IMPACT OF THE NATIONAL ENERGY MIX EVOLUTION OVER THE ROMANIAN ENERGY MARKET FOR 2030 PERSPECTIVE

IMPACTUL EVOLUȚIEI MIXULUI ENERGETIC NAȚIONAL ASUPRA PIEȚEI DE ENERGIE DIN ROMÂNIA ÎN PERSPECTIVA ETAPEI 2030

Adrian TUDOR[1], Bogdan ACHIM[2], Florin CIAUȘIU[3], Andrei STAN[4]

Abstract: *The paper approaches one of the most discussed topics in the energy sector, namely the impact on the 2030 power mix structure and on the energy price of commissioning renewable capacity, according to the strategic directions assumed by Romania. Presented case study reunites three distinct power plants (pumped storage, wind and PV) in a single virtual power plant configuration. A digital optimization model has been built for the simulation of joint operation of the three plants, with consideration of the specific technology aspects. Also, the feasibility of the investment of such caliber (EUR 4 bill.) is investigated.*

Keywords: electricity price, power mix, 2030 horizon, virtual power plant, renewables, pumped storage, wind, PV.

Rezumat: *Lucrarea abordează poate una dintre cele mai de actualitate teme de discuție în sectorul energie, și anume impactul instalării de capacități regenerabile asupra structurii mixului energetic pe orizont 2030 și asupra prețului energiei, în conformitate cu direcțiile strategice asumate de Romania. Studiul de caz prezentat reunește trei centrale electrice distincte (acumulare prin pompaj, eoliană și fotovoltaică) într-o configurație de centrală electrică virtuală. A fost construit un model digital de optimizare pentru operarea în comun a celor trei centrale, cu considerarea aspectelor specifice ale celor trei*

[1] Energy Efficiency Analyst, TRACTEBEL ENGIE Romania, e-mail: adrian.tudor@tractebel.engie.com
[2] Market Consultant, TRACTEBEL ENGIE Romania, e-mail: bogdan.achim@tractebel.engie.com
[3] Head of Consultancy Department, TRACTEBEL ENGIE Romania, e-mail: florin.ciausiu@tractebel.engie.com
[4] Power Systems Analyst, TRACTEBEL ENGIE Romania, e-mail: andrei.stan@tractebel.engie.com

tehnologii, fiind de asemenea investigată fezabilitatea unei investiții de asememenea calibru (cca.4 mld.EUR).

Cuvinte cheie: preț energie electrică, mix energetic, orizont 2030, centrală electrică virtuală, surse de energie regenerabilă, acumulare prin pompaj, eolian, fotovoltaic.

1. Introduction

As the world enters a new era characterized by energy shortages and higher prices, renewable energy sources offer a promising solution to mitigate these issues, free from the constraints of embargoes, wars, or other political decisions. [1]

The swift expansion of photovoltaic wind turbines technology raises critical concerns regarding their impact on established electricity systems. These concerns encompass a broad range of topics, including the short- and long-term implications for wholesale and retail electricity prices, the dependability of electricity delivery, and the effects on investment incentives in electricity generation facilities. [2]

According to IEA [3], renewables will become the largest source of global electricity generation by early 2025, surpassing coal, reaching 38% share of the power mix in 2027. Also, Within the next five years, electricity generated from wind and solar PV will more than double, accounting for nearly 20% of global power generation by 2027.

In this paper we will analyze the evolution of energy prices in Romania in 2019 – 2022 period in order to identify the primary factors that have influenced their fluctuations. We will also examine the changes in the Romania's energy mix, with the focus on the adoption of renewable energy sources, mainly wind and solar power.

Moreover, the article will highlight the importance of conducting dedicated studies for the integration of renewable energy sources and energy storage systems, as this could significantly impact the future evolution of energy prices in Romania. The integration of renewable energy sources and storage systems is a critical step towards a sustainable and greener energy future and can help mitigate the challenges associated with variable energy generation.

Overall, this article will contribute to the understanding of the energy sector in Romania and also provide valuable insights into the potential impact of renewable energy sources on energy prices. Furthermore, it will highlight

the importance of conducting dedicated studies in this area to ensure a sustainable and affordable energy transition.

2. Look-back on price evolution

The year 2022 saw a worldwide energy crisis caused by a combination of factors, including the rebound from the pandemic, Russia's invasion of Ukraine, and supply chain disruptions. Consequently, prices of energy commodities skyrocketed, and there was a notable increase in wholesale electricity prices in Romania, especially during the second half of the year.

Before the pandemic, electricity was traded at "normal prices" of around 50 - 60 EUR/MWh on both spot and forward markets.

With the onset of the pandemic and the interruption of almost all economic activities, energy prices decreased significantly because the energy demand was very low, reaching a price level of 25 EUR/MWh in April and May 2020.

However, with the industry rebound after COVID-19 pandemic (especially after May 2021), prices began to rise steadily.

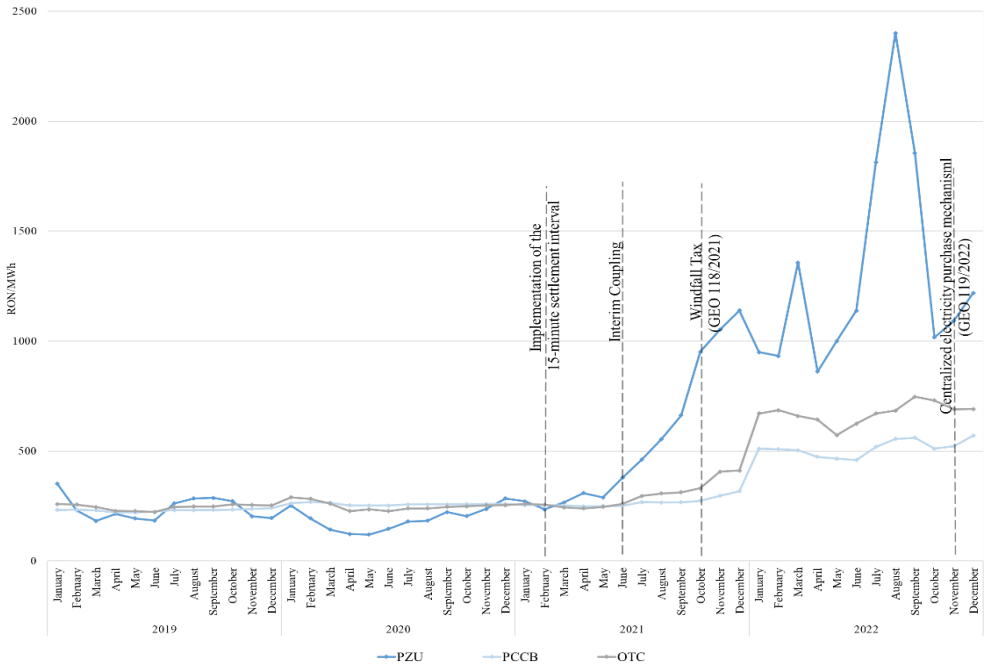

Figure 1. Electricity price evolution [4]

Also, in June 2021, the transition to the functioning in the coupled mechanism at the European level took place, specifically the coupling of Romanian Market with Germany, Austria, and Poland Market, mechanism known as Interim Coupling. Through this coupling, there was also an implicit alignment of prices with European markets.

Furthermore, the cost of emissions certificates soared to unprecedented levels, as illustrated in the chart below. After peaking at over 90 euros in February 2022, it remained relatively stable within the 70 – 90 Euro range in the subsequent months.

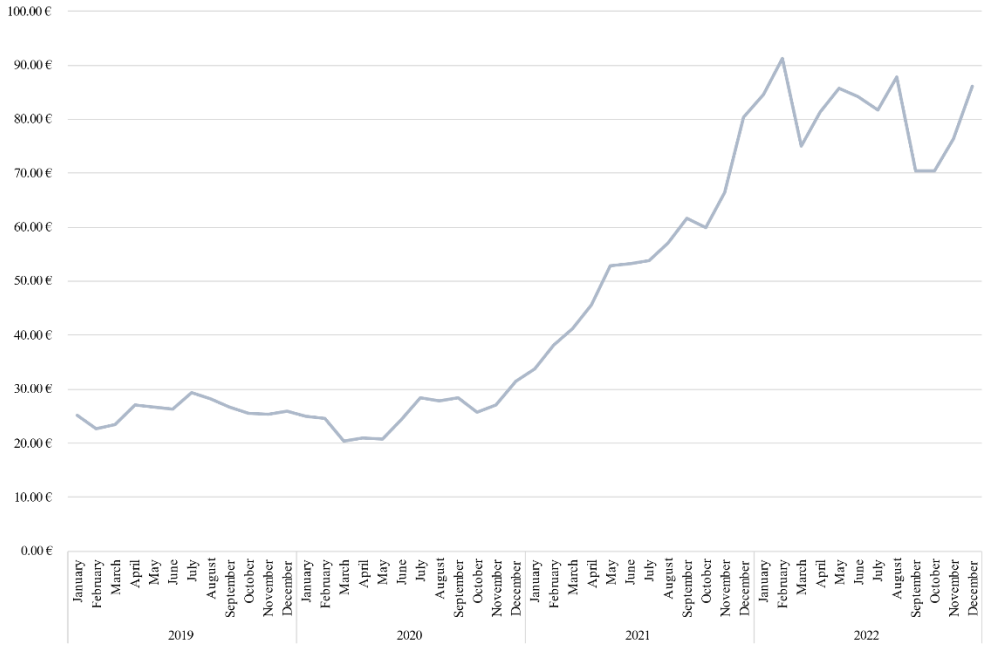

Figure 2. CO_2 allowances price evolution [5]

At the same time, this period coincided with the resumption of economic activities after the pandemic period, and starting in June 2021, the prices of electricity and natural gas began to rise due to the increased demand for energy that emerged with the reopening of the economy, and later due to tensions between Russia and Ukraine.

The price increase reached a peak in August 2022 when the average Day Ahead Market (DAM) price for that month was almost 500 EUR/MWh (30% higher than the previous month and 4 times higher than August 2021), reaching

values of over 900 EUR/MWh at certain hourly intervals, with the maximum being on August 30th when the price was 964 EUR/MWh for 2 hourly intervals.

3. Energy mix

Analyzing Romania's energy mix in terms of installed power and its composition, according to data published on OPCOM [4] and TRANSELECTRICA [6], a certain consistency can be observed in the renewable energy part of the energy mix between 2019 and 2022. However, a considerable decrease can be noticed in the conventional fuel part, specifically about 1,800 MW of coal and 400 MW of natural gas. Additionally, in 2022 compared to 2021, there is a slight increase in coal in the energy mix, due to the energy crisis.

In terms of energy mix, the perspective for 2030, consists of commissioning approximately 6,000 MW of new renewable energy (mainly wind and solar), and closing down coal-based energy capacities by 2030. [7]

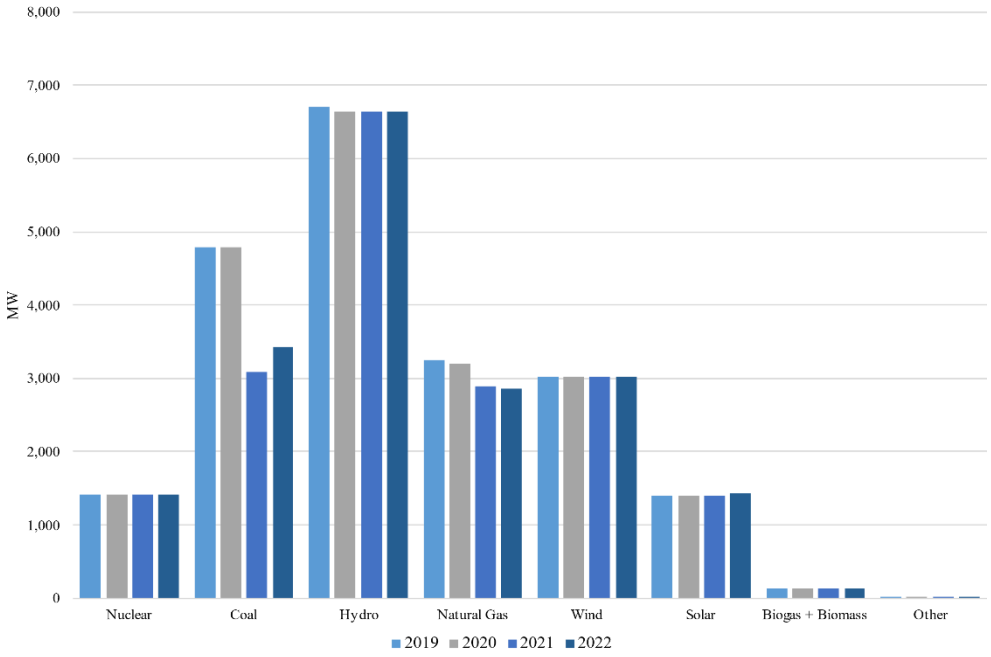

Figure 3. Installed power energy mix by source of energy.

The share of energy sources that make up the energy mix for the year 2022 indicates that approximately 60% of Romania's installed power is green energy (hydro, wind, and solar), as shown in the graph below.

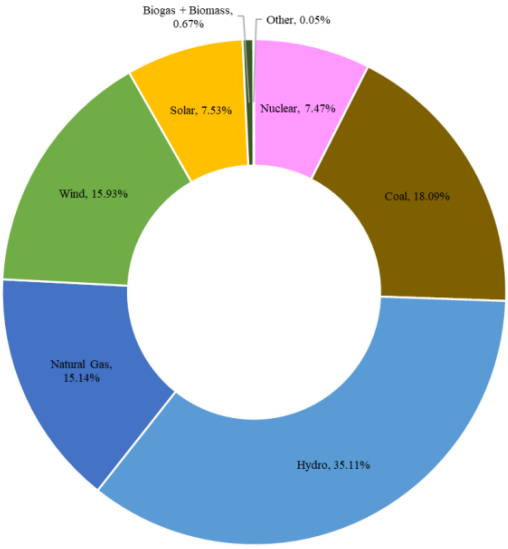

Figure 4. Installed power energy mix in 2022.

Regarding the energy mix reported for the electricity production in 2022, the share of green energy (hydro, wind, and solar) in the energy mix composition decreases compared to the situation above, reaching a value slightly above 40%, as can be seen in the graph below.

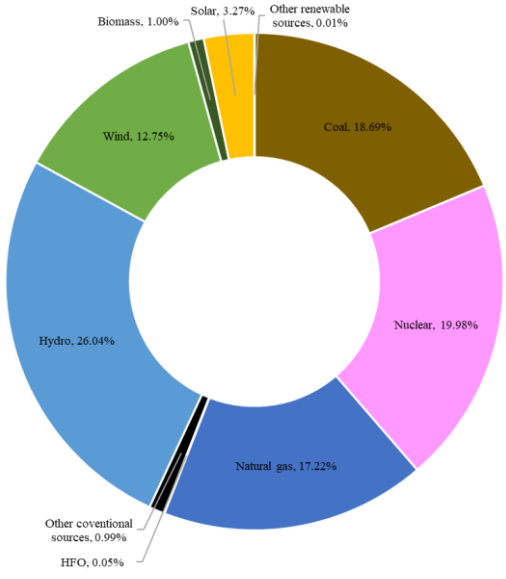

Figure 5. Electricity production mix by energy source in 2022

In this article, we have assumed the projection of approximately 6 GW in net capacities for 2030, considering the Decarbonisation Plan for CE Oltenia 2020 – 2030 with almost 5 GW of coal-based power plant being decommissioned until 2030.

On the decommissioning side, according to the Decarbonisation Plan for CE Oltenia 2020 – 2030, almost 5 GW of coal-based power plant will be closed until 2030.

On the commissioning side the projection reflects an increase of 2.3 GW in the new wind capacities and approximately 3 GW from repowering and an increase of around 3.7 GW of solar and 1.35 GW from repowering.

As for the new natural gas capacities the projection indicates an increase of 3.5 GW for 2030 (850 MW Isalnita, 475 MW Turceni, 1500 MW Mintia, 295 MW Craiova and 430 MW Iernut). Also, according to Nuclearelectrica, Unit 3 of CNE Cernavoda will be commissioned in 2030.

In the figure below can be seen the projected calendar for all power plant commissioning and decommissioning by energy source from which result that approximately net 5.6 GW in new capacities will be commissioned until 2030 (+6 GW from renewables, -5 GW coal, +3.6 GW gas and +0.7 GW nuclear).

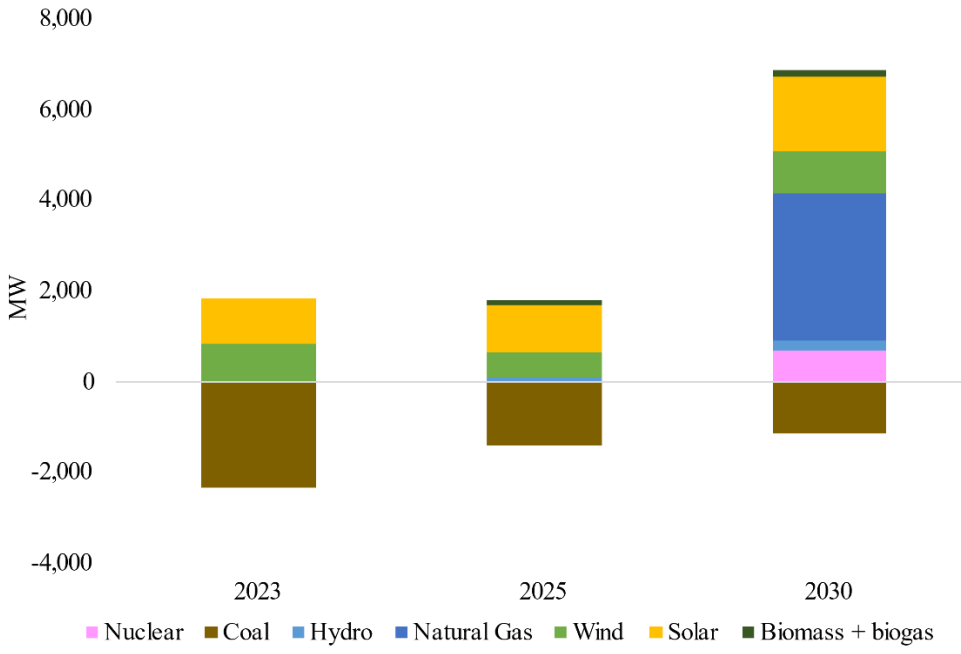

Figure 6. Calendar of commissioning and decommissioning by energy source, in MW

The evolution of the Romania's energy mix during the period 2022 – 2025 – 2030, based on the data mentioned above, is presented in Figure 7.

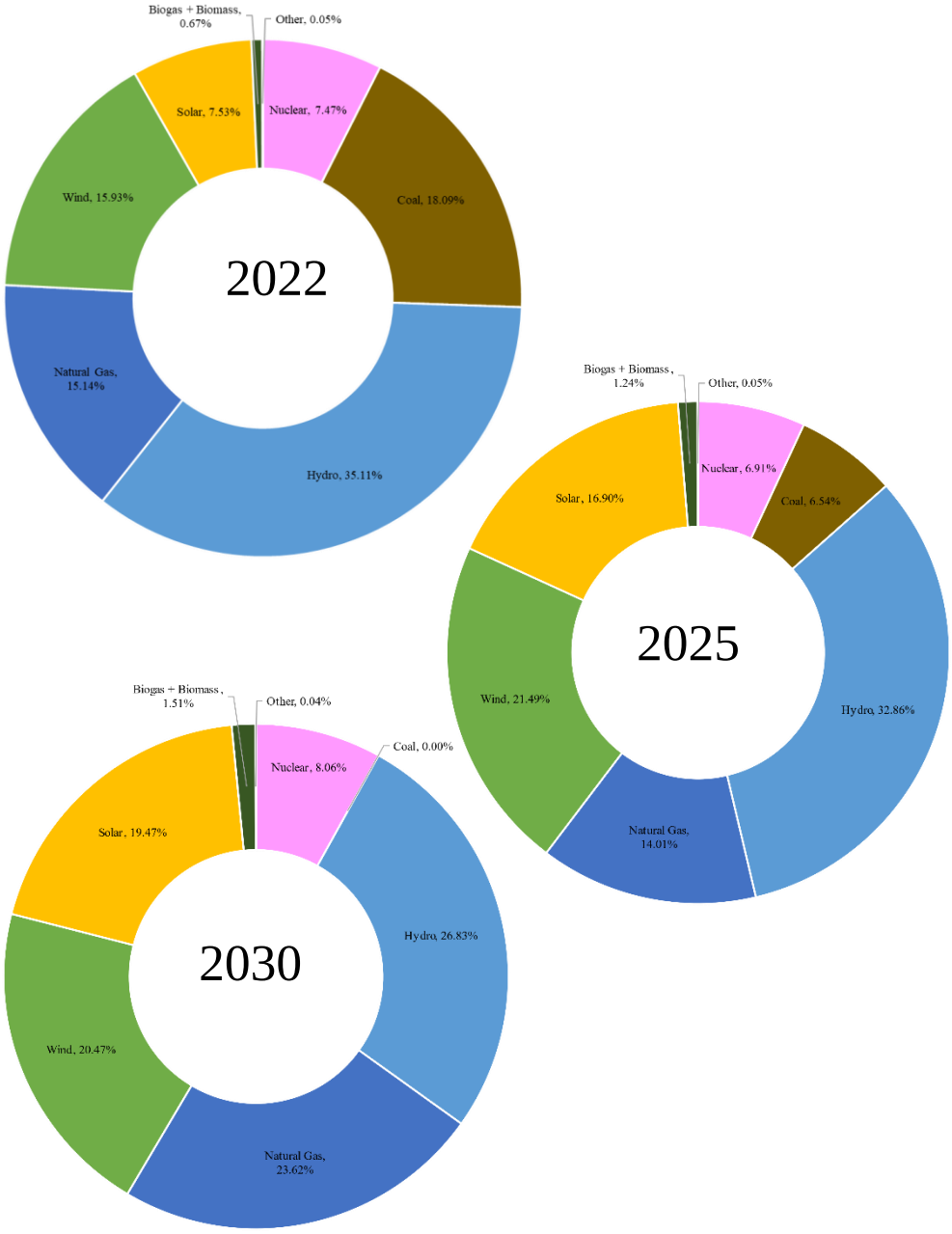

Figure 7. Romania's energy mix evolution 2022 – 2025 – 2030

4. RES impact on energy market

Through the National Integrated Plan for Energy and Climate Change 2021-2030, Romania has assumed a target of 30.7% for renewable energy sources (RES) by the year 2030.[8] During the Energy Efficiency for Sustainable Business conference, on March 27th 2023, Secretary of State in the Ministry of Energy, Casian Nitulescu, stated that following a reanalysis, Romania's target for renewable sources in 2030 is 34%.[15]

Assuming that the energy market in Romania will operate under the same regulatory framework in 2030 as it does in 2022, we estimate that the price of generated electricity will decrease compared to the current moment following the integration of 6,000 MW of new renewable energy into the energy mix, as well as the closure of coal-based capacities. This is due to the decrease in production costs, as shown in Figure 8 [16], and the priority order according to the support scheme. The biggest impact on the price will be in the day-ahead market (DAM) but since the share of DAM in the entire energy market in Romania is very high, around 50%, the entire market will follow a decreasing trend caused by DAM.

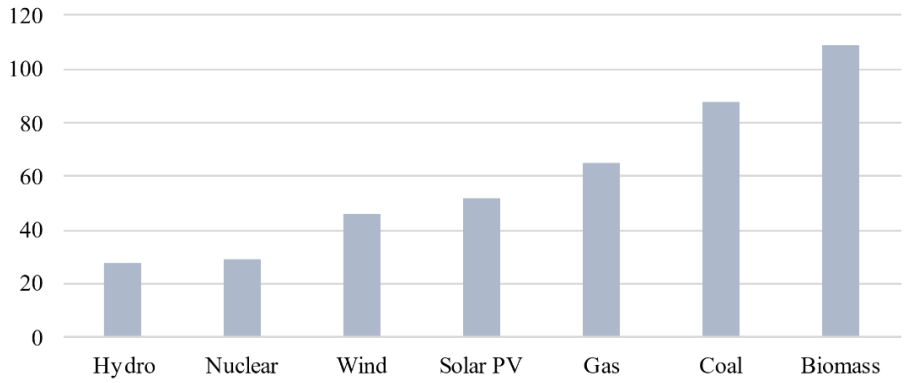

Figure 8. Estimative Costs of Generating Electricity in EUR/MWh

Regarding the balancing market, the price is expected to increase due to the integration of variable energy sources into the energy mix, which will lead to a considerable increase in the forecasting error and, therefore, to a greater pressure on the system balancing.

Since renewable energy sources are variable and dependent on weather conditions, they require additional measures to balance supply and demand. This thing has led to the development of modern technologies and practices

to support the integration of renewables into the grid, including energy storage systems and demand response programs. However, while renewables have been shown to have a positive impact on the environment and can offer cost savings in the long term, their integration into the energy system is not without its challenges.

To address that, we will explore a case study that examines the impact of renewables on energy prices (including balancing prices) and the measures that have been taken to address these challenges.

5. Case study

One 1,800 MW Virtual Power Plant (VPP) is studied, including pumped storage (PSPP), wind farm (WPP) and photovoltaics (PVPP) capacity. PSPP capacity is servicing multiple purposes, starting with servitude (a minimal water flow to be preserved for downstream potable water supply, irrigation and shoreline vegetation survival), and ending with providing backup for WPP, PVPP and third parties, as well as providing system services to the TSO (Transelectrica). Main project inputs are summarized in the table below.

Table 1. **Key inputs of the VPP studied**

Key input	Value	Unit
Analysis horizon	60	years
PSPP time of service	50	years
WPP time of service	20	years
PVPP time of service	20	years
Discounting rate	9	%/yr
Inflation rate	2	%/yr
DAM/Imbalance price escalation	2.5/3	%/yr
VPP total installed power	1,800	MW
VPP construction period	120	months
CAPEX (est.)	4,040	mill.EUR
OPEX (est.)	500	mill.EUR/year1
PSPP installed power	800	MW
WPP installed power	700	MW
PVPP installed power	300	MW

Additional inputs addressing technical and financial aspects of VPP operation are listed below:

- PSPP servitude;
- Precipitation avg. rate by month/season;

- Evaporation avg. rate by month/season;
- PSPP pumping consumption.;
- Central/local substation losses;
- Primary regulation (FCR);
- Secondary regulation (aFRR+/-) limits;
- Fast tertiary regulation (mFRR+/-) limits;
- 3rd party backup contract limits;
- bilateral contract limits;
- DAM sale/buy limits;
- Primary regulation reservation;
- Secondary regulation reservation;
- Fast tertiary regulation reservation;
- Wind forecast imbalance;
- Solar forecast imbalance;
- Imbalance price;
- Excedent penalty;
- Deficit penalty;
- Bilateral contract price;
- DAM price;
- Injection tax.

Due to high volatility and erratic evolution of imbalance and market clearing prices registered on the Balancing Market and respectively, on the Day-Ahead Market, price forecasting over the analysis horizon was done with stochastic techniques based on random number generation.

An optimization model has been built, with the main objective of maximizing the net value of the VPP investment. Main attributes of the model are listed below:

- objective function of max NPV/IRR;
- variable array of upper lake charge/discharge hourly amounts;
- variable array of system services reservation amounts;
- variable bilateral contract/3rd party backup amounts;
- min/max power restrictions

After termination of the service period of 20 years, the WPP and PVPP are replaced at a fraction of the initial investment cost, this having been translated into replacement costs incurred in year 30 and year 50. A similar reasoning applies to the central/local substations connecting the hydro, wind and solar capacities with the high voltage grid. The results obtained are presented in the following table and graphs.

Table 2. **Indicative VPP feasibility**

Indicator	Value	Unit
NPV	10.8	EUR bill.
IRR	20.4	%/yr

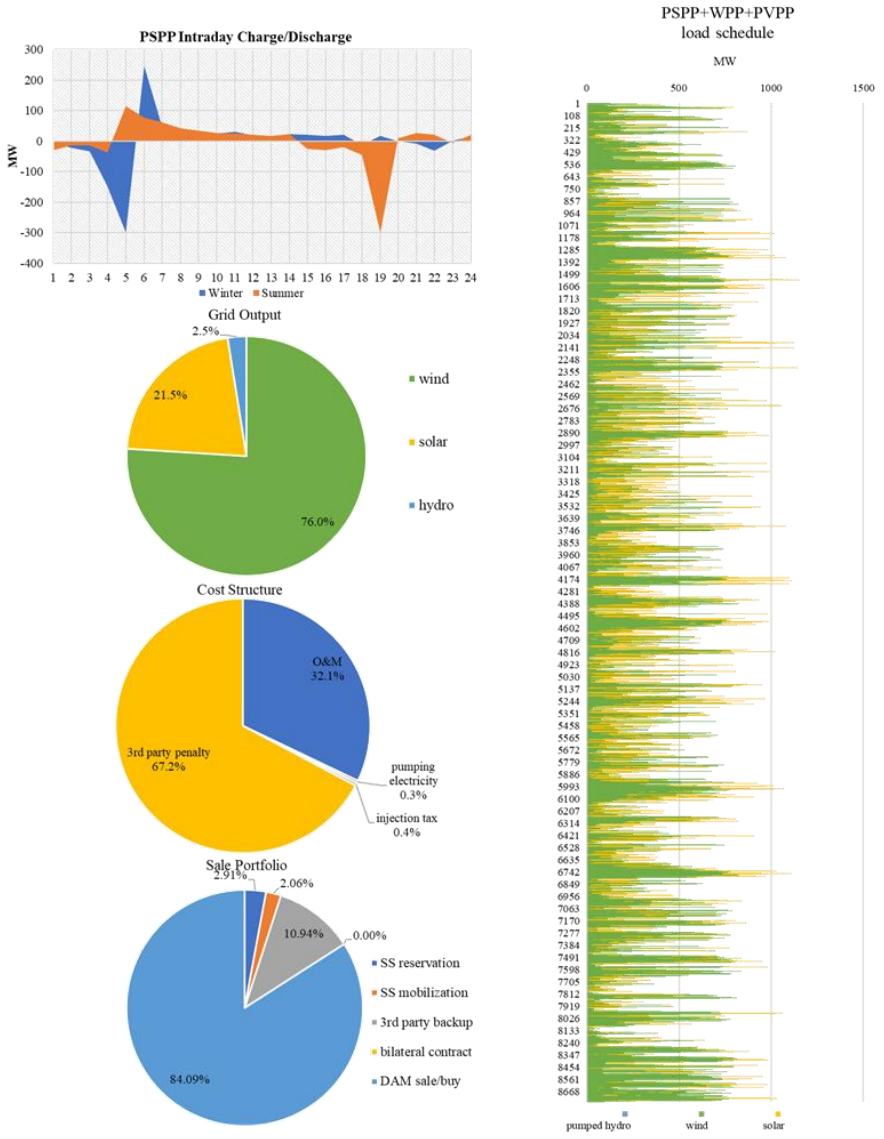

Figure 9. VPP indicators

Some aspects deserve to be mentioned from analyzing the figures above:

- upper lake charge/discharge daily profile is differing from winter to summer season – in summer, the PSPP is pumping in early morning and generates electricity during the night peak, while in winter, optimal PSPP load incurs discharging in early morning, followed by immediately charging during intervals 6-7
- with regards to hydro/wind/solar contribution to the energy delivered to the grid, it can be noticed the low participation of hydro – 2.5% only. This is mainly the result of VPP reserving ancillary services and implicitly conserving the associated power bands for service mobilization – it is more beneficial to store water rather than convert it to energy.
- the share of imbalance costs occupies two thirds of the total operation cost, followed by O&M costs associated to hydro, wind, solar and central/local substations. A remaining low share (<1%) is held by pumping costs and injection tax – imbalance penalties are low enough as to afford higher sales with higher imbalances.
- concerning the sale portfolio of the VPP, its structure is dictated by price values predicted on the DAM, as compared to bilateral/3rd party contract and ancillary services prices. It can be noted that the large share of DAM sales (84%), while 3rd party backup contract goes for 10% and ancillary services reservation + mobilization account for the remaining 5%.
- another aspect to emphasize is the power interval where the VPP load is varying – from - 45 to 1,126 MW, giving a more accurate and closer to reality info with regard to the maximum power delivered to the grid, which is substantially less than the VPP total capacity of 1,800 MW – it is debatable whether the VPP connection permit should have the total capacity figure inscribed, since in normal operation the grid output is 35% lower at most.

6. Conclusions

In 2022, a global energy crisis led to soaring energy prices worldwide, including Romania. Factors such as the pandemic rebound, Russia's invasion of Ukraine, and supply chain disruptions contributed to the overall rise of the prices. This highlights the need for more sustainable and resilient energy systems to mitigate the impacts of future crises.

In the perspective of 2030, Romania's goal is to reach a share of green energy level of approximately 40%, which is almost double compared to the year 2022, while also achieving the decarbonization objective of stopping 5,000 MW of coal-based capacities.

Considering that the share of renewables in the energy generation mix is expected to increase at national level from approximately 25% in 2022 to 40% in 2030, the share of classical generating units that can provide system services estimated to remain approximately constant at 50% (as per existing strategy) will need to increase as well in order to secure the stable operation of the national power system.

Simulation with Tractebel long-term forecast model reveals an average market price decrease of ~34% for 2030 perspective, as compared to 2022, thanks to renewable capacity significant increase into the power mix and an enhanced power consumption of about ~6 TWh at national level.

Dedicated market integration studies is recommended to be put in place for the future RES projects to be implemented at national level as detailed economic assessments complementary to the technical grid integration aspects. These will facilitate the access to key information for the investors in RES projects to be implemented at national level.

Beside obvious benefits related to lower average electricity price and reduced GHG emissions, further commissioning of extra 6 GW net generation capacity in Romania will raise at a new level the load balancing task, since a larger share of the power mix will consist in intermittent sources (mainly wind and PV). This is posing a series of issues necessary to be solved at macro level, as follows:

- commission additional balancing capacity, to offset increased system imbalances ;
- build additional power evacuation capacity (HV OHLs and substations) for unloading the power excess areas and facilitating increased export ;
- incentivize the national consumption increase, as additional export is limited by technical capacity, but also by competition on the neighboring markets .

In such context, commissioning of Virtual Power Plant (VPP) concepts including water storage capacity is warmly welcomed. However, owning a pumped storage plant is not free of specific risks such as:

- capacity erosion by draught, with higher than predicted evaporation and much lower precipitation rates;
- probability of having the regulator increasing servitude during the PSPP time of service;
- capacity requisition / mobilization by the TSO for black start purposes.

All the above should be subject to further regulation, to mitigate risks and correctly remunerate the VPP owners.

Romania will be facing multiple challenges by 2030, related to the transition to a greener power mix such as: integration of a large amount of extra renewable power, adding an appropriate balancing capacity, commissioning new T&D infrastructure, increasing power consumption at national level and issuing regulations harmonized with those valid at communitarian level. The success of this undertaking is conditioned by political awareness and implication of the energy sector professionals.

R E F E R E N C E S

[1] *G. I. Maniatis, N. T. Milonas* „The impact of wind and solar power generation on the level and volatility of wholesale electricity prices in Greece,"

[2] *Z. Csereklyei, S. Qu, T. Ancev* „The effect of wind and solar power generation on wholesale electricity prices in Australia,"

[3] Renewables 2022, Analysis and forecast to 2027, IEA – Renewables 2022 – Analysis - IEA

[4] OPCOM – www.opcom.ro

[5] Investing.com – www.investing.com

[6] TRANSELECTRICA – www.transelectrica.ro

[7] OUG 108/2022 – legislatie.just.ro/Public/DetaliiDocument/256928

[8] NUCLEARELECTRICA - www.nuclearelectrica.ro/activitati-pentru-dezvoltarea-proiectelor/unitatile-3-si-4/

[9] Long-term strategy of romania for reducing greenhouse gas emissions – http://www.mmediu.ro/app/webroot/uploads/files/Strategia%20%20pe%20Termen%20Lung%20a%20RO%20pentru%20Reducerea%20Emisiilor%20de%20GES.pdf

[10] Romanian Government – Întrevederea prim-ministrului Nicolae-Ionel Ciucă cu reprezentanții companiei Mass Global Energy Rom (gov.ro)

[11] CEO – COMUNICAT - Complexul Energetic Oltenia (ceoltenia.ro)

[12] ROMGAZ – Producție energie electrică | Romgaz

[13] The 2021-2030 Integrated National Energy and Climate Plan - https://energy.ec.europa.eu/system/files/2020-06/ro_final_necp_main_en_0.pdf

[14] Ministry of Energy – https://energie.gov.ro/wp-content/uploads/2022/05/Anexa-1-Inchideri-capacitati-1.pdf

[15] Agerpres - https://www.agerpres.ro/economic-intern/2023/03/27/romania-va-ajunge-la-34-surse-de-energie-regenerabila-dupa-o-analiza-a-planului-in-domeniul-energiei-secretar-de-stat--1082304

[16] Projected Costs of Generating Electricity 2020, IEA – https://www.iea.org/reports/projected-costs-of-generating-electricity-2020