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# TECHO-ECONOMIC ANALYSIS OF ENHANCED PERFORMANCE OF LARGE-SCALE WIND POWER GENERATION USING UNDERGROUND HYDROGEN STORAGE

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**Abstract**

The intermittent nature of wind power generation creates mismatches between electricity supply and demand, limiting its penetration in modern electricity grids. We explore the impact of salt cavern storage of hydrogen gas produced using water electrolysis during periods of excess wind power generation on overall project finances for a hypothetical 1 GW electricity market. The project includes CAPEX, OPEX, and transmission costs for 500 2-MW wind turbines. We calculate rate of return (ROR) for a 30-year project over a range of ten variables including cavern size, cavern installation costs, cost of hydrolysis, transmission costs, production tax credit, and compression costs.

We perform a global sensitivity analysis on 1,056 scenarios covering the full range of typical project variables. We use four years of publicly available data on wind power generation from PJM and compare it to electricity demand during the same time period. Using Riemann sums to calculate excess wind power generation for 52 weeks, we find that average capacity factor can be improved up to 24% using hydrogen storage. While capacity factor can be adjusted based on engineering design, it typically comes at a cost of power generation in traditional wind farms.

Our key finding is that with salt cavern storage of hydrogen the capacity factor can be enhanced without losing power generation capacity: the 1 GW wind farm is able to utilize an additional 41 GWh of energy in the form of hydrogen. While the rate of return ranges from approximately 8% to 20% for non-storage scenarios, the rate of return ranges between 20% to 35% when including storage costs and benefits.

We explore the cost of hydrolysis between $0 to $168M per year. We consider the case of hydrolysis having zero cost to correlate to the practice of pricing excess wind power generation at $0/kWh—if excess wind power has zero value, then using it to generate hydrogen via hydrolysis has zero cost. While the scenarios with zero hydrolysis cost have the highest RORs, many of the cases with $168M/year hydrolysis costs still have RORs in excess of 30%. Overall, we find that the additional CAPEX and OPEX of salt cavern installation are far outweighed by the benefits of hydrogen storage as a large-scale renewable energy battery.

**Key words:** Caverns for Gas Storage, Hydrogen Storage, Wind Power Generation, Sensitivity Analysis, Techno-economic Optimization