Hybrid Heat Pumps
Midwest Energy Solutions Conference
February 1, 2022

Ryan Kerr
Senior Manager, Emerging Technologies
rkerr@gti.energy
847-768-0941
Decarbonizing Buildings

Two Branches for Decarbonization Pathways

More than half of homes & businesses have fuel-fired heating. Broad decarbonization pathways are:

<table>
<thead>
<tr>
<th>Primarily Fuel-fired Pathway</th>
<th>Technology Needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mostly Applicable to</td>
<td></td>
</tr>
<tr>
<td>Existing Buildings</td>
<td></td>
</tr>
<tr>
<td>Cold/Very-cold Climate Regions</td>
<td></td>
</tr>
<tr>
<td>Thermally Intensive Loads</td>
<td></td>
</tr>
<tr>
<td>Regions Rich With Decarb. Fuels</td>
<td></td>
</tr>
<tr>
<td>Gas Energy Efficiency ✓</td>
<td></td>
</tr>
<tr>
<td>Thermally-driven Heat Pumps ≈</td>
<td></td>
</tr>
<tr>
<td>Micro-CHP / Fuel Cells</td>
<td></td>
</tr>
<tr>
<td>Hydrogen-fueled Equipment</td>
<td></td>
</tr>
</tbody>
</table>

Decarb. pathways differ by age, size, and location:
- 80% of US homes were built before 2000*
- Average lifespan of US home is 130 years**

<table>
<thead>
<tr>
<th>Primarily Electric Pathway</th>
<th>Technology Needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mostly Applicable to</td>
<td></td>
</tr>
<tr>
<td>New Construction</td>
<td></td>
</tr>
<tr>
<td>Mild/Hot Climates</td>
<td></td>
</tr>
<tr>
<td>Low Energy/Net-zero Design</td>
<td></td>
</tr>
<tr>
<td>Renewable Electricity-Rich Regions</td>
<td></td>
</tr>
<tr>
<td>Grid-interactive Controls</td>
<td></td>
</tr>
<tr>
<td>Dist. Energy Resources</td>
<td></td>
</tr>
<tr>
<td>Hybrid Equipment/Systems</td>
<td></td>
</tr>
<tr>
<td>BTM Energy Storage</td>
<td></td>
</tr>
</tbody>
</table>
Decarbonize now with Dual-Fuel Hybrid HVAC

Example ASHP paired with Low-capacity furnace = 15,000 BTU modulating to 6,000 BTU

Key Concept: Cutoff Point for fuel crossover
What might be the rationale for hybrid heat pumps?

• **Society**
  - Reduce CO₂ emissions cost-effectively
  - Utilizes existing infrastructure

• **Utility**
  - Strategic Electrification
  - Adding winter load with a safety net
  - Opportunity to develop non-wires solutions

• **Customer**
  - Leverage best attributes of two heating technologies
  - Ready retrofit (AC replacement)
  - Opportunity to control for different objectives (cost, efficiency, emissions)
## Partial List of Residential Hybrid HVACs

<table>
<thead>
<tr>
<th>System Name</th>
<th>Heat Pump Brand / Part # / Manual</th>
<th>Furnace Brand / Part # / Manual</th>
<th>Thermostat Brand / Part # / Manual</th>
<th>Operating Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dettson</td>
<td>Dettson COND-**-01</td>
<td>Dettson C**-M-V</td>
<td>Dettson R02P032</td>
<td>Outdoor air temp</td>
</tr>
<tr>
<td>Carrier</td>
<td>Carrier 25VNA4</td>
<td>Carrier 59MN7</td>
<td>Carrier SYSTXCCITC</td>
<td>Cost</td>
</tr>
<tr>
<td>Rheem</td>
<td>Rheem RP20</td>
<td>Rheem R98V</td>
<td>Rheem RETST700SYS</td>
<td>Outdoor air temp</td>
</tr>
<tr>
<td>York</td>
<td>York YZV24</td>
<td>York YP9C</td>
<td>York Hx3</td>
<td>Outdoor air temp</td>
</tr>
<tr>
<td>Goodman</td>
<td>Goodman GVZC20</td>
<td>Goodman GMVM97</td>
<td>Goodman CTK04</td>
<td>Outdoor air temp</td>
</tr>
<tr>
<td>Amana</td>
<td>Amana AVZC20</td>
<td>Amana AMVM97</td>
<td>Amana CTK04</td>
<td>Outdoor air temp</td>
</tr>
<tr>
<td>Venstar – Goodman</td>
<td>Goodman GSZC18</td>
<td>Goodman GMES96</td>
<td>Venstar T7850</td>
<td>Outdoor air temp</td>
</tr>
<tr>
<td>Amazon – Goodman</td>
<td>Goodman GSZC18</td>
<td>Goodman GMES96</td>
<td>Amazon Ecobee</td>
<td>Outdoor air temp</td>
</tr>
<tr>
<td>Google – Goodman</td>
<td>Goodman GSZC18</td>
<td>Goodman GMES96</td>
<td>Google Nest</td>
<td>Outdoor air temp</td>
</tr>
<tr>
<td>Honeywell – Goodman</td>
<td>Goodman GSZC18</td>
<td>Goodman GMES96</td>
<td>Honeywell VisionPRO 8000</td>
<td>Outdoor air temp</td>
</tr>
<tr>
<td>Many More</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Many More</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Some commercial Hybrid HVACs emerging too…

<table>
<thead>
<tr>
<th>Application</th>
<th>Brand</th>
<th>Part #</th>
<th>Ratings</th>
<th>Capacities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light-commercial</td>
<td>Carrier</td>
<td>48VR</td>
<td>SEER 15.5 HSPF 8.5 AFUE 80</td>
<td>2 – 5 ton 40 – 130 MBH</td>
</tr>
<tr>
<td></td>
<td>Trane (American Standard)</td>
<td>XL16c (4DCZ60)</td>
<td>SEER 16 HSPF 9 AFUE 80</td>
<td>2 – 5 ton 75 – 120 MBH</td>
</tr>
<tr>
<td></td>
<td>Goodman (Amana)</td>
<td>GPD (APD)</td>
<td>SEER 14.5 HSPF 8 AFUE 80</td>
<td>2 – 5 ton 60 – 140 MBH</td>
</tr>
<tr>
<td>Commercial</td>
<td>Trane</td>
<td>RT-PRC087</td>
<td>SEER 15 HSPF 9 AFUE 80</td>
<td>3 – 10 ton 48 – 200 MBH</td>
</tr>
<tr>
<td></td>
<td>Allied Commercial</td>
<td>KDB</td>
<td>SEER 15 HSPF 9 AFUE 80</td>
<td>7.5 – 10 ton 13 – 240 MBH</td>
</tr>
</tbody>
</table>
Peak Energy Comparison

Impact of Space Heating Electrification On State January Electricity Consumption (% of Current Summer Peak)

Illinois Monthly Residential Energy Use

Winter Heating from 0°F to 70°F ...is like... Summer Cooling from 145°F to 75°F

Source: Analysis of DOE Energy Information Administration data
Source: DOE-EIA
Residential Hybrid (Dual-fuel) Space Heating

Average Hourly Electricity Consumption Rate (kW) - (Cold Weather Home Pre-2010 Construction)

- Gas (Furnace + Tankless Water Heater)
- Electric (Heat Pump + Heat Pump Water Heater)
- Gas Furnace + Electric Heat Pump

Source: GTI Analysis
Air Source Heat Pump (ASHP) Performance

Capacities

Efficiencies

Source: GTI Lab Data
Hybrid Controls – Capacity Balance Point

Example Only

- Building Heating Load
- Balance Point
- ASHP Capacity
- Heat Supplied by Furnace
- Heat Supplied by Heat Pump

Outside Air Temperature °F

Heat Supplied by Heat Pump

MBH

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH

Outside Air Temperature °F

Balance Point

Outside Air Temperature °F

Heat Supplied by Furnace

MBH
Hybrid Controls – Efficiency Cutoffs

Example Only

Outside Air Temperature °F

MBH

Coefficient of Performance

Heat Supplied by Heat Pump

Heat Supplied by Furnace

Building Heating Load

Cutoff Point

ASHP Efficiency

Example Only
Hybrid Controls – Cost Cutoffs

Example Only

Outside Air Temperature °F

Operating Cost $/MBH

MBH

Heat Pump

Heat Supplied by Furnace

Cutoff Point

Building Heating Load

ASHP Operating Cost

Furnace Operating Cost

Heat Supplied by Furnace

Heat Pump

Example Only
Smart(er) Hybrid HVAC Control

Smart (Connected)

Works with any connected thermostat to make it smarter

Smarter (AI)

Real time pricing

Environmental Perspective

Customer Perspective

Source: Angela Tanghetti, CEC
Current and Prior work:

• **Deep Energy Retrofits with Hybrids (2019):** In IL, seven affordable housing units received envelope and mechanical retrofits with hybrid systems. Field monitoring showed **unanticipated large electric use** from heat pump units and associated **high utility bills**.

• **Low-Capacity Hybrid HVAC (2021):** In NY, five-site demo supplemented with GTI virtual test home approach yielded knowledge on how hybrids perform in three very different electric grid subregions with different operating cost drivers and GHG impacts.

• **Smart Fuel-Switching Controller – Lab Evaluation for Nicor Gas:** Just getting underway, this lab project will evaluate BKR Energy system and build out US capabilities for cost or GHG-driven control strategies.
What are Your Hybrid Research Needs?

- Market landscape assessment
- Manufacturer Engagement
- Developing Methods of Test
- Laboratory evaluation of controls (VTH)
- Field demonstration of controls
- Design and Operating Guidelines
- Proving grid responsiveness (DR)
- Integrating grid backup
- Sharing results and details of hybrid pilots