UNIVERSITÀ CATTOLICA del Sacro Cuore

HEDGING STRATEGIES FOR VALUE OPTIMIZATION IN PHOTOVOLTAIC ENERGY PRODUCTION

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CONTENT

BACKGROUND & PURPOSE

Increasing need for sustainable energy met by renewable energy solutions

Extreme variability in solar power due to weather and price unpredictability

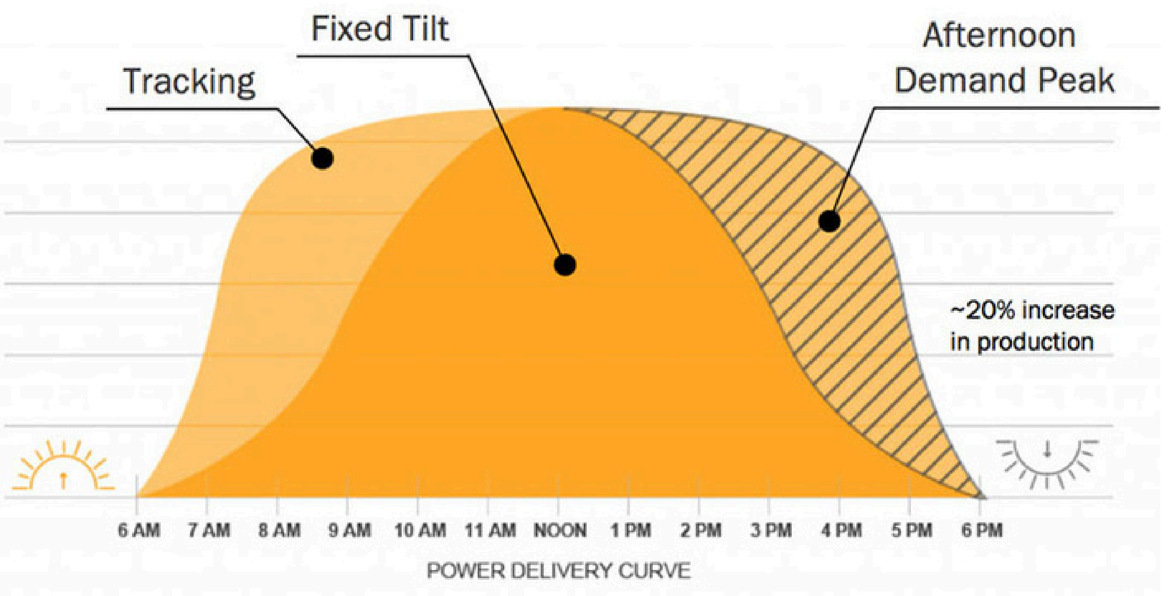
Implementation of an effective **hedging strategy** for optimizing the energy portfolio of PV tracker systems

sorgenia

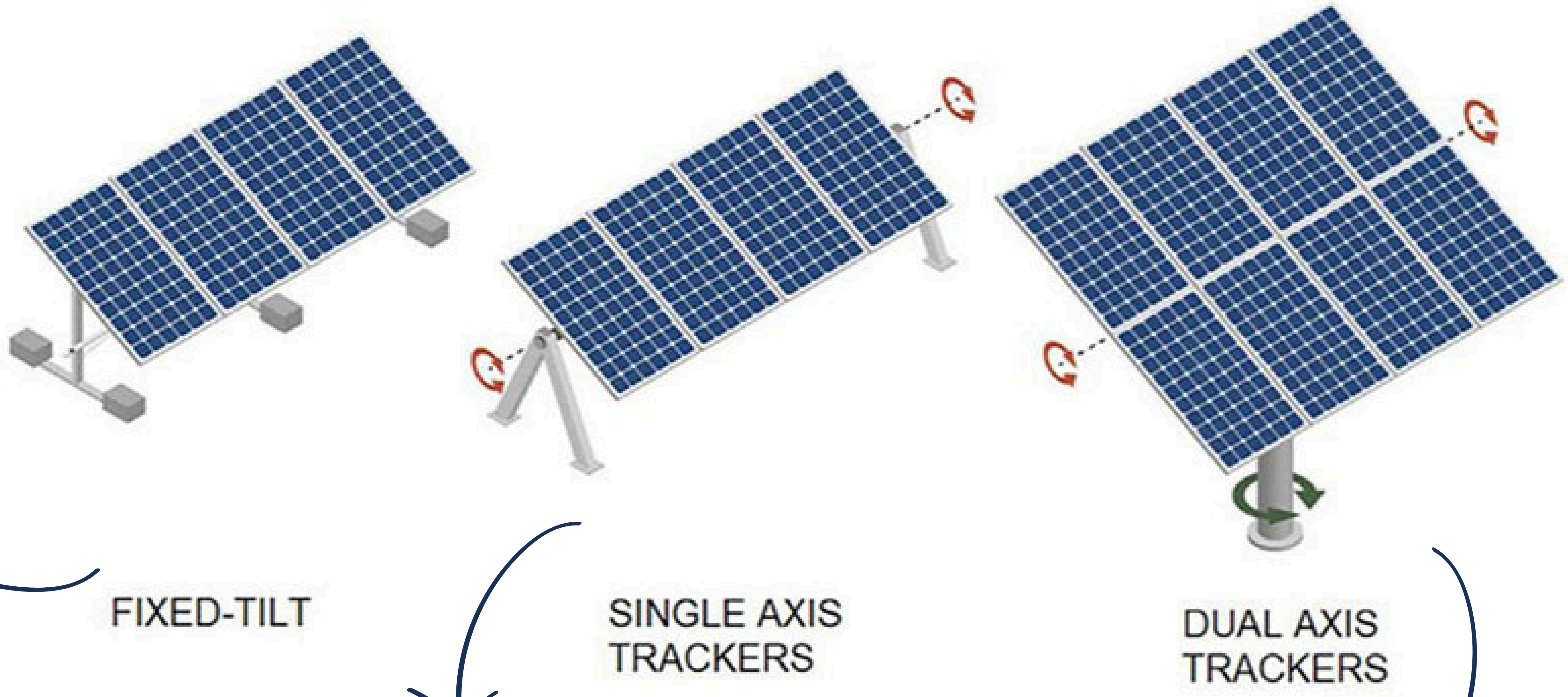
First non-incumbent company in the italian liberalized energy market

PV TRACKER SYSTEMS

PV tracker systems optimize solar panel performance by aligning with the sun's path, reducing Levelized Cost of Energy (LCOE) and increasing competitiveness against traditional energy sources



Standard systems replaced by trackers to improve performances



Simple design, low maintenance costs, good reliability

BUT

Limited technology upgrade capabilities

More advanced and flexible

BUT

Higher maintenance efforts and expenses

THE DATASET

Historical data provided by GME, responsible for managing and regulating the Italian electricity market

Hour	pr_idx_north	pr_idx_sud	Year	Month	Day	Weekday
1	50.87000	50.87000	2021	1	1	4
2	48.19000	48.19000	2021	1	1	4
3	44.67966	44.67966	2021	1	1	4
4	42.92193	42.92193	2021	1	1	4
5	40.39151	40.39151	2021	1	1	4
		...				
1	170.28000	170.28000	2022	1	1	5
2	155.72000	155.72000	2022	1	1	5

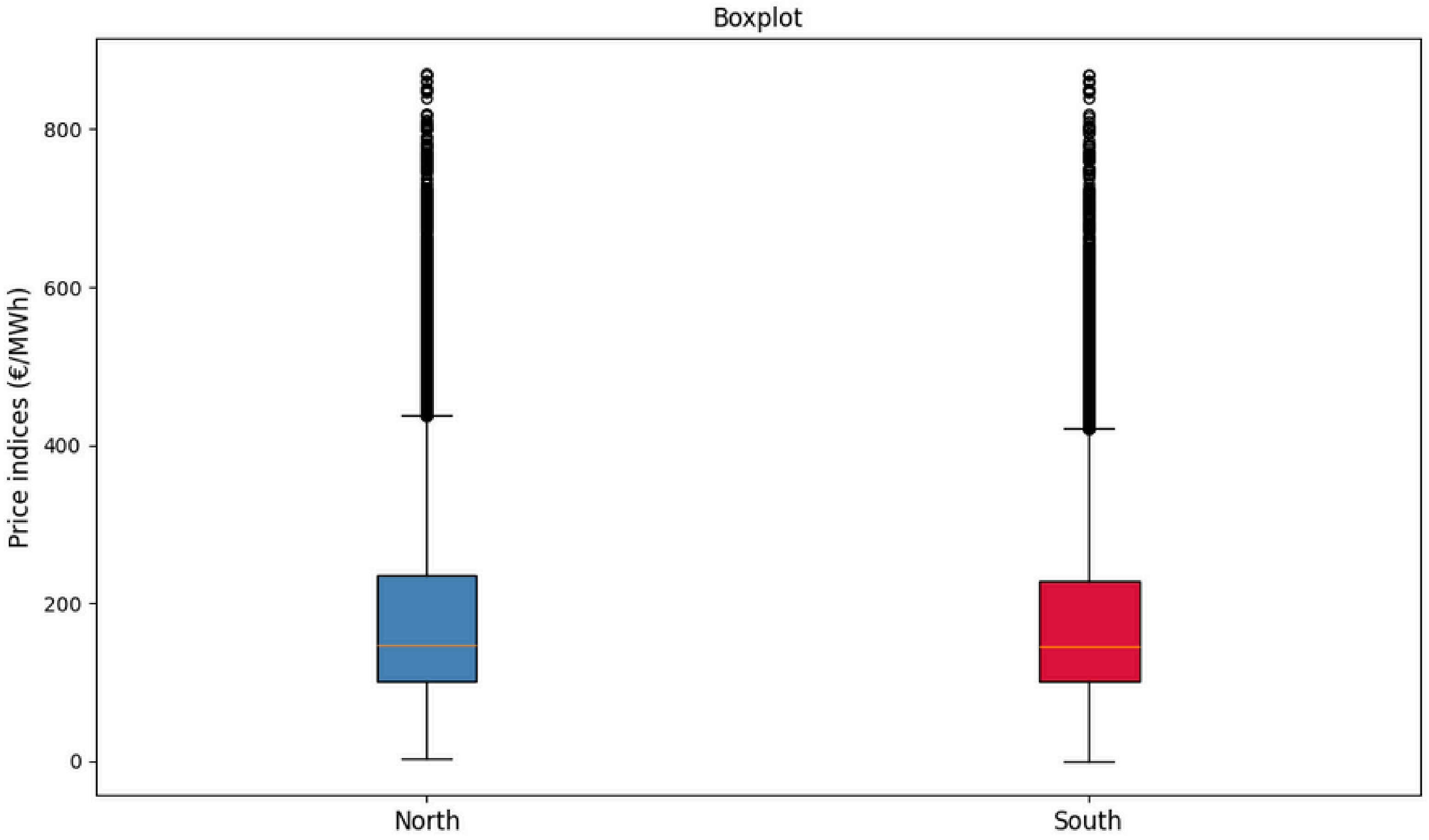
26.280 hourly price index observations (**€/MWh**) for northern and southern Italy, spanning 2021–2023

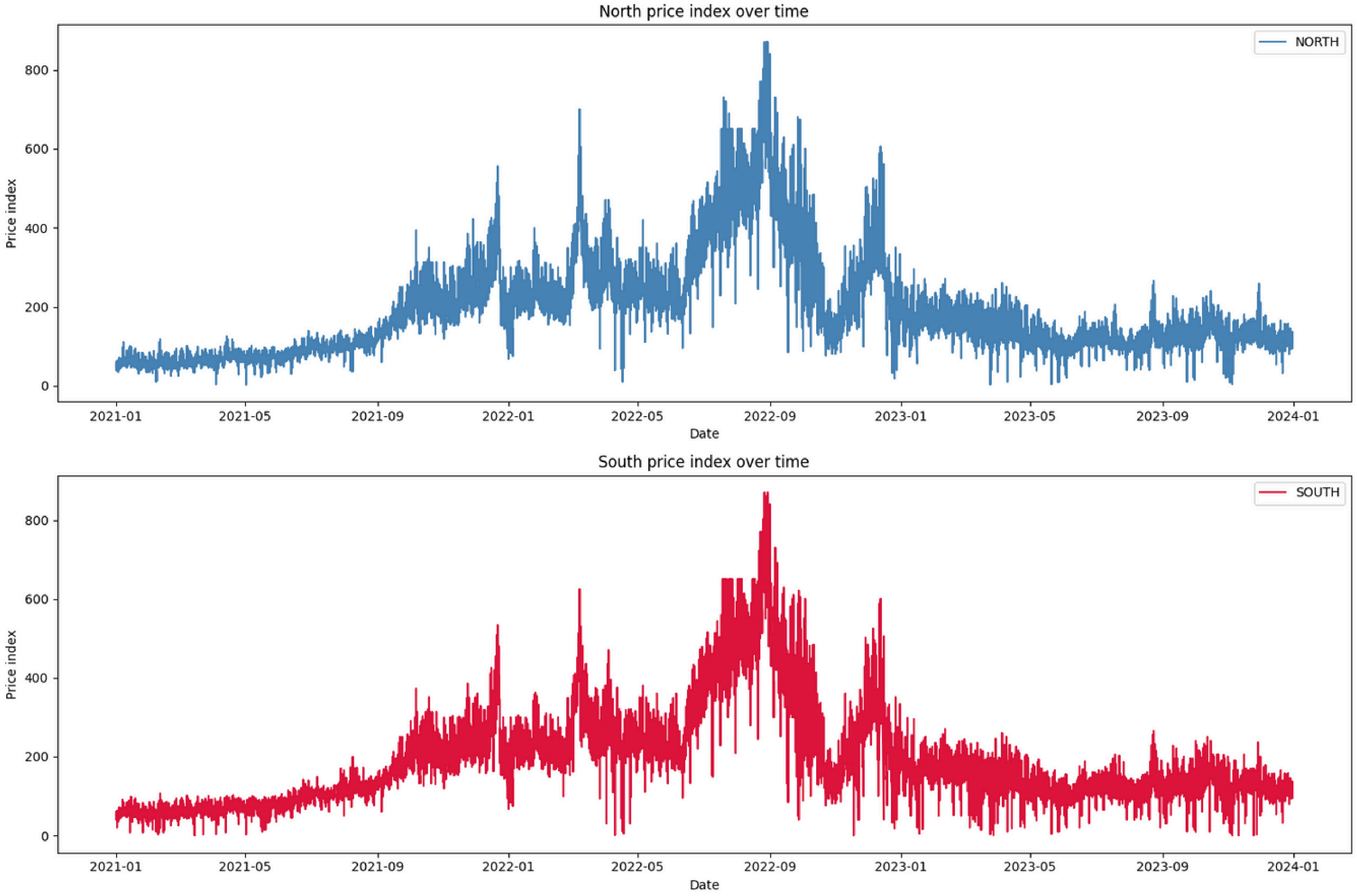
TRACK_NORD	TRACK_SUD	Month	Day	Hour	Weekday
0.0	0.0	1	1	1	6
0.0	0.0	1	1	2	6
0.0	0.0	1	1	3	6
0.261617	0.275819	1	1	12	6
0.265387	0.282107	1	1	13	6
0.273641	0.295508	1	1	14	6

PV *energy production* (**MWh**) for 2023 as a representative year

PRICE INDEX

Significant presence of **outliers** (above 400 €/MWh), influenced by the impact of the Ukraine war in 2022

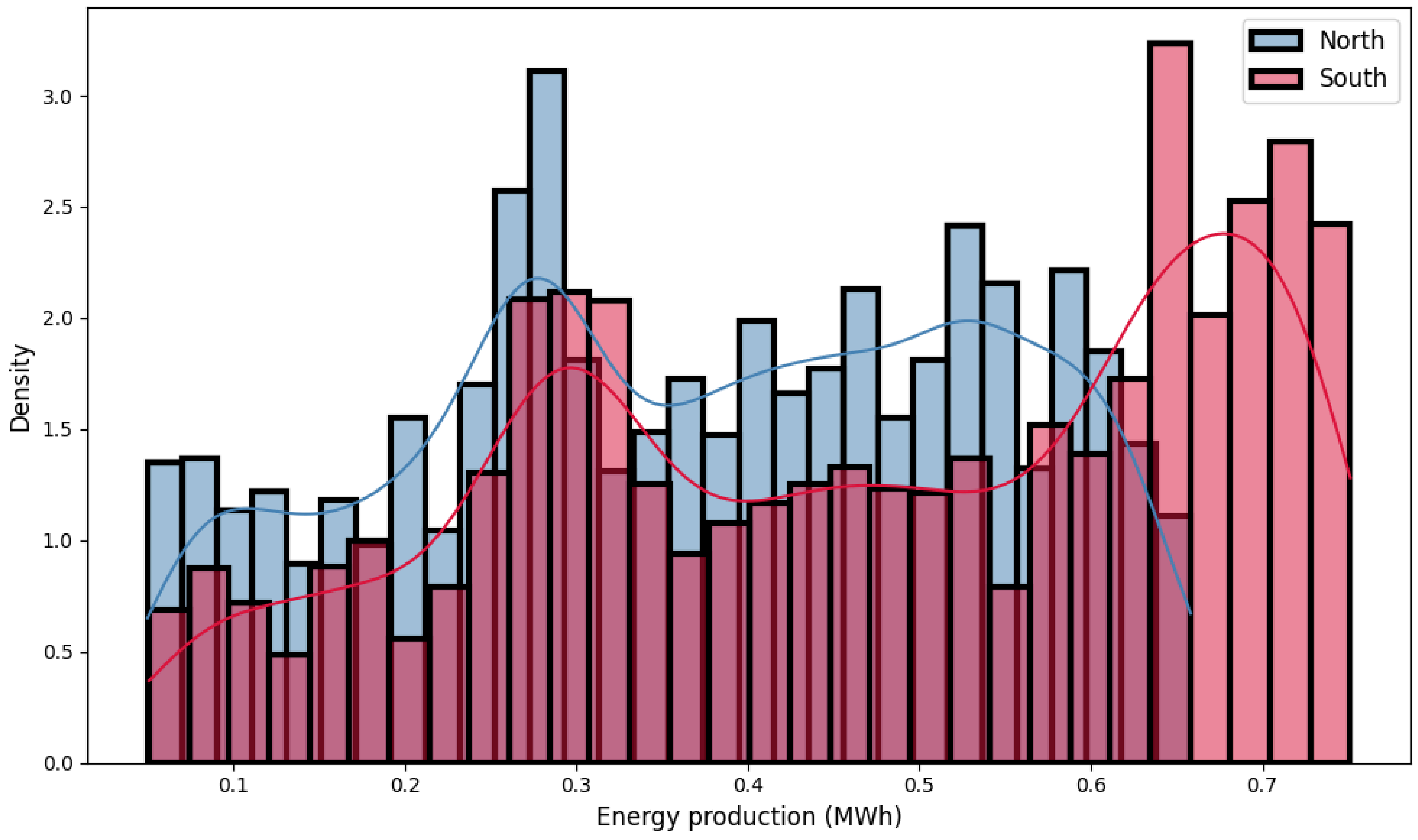


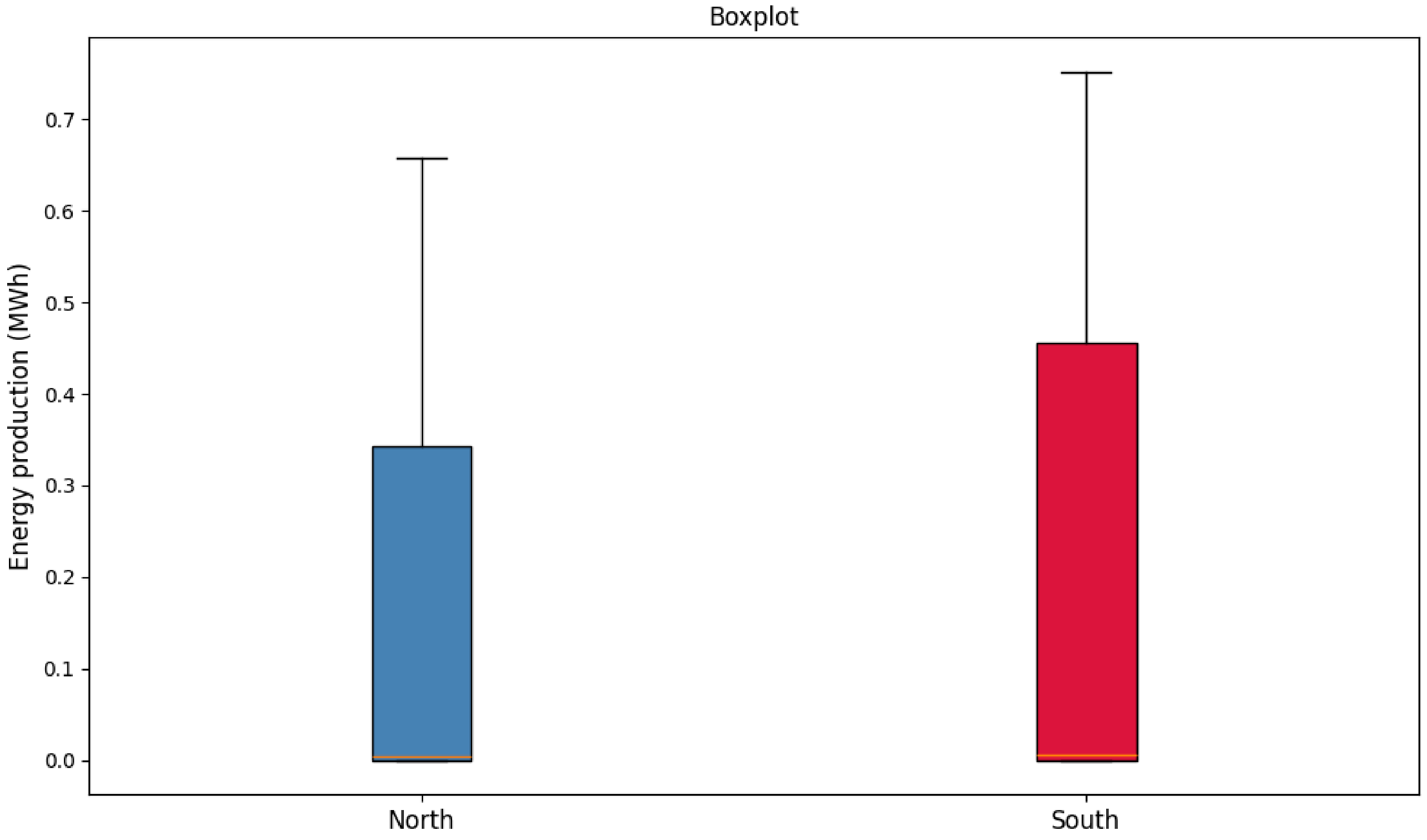


VOLUME

Significant number of nighttime hours with zero energy production in the dataset

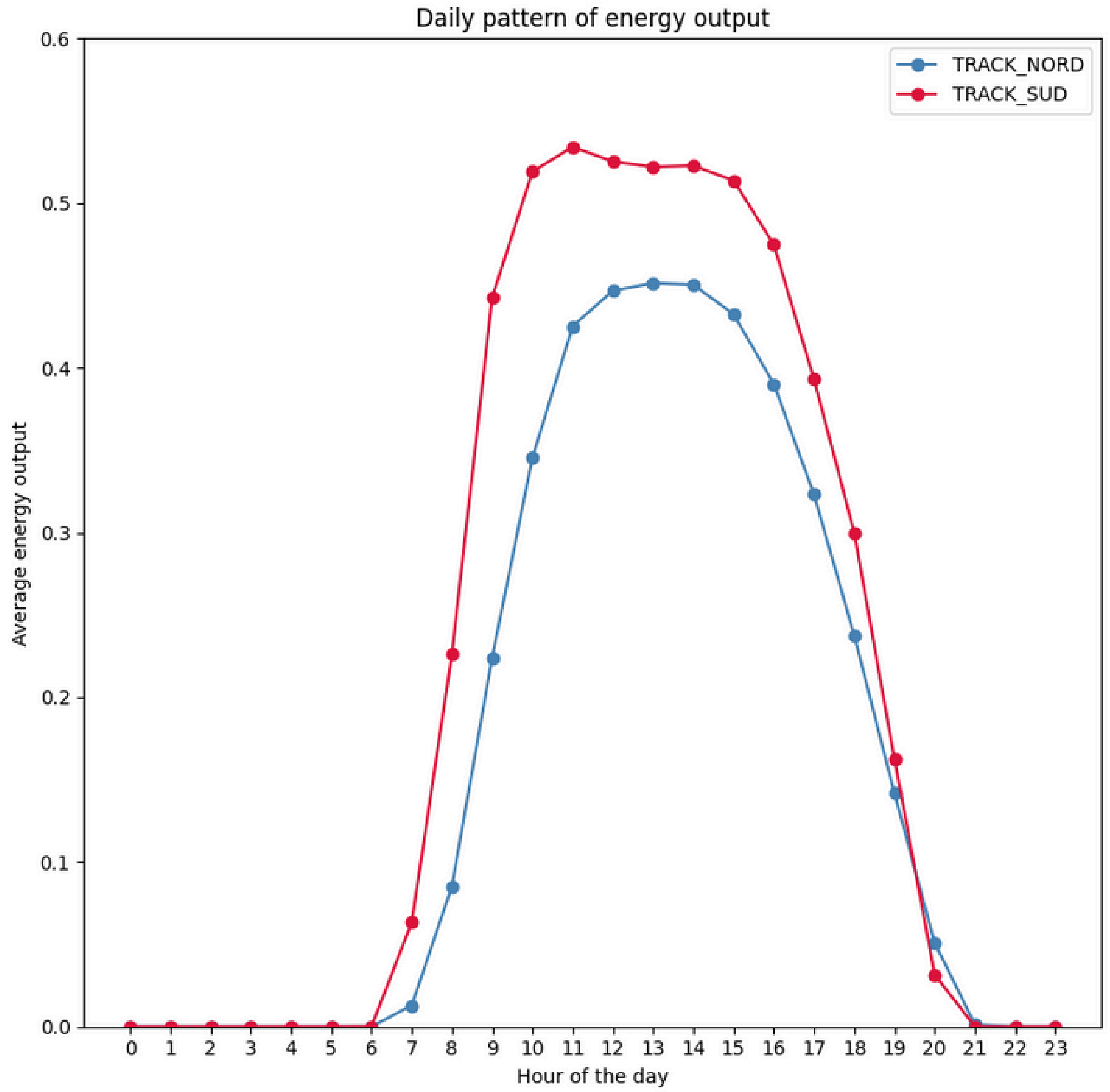
Histogram of energy production without considering zero values shows a smoother distribution of the produced energy data





Comparable energy production trends, with slightly higher values in the southern region than in the north

IDEAL PRODUCTION CURVE



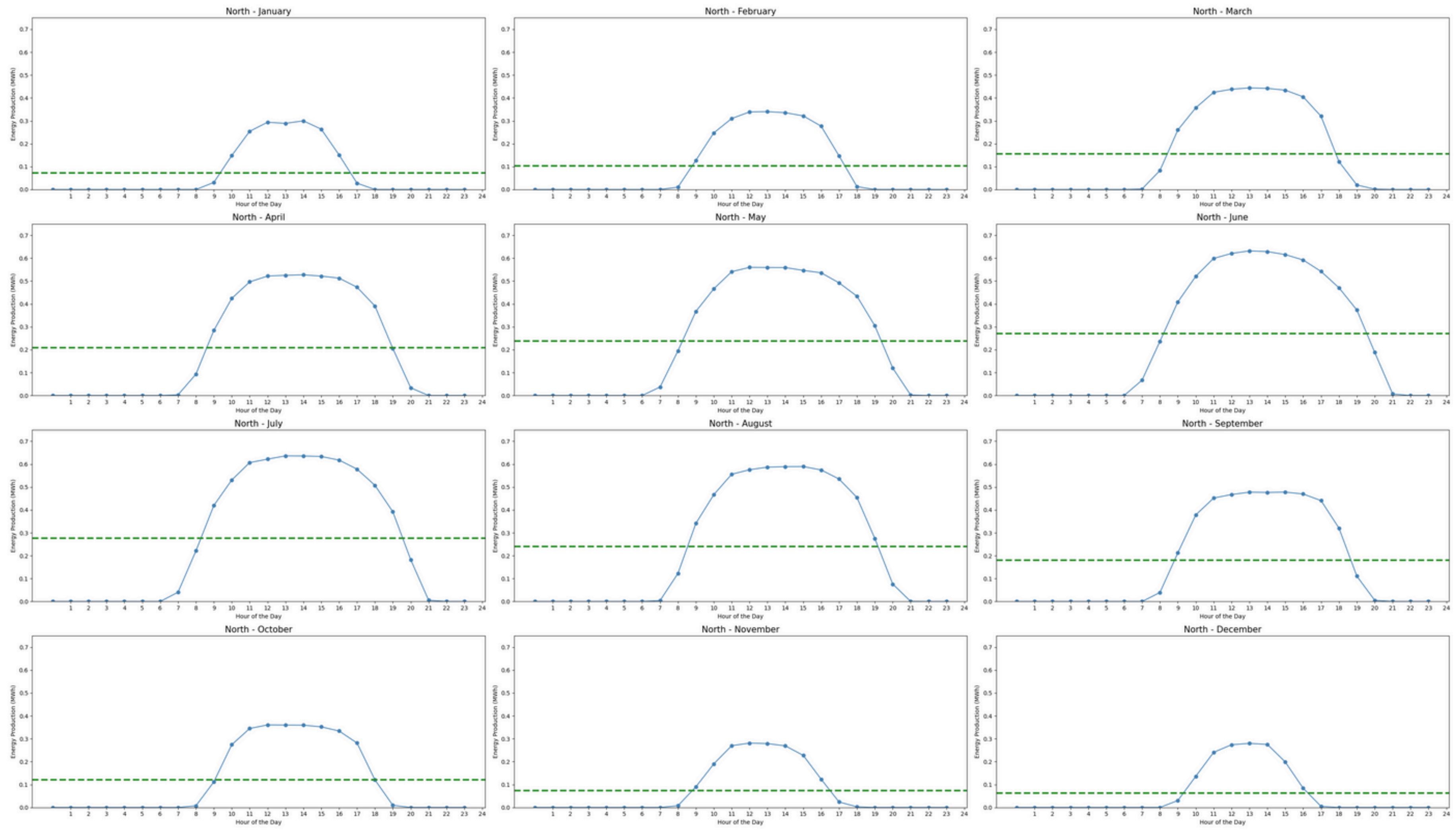
$$Energy\,portfolio = A - \alpha \cdot B$$

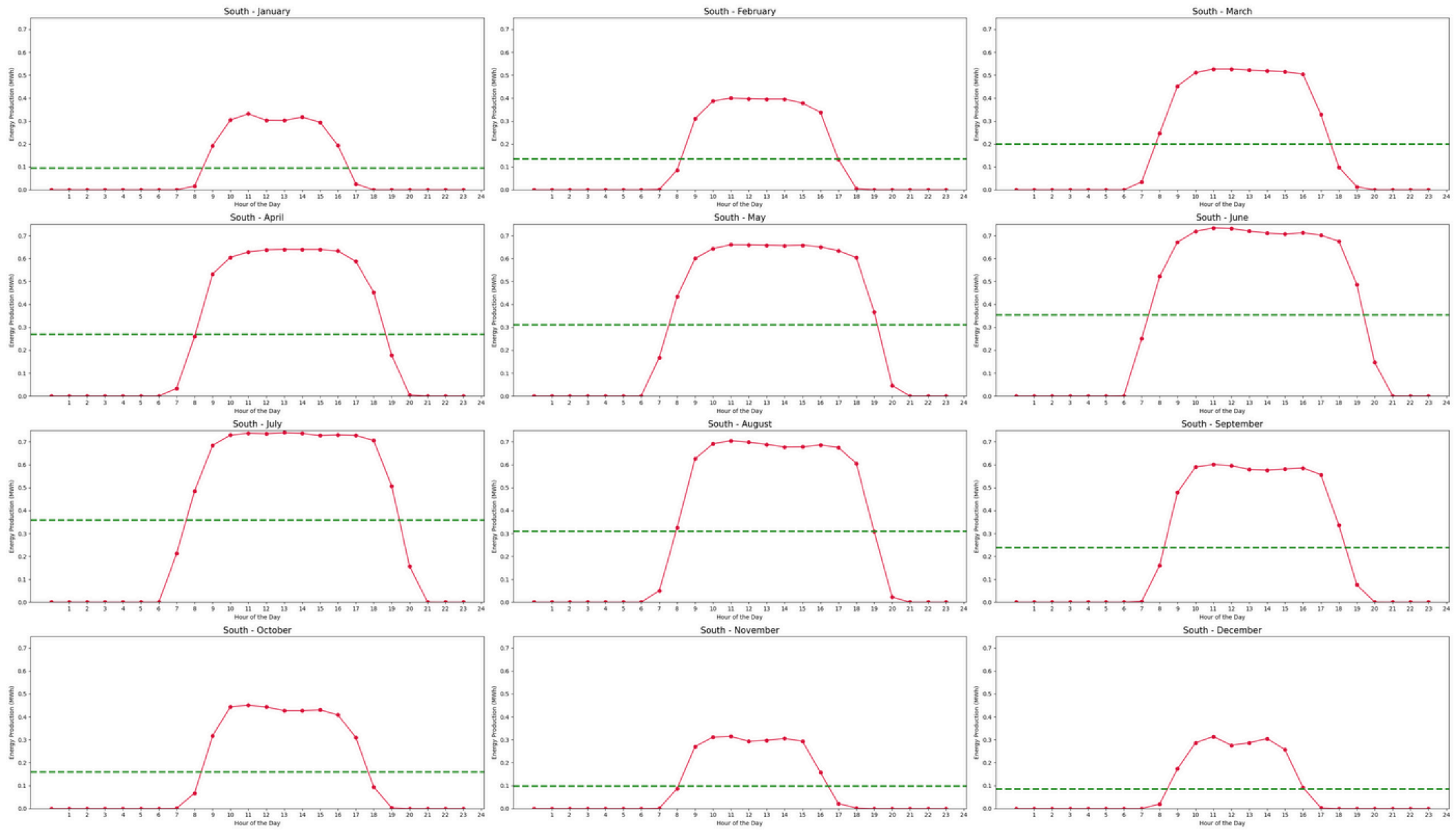
- **A**: PV energy production, with a bell-shaped daily profile peaking at midday
- **B**: Market exposure linked to electricity generated and its price variability
- **α**: Hedging coefficient indicating the level of risk coverage
- **α*B**: Combined exposure to electricity market price fluctuations

Only theoretical -> no existing energy products able to produce following this bell-shaped function -> hedging strategy to mitigate the financial risk

MONTHLY PRODUCTION EXAMINATION

Ideal production curve represents average hourly energy production per month, highlighting typical daily patterns





Strong **seasonal** variability in average energy production across both regions, with higher overall production in the **south** compared to the north

MODEL FORMULATION AND APPROACH

Goal: optimize the hedging coefficient *a* by finding the **baseload** -> a constant quantity of energy that, when sold at a fixed average price over a specified period, generates the same revenue as the actual production sold at varying prices during that period

This strategy aims to obtain a *zero profit/loss balance*, stabilizing the financial outcomes and ensuring long-term stability

Mathematically:

$$E_{\text{baseload}} \cdot P_{\text{avg}} \cdot T = V_{\text{tot}}$$

with:

$$V_{\text{tot}} = \int_0^T E(t) \cdot P(t) \, dt$$

MODEL FORMULATION AND APPROACH

Steps for computing the baseload:

1. $$\text{Total production value} = \sum (\text{price} \cdot \text{volume})$$

2. $$\text{Average price} = \frac{\sum \text{price}}{\text{number of days}}$$

3. $$\text{Energy-equivalent quantity} = \frac{\text{Total production value}}{\text{Average price}}$$

4. $$\textbf{Baseload (MW)} = \frac{\text{Energy-equivalent quantity}}{\text{number of hours}}$$

For each temporal basis and separately for the north and south zones

MODEL OUTCOMES

Baseload values consistent in 2021 and 2023

Year	North baseload	South baseload
2021	0.15	0.19
2022	0.18	0.23
2023	0.15	0.19

Mean of monthly values ALWAYS higher than yearly baseloads

Main factors:

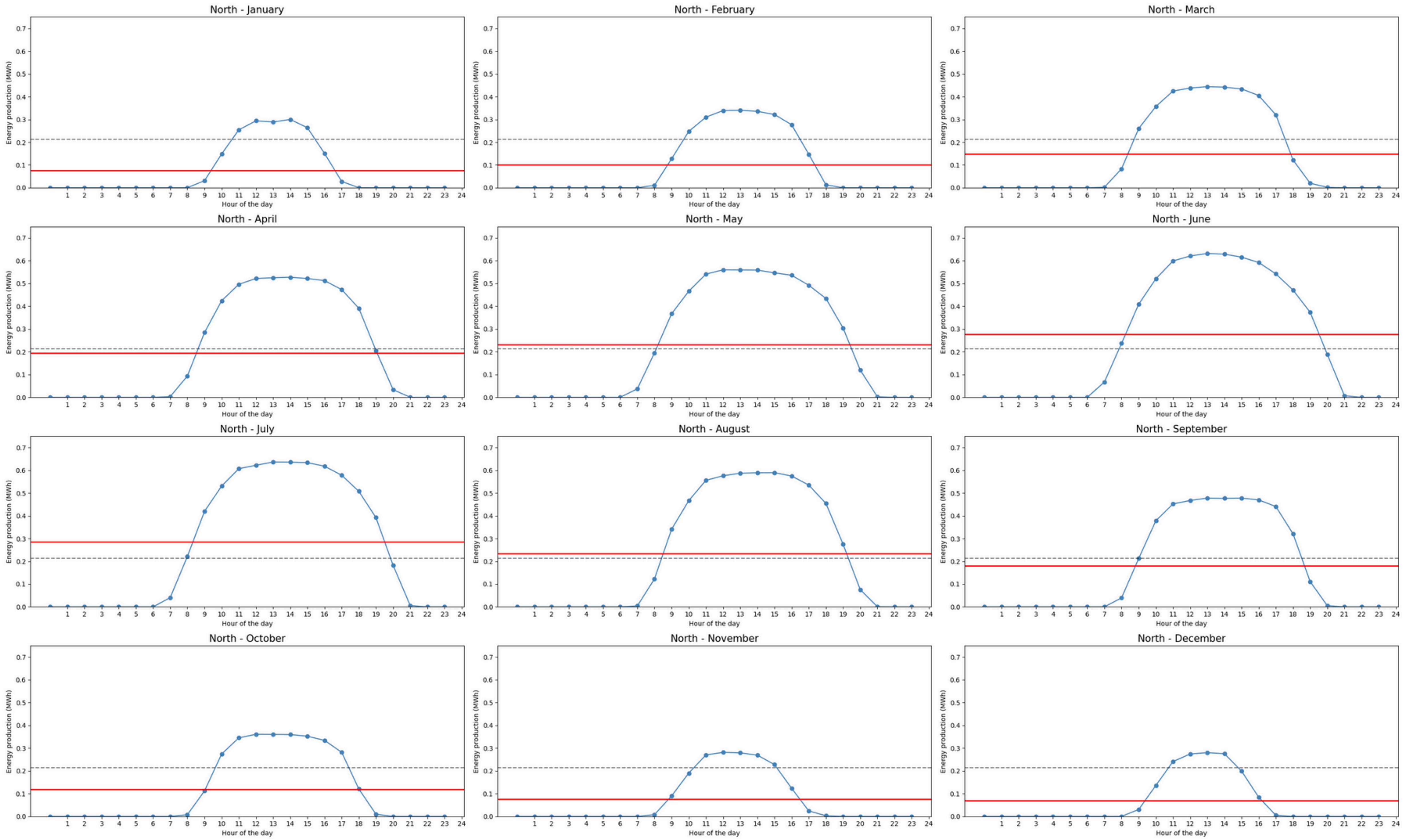
- Seasonal fluctuations smoothed out by yearly basis
- Short-term demand spikes influence monthly values
- Yearly values reduce volatilty since based on longer period and more data points

Year	North monthly mean	South monthly mean
2021	0.17	0.21
2022	0.21	0.16
2023	0.17	0.20

Month	North Baseload			South Baseload		
	2021	2022	2023	2021	2022	2023
January	0.08	0.10	0.08	0.10	0.08	0.10
February	0.11	0.14	0.10	0.13	0.10	0.13
March	0.15	0.19	0.15	0.18	0.14	0.16
April	0.20	0.26	0.19	0.24	0.19	0.23
May	0.24	0.30	0.23	0.30	0.23	0.29
June	0.28	0.35	0.28	0.35	0.26	0.34
July	0.29	0.36	0.29	0.35	0.27	0.35
August	0.24	0.30	0.23	0.30	0.22	0.29
September	0.18	0.23	0.18	0.23	0.17	0.22
October	0.12	0.15	0.12	0.15	0.12	0.15
November	0.08	0.10	0.07	0.10	0.07	0.09
December	0.07	0.08	0.07	0.08	0.06	0.08

Highest values during the summer and lowest ones during the colder months

MODEL OUTCOMES



Half of the months show a baseload quantity above the monthly average

IMPROVING SOLUTION: QUARTERLY BASIS

Quarter	North Baseload			South Baseload		
	2021	2022	2023	2021	2022	2023
Q1	0.11	0.11	0.11	0.14	0.14	0.13
Q2	0.24	0.23	0.22	0.30	0.30	0.29
Q3	0.24	0.23	0.22	0.30	0.29	0.29
Q4	0.09	0.09	0.08	0.11	0.11	0.11

Steady pattern of the highest values during central months (Q2 and Q3) and the lowest ones in Q1 and Q4

Year	North quarterly mean	South quarterly mean
2021	0.17	0.21
2022	0.16	0.21
2023	0.16	0.21

Quarterly basis offers a ***balance*** between monthly and yearly calculations:

- Allows for optimization while improving the simplicity of yearly calculations
- Provides flexibility of monthly adjustments without high costs and time consumption

Once again *no match* between quarterly averages and yearly values

CONCLUSION

- A company's energy portfolio is affected by considerable seasonal fluctuations and price volatility, making the implementation of a hedging strategy a potential solution to minimize this financial risks.
- The optimal approach is the **quarterly baseload** calculation, which offers the best balance between the *monthly* and *yearly* approaches, effectively addressing market and seasonal variations while keeping costs and complexity manageable.
- **Future research** could explore long-term trends in solar irradiation, incorporate additional factors such as weather conditions, and utilize hourly simulations through Monte Carlo methods, while also refining the strategy with machine learning regression models to predict the hourly energy production of PV systems.

THANK YOU FOR YOUR ATTENTION!