Harvesting Albania's Potential: The Case for Implementing a Wind-Solar Hybrid Park

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Abstract

This theoretical study delves into the conceptual underpinnings and theoretical frameworks essential for the establishment of a wind-solar hybrid park in Albania. Drawing upon established theories in renewable energy integration, this research examines the fundamental principles of wind and solar technologies, emphasizing their complementary attributes within a hybrid park setting. Theoretical models elucidating the integration, coordination, and optimization of these renewable sources are explored, aiming to address challenges such as intermittency and grid stability. The study further investigates theoretical frameworks concerning economic feasibility, policy support, and environmental sustainability, crucial for the successful implementation of such an initiative in Albania's energy landscape. By synthesizing theoretical foundations, this study offers insights into the theoretical groundwork *necessary to inform and guide the practical realization of a wind-solar hybrid park in Albania.*

***Keywords**: Wind-solar hybrid park, Renewable Energy, Feasibility, Electrical energy, Frameworks*

Wind Energy Potential in Albania

The main wind directions in our country are northwest-southeast and southwest-northeast, with a predominant direction towards the ground. Within the territory, the direction and intensity of the wind vary significantly from one area to another over time. The measurements from the hydrometeorological institute, for many years, have aimed primarily to provide meteorological data on weather to the aviation and maritime services. Quite high speeds have been recorded at the stations in Pukë, Vlorë, Borsh, Kryevidh, Gllava, Xarrë, Sheqeras, and Durrës. For these stations, values lower than 3 m/s have not been recorded in any case. In other areas like Tirana, Rrëshen, etc., low average speeds have also been recorded during the cold season. Analyzing the average distribution of annual wind hours, it turns out that relatively high speeds are not only recorded during midday but also during mornings when the wind normally registers lower speeds. Analyzing the results in areas with high wind flow, it's observed that the average speed exceeding 3m/s is present throughout the year and that exceeding 5m/s occurs during midday. It's worth mentioning that current wind energy production technology has developed turbines that automatically orient themselves according to the wind direction. Observations of anemometer diagrams for several stations have calculated the time intervals during which the wind speed throughout a year is greater than 5m/s. Considering that wind power is proportional to its cubic value, it results that suitable conditions for energy resources are offered in many parts of our territory. Based on the data from the Hydrometeorological Institute in Table 1, an overview of wind speed and energy density for the areas surrounding the proposed zone is presented, allowing us to assess the wind potential with performance indicators of 10-30%.

In Albania, the prevailing winds throughout the year are those from the northern quadrant, followed by those from the southern quadrant. Winds from the western and eastern quadrants occur less frequently. The origin of these winds lies beyond Albania's borders, except for locally characterized winds, such as sea and land breezes, valley winds, etc.

Another characteristic is the absence of prevailing winds from the west in any location. The prevalence of south and southwest directions is observed only in specific areas (southern in Erseke, while southwest in Korca). Due to the highly fragmented relief caused by valleys and gorges, the winds experience significant deflections throughout the year.

TABLE 1: Annual Distribution of wind direction in %

Meteorological Stacions	Q	N	NE	E	SE	S	SW	W	NW
Shkoder-A	58.5	0.7	2.6	12.4	7.2	6.1	4.1	4.8	3.6
Durres	6.2	27.8	4.3	3.8	21.9	7.6	6.6	13.3	8.5
Tirane-A	39.3	3.7	3	3.3	18.2	5.2	7.8	4.2	15.2
Elbasan	40.1	2.4	18.2	12.5	3.1	2.5	11.2	4.9	5.1
Lushnje	36	6.9	11.8	17.9	4.1	1.9	3.3	6.4	11.6
Kucove	41.8	2.8	1.8	2.4	26.4	2.8	2	6.8	13.1
Fier	19.9	5.4	5.9	15.4	20.2	5.8	6.6	7.8	13
Vlore	40.2	3.5	6.7	17.1	3.2	7.6	5.3	6.5	9.8
Borsh	14.7	22.3	10.3	0.5	4.6	8.7	12.4	3.5	23
Sarande	12.4	7.6	31.5	8.1	8.2	10.1	12.4	6.9	2.5
Burrel	44.8	6.7	2.3	6.3	4.8	8.7	7.1	7.5	11.7
Gjirokaster	43	3	0.3	1	15.4	10.9	3.3	7.6	15.2
Kukes	58.2	12	10.1	0.6	0.7	8.5	8	1	0.9
Peshkopi	44.5	1.7	4.7	9.5	11.9	4	6.7	9.5	7.4
Pogradec	49.8	14.5	4.5	0.8	4	11.2	6.1	5.1	3.8
Korce	51.2	10.3	5.5	7.1	5.8	2.2	13.2	2.4	2.3
Voskopoje	35	5.7	5.3	9.4	10.2	4.2	5.4	7.9	16.8
Erseke	48.3	10	3.3	2.6	3.6	13.4	7.9	4.4	6.5

A Wind Speed

Various forms of relief influence not only the direction but also the speed of the wind. Primarily, wind speed is determined by baric gradient. In the specific conditions of our country, wind speed increases or decreases depending on different relief forms. While the seasonal pattern in wind direction is not pronounced, there are noticeable changes from region to region. Overall, wind speed during autumn and summer tends to be lower compared to other seasons.

Extensive material analysis on wind speed reveals variations month by month. Generally, higher speeds are observed during winter months. The characteristics of winter months persist in March. In some regions, these characteristics endure into April as well.

TABLE 2: Average Wind Speed in m/s

Seasons	Shkoder-A	Durres	Tirane-A	Elbasan	Lushnje	Kucove	Fier	Vlore	Borsh	Sarande	Burrel	Gjirokaster	Kukes	Peshkopi	Pogradec	Korce	Voskopoje	Erseke
Winter	0.2	4.6	1.8	3.1	0.2	2.3	3	3.1	3.5	3.9	1.8	2.1	3.5	1.8	2.1	2.4	2.7	2.6
Spring	2.2	3.9	1.8	2.3	2.7	2.2	3.1	2.6	2.8	3.4	1.8	2.6	3.1	2.2	1.6	2.7	2.7	2.5
Summer	1.9	3.3	1.7	1.7	2.7	2	2.6	2.1	2.5	3	1.7	2.9	2.3	1.8	1.1	1.7	2.1	1.5
Autumn	1.8	3.7	1.5	1.7	2.7	1.8	2.5	2.3	2.9	3.6	1.5	1.7	2.3	1.7	1.6	2.2	2.2	1.9
Annual	**2**	**3.8**	**1.7**	**2.2**	**2.8**	**2.1**	**2.8**	**2.5**	**2.9**	**3.4**	**1.7**	**2.4**	**2.8**	**1.8**	**1.6**	**2.2**	**2.4**	**2.2**

Solar energy in Albania

Albania has a favorable geographical position in the Mediterranean basin and very favorable climatic conditions for the use of solar energy, with a high intensity of solar radiation, a duration of this radiation, temperature, humidity, etc. Mediterranean climate with a mild and humid winter and a hot and dry summer determines a higher energy potential than the average energy potential for the use of solar energy, with a high intensity of solar radiation, estimated at slightly more than 1300-1500 kWh/m2/year. The country has an average of 2400 hours of sunshine. However, its western and southwestern parts can reach up to 2550 hours of sunshine. The selected and evaluated land, deemed quite favorable to produce electrical energy through solar panels, is in the city of Fier in western Albania.

TABLE 3: Solar Radiation for some cities of Albania (IGJEUM)

Month/ City	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
	55.3	68.0	102.4	128.9	162.9		200.0	174.6	135.5		64.4	55.8
Shkodra	9	7	2	8	9	182.7	4	6	7	91.24	2	1
	60.9	72.7	103.8	130.6		194.8	207.3	189.6	142.1	102.1	67.9	60.1
Tirana	7	9	5	1	172.7	3	1	7	6	1	8	2
	67.3	***77.9***	***121.7***	***156.2***	***196.2***	***215.1***	***226.3***		***157.9***	***112.1***	***76.1***	***67.1***
Fier	***2***	***9***	***9***	***5***	***3***	***4***	***2***	***212.1***	***6***	***6***	***2***	***5***
	70.0	71.2	101.9	144.3	179.9	204.4	221.6	208.8	163.2	118.2	83.4	79.3
Vlora	6	2	7	8	8	4	9	9	1	2	1	4
	70.6	77.0	102.5	142.9	174.0	192.4	214.4	200.1	166.6	118.2	79.9	71.7
Durres	1	2	6	1	7	4	5	7	2	2	2	9
	70.6	74.7		137.4	175.4	195.1	213.8	199.5	161.6	111.2		72.9
Kucova	4	1	97.91	9	1	1	2	4	2	7	77.6	6

The assessments show that the most favored regions for natural energy potential are again the western regions. Therefore, every square meter of horizontal surface in these areas during the period from November to March receives up to 380 kWh/year, while the territorial average for this period is around 340 kWh/year. The distribution of sunlight (number of sunshine hours) and especially that of annual sunlight, which in these cases is used as an indicator of brightness, is around 2400 hours throughout the territory, while in the western part, it's over 2500 hours and in the Myzeqe area, it reaches over 2700 hours. The highest values of daily sunlight intensity are observed during the warm period of the year and especially in the summer months. To be more specific, in December, the daily sunlight intensity is around 2.3 kWh/m2 per day, while in July, this value is around 8.030 kWh/m2 per day. The daily sunshine in the western part of Albania is more than 5.5 hours. The only exceptions are the three winter months. In the practical use of solar energy, "good days" are considered those with daily sunshine of no less than 5.5 hours. Calculations have also been made for "bad days" (these days are those in which daily sunshine is less than 1.5 hours). The analysis of this parameter confirms that the western part of Albania is more favorable than the inland part in terms of using solar energy. In our country, the number of sunny days ranges from an average of 240-260 days per year to a maximum of 280-300 days. However, areas proposed for the diversification of renewable natural resource utilization also have satisfying sunlight radiation. A table with solar radiation for 26 meteorological stations, is provided below in Table No.4.

TABLE 4. Average Values of Solar Radiation kWh/m2

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	**Average**
Razem	52.7	64.6	98.10	123.60	159.80	174.10	197.50	173.70	129.80	90.80	54.40	45.90	1365.00
Shkoder	53.8	66.7	103.60	132.90	168.70	189.50	203.70	179.00	133.3	92.9	55.2	47.2	1426.5
Kukes	44.3	59.9	93.30	125.00	160.40	182.60	196.50	172.10	123.9	83.2	48.3	38.9	1328.4
Puke	52.1	64.9	101.90	126.70	170.50	158.00	202.70	182.60	135.8	91.2	56.1	46.2	1388.7
Lezhe	55.5	69.5	106.30	137.40	173.70	199.10	213.90	186.60	139.3	96.2	59.7	49.8	1487
Peshkopi	50	65.9	100.10	129.80	164.40	184.60	199.90	175.90	130.7	92.3	54.4	43.5	1391.3
Mamurras	55.5	68.5	104.40	134.50	169.50	189.20	203.20	180.10	135.2	93.6	58.8	48.6	1441.2
Burrel	54.6	67.9	102.70	132.60	171.20	185.50	201.30	175.40	132.7	94.1	57.1	46.7	1421.7
Kamez	58	71.2	104.70	136.10	174.00	195.40	211.60	186.60	138.6	100.1	60.5	49.2	1486
Tirane	56.7	69.7	103.70	134.00	173.70	194.30	210.20	185.70	138.9	98.9	59.4	47.9	1473.3
Durres	57	72.3	108.60	140.80	177.60	196.70	210.90	186.90	142.5	100.3	60.5	48.6	1502.8
Elbasan	58.4	71.6	103.5	132.5	168.1	187.3	202.1	180.9	135.5	98.2	60.3	50.1	1448.5
Lushnje	58.1	72.5	107.2	138.4	178	198.7	211.9	184.2	137.3	95.3	60	48.9	1490.5
Pogradec	53.8	68.3	101.2	134.7	170.8	192.1	208.1	182.2	133.3	93.5	58.5	47.3	1443.8
Kucove	59.2	73	106.5	139.4	178.3	198.5	211.4	187.3	137.4	98.8	61.8	51.3	1502.6
Fier	**60.2**	**75**	**111.5**	**145.9**	**185.7**	**208.4**	**223.5**	**197.1**	**144.7**	**103**	**64.4**	**52.9**	**1572.2**
Sheqeras	53.8	69.1	103.5	135.6	171.1	188.6	207.5	185.9	137.3	95.9	59.2	46.8	1454.5
Voskopoje	53.3	67.4	99.8	133.3	171.4	193.7	208.3	181.9	133.2	94.2	57.6	47.2	1441.2
Korce	53.9	69.6	102.2	132.8	167.4	188.9	203.6	179.3	132.8	93.9	59.2	47.1	1430.6
Gllave	57.9	71.8	104.4	127.3	164.8	180.3	195.8	176	134.8	97.2	61.7	50.8	1423
Vlore	59.9	74	109.6	142.7	181.6	202.6	216.5	191.5	144.2	102.1	63.6	52.1	1540.3
Erseke	57.7	73.5	105.6	134	170.2	191.3	208.9	179.6	135.6	97.3	62.9	51.9	1468.3
Gjirokaster	55.2	69.7	104.1	135.9	176.4	198	211	186	136.9	96	58.8	47.5	1475.3
Borsh	29.3	71.9	104.2	134.5	266.2	192.3	203.8	183	136.6	97.6	62	50.4	1561.6
Sarande	60.1	74	109.2	138.8	178.7	197.1	209.8	186.1	140	100.8	65.3	54.1	1514
Xarre	62	74.5	110.8	140.4	181.4	201.1	212.2	188.7	142.6	101.7	66.9	55.5	1537.7

Hybrid Park

Hybrid parks, combining wind and solar energy, offer several advantages that make them an attractive choice for energy generation:

- Resource Complementarity: Wind and solar energy sources often complement each other. Wind tends to blow more strongly during certain times of the day or year when sunlight might be less available. By combining both, the system can generate power more consistently throughout the day and across seasons.
- Stable Energy Production: When one source experiences fluctuations or downtime due to weather conditions (e.g., low wind or night-time for solar), the other source might still be active. This helps maintain a more consistent power supply.
- Maximized Land Use: Combining wind and solar in a single location optimizes land use. The land can be utilized effectively to generate both types of renewable energy, reducing the need for additional space and land clearance.
- Redundancy and Reliability: Hybrid systems provide a level of redundancy in power generation. If one system encounters issues, the other can continue producing electricity, enhancing overall system reliability.
- Diversification of Energy Sources: Relying on multiple sources of renewable energy reduces dependency on a single technology or energy source. This diversification helps mitigate risks associated with intermittent and maximizes energy production.
- Economic Efficiency: In certain regions, a combination of wind and solar might capture various government incentives, subsidies, or support programs for renewable energy, making the project economically viable.
- Optimized Infrastructure: Some infrastructure components, such as grid connections or storage solutions, can be shared between wind and solar systems, reducing overall infrastructure costs.
- Environmental Benefits: Both wind and solar energy are clean and renewable sources, contributing to lower greenhouse gas emissions and reducing the environmental impact of energy generation.

The combination of these factors makes hybrid wind-solar parks an attractive choice for meeting energy demands sustainably, efficiently, and reliably, especially in areas where both wind and solar resources are available.

A Technical Analyses

Calculating the expected energy output from different renewable sources like solar panels and wind turbines. Formulas involve factors like average sun hours, wind speed, efficiency ratings of equipment, etc.

- *Energy output formula for solar panels:*

$$P = S_i A \eta t$$

Where:
P – Energy Output
S_i – Solar irradiance
A - Area of Solar Panels
η - efficiency of the solar panels in converting sunlight into electricity
t - Time is the duration for which the solar panels are operational

- *Energy output formula for wind turbines:*

$$P = \frac{1}{2} C_p \rho A U^3$$

Where:

ρ - the density of air
C_p - power coefficient
A – rotor swept area
U – free wind speed

Investment Analysis

There are several methods for the economic and financial evaluation of a project, among which the most used are the Net Present Value (NPV) and the Internal Rate of Return (IRR). These methods take into consideration numerous factors, particularly designed to facilitate the valuation of money over time. NPV is a figure that expresses the value of an investment in current monetary terms. A project should only be considered when the NPV results in a positive value. The formula for calculating NPV is as follows.

$$\text{NPV} = \sum_{i=1}^{i=n} \frac{R_i - (I_i + O_i + M_i)}{(1+r)^i} + V_r$$

Where:

- Ii = investment in period i
- Ri = revenues in period i
- Oi = operating expenses in period i
- Mi = maintenance expenses in period i
- V = residual value of the investment over time, where the equipment's lifespan exceeds the project's duration
- r = periodic inflation
- n = project lifespan

IRR or Internal Rate of Return determines the interest rate that is equivalent to the expected rate of return from the project. When this interest rate is known, it is compared to the interest rate that would be earned by investing this money in other projects or investments. If the IRR is lower than the cost of borrowed capital for investing in the project, the project would financially fail. However, in such projects, the IRR value should be several points above the borrowing interest rate to compensate for risk, time, and issues accompanying the project.

Financial Analysis

The investment made will involve both cost expenses and revenue generated from energy production. Cost expenses include a fixed component comprising capital costs, insurance, various taxes, and a variable component primarily represented by operating and maintenance expenses, wages, income taxes (profit tax, VAT), etc. At the end of the project, the remaining value after summing expenses and revenues should typically be positive in favor of the revenues generated from the sale of electrical energy. Economic-financial analysis is precisely a comparison of costs and economic benefits that provides the investor with necessary information to decide whether to proceed with the project or abandon it. Such a choice can also be made among different projects so that the investor selects the one yielding the greatest economic benefits.

Economic-financial analysis can be conducted either by including the effects of inflation or by disregarding them. Working with a constant monetary value has the advantage of conducting an analysis independent of inflation. However, if there are reasons to believe that certain factors will cause inflationary effects, these should be treated with different inflation values. For example, assuming that electricity tariffs will increase 3% less than the inflation rate while other factors remain constant in value, the price of electricity would show a 3% decrease annually in the economic analysis.

The evaluation of investment costs, determined through the implementation budget estimates, including civil construction works and the procurement and installation of equipment, constitutes the first step of an economic assessment. Further evaluation of other expenses such as operational costs (labor), various taxes, revenues, and taxes on them are essential for conducting an economic-financial analysis to decide whether the project will proceed or be abandoned.

Theoretically, there are several methods for the economic-financial valuation of a specific investment based on concession, including:

- *Time value of money method*: It represents the concept that 1 (one) EURO received today is more valuable than 1 (one) EURO received in the future because the EURO received today can be invested to earn interest. This analysis generally involves a relationship between a certain amount of money, a specific time, and a specified interest rate.
- *Payback method*: It is a static method that represents the number of years required for the invested capital to be compensated by the income resulting from the sale of goods, in our case, the sale of electrical energy.
- *Return on Investment method (ROI):* It is another static method based on the calculation of average annual incomes, net annual costs, such as depreciation as a percentage of the original investment value.

$$ROI = \left(\frac{\text{Net Profit}}{Investment\ cost} \right) \times 100$$

- *Net Present Value (NPV) Method*: It is a dynamic method that compares the sum of the present values of income each year with the initial investment.
- *Internal Rate of Return (IRR) Method*: It is a dynamic method where the discount rate equals the present value of income (e.g., revenue from selling electrical energy) with the initial investment of the project, making NPV=0.
- Benefit – Cost Ratio Method: It is a dynamic method based on comparing the net present value of benefits and investment based on a ratio.

Project development stages

Exploring the sequential stages involved in Developing hybrid farms that combine wind and solar energy systems, it starts with ideation and site selection. Progressing through meticulous planning and execution, emphasis lies on integrating both energy sources. The importance of constant monitoring for optimization is highlighted, concluding with the collaborative journey toward sustainable energy production in hybrid parks.

Stage 1: Site Identification/Concept (7, 1)

- Identification of Potential Site
- Funding of project development
- Development of rough technical Concept

Stage 2: Prefeasibility study (2)

- Assessment of Different Technical Options
- Approximate Cost/Benefits
- Permitting needs

Stage 3: Feasibility Study (3)

- Technical and Financial evaluation of preferred option
- Assessment of financing options
- Initiation of permitting process
- Development of tough technical concept

Stage 4: Financial/Contracts (4)

- Permitting
- Contracting strategy
- Supplier selection and negotiations
- Financing of project

Stage 5: Detailed Design (5)

- Preparation of detailed design
- Preparation of project implementation schedule
- Finalization of permitting process

Stage 6: Construction (6)

- Construction

Stage 7: Commissioning

- Performance testing
- Preparation of As Build Design

The legal framework for new generation power plants in Albania is primarily governed by several key laws and regulations related to energy, environment, and investment. Here are some of the important elements of the legal framework for establishing new generation power plants in Albania:

Energy Sector Laws and Regulations

- Law on the Electricity Sector: Defines the legal framework for the generation, transmission, distribution, and supply of electricity. It outlines licensing procedures, market rules, and regulatory oversight.
- Renewable Energy Laws: Specific laws or regulations that promote and regulate renewable energy sources, offering incentives, feed-in tariffs, or other support mechanisms to encourage investment in clean energy generation.

Environmental Legislation

- Environmental Protection Law: Sets standards for environmental impact assessments (EIAs), emission controls, and compliance requirements for power plants to ensure minimal environmental impact.
- Environmental Impact Assessment (EIA) Regulations: Mandate the assessment and approval process for proposed projects to evaluate potential environmental effects and mitigation measures.

Licensing and Permitting

- Energy Regulatory Authority (ERE): Responsible for issuing licenses, regulating tariffs, and overseeing compliance in the energy sector.
- Generation License: Required for power plant operators to legally generate and sell electricity, outlining technical, financial, and operational requirements.

Grid Connection and System Operation

- Transmission System Operator (TSO): Manages the transmission grid and ensures the connection of new generation plants to the grid in compliance with technical standards and regulations.
- Connection Agreement: Specifies the technical and commercial conditions for connecting the power plant to the national grid.

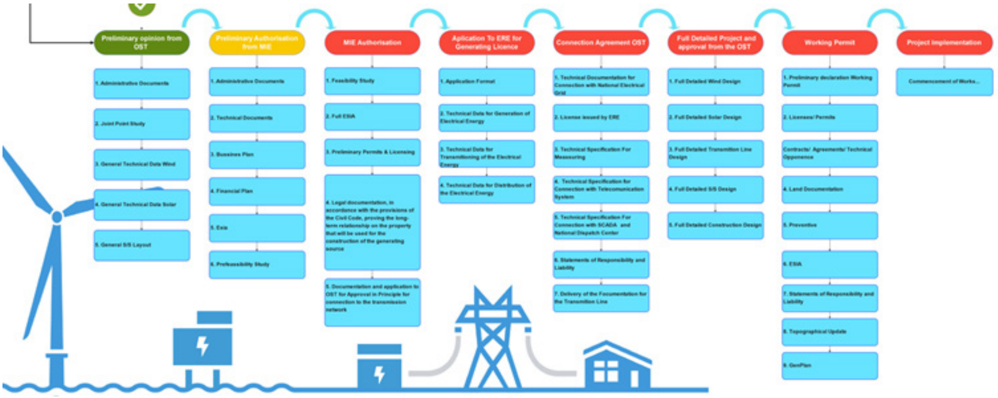
Investment and Contracts

- Investment Promotion Legislation: Laws promoting foreign investment and providing incentives for energy projects.
- Power Purchase Agreements (PPAs): Contracts between power producers and off-takers (utilities or consumers) defining terms for selling electricity, pricing, and other commercial aspects.

Regulatory Stability and Dispute Resolution

- Stability Agreements: Some countries offer stability agreements that assure investors of stability in regulations and protect them from adverse changes in laws.

FIGURE 1. Project Development Milestones for Albania Legal Framework



Actual Electro-energetic situation of Albania

The total consumption of electrical energy (EE) in the country during this period has been covered by EE generation from KESH sh.a (Albanian Power Corporation), independent EE producers, priority EE producers, as well as EE imports.

For the year 2022, domestic EE generation was 7,002 GWh, while the total EE consumption in our country was 7,924 GWh, with a net EE import difference of 921 GWh. The net balance of electrical energy exchange for this period, amounting to 921 GWh, results from an export difference of 2,123 GWh and an import realized at 3,044 GWh. This difference is understandable due to the Albanian electricity system being based on hydropower resources. During periods with abundant rainfall, EE is exported, while during periods with low rainfall, EE is imported to meet demand.

In conclusion, it can be stated that in our country, the profile of EE generation does not always align with consumption. Therefore, diversification of EE generation resources will influence reducing the quantity of imported EE. The losses of EE in the distribution network during the year 2022 were 19.7%, with a slight increase of 0.1% compared to the target set in Decision of the Council of Ministers no. 758, dated 09.12.2021. The total losses for the year 2021 in the distribution system reached 20.62%. The year 2022 resulted in a lower level of losses compared to 2021.

The level of losses in the transmission system for the year 2022 was 199,994 MWh or 2.09% of the transmitted electrical energy. This level of electrical energy losses in the transmission system for the year 2022 resulted in a slight decrease compared to 2021, which was 2.13%.

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