



Behind-the-Meter Energy Storage

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Executive Committee Meeting

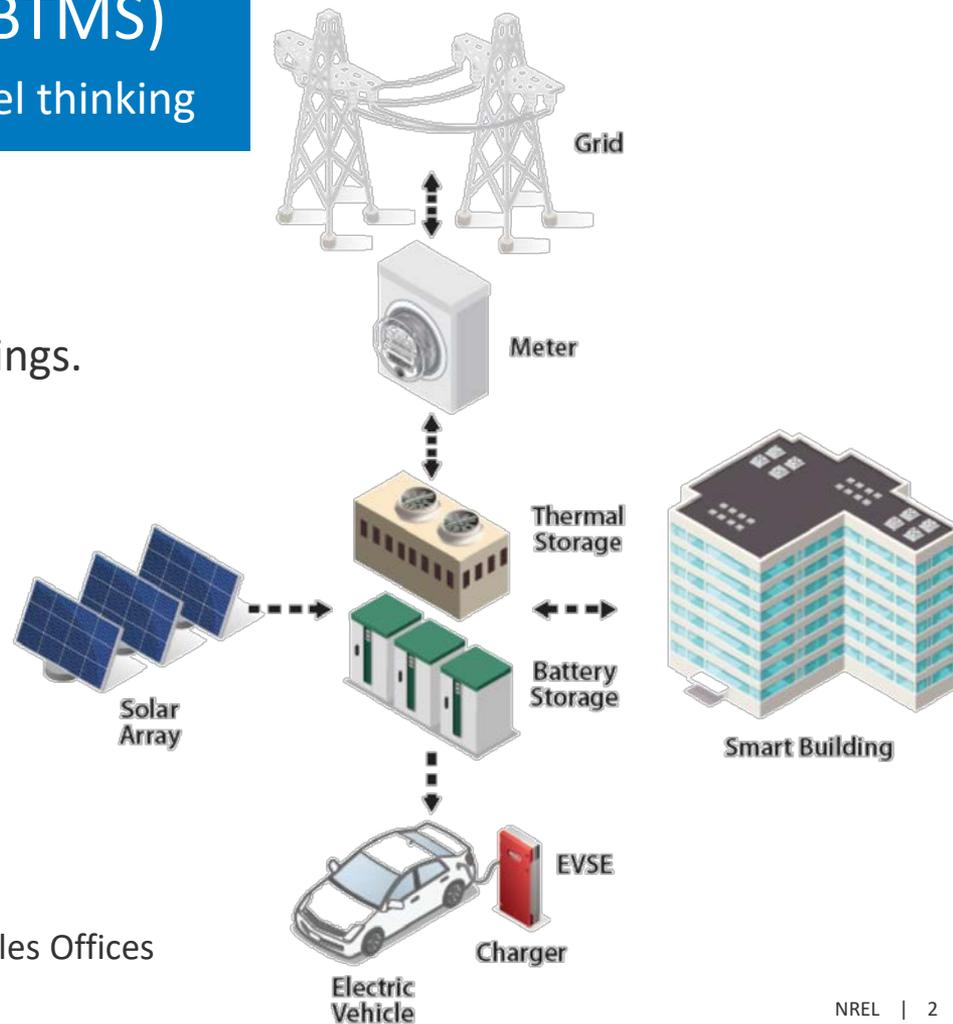
Behind-the-Meter Storage (BTMS)

Early-stage research guided by system-level thinking

- **Buildings** are largest electrical load.
- **Electric vehicles** will be charged at buildings.
- **Photovoltaics** will be everywhere.

To mitigate the impact of these trends on the electric grid, we need flexibility:

- More intelligent controls
- **Thermal energy storage**
- **Electrochemical energy storage**



A partnership between the DOE Buildings, Solar, and Vehicles Offices

Why Storage?

To minimize the impact on building occupants—comfort, health, convenience, productivity—we need storage to allow us to decouple the time of energy demand from the time of energy generation.

Building Thermal Energy Storage



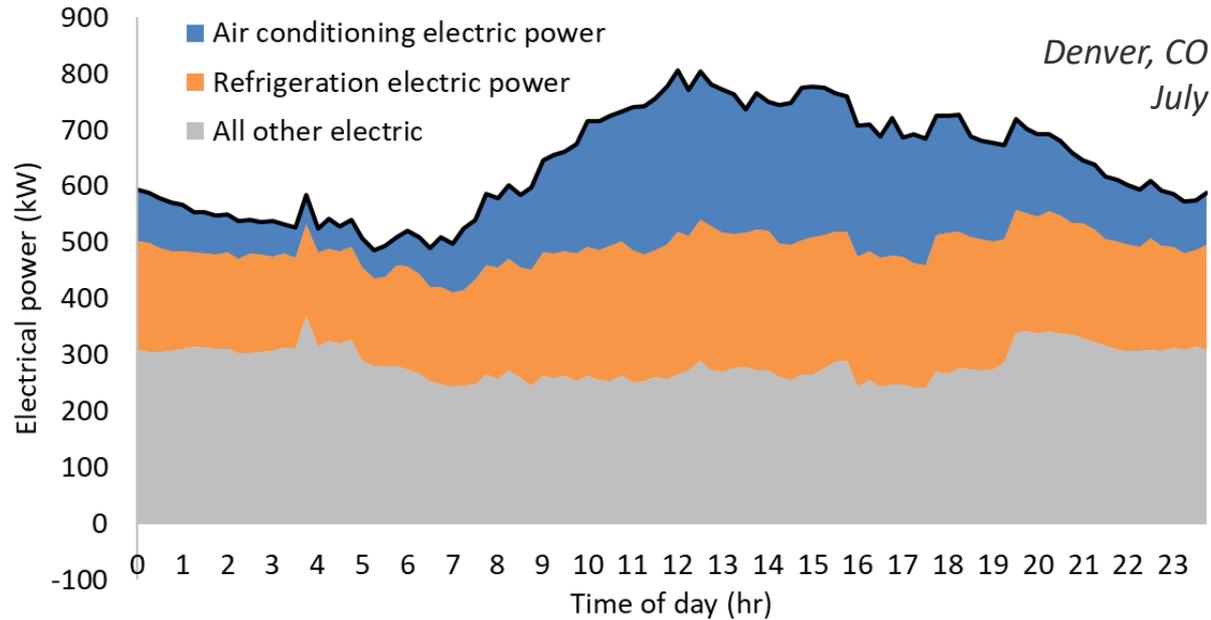
A 19th-century technology



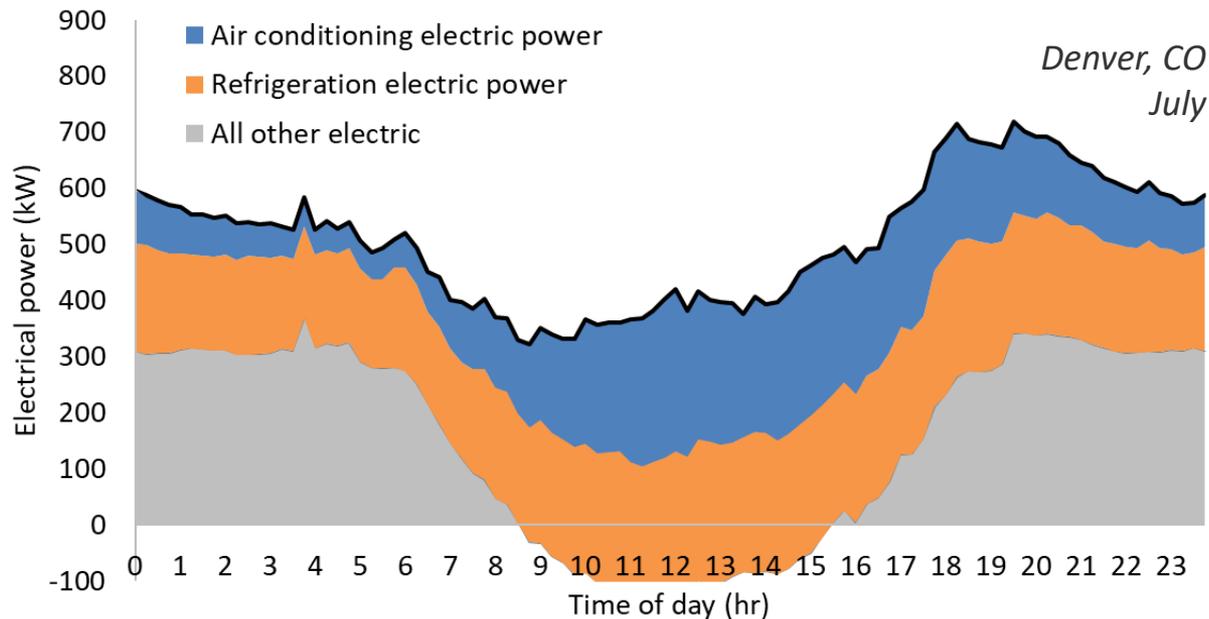
Adapted to the 20th century



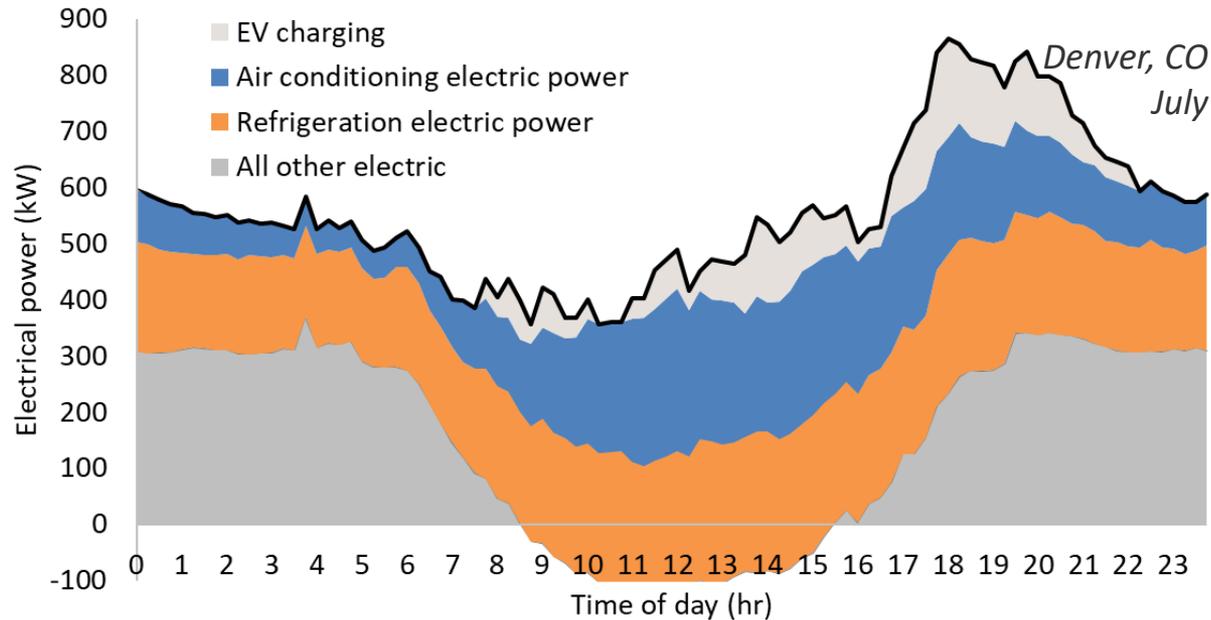
Typical Load of Grocery Retail Building



...with Behind-the-Meter Photovoltaics



...Add Behind-the-Meter EV Charging



Building Thermal Energy Storage



- Provides cooling



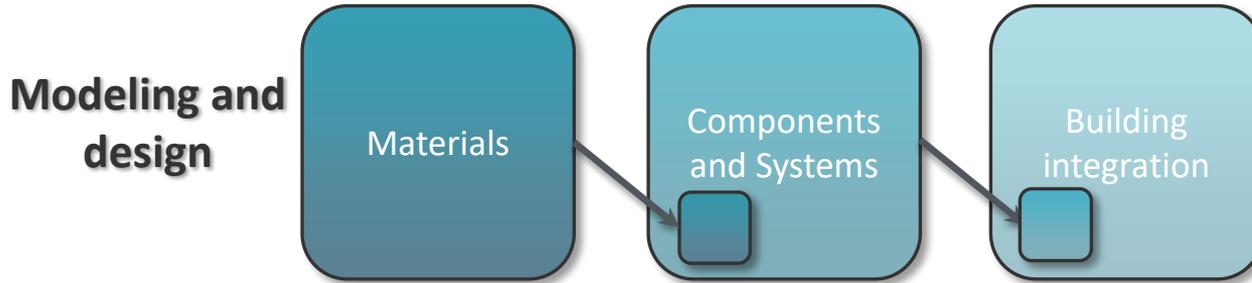
- Day to night load shifting
- Slow



- PV everywhere
- Electric vehicle charging
- Faster ramp rates
- Flexibility

***We need new approaches to adapt to the 21st century
- materials, integration, controls***

Connecting Research Scales: Materials to Systems to Building Integration



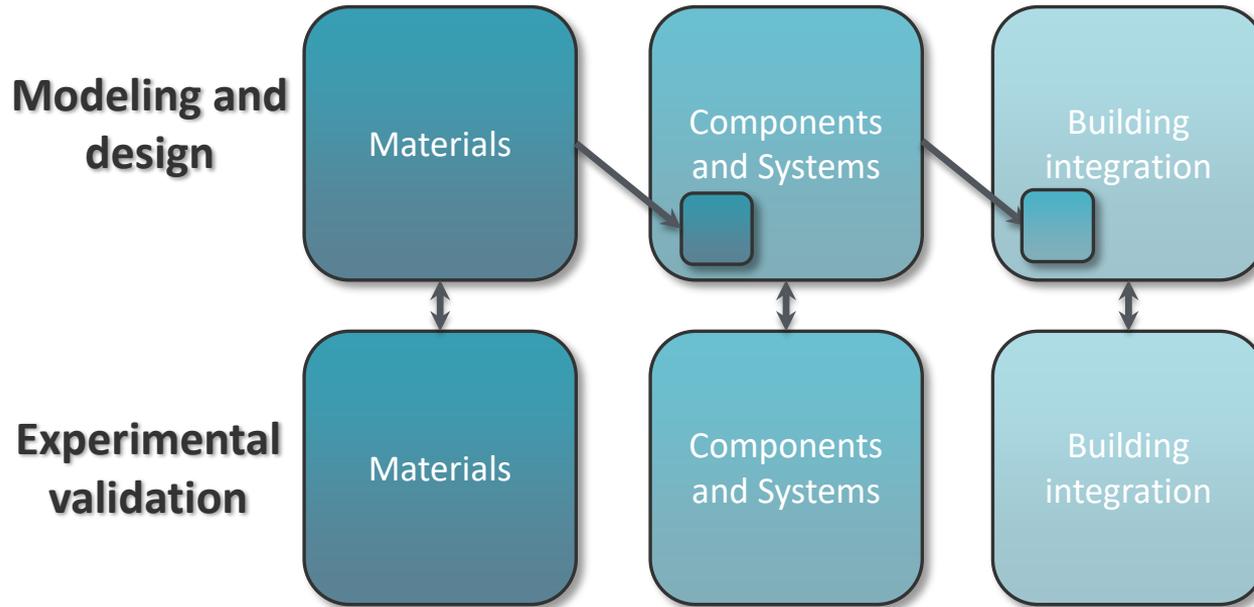
What are the impacts of new materials and systems on energy efficiency and energy costs across different building types and climates?



What R&D improvements are needed to increase the economic viability of behind the meter storage?



Connecting Research Scales: Materials to Systems to Building Integration





Material

$$\Delta H_{fusion}$$

$$T_t$$

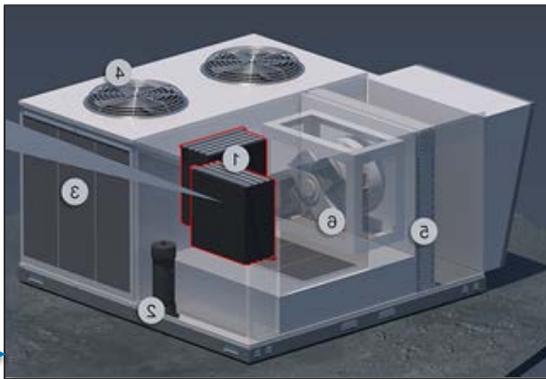
$$k$$



Component

$$kWh_{th}$$

$$kW_{th}$$



System

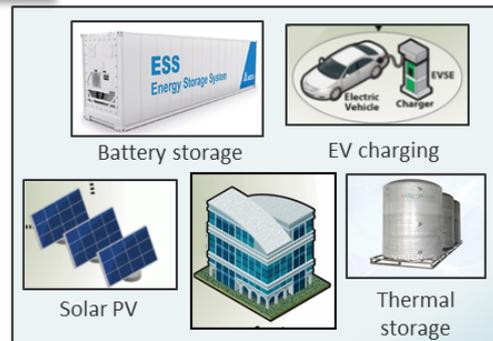
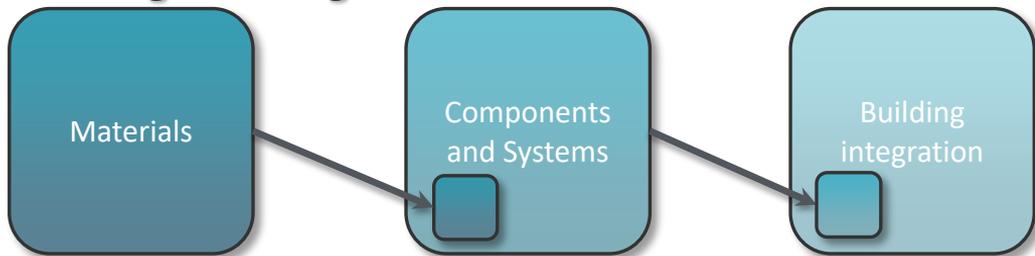
$$kW_e$$

$$COP$$

$$controls$$

$$costs$$

Modeling and design



Integration

Materials Characterization



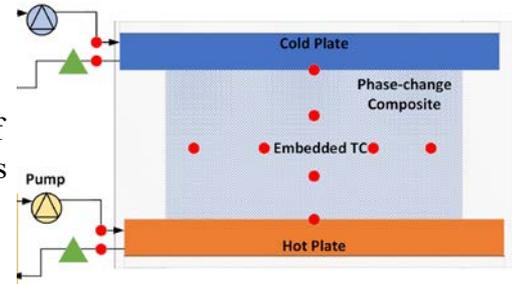
Differential scanning calorimetry

- Phase-change enthalpy (heat of fusion) and transition temperature



PCM cycling stand

- Cycling degradation of phase-change materials



Thermal conductivity:

- Guarded hot plate (at left) and 3-omega method setup enables measurement of thermal conductivity for bulk and thin-film materials

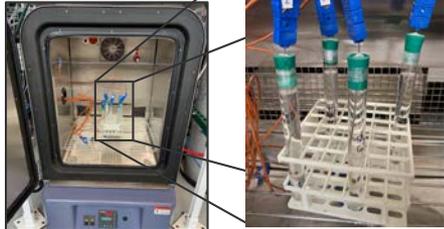
Vapor sorption analyzer/TGA

- Thermogravimetric analysis with humidity control
- Absorption and adsorption isotherms for liquid and solid thermochemical materials



Temperature history calorimetry

- Phase-change enthalpy (heat of fusion) and transition temperature
- Thermal cycling experiments
- Larger samples than DSC



Microscopy

- Morphology/microstructure characterization
- Scanning electron microscope, various optical microscopes



Component and System Characterization

Materials

Components
and Systems

Building
integration



Control and measure:

- Four airstreams (50-5000 cfm) with inlet/outlet flow, T, humidity
- Chilled-water flow and T
- Hot-water flow and T

Current and previous projects:

- HVAC equipment
- Server cooling racks
- Thermal energy storage
- Heat exchangers

Integration and Controls Experiments

Materials

Components and Systems

Building integration

Commercial Buildings Integration

Behind-the-Meter Storage

Electric Vehicles

