THE STRATEGIC DEVELOPMENT OF THE RENEWABLE ENERGY SECTOR IN MOLDOVA: MODELS FOR INVESTMENT MANAGEMENT

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SUMMARY

The periodic paradigm shifts operating on the energy markets require higher innovative approaches to facilitate the management of energy portfolios and the design of mechanisms for an accelerated renewable energy integration. Thus, international organizations, policy makers and managerial boards are continuously seeking for policy amendments and adjustments that would enhance the investments in the renewable energy sector and stimulate the transition towards the smart energy grids' models.

The current study aims to review and apply some of the existing models for the management of renewable energy investments, using as a case study Moldova's economy structure and its statistical data. The study is based on systemic research methods, forecasting models and estimates to identify most productive management tactics, able to ensure the proper integration of smart energies into the energy network. The author presents a model for forecasting the demand of the renewable energy market in Moldova till 2025 and 2030 year with an emphasis on the electricity segment. It also points out opinions and estimates that reflect a different perspective on the effects of investments' management at the electricity segment level and proposes solutions that may help decision-makers in the development and integration of the country's renewable energy policy. The study offers the necessary evidence and grounded solutions for attracting and promoting investments in renewable energy projects, whereas the obtained methodology and results have a general relevance for other countries in the region with emerging economies.

Keywords: *renewable energy, investment management models, demand forecast*

Schimbările periodice de paradigmă operate pe piețele energetice necesită abordări inovatoare pentru a facilita gestionarea portofoliilor energetice și formarea mecanismelor pentru accelerarea integrării energiei regenerabile. Organizațiile internaționale, factorii de decizie și investitorii urmăresc introducerea continua de amendamente și ajustări a politicilor menite să sporească investițiile în sectorul energiei regenerabile și să faciliteze tranziția către modelele rețelelor energetice inteligente.

Lucrarea își propune să revizuiască și să aplice unele modelele existente pentru managementul investițiilor în energie regenerabilă, folosind datele statistice și structura economiei Moldovei ca studiu de caz. Studiul este bazat pe metode sistemice de cercetare, modele de previziune și estimări pentru a identifica tactici productive de management, capabile să asigure integrarea corespunzătoare în rețeaua energetică a energiilor inteligente. Autorul prezintă un model de prognoză a cererii pieței de energie regenerabilă din Moldova până în anii 2025 și 2030, cu accent pe segmentul energiei electrice. Sunt prezentate estimări care reflectă o optică nouă asupra efectelor managementului investițiilor în energia electrică, propuse câteva soluții care ar putea ajuta factorii de decizie în elaborarea și integrarea politicii de energie regenerabilă a țării. Studiul oferă mai multe raționamente și soluții argumentate care ar contribui la atragerea și promovarea investițiilor în energie regenerabilă, iar metodologia și rezultatele obținute au o relevanță generală pentru alte țări din regiune cu economii emergente.

Cuvinte cheie: *energie regenerabilă, modele de management a investițiilor, prognoza cererii*

Периодические изменения парадигмы, действующие на энергетических рынках, требуют инновационных подходов, чтобы способствовать управлению энергетическими портфелями, а так же формированию механизмов оценки интеграции возобновляемых источников энергии. Таким образом, международные организации, институты власти и инвесторы ожидают постоянного внесения поправок и корректировок в политику, направленных на увеличение инвестиций в сектор возобновляемых источников энергии и облегчение перехода к моделям интеллектуальных энергосистем.

Целью статьи является обзор и применение некоторых существующих моделей значимых для управления инвестициями в возобновляемые источники энергии на основе использования статистических данных и структуры экономики Молдовы в качестве примера. Исследование основано на применении системных методов, прогнозных моделей и оценок для определения продуктивной тактики управления, способной обеспечить правильную интеграцию в энергетическую сеть возобновляемых энергий. Автор предлагает модель по прогнозированию спроса рынка возобновляемых источников энергии в Молдове до 2025 и 2030 годов, акцентируя внимание на сектор электроэнергии, представляет концепции и оценки, отражающие различный взгляд на эффект, получаемый от вложения инвестиций в электроэнергетику, а также предлагает некоторые решения, которые могут помочь лицам, принимающим решения в разработке и интеграции политики страны в области возобновляемых источников энергии. В исследовании предложены аргументированные обоснования и решения, которые будут способствовать привлечению и продвижению инвестиций в возобновляемые источники энергии, а методология исследования и полученные результаты имеют актуальность и могут быть полезны для других стран региона с развивающейся экономикой.

Ключевые слова: *возобновляемая энергия, модели управления инвестициями, прогноз спроса*

INTRODUCTION

Moldova is a European landlocked, post-Soviet country with an emerging upper middle-income economy still undergoing a transition phase in terms of economic structures and operating regimes. It is important to note that Moldova has minor reserves of coal, oil, and natural gas, as well as a moderate hydropower potential. As a result, the country heavily relies on energy imports, primarily from Russia, Ukraine, and Romania. This dependence poses continuous security challenges in energy supply, leading to an unreliable and sometimes costly access to energy in various forms and technologies.

Currently, Moldova is making significant efforts to establish competitive renewable energy market niches capable of penetrating the energy market and competing with the conventional technologies. However, the country faces major issues with its energy infrastructure, including outdated installations and low-quality thermal insulation in both residential and public buildings. Consequently, Moldova's economy exhibits a high degree of energy intensity, surpassing the average energy intensity values of European countries.

The technical deficiencies, coupled with legislative gaps and the lack of stable governmental frameworks for renewable energy sources (RES) deployment, create an environment of investment reluctance. Investors perceive high levels of risk associated with the established business regulatory frameworks in which they would operate while entering Moldova's renewable energy market.

Overall, Moldova's energy landscape requires substantial improvements in infrastructure, legislation, and governmental support to enhance energy security, reduce energy intensity, and attract sustainable investments in renewable energy technologies (RET).

Over the last ten years, Moldova registered an increase in both primary and final energy consumption of about 16,4% and 21,5% respectively. The data of the National Bureau of Statistics (NBS) show that Moldova's final energy demand increased by an average of 1-2% per year, reaching the level of 2,924 thousand toe in 2021. After 2019 year, the gross domestic consumption decreased due to the stagnant economy affected by the COVID-19 pandemic, registering a level of only 2,670 thousand toe in 2020. However, in 2021, thanks to the economic recovery processes after the lift of all restrictions on businesses, the final energy consumption recovered and recorded the highest level since the 2010 year. Currently, only 20% (or 0,98 TWh) of the electricity that Moldova needs (3,85 TWh)) is produced and generated in the country (excluding the plan on the left side of Nistru River, at Cuciurgan), mainly by the combined heating and power plants, and only 13,4% of it comes from RES sources.

In the context of the energy crisis that began in 2021-2022, Moldova's energy vulnerability has worsened, exposing chronic problems within the system. As a result, given the recent progress in developing electric power frameworks and the country's obtained status of an EU accession candidate. Moldova is committed to transposing European targets aiming to achieve a 34% share of renewable generation in final electricity consumption by 2025. This target would require a capacity of approximately 450 MW, based on electricity consumption levels from the year 2020, and would primarily rely on photovoltaic, wind, hydrological, and cogeneration-based projects.

On the same note, it is essential to mention that at the beginning of the year 2023, the main national energy operator and distributor - Moldelectrica, reported a total of 62 requests for connection to the electricity network submitted between 2016 and the end of 2022. These requests aim to connect future power plants for electricity production based on renewable energy sources (RES) technologies such as solar, wind, and biogas, potentially leading to a total capacity of 1,22 GW. Most of these power plants are expected to become operational in the near future, which requires a strengthened electric power system to accommodate these new sources of generation.

Consequently, a series of physical replanning and enhancements, along with amendments to the regulations and norms of the political and legal frameworks, are critically needed. These measures will establish the activities of market actors and ensure they are prepared for the active absorption of RES sources in the energy system.

Gropa's research studies (2018) demonstrated that the local power system would be capable of absorbing approximately 1 GW of renewable sources, considering current infrastructure conditions. However, an increased absorption of solar and wind generation would pose a significant challenge since Moldova relies entirely on Ukraine for grid balancing.

To address this issue, the government decided to impose ceilings on the development of RES capacities, aiming to avoid network management problems and the high costs associated with balancing RES generation. The Government of Moldova is actively interested in fostering a business environment that facilitates the development of projects based on RETs.

LITERATURE REVIEW

Energy transition processes depend on market saturation levels at certain stages and long-term quantitative energy demand forecasts. Adapting the modeling of RES energy portfolios to future market needs is based on long- and medium-term energy demand forecasts. The investment management models are essential in the planning, testing, streamlining, and development of energy markets at local, regional and national levels.

The development of the energy demand forecasting models started around 1985 year, it spiked after 2005 and continues till nowadays. Initially, there was a stringent need to assess the energy planning models to determine the long-term and medium-term evolution of energy markets, and later, when the RETs penetrated the energy markets, the need for a more rigid and rigorous management of energy supply and demand fluctuations arose. Based on the realities of the modern energy markets, there was also the need to develop energy forecasting models that would allow the identification of more efficient investment management models that would align to word's current pace of innovation, conducted operations on the market and globalization of the economies. Also, given the constant increase in worldwide energy consumption, it has become imperative to entail targeted energy consumption efficiency models both at the industrial level and at the level of individual households. Ultimately, the biggest concern of researchers and academia in the development of energy production models is the minimal environmental impact and/or carbon capture, so that the climate change process is slowed down (Nasalciuc, 2016a), in accordance with the sustainable development principles (Greene D. L., 2009), and with the World Energy Council's "Energy Trilemma Index" (2002), which considers: 1) "a nation's capacity to meet current and future energy demand reliably, withstand and bounce back swiftly from system shocks with minimal disruption to supplies, 2) a country's ability to provide universal access to affordable, fairly priced and abundant energy for domestic and commercial use, and 3) a country's energy system transition towards mitigating and avoiding potential environmental harm and climate change impacts".

The specialized literature is generous in terms of case-studies researching various RES investments implemented in different regions of the world (Schwerhoff et. al., 2017; Schinko & Komendantova 2016; Abdullahi et al., 2017; Movilla et al., 2013), or for different RETs (Shaktawat & Vadhera, 2021; Schiera et al., 2019; Qiu et al., 2020). There are also a series of research papers that assess the major barriers for large-scale RES investments and the associated risk management practices (Egli, 2020; Kitzing, 2014; Liu & Zeng, 2017; Nasalciuc, 2016b), that can serve for planning of policy adjustments. At the same time, there is a limited number of studies that assess and apply different models for investment management of RES at the macro level (Lee et al., 2017), investment planning (Taghizadeh & Yoshino, 2020; Cohen et al., 2021; Cohen J. J. et al., 2021) and planning from the environmental point of view (Dato, 2018). These gaps can be filled by models selected and adapted to the energy sector, considering the expected effects, the profile/design of the energy market, the portfolio of managed sources, the structure of the economy and the socio-economic situation.

In carrying out a deep study of RES investments' management, the author reviewed the literature, especially the one applicable and considered by the European market, (Kleinpeter, 1995; Prasad et al., 2014) that determines and identifies the existing models used in the management process of energy sector investments that can serve for the design of the necessary resources, the substantiation of investments (at the same time being an argument for the definition of policies aimed at promoting the energy transition), and propose the following classification of energy management models:

- *Energy demand analysis and forecasting models*
- *Energy supply planning models*
- *Energy optimization models (integrated energy supply and demand models)*
- *Emission reduction models*

In this study we will focus primarily on the demand analysis and forecasting models to provide qualitative findings to inform the energy market policy design and identification of RES market development targets. Analysis and systematization of existing literature (Deeble & Probert, 1986; Sterman,1988; Sterman & Davidsen, 1988; Labys,1990; Zmeureanu, 1992; Badri, 1992; Michalik, et al., 1997; Debnath & Mourshed, 2018) provide a certified methodological basis for identifying energy markets' development stages, analysing the energy demand and for designing long- and medium-term management directions.

Studies (Ang & Zhang, 2000; Ang, 2004) show that energy demand can be researched using the decomposition method by identifying changes in the economy based on the following three factors:

- *changes in the technological efficiency of energy use at the sector level;*
- *changes in the structure of economic activities; or*
- *changes at the level of economic activities.*

The economic activities, which are reflected in changes of economic production from one period to another (e.g., increases in total production of economies), as well as changes in the structure of economic activities observed at the sectoral level (e.g., transitioning to service-based economies like in Great Britain), and the efficiency of energy consumption in different industries, all drive fluctuations in energy demand levels over time. The results of the referenced studies (Ang & Zhang, 2000; Ang, 2004) demonstrate that the structure of the economy plays a significant role in determining energy intensity values, which in turn directly affects energy demand levels.

DATA SOURCES AND METHODS

Energy demand forecasting involves the prediction of the future energy demand based on the observation of historical demand trends that consider the demand growth rate, the demand elasticity, and the energy intensity.

- **Demand growth rate** – indicator that measures the growth rate of energy demand either from one year to another or from one period to another. Therefore:

$$\mathbf{a = (Et+1 - Et)/Et} \qquad \mathbf{(1)}$$

where: a – annual increase in demand; Et+1 – energy consumption in year *t* + 1 and Et – energy demand in year *t*

- **Elasticity of demand** – indicator that measures the variation of demand (in %) under conditions where the determining variable changes by 1%. In economic analysis, the variables of elasticity most often used are - economic activity (GDP), price and income. The demand elasticity indicator can be measured by using the correlation of the annual growth rate of energy consumption and the determining variable or through the lens of econometric correlations related to time series data.

$$\mathbf{e_t = \frac{\Delta^{EC_t}/_{EC_t}}{\Delta^{I_t}/_{I_t}}} \qquad \mathbf{(2)}$$

where: t – a given period of time; EC – energy consumption; I – the determining variable of energy consumption such as GDP, added value, price, income, etc. and Δ – variable change.

Usually, GDP growth shows a positive correlation with energy demand growth, respectively in the situation when the GDP growth is greater than 1%, the demand is elastic in relation to the gross domestic product and in the situation when the elasticity is $0<e_{GDP}<1$, the demand is considered inelastic. In most cases, developed countries express inelastic demand vis-à-vis gross domestic product and developing countries tend to consume larger amounts of energy to ensure the growth of economies that invest in industrial activities and provide higher levels of consumer demand from the residential sector. On the other hand, demand elasticity is inversely proportional to each percentage increase in the energy price, implying that higher energy prices result in decreased energy demand, at least for the short term. Consumers may be unable to adjust their budgets in response to energy price hikes, leading to reduced energy consumption. However, in the long term, elasticity tends to adjust as consumer budgets adapt to the higher prices. Moreover, the price elasticity of demand for energy varies depending on the type of fuel used in the energy production process.

Energy Intensity (EI) – measures the amount of energy required (aggregated or disaggregated) per unit of economic production.

$$\mathbf{EI_t = \frac{\sum_{i=1}^{n} E_{it}}{I_t}} \qquad \mathbf{(3)}$$

where: E_{it} = energy consumption for each type of energy in year *t*, I_t = the determining variable of energy consumption – GDP volume per national economic sector.

In the comparative analysis of the levels of energy intensities at the macroeconomic level as well as for the non-productive sectors - transport and residential, it is recommended to use the determinant variable - GDP, and in the case of productive sectors such as commercial, industrial and agricultural, the use of added value as the determinant variable. However, comparing the energy intensity at the level of different countries is a difficult task since both the GDP and the added value are aggregated and structured variables at the level of each country, presenting particularities of measurement. For example, in the measurement of GDP there may be measurement gaps when the economy operates under the conditions of informal economies (most often found in developing countries) or in the case of converting GDP at the same exchange rate - in the most frequent cases the conversion to USD is chosen, which does not always express the real dynamics in the economic sector.

The study uses the regression method for forecasting the medium-term (for a period of five years or less) and long-term time frames (for a period of 10 years or more) for modelling the renewable energy demand forecast. Also, based on the model described in the papers of Ang & Zhang (2000) and Ang (2004) for the changes in total energy demand, we have:

$$\mathbf{E} = \mathbf{Q} \sum \left(\frac{E_i}{Q_i} \frac{Q_i}{Q} \right) = Q \sum EI_i S_i \qquad \mathbf{(4)}$$

where: EI_i – the energy intensity at the level of sector *i* (e.g. the rate of energy consumption relative to the economic production of the sector); S_i – the structure of sector *i* (e.g. the contribution of the production of sector i to the total production of the economy); Q – the total productivity of the economy; Q_i – the productivity of sector *i*; E – total energy consumption; E_i – energy consumption of sector *i*.

When attempting to identify the changes impact of one of the three factors listed above over energy consumption, we will have:

- *for changes in the technological efficiency of energy use at the sector level:* $I = (Q^0) \sum (EI_i^t - EI_i^0) S_i^0$
- *for changes in the structure of economic activities:* $S = (Q^0) \sum (S_i^t - S_i^0) EI_i^0$
- *for changes at the level of economic activities:* $Q = (Q^t - Q^0) \sum (EI_i^0 S_i^0)$

All provided models may be applied to Moldova's case study and the results may inform the decision makers on the necessary measures that have to be adopted for a rapid integration of RES sources into the national portfolio of energy.

Observing historical energy demand trends in Moldova serves as the primary foundation for evaluating future demand growth levels, the degree of demand elasticity, and the energy intensity rate. These indicators play a crucial role in medium and long-term market evolution forecasting exercises and in planning national energy portfolios that balance the integration of RES and conventional energy generations. The application of this approach in the long-term energy market planning ensures that the energy system develops and adapts effectively to market transitions.

In order to identify the average annual growth rate of final energy consumption as well as to identify the levels of final energy/electricity consumption towards 2025 and 2030 year, the following relationships were used:

$$r = \left(\frac{v_2}{v_1} \right)^{1/n} - 1 \ \text{ and } \ v_2 = v_1 (1 + r)^n \qquad \mathbf{(5)}$$

where: v_1 – total final energy consumption in T_1, v_2 – total final energy consumption in T_2, n – number of years.

Also, to determine the elasticity of the energy demand of Moldova, according to the relation (3), in relation to the selected elasticity variables (in our case - economic activity - GDP) according, we will identify the type of economic policy carried out by the decision-makers with regards to new investments and the type of prioritized economic activities.

$$E_{PIB} = \frac{\Delta^{EC_t} / EC_t}{\Delta^{I_t} / I_t} \qquad \mathbf{(6)}$$

MAIN RESULTS

The analysis of the historical energy demand trends and the assessment of its growth forecast for 2025 and 2030, considering the data published by Moldova's National Bureau of Statistics (NBS) in the period of 2010-2021 years and the data of the World Bank (for the GDP indicator), is structured as follows (Table 1.):

Table 1.
Forecast of energy demand growth trends in Moldova for 2025 and 2030 year

Indicators	2011	2013	2015	2017	2019	2021	Foreseen levels	2025	2030
GDP (M USD)	8 414	9 497	7 745	9 670	11 970	13 680		16 812	21 755
Total final consumption (thousands toe)	2 406	2 390	2 455	2 719	2,739	2,924		3 164	3 491
Final electricity consumption (MWh)	3 384	3 559	3 687	3 687	3 803	4 129		4 472	4 942
Annual growth rate of final energy consumption	-	-0,003	0,014	0,052	0,004	0,033			
Annual growth rate of final electricity consumption	-	0,025	0,018	0	0,016	0,042			
Annual GDP growth rate	-	0,062	-0,097	0,117	0,113	0,069			
Average annual growth rate of final energy consumption (r1)									0,01989249
Average rate of annual increase in electricity consumption (r2)									0,02016983
Average GDP growth rate									0,52897438

Source: calculated based on NBS and the World Bank (WB) data

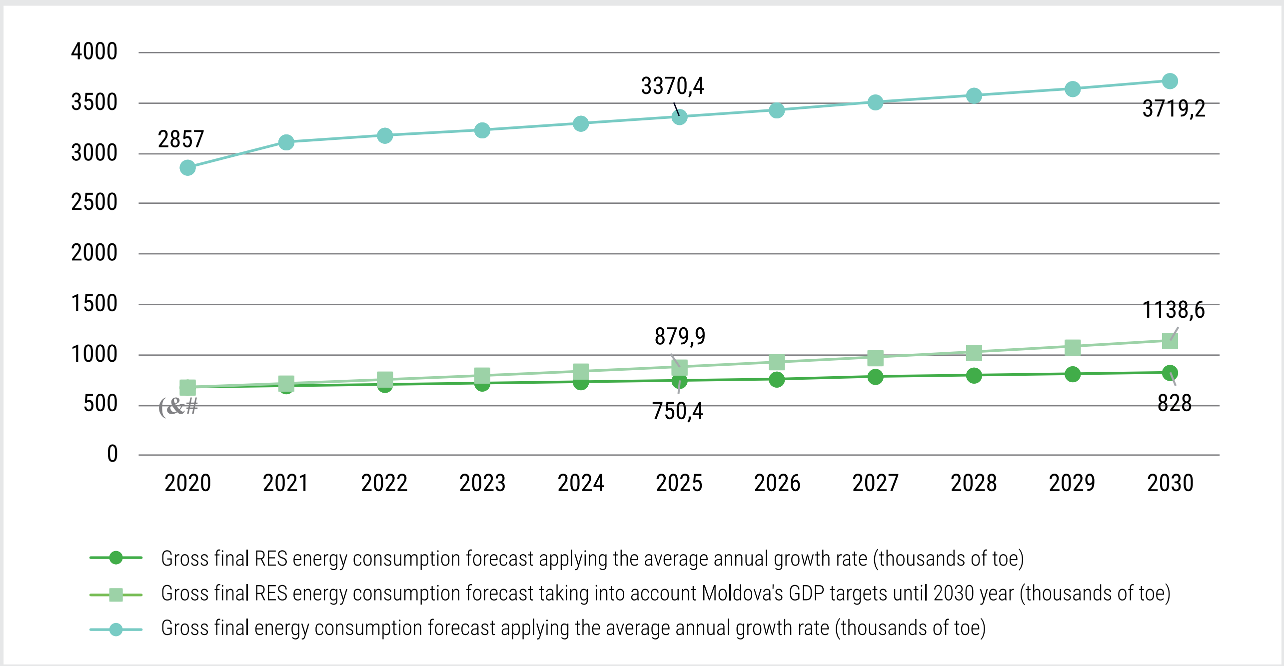
When considering the historical final energy consumption trends, we can observe the continuity of energy and electricity consumption growth by 10,74% towards 2025 year and by 22,19% towards 2030 year. The trend of 1,99% annual growth of energy demand is necessary when considering Moldova's current demographic situation as well as the current economic development rates. Thus, for the pessimistic scenario we will consider the registered shares of renewable energy (24,3%) in gross final energy consumption (2 857 thousand toe) of the 2020 year, which is considered as baseline data, and will apply the average annual growth rate of the identified final energy consumption. To continue evaluating the growth rate of Moldova's energy demand in the medium (toward 2025 year) and long term (toward 2030 year), it is necessary to consider the following strategic country targets:

- *The 3,5% target of annual GDP growth till 2030 year according to the National Development Strategy (NDS) of Moldova until 2030 year.*
- *The inflow of foreign direct investments as a share of GDP, which sets a target of 3,5% annually until 2026 year and of 4% until 2030 year (NDS, 2020).*
- *The target of 410 MW of new electrical RES capacity installed by 2025 year, mostly from wind and photovoltaic sources (amendment of Government Decision (HG 401/2021).*

Also, when applying the relation (6), we obtain EPIB =0,177/ 0,385 = 0,46 and respectively a relatively inelastic demand vis-à-vis the country's GDP (0 <EPIB< 1). Thus, a 3,5% annual increase in GDP predicted in the SND until 2030 will be directly proportionally reflected in the levels of gross energy consumption, including those of RES energy (Figure 1.):

Figure 1.

Forecast of RES gross final energy consumption evolution applying the average annual growth rate of final energy consumption and considering the forecast levels of GDP until 2030 year (in thousands toe)



Source: calculated based on NBS and the World Bank (WB) data

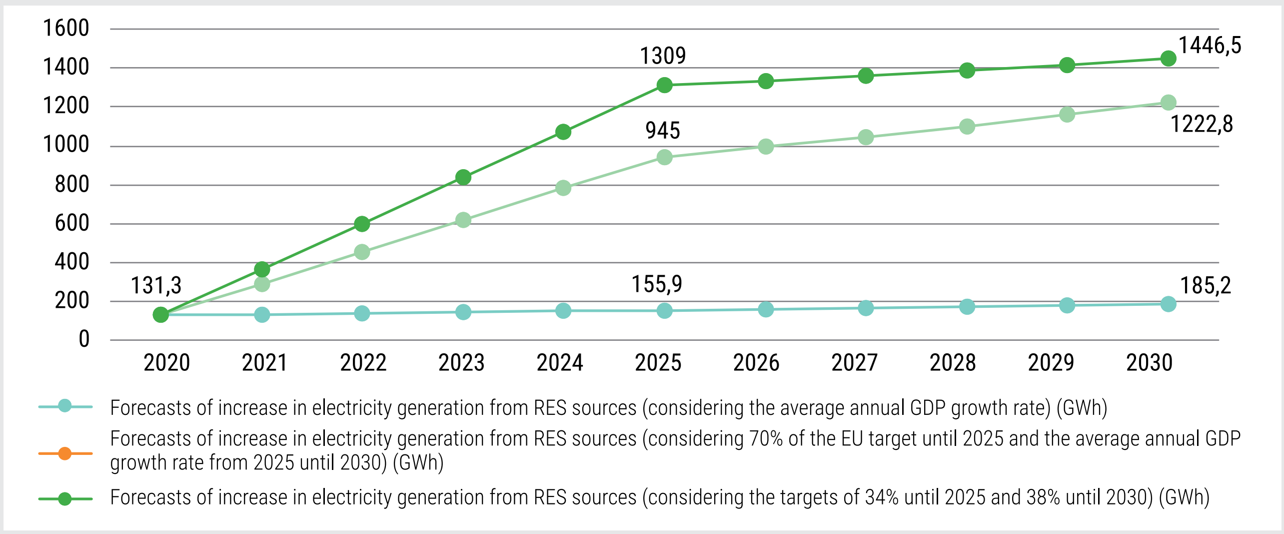
The results show that under the pessimistic RES energy demand forecast model, the growth trend of final gross consumption of RES energy towards 2030 year shows an increase of 21,77%. An average scenario for forecasting future RES energy demands would consider the predicted rates of economic development and the future needs of the country, while the optimistic scenario would consider the future targets set for RES shares in gross final energy consumption until 2025/2030 years.

Even though Moldova secures 24,3% of its total energy supply from RES sources, these indicators are determined by the solid biofuels widely used in the residential sector, especially in the rural areas of the country. However, in terms of the supply and consumption of electricity from RES sources, a critical level of only 13% of final consumption is recorded, which imposes serious problems on national security if considering the emerging trends of electrification of final consumption as well as consumption levels observed at the international level. Based on the above, we propose extracting the electricity segment from the proposed forecasts and projecting them until 2025 year and respectively until 2030 year considering (Figure 2.):

- *The historical average annual GDP growth rate of 5,29% during the period of 2011-2021 years;*
- *EU's target of 34% generation from renewable sources in the final electricity consumption (until 2025 year) and respectively 38% (until 2030 year);*
- *The current regional and international energy crisis urges the need to identify funding sources for investments in new RES plants, which will be develop quite actively until 2025 year;*
- *The undeveloped potential of Moldova's energy from RES sources amounts to approximately 27 GW of capacity (IRENA, 2019);*
- *RES distributive generation leads to little losses in the electrical network, respectively we will consider the electricity generation from RES sources equal to its consumption;*
- *In the period of 2025-2030 years, the generation of electricity from RES sources will slow down due to the infrastructure limitations of the electricity networks that exist, as well as the existing balancing limitations.*

Figure 2.

Forecasts of RES electricity generation growth considering the optimistic, medium and pessimistic scenarios



Source: calculated based on NBS and the World Bank (WB) data

The optimistic and medium scenarios of the proposed forecast envisage reaching ambitious but realistic levels of RES technologies' integration in final consumption of the economic and residential sectors. It is worth mentioning that the current national electric system and infrastructure network can absorb the proposed volumes of intermittent energy, whereas maintaining the same ambitious levels of RES integration after the 2025 year is conditioned by ambitious investments in the modernization and adjustment of the national energy infrastructure.

To determine the extent to which some segments of Moldova's economy are energy consumers, it is necessary to measure the energy intensity indicator of the various national economic sectors according to the formula (4). As input data, NBS data will be used that reflect the amounts of energy required for the economic production of the industrial, agricultural and services' sectors, as well as World Bank's data on GDP levels in Moldova (Table 2.):

Table 2.

The evolution of energy intensity levels of Moldova's economy in the period of 2011-2021 year

Sector/Indicator	2011	2013	2015	2017	2019	2021
Final Energy Consumption (thousand toe)	2 406	2 390	2 455	2 719	2 739	2 924
GDP (M USD)	8 414	9 497	7 745	9 670	11 970	13 680
Total Energy Intensity (EI) (toe/GDP unit)	0,285	0,251	0,317	0,281	0,229	0,214
Final Energy Consumption of the Agricultural Sector (thousands toe)	69	64	74	107	123	161
Agricultural Sector GDP						
(M USD)	957,5	1 096,9	891,4	1 109,1	1 217,3	1 421,4
Agricultural Sector EI (toe/GDP unit)	0,072	0,058	0,083	0,096	0,101	0,096
Final Energy Consumption of the Industrial Sector (thousands toe)	235	257	209	217	234	245
Industrial Sector GDP (M USD)	1 759,4	2 051,3	1 757,3	2 114,8	2 696,8	2 819,4
Industrial Sector EI (toe/GDP unit)	0,134	0,125	0,119	0,103	0,087	0,081
Final Energy Consumption of the Services Sector (thousands toe)	277	259	260	267	272	290
Services Sector GDP (M USD)	4 507,4	5 014,4	4 097,1	5 144,4	6 502,1	7 503,5
Services Sector EI (toe/GDP unit)	0,061	0,052	0,063	0,052	0,042	0,037

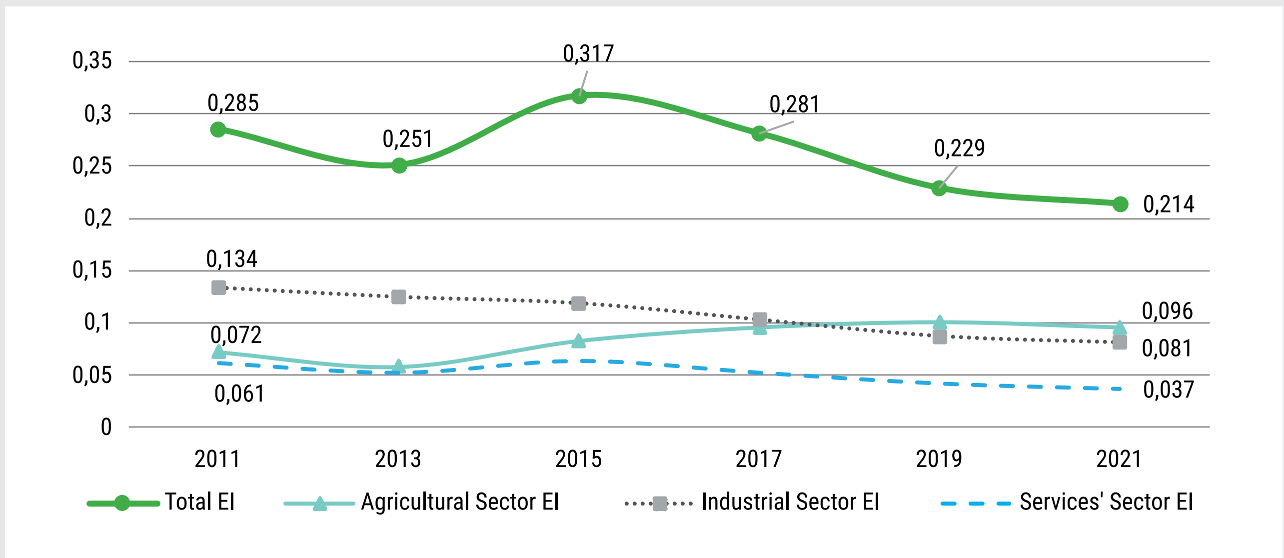
Source: calculated based on NBS and the World Bank (WB) data

In order to identify the energy intensity levels of the three economic sectors of Moldova was used the (3) relationship. As we can see, the aggregated final energy intensity at the economy level shows a 33,17% decrease trend during the 2011-2021 years. This result demonstrates that Moldova is going through various transitions in terms of the development and specialization of the national economy, including changes in the structure of the economy, with the dominant engine of country's economic growth being the services' sector. Thus, the analysis identified a 64,86% decrease in energy intensity of the services' sector and a 65,43% decrease for the industrial sector. During the entire analysed period, the services' sector contributed with more than 50% to the country's GDP composition and the volume of GDP poured into the total GDP increased by 66%. Similarly, in the industry sector, which contributed on average with more than 20% to the country's GDP composition, a 60% increase in the GDP volume of the sector poured into the total GDP is attested. Therefore, we can rely on an improved yield of the economic productivity of the services and industry sectors, that is a result of the energy management solutions and technologies implementation, as well as a possible migration towards the types of economic activities that are less energy-consuming, which leads to the efficiency of economic activities.

At the same time, a trend of 25% increase in the energy intensity of the agricultural sector was identified, given that the sector recorded a 48% increase in the volume of GDP poured into the total GDP, but also a historic decrease of 1 % in the contributions to the country's GDP composition. In this case we can talk about an astringent need to integrate efficient technologies and processes while maintaining high standards of labor competitiveness, product quality and compliance with European and international standards and to aggressively develop market linkages to facilitate trade and investment, especially under the DCFTA trade liberalization agreement with the EU.

Monitoring the energy intensity of economies is a tool that provides valuable data for informing the adaptation of energy sector management policies and development strategies towards transitions focused on less energy-consuming activities, more active RES generation, and higher energy efficiency rates (see Figure 3):

Figure 3.
The evolution of Moldova's energy intensity levels during 2011-2021 years



Source: calculated based on NBS and the World Bank (WB) data

During the period of 2015-2021 years (Figure 3), the intensity of Moldova's economy registered a 33,17% improvement of production efficiency. This trend is primarily determined by the industrial and services' sectors, which show decreases of 65,43% and 64,86%, respectively, while the agricultural sector registers an increase of approximately 25,0%, given the traditional energy consumption at the level of several economic subsectors.

The analysis of the energy demand includes the indicator of the total productivity of the economy, which refers to the measurements of the outputs of the production processes at the level of economic sectors and their efficiency (Table 3).

Table 3.
Analysis of the energy efficiency of production processes at the level of the main Moldova's economic sectors

	2011	2013	2015	2017	2019
Total Productivity Factor (Q)*	0,94	0,98	0,95	1,0	1,03
Si(agriculture)	11,38	11,55	11,51	11,47	10,17
Si(industry)	20,91	21,60	22,69	21,87	22,53
Si(services)	53,57	52,80	52,98	53,20	54,32
EIi (agriculture)	0,072	0,058	0,083	0,096	0,101
EIi (industry)	0,134	0,125	0,119	0,103	0,087
EIi (services)	0,061	0,052	0,063	0,052	0,042
I(agriculture)	-	-0,158	-0,153	0,241	0,524
I (industry)	-	-0,191	-0,517	-1,203	-2,367
I (services)	-	-0,466	-0,352	-0,851	-1,958
S(agriculture)	-	0,009	0,024	0,037	-0,085
S(industry)	-	0,085	0,279	0,353	0,453
S(services)	-	-0,039	-0,081	-0,089	-0,042
Q(agriculture)	-	0,027	0,048	0,121	0,205
Q(industry)	-	0,108	0,135	0,247	0,392
Q(services)	-	0,110	0,167	0,304	0,456

Source: author's calculations
**Note: The University of Groningen database was used for the total productivity factor indicator (https://www.rug.nl/ggdc/productivity/pwt/)*

Also, to analyse the changes in the total energy demand of the three economic sectors of Moldova, the (4) relationships were used.

DISCUSSIONS

The results show that at the level of changes in the technological efficiency of energy use (I) is recorded an increase of 320,17% for the services' sector and for the industrial sector the increase is by 12 times. In the services sector, the improvement of the indicator was possible thanks to the active adoption of modern and efficient technologies. In the industrial sector, the processes driving the improvement of the technological efficiency of energy use showed a greater amplitude, which was determined by the active adoption of efficient technologies and the more efficient allocation of resources. In the agricultural sector, the situation is different. It regressed by 231,65% during the analyzed period, mainly due to inadequate risk mitigation measures related to limited access to irrigation and meteorological factors. Additionally, the reduced adoption of modern and innovative agricultural technologies with energy-efficient consumption has contributed to this regression.

At the same time, for the indicator of changes in the structure of economic activities (S), a decommissioning economic process in the agricultural sector is identified. This process is attributed to the sector's failure to adapt to modern and innovative market structures, as well as its reliance on outdated methods and processes from a systemic perspective. The industrial sector recorded a remarkable improvement in the structure of economic activities of 432,94%, which speaks of an active transition of economic activities to modern market structures, and a continuous monitoring and evaluation of economic processes to continuously adapt the economic activities. In the case of the services sector, we can identify a 7,69% decrease in the efficiency of the structure of economic activities, which is not significant and doesn't impact other indicators analyzed in the study. The agricultural sector's structure of economic activities recorded the most dramatic regress in the period of 2005-2010 years, with an 844,44% decrease trend in the efficiency of the established market structures.

Respectively, the rise in energy intensity trends within the national economy could also be attributed to a potentially more significant shift towards an informal economy. Although there are observed trends of improving energy intensity in the economy, Moldova's companies have made very limited progress in terms of efficiency and competitiveness. The World Bank (WB, 2013) study findings during the 2003-2011 years demonstrate a negative total factor productivity of the economy in both the industrial and agricultural sectors, with modest progress recorded in the services sector. The main obstacles that Moldova's economy is facing are political instability, corruption, an unprepared and uneducated workforce, as well as a reduced access to financing (EBRD, 2014). The results identified at the economy's intensity level of Moldova can be explained by identifying changes in the technological efficiency of energy use at the level of economic sectors, changes in the structure of economic activities, or changes at the level of economic activities.

In order to achieve a higher level of development of the RES market in Moldova and prevent the emergence of energy shortage problems on the local market, it is crucial to protect the interests of economic agents and citizens. Additionally, a robust RES market represents an essential source of investment for the country's economic development. To achieve this, it is necessary to attract the required volume of investments by promoting innovative market reforms, implementing a liberalization agenda, and ensuring equal competition within the sector.

Moldova's energy consumption tends to remain relatively uniform compared to its GDP growth levels. The country does not invest significantly in economic growth or new industrial activities and processes, primarily focusing on ensuring the necessary energy demand levels for consumers in the residential sector. These findings underscore Moldova's position among the group of former socialist countries that still exhibit features of inherited economies and are actively engaged in the process of restructuring their economies.

CONCLUSIONS

The decreasing trend of final energy intensity is expected to align to the values recorded in developed European countries as Moldova's national economy transitions towards the structure and models seen in Western economies. This improvement in energy intensity is driven by more rational energy consumption and increasing technology adoption in the industrial and service sectors.

However, the agricultural sector shows a contrasting trend with increasing energy intensity over time. This can be attributed to the low integration rate of modern and innovative agricultural technologies and energy-efficient processes. The lack of integration hampers efforts to mitigate risks related to limited access to irrigation, meteorological data factors, and compliance with high workforce competitiveness and product quality standards required to meet European and international benchmarks.

The research presented in this paper expands the existing knowledge on RES investment management. The focus on forecasting RES integration scenarios, particularly in the electricity segment, and promoting investments in Moldova until 2025 and 2030 is commendable. The findings from this research can serve as valuable insights for policymakers in designing renewable energy policies and encouraging investments in modern renewable energy technologies to produce electricity.

Moreover, the proposed methodology and results hold general relevance and can be applied in assessments for other countries in the region with emerging economies. To enhance the research further, incorporating expert interviews and case study assessments could help explore other nuances and aspects within the sector that contribute to the topic under investigation. This comprehensive approach would enrich the study and offer a more robust foundation for policy recommendations and investment decisions.

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