Extended Abstract

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THE EFFECT OF DEPLOYING LARGE-SCALE ENERGY STORAGES IN ITALY

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1. Overview

Large-scale energy storage (LES) systems are essential to achieve net-zero emissions by 2050 and decarbonise the energy system (IEA, 2022). Globally, it is estimated that investments in LES need to scale up significantly, reaching 1.5–2.5 TW and 85–140 TWh by 2040, with an estimated cost of up to $3 trillion (McKinsey, 2021). Pumped hydro energy storage has long supported power grids during peak times, but this is no longer sufficient, and orders of magnitude more than current energy storage capability are required to meet net-zero carbon scenarios and to deal with the intermittency of renewable energy sources (EntsoE, 2023).

In this context, a key aspect to consider is the location where energy storages are deployed, as this can substantially impact the actual carbon emission reduction and social welfare. This is particularly relevant in constrained networks, where energy storages may actually contribute to shifting the generation mix towards dirtier sources, increasing carbon emissions (Bardwell et al., 2023).

This work aims at assessing the effect on carbon emissions and social welfare of deploying large-scale energy storages in different areas of Italy, with a focus on lithium-ion (Lithium-iron-phosphate, LFP) batteries. A sensitivity analysis is also performed to estimate how different combinations of rated power and energy storage capacity may affect the results, while accounting for both operation and investment costs. A high-fidelity network model of the Italian electricity system consisting of 2,129 electrical elements (including AC transmission lines, transformers, and HVDC cables) is developed. We use this network and actual market data (GME, 2023) to simulate the Italian day-ahead electricity market clearing process, and assess how deploying large-scale energy storages in different locations in Italy can affect social welfare and carbon emissions.

2. Methods

The high-fidelity Italian transmission network has been created by using the data of the European high-voltage transmission grid obtained from EntsoE (EntsoE, 2022), which includes the existing Italian grid (sketched in Figure 1), as well as the planned expansions up to 2025. The resulting high-fidelity Italian network consists of 937 AC transmission lines (ranging from 500 kV to 117 kV), 1,188 transformers (including 11 symmetrical phase-shifting devices), and 4 HVDC cables. To assess the change in social welfare due to the deployment of energy storages, we simulated the Italian day-ahead market clearing using the real market data obtained from the Italian market operator (GME, 2023). To account for seasonal effects, we use the data referring to both January 2023 and August 2022. Each day includes approximately 65,000 market orders, on average. To assess the effect on social welfare of deploying LES, we have explicitly considered both fixed and variable costs of investing and operating lithium-ion batteries, which have been obtained from Viswanathan et al., (2022), Hunter et al., (2021), and Schmidt et al., (2019). These costs are reported in

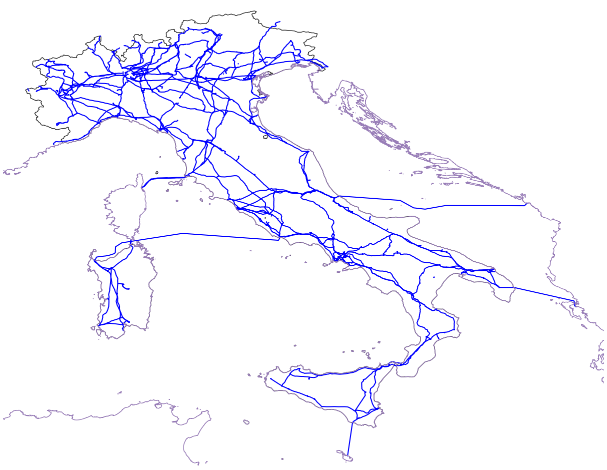

Figure 1 Italian high-voltage (≥220kV) transmission network.

Table 1 together with additional parameters including depth-of-discharge (DoD), round-trip efficiency, decommissioning costs, and construction time. Fixed operation and management costs include replacement expenditures of key components, such as battery stacks (approximately every six years) to account for degradation and ageing.

Parameters	Unit of Measure	Lithium-ion LFP 10 MW, 2h	Lithium-ion LFP 10 MW, 8h	Lithium-ion LFP 100 MW, 2h
Rated Power	MW_{cap}	10	10	100
Duration	hours	2	8	2
Capex - Energy	USD/kWh_{cap}	461.15	382.87	427.18
Capex - Power	USD/kW_{cap}	922	3,063	854
Fixed O&M	USD/kW_{cap}-y	2.79	8.12	2.56
Var O&M – Charg.	USD/MWh	-	-	-
Var O&M – Disch.	USD/MWh	3.10	3.10	3.10
Decommiss. costs	USD/kWh_{cap}	2.65	2.65	2.65
Round-trip Eff.	%	83%	83%	83%
Construction time	years	1	1	1
Prj operational life	years	20	20	20
DoD	%	80%	80%	80%
Disc. factor (WACC)	%	8%	8%	8%

Table 1 Cost parameters for lithium-ion batteries.

3. Expected results and conclusion

To assess the impact on carbon emissions and social welfare, we will compare a base case without storage, with several test cases obtained by placing energy storages in different locations of the Italian grid, using the developed high-fidelity network. In addition, to determine how different combinations of rated power and energy storage capacity may affect the results, we will perform a sensitivity analysis considering three different combinations for each location, whose parameters are reported in Table 2, where the duration is defined as the energy capacity to rated power ratio.

Technology	Rated Power Capacity (MW)	Duration (h)
Lithium-ion LFP	10	2
Lithium-ion LFP	10	8
Lithium-ion LFP	100	2

Table 2 Combination of rated power and duration used in the sensitivity analysis.

From the results, currently under investigation, we expect to highlight a significant benefit from deploying energy storage systems, particularly in constrained areas such as the island of Sardinia and the southern regions of Italy. We also expect that the actual carbon abatement will be substantially affected by location, particularly depending on the proximity to dirtier sources, such as coal power plants.

References

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