Energy Storage Refrigerator Team

Cleantech to Market Presentation

May 6th, 2011
Our Team

Advisors

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C2M Project Team

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Computer Science
Key market trends drive the need for energy storage technologies

- Increasing Renewable Energy Use
- High Peak Energy Production Costs
- Growing Adoption of Time-of-Use Rate Structures

Mitigate Impact of Supply Variability
Shave Peak Consumption
Cost-efficient Consumption
Value Proposition

Our technology uses freezers to enable **cost-efficient, distributed, and highly scalable energy storage** that provides a range of services to electrical utilities and cost savings to end-users **with no behavior or service change necessary.**
Our technology enhances refrigerators’ energy storage

**Our Solution**

- Conventional fridges already have energy storage
- Storage enhanced by inserting phase-change material into freezer
- Energy from latent heat of formation (freeze/thaw)
- Programmable embedded communicating controller
- Low-temperature “ice battery”
  - Delay compressor cycles
  - Aggregation potential

1” of freezer height → 1 kWh → 20 hrs. of operation
Modified freezers can avoid peak electricity costs

- Freezers have predictable periodic electricity use
- Most consumers pay one price for electricity
- With time-of-use rates, electricity costs more during peak hours
- Our technology can leverage time-of-use rates to save money
Aggregating modified freezers provides additional value

**Storage on the Grid**

**Grid Ancillary Services**
- Portfolio of electricity resources used to balance grid supply and demand on short and long time scales

**Examples**
- Generation shortage
- Generation surplus
- Peak shaving

**Legend:**
- Compressor On
- Compressor Off
Thermal storage freezers have a competitive advantage

<table>
<thead>
<tr>
<th>Competitive Advantage</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distributed storage</td>
<td>Avoid constrained transmission</td>
</tr>
<tr>
<td>Scalable</td>
<td>Wide range of services</td>
</tr>
<tr>
<td>No behavior/service change</td>
<td>High customer satisfaction</td>
</tr>
<tr>
<td>Inexpensive</td>
<td>Cost competitive solution</td>
</tr>
<tr>
<td>Bi-directional</td>
<td>Surpluses and deficits</td>
</tr>
<tr>
<td>One-way energy conversion</td>
<td>Minimal discharge loss</td>
</tr>
<tr>
<td>Long discharge duration</td>
<td>Wide range of services</td>
</tr>
</tbody>
</table>
End-users are willing to pay to avoid peak electricity costs

**Benefit:** Lower capital costs due to balanced demand

**Benefit:** Shift peak consumption to off-peak periods

**Benefit:** Increased sales and premium product

**Utilities**

**Technology Provider**

**Manufacturers/Partners**

**End-Users**

Reduced electricity payments to utilities
The savings from peak cost avoidance are substantial

<table>
<thead>
<tr>
<th></th>
<th>Typical CA Residential Customer</th>
<th>Typical CA Commercial Customer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Peak</td>
<td>Off Peak</td>
</tr>
<tr>
<td>($) per year</td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>Peak</td>
<td>$12</td>
<td>$17</td>
</tr>
<tr>
<td>Partial Peak</td>
<td>$14</td>
<td>$27</td>
</tr>
<tr>
<td>Off Peak</td>
<td>$33</td>
<td>$35</td>
</tr>
<tr>
<td></td>
<td>16% Reduction $9 per year</td>
<td>15% Reduction $435 per year</td>
</tr>
<tr>
<td></td>
<td>$327M savings in CA (100% TOU)</td>
<td></td>
</tr>
</tbody>
</table>

1 PG&E E-6 TOU rate structure
2 PG&E E-19 TOU rate structure
Aggregated capacity can be sold as ancillary services to utilities

**Benefit:** Lower capital costs to provide ancillary services

**Benefit:** Shared revenue from ancillary service markets

**Benefit:** Avoided fossil generation

**Benefit:** Increased sales and premium product
Frequency regulation is the most suitable ancillary service.

Frequency regulation is a large, growing market where our technology has the greatest competitive advantage.
FR is growing rapidly but has strict technical requirements.

The CA market for regulation is projected to double by 2020 to ~$125M.

This is driven by a 2x increase in regulation capacity requirements to support 33% RPS.

The technology can meet the requirements for market participation.

<table>
<thead>
<tr>
<th>California ISO 2009 Frequency Regulation Requirements</th>
<th>Meet Requirement?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response Time</td>
<td>&lt;1 min</td>
</tr>
<tr>
<td>Minimum Required Bid</td>
<td>500 kW</td>
</tr>
<tr>
<td>Protocol</td>
<td>Automatic Generation Control (AGC)</td>
</tr>
<tr>
<td>Duration</td>
<td>15 min (day- ahead); 60 min (real-time)</td>
</tr>
</tbody>
</table>
End user segments require different deployment strategies

<table>
<thead>
<tr>
<th>Residential Refrigeration</th>
<th>Key Market Characteristics</th>
<th>Commercial Refrigeration</th>
</tr>
</thead>
<tbody>
<tr>
<td>438 kWh</td>
<td>Typical annual energy use per customer</td>
<td>21,400 kWh</td>
</tr>
<tr>
<td>145 M</td>
<td>Total number of customers in US</td>
<td>2.5 M</td>
</tr>
<tr>
<td>151 TWh</td>
<td>Total annual energy consumption in US</td>
<td>118 TWh</td>
</tr>
<tr>
<td>90% / 4 mfgrs</td>
<td>Market concentration</td>
<td>35% / 4 mfgrs</td>
</tr>
<tr>
<td>High</td>
<td>Potential for retrofit to violate warranty</td>
<td>Low</td>
</tr>
<tr>
<td>Low</td>
<td>Customization of units</td>
<td>High</td>
</tr>
</tbody>
</table>

Replace
Recommended path to deployment
Retrofit
Commercial retrofits will proliferate our technology faster

Commercial retrofits can achieve meaningful penetration faster…

…and face fewer hurdles than residential replacements

8-10 yrs to design a new residential refrigerator
– GE

Walk-in freezers can easily accommodate a retrofit
– Food Service Technology Center

Commercial TOU rate penetration is 30% and is being driven towards 100%
– PG&E

No plans (TOU/Rebate) to reduce residential peak consumption within the next 5 years
– PG&E

Growth of residential DR depends on smart meters for communication
– Akuacom & EnerNOC
Go-to-Market Strategy

**Applications**
- Peak Cost Avoidance
- Frequency Regulation

**Market Trends**
- High commercial TOU penetration
- RPS enacted
- FERC proposes “pay for performance”
- High residential TOU & AMI penetration
- Large and growing renewable fleet
- Storage widely adopted for ancillary svcs.

**Business Requirements**
- Build commercial customer base
- Limited communication necessary
- Revenue from freezer end-users
- Capacity must meet ISO minimum bids
- Two-way, responsive communication
- Revenue from ancillary service markets
Patent and Licensing Considerations

**Patent Process**

File invention disclosure with UC Berkeley → UC Berkeley files provisional patent → UC Berkeley files US and international patents

**Licensing Options**

Pursue profits or proliferate technology?

- Start business and retrofit refrigerators
- Co-develop technology with one manufacturer

Proliferate technology through manufacturers →

- Start business and sign exclusive license with UC Berkeley
- UC Berkeley signs exclusive license with an appliance manufacturer
- UC Berkeley signs non-exclusive licenses with appliance manufacturers
- Publish technology in public domain without any patents
Summary of Recommendations

**Application Recommendations**
- Short Term: Avoid peak electricity costs for end-users
- Long Term: Frequency regulation

**Target Customer Base**
- Build commercial customer base via retrofits
- Target residential market through appliance manufacturer(s)

**Technology Implications**
- Design commercial freezer prototypes
- Ensure communication and protocol requirements can be met

**IP Strategy Considerations**
- Begin UC Berkeley patenting process
- Determine long-term technology deployment strategy
Q&A
Appendix
System Design of Typical Commercial Walk-in Refrigerator or Freezer
A thermal storage freezer is more responsive, highly scalable, and can provide a breadth of grid services competitively.

Discharge time and cost are competitive advantages for a single refrigerator – ease of aggregation and distribution of capacity make this valuable for a wide range of applications.
The value of energy storage increases as it approaches the edge of the grid.

Source: IceEnergy, Inc.
The market for grid ancillary services is large and growing, as is the share services provided by non-generation resources.

- In Texas, growth in renewables has driven a large increase in ancillary service procurement.
- An increasing proportion of these services is provided by non-generation resources → ~$100M spent in 2010.

$800M Current
>$3B Projected

The estimated market potential for ancillary services in major global economies will grow as renewables are adopted.
**Frequency regulation is an ideal applications based on key selection criteria**

<table>
<thead>
<tr>
<th>Potential Applications</th>
<th>Market Size</th>
<th>Market Growth</th>
<th>Technology Advantage</th>
<th>Regulatory/Market Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Regulation</td>
<td>![Condition]</td>
<td>![Condition]</td>
<td>![Condition]</td>
<td>![Condition]</td>
</tr>
<tr>
<td>Spinning Reserve</td>
<td>![Condition]</td>
<td>![Condition]</td>
<td>![Condition]</td>
<td>![Condition]</td>
</tr>
<tr>
<td>Non-Spinning Reserve</td>
<td>![Condition]</td>
<td>![Condition]</td>
<td>![Condition]</td>
<td>![Condition]</td>
</tr>
<tr>
<td>Load Following</td>
<td>![Condition]</td>
<td>![Condition]</td>
<td>![Condition]</td>
<td>![Condition]</td>
</tr>
<tr>
<td>Day Ahead Demand Response</td>
<td>![Condition]</td>
<td>![Condition]</td>
<td>![Condition]</td>
<td>![Condition]</td>
</tr>
<tr>
<td>Capacity Curtailment</td>
<td>![Condition]</td>
<td>![Condition]</td>
<td>![Condition]</td>
<td>![Condition]</td>
</tr>
</tbody>
</table>

- **Greatest Competitive Advantage**
- **Strong Competitive Advantage**
- **Weaker Competitive Advantage**

**Grid Services**

Unfavorable Conditions

- ![Condition] Favorable Conditions

- 25 -
Case Study: Frequency Regulation (FR) in CAISO

**Definition:** Addressing the balance between the network’s load and power generated – when there is more load than power generated, frequency drops below 60 Hz and vice versa

### Increasing Demand for FR

California ISO Expected Increase in Regulation Capacity (MW) requirements at 20% and 33% RPS

<table>
<thead>
<tr>
<th></th>
<th>2006</th>
<th>2012</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Reg Up</td>
<td>277</td>
<td>502</td>
<td>1,135</td>
</tr>
<tr>
<td>Requirement (MW)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum Reg Down</td>
<td>-382</td>
<td>-569</td>
<td>-1,097</td>
</tr>
<tr>
<td>Requirement (MW)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

“PJM expects the requirement for regulation to increase from **1,000 MW today to 2,000 MW** when we reach 20% wind penetration.” – Terry Boston, CEO of PJM

### Market Prices and Size

California ISO Expected FR Market Size based on Average 2009 Prices for Regulation Up and Down

<table>
<thead>
<tr>
<th></th>
<th>Avg. 2009 Price ($/MWhr)</th>
<th>Estimated Market Size ($K)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2009</td>
<td>2012</td>
</tr>
<tr>
<td>Regulation Up</td>
<td>7.51</td>
<td>25,625</td>
</tr>
<tr>
<td>Regulation Down</td>
<td>6.01</td>
<td>25,034</td>
</tr>
</tbody>
</table>

CAISO Frequency Regulation market is expected to be **~$60M in 2012 and ~$125M in 2020**

### Technology Requirements

California ISO 2009 Frequency Regulation Requirements

<table>
<thead>
<tr>
<th></th>
<th>Response Time</th>
<th>Time to Reach Bid</th>
<th>Required Telemetry</th>
<th>Minimum Required Bid</th>
<th>Protocol</th>
<th>Duration</th>
<th>Market Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulation Up &amp; Down</td>
<td>&lt;1 min</td>
<td>&lt;10 min</td>
<td>4 sec</td>
<td>500 kW</td>
<td>Automatic Generation Control (AGC)</td>
<td>15 min (day-ahead); 60 min (real-time)</td>
<td>Day-ahead &amp; real-time</td>
</tr>
</tbody>
</table>
Residential: Improve Electricity Purchasing Power with PG&E TOU rates

**Definition:** Enable customers paying time-of-use (TOU) electricity rates to shift purchases from on-peak prices to off-peak prices

### TOU Rate Schedule for Residential

<table>
<thead>
<tr>
<th></th>
<th>Demand Charges (per kW)</th>
<th>Total Energy Charge (per kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOU</td>
<td>Secondary</td>
<td>TOU</td>
</tr>
<tr>
<td><strong>Summer</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max. Peak</td>
<td>-</td>
<td>Peak</td>
</tr>
<tr>
<td>Part. Peak</td>
<td>-</td>
<td>Part. Peak</td>
</tr>
<tr>
<td>Maximum</td>
<td>-</td>
<td>Off Peak</td>
</tr>
<tr>
<td><strong>Winter</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part. Peak</td>
<td>-</td>
<td>Part Peak</td>
</tr>
<tr>
<td>Maximum</td>
<td>-</td>
<td>Off Peak</td>
</tr>
</tbody>
</table>

### Model Assumptions
- Residential refrigerator/freezer uses 200W of power
- PG&E E-6 rate structure applied over 1 year
- Shed summer peak, 1/3 winter partial peak

### Per Freezer

<table>
<thead>
<tr>
<th></th>
<th>Electricity Costs</th>
<th>Electricity Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Demand Energy</td>
<td>Demand Energy</td>
</tr>
<tr>
<td><strong>Summer Weekdays</strong></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>$32.29</td>
<td>$8.58</td>
</tr>
<tr>
<td><strong>Winter &amp; Summer Weekends</strong></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>$23.51</td>
<td>$0.37</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$55.79</td>
<td><strong>$8.95</strong></td>
</tr>
</tbody>
</table>

**Key Takeaways:**
- Each residential refrigerator can save **16% of electricity costs** per year ($8.95) by shedding peak time load
- Residential refrigerator savings in California are **$3.3M** at 1% TOU and **$327M** at 100%
**Commercial: Improve Electricity Purchasing Power with PG&E TOU rates**

**Definition:** Enable customers paying time-of-use (TOU) electricity rates to shift purchases from on-peak prices to off-peak prices

### TOU Rate Schedule for Supermarket

**PG&E E-19 TOU Rate Schedule, as of 03/01/2011**

<table>
<thead>
<tr>
<th></th>
<th>Demand Charges (per kW)</th>
<th>Total Energy Charge (per kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TOU</strong></td>
<td><strong>Secondary</strong></td>
<td><strong>TOU</strong></td>
</tr>
<tr>
<td>Summer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max. Peak</td>
<td>$12.11</td>
<td>Peak</td>
</tr>
<tr>
<td>Part. Peak</td>
<td>$2.81</td>
<td>Part. Peak</td>
</tr>
<tr>
<td>Maximum</td>
<td>$9.27</td>
<td>Off Peak</td>
</tr>
<tr>
<td>Winter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part. Peak</td>
<td>$1.22</td>
<td>Part Peak</td>
</tr>
<tr>
<td>Maximum</td>
<td>$9.27</td>
<td>Off Peak</td>
</tr>
</tbody>
</table>

### Model Assumptions

- Walk-in freezer (15m²) uses 2.4 kW of power
- PG&E E-19 rate structure applied over 1 year
- Shed summer peak, 1/3 winter partial peak
- CA commercial avg. cost of electricity = 12.53 ¢/kWhr

### Electricity Costs

<table>
<thead>
<tr>
<th>Per Freezer</th>
<th>Electricity Costs (Demand)</th>
<th>Electricity Costs (Energy)</th>
<th>Electricity Savings (Demand)</th>
<th>Electricity Savings (Energy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer Weekdays</td>
<td>$619.26</td>
<td>$1,051.00</td>
<td>$310.02</td>
<td>$112.32</td>
</tr>
<tr>
<td>Winter &amp; Summer Weekends</td>
<td>$268.54</td>
<td>$922.21</td>
<td>$0.00</td>
<td>$12.26</td>
</tr>
<tr>
<td>Total</td>
<td>$887.80</td>
<td>$1973.21</td>
<td><strong>$310.02</strong></td>
<td><strong>$124.58</strong></td>
</tr>
</tbody>
</table>

### Key Takeaways:

- Each commercial freezer can save **15% of electricity costs** per year ($434.60) by shedding peak time load
- Commercial freezers savings in California are **$22M** at 30% TOU and **$73M** at 100%
Commercial refrigeration appears to be best suited for near term penetration

<table>
<thead>
<tr>
<th></th>
<th>Residential</th>
<th>Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refrigeration as % of electricity use</td>
<td>10% ✔️</td>
<td>10% ✔️</td>
</tr>
<tr>
<td>Average energy consumption per year</td>
<td>438 kWh</td>
<td>21,400 kWh(1) ✔️</td>
</tr>
<tr>
<td>Maximum energy storage</td>
<td>1 kWh</td>
<td>72 kWh(2)  ✔️</td>
</tr>
<tr>
<td>Customers needed to provide 500 kW</td>
<td>10,000</td>
<td>234        ✔️</td>
</tr>
<tr>
<td>Variable electricity rate penetration in CA</td>
<td>1%</td>
<td>30% ✔️</td>
</tr>
<tr>
<td>Willingness to sacrifice freezer space</td>
<td>Low</td>
<td>High       ✔️</td>
</tr>
<tr>
<td>Distribution of customers across grid</td>
<td>High ✔️</td>
<td>Medium</td>
</tr>
<tr>
<td>Savings per customer</td>
<td>Low</td>
<td>Med-High   ✔️</td>
</tr>
</tbody>
</table>

1 Based on energy consumption of a 15m² walk-in freezer
2 Assumes thermal battery size is 16” x 20” x 72”
## Installed and Approved Smart Meter Penetration

50.5 million smart meters have been installed or approved of which 38 million are electric. That 38 million represents 25% of the 150 million electric meters in the U.S.

### Installed
- AEP OH: 0.2 million
- AEP TX: 0.1 m
- Alliant: 0.5 m
- CenterPoint: 0.5 m
- Delmarva: 0.2 m
- Exelon: 0.2 m
- FPL: 0.6 m
- Idaho Power: 0.1 m
- Oncor: 1.3 m
- PG&E: 6.5 m
- PGE: 0.8 m
- PPL: 1.4 m
- SCE: 1.4 m
- SDG&E: 1.2 m
- Southern Company: 1.0 m

**Total Installed:** 16.5 million (11% of US meters)

### Approved
- AEP TX: 0.9 million additional
- Alliant: 0.9 m
- BGE: 2.0 m
- Bluebonnet: 0.1 m
- Burbank Water & Power: 0.1 m
- CenterPoint: 1.9 m
- CPS Energy: 1.0 m
- Delmarva: 0.2 m
- Exelon: 2.0 m
- FPL: 3.9 m
- Idaho Power: 0.4 m
- PG&E: 3.6 m
- Oncor: 1.7 m
- Pepco: 0.8 m
- SCE: 3.6 m
- SCG: 6.0 m
- SDG&E: 1.1 m
- Silicon Valley Power: 0.1 m
- Southern Company: 3.6 m
- TNMP: 0.2 m
- Westar Energy: 0.1 m

**Total Approved:** 34.2 million (23% of US meters)
Interviews Conducted

• Aaron Breidenbaugh – Director of Regulatory Affairs, EnerNoc
• Andrew Bell – Analysis and Rates Department, PG&E
• Amanda Stevens – ENERGY STAR Appliance Program, EPA
• Doug Frazee – Energy, Environment & Transportation Consultant, ICF International
• Scott Welham – General Manager of Advanced Technology, GE
• Michael Cohen – Office of Intellectual Property and Industry Research Alliances, UC Berkeley
• Jim Detmers – Former VP Operations, CAISO
• Duncan Callaway – Energy & Resources Group, UC Berkeley
• Sila Kiliccote – Demand Response Research Center, Lawrence Berkeley Labs
• Rich Brown – Environmental Energy Technologies Division, Lawrence Berkeley Labs
• Ilan Gur – Senior Commercialization Advisor, ARPA-E
• Len Conapinski – Patent Law Expert
• Don Fisher – Food Service Technology Center
• Paul Lipkin – Akuacom