacular rise, prompting importing countries to increase government intervention to control consumption and diversify energy supply, thus increasing energy independence.

By the late 1990s, interest in the development of renewable energy sources (RES) was fueled by concerns about global climate change. During the 2000s, the rapid rise in the prices of energy commodities, especially oil, further intensified this trend.

As a result of these events, renewable energy technology experienced a rapid expansion. According to data provided by REN22 in 2023, Renewable electricity represents 30% of total electricity generation. International Energy Agency (IEA) forecasts indicate a 50% increase in demand for renewable energy by 2030 (REN21, 2017).

In parallel, in many countries of the world, the share of "clean" energy in total electricity production significantly exceeds the global average of 20%. For example, in Denmark, this proportion reached 67% in 2023 (International Trade Administration, 2024), while in Germany, it reached 60% (Fraunhofer Institute for Solar Energy Systems ISE, 2024). In turn, in Portugal, Greece, Spain and the United Kingdom, this proportion varies between 20% and 24% (REN21, 2019).

The subject of renewable energy is of even more pressing importance for Moldova, considering that the country has no energy resources of its own and is practically completely dependent on imports of fossil fuels and electricity (The integrated national energy and climate plan of Moldova for the period 2025-2030, 2024). Therefore, measures to encourage the use of energy resources available in the country such as biomass, renewable solar and wind energy sources become imperative.

Renewable energy is derived from inexhaustible resources such as wind, solar radiation and water flows. These natural resources are exploited to produce energy in a sustainable and environmentally friendly manner.

Renewable energy can be accessed in a variety of countries regardless of their geographic location, while traditional energy sources are only available to certain regions. This characteristic makes renewable energy very attractive to many states, including Moldova, which aspire to energy independence, sustainability and long-term cost reduction. For this reason, Moldova establishes its trajectories for the development of the renewable energy sector, aiming to ensure access to autonomous and sustainable energy sources.

In this analysis, we will focus on renewable energy as a cornerstone for economic development, paving the way toward sustainable growth and enhanced living standards. Investments in renewable energy infrastructure not only create job opportunities but also stimulate economic expansion, leading to higher income levels and fostering economic stability (Nemet, 2006).

Additionally, the accessibility of renewable energy sources plays a pivotal role in advancing human development. Unlike traditional energy sources, renewable energy technologies like solar and wind power often feature de-

centralized distribution networks, making energy more reachable to remote and underserved communities (International Renewable Energy Agency, 2019). Increased energy access translates into greater economic productivity, improved healthcare services, and enhanced educational opportunities, thereby contributing to comprehensive human development.

The environmental sustainability offered by renewable energy further strengthens its impact on human development. By emitting fewer greenhouse gases and reducing environmental pollution, renewable energy technologies contribute to cleaner air and water, mitigating public health risks and enhancing overall well-being (United Nations Development Programme, 2020).

Moreover, transitioning to renewable energy enhances energy security, a critical aspect of human development. Diversifying energy sources decreases reliance on imported fossil fuels, ensuring a stable and dependable energy supply (International Energy Agency, 2020). This stability not only supports economic activities but also secures access to vital services, reinforcing societal resilience against energy crises or disruptions.

Investments in renewable energy offer significant environmental benefits, such as reducing greenhouse gas emissions and supporting land reclamation and biodiversity (Dhar et al., 2020). However, challenges include the intermittent nature of sources like solar and wind, leading to reliability issues, and the need to manage environmental impacts like habitat disruption (Gayen et al., 2024). Economic and policy barriers, such as high initial costs and regulatory hurdles, also pose significant challenges to the expansion of renewable energy capacities (Hamburger & Harangozo, 2018).

Nevertheless, the pursuit of renewable energy fosters education and innovation, driving progress in human capital development. Investments in education and research and development within the renewable energy sector spur technological innovation and cultivate skilled labor (Jacobsson & Lauber, 2006). By nurturing a culture of innovation and knowledge-sharing, renewable energy initiatives contribute to higher levels of education and innovation, propelling societies toward greater heights of human development.

## RENEWABLE ENERGY LANDSCAPE IN MOLDOVA

Moldova's renewable energy sector has experienced notable growth in recent years, driven by governmental initiatives, international collaborations, and advancements in technology. Wind, solar, biomass, and hydropower are prominent renewable energy sources being developed in the country. The government has implemented various policies to incentivize renewable energy deployment, including feed-in tariffs and investment incentives. Despite progress, challenges such as limited infrastructure and financing constraints persist, hindering the sector's full potential.

# DATA SOURCES AND USED METHODS

The dataset spans from 1995 to 2021, inclusive. Table 1 provides a concise overview of the variables. Due to limited data availability, the analysis couldn't be extended beyond this timeframe. All variables, except Total Solar Irradiance (TSI), were sourced from the World Bank Open Source Data.

We regard the Human Development Index (HDI) as a suitable metric for measuring welfare in Moldova. The HDI is derived from the life expectancy index, education index, and GINI index. Moldova's HDI, with a mean of 705.5926 and a range of 617 to 776 across the observed years, mirrors progress in vital areas like life expectancy, education, and living standards.

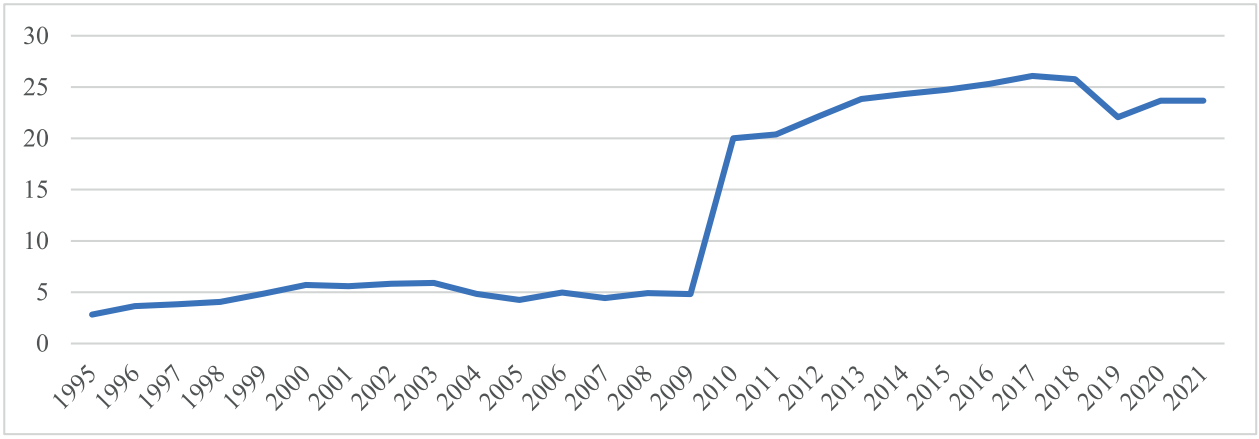
A higher HDI indicates greater human development, implying improved access to healthcare, education, and economic opportunities for the populace. Moldova has prioritized efforts to enhance HDI through governmental policies and development initiatives, aiming to elevate living standards and boost citizen well-being.

Despite advancements in some areas, Moldova encounters challenges in sustaining HDI improvements across all dimensions. Economic disparities, healthcare accessibility, and educational quality remain concerns, impacting the overall HDI score and underscoring the necessity for targeted interventions to address structural issues.

Renewable Energy Consumption (% of total final energy consumption) emerges as a significant focus of our analysis, revealing a notable trend illustrated in Figure 1: a substantial surge from 5% in 2009 to 20% in 2010. This remarkable increase warrants investigation into its driving forces, which may include policy interventions, technological advancements, or shifts in governance. Remarkably, this upswing coincides with Moldova's transition from a communist regime to a more liberal governance structure in 2009. Further exploration of these dynamics will be crucial for our subsequent analysis.

## Figure 1

*Renewable Energy Consumption (% of total final energy consumption) in the Republic of Moldova*




*Source:* The World Bank, https://data.worldbank.org/country/MD

The Total Solar Irradiance (TSI) data was obtained from Copernicus' Climate Data Store, specifically utilizing RMIB's (Royal Meteorological Institute of Belgium) data on TSI for the precise coordinates of Moldova. TSI represents the total solar power received per unit area at the Earth's atmosphere's top. In the context of Moldova, TSI serves as a crucial metric for assessing solar energy availability and the potential for solar power generation. With an average TSI of 1361.349 W/m² observed across the country, Moldova enjoys relatively consistent levels of solar radiation throughout the year. This solar resource offers opportunities for leveraging solar energy technologies to meet energy needs, mitigate greenhouse gas emissions, and bolster energy security.

TSI data provides valuable insights for policymakers, energy planners, and renewable energy developers in Moldova. By comprehending the spatial and temporal fluctuations of solar irradiance, stakeholders can optimize the deployment of solar energy systems, such as photovoltaic panels and concentrated solar power plants, to maximize energy output and economic advantages.

## Table 1

*Variable Description*

| Variable | HDI | Renewable energy consumption (% of total final energy consumption) | Total Solar Irradiance (1 Astronomical Unit) | Total greenhouse gas emissions (kt of CO2 equivalent) | Nitrous oxide emissions (thousand metric tons of CO2 equivalent) | Annual freshwater withdrawals, total (% of internal resources) |
|---|---|---|---|---|---|---|
| **Obs** | 27 | 27 | 27 | 27 | 27 | 27 |
| **Mean** | 705.5926 | 13.05704 | 1361.349 | 12990.59 | 966.7258 | 65.60742 |
| **Std. Dev.** | 54.1126 | 9.616174 | 0.3889613 | 1551.056 | 173.7366 | 32.96014 |
| **Min** | 617 | 2.84 | 1360.896 | 11426.03 | 741.3358 | 51.66667 |
| **Max** | 776 | 26.07 | 1362.274 | 18557.85 | 1474.54 | 211.3333 |

*Source:* The World Bank, https://data.worldbank.org/country/MD , Copernicus DOI, Dewitte, S., & Nevens, S. (2021): https://doi.org/10.24381/cds.85a8f66e

To investigate the influence of renewable energy consumption on welfare indicators in Moldova, we initially employ a *standard Ordinary Least Squares (OLS) regression*, regressing the Human Development Index (HDI) on Renewable Energy Consumption, as depicted in the primary equation below.

Where $y$ is the natural log HDI, $R$ is Renewable Energy Consumption in year t and $X$ are other controls as showed in columns 2 and 3 in Table 2. $\delta$ is the main coefficient of interest, given that it presents the effect of renewable energy consumption on the HDI. We later employ 2SLS.

# MAIN RESULTS AND DISCUSSION

Table 2 reveals that while there seems to be a positive correlation between renewable energy consumption and HDI in Model 1, this connection becomes less evident when additional variables are incorporated into the analysis. Other variables like total greenhouse gas (GHG) emissions, nitrous oxide emissions, and freshwater withdrawals display inconsistent or statistically insignificant relationships with HDI across various models, with results that are largely economically insignificant.

## *Table 2*

*OLS Results*

| | 1 | 2 | 3 |
|---|---|---|---|
| **Renewable Energy** | 0.0067896*** | 0.0069638 | 0.0058522 |
| **Total Greenhouse Gas Emissions** | | -2.19e-06 | 1.13e-06 |
| **Nitrous Oxide Emissions** | | -0.0001044 | -0.0000386 |
| **Annual Freshwater Withdrawals** | | | -0.0007672 |
| **Constant** | 6.467488 | 6.594643 | 6.552693 |
| **Number of obs** | 27 | 27 | 27 |
| **Procedure** | OLS | OLS | OLS |
| **F-statistic** | 67.94 | 26.06 | 27.88 |
| **R-squared** | 0.6999 | 0.7727 | 0.8182 |
| **Root MSE** | 0.04359 | 0.03956 | 0.03617 |

*Source: **: 5% sig. ***: 1% sig. P-values based on regression analysis. Elaborated by the author based on data from: The World Bank, https://data.worldbank.org/country/MD , Copernicus DOI, Dewitte, S., & Nevens, S. (2021): https://doi.org/10.24381/cds.85a8f66e*

We proceed with 2SLS regression, an econometric technique designed to address endogeneity issues and ensure robust estimates of the relationship between renewable energy consumption and welfare outcomes. Endogeneity arises when independent variables correlate with the error term in regression analysis, leading to biased and inconsistent parameter estimates. In our study, focusing on the impact of renewable energy consumption on welfare outcomes such as the Human Development Index (HDI), endogeneity may arise from omitted variables, reverse causality, or measurement errors.

2SLS regression tackles endogeneity by employing instrumental variables (IVs) to instrument for the endogenous variables. In our analysis, we utilize Total Solar Irradiance (TSI) as an instrument for Renewable Energy Consumption, which is relevant to our context. We assume TSI is an exogenous instrument and does not directly affect HDI apart from its relationship with the main regressor. However, it's worth noting that TSI may not encompass all forms of renewable energy and primarily focuses on solar power generation, but due to data constraints, this was our optimal choice.

The results for this 2SLS analysis are presented in Table 3. In Column 3, the coefficient for renewable energy consumption is 0.0161518. This indicates that a one-percentage-point increase in renewable energy consumption of total energy consumption is associated with an approximate 1.6% increase in HDI. In simpler terms, as renewable energy consumption rises, there is a corresponding positive impact on HDI.

*Table 3*

*2SLS Results*

| | 1 | 2 | 3 |
|---|---|---|---|
| **Renewable Energy** | 0.0208114*** | 0.0148306** | 0.0161518** |
| **Total Greenhouse Gas Emissions** | - | 0.0000524 | 0.0000513 |
| **Nitrous Oxide Emissions** | - | -0.0005753 | -0.0006536 |
| **Annual Freshwater Withdrawals** | - | - | 0.0007105 |
| **Constant** | 6.284405 | 6.238264 | 6.263893 |
| **Procedure** | IV | IV | IV |
| **Number of obs** | 27 | 27 | 27 |
| **R-squared** | - | 0.1739 | 0.0052 |
| **Root MSE** | 0.13881 | 0.0696 | 0.07638 |

*Source: **: 5% sig. ***: 1% sig. P-values based on regression analysis. Elaborated by the author based on the data from: The World Bank, https://data.worldbank.org/country/MD, Copernicus DOI, Dewitte, S., & Nevens, S. (2021): https://doi.org/10.24381/cds.85a8f66e*

We now explore the energy policy of Moldova, which has undergone significant evolution towards promoting and developing renewable energy sources. In this regard, various policies and measures have been adopted and implemented to stimulate investments in renewable energy infrastructure and facilitate the use of this source across the country (The energy strategy of the Republic Moldova until 2030, 2013).

An essential pillar of this policy is Law No. 10 of February 26, 2016, which outlines the regulatory framework for electricity derived from renewable sources (Law of the republic of Moldova regarding the promotion of the use of energy from renewable sources, 2016). This law establishes clear and transparent rules for renewable energy producers and consumers, thereby encouraging the development and implementation of projects in this field.

Another important instrument is the Integrated National Plan for Energy and Climate (INPEC) 2025-2030, which aims to promote energy efficiency and renewable energy sources in Moldova. This plan sets ambitious targets and concrete measures for the development of the renewable energy sector, including stimulating private investments and research in the field (The integrated national energy and climate plan of Moldova for the period 2025-2030, 2024).

In line with the INPEC, Moldova aims to achieve a share of 27% renewable energy in final energy consumption by 2030. Additionally, the strategy includes national objectives for 2030, such as improving energy efficiency by 20% and reducing CO2 emissions by 25%.

Through these initiatives, Moldova seeks to create a competitive and environmentally sustainable energy sector integrated into European infrastructure and energy markets. This approach aims to ensure an adequate level of energy security and affordable prices for consumers.

To achieve these objectives, Moldova aims to align its policies as closely as possible with the overall objectives of the European Union's energy and climate policy, reflected in recent legislation such as the European Green Deal, Fit for 55, and REPowerEU, the Paris Agreement, and commitments made within the Energy Community (Energy Strategy of Moldova 2050, 2022). It is recognized that the energy sector is responsible for a significant proportion of national greenhouse gas emissions, which is why it is considered a priority area for future actions.

Thus, Moldova's policy for the development of renewable energy is in continuous evolution and implementation, with a particular focus on reducing dependence on traditional energy sources and contributing to global efforts to combat climate change by adopting clean and renewable energy sources. This orientation reflects the country's firm commitment to building a sustainable and competitive energy future, thus contributing to the sustainable development of the entire society.

# CONCLUSION

In conclusion, the analysis highlights the significant impact of renewable energy consumption on human development, confirming the positive relationship between the use of renewable energy and human development indicators. By employing robust econometric techniques, such as instrumenting renewable energy consumption through total solar irradiance, we have demonstrated that increased adoption of renewable energy positively influences human development indicators in Moldova.

Following the study carried out by 2SLS analysis, it was found that the coefficient for renewable energy consumption is 0.0161518. This result indicates that an increase of 1 percentage point in the consumption of renewable energy from the total energy consumption is associated with an increase of about 1.6% in the Human Development Index (HDI).

In light of these findings, decision-makers, stakeholders, and communities are encouraged to prioritize and accelerate the adoption of renewable energy solutions. By harnessing the economic, social, and environmental benefits of renewable energy, countries can advance their agendas for sustainable development and achieve tangible improvements in human well-being and quality of life.

Energy policy in the field of renewable energy is crucial for sustainable development in Moldova. Effective policies in this area significantly impact the environment, economy, and society. By promoting renewable energy, Moldova can reduce its dependence on traditional energy sources, enhancing energy security and reducing greenhouse gas emissions. Additionally, renewable energy investments create new business opportunities and jobs, driving economic growth and innovation. These investments also improve energy access in rural and isolated communities, enhancing quality of life and reducing social disparities. Thus, developing and implementing coherent renewable energy policies are vital for Moldova's sustainable development and achieving its environmental, energy, and economic goals.

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