Energy Storage to Decarbonize the Industrial Sector Through Direct Electrification

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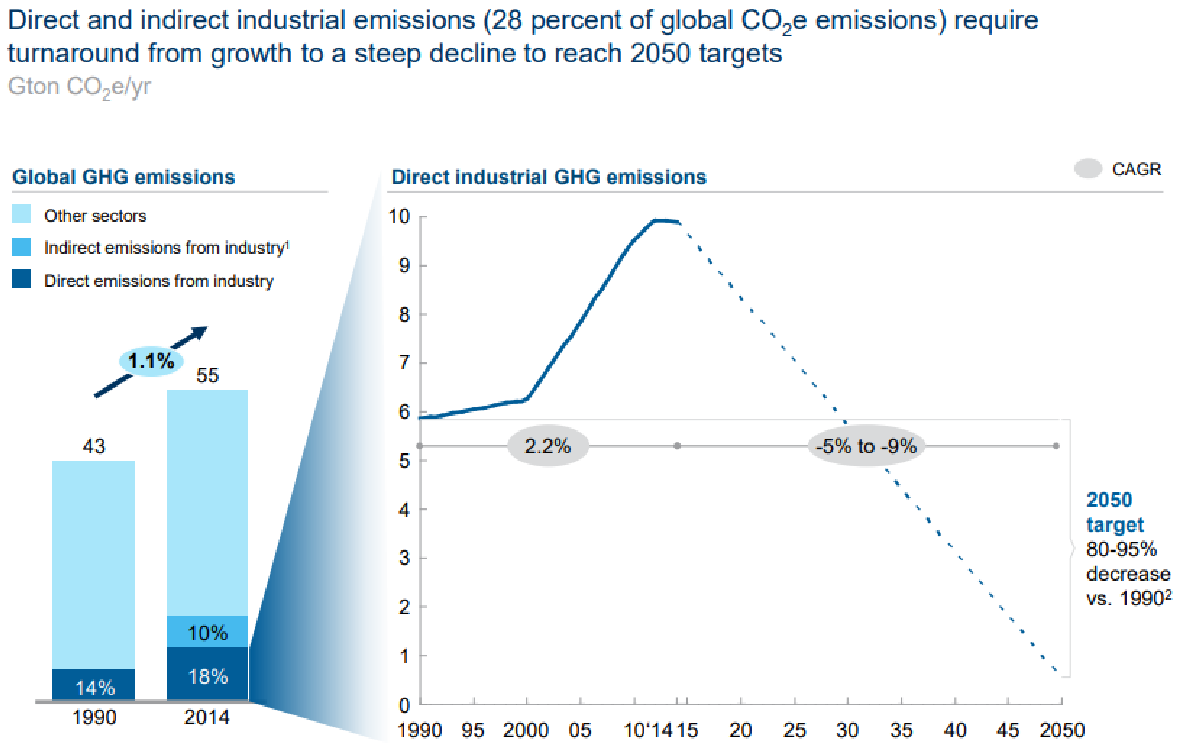
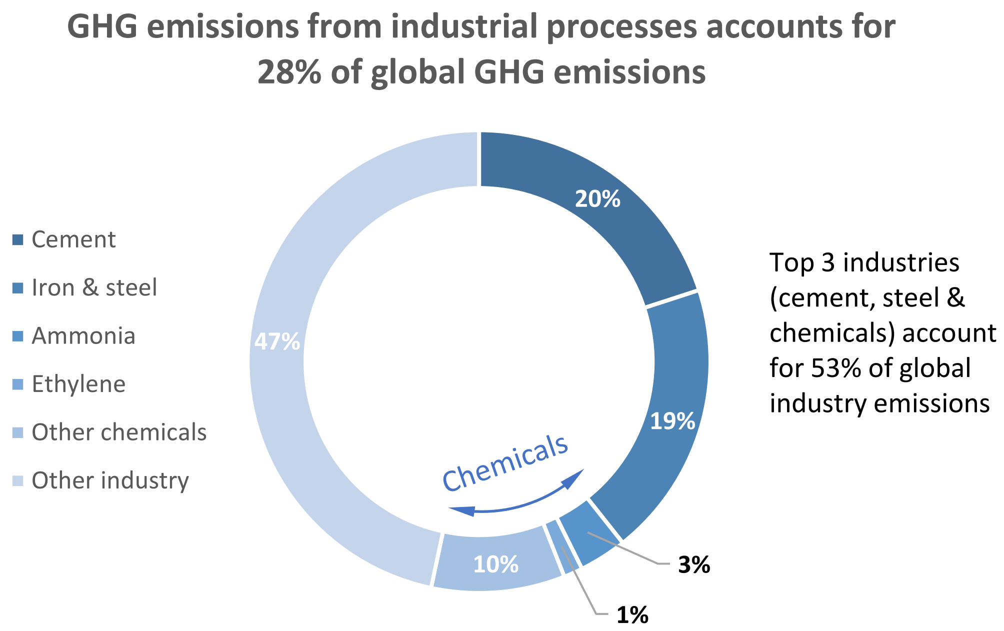
Current Status of the Industrial Sector's GHG emissions



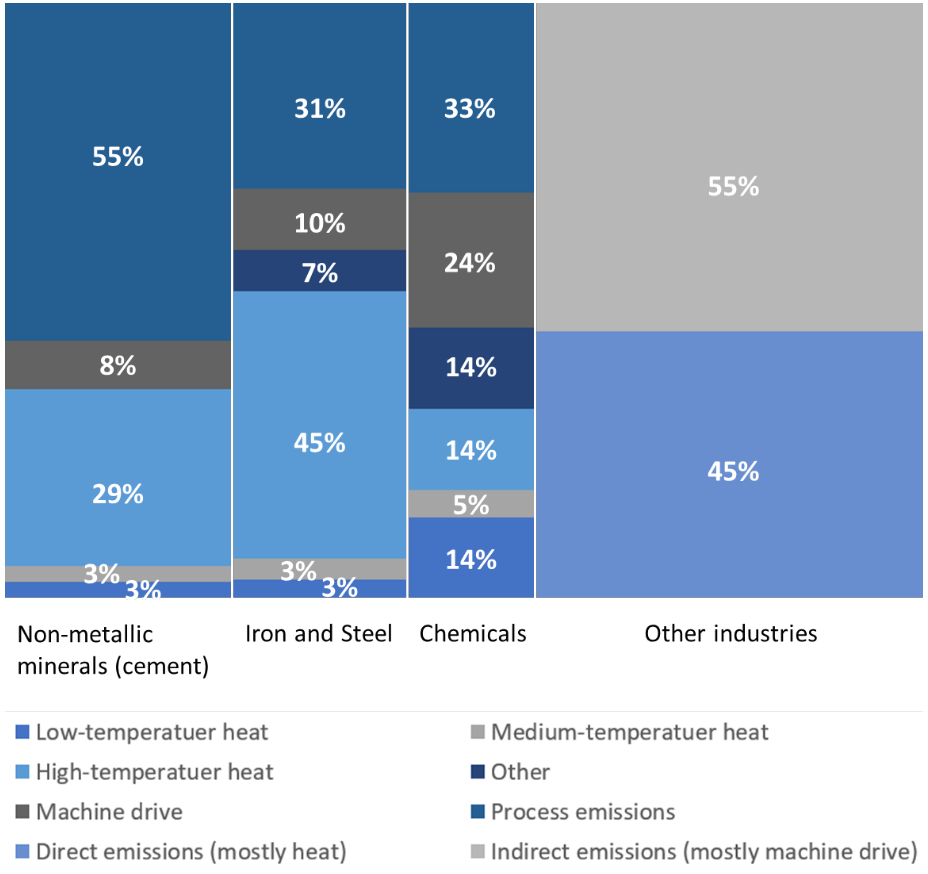


- Direct GHG emissions from industrial processes, along with indirect GHG emissions resulting from the generation of electricity used by industry, account for 28% of global GHG emissions
- Production of cement, steel, ammonia, and ethylene emitted 53% of total industry emissions (~15% of global emissions).

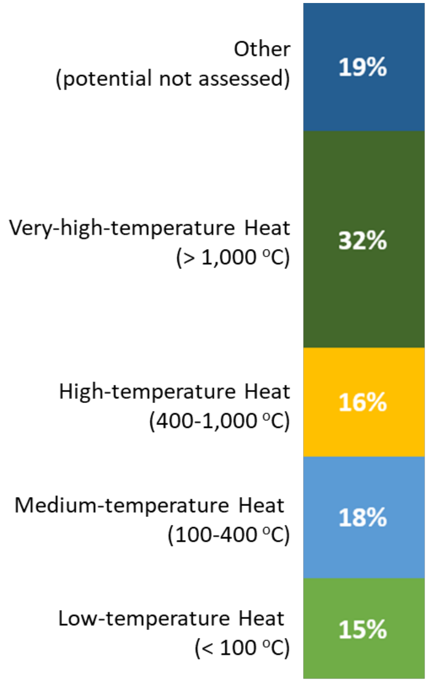
"Decarbonization of industrial sectors: the next frontier", McKinsey & Company, 2018

Options for Decarbonizing Industry: zero-carbon electricity for direct electrification

40% of emissions in industry are related to fuel combustion for heat.



Almost half of fuel consumed for energy can be electrified with technology available today.



	Examples of processes	Technology status
Very-high-temperature Heat (> 1,000 °C)	Melting in glass furnace, reheating of slab in hot strip mill, and calcination of limestone for cement production	Research or pilot phase
High-temperature Heat (400-1,000 °C)	Steam reforming and cracking in the petrochemical industry	Available today
Medium-temperature Heat (100-400 °C)	Drying, evaporation, distillation, and activation	Available today
Low-temperature Heat (< 100 °C)	Washing, rinsing, and food preparation	Available today

The price of electricity must be below $70/MWh to make a complete switch from fossil fuel to make electricity economical.

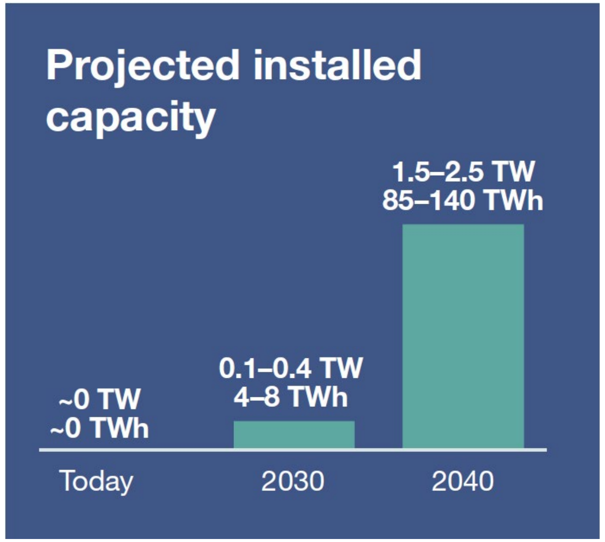
"Plugging in: What electrification can do for industry", McKinsey & Company, 2020
"Decarbonization of industrial sectors: the next frontier", McKinsey & Company, 2018

Long duration energy storage (LDES) for zero-carbon electricity

LDES can play a crucial role in addressing different flexibility duration needs for renewable energy.

Flexibility Duration Needs	Power System Challenges Addressed
Intraday Flexibility	Provide grid stability and peak shifting
Multiday and multiweek flexibility	Address multi-day imbalances and grid congestion
Seasonal flexibility	Address natural variability of solar, wind and extreme weather events

Li-ion batteries are only economically competitive for storage duration < 4 h. With increasing renewable energy shares in the power mix, the need for 8-12h flexibility is projected to grow and become a significant market for LDES technologies.



LDES has the potential to deploy 85 to 140 TWh by 2040 and store up to 10% of all electricity consumed. By 2040, LDES deployment could result in the avoidance of 1.5 to 2.3 Gt of CO_2 equivalent per year.

"Net-zero power: Long duration energy storage for a renewable grid", LDES Council, McKinsey & Company, 2021

UEP Energy Storage System

Sustainable

- Aqueous zinc manganese dioxide technology
- Recyclable
- Non-flammable and non-toxic

Superior

- Long cycle life
- High temperature capability

Scalable

- Safe for indoor applications
- Manufacturing operations in US & India

Abundant

- Established supply chain available on every continent
- Ultra low-cost raw materials
- $20M/GWh in factory capex

UEP Gen 1 Cell
4.1” (D) x 7.63” (H)

UEP 4D Module
8.5” (W) x 8.5” (H) x 21.5”(D)
10 cells, traditional in size to lead acid at half the weight.

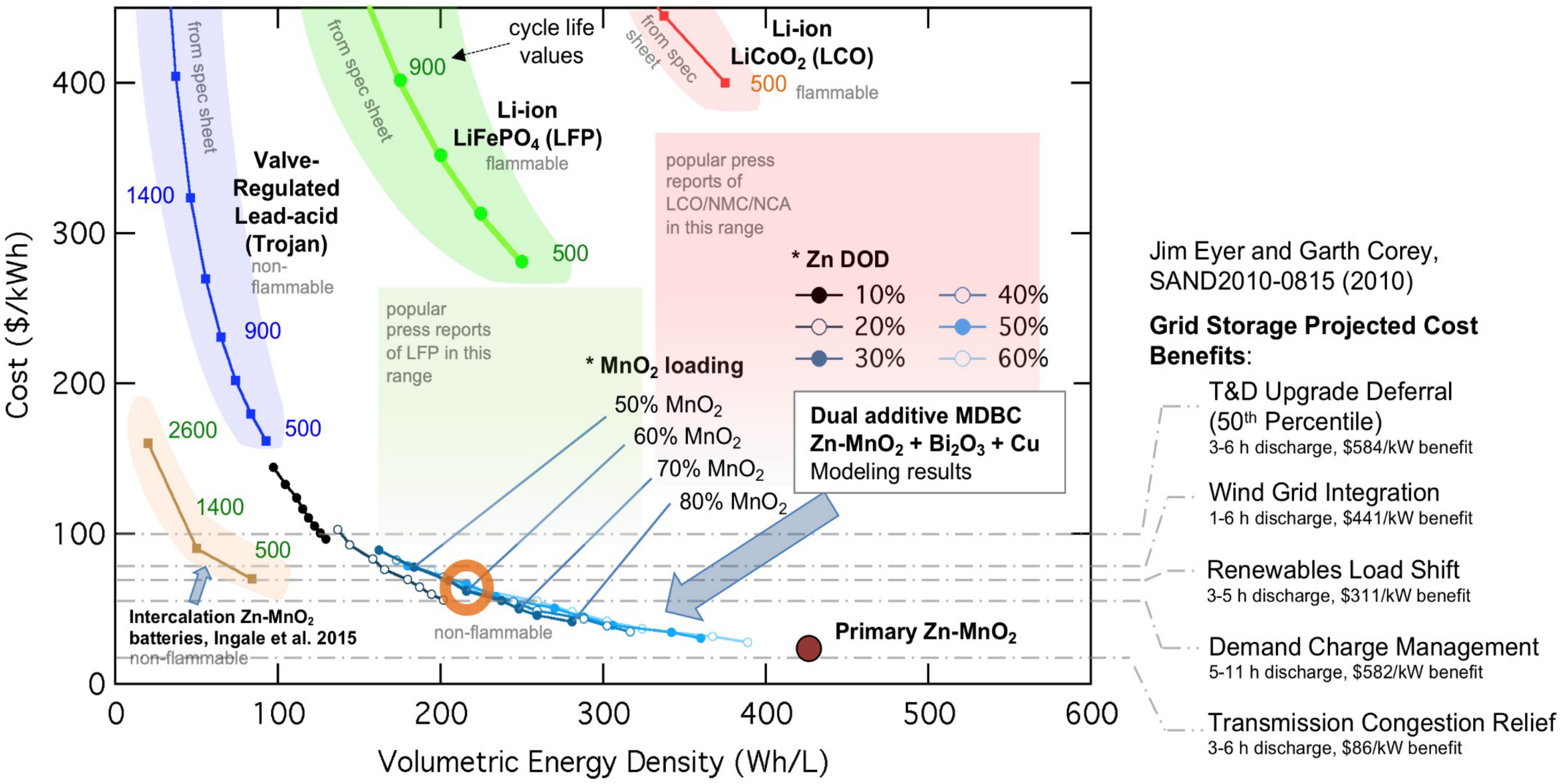
UEP Standard 4D Battery Cabinet
55” (W) x 82” (H) x 28” (D)
40 4D modules fit into a standard battery cabinet.

ZEUS Energy Storage System

- Flexible design for large commercial and utility scale projects
- Modular inverter allowing integration with solar PV for DC coupling
- Configurable for 2-24 h charge/discharge cycles
- ZEUS container is modularized for small or large indoor/outdoor installations
- Unit Dimensions: W 23’5” x D (6’5”) x H (8’3”)

Backup Duration	AC Power / Energy Available per ZEUS
24 Hour Standard	188 kW / 4,500 kWh
5 Hour Standard	750 kW / 3,750 kWh
2 Hour Standard	1,000 kW/ 2,000 kWh

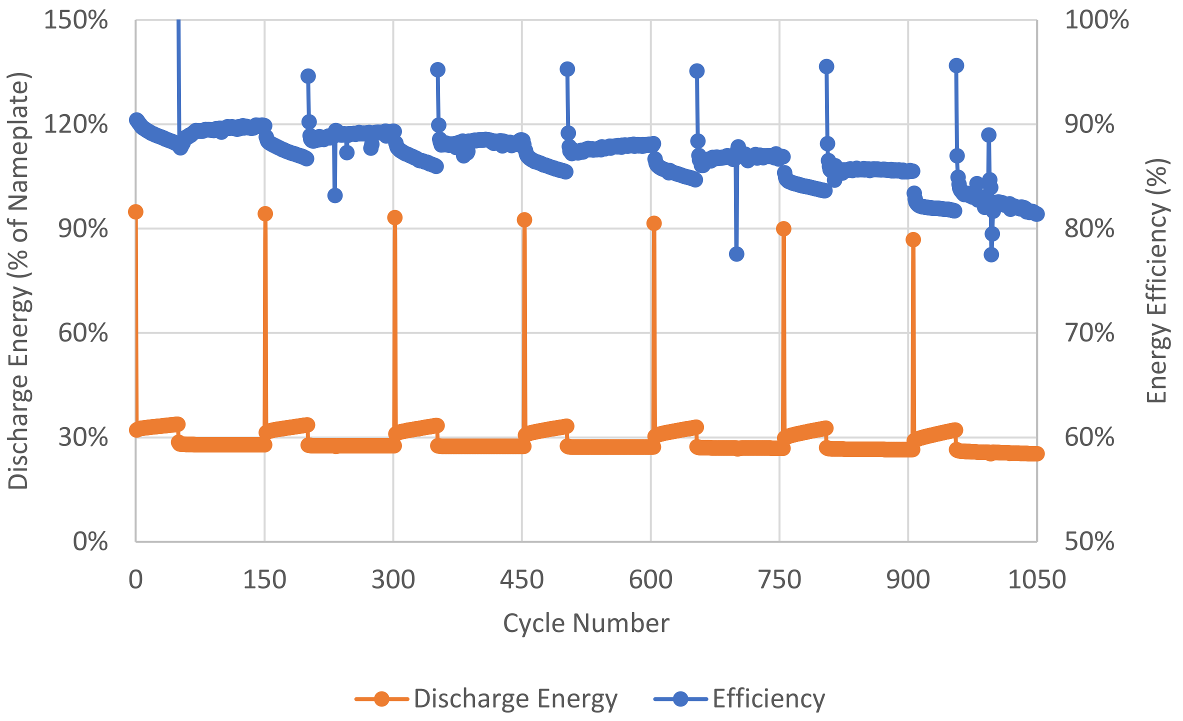
Cost Reduction Trajectory for UEP Zn-MnO_2 Grid Batteries

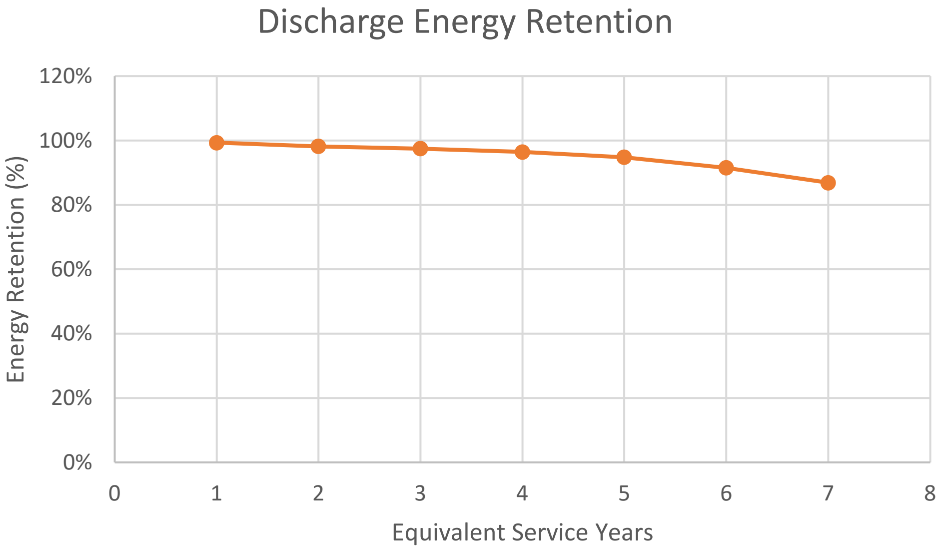


*Turney; Yadav; **Gallaway**; et al, "Aqueous Mn-Zn and Ni-Zn Batteries for Sustainable Energy Storage." in Energy-Sustainable Advanced Materials, **2021**.*

UEP Battery Cycles for 7 years & Counting:

Solar Microgrid IEC 61427-1 Cycling Protocol Data





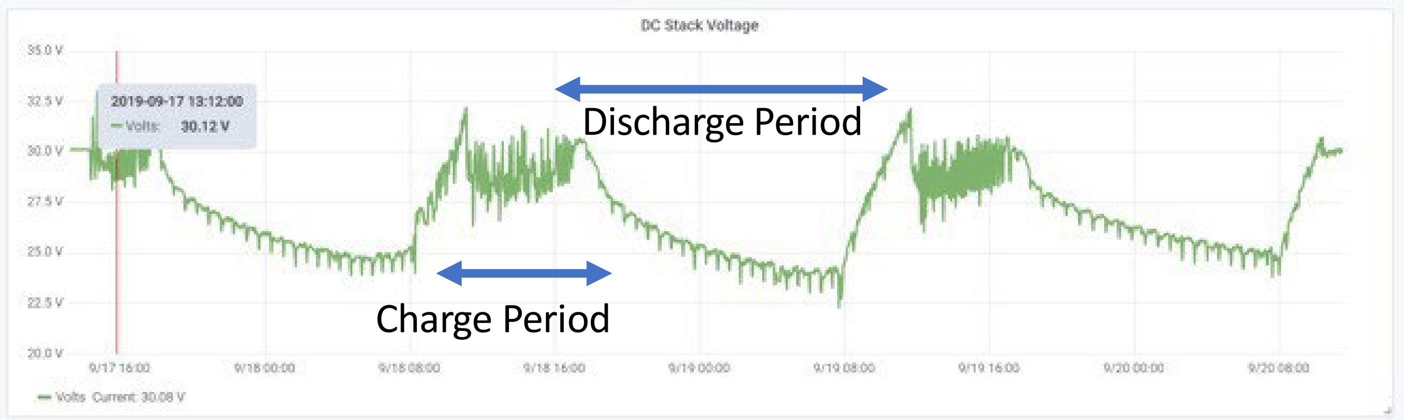
Note: Battery is still cycling in the 8th year under IEC 61427-1 protocol.

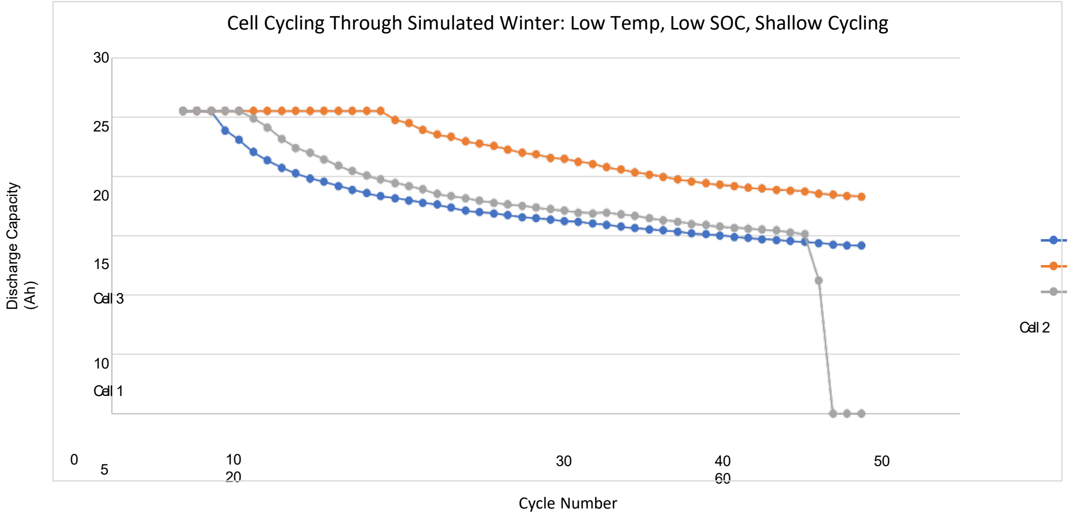
- IEC 61427-1 protocol is an accelerated simulation in extreme conditions for secondary batteries in photovoltaic applications.
- Test Protocol is in 2 Successive Phases at 40 °C:
  - Phase A: 3h C/10 charge and 3h C/10 discharge cycling at low state of charge for 50 cycles.
  - Phase B: 6h charge and 2h C/8 discharge cycling at high state of charge for 100 cycles.
  - If on completion of these two phases 80% of initial capacity is retained, then the battery is deemed to have completed a year of service in a solar microgrid successfully.

Navajo Tribal Utility Authority (NTUA) Solar Microgrid

Data on Cycling at -4°C

- 13 kWh solar microgrid system to be deployed in October 2021
- System uses a standard Outback inverter and seats on a self-contained pod





Top: System voltage test for 3 days. The system ran for 3 days paired with solar, charging when the sun was available and discharging during other times

Bottom: Cell testing at low temperature (-4°C) to simulate winter field conditions. Cells ran successfully through the testing period.