Behind-the-Meter Storage

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Partnership with the U. S. Department of Energy
Vehicle Technology Office, Buildings Technology
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of Electricity

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Reducing CO₂

Total U.S. Greenhouse Gas Emissions
by Economic Sector in 2018

Transportation (28.2 percent of 2018 greenhouse gas emissions)
– The transportation sector generates the largest share of greenhouse gas emissions.

<https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions>

No problem EVs are on there way

GM-ESTIMATED 350+MILE RANGE†
CHARGE NEARLY 100 MI. IN 10 MIN.†

<https://www.gmc.com/electric/hummer-ev>

Consequences of EV deployment

Source: California Energy Commission and NREL

What if California meets its EV targets – and we have not prepared

Not everyone can charge at work or at home
= no chance of owning an EV

One solution is the gas station equivalents.

So worst case in this example could be Multi MW power requirements

Time for major supply upgrade could include years of planning and permitting.

Demand charges could make this very expensive

Fast charging is a goal for all OEMs

VTO target (aggressive) ~ 200 miles in 10 minutes

Multi CCCV

Medium and Heavy Duty Vehicles make this worst

Behind-The-Meter Storage (BTMS)

Low TRL Work Guided by System Level Thinking.

- Focus on specific end user outcomes
- Minimize cost of energy to user
- Buildings are the largest electrical users.
- EVs will be charged at buildings.
- Demand charges need to be eliminated.
- Grid impacts minimized.
- Integration of PV is/will be common.
- Both electrons and heat need to be stored.
- New batteries are needed
- New thermal storage are needed

A partnership with the Buildings, Solar, and Vehicles Offices

BTMS: Basic Premises

- **Technologically agnostic** in the approach to storage systems (both electrochemical and thermal storage).
- **EV Charging will occur at buildings.**
- All low TRL research will be guided by the system requirements.
- **Non-critical materials will be a foundation.**
- Current targets for vehicles will not lead to batteries that meet long-term storage requirements.
- Thermal storage and management will enable optimizing energy efficiency and minimizing cost in buildings applications.
- **System safety is critical in a building environment.**
- Testing of new materials in full systems will be the metric for success (safety, lifetime, energy density, and cost).
- This project takes advantage of the major investment the **VTO** Battery program has made in infrastructure, capabilities, and materials development coupled with the **BTO's** investments in thermal management and storage.
- Ongoing and integrated cost analysis will be essential to success.

Analysis Process

Key Question

What are the **optimal** system designs and energy flows for **thermal** and **electrochemical** behind-the-meter-storage with on-site **PV** generation enabling **fast EV charging** if we vary climate, building type, and utility rate structure?

Optimize System Sizing to Minimize Cost: PV + SB + EV + TES

- Solar photovoltaic (PV)
- Stationary battery (SB)
- Thermal energy storage (TES)

Materials Choices

Electrical Energy Storage

What do we need?

- Cost - upfront vs total cost
- Performance
- Lifetime
- Safety

Systems under evaluation

- Lithium ion various
- Lead Acid
- Nickel Zinc
- Nickel Metal Hydride

Volumetric limitations preclude current flow battery systems

Vehicle batteries may not lead to the best outcome

Long life cell chemistries

LTO anodes

LMO//LTO Chemistry

$\text{Ni}_{0.9}\text{Mn}_{0.1}$ (1.0 M LiPF_6 in EC)

$\text{Ni}_{0.9}\text{Mn}_{0.05}\text{Co}_{0.05}$ (1.0 M LiPF_6 in EC)

LMR-NM Materials

Cell Design

Effect of thickness on LTO utilization

- Capacity utilization (delithiation) as a function of electrode thickness under various delithiation rates for LTO versus Li metal in coin cells (Gen2 electrolyte, 30 °C, 1.0 to 2.0 V).

Cell Testing

Test Protocols for BTMS Cycle Life Target

- The BTMS Cycle Life Testing Protocol tests a battery designed to provide peak shaving for 24 10-minute fast charges at peak station power each day
- This yields 2 cycles/day
 - The two illustrated scenarios show the extreme cases of vehicle arrival that can utilize maximum battery capacity over 24 hours

Cycle Life Target	Calendar Life Target
10,000 Cycles	20 Years

Rack Design

Enabling Technologies for Advanced Rack Design

- Need to address the hazards associated with lithium-ion batteries used in stationary applications for BTMS to become a reality.
- BTMS program is assuming that existing and future quality control measures at battery manufacturing facilities will not eliminate all single cell thermal runaway events.
- We are developing a strategy to enable a fail-safe rack design over a three-year period. “Fail-safe” is defined as preventing cell to cell propagation in a best-case scenario and preventing rack to rack propagation in a worst-case scenario.

Thermal Storage

Thermal Storage Materials Research

nature
energy

ARTICLES

<https://doi.org/10.1038/s41560-021-00778-w>

Check for updates

Rate capability and Ragone plots for phase change thermal energy storage

Jason Woods , Allison Mahvi , Anurag Goyal , Eric Kozubal , Adewale Odukamaiya and Roderick Jackson

Fig. 5 | Effect of PCM thickness on Ragone curves for two thermal conductivities. Specific power and energy are shown for thicknesses (th) between 1.75 and 7 cm. **a**, $1 \text{ W m}^{-1} \text{ K}^{-1}$. **b**, $10 \text{ W m}^{-1} \text{ K}^{-1}$. All other thermophysical properties, including the latent heat, are kept the same. The lines are shown as guides for the eye between the evaluated C-rates. To access the full capacity of the system, the thickness of the PCM is limited at high power rates and low thermal conductivities.

VTO-BTO Laboratory

Unique ARIES Resources

- 560kWh Thermal Storage
- 350kW+ Ev Chargers
- 40kWh Li-Ion Battery
- 30 Ton Chiller
- Building Controls
- 3 Commercial building simulators