TODAY’S PRESENTATION

- Background
- Key research questions
- Study design
THERE HAS BEEN A LARGE INCREASE IN INSTALLED RESIDENTIAL STORAGE CAPACITY OVER THE LAST 5 YEARS*

* Graph based on CA installations
THE % OF SOLAR SITES BEING PAIRED WITH STORAGE IS INCREASING*

Graph based on CA installations
HOW IS BEHIND THE METER BATTERY STORAGE BEING USED? (SAMPLE BATTERIES – SELECTED DAYS)

- Batteries are absorbing customer solar generation and helping meet customer loads
- They are not being used to meet grid needs
- They typically charge as soon as solar production ramps up
- They don’t always solve ramping needs because they often reach full capacity mid-day to early afternoon
- They rarely export to the grid
THE CUSTOMER BATTERY SETTINGS OPTIONS MATTER AND VARY BY PROVIDER

- Tesla main modes
  - Back-up only
  - Self-powered
  - Time of use balanced
  - Time of use cost saving

- Time of use only works if the user edits the price schedule

- % Reserved for power outages

- Storm-watch
PHASE I KEY RESEARCH QUESTIONS

What are the enrollment rates for existing battery storage?

How do incentive levels and amount of outreach affect participation rates for existing battery owners?

What are the enrollment rates for solar intercepts (battery storage offered to sites installing solar)?

How are battery storage customers using the storage on their own?

• What are the settings? Back-up only, self-powered, or time based response?
• How much power do people reserve for backup?
• What are typical charge and discharge patterns?
• How well does their “natural battery use” with grid needs? What is the untapped value
• Do the use patterns vary by rate type, solar-ownership, EV ownership?

What are the load changes associated with:

• TOU
• RTP
• Event based response
• Load shaping events
How quickly do the batteries respond (latency) to external instructions?

Can we feed specific discharge (e.g., T&D load relief) and or charge shapes (e.g., load building) to the batteries?

Are the batteries able to respond to over/under frequency and voltage?

What use cases can be stacked realistically?

What baseline methods, if any, should be used?

How effective are existing algorithms?

Is the technology ready for a program?

What is the optimal design and cost-effectiveness of a battery storage program?
STUDY ENROLLMENT DESIGN TESTS

Eligible Pool

- $25/kWh Total Incentive
  - 75% Up-Front
  - 60% Up-Front
  - 75% Up-Front
  - 90% Up-Front

- $50/kWh Total Incentive
  - 60% Up-Front
  - 75% Up-Front
  - 90% Up-Front

- $100/kWh Total Incentive
  - 60% Up-Front
  - 75% Up-Front
  - 90% Up-Front

- $150/kWh Total Incentive
  - 75% Up-Front

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DATA DRIVEN RESEARCH AND INSIGHTS
## STUDY DESIGN – PHASE I

### Phase I Sample Baseline Period – Assess Data & Implement Pricing

<table>
<thead>
<tr>
<th></th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
<th>Week 5</th>
<th>Week 6</th>
<th>Week 7</th>
<th>Week 8</th>
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<tbody>
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<td><img src="#" alt="TOU" /></td>
<td><img src="#" alt="TOU" /></td>
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<td><img src="#" alt="RTP" /></td>
<td><img src="#" alt="RTP" /></td>
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</tbody>
</table>

- How are customers using storage on their own?
- What are the load changes associated with TOU?
- What are the load changes associated with RTP?
### STUDY DESIGN – PHASE I

#### Phase I Sample Event Implementation

<table>
<thead>
<tr>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
<th>Week 5</th>
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</table>

- **What are the load changes associated with:**
  - **Event only** - e.g., give us what you can from 4 hours, starting at 5 pm
  - **Load modifying event** – provide a utility specified discharge (or charge shape)

**Control** | **TOU** | **RTP** | **Available for event dispatch**
EXAMPLE OF THE STUDY DESIGN: HEAT PUMP WATER HEATERS

Efficiency
0.15 kW per unit (4-9 pm) + Storage
0.03 kW per unit (4-9 pm)

Efficiency impact
Storage Impact

Pre-heating water from 1-3 pm in advance of the peak period
## OPERATIONS PLAN – WHAT TO TEST

<table>
<thead>
<tr>
<th>Event Type</th>
<th>Advance notice</th>
<th>Event duration</th>
<th>Event start</th>
<th>Weather conditions</th>
<th>Season</th>
<th>Day of week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block reduction (discharge)</td>
<td>24 hours</td>
<td>15 minutes</td>
<td>12:00 PM</td>
<td>Very hot</td>
<td>Winter</td>
<td>Weekday</td>
</tr>
<tr>
<td>Load reduction shape (discharge)</td>
<td>6 hours</td>
<td>1 hour</td>
<td>1:00 PM</td>
<td>Hot</td>
<td>Summer</td>
<td>Weekend</td>
</tr>
<tr>
<td>Zero building use (discharge)</td>
<td>3 hour</td>
<td>2 hours</td>
<td>2:00 PM</td>
<td>Moderate</td>
<td>Shoulder</td>
<td></td>
</tr>
<tr>
<td>Block load building (charge)</td>
<td>1 hour</td>
<td>3 hours</td>
<td>3:00 PM</td>
<td>Cloudy/rainy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Load building shape (charge)</td>
<td>10 min</td>
<td>4 hours</td>
<td>4:00 PM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absorb solar peak (charge)</td>
<td>0 min</td>
<td>5 hours</td>
<td>5:00 PM</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>6 hours</td>
<td>6:00 PM</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>7 hours</td>
<td>7:00 PM</td>
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</table>
**WHAT AN EVENT OPERATION PLAN MAY LOOK LIKE**

<table>
<thead>
<tr>
<th>Phase</th>
<th>Event No</th>
<th>Test Element</th>
<th>Event Type</th>
<th>Advance notice</th>
<th>Event start</th>
<th>Event duration</th>
<th>Weather conditions</th>
<th>Season</th>
<th>Day of Week</th>
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</thead>
<tbody>
<tr>
<td>Phase I (First 6 months)</td>
<td>1 Base</td>
<td>Base</td>
<td>Block reduction (discharge)</td>
<td>24 hours</td>
<td>4:00 PM</td>
<td>4 hours</td>
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<td>Not Tested</td>
<td>Not Tested</td>
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<tr>
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<td>2 Advanced notice</td>
<td>Block reduction (discharge)</td>
<td>6 hours</td>
<td>4:00 PM</td>
<td>4 hours</td>
<td>Not Tested</td>
<td>Not Tested</td>
<td>Not Tested</td>
<td>Not Tested</td>
</tr>
<tr>
<td></td>
<td>3 Advanced notice</td>
<td>Block reduction (discharge)</td>
<td>3 hour</td>
<td>4:00 PM</td>
<td>4 hours</td>
<td>Not Tested</td>
<td>Not Tested</td>
<td>Not Tested</td>
<td>Not Tested</td>
</tr>
<tr>
<td></td>
<td>4 Advanced notice</td>
<td>Block reduction (discharge)</td>
<td>1 hour</td>
<td>4:00 PM</td>
<td>4 hours</td>
<td>Not Tested</td>
<td>Not Tested</td>
<td>Not Tested</td>
<td>Not Tested</td>
</tr>
<tr>
<td></td>
<td>5 Event duration</td>
<td>Block reduction (discharge)</td>
<td>24 hours</td>
<td>4:00 PM</td>
<td>2 hours</td>
<td>Not Tested</td>
<td>Not Tested</td>
<td>Not Tested</td>
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<tr>
<td></td>
<td>6 Event duration</td>
<td>Block reduction (discharge)</td>
<td>24 hours</td>
<td>4:00 PM</td>
<td>6 hours</td>
<td>Not Tested</td>
<td>Not Tested</td>
<td>Not Tested</td>
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<tr>
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<td>7 Event start</td>
<td>Block reduction (discharge)</td>
<td>24 hours</td>
<td>2:00 PM</td>
<td>4 hours</td>
<td>Not Tested</td>
<td>Not Tested</td>
<td>Not Tested</td>
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<td>8 Event start</td>
<td>Block reduction (discharge)</td>
<td>24 hours</td>
<td>6:00 PM</td>
<td>4 hours</td>
<td>Not Tested</td>
<td>Not Tested</td>
<td>Not Tested</td>
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<tr>
<td></td>
<td>9 Event Type</td>
<td>Load reduction shape (discharge)</td>
<td>24 hours</td>
<td>4:00 PM</td>
<td>4 hours</td>
<td>Not Tested</td>
<td>Not Tested</td>
<td>Not Tested</td>
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<tr>
<td></td>
<td>10 Advanced notice</td>
<td>Load reduction shape (discharge)</td>
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<td>4:00 PM</td>
<td>4 hours</td>
<td>Not Tested</td>
<td>Not Tested</td>
<td>Not Tested</td>
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<td></td>
<td>11 Advanced notice</td>
<td>Load reduction shape (discharge)</td>
<td>3 hour</td>
<td>4:00 PM</td>
<td>4 hours</td>
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<td>Not Tested</td>
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<td>12 Advanced notice</td>
<td>Load reduction shape (discharge)</td>
<td>1 hour</td>
<td>4:00 PM</td>
<td>4 hours</td>
<td>Not Tested</td>
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<td>Not Tested</td>
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<tr>
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<td>13 Event duration</td>
<td>Load reduction shape (discharge)</td>
<td>24 hours</td>
<td>4:00 PM</td>
<td>2 hours</td>
<td>Not Tested</td>
<td>Not Tested</td>
<td>Not Tested</td>
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<tr>
<td></td>
<td>14 Event duration</td>
<td>Load reduction shape (discharge)</td>
<td>24 hours</td>
<td>4:00 PM</td>
<td>6 hours</td>
<td>Not Tested</td>
<td>Not Tested</td>
<td>Not Tested</td>
<td>Not Tested</td>
</tr>
<tr>
<td></td>
<td>15 Event start</td>
<td>Load reduction shape (discharge)</td>
<td>24 hours</td>
<td>2:00 PM</td>
<td>4 hours</td>
<td>Not Tested</td>
<td>Not Tested</td>
<td>Not Tested</td>
<td>Not Tested</td>
</tr>
<tr>
<td></td>
<td>16 Event start</td>
<td>Load reduction shape (discharge)</td>
<td>24 hours</td>
<td>6:00 PM</td>
<td>4 hours</td>
<td>Not Tested</td>
<td>Not Tested</td>
<td>Not Tested</td>
<td>Not Tested</td>
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</tbody>
</table>
QUESTIONS?

Stephanie Bieler
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ADDITIONAL SLIDES
STUDY GOALS

- Determine if battery storage is ready to be added to future residential pilot programs and provide:
  - **Reliable load reduction** – ability to deliver the amount of load reduction that is promised
  - **Meaningful load reduction** – when and how battery storage can provide value to the grid in DR programs
  - **Cost-effectiveness** – ensure DR Programs remain cost effective with battery storage

- Assess additional grid services that batteries can provide, including:
  - **Speed of response** – the speed of distributed battery storage response
  - **Load building** – the ability to increase minimum load and thus decrease ramping capacity needs and increase hosting capacity

- Increase number of customers with battery storage participating in DR programs:
  - Identify how to remove significant barriers for DER aggregators and their customers to use battery storage when participating in DR programs
**BACKGROUND AND OVERVIEW**

**Study design** (<1 month)

**Recruitment** (2 months)

**Incentive administration**

**Operations** (12 months)

**Evaluation** (near real time)

**Program design elements**
- TOU
- RTP signals
- Event based DR
- Load shaping events
- Ancillary services
  - Contingency reserves
  - Frequency regulation
  - Under frequency/voltage relays

New Recruits
n = 100

Existing Battery Owners
n = 100

**New Recruits**

**Existing Battery Owners**
### ELIGIBLE POOL

- **$250 sign-up incentive (10%)**
- **$10 per kWh annual incentive (10%)**
- **$5 per kWh annual incentive (10%)**

- **$500 sign-up incentive (30%)**
- **$10 per kWh annual incentive (20%)**
- **$5 per kWh annual incentive (10%)**

- **$1000 sign-up incentive (40%)**
- **$10 per kWh annual incentive (30%)**
- **$5 per kWh annual incentive (10%)**

- **$1500 sign-up incentive (20%)**
- **$10 per kWh annual incentive (20%)**
- **$5 per kWh annual incentive (10%)**
ESTIMATING THE IMPACTS OF OUTREACH & INCENTIVE

Marketing, incentives, and program characteristics affect the likelihood of adoption

 Avg. Customer

3x touches

$100 one-time incentive

$15 recurring incentive

Phone call

Installation required

Dispatch frequency

Installation required

Phone call

Dispatch frequency

$100 one-time incentive

$15 recurring incentive

3x Touches

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DATA DRIVEN RESEARCH AND INSIGHTS
### STUDY DESIGN – PHASE II

#### Phase II Advanced Controls

<table>
<thead>
<tr>
<th>Randomly assign 3 groups</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
<th>Week 5</th>
<th>Week 6</th>
<th>Week 7</th>
<th>Week 8</th>
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</thead>
<tbody>
<tr>
<td>Control</td>
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- How quickly do the batteries respond (latency) to external instructions?
- Contingency reserves
- Regulation
- Battery performance for over/under frequency and voltage