Track 2A
Decarbonized District Energy Network for New Stanford Campus
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Stanford Energy Operations

- Main Campus Replacement CEF
  - Electric-driven heat recovery system
- Building Electrification
- Reliable Energy Supply
- Cost Effective
- Sustainable

By Dec 2021 when next solar plant comes online

68% reduction in campus greenhouse gas emissions by 2016

By Dec 2021 when LWHE comes online

18% reduction in campus drinking water use by 2015

$520 million saved over next 35 years

15% with Direct Access and 100% solar PPAs
Stanford Energy Operations

- **Electricity**
  - 250,000,000 kWh/yr
  - 435 locations

- **Low Temperature Hot Water**
  - 600,000 mmBtu/yr
  - 174 locations

- **Chilled Water**
  - 60,000,000 ton-hrs/yr
  - 147 locations

- **Steam**
  - 36,000 mmBtu/yr
  - 17 locations

- **Staff of 42**
- **$100M O&M Budget**
- **$28M Energy Cost**
  - $26M Electricity
  - $1M Natural Gas
  - $1M Water
Stanford Energy Operations

- Stanford in Redwood City
  - New campus developed for 2,700 Stanford staff members
  - Allows main campus growth
- Extension of Stanford sustainability
- Demonstrates **scalability**
- Remotely operated
Stanford in Redwood City – Initial Concept
Stanford in Redwood City – Cooling Options

- Packaged DX air-cooled units
- Packaged DX water-cooled units
- Building-level hydronic cooling
- District hydronic cooling
- District hydronic cooling with partial-shift TES
- District hydronic cooling with full-shift TES
Life Cycle Cost Analysis – Cooling Options

Capital, Operations and Maintenance, Water, Energy, and Carbon NPC

- Packaged A/C: $26.2M, 276 Million Gallons, 83 GWh
- District w/o TES: $27.6M, 12,800 MTCDE, 43 GWh
- District w/ 11k TES: $23.6M, 11,300 MTCDE, 38 GWh
- District w/ 22k TES: $26.6M, 11,600 MTCDE, 39 GWh

Legend:
- Carbon ($)  
- Energy ($)  
- Water ($)  
- Operations ($)  
- Capital ($)  
- Carbon Emissions  
- Regional Water  
- Energy
Stanford in Redwood City – Heating Options

- Building-level hydronic boiler
- Central hydronic boiler
- Central heat recovery chiller
Life Cycle Cost Analysis – Heating Options

Capital, Operations and Maintenance, Water, Energy, and Carbon NPC

- Unitary Hydronic Boiler
  - Capital: $6.3M
  - Energy: $2.8M
  - Operations: $2.0M
  - Maintenance: $0.2M

- Central Hydronic Boiler
  - Capital: $6.9M
  - Energy: $2.0M
  - Operations: $1.4M
  - Maintenance: $0.2M

- Central Heat Recovery Chiller
  - Capital: $13.9M
  - Energy: $1.5M
  - Operations: $1.0M
  - Maintenance: $0.0M

30-year Capital, Operations and Maintenance, Water, Energy, and Carbon NPC

- 6,900 MTCDE
- 2,14 Million Gallons
- 142,075 MMBtu

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AEI / Affiliated Engineers, Inc.
## Comparison of BAU to Selected Option

<table>
<thead>
<tr>
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<th>Packaged DX Cooling Units and Unitary Hydronic Boilers</th>
<th>District Combined Heating and Cooling System with TES</th>
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<tbody>
<tr>
<td><strong>Lifecycle Carbon Emissions</strong></td>
<td>31,600 MTCDE (Scope 1 and 2)</td>
<td>Scope 1 and 2 near zero carbon within two years when offsite green power is online Minimal Scope 1 emitted by natural gas cooking and backup heating</td>
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<tr>
<td><strong>Present Value of Capital</strong></td>
<td>$32.5M</td>
<td>$30.2</td>
</tr>
<tr>
<td><strong>Total Present Cost</strong></td>
<td>$77.8M</td>
<td>$48.1</td>
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<tr>
<td><strong>Lifecycle Energy Consumption</strong></td>
<td>430,000 MMBtu</td>
<td>140,000 MMBtu</td>
</tr>
<tr>
<td><strong>Average COP</strong></td>
<td>3.02</td>
<td>8.96</td>
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<tr>
<td><strong>38% Savings</strong></td>
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<td><strong>67% Reduction</strong></td>
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Stanford in Redwood City – Initial Development
Separate Heating and Cooling (SHC)
Combined Heating and Cooling (CHC)
Campus Energy Flow
Annual Combined Heating and Cooling

25% of Cooling Demand is Recovered

60% of Heating Demand is Supplied by CHC
Assumptions
Above 70°F OADB: 55°F SAT and 74°F RAT
Below 60°F OADB: 62°F SAT and 68°F RAT
Annual Combined Heating and Cooling

25% of Cooling Demand is Recovered

60% of Heating Demand is Supplied by CHC
Annual Combined Heating and Cooling with BASH

25% of Cooling Demand is Recovered

40% of Heating Demand is Supplied by BASH
60% of Heating Demand is Supplied by CHC
Building Exhaust Heat Recovery (BEHR)

Assumptions
Above 70°F OADB: 55°F SAT and 74°F RAT
Below 60°F OADB: 62°F SAT and 68°F RAT
CHC and BASH+BEHR Benefits Across the Country
Other Low Grade Heat Sources

- Building Air Source Heat (people, computers, lights, etc.)
- Lower temperature refrigeration on campus
- Engine coolant
- Building Exhaust Heat Recovery
- Irrigation or domestic water flow
- Wastewater influent/effluent flow
- Ambient air
- Solar thermal
- Electricity
- Adjacent industry
- Surface water
- Geothermal
Construction Completed in 2019
Lessons Learned

- **Ultra-low 110°F heating water supply temperature**
  - VAV reheat system control
  - VAV reheat system selection
  - Alternative building heating strategies
  - Domestic hot water
  - Other heat sinks

- **Any heat pump system**
  - Refrigerant compressors
  - Differential temperature
  - Supply to return bypasses
  - Three way valves
  - Low-grade heat sources
  - Thermal storage
Questions?

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