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ASSESSING THE IMPACT OF PNIEC IMPLEMENTATION DELAYS ON THE BUSINESS MODELS OF PUMPED HYDRO STORAGE PROJECTS

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ABSTRACT

This study analyzes how delays in meeting the targets of the Integrated National Energy and Climate Plan (PNIEC) affect the economic viability of pumped hydro storage (PHS) plants in Spain. Using statistical regression models and optimization algorithms, the performance of a 165 MW plant is evaluated up to the year 2050. The results indicate that delays in renewable infrastructure reduce the price spread, decreasing profitability by up to 28%.

INTRODUCTION

Pumped hydro storage is the most mature storage technology and allows the integration of renewables through price arbitrage.

• **Operation**: Water is pumped to the upper reservoir during off-peak hours and used to generate electricity through turbines during peak demand hours.

• **Current context**: Profitability depends on market volatility (spread), which increases with the penetration of renewables, especially solar photovoltaics.

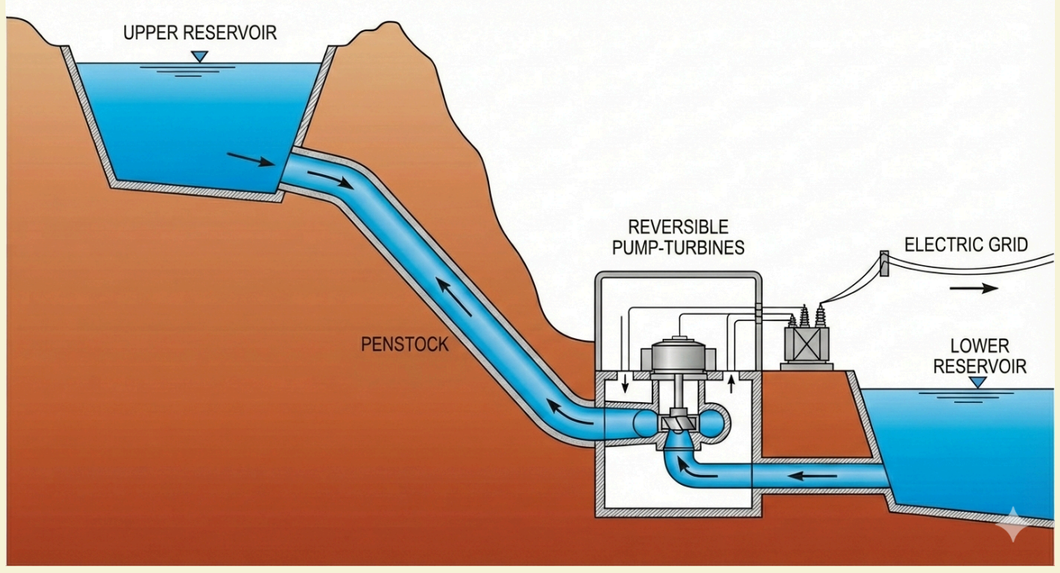
• **Problem**: At the current rate, it is unlikely that the National Integrated Energy and Climate Plan (PNIEC) targets for 2030 will be met, which directly impacts the energy storage business model.

ANNUAL INSTALLATION RATE REQUIRED TO MEET PNIEC TARGETS IN 2030, 2035, OR 2040

It is virtually impossible to achieve the PNIEC targets by 2030, but they could be achieved by 2035 or 2040 depending on the annual construction rates

	WIND	PV	PHS	
2030	5,778.74	5,358.48	3,042.40	MW/year
2035	2,889.37	2,679.24	1,521.20	MW/year
2040	1,926.25	1,786.16	1,014.13	MW/year

COMPONENTS OF A PUMPED HYDRAULIC STORAGE SYSTEM



OPERATING MODEL OF A STAND-ALONE PUMPED HYDRO STORAGE (PHS)

A 165 MW "stand-alone" pumping project directly connected to the grid is analyzed.

• **Strategy**: Identifying revenue streams through revenue stacking and minimizing supply costs.

• **Algorithm**: Daily selection of the best times for pumping (minimum prices) and turbine operation (maximum prices).

• **Configuration**: Turbine capacity of 150 MW to compensate for hydraulic and mechanical losses.

PRICE FORECAST (2026-2050)

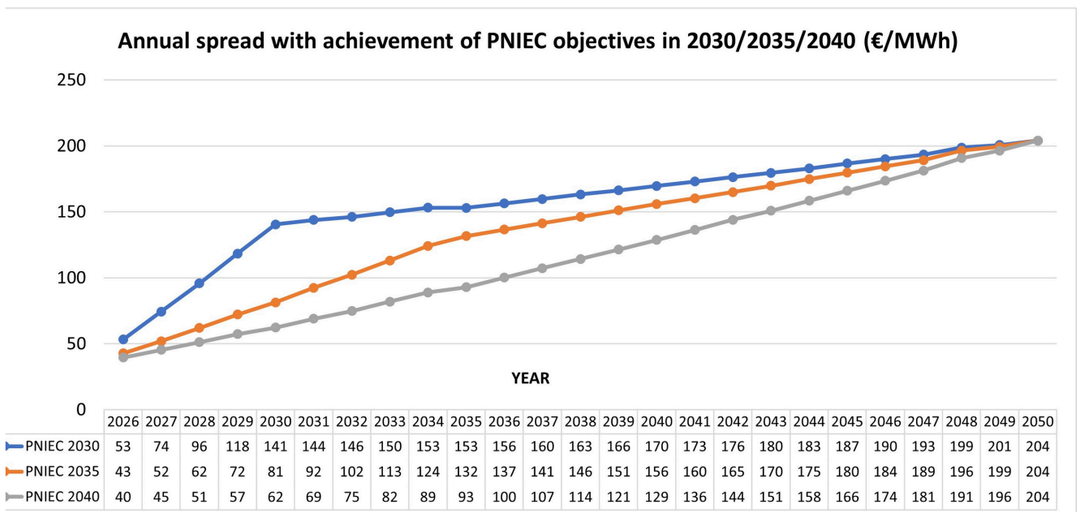
A statistical regression model with 19 explanatory variables (R^2 of 84.1%) is used.

• Key variables: Brent oil prices, gas prices, CO2 prices, and installed wind, PV, hydro, CCGT and nuclear power capacity.

RESULTS

The ***economic balance*** is calculated for 12 cases combining pumping hours (from 4 to 7 hours) and PNIEC scenarios (assuming the targets are met by 2030, 2035 or 2040)

Pumping strategy	PNIEC 2030	PNIEC 2035	PNIEC 2040
4 hours	885.9	765.4	645.0
5 hours	1,055.0	911.1	767.5
6 hours	1,188.5	1,025.2	862.3
7 hours	1,293.6	1,114.1	935.0



ANALYSIS

• **Impact of the delay**: If the National Integrated Energy and Climate Plan (PNIEC) is delayed until 2040, performance falls by 28% compared to the 2030 scenario.

• **Optimization**: Increasing pumping to 7 hours per day improves financial performance by 46%.

• **Spread Evolution**: The price differential widens faster in the 2030 scenario, stabilizing profitability sooner.

CONCLUSIONS

1. Pumped storage is critical for system stability and renewable energy integration.

2. Economic viability is intrinsically linked to meeting strategic decarbonization deadlines.

3. It is urgent to accelerate infrastructure development to attract the necessary investment in these long-life facilities.

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