Strategic Electrification

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Panelists
Asa S. Hopkins, PhD
Kenji Takahashi
Danielle Goldberg

Moderator: Bruce Biewald, Founder and CEO

@SynapseEnergy
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Who we are

Synapse Energy Economics

• Founded in 1996 by CEO Bruce Biewald

• Research and consulting firm specializing in energy, economic, and environmental topics

• Services include economic and technical analyses, regulatory support, research and report writing, policy analysis and development, representation in stakeholder committees, facilitation, trainings, and expert witness services for public interest and government clients

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Agenda

• Analyzing Strategic Electrification – The Big Picture
• Fuel Switching with Heat Pumps
Analyzing Strategic Electrification
The Big Picture
Outline

• Why electrification?

• Defining “strategic electrification”

• Hitting 2050 GHG goals
  • Markets transition
  • Resulting impacts and implications

• Based on work for the Northeast Energy Efficiency Partnerships (NEEP) on electrification in New England and New York

• Also draw upon Minnesota work supported by another client
Decarbonizing via EE and zero-carbon electricity falls short

95% zero carbon electricity on the grid, plus aggressive electric and thermal energy efficiency (Northeast example):

To get deep decarbonization, Northeast needs to switch direct fuel use to zero- or low-carbon sources, like electricity.

Fossil fuel used for space heat, water heat, and mobility:
Finding the sweet spot

Efficiency
- Condensing Space & Water Heat
- Efficient Appliances
  - Hybrid Cars
  - LEDs
  - CHP

Flexibility
- Ponded Hydro
- Biogas
- Batteries
- Pumped Hydro
- Interruptible Loads

Low-Carbon Supply
- Solar
- Wind
- Run-of-River Hydro
- Wood
- Nuclear
- Biofuels

Electrification
- PHEVs
- HP Space Heat
- Freight and Transit
- HP Water Heat
- Light Duty EVs
- ResistanceWHs

Strategic Electrification

Asa S. Hopkins
“Strategic Electrification” means...

• powering end uses with electricity instead of fossil fuels

• in a way that increases energy efficiency and reduces pollution,

• while lowering costs to customers and society,

• as part of an integrated approach to deep decarbonization.
Getting to 80% GHG reduction by 2050

Assume we do the “right” things on efficiency, flexibility, and low-carbon electric supply:

- How fast do electrification markets need to transform to get to 80% GHG reduction?
- What if we also plan to use some bioenergy?
- What are the electric supply needs?
- What impacts should we expect on the grid, and on consumers?
“Max Electric” case: 80% via electrification

GHG emissions 77% below 2001 levels by 2050 electrifying heat and on-road transport (get the rest from miscellaneous uses)

Electric consumption rises 55% from current levels

Markets need to transform fast

Residential Heat Pump Market

Electric Car & Light Truck Market
“Plausibly Optimistic” case: 69% from electrification

Res. HP market penetration: 5-15 years slower than “all-in” case

Need biogas/biofuels to get to 80% reduction

Light EV same through 2025, but slower after

Annual electric consumption rises 30% from current
Results vary by region: Minnesota example

- Accelerate energy efficiency (20%-33% reduction from the Reference case by 2050)
- By 2050:
  - Heat pumps provide 63%-75% of space and water heat
  - 89% of light-duty miles on electricity
- 80% GHG reduction from 2015 levels if electricity is 90+% zero-carbon
Shifting Northeastern seasonal load shape

- January consumption passes August in the mid-2030s
- Need new low-carbon electricity supplies, biased toward winter
- One grid challenge: Reach and integrate new variable supplies
Higher efficiency HPs have grid benefits

- Illustrative calculation indicates that higher-efficiency HPs can delay the region’s shift to winter peaking by 4-5 years
- Clustering on distribution system winter peaks sooner
- Potential for substantial T&D cost savings from winter EE
Future work

• What about other regions, climate zones, relative fuel prices, and electric emissions?
  • What about a two-week “arctic” period like we just had?
• How good do building shells need to be to allow heat pumps to shine for customers and be good citizens on the grid?
  • How much electrification before distribution circuits require upgrades?
• How will the grid and power supply meet the need for a very different seasonal load shape, supplied by low-carbon resources?
• What rates and incentive structures are best suited to move electrification markets at the pace required?
• What’s the relative cost-effectiveness of electrification vs. renewable gas?
Fuel Switching with Heat Pumps
Background

- Massachusetts state policies and regulations support strategic electrification
- The Cape Light Compact asked Synapse to assess the cost-effectiveness of fuel switching with heat pumps for the 2019-2021 Three-Year Energy Efficiency Plan
- Cape residents have limited access to natural gas
- Alternatives to oil, propane, and electric resistance heating systems
Conventional HVAC Options
Air Source Heat Pumps
### Scenarios for Heating Options

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keep Existing</td>
<td>- Keeps their existing system as supplemental heating</td>
</tr>
<tr>
<td>Replace-on-Failure</td>
<td>- Removes the existing heating system completely at the end of its useful life</td>
</tr>
<tr>
<td>Early Retirement</td>
<td>- Removes the existing heating system completely before the end of its useful life</td>
</tr>
</tbody>
</table>
**Fuel Types**

### Heating options

- Oil
- Electric
- Propane
  - Electric Baseline
  - Gas Baseline

### Cooling options

- ENERGYSTAR Central AC
- ENERGYSTAR Window AC
- Standard Central AC
- Standard Window AC
- No AC
- ccASHP
Heat Pump Performance

Source: Cadmus (2016), Ductless Mini-Split Heat Pump Impact Evaluation
Benefit Cost Analysis Framework

- **Total Resource Cost (TRC) test** - Massachusetts’ primary cost-effectiveness screening test for energy efficiency programs

- **Upfront Costs**
  - Incremental cost of a new heat pump

- **Key Benefit Costs**
  - Avoided cost of fossil fuels (heating)
  - Avoided cost of electricity (heating & cooling)
  - Avoided cost of generation capacity (cooling)
  - Avoided transmission and distribution (cooling)
  - DRIPE (demand reduction induced price effects) (heating & cooling)
## Cost Assumptions by Scenario

<table>
<thead>
<tr>
<th>Heat Pump Type</th>
<th>Incremental Cost ($ per site)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat pump (keep existing)</td>
<td>$0</td>
</tr>
<tr>
<td>2.5 ton</td>
<td></td>
</tr>
<tr>
<td>Heat pump (ROF)</td>
<td>$2,000</td>
</tr>
<tr>
<td>4 ton</td>
<td></td>
</tr>
<tr>
<td>Heat Pump (early retirement)</td>
<td>$4,000</td>
</tr>
<tr>
<td>4 ton</td>
<td></td>
</tr>
</tbody>
</table>

*Note: The chart shows the incremental cost comparisons for different heat pump options.*
Keep Existing and ROF Results

*We modeled both boilers and furnaces, but these results are specific to furnaces. Boilers were uniformly more cost-effective to replace.
Early Retirement - Benefits

- Benefits, Oil
- Benefits, Propane
- Benefits, Electric

Benefits (\$)

Age of Existing Equipment at Replacement
Early Retirement – Oil and Propane

Graph showing Benefit-Cost Ratio versus Age of Existing Equipment at Replacement for Oil and Propane with different baseline scenarios.
Early Retirement – Electric

- Electric Existing with Gas Baseline, Standard Central AC
- Electric Existing with Gas Baseline, ENERGYSTAR Central AC
- Electric Existing with Gas Baseline, Standard Window AC
- Electric Existing with Gas Baseline, No AC

Age of Existing Equipment at Replacement vs. Benefit-Cost Ratio
# Customer Payback Period

<table>
<thead>
<tr>
<th>Heating and Cooling Scenarios</th>
<th>Annual Bill Savings ($)</th>
<th>Payback Period without Incentive (Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating, ROF, Oil</td>
<td>$255</td>
<td>25+</td>
</tr>
<tr>
<td>Heating, ROF, Electric (Gas BL)</td>
<td>-$261</td>
<td>None</td>
</tr>
<tr>
<td>Heating, ROF, Propane</td>
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<td>9</td>
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<tr>
<td>Heating, Keep, Oil</td>
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<td>24</td>
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<tr>
<td>Heating, Keep, Electric</td>
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<td>4</td>
</tr>
<tr>
<td>Heating, Keep, Propane</td>
<td>$1,654</td>
<td>6</td>
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</tbody>
</table>
Questions?
webinar@synapse-energy.com
Want to team up with us?

Synapse provides:

- Economic and power system modeling
- Research and report writing
- Policy analysis and development
- Representation in voting and stakeholder committees
- Economic and technical analysis
- Expert witness services
- Regulatory support
- Facilitation and trainings
- Development of analytical tools
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Kenji Takahashi, ktakahashi@synapse-energy.com
Danielle Goldberg, dgoldberg@synapse-energy.com
Extra Slides
# Extra - Heating Costs and Savings

<table>
<thead>
<tr>
<th>Heating Scenario</th>
<th>Baseline System</th>
<th>Gross Annual Electricity Saved (kWh)</th>
<th>Gross Annual Fuel Saved (MMBtu)</th>
<th>Installed Cost: Baseline ($)</th>
<th>Installed Cost: ccASHP ($)</th>
<th>Total Resource Cost ($)</th>
<th>Replacement Discount Credit ($)</th>
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</thead>
<tbody>
<tr>
<td>Heating, ROF, Oil</td>
<td>Oil Baseline</td>
<td>(5,752)</td>
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<td>84</td>
<td>3,640</td>
<td>15,543</td>
<td>11,903</td>
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<tr>
<td>Heating, ROF, Electric (Gas BL)</td>
<td>Gas Baseline</td>
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<td>82</td>
<td>4,541</td>
<td>15,543</td>
<td>11,002</td>
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<td>Heating, ROF, Propane</td>
<td>Propane Baseline</td>
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<td>82</td>
<td>3,640</td>
<td>15,543</td>
<td>11,903</td>
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<tr>
<td>Heating, Keep, Oil</td>
<td>Oil Existing</td>
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<tr>
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<td>Oil Baseline</td>
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<td>84</td>
<td>3,640</td>
<td>15,543</td>
<td>15,543</td>
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<td>Heating, Early Retire, Replace, Oil (RE)</td>
<td>Oil Existing</td>
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<td>-</td>
<td>-</td>
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<tr>
<td>Heating, Early Retire, Replace, Electric (EE) (Gas BL)</td>
<td>Gas Baseline</td>
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<td></td>
<td>82</td>
<td>4,541</td>
<td>15,543</td>
<td>15,543</td>
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<td>Electric Existing</td>
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<td>Heating, Early Retire, Replace, Propane (EE)</td>
<td>Propane Baseline</td>
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<td>82</td>
<td>3,640</td>
<td>15,543</td>
<td>15,543</td>
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<tr>
<td>Heating, Early Retire, Replace, Propane (RE)</td>
<td>Propane Existing</td>
<td>(5,752)</td>
<td></td>
<td>90</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Cooling Scenario</th>
<th>Annual Consumption (kWh)</th>
<th>Incremental Savings to Heat Pumps (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Window AC (Standard)</td>
<td>445</td>
<td>301</td>
</tr>
<tr>
<td>Window AC (Energy Star)</td>
<td>404</td>
<td>260</td>
</tr>
<tr>
<td>Central AC (Standard), 2.5 ton</td>
<td>1,080</td>
<td>936</td>
</tr>
<tr>
<td>Central AC (Energy Star), 2.5 ton</td>
<td>745</td>
<td>601</td>
</tr>
<tr>
<td>Heat Pump</td>
<td>144</td>
<td>-</td>
</tr>
</tbody>
</table>
## Extra - Key Inputs

<table>
<thead>
<tr>
<th>Cooling System</th>
<th>Cooling Capacity (BTU/Hr)</th>
<th>EER/SEER (BTU/W·h)</th>
<th>EFLH (Equivalent Full Load Hours) (Hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling, Retire, Window (Standard)</td>
<td>10,000</td>
<td>9.8</td>
<td>218</td>
</tr>
<tr>
<td>Cooling, Retire, Window (ENERGY STAR)</td>
<td>10,000</td>
<td>10.8</td>
<td>218</td>
</tr>
<tr>
<td>Cooling, Retire, Central (Standard)</td>
<td>30,000</td>
<td>10.0</td>
<td>360</td>
</tr>
<tr>
<td>Cooling, Retire, Central (ENERGY STAR)</td>
<td>30,000</td>
<td>14.5</td>
<td>360</td>
</tr>
<tr>
<td>Heat Pump</td>
<td>14,680</td>
<td>22.3</td>
<td>218</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cooling System</th>
<th>Units/Household</th>
<th>Incremental Cost/Unit ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling, Retire, Window (Standard)</td>
<td>2</td>
<td>$</td>
</tr>
<tr>
<td>Cooling, Retire, Window (ENERGY STAR)</td>
<td>2</td>
<td>$</td>
</tr>
<tr>
<td>Cooling, Retire, Central (Standard)</td>
<td>1</td>
<td>$</td>
</tr>
<tr>
<td>Cooling, Retire, Central (ENERGY STAR)</td>
<td>1</td>
<td>$</td>
</tr>
<tr>
<td>Heat Pump</td>
<td>1</td>
<td>$</td>
</tr>
</tbody>
</table>
# Extra - Key Inputs

## Heat Pump Data - Single Family Application

<table>
<thead>
<tr>
<th></th>
<th>ccASHP + Existing System</th>
<th>ccASHP only System</th>
</tr>
</thead>
<tbody>
<tr>
<td>ccASHP size</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temp threshold for sizing ccASHP operation (F)</td>
<td>20.0</td>
<td>13.0</td>
</tr>
<tr>
<td>Manual S system size safety margin/buffer (%)</td>
<td>100%</td>
<td>130%</td>
</tr>
<tr>
<td>ccASHP capacity adjustment factor for a 47 F level (%)</td>
<td>120%</td>
<td>120%</td>
</tr>
<tr>
<td>ccASHP heating size with a size buffer (kBtu/h)</td>
<td>23.1</td>
<td>34.7</td>
</tr>
<tr>
<td>Peak heating load at temp threshold (kBtu/h)</td>
<td>23.1</td>
<td>26.7</td>
</tr>
<tr>
<td>ccASHP heating size at 47 F (kBtu/h)</td>
<td>27.8</td>
<td>41.8</td>
</tr>
<tr>
<td>ccASHP heating size at 47 F (ton)</td>
<td>2.5</td>
<td>4.0</td>
</tr>
<tr>
<td># of hours for supplemental heating operation</td>
<td>216.0</td>
<td>N/A</td>
</tr>
<tr>
<td>% supplemental heating operation</td>
<td>2.5%</td>
<td>N/A</td>
</tr>
<tr>
<td>Total load served by supplemental heating (MMBtu)</td>
<td>5.5</td>
<td>N/A</td>
</tr>
<tr>
<td>ccASHP efficiency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COP</td>
<td>3.1</td>
<td>3.0</td>
</tr>
<tr>
<td>ccASHP price</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ccASHP price per house</td>
<td>9,714</td>
<td>15,543</td>
</tr>
<tr>
<td>Heating load</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual heating load* (MMBtu)</td>
<td>70.0</td>
<td>70.0</td>
</tr>
<tr>
<td>Annual load served by ccASHP (MMBtu)</td>
<td>64.5</td>
<td>70.0</td>
</tr>
</tbody>
</table>