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Pumped hydroelectric storage utilization assessment: Forerunner of renewable energy integration or Trojan horse?

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Abstract

Pumped hydroelectric storage (PHS) is the main utility-scale storage technology. Although PHS systems generally constitute a fraction of generation, they receive increasing attention due to their potential balancing role towards higher penetration of variable renewable energy sources (RES). In the European context it is widely believed that PHS are key elements of the ongoing energy transition. The present analysis examines if this assumption is valid and PHS utilization grows parallel to RES. We collected, harmonised and analysed datasets for 1991–2016 revealing an uneven utilization among European states. While certain countries increased the utilization rates of PHS by a factor of three to four, in several others PHS units are heavily under-utilized. In three extreme cases the utilization rate, compared to the past, is at 10-25% level. We analysed this controversy by identifying tendencies in the electricity markets, ownership and management status in the various countries, as well as competition with other technologies with balancing potential. Finally, we developed a new approach to display PHS tendencies in a compact picture. Building on the growth-share matrix Economics framework, we identified the strategic direction of PHS for each of the analysed countries.

Keywords: pumped storage, hydropower, renewable energy sources, electricity markets, large-scale electricity storage, utilization strategies

Highlights. ¹

- PHS utilization analysis in EU by introducing a growth–share (*Boston*) matrix
- PHS yearly utilization shrunk by a factor of 4 in Italy and Poland and 10 in Greece
- PHS yearly utilization nearly doubled in Austria, Portugal and Czech Republic
- Identified obstacles: single ownership, low wholesale prices margins

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¹ABBREVIATIONS C_{pump} : Production cost of PHS [€]; **CAP**: Power capacity of PHS [GW]; Δp : Difference between electricity purchase and selling prices [€]; E_{in} : Energy input in pumping operation of PHS [kWh]; E_{out} : Energy output in production operation of PHS [kWh]; **ECP**: Electricity consumption of PHS pumping operation [GWh]; **GSM**: Growth–share matrix; **JRC**: European Commission Joint Research Centre (JRC); **MGR**: Market growth rate; **MR**: Marginal revenue of production for each PHS station [€]; **MS**: European Union Member State; P_{sell} : Electricity selling price [€]; **RDV**: Normalised range of demand's variability [GWh]; **RMS**: Relative market share; **RTE**: Round-trip efficiency; **VOC**: Variable operating cost [€]

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