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Optimal Integration of hybrid pumped storage hydropower to increase renewables penetration and reduce CO_2 emissions

7 AFFORDABLE AND CLEAN ENERGY

13 CLIMATE ACTION

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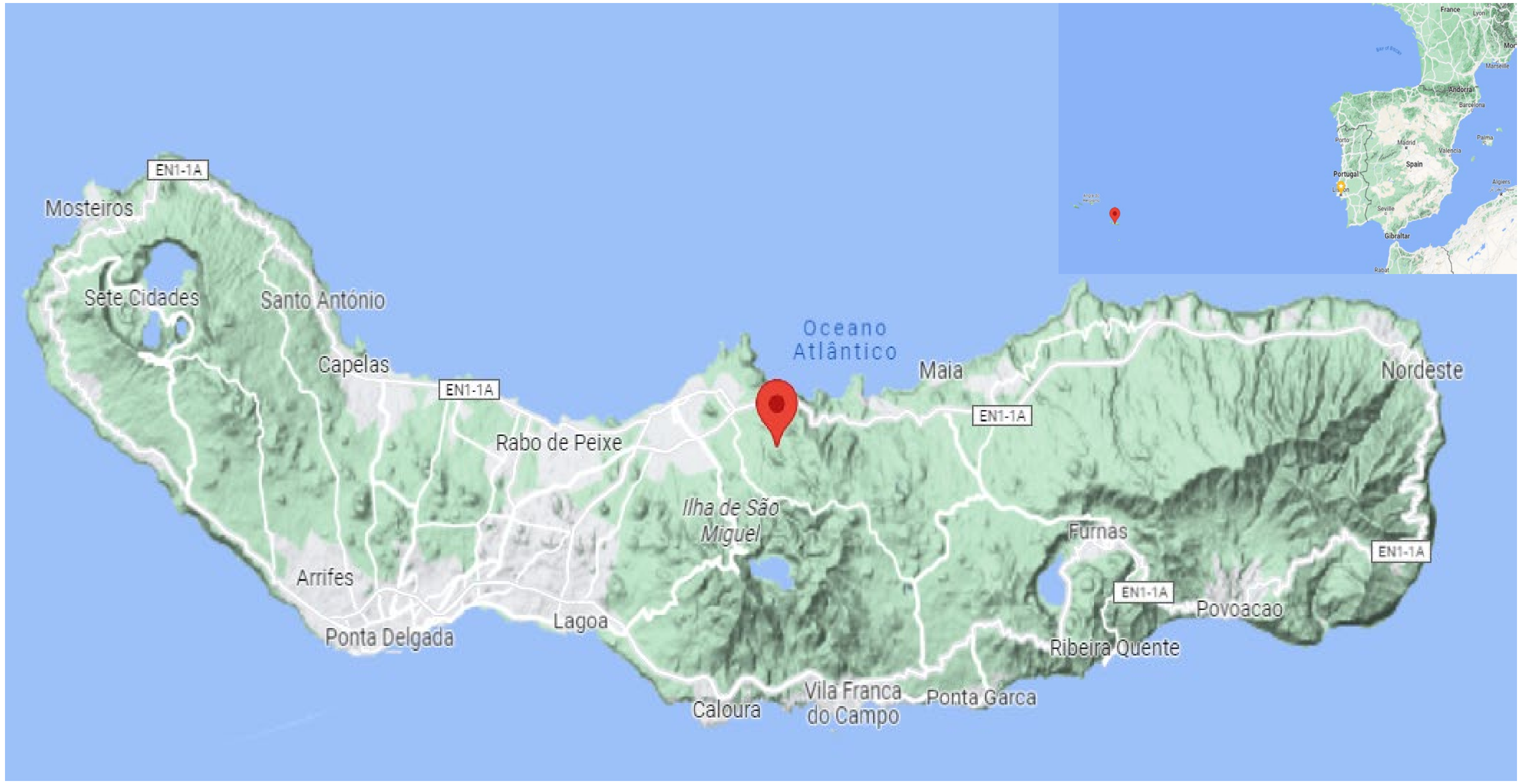
Key questions

- Why the presence of PSH as an integrated storage system in the existing grid is inevitable?
- How can a given amount of energy be stored at minimum cost with optimal scheduling?
- How does PSH actively contribute to reducing the energy sector's global carbon footprint by supporting the integration of wind and solar energy?
- Which type of PSH scheme can effectively reduce the cost of the power grid due to diesel generators by absorbing and storing excess VREs and meeting peak demand during high power consumption?
- How can this model prove the effectiveness of PSH deployment in the hybrid system?

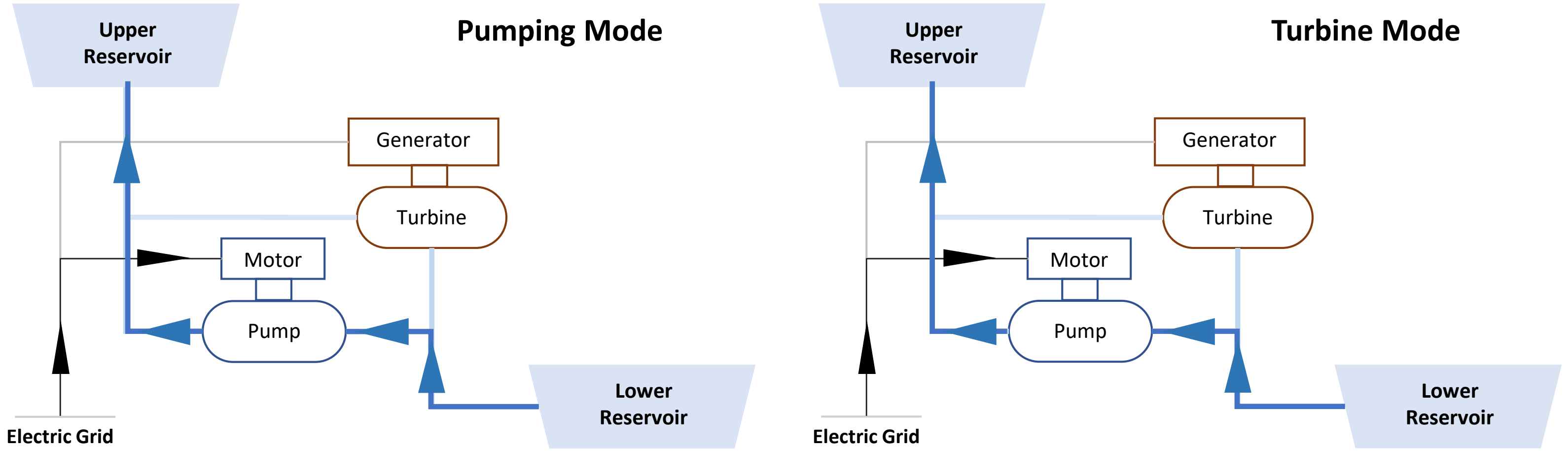
Study case and data

- A typical annual load electricity load obtain from REN
- Hourly weather data from Renewables.ninja
- The highest and lowest recorded wind speeds
  were 24.85 and 0.14 m/s
- Solar irradiance was 1.009 and 0 kW/m^2
- Hourly energy price was 180.3 €/MWh, while the cheapest was 12.15 €/MWh

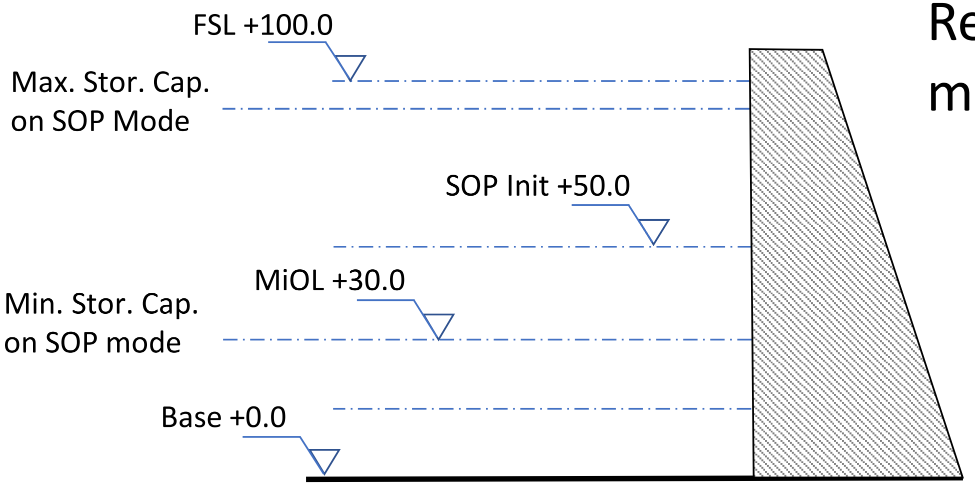


Operation mode

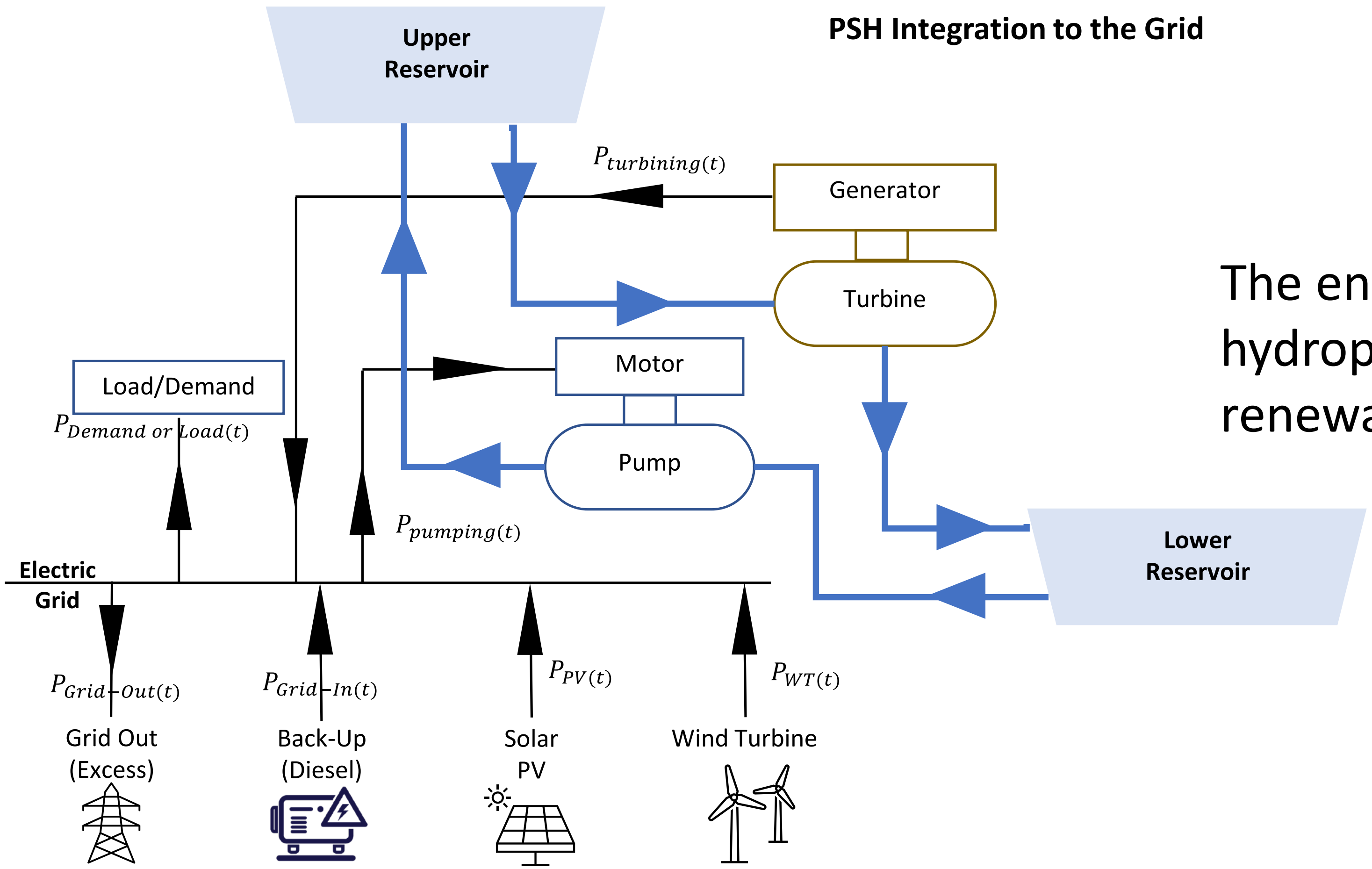
Pumping and turbine mode operation of PSH (Closed Loop)



Reservoir operation simplified model



System integration and optimization



The energy system of pumped storage hydropower integration with intermittent renewables and electrical power grid

Operation scenarios/schemes

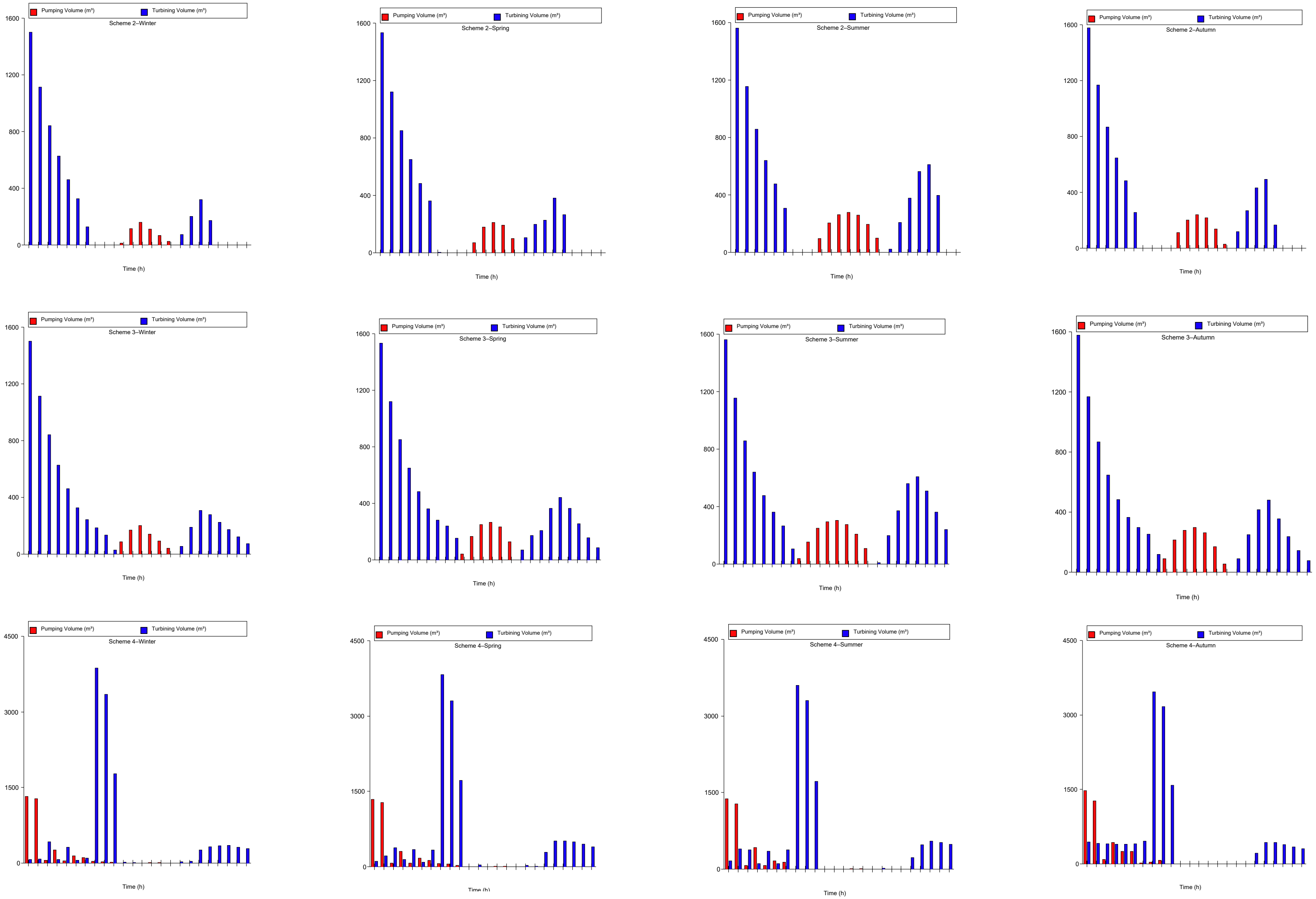
- **Scenario 1**, *no PSH is used*; renewable generation determines whether electricity is injected into the system from the grid, i.e., grid-in, or whether excess produced electricity is exported from the system to the grid, i.e., grid-out.
- **Scenario 2**, the pumped storage mode is enabled and tied exclusively to the positive value of the State of Pumping (SoP).
- **Scenario 3,** *with adjusted PSH,* the SoP is flexibly adjusted to decide whether the hourly operation should be in turbine or pumping mode based on the maximum pumping rate and the previous state of the SoP.
- **Scenario 4,** *with optimized PSH,* to minimize the costs associated with integrating pumped storage power plants into hybrid solutions by varying the hourly output of pumps, turbines, grid injection, and grid withdrawal.

Operation assumptions

- Pumped storage is assumed to have no losses due to evaporation or leaks in the pipelines and reservoirs.
- The PSH schematic model is integrated to rapidly ramp-up generation during peak periods as the available hydro fixed resources capacity further expands variable renewable energy (VREs).
- The flow rate follows the power generation and varies dynamically per hour, depending on the adjustment scheme.
- Emission reduction is based on a developed algorithm that simultaneously reduces the total applied cost.

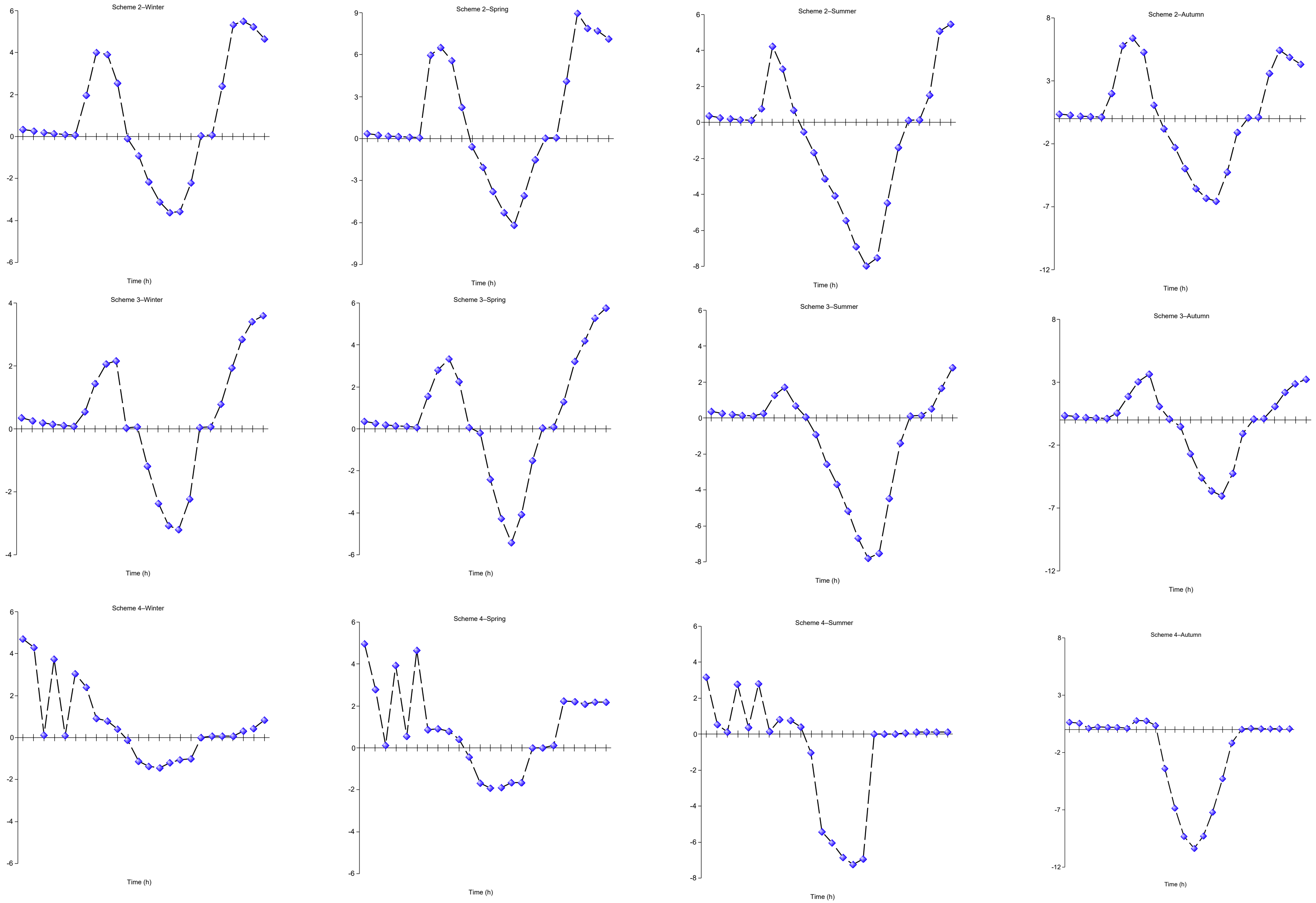
Results

Daily Pumping and Turbining Volumetric Profile within Different Schemes and Seasons



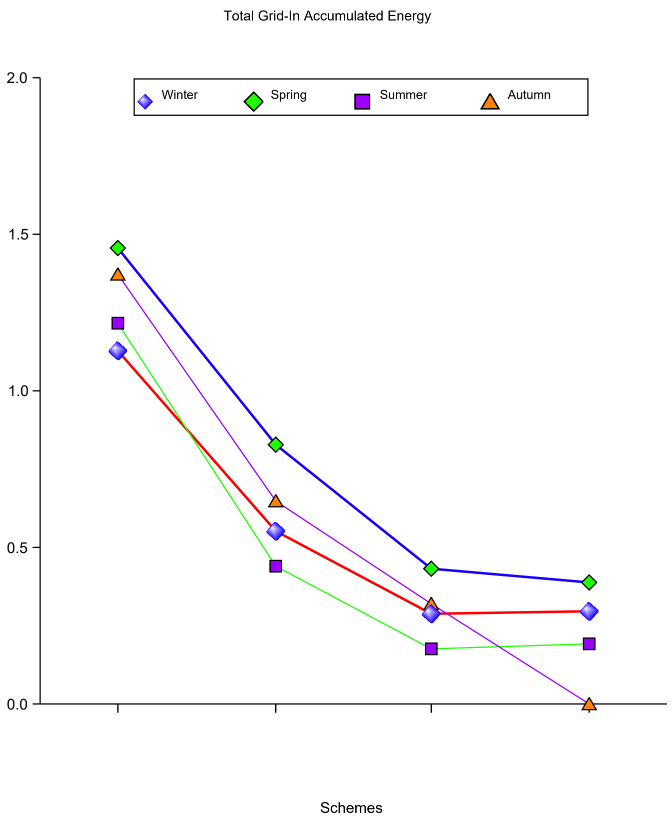
Results

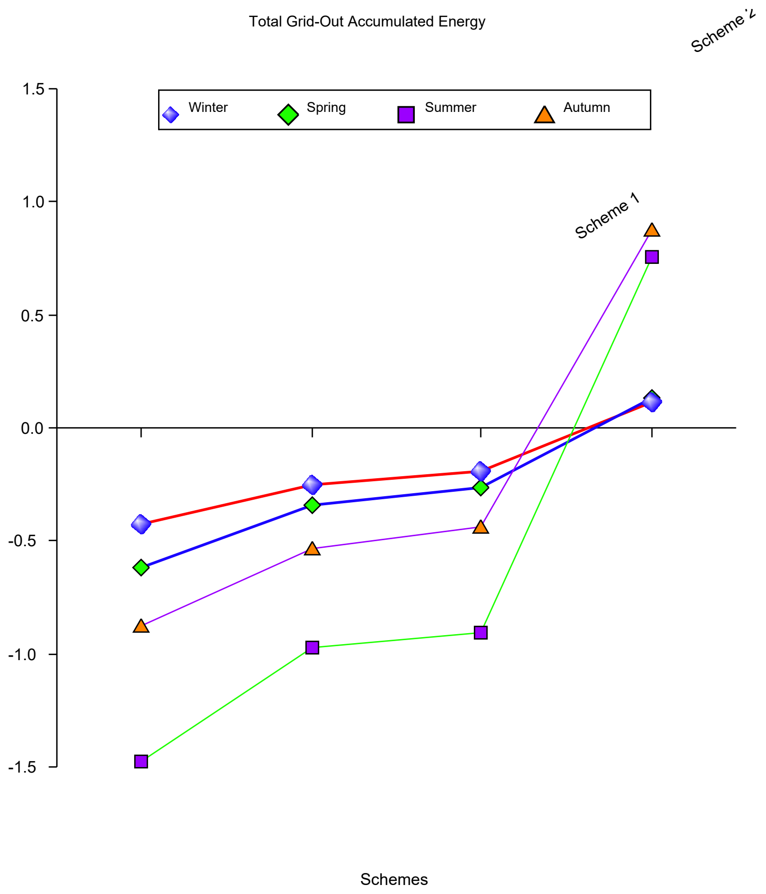
Daily Cost Distributions within Different Schemes and Seasons

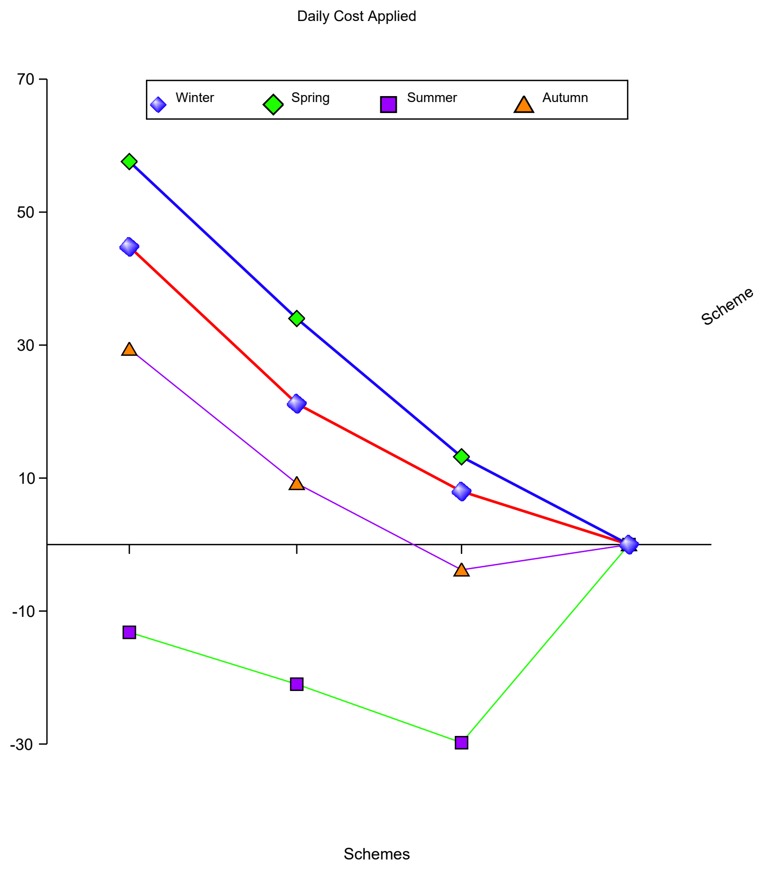


Results

Grid-In, Grid-Out, and Cost Applied within Different Schemes and Seasons

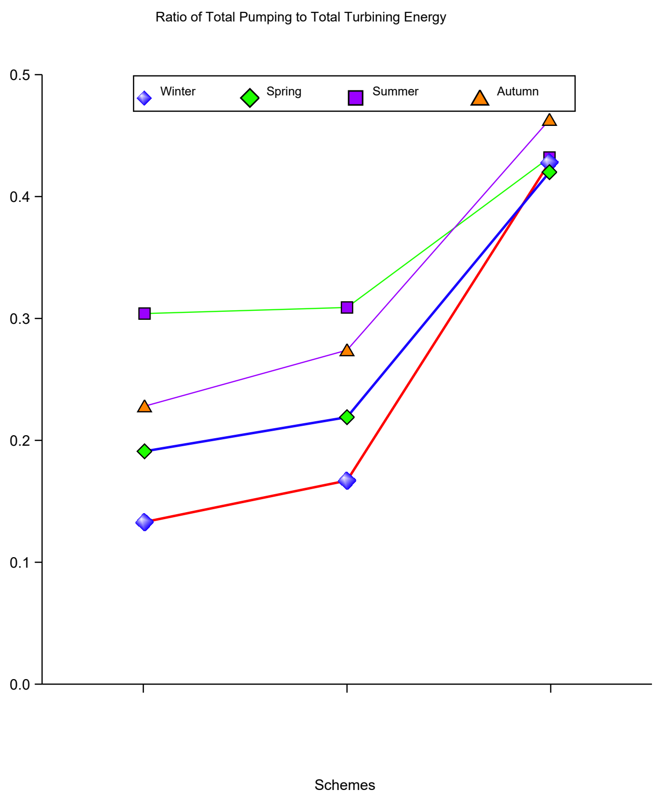


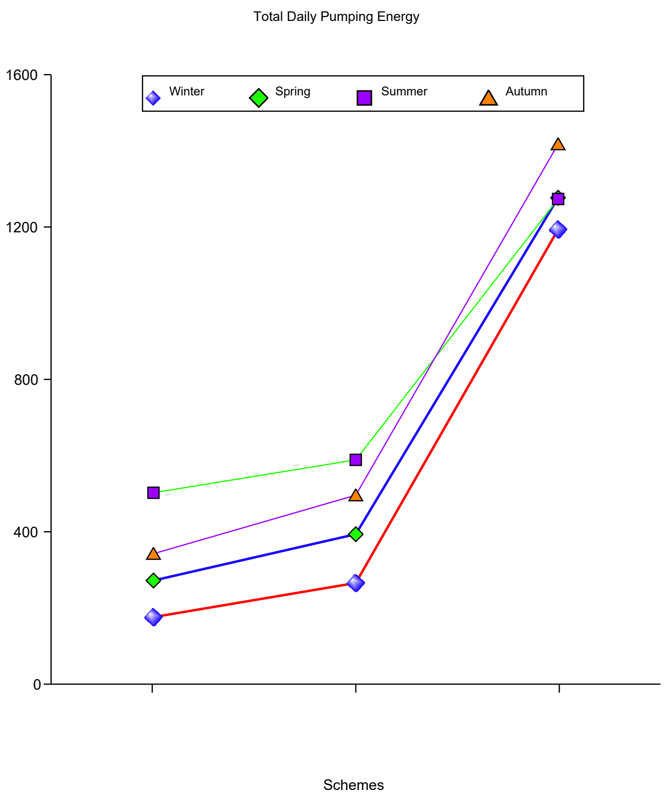


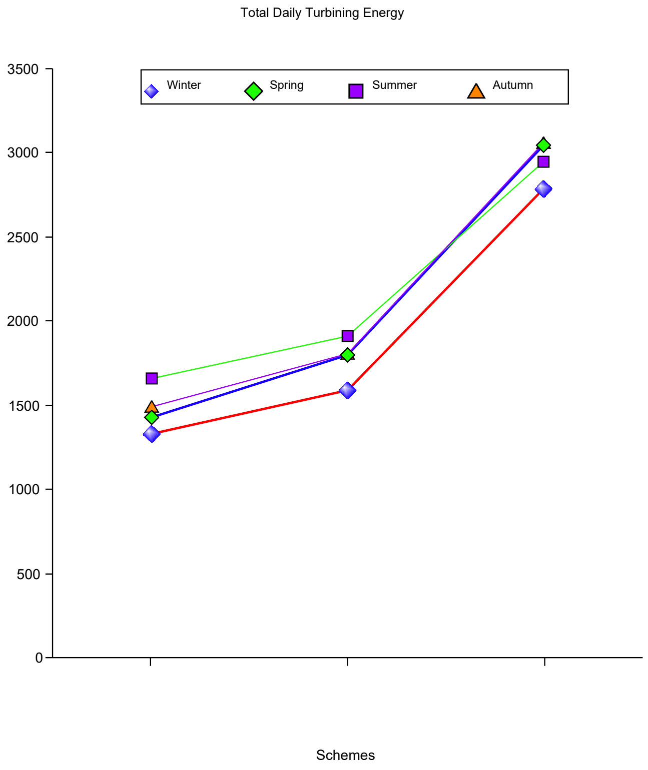


Results

Pumping Ratio to Turbining Energy, Pumping and Turbining within Different Schemes and Seasons

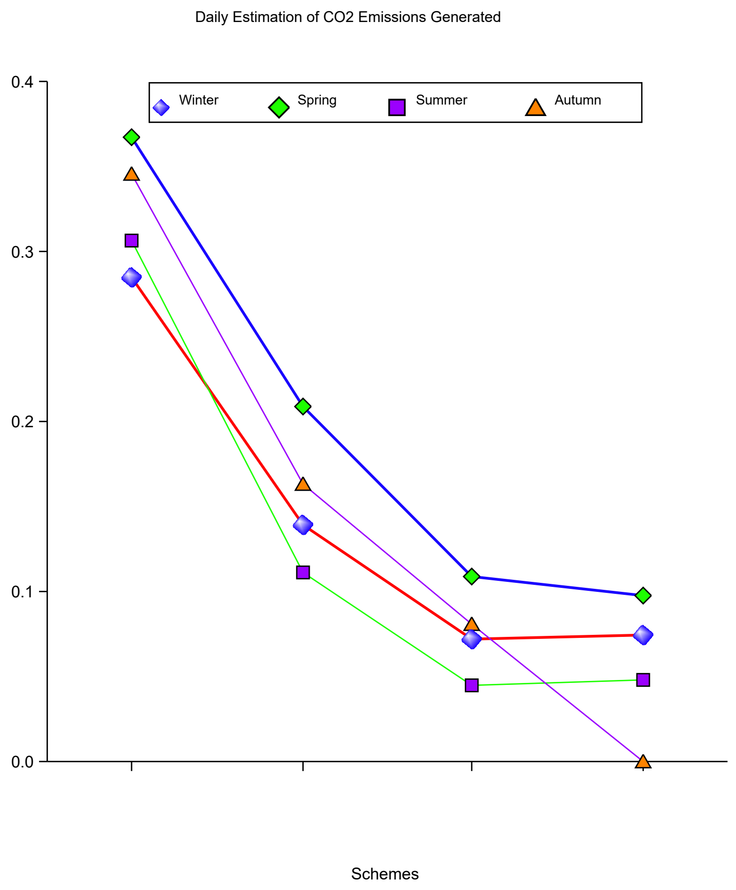


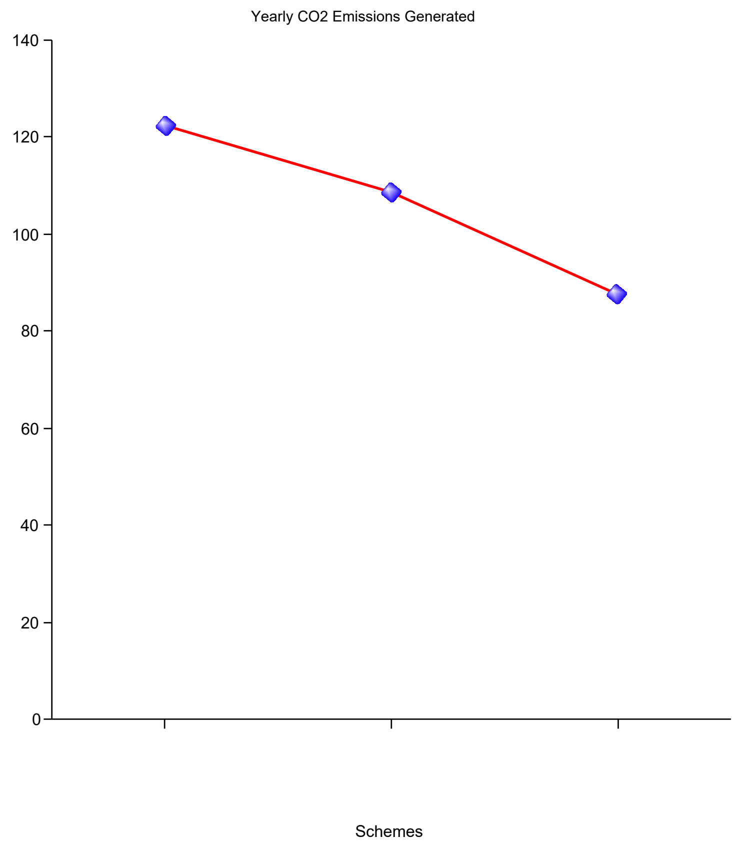




Results

CO$_2$ emissions estimation within Different Schemes and seasons





Conclusions

- A PSH energy solution can minimize CO_2 emissions by reducing the accumulated grid-in energy supplied by fossil fuel-based generation.
- CO_2 reduction with Scheme 4 can reach up to 84% in summer and 100% in Autumn, while daily costs can be reduced by more than 90% in all seasons.
- With an optimized and adjustable scheme, PSH can also provide a wider range of up- and down-ramps while varying the power system in generation and pumping modes.
- A hybrid genset combined with PSH has shifted, stored, and reused generated energy until an appropriate load is available for system reserves and variable energy integration.
- Focusing on supply and demand while minimizing costs and reducing the carbon footprint will behave differently in each situation, depending on the weather conditions.

Thank You!

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