Leveraging the rail network for electric grid resilience

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ENERGY TECHNOLOGIES AREA
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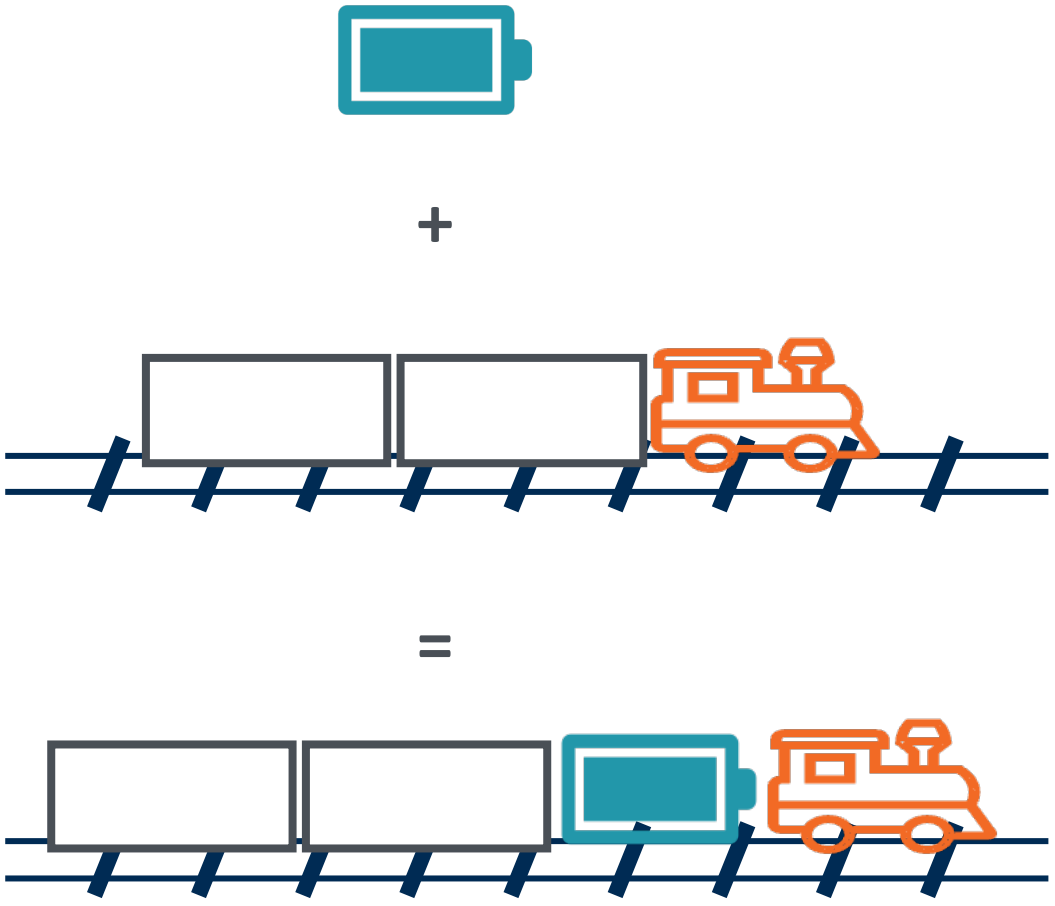
Benefits of Rail



One train can carry **1 gigawatt-hour (GWh) of battery storage** - roughly equivalent to the battery-carrying capability of **1,000 semi-trucks**

At over 140,000 miles, the US rail network is the largest in the world, with **rights-of-way and large amounts of real-estate** in some of the most population-dense and transmission-congested regions

Daily and weekly routes already **moving freight interregionally and across the country**

Supplementing transmission expansion with RMES

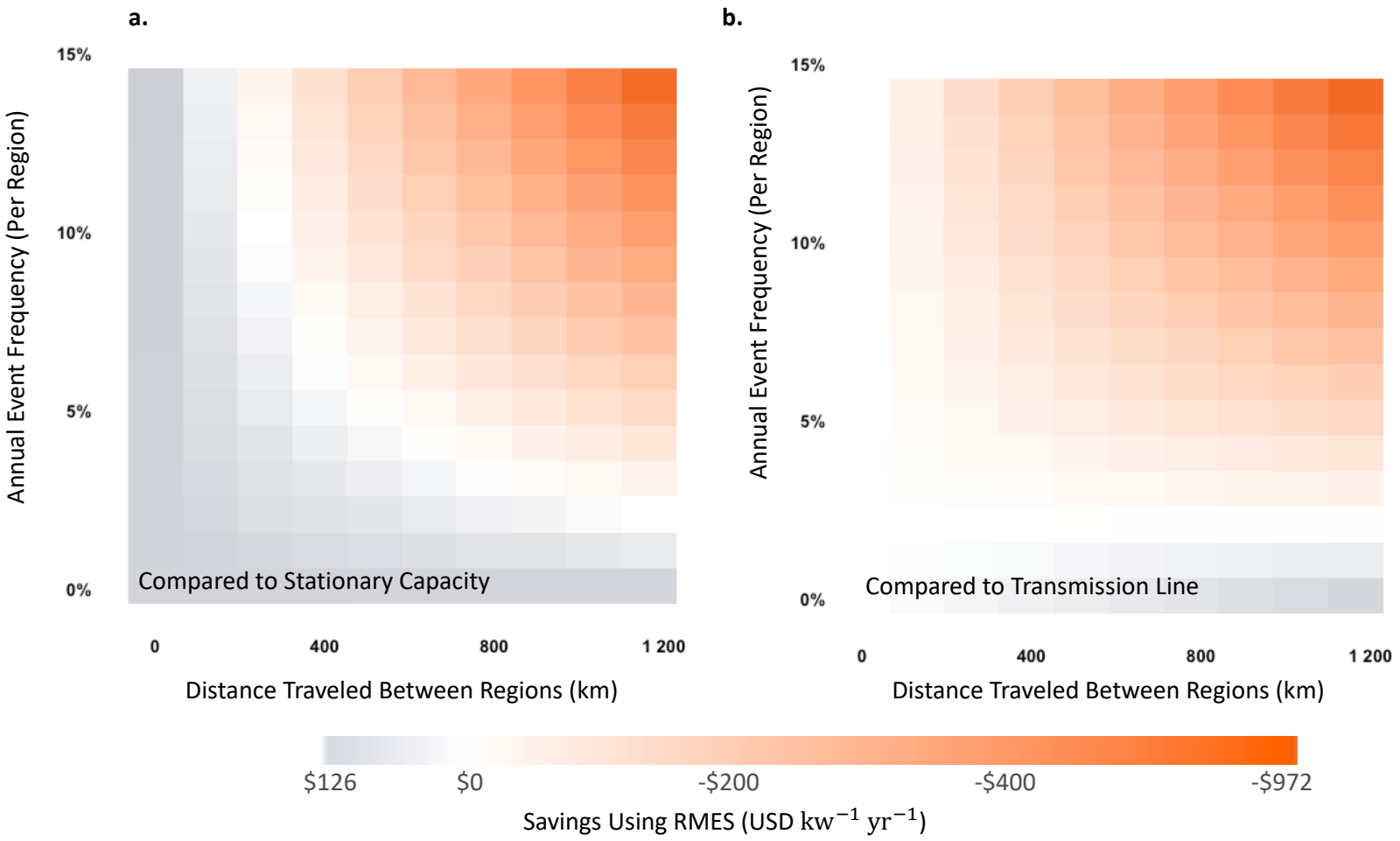
Utilizing the existing rail network to transmit power between regions avoids the expense and politically/logistically challenges of transmission investments

Current Approach

Proposed Approach

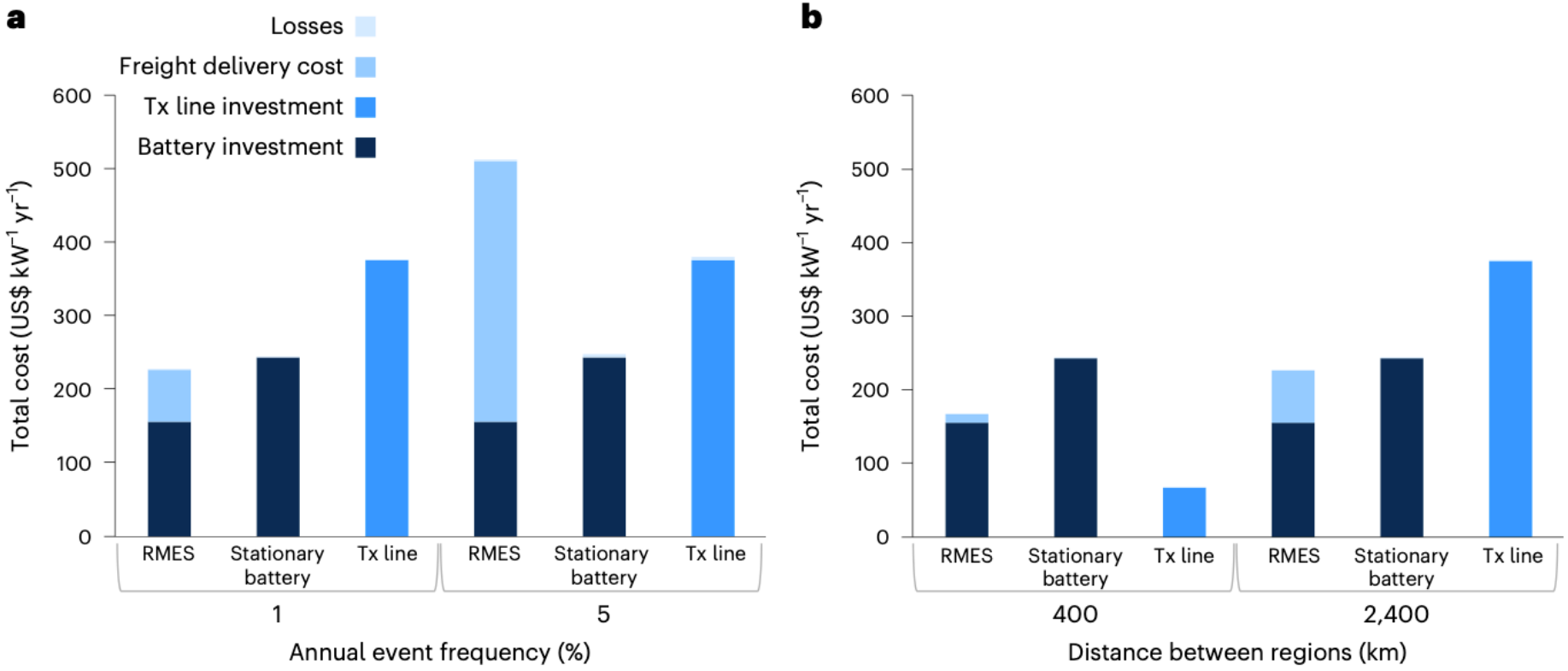
RESULTS

Benefits of RMES



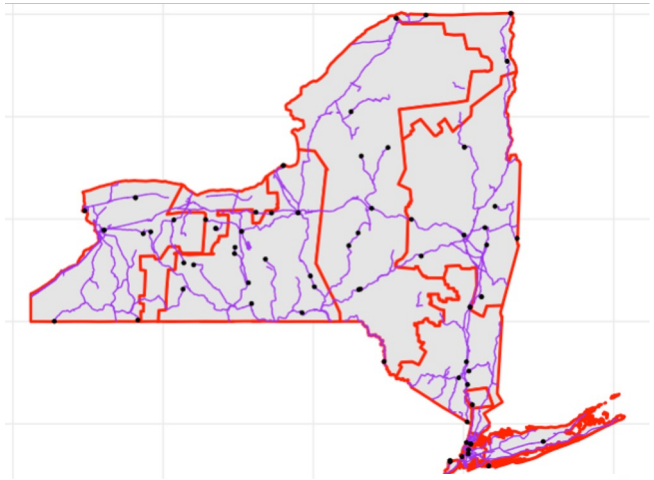
RESULTS

Cost Breakdown

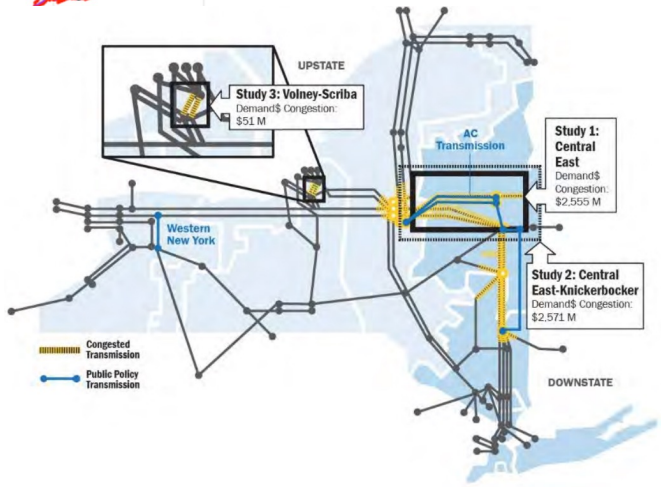


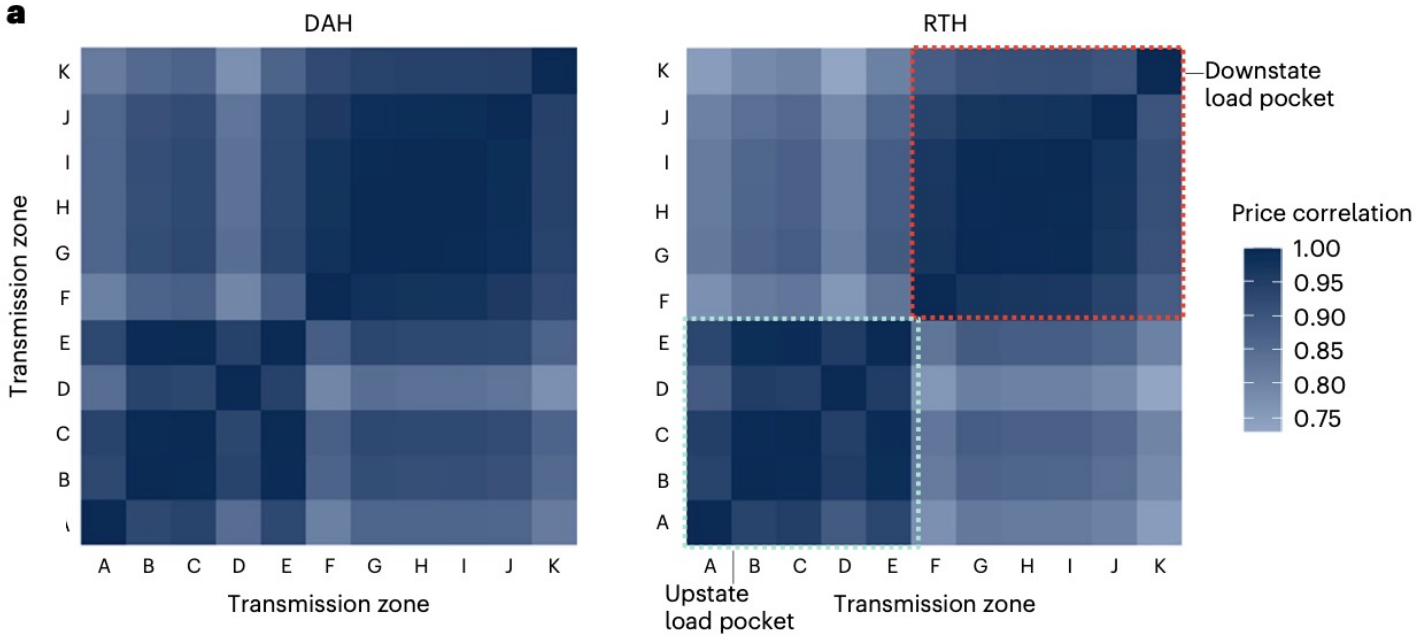
Transmission-Constrained Capacity Zones

NYISO has historically overbuilt capacity in zones due to transmission constraints. Moving storage between zones could avoid this excess capacity buildout and renewable curtailment



Rail network in **purple**

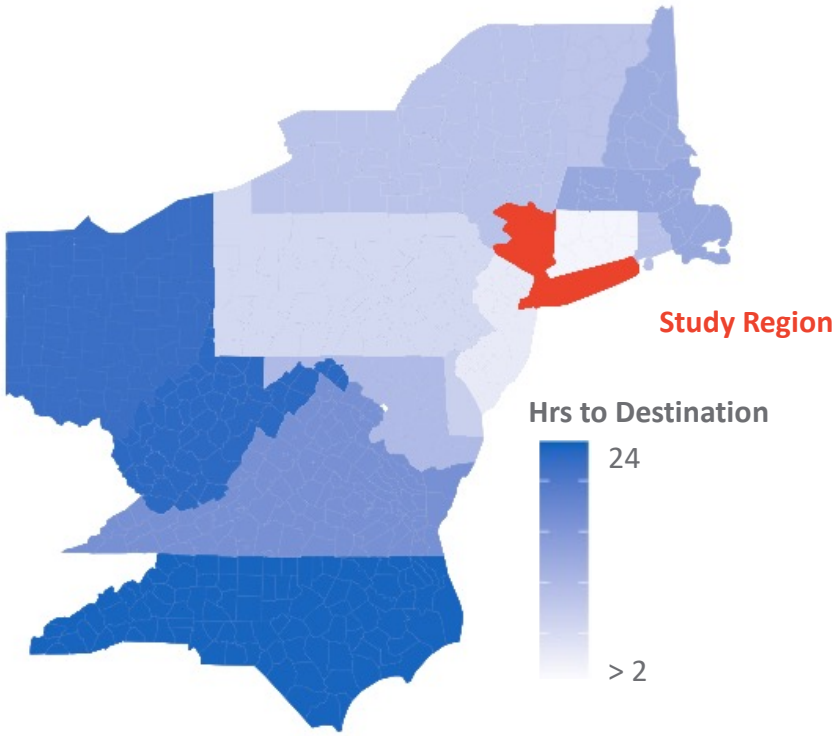




CASE STUDY: NYISO

NYISO's Grid Resilience Goals

Areas within 24-hour rail travel time to NYISO Zones G-K



1. **Interregional Coordination:** Significant access to RMES in other states within a 24 hours, allowing for interregional asset sharing during times of acute stress

2. **Transmission Investment for Resource Diversification:** Intra- and interstate RMES would increase diverse resource access at a lower cost

3. **Clean Supply in Load Centers:** RMES would increase the load center access to clean electricity supply without expensive transmission investments or dedicated supply within city limits

Questions?

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APPENDIX

Electrification of Freight Shipping with Containerized Batteries

Economic, environmental and grid-resilience benefits of converting diesel trains to battery-electric

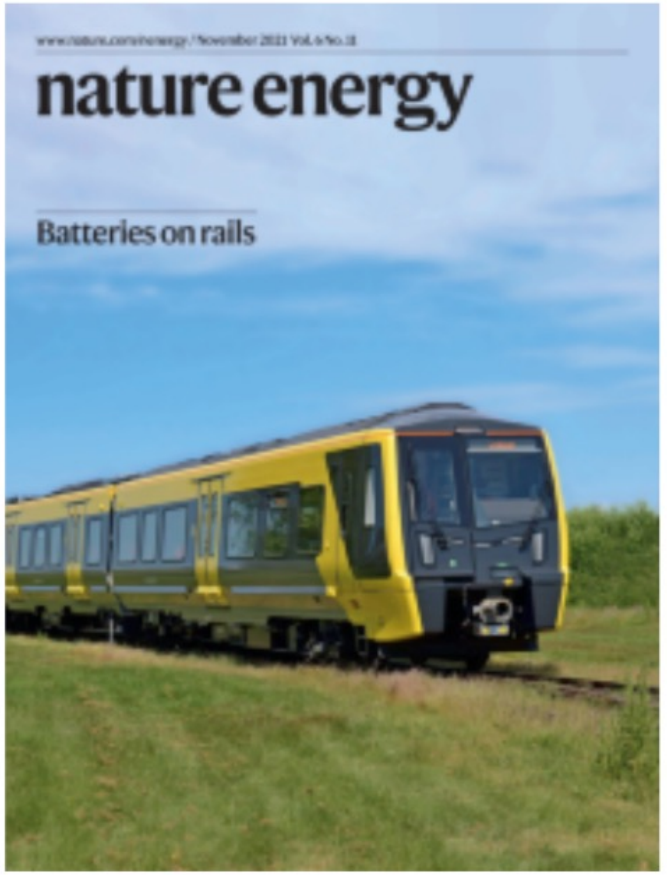
Natalie D. Popovich, Deepak Rajagopal, Elif Tasar & Amol Phadke

- Techno-economic feasibility of **retrofitting existing electric locomotives** with 9MWh battery tender cars
- Battery-electric tender cars are **cost-competitive with diesel at $100/kWh battery prices** and industrial electricity tariffs

Rapid battery cost declines accelerate the prospects of all-electric interregional container shipping

Jessica Kersey, Natalie D. Popovich & Amol A. Phadke

- Techno-economic feasibility of **containership battery electrification** for 104 unique scenarios
- **1,500 km range is electrifiable now**; 5,000 km range in near future



Industry battery-powered freight pilot projects are underway

United States

Union Pacific Railroad - $100 million investment in 20 battery electric locomotives; announced January 2022

Source: Union Pacific

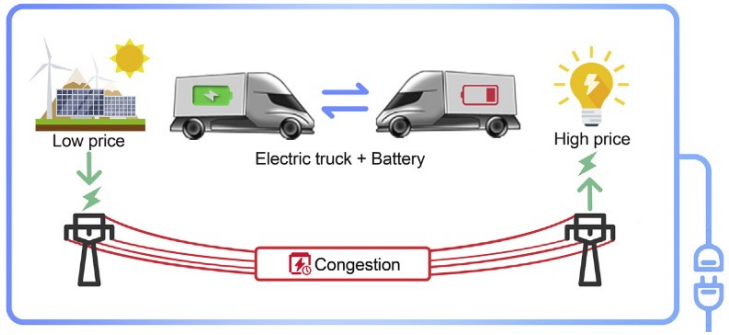
Internationally

- **Maersk** - 600 kWh container ship battery for hybrid operation; sails between west Africa and east Asia
- **Current Direct** - swappable container waterborne transport battery; funded by European Commission

Source: Wartsila, European Commission, Green Car Congress, 2022

APPENDIX

Other work on mobile energy storage



*He, G. et al. Utility-Scale Portable Energy Storage Systems. Joule **5**, 379–392 (2021)*

Assessment of curtailed wind energy potential for off-grid applications through mobile battery storage

Muhammad Bilal Siddique , Jagruti Thakur *

Operational flexibility enhancements using mobile energy storage in day-ahead electricity market by game-theoretic approach

Zhijun Qin [a], Yuhong Mo [a], Hui Liu [a], Yihui Zhang [b]

Existing Studies:

Focus on **LMP arbitrage and operational flexibility**

Mostly limited to **on-road methods** of transport (passenger vehicles, trucks, electric school buses) which are **constrained in weight-carrying capacity**

Local scale, not addressing **systemic reliability challenges at the national scale**