How much storage do we need for the energy transition?

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World openTEPES Conference

2nd World openTEPES Conference | Madrid, 19th of July 2023

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1. Introduction

- Decarbonization targets will increase the share of VRES in power systems
- How do we ensure that supply meets demand?
  - Overinstalling VRES
  - Installing storage
  - Making demand flexible
- In this paper we look at storage needs, and their economic rationale
  - Will markets deliver?
  - If not, how much do we need?

2. Our contribution

- Precise representation of the power system (with OpenTEPES)
- Characterization of hydro
- Extreme years
- Multiple flexibility options and their interactions

3. Methodology

- First, we determine the storage needs for a worst-case scenario (understanding as such a dry, low-wind year). For that, we run the OpenTEPES model (described below) in a generation-expansion mode, although we set the power installed in the system to the figures presented in the Spanish National Energy Plan. Therefore, we allow for investments in storage, and also allow for increasing the power installed of VRES if there are non-supplied-energy issues in the system.

- Then, we fix the investment variables, and run the model for an average scenario, which allows us to represent the normal operation of the storage built in the previous stage (as well as of the generation fleet).

- Finally, we run some sensitivity analysis for hydro flexibility, demand response, or low-VRES scenarios to test the robustness of the results and the implications of these alternative scenarios.

4. Results 2030

	Installed Power [MW]		Storage [GWh]	CCGT production [GWh]	Storage balance [GWh]	Spillage [GWh]	Total costs [M€]	Investment cost [M€]	Weighted marginal cost [€/MWh]
	Batteries	Pump storage							
Reference case	217	944	28.20	24106	-3428	35449	3989	53.5	63.47
Lower CCGT efficiency	278	1258	34.05	23975	-3510	35221	4321	70.2	71.60
No Demand Response	347	1497	36.65	24506	-4089	35501	4064	75.0	62.67
Exports	556	1881	44.67	27054	-6476	7891	4604	110.6	92.12
Inflexible Hydro	231	929	28.17	26715	-2991	38376	4254	53.6	62.29
Dunkelflaute	184	912	27.13	27353	-3760	32629	4339	50.2	65.68

4. Results 2030

		Production [M€]	Consumption [M€]	Down reserve [M€]	Up reserve [M€]	Annualized investment cost [M€]	Profit [M€]	Profit [M€/GW]	Profit [€/MWh]
Reference case	Batteries	2.84	-1.45	2.27	1.8	-9.21	-3.75	-17.28	-10.25
	Pump Storage	30.3	-8.32	0.61	2.61	-40.09	-14.89	-15.77	-17.02
Lower CCGT efficiency	Batteries	3.98	-2.06	2.85	2.36	-11.76	-4.63	-16.65	-9.72
	Pump Storage	43.02	-12.32	0.87	3.41	-53.7	-18.72	-14.88	-16.73
No Demand Response	Batteries	5.38	-2.39	3.34	2.88	-14.69	-5.48	-15.79	-9.22
	Pump Storage	47.53	-13.43	0.69	3.45	-56.13	-17.89	-11.95	-12.94
Exports	Batteries	14.28	-9.64	8.69	6.75	-23.51	-3.43	-6.17	-6.66
	Pump Storage	95.85	-48.48	1.52	7.69	-82.91	-26.33	-14	-11.26
Inflexible Hydro	Batteries	2.98	-1.57	2.77	2.03	-9.77	-3.56	-15.41	-9.37
	Pump Storage	29.7	-7.75	0.95	2.87	-39.61	-13.84	-14.9	-18.73
Dunkelflaute	Batteries	2.36	-1.22	2.1	1.55	-7.79	-3	-16.3	-10.22
	Pump Storage	29.62	-8.17	0.65	2.65	-38.23	-13.48	-14.78	-15.76

5. Conclusions

- We need specific mechanisms to invest in the storage required
- Batteries compete with Demand Response (and conventional generation)
- Pump storage plays a critical role, but cannot provide seasonal storage
- Seasonal storage is needed in 2050
- Demand flexibility is key (particularly in 2050, with H2 production)
- Hydro operation is also relevant

Thank you

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