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LOW AND NEGATIVE ELECTRICITY PRICES: A THREAT OR INCENTIVE FOR RES INVESTMENTS

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Abstract: *The global energy landscape has been significantly shaped by rising energy prices and the increasing demand for energy resources, driven by factors such as global warming. In this context, the role of renewable energy sources (RES) has become crucial in shaping the future of the energy sector. This paper explores the impact of low and negative electricity prices on the investment climate in renewable energy, focusing on both global trends and the specific case of Moldova. It analyzes the factors contributing to the overproduction of electricity from RES, such as high shares of variable generation, limited energy storage capacity, insufficient grid flexibility, and rigid tariff systems. The study examines the experience of European countries with record periods of negative electricity prices and discusses the risks and potential solutions for Moldova, a country undergoing rapid growth in its renewable energy capacities. The paper highlights the need for investments in energy storage technologies, flexible consumption mechanisms, and balancing systems, alongside the development of interconnection infrastructure to export surplus renewable energy. It concludes that while Moldova's risk of electricity overproduction remains relatively low, proactive measures and investments in energy infrastructure are essential to mitigate future challenges associated with negative electricity prices and to optimize the use of renewable energy sources.*

Keywords: *Renewable energy, negative electricity prices, Moldova, energy storage, investment, grid flexibility, solar energy, wind energy.*

UDC: *330.322:620.91(478)*

Classification JEL: *Q42, Q43, Q47, Q48.*

1. Introduction

In recent years, both globally and regionally, including in the Republic of Moldova, an energy crisis has been unfolding, driven by rising energy prices and the risks associated with insufficient energy supply to the country. The energy sector functions as a vital artery for the economy and industrial development. However, electricity and heat are often produced using outdated technologies and, for various reasons, operated under suboptimal efficiency conditions.

The development of the energy sector plays a critical role in stimulating economic growth. At the same time, economic growth itself is a key driver of increasing demand for energy resources. Investments in the energy sector have the potential to significantly accelerate the development of various branches of the national economy and contribute to GDP growth.

Currently, global investment is increasingly focused on green energy. Investments in renewable energy sources (RES) are becoming a primary driver for the transformation and modernization of the energy sector. According to forecasts, global electricity consumption is expected to reach 29.1 thousand TWh by the end of 2024, marking a 4.2% year-on-year increase. This would represent the highest growth rate since 2007, excluding the post-crisis and post-pandemic rebounds of over 6% observed in 2010 and 2021.

In 2025, the growth rate is expected to remain nearly unchanged, with electricity consumption projected to increase by 4.1%, reaching 30.3 thousand TWh. For comparison, in 2023, consumption grew by 2.5%, amounting to 27.9 thousand TWh.

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One of the key drivers behind the accelerating growth in electricity demand, according to the report's authors, is global warming. "Heatwaves stressed power systems around the world in 2024. With global temperatures reaching record highs, demand for electricity used in cooling surged sharply, placing significant pressure on energy systems," the report states.

Renewable energy generation is expected to grow by 11.8% in 2024 and 12% in 2025, reaching 10 thousand TWh and 11.2 thousand TWh, respectively, according to the International Energy Agency (IEA). Thus, the growth rate will more than double compared to 2023, when it stood at 5% (up to 9 thousand TWh).

In 2023, the share of renewables in global electricity supply rose to 30%, and it is expected to increase to 35% by 2025. Solar energy alone will account for around 50% of the global increase in electricity demand, and together with wind energy, will cover nearly 75% of that growth.[1]

Currently, approximately $2 trillion globally is expected to be allocated to clean technologies, including renewable energy sources, electric vehicles, nuclear energy, grid infrastructure, energy storage, low-emission fuels, efficiency improvements, and heat pumps. The remaining $1 trillion is projected to be spent on fossil fuels such as gas, oil, and coal.[2]

According to the IEA, global electricity demand is set to grow by approximately 4% in 2024, compared to 2.5% in 2023. This would represent the highest annual growth rate since 2007 (excluding the recovery periods following the global financial crisis and the COVID-19 pandemic). The report also notes that significant growth in electricity consumption will continue into 2025, again reaching about 4%.[3]

As a result of the substantial increase in investments in renewables and the growing number of commissioned RES capacities, the world is increasingly witnessing electricity oversupply, which leads to low or even negative electricity prices. Naturally, the irreversibility of long-term investments in energy infrastructure slows down the pace of such changes. However, the flow of commercially viable innovations and investments in new technologies has become clearly evident.

The strongest output in power generation from solar parks in Germany since September pushed prices in several countries into negative territory.

Intraday power in Germany traded as low as €-17.73 per megawatt-hour for the period from 1 p.m. to 2 p.m., according to data from Epex Spot SE. Prices in the Netherlands and Belgium also dropped below zero.

Negative prices are becoming more frequent across Europe as renewable power floods the grid and supply outstrips demand. While that's good for some consumers in mainly northern Europe, they are a worry for investors in solar and wind because sub-zero prices cripple returns.[4]

2. Literature Review

The transition to renewable energy sources (RES) is a key focus of global energy policy. While many countries have integrated RES into their energy mix, challenges remain - particularly regarding economic sustainability. Fluctuating electricity prices, including negative price events caused by oversupply and low demand, create uncertainty for investors and threaten the financial viability of RES projects. This literature review explores how low and negative prices impact RES investments, with an emphasis on global patterns and Moldova's experience.

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Key Concepts and Theoretical Background

Electricity prices play a critical role in shaping the investment climate. As Stern (2016) notes, price fluctuations can either stimulate or hinder investment, depending on expected trends and market stability. Couture and Gagnon (2010) highlight that persistently low prices, while favorable to consumers, reduce profitability and weaken incentives to invest in renewable energy.

Negative electricity prices typically emerge during periods of surplus generation, especially from intermittent sources like solar and wind—combined with low demand. Bunn and Bunn (2019) argue that such market imbalances distort price signals and threaten the economic sustainability of RES investments.

Global Trends in Price Volatility

Low and negative electricity prices have become increasingly common, especially in European markets. IEA (2024) reports that countries with high RES penetration, such as Germany and Denmark, regularly experience negative prices during peak production periods. Bloomberg (2025) finds that these occurrences are rising and may destabilize market structures.

Arenas and Martínez (2020) emphasize that traditional pricing mechanisms are poorly equipped to manage high RES penetration, and innovative policy tools are needed to maintain investor confidence, especially for capital-intensive RES projects.

Impact on RES Investment

Negative prices reduce revenue streams for RES projects, particularly those dependent on selling electricity into the market. Zhou et al. (2021) found that such conditions in the EU led to notable financial losses for wind and solar projects, discouraging further investment. Stern (2016) adds that investment risk increases in markets where prices are volatile or unpredictable, deterring private sector engagement.

The Moldovan Context

Moldova has expanded RES, especially in solar, supported by green certificates and the 2016 Renewable Energy Law. AGORA (2025) reports steady growth in solar capacity, and Energocom (2024) confirms ongoing integration efforts. However, Moldova's dependence on imports and limited local generation make the energy market sensitive to regional price swings. The impact of such fluctuations on RES investment in Moldova remains insufficiently studied.

Research Gap

Existing literature largely overlooks how price volatility affects RES development in small and emerging markets like Moldova. This study aims to fill that gap by analyzing how negative price events influence investment risks and returns in Moldova's renewable energy sector.

3. Methodology

In recent years, due to the risk of electricity shortages, as well as the complete cessation of supplies and the subsequent rise in energy resource prices, there has been an urgent need to increase electricity production in Moldova, primarily from renewable energy sources. However, the rapid introduction of new capacities has led to the risk of electricity production exceeding consumption. An example of this can be seen in many European countries. For this study, we will examine the introduction of renewable energy capacities worldwide and in one European country. We will also consider periods in European countries when electricity prices were negative, analyze the situation in Moldova

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concerning the installed renewable energy capacities, analyze peak electricity consumption and production in Moldova throughout the year, as well as during the maximum production periods during the day, and identify the risks and potential solutions.

4. Results and Discussion

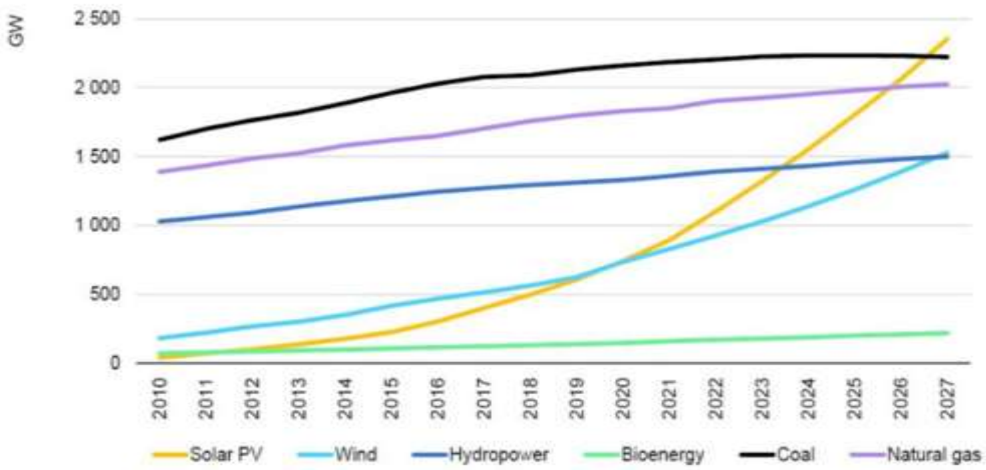

Figure 1. Cumulative power capacity by technology, 2010-2027

Source: www.renen.ru

The growth of renewable energy capacities will accelerate, according to the agency. This primarily concerns solar and wind generation. Currently, it is expected that global renewable energy capacities will increase by 2400 gigawatts (GW) from 2022 to 2027, which roughly corresponds to the current capacity of China's power sector, the agency notes. The report states that renewable energy sources will account for more than 90% of the global growth in electricity production over the next five years, and by the beginning of 2025, they will surpass coal-fired generation, becoming the largest electricity producer on Earth. The share of renewable energy in generation will increase by ten percent, reaching 38%.[5]

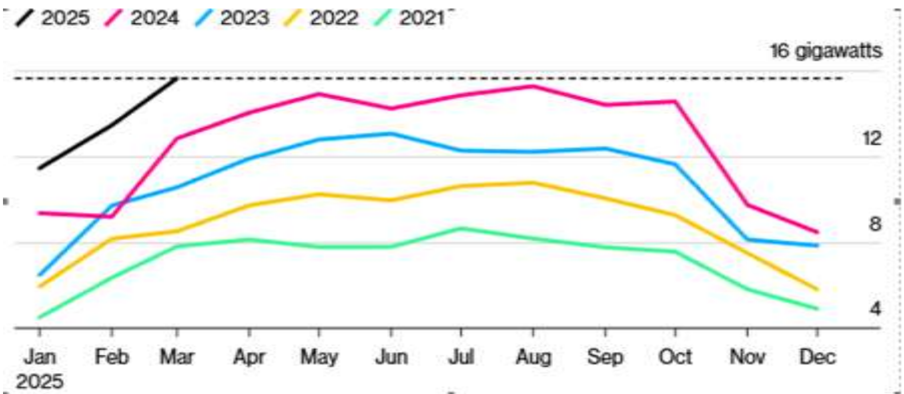

Figure 2. Highest solar generation in each month in France

Source: www.bloomberg.com

As we can see, electricity generation from solar panels in France has been growing every year, and the beginning of 2025 has also shown a significant increase. This indicates a continuing trend in the growth of solar energy output.[7]

Ultimately, the increase in renewable energy capacity leads to more frequent imbalances between electricity production and consumption. The main reasons for this are as follows:

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High share of variable generation

Renewable energy sources such as solar and wind depend on weather conditions and cannot flexibly respond to changes in demand. On sunny or windy days, when generation exceeds consumption, a surplus of electricity occurs, with no immediate way to utilize it.

Limited energy storage capacity

Although storage technologies (such as battery systems and pumped hydro storage) are advancing, they currently lack the capacity to fully balance sudden fluctuations in generation and consumption. As a result, surplus energy must either be exported (if possible) or electricity prices are reduced to zero - or even negative values - to stimulate demand.

Insufficient grid flexibility

Traditional power plants (thermal, nuclear, hydro) cannot quickly adapt to the variability of renewable generation. For example, coal and nuclear plants typically operate in baseload mode and are unable to rapidly reduce output when excess energy is generated.

Rigid tariff models and subsidies

In many countries, renewable energy sources have priority access to the grid, and grid operators are obligated to purchase their electricity. This leads to a situation where, during times of excess supply, prices must be reduced to prevent grid overload.

Export limitations

If a country cannot quickly export its surplus electricity (e.g., due to congested interconnectors), an oversupply arises on the domestic market, which can trigger negative prices.

Let us now examine the experience of several European countries in terms of record durations of negative electricity prices.

Table 1. Hours with negative prices in Europe

Year	UK	France	Germany	Spain
2020	0	102	298	0
2021	7	64	139	0
2022	26	12	83	0
2023	106	144	292	0
2024	179	356	468	247

Source: http://www. www.komersant.info

Last year, European power markets experienced record periods of negative electricity prices as the rapid expansion of wind and solar capacity boosted generation. In Germany, there was a 60% increase compared to the previous year, reaching 468 hours, according to data from Epex Spot. In France, the number of hours with negative prices more than doubled to 356.

On the sunniest or windiest days, electricity can flood the grid, causing prices to drop below zero and leading to situations where consumers are paid to use electricity. However, due to how subsidies for renewable generators are structured, some producers are incentivized to continue generating even when prices fall below zero, further distorting the market. Experts are urging governments to adjust these mechanisms and help reduce the occurrence of negative prices. [6]

Let's look at the situation in Moldova. In recent years, investments in renewable energy sources have been actively developing in Moldova. Especially in the installation of solar panels and wind generators.

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	Producer					
	Law 160-XVI/2007	Law 10/2016/fixed tariff	Free market	Net Acounting	Net invoicing	TOTAL
Solar panels	0,59	132,62	134,00	115,31	32,71	415,23
Wind power plants	27,23		151,65			178,88
Biogas	5,17	1,84				7,01
Hydropower	0,25		16,50			16,75
Total	33,24	134,46	302,15	115,31	32,71	617,87

Figure 3. Existing RES electricity production capacities at the end of January 2025, MW

Source: www.cned.gov.md

The installed capacity of renewable energy sources (RES) reached 617.87 MW at the beginning of 2025, representing a 1.8-fold increase compared to 2024.[8] This trend continued throughout 2024, and according to data from the state-owned company Energocom, nearly twice as much green electricity was generated each month compared to 2023.

Let us now examine the annual commissioning of RES capacities.

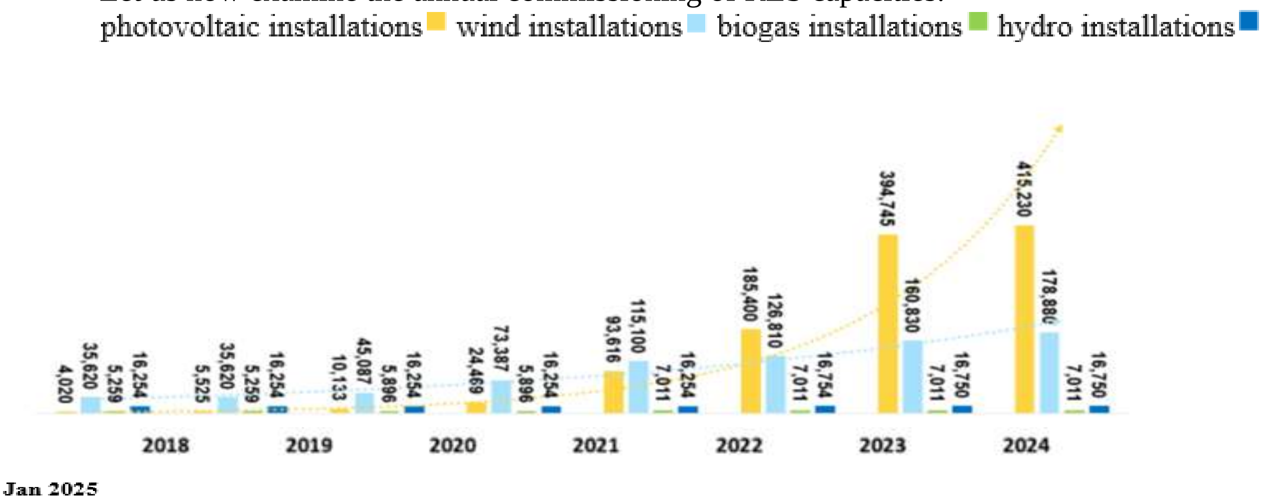

Figure 4. Evolution of installed RES capacities in the period 2018 – January 2025, MW

Source: www.cned.gov.md

As we can see, compared to 2018, by the beginning of 2025 the amount of installed RES capacity has increased several times.[8] During 2025, two large photovoltaic power plants are scheduled to be built: one in Negureni (Telenești district) with an installed capacity of 40 MW, and another in Rădeni (Strășeni district) with a capacity of 50 MW. This means that the total installed RES capacity will exceed 700 MW, while total electricity consumption in our country during spring and autumn does not exceed this amount.[9]

Let us consider the ratio of the maximum peak electricity consumption in Moldova and the capacity of renewable energy power plants commissioned in relation to peak production during the day. When examining the data from the table over the course of the year, it can be observed that the installed capacity of renewable energy sources (RES) at the beginning of 2025 reaches its maximum value relative to the peak energy consumption each month during the spring and autumn months, reaching up to 88%. With further

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increases in the commissioning of new capacities, this figure may exceed the 100% threshold. Since we know that the installed power plants only generate a portion of their installed capacity throughout the year, we determined that the maximum value relative to peak demand reaches up to 20% in the autumn.

Table 2. Maximum electricity consumption, power and peak production in Moldova at the beginning of 2025

Indicator	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Maximum peak consumption of MW per unit of time per year	948	948	750	700	700	900	900	900	900	900	900	948
Solar panel power, MW	412.53	412.53	412.53	412.53	412.53	412.53	412.53	412.53	412.53	412.53	412.53	412.53
Wind energy power, MW	23.76	23.76	23.76	23.76	23.76	23.76	23.76	23.76	23.76	23.76	23.76	23.76
Other RES, MW	181.36	181.36	181.36	181.36	181.36	181.36	181.36	181.36	181.36	181.36	181.36	181.36
Total RES capacity, MW	617.67	617.67	617.67	617.67	617.67	617.67	617.67	617.67	617.67	617.67	617.67	617.67
Ratio of RES power to peak values, %	**65%**	**65%**	**82%**	**88%**	**88%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**65%**
Average power used by wind turbines, MW	41	55	55	41	41	41	41	41	41	41	55	55
Average power used by solar panels, MW	21	21	54	62	62	100	100	100	62	62	21	21
Total average power, MW	110	121	228	228	228	280	280	280	228	228	117	117
Ratio of average power to peak values, %	11%	13%	30%	33%	33%	31%	31%	31%	25%	25%	13%	12%
Electricity production by wind power plants, MW	41 196	55 193	55 193	41 196	41 196	41 196	41 196	41 196	41 196	41 196	55 193	55 193
Electricity production by solar power plants, MW	15 447	15 447	39 734	45 607	45 607	73 552	73 552	73 552	45 607	45 607	15 447	15 447
The maximum power of solar and wind power plants in 9:00 to 15:00, MW	109	111	222	238	238	300	300	300	238	238	111	111
Ratio of RES peak production to peak demand 9:00 to 15:00	**12%**	**12%**	**30%**	**34%**	**34%**	**36%**	**36%**	**36%**	**32%**	**32%**	**12%**	**12%**

Source: compiled by the author based on data from https:// cned.gov.md, logos-pres.md, Energocom.md, MyBusiness.md, ener-gy.com.ua, www.llnl.gov, solar.md, e-solarpower.ru

The period during the day when solar and wind power plants together generate the maximum output is from 9 AM to 3 PM. As a result, we determined that the maximum generation relative to peak demand reaches 36% in the summer period, which indicates that moments when the generation of electricity from RES exceeds the maximum demand are rare. Therefore, the risks associated with low or negative prices remain insignificant. In 2024, Energocom purchased 4.5 million MWh of electricity, and according to the calculation data from the table, the electricity generated from RES at these capacities will account for 22.9% of the purchased electricity. [8,9,13,23,25,26]

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In 2030, the government set a target to achieve 30% of electricity generation from RES. [10]. Accordingly, based on the growth model from 2024, the table of capacities will look as follows.

Producer	Law 160-XVI/2007	Law 10/2016/fixed tariff	Free market	Net Acounting	Net invoicing	TOTAL
Solar panels	0,59	182,27	224,26	115,31	58,43	580,87
Wind power plants	27,23		199			226,41
Biogas	5,17	1,84				7,01
Hydropower	0,25		16,5			16,75
Total	33,24	184,11	439,94	115,31	58,43	834,04

Figure 5. Capacities to be installed for electricity production from RES in MW as of 01.01.2030

Source: compiled by the author based on data from https:// cned.gov.md

To achieve 30% electricity generation from RES relative to the consumption volume of 4.5 million MWh for the current year, it is necessary to increase the capacity to 834.04 MW, which is 34.5% higher than at the beginning of 2025.[8]

Based on this data, we will obtain a new table showing the relationship between maximum peak electricity consumption and the installed capacity of RES power plants in relation to peak generation throughout the day.

Table 3. Maximum electricity consumption, power and peak production in Moldova in 2030

Indicator	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maximum peak consumption of MW per unit of time per year	948	948	750	700	700	900	900	900	700	700	750	948
Solar panel power, MW	582.52	582.52	582.52	582.52	582.52	582.52	582.52	582.52	582.52	582.52	582.52	582.52
Wind energy power, MW	23.76	23.76	23.76	23.76	23.76	23.76	23.76	23.76	23.76	23.76	23.76	23.76
Other RES, MW	331.03	331.03	331.03	331.03	331.03	331.03	331.03	331.03	331.03	331.03	331.03	331.03
Total RES capacity, MW	937.31	937.31	937.31	937.31	937.31	937.31	937.31	937.31	937.31	937.31	937.31	937.31
Ratio of RES power to peak values, %	88%	88%	111%	134%	134%	104%	104%	104%	134%	134%	125%	99%
Average power used by wind turbines, MW	70	70	70	52	52	52	52	52	52	52	70	70
Average power used by solar panels, MW	29	29	87	139	139	193	193	193	139	139	29	29
Total average power, MW	132	132	235	266	266	320	320	320	266	266	152	152
Ratio of average power to peak values, %	13%	13%	31%	38%	38%	36%	36%	36%	38%	38%	20%	16%
Electricity production by wind power plants, MW	52 142	52 142	52 142	38 912	38 912	38 912	38 912	38 912	38 912	38 912	52 142	52 142
Electricity production by solar power plants, MW	21 698	21 698	65 181	93 627	93 627	130 876	130 876	130 876	93 627	93 627	21 698	21 698
The maximum power of solar and wind power plants in 9:00 to 15:00, MW	168	168	305	315	315	443	443	443	315	315	168	168
Ratio of RES peak production to peak demand at 9:00 to 15:00	16%	16%	41%	45%	45%	49%	49%	49%	45%	45%	30%	18%

Source: compiled by the author based on data from https:// cned.gov.md, logos-pres.md, Energocom.md, MyBusiness.md, ener-gy.com.ua, www.llnl.gov, solar.md, e-solarpower.ru, agora.md

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According to the table, generation capacities reach up to **119% of peak demand** during the autumn and spring periods, which indicates **a risk of electricity overproduction** if all renewable energy sources (RES) operate at their maximum capacity simultaneously. However, such occurrences remain rare at this stage.

If we consider the **average monthly electricity generation from RES**, the **maximum ratio of generation to peak demand** is observed in **October and the summer months**, reaching up to **25%**.

The **maximum daily generation** from RES in relation to peak demand reaches **49% during the summer period**, indicating that during certain times of the day - when there is both good solar irradiance and strong wind - the amount of electricity generated from renewables may exceed Moldova's current consumption. However, such instances remain relatively infrequent. [8, 9, 10, 13, 23, 25, 26]

Table 4. Key Mitigation Measures for RES Overproduction and Low/Negative Electricity Prices

Mitigation Measure	Description	Effect on Market
Electricity storage systems	Store excess energy in batteries or pumped hydro storage	Reduces curtailment and helps balance supply and demand
Demand response programs	Incentivize consumers to shift usage to periods of high RES output	Increases demand when supply is high, stabilizing prices
Grid interconnections	Export/import electricity across borders or regions	Enhances flexibility, reduces local overproduction
Flexible backup generation	Use gas or hydro plants that can quickly ramp up/down	Ensures grid stability without displacing RES
Dynamic pricing mechanisms	Real-time or time-of-use tariffs that reflect electricity market conditions	Aligns consumer behavior with RES generation patterns
Curtailment with compensation	Controlled reduction of RES output, compensated financially	Prevents extreme price drops, protects investor returns
Green hydrogen production	Use excess electricity to produce hydrogen as an energy carrier	Converts surplus into storable, tradable energy resource

Source: Compiled by the author based on multiple academic and policy reports (IEA, 2023; Agora Energiewende, 2022; European Commission, 2023).

5. Conclusions

Low and negative prices reduce the revenues of renewable energy producers and producers in a market where there are no fixed contracts or support mechanisms like Feed-in Tariffs (FiT) or Contracts for Difference (CfD).

Long-term investors may fear income instability, which makes projects less attractive for financing. If low prices become common, this can reduce interest in building new renewable energy capacities as the expected return on investment decreases.

This is especially true for markets without sufficient flexibility or energy storage support mechanisms. Renewable energy producers may face situations where generation must be curtailed to avoid losses. This reduces the effective use of installed capacity and can affect the profitability of the investment.

In Europe, these moments have arrived much earlier due to the high share of renewable energy sources in electricity generation.

In Moldova, the risk of overproduction exists and will increase in the future, but it is still significantly lower than in Europe. However, it is worth preparing for this in advance. To do this, investments in energy storage devices (batteries, pumped storage

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stations) or flexible consumption mechanisms (demand response) are needed, which increases the total costs of projects.

Investors may increasingly invest in battery energy storage systems (BESS) and Power-to-X technologies (e.g., hydrogen production). This encourages the development of new business models, such as selling electricity during peak demand periods. Investments in balancing systems are needed, which requires additional resources. With the development of interconnection infrastructure, it will be possible to export cheap renewable energy to regions with higher demand, contributing to the growth of investments in new projects.New instruments are emerging to optimize the use of renewable energy sources, including flexible tariff systems and Contracts for Difference. In some countries, the practice of paying for consumption flexibility is being developed, which increases the economic efficiency of renewable energy sources.

Therefore, it is worth preparing and conducting all surveys, checks, and additional investments today to be ready for the consequences of excessive electricity supply and the emergence of negative prices in the future.

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