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<tr>
<th><strong>Docket Number:</strong></th>
<th>21-IEPR-06</th>
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<tbody>
<tr>
<td><strong>Project Title:</strong></td>
<td>Building Decarbonization and Energy Efficiency</td>
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<tr>
<td><strong>TN #:</strong></td>
<td>239952</td>
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<tr>
<td><strong>Document Title:</strong></td>
<td>Presentation - Grid Interactive Efficient Buildings Technology, a Case Study and the Demand Response Potential Study</td>
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<tr>
<td><strong>Description:</strong></td>
<td>S1.2A Mary Ann Piette, LBNL</td>
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<td><strong>Filer:</strong></td>
<td>Raquel Kravitz</td>
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<tr>
<td><strong>Organization:</strong></td>
<td>Lawrence Berkeley National Laboratory</td>
</tr>
<tr>
<td><strong>Submitter Role:</strong></td>
<td>Public Agency</td>
</tr>
<tr>
<td><strong>Submission Date:</strong></td>
<td>10/4/2021 12:17:10 PM</td>
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<td><strong>Docketed Date:</strong></td>
<td>10/4/2021</td>
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Grid Interactive Efficient Buildings: Technology, a Case Study and the Demand Response Potential Study

Presentation to the IEPR Workshop on GEBs
Sep 24, 2021

Mary Ann Piette
Division Director, Building Technology and Urban Systems
Research Sponsors: US DOE BTO, CPUC and CEC
<table>
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<th>Issues Motivating Advanced Buildings Technologies</th>
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<td>Oil Embargo</td>
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<td>Indoor Health</td>
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<td>Climate Change</td>
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<td>Equity Energy and Environmental Justice</td>
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</table>

- **Oil Embargo**
- **Indoor Health**
- **Urbanization**
- **Changing Electric Grid**
- **Climate Change**
- **Equity Energy and Environmental Justice**
Grid Interactive Efficient Buildings Use Efficient Devices

Efficient Components

- LED Lighting
- Facades
- HVAC
- Plug Loads
Grid Interactive Efficient Buildings Are Integrated

Efficient Components

- LED Lighting
- Facades

Integrated Building Systems

- HVAC
- Plug Loads
Grid Interactive Efficient Buildings (GEBs) Communicate with Grid and Optimize Use of Clean Energy

**Efficient Components**
- LED Lighting
- Facades
- HVAC
- Plug Loads

**Integrated Building Systems**

**Grid-Interactive Efficient Buildings**

**CAISO Generation and Demand**
- May 27, 2019
- Total Curtailment = 39 GW; 16% of total renewable potential
- Net Load Ramp: 4-hour = 9.8GW; 1-hour = 3.7GW

- Generation:
  - Green: Exports
  - Dark Green: Renewables
  - Orange: Curtailment
  - Yellow: Imports
  - Red: Thermal
  - Blue: Large Hydro
  - Purple: Nuclear

- System Demand:
  - Tot. Load
  - Net Load
  - Net w/o Curtail.
GEB Technology Will Unlock Opportunities to Improve Building Efficiency plus Deep Grid-Interactivity

DF-ENABLED TECHNOLOGIES

- Building Automation Systems
- Smart Home Automation Systems
- Connected Lighting
- Multi-Building Control
- Appliances and MELs
- Predictive Control

COMMERCIALY AVAILABLE

- Smart Thermostats
- Water Heaters
- Automated Window Attachments
- Heat Pump Water Heaters
- Dynamic Glazing
- District Energy TES

PILOTS & LIMITED AVAILABILITY

- Heat Pumps
- TES in HVAC
- HVAC and Hot Water Combo Systems
- TES in Refrigeration

IN DEVELOPMENT

- Predictive Control
- Multi-Building Control
- New TES Materials
- TES in Building Envelope
- Thermal Energy Systems

PHYSICAL SYSTEMS

GEB TECHNOLOGY LAYERS

- Supervisory Control
- Physical Systems
- Local Control
- Thermal Energy Systems

Need to expand control R&D to integrate with PV, EVs, Elec Storage
GEB Predictive Control Reduces GHG and Energy Costs

Predictive Control with PV and Thermal Energy Storage
- Identified optimal control for campus chiller plants w/ TES and PV to decarbonize and stabilizing the grid

Societal/Market Impact
- CO2 reduction of ~1 mTCO2e/day while reducing peak demand $.
- Approx 2500 miles in a car at 22 mpg.

Experimental assessment of renewable energy integration and carbon reduction: daily averaged net power profile

Reduction of excessive power sent to grid
ramping rate reduction

net power consumption [kW]

hour of a day

hour of day

before
after
CPUC Demand Response Potential Studies Explore Size and Value of GEBs

- **Shape**: persistent daily load modifications
- **Shed**: acts like virtual *generation* capacity
- **Shift**: acts like a virtual *storage* resource
- **Shimmy**: acts like a virtual *regulation*/ancillary services resource

- Phases 1, 2 and 3 provided the shed capacity (GW) and shift (GWh) from GEBs. Buildings could provide about 2 GW at $200/kW-yr Levelized cost for 2025.

- Current modeling (Phase 4) will cover new end-uses and update customer data.

- Key questions: **How large** is Shed and Shift resource, **where** are resources and **when** is it available, and at **what cost**?

- **Key takaway**: Shift can play important role in California’s renewable grid, but it will need to grow. We can explore ways to bring down costs and drive participation.
Enabling Technology Modeling Framework

Components:

Costs
- Initial
- Operating

Performance
- Speed of response
- Magnitude
- Persistence

Propensity to Adopt
- Based on customer factors
Shift DR in California: 4-6 GWh of virtual storage cheaper than BTM batteries (~$150/yr/kWh), about 40% from buildings, a significant portion of current grid challenges.

Electrification will introduce a new Shift resource, modeled in new Phase 4.

Shift resource will be much larger if customer participation is higher than observed historically for Shed DR.

With ~1 percent of load shifted in 2017, ~150 GWh of total curtailment could have been avoided (~50% of curtailment), replacing non-renewable generation with zero-carbon renewable energy.
Cost Barriers to Enabling Shift
Reducing technology costs can unlock new resources

Residential Shift-enabling technologies tend to be expensive.
New Load-Shape Clusters

Residential: double-peakers

Cluster 9, N=2884
New Load-Shape Clusters

Residential: daytime occupants

Cluster 10, N=1996

Unweighted

Weighted

Rate class
- EV-TOU-Care
- EV-TOU-nonCare
- nonEV-TOU-Care
- nonEV-TOU-nonCare
- nonEV-nonTou-Care
- nonEV-nonTou-nonCare

Building type
- multi_fam
- single_fam

Climate region
- nat-dry
- marine

All electric
- False
- True

Net metered
- False
- True

eta.lbl.gov
New Load-Shape Clusters

Residential: EV rate responders

Cluster 7, N=1112

Rate class
- EVTOU-Care
- EVTOU-nonCare
- nonEV-TOU-Care
- nonEV-TOU-nonCare
- nonEV-nonTOU-Care
- nonEV-nonTOU-nonCare

Building type
- master_mtr
- multi_fam
- sn_fam

Climate region
- hot-dry
- marine

All electric
- False
- True

Net metered
- False
- True
Recent updated AMI data analysis expands scope of buildings and end uses

<table>
<thead>
<tr>
<th>Residential Sector</th>
<th>Commercial Sector</th>
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<tbody>
<tr>
<td><strong>Building Types</strong></td>
<td><strong>End Uses</strong></td>
</tr>
<tr>
<td>• Single-family</td>
<td>• Cooling</td>
</tr>
<tr>
<td>• Multi-family</td>
<td>• Heating</td>
</tr>
<tr>
<td>• Master meter</td>
<td>• Ventilation</td>
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<tr>
<td></td>
<td>• Indoor Lighting</td>
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<td></td>
<td>• Outdoor lighting</td>
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<td></td>
<td>• Cooking</td>
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<td></td>
<td>• Dishwasher</td>
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<td></td>
<td>• Clothes Washer</td>
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<td>• Clothes Dryer</td>
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<td>• Refrigerator</td>
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<td>• Freezer</td>
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<td>• Pool pump</td>
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<td></td>
<td>• Spa heater</td>
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<td>• Television</td>
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<td></td>
<td>• Office equipment</td>
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<td></td>
<td>• PCs</td>
</tr>
<tr>
<td>• <strong>Water heating</strong></td>
<td>• EV level 1</td>
</tr>
<tr>
<td>• EV level 2</td>
<td>• EV level 2</td>
</tr>
<tr>
<td>• Rooftop PV</td>
<td>• Rooftop PV</td>
</tr>
</tbody>
</table>

Entries in red under development from AMI data in Phase 4
Summary and Future Directions

- **GEBs are critical for decarbonization**
- **Key technologies**: heat pumps, envelope, controls, communications, integration with EVs, PV, storage
- **Customer Engagement**: We need more of it!
- **The California Load Flexibility Research and Deployment Hub**: will enable automated flexible demand