



Sustainable energy in Superior, WI

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01

Community Overview

Community Overview- Natural Resources

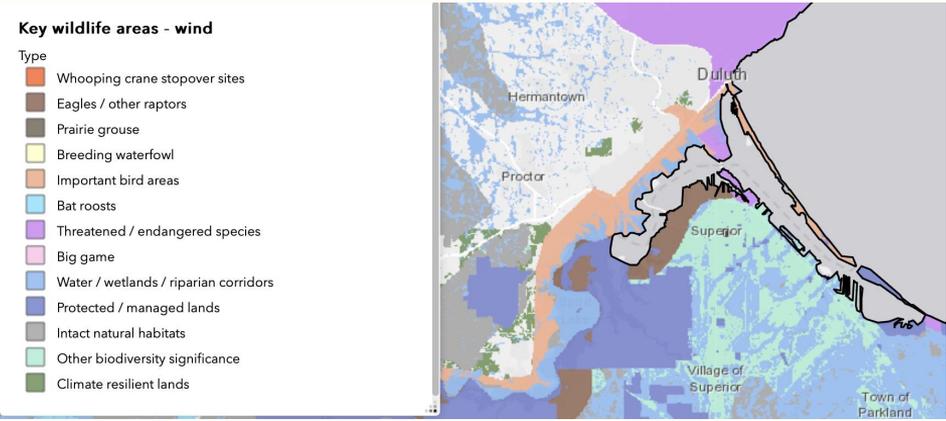
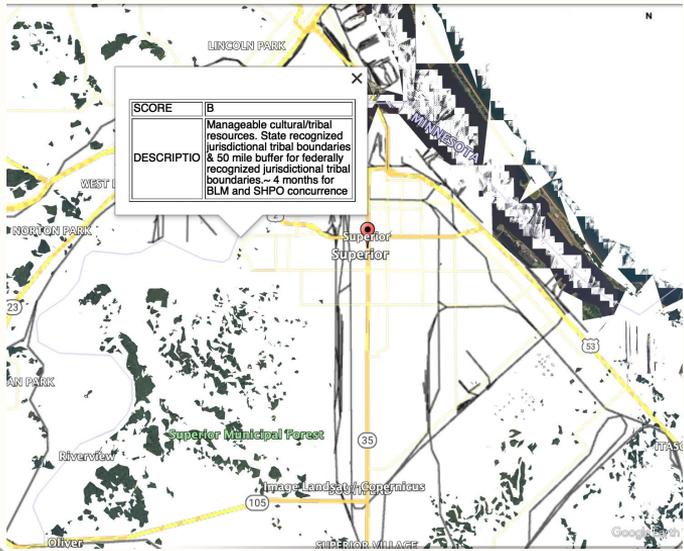


- Wetlands
- Forests



- Lake Superior
- St Louis River Estuary

Community Overview- Protected Areas





02

Energy Supply Portfolio

Current Renewables

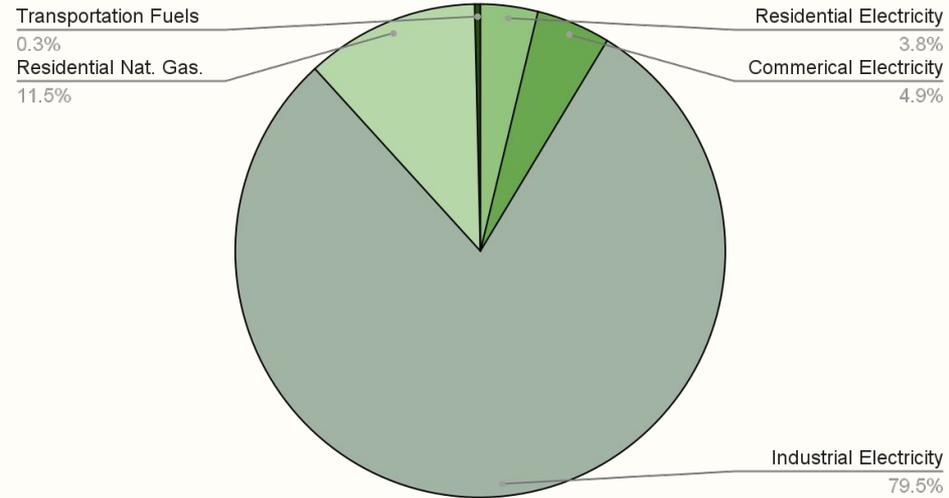
- **Solar Garden**
 - **Opened 2023**
 - **Powers 121 homes**
 - **Energy data not published**



Energy Demand

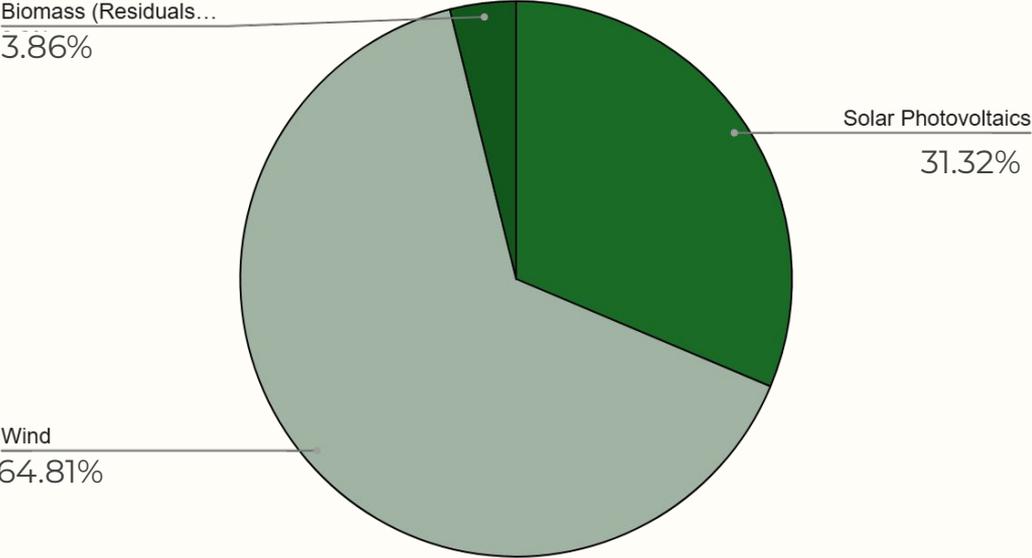
- 2016 City Energy Profile,
 - Includes equivalent electricity for transportation fuels and residential natural gas.
 - 20% increase for growth.

Energy Demand by Source



* Not included, Commercial and Industrial Natural Gas

Percentage of Total Energy Generated per Source.



Renewable Source	Annual Energy (MWh) from Source
Solar PV	751,877
Wind	1,555,745
Biomass	92,767.14
Total Energy Demand (MWh)	2,354,806
Total Energy Produced (MWh)	2,400,389



Renewable Source #1: Solar Photovoltaics

- Relative moderate global irradiance.
 - Under ideal tilt conditions.
- Available pre-cleared agricultural & unused land.
- Potential for Bifacial Panels.
- Accounts for 31.32% of Energy Production.
 - Annual Energy Production of 751,877 MWh.
- Max Power of 550 MW.

- Footprint:
289.47 Hectare

- LCOE (\$/kWh):
0.0897



Renewable Source #2: Offshore Wind

- Moderate wind speeds at 100 meters offshore.
- Available space in Lake Superior.
- Utilizes Senvion 6.2M152 offshore turbine.
 - Turbine Power Curve
- Accounts for 64.81% of Energy Production.
 - Annual Energy Production of 1,555,745 MWh.
- Max Power of 615 MW.

- Footprint:
12,100 Hectare

- LCOE (\$/kWh):
0.0747

- Turbine #:
100



Image from Wikimedia Commons.

Renewable Source #3: Biomass, Agricultural & Residual

- Available agricultural space.
- Considerable forestry residuals.
- Switchgrass for climate considerations.
 - Supplement forestry residuals.
- Accounts for 3.86% of Energy Production.
 - Annual Energy Production of 92,767.14 MWh.
- Max Power of 9.4 MW.

● Footprint (AG):
225.81 Hectare

● Footprint (Res):
N/A

● LCOE (\$/kWh):
0.1203

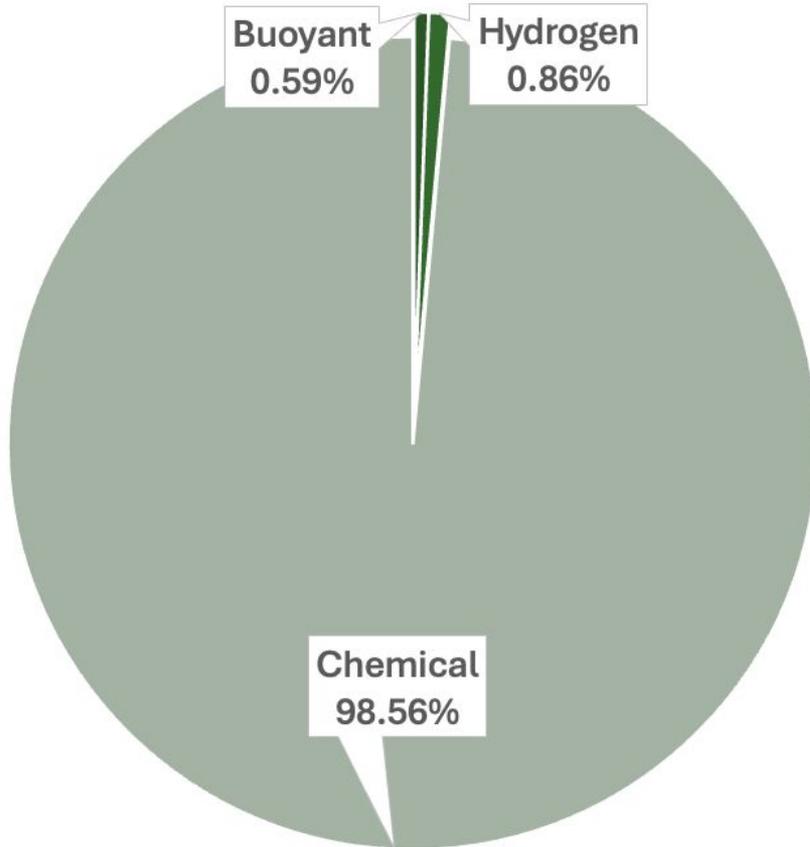




03

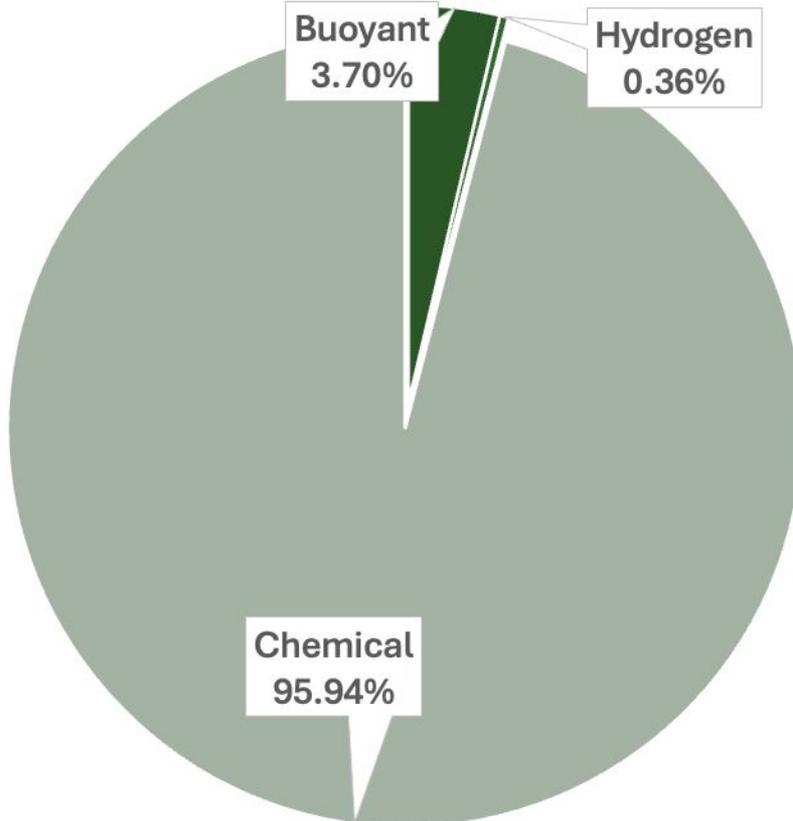
Energy Storage Portfolio

% of Required Energy Storage in MWh or 6 hours at 50% of Superior's Max Power Demand



Storage Type	Amount of Energy Stored (In MWh)
Buoyant	36.97 MWh
Hydrogen	54 MWh
Chemical	6,204.55 MWh
Minimum Storage Needed	1,008.05 MWh
Total Storage Provided	6,295.52 MWh

% of Required Power Storage in MW for 6 hours at 50% of Superior's Max Power Demand



Storage Type	Amount of Power Stored (In MW)
Buoyant	6.15 MW
Hydrogen	0.6 MW
Chemical	159.5 MW
Minimum Storage Needed	166.01 MW
Total Storage Provided	166.25 MW



Storage Source #1: Tesla Megapack Lithium Iron Phosphate Batteries

- 5 unit of 2-hour Megapacks
 - 2.6 MW of Power, 19.3 MWh of Energy
- 5 units of 4-hour Megapacks
 - 4.9 MW of Power, 19.6 MWh of Energy



**Combined to create
one unit for our purposes**

- Footprint: 0.196 ha

- Array of 55 battery units
- Total stored energy: 38.9MWh (14.5 MW for 6 hours)

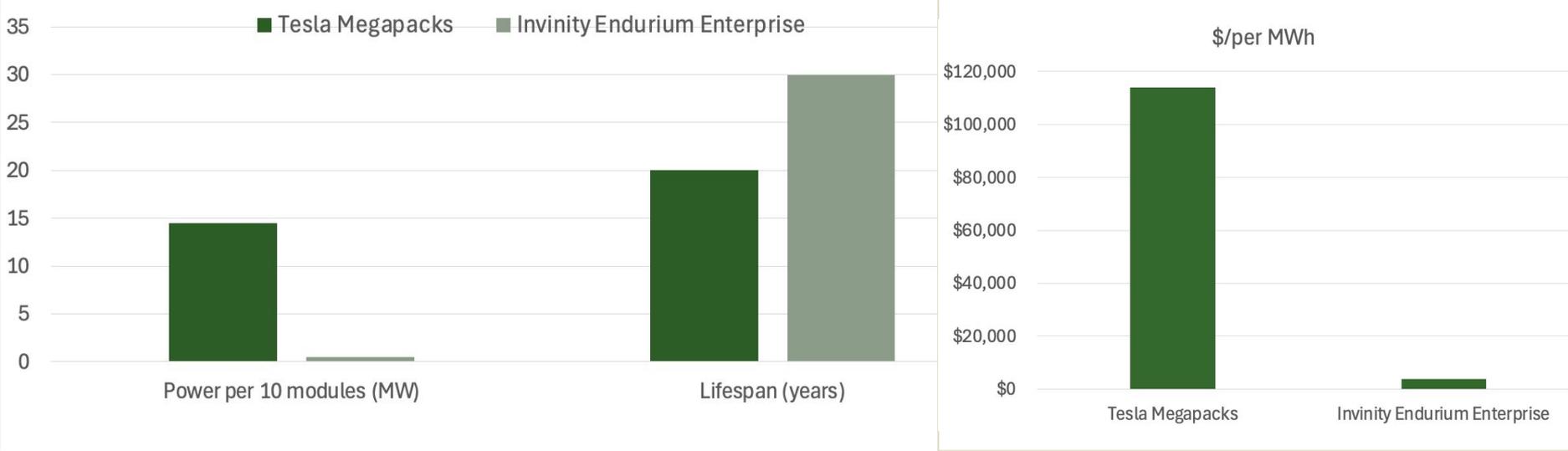
- Cost per unit: \$9,579,650
- Installation: ~150,000



Benefits of Lithium Iron Phosphate Batteries

- greater safety measures,
- long and low maintenance lifespan,
- significantly greater power output

Comparison of Lifespan, Cost per MWh, and Power Output Between Li+ Iron and Flow Batteries

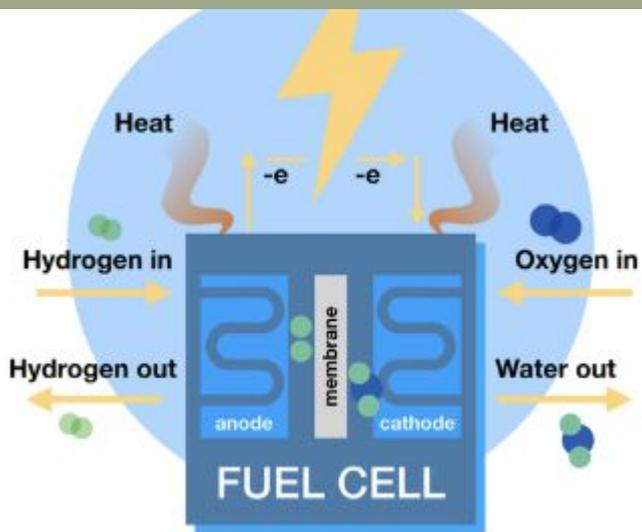


Storage Source #2: Hydrogen Storage

- Proton Exchange Membrane (PEM) fuel cell
- One facility runs for 6 hrs at 0.6MW, generating 3.6MWh
- Array of 15 facilities
- Total stored energy: 54 MWh (0.6 MW for 6 hours)

● Footprint: 27 ha

- Closed-loop system
 - Minimize water needs
 - Purer water input



paylesspower.com



Image by Daniel Megias via iStock

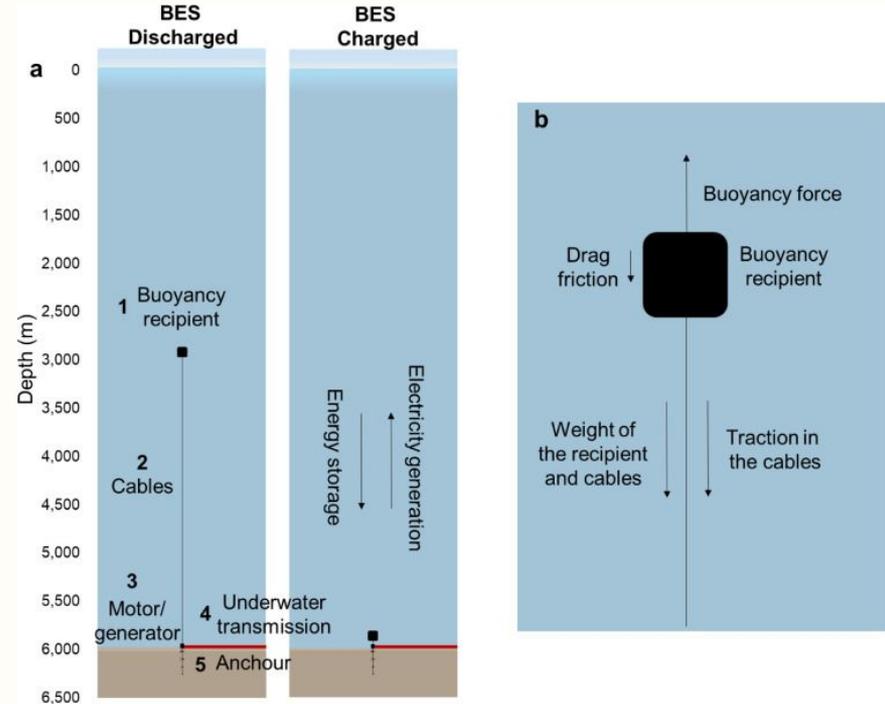
Storage Source #3: Buoyant Storage

- Solid Structure Gas Floats
- 300 floats, 240m³
- 230m depth available
- Site run for 6 hrs at 6.15MW, generating 36.97MWh

● Footprint: 12 ha



From “How the Ocean Could be the Future of Energy Storage” on Youtube



04

Impacts, Mitigation, & Safety

Wind Energy Concerns

Bird Migration

- Superior's critical location in the Mississippi Flyway



Mitigation



Turbines in Norway, May et. al, 2020

Solar Energy Concerns

Land Usage and Degradation



Mitigation

- Being mindful of Building locations, not on wetlands
- Using native plant cover in solar PV areas → combats land degradation and soil erosion
- Funding the placement of 50 Hectares of forestland to be conserved

Biomass Concerns

Air Quality

- Electrostatic Precipitators (ESP) help reduce emissions of fuels burning
- ESPs are over 99% effective for industrial-scale operations ([NIH.gov](https://www.nih.gov))



Img from Kingfisher Industrial Services, LTD.

Storage Concerns

Chemical Batteries

- Minimal concern

Solution

- 10ft Buffer zone

Buoyant Storage

- Shipping lanes
- Aquatic biodiversity

Solution

- Sound shielding tech

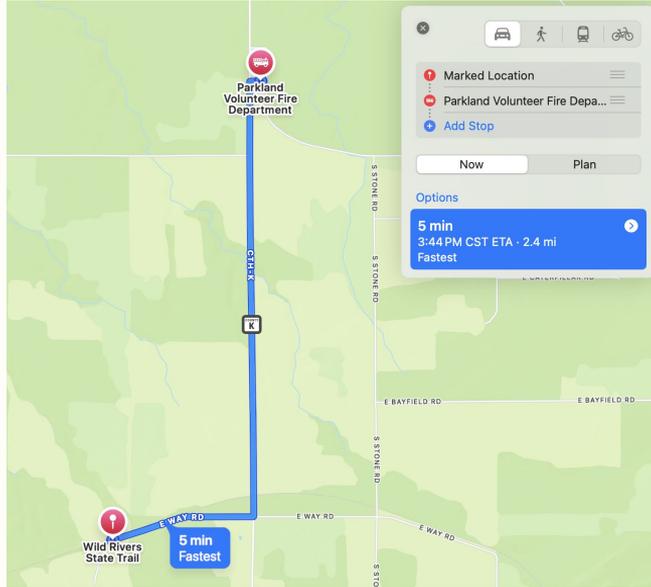
Hydrogen

- Water usage
- Combustible nature

Solution

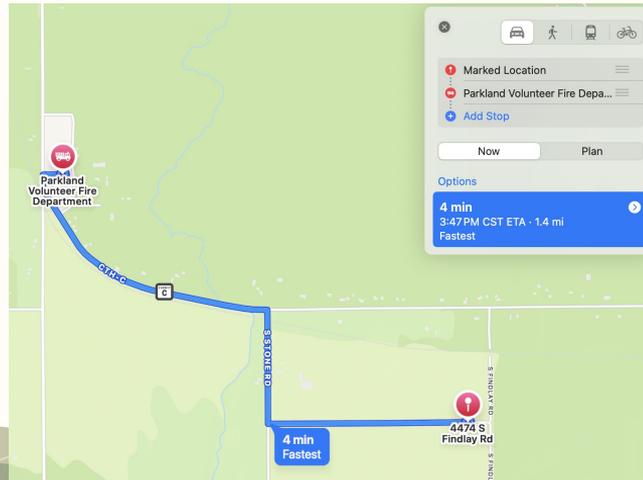
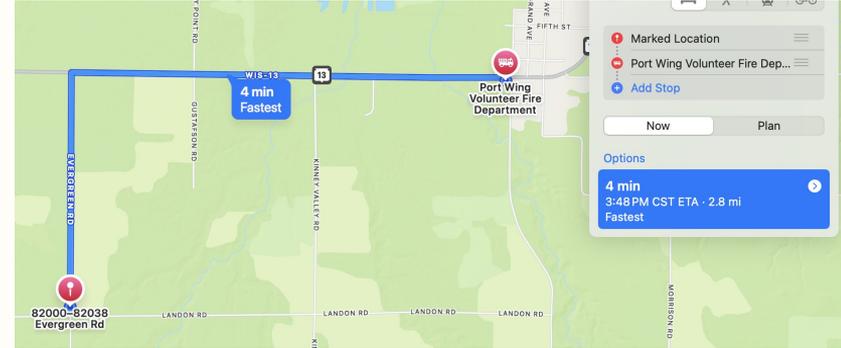
- 10ft Buffer zone
- Closed-loop system

Distance Between Storage Sites and Nearest Fire Department



Battery Site

Buoyant Offshore Site



Hydrogen Site



05

Conclusion

Images: SunEnergy1, wikimedia commons, [tesla.com/megapack](https://www.tesla.com/megapack) , Daniel Megias via istock, and “How the Ocean Could be the Future of Energy Storage” on Youtube

Just to review...



Thank you

Any questions?

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