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FIGURE 5. Illustration of the hourly net load and locational marginal prices at p10 of the baseline operation in the 2050 WI. The red line in (7a) indicates zero net load, i.e., the electricity demand is equivalent to variable renewable energy availability.

FIGURE 8. Price-taker targets and PLEXOS ST energy storage end volumes comparison for a 2,000 MW, 40% round-trip efficiency, and 1-month duration energy storage device in 2050.

FIGURE 10. 12-month fill profile for a 2,000 MW energy storage resource with 40%, 60%, 70%, and 80% round-trip efficiencies and 9-day (0.43 TWh), 24-day (1.15 TWh), 30-day (1.44 TWh), and 32-day (1.54 TWh) discharging, respectively.

FIGURE 11. Average daily discharge (generation), charging, and received price profiles for a 2,000 MW, 40% round-trip efficiency, and 1-month duration energy storage device in 2050.

FIGURE 12. Average monthly discharge, charging, and received price profiles for a 2,000 MW, 40% round-trip efficiency, and 1-month duration energy storage device in 2050.

FIGURE 13. Annual system benefits including fuel, VO&M, and startup and shutdown cost reduction associated with the maximum benefit long-duration energy storage including energy storages with (A) 40% round-trip efficiency and 9-day duration, (B) 60% round-trip efficiency and 24-day duration, (C) 70% round-trip efficiency and 30-day duration, and (D) 80% round-trip efficiency and 32-day duration.

FIGURE 14. The annual generation mix changes associated with the maximum benefit long-duration energy storage including energy storages with (A) 40% round-trip efficiency and 9-day duration, (B) 60% round-trip efficiency and 24-day duration, (C) 70% round-trip efficiency and 30-day duration, and (D) 80% round-trip efficiency and 32-day duration.

FIGURE 15. The annual benefits from providing ancillary services including flexibility, regulation, and spinning reserves associated with the maximum benefit long-duration energy storage with 40, 60, 70, and 80% round-trip efficiencies.

FIGURE 16. The annual diurnal and seasonal benefits comparison (value and percentage of the total system benefit) associated with the maximum benefit long-duration energy storage scenarios in 2050 WI system including energy storages with (A) 40% round-trip efficiency and 9-day duration, (B) 60% round-trip efficiency and 24-day duration, (C) 70% round-trip efficiency and 30-day duration, and (D) 80% round-trip efficiency and 32-day duration.

FIGURE 17. The share of charging energy from otherwise curtailed variable renewable energy and curtailment reduction values associated with the maximum benefit long-duration energy storages including energy storages with (A) 40% round-trip efficiency and 9-day duration, (B) 60% round-trip efficiency and 24-day duration, (C) 70% round-trip efficiency and 30-day duration, and (D) 80% round-trip efficiency and 32-day duration.

FIGURE 18. Annual CO2 emission reduction associated with the maximum benefit long-duration energy storage including energy storages with (A) 40% round-trip efficiency and 9-day duration, (B) 60% round-trip efficiency and 24-day duration, (C) 70% round-trip efficiency and 30-day duration, and (D) 80% round-trip efficiency and 32-day duration.

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