Advanced Rooftop Controller

Preliminary Seventh Power Plan Energy Efficiency Estimates

Conservation Resources Advisory Committee Meeting

December 17, 2014
Presentation Outline

- Advanced Rooftop Controller (ARC) measure background and definition
- High Level Summary of HVAC-related data in the Commercial Building Stock Assessment (CBSA)
- Measure data and preliminary potential estimates for the Seventh Plan
What is the Measure?

- Advanced Rooftop Controller (ARC) — a controller applied to single zone rooftop systems with constant speed fans
- Most commercial buildings are over-ventilated
  - Constant speed fans are set to run when the building is occupied
- The controller modulates the supply fan to reduce energy consumption
Overlap in 6P Measures

- The ARC measure may have some overlap with the following 6P Measures, and will be accounted for:
  - Rooftop Optimization and Repair
  - Demand Control Ventilation

<table>
<thead>
<tr>
<th>Sixth Plan Measure</th>
<th>aMW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand Control Ventilation-New</td>
<td>3</td>
</tr>
<tr>
<td>Demand Control Ventilation-NR</td>
<td>3</td>
</tr>
<tr>
<td>Demand Control Ventilation-Retro</td>
<td>19</td>
</tr>
<tr>
<td>Package Roof Top Optimization and Repair-New</td>
<td>4</td>
</tr>
<tr>
<td>Package Roof Top Optimization and Repair-NR</td>
<td>8</td>
</tr>
<tr>
<td>Package Roof Top Optimization and Repair-Retro</td>
<td>14</td>
</tr>
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</table>
# 7P Commercial Building Types

<table>
<thead>
<tr>
<th>Primary Activity</th>
<th>7P Building Type</th>
<th>Gross Floor Area in Square Feet</th>
<th>6P Building Type</th>
<th>Gross Floor Area in Square Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office</td>
<td>Large Office</td>
<td>&gt;50,000</td>
<td>Large Office</td>
<td>&gt;100,000</td>
</tr>
<tr>
<td>Office</td>
<td>Medium Office</td>
<td>5,000 to 50,000</td>
<td>Medium Office</td>
<td>20,000 to 100,000</td>
</tr>
<tr>
<td>Office</td>
<td>Small Office</td>
<td>&lt;5,000</td>
<td>Small Office</td>
<td>&lt; 20,000</td>
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<tr>
<td>Retail</td>
<td>Ex Large Retail</td>
<td>&gt;100,000</td>
<td>Big Box</td>
<td>&gt; 50,000</td>
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<tr>
<td>Retail</td>
<td>Large Retail</td>
<td>50,000 - 100,000</td>
<td>Small Box</td>
<td>&lt;50,000</td>
</tr>
<tr>
<td>Retail</td>
<td>Medium Retail</td>
<td>5000 - 50,000</td>
<td>High End</td>
<td>&lt; 20,000</td>
</tr>
<tr>
<td>Retail</td>
<td>Small Retail</td>
<td>&lt;5000</td>
<td>Anchor</td>
<td>&gt; 50,000</td>
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<tr>
<td>School</td>
<td>School K-12</td>
<td>Any</td>
<td>K-12</td>
<td>Any</td>
</tr>
<tr>
<td>School</td>
<td>University</td>
<td>Any</td>
<td>University</td>
<td>Any</td>
</tr>
<tr>
<td>Warehouse</td>
<td>Warehouse</td>
<td>Any</td>
<td>Warehouse</td>
<td>Any</td>
</tr>
<tr>
<td>Retail Food Sales</td>
<td>Supermarket</td>
<td>&gt; 5000</td>
<td>Supermarket</td>
<td>&gt; 5000</td>
</tr>
<tr>
<td>Retail Food Sales</td>
<td>MiniMart</td>
<td>&lt; 5000</td>
<td>MiniMart</td>
<td>&lt; 5000</td>
</tr>
<tr>
<td>Restaurant</td>
<td>Restaurant</td>
<td>Any</td>
<td>Restaurant</td>
<td>Any</td>
</tr>
<tr>
<td>Lodging</td>
<td>Lodging</td>
<td>Any</td>
<td>Lodging</td>
<td>Any</td>
</tr>
<tr>
<td>Health Care</td>
<td>Hospital</td>
<td>Any</td>
<td>Hospital</td>
<td>Any</td>
</tr>
<tr>
<td>Health Care</td>
<td>Residential Care</td>
<td>Any</td>
<td>OtherHealth</td>
<td>Any</td>
</tr>
<tr>
<td>Assembly</td>
<td>Assembly</td>
<td>Any</td>
<td>Assembly</td>
<td>Any</td>
</tr>
<tr>
<td>Other</td>
<td>Other</td>
<td>Any</td>
<td>Other</td>
<td>Any</td>
</tr>
</tbody>
</table>
**Floor Space by Building Type**

(Source: CBSA, excluding University and Hospitals)

**Total Regional Commercial Building Floor Area = 3,122 Million SF**

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Regional Floor Area (Million Sq Ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly</td>
<td>369</td>
</tr>
<tr>
<td>Food Service</td>
<td>53</td>
</tr>
<tr>
<td>Grocery</td>
<td>77</td>
</tr>
<tr>
<td>Lodging</td>
<td>171</td>
</tr>
<tr>
<td>Office</td>
<td>734</td>
</tr>
<tr>
<td>Residential Care</td>
<td>125</td>
</tr>
<tr>
<td>Retail</td>
<td>571</td>
</tr>
<tr>
<td>School</td>
<td>245</td>
</tr>
<tr>
<td>Warehouse</td>
<td>442</td>
</tr>
<tr>
<td>Other</td>
<td>333</td>
</tr>
</tbody>
</table>

*Units: Regional Floor Area (Million Sq Ft), % of row total*
Distribution System by Floor Area

Distribution System Type

- MZ VAV
- CV Reheat
- MZ Other
- SZ Ducted
- Water-source HP Loop
- Zonal

Million SF (region)

The ARC measure applies to these systems.
Cooling Equipment by SF

Cooled Floorspace by System Type

The ARC measure applies to these equipment types.
Fan Control Type

**Fan Control in SZ Ducted Systems**

- Constant Speed Fan: 35%
- Intermittent Fan: 60%
- Variable Speed: 5%

Legend:
- Blue: Constant Speed Fan
- Light Blue: Intermittent Fan
- Red: Variable Speed

Source: Northwest Power and Conservation Council
## RTU Systems by Size

### RTU Systems and Run Hours

<table>
<thead>
<tr>
<th>Size Category (tons)</th>
<th>Regional Units</th>
<th>Regional Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10</td>
<td>74,216</td>
<td>303,009,658</td>
</tr>
<tr>
<td>10-15</td>
<td>25,335</td>
<td>113,375,445</td>
</tr>
<tr>
<td>&gt;15</td>
<td>25,150</td>
<td>135,134,437</td>
</tr>
<tr>
<td>Grand Total</td>
<td>124,702</td>
<td>551,519,540</td>
</tr>
</tbody>
</table>
ARC-Applicable Units

Currently including only RTU and HP

But could apply to some MAU and AHU equipment also
Advanced Rooftop Controller (ARC) Retrofit: Field-Test Results

- The ARC measure is based primarily on the ARC Retrofit study conducted by Pacific Northwest National Laboratory.
- Study completed in 2013
Overview of the Study

- Pre and post measurements of 66 units in 8 different building types
- One-minute interval data over a 12-month period
- Four different US climate zones
- Controls alternated between standard (pre-retrofit mode) and advanced control modes on daily basis
- Methods per the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) Guideline 14
- 91% of the savings from this measure comes from fan energy savings
ARC Equipment

- At least one new variable frequency drive (VFD)
- One new digital controller
- One new damper actuator (or modified damper actuator that interfaces to the new controller)
- Multiple sensors (discharge-air temperature, return-air temperature, outdoor-air temperature, mixed-air temperature, space temperature, return air or space CO2, power, etc.)
- The ability to access the RTU (or network of RTUs) via a web interface
- A variety of other components, depending on the vendor
Savings Components

- There are four primary components to the ARC savings:
  - Supply Fan Speed Controls (approximately 91% of total savings)
  - Integrated Air-side Economizer Controls
  - Cooling Capacity Controls
    - Simple on/off, and staged cooling
  - Demand-Controlled Ventilation Controls
    - Return-air CO2
## ARC Measure Savings

### Measure Savings Data from PNNL Report

<table>
<thead>
<tr>
<th>Size Category</th>
<th>Equipment Type</th>
<th>Rate (kWh/h)</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10</td>
<td>RTU Capacity &lt;10 tons</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>10-15</td>
<td>RTU Capacity 10-15 tons</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>&gt;15</td>
<td>RTU Capacity &gt;15 tons</td>
<td>4.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>AC Units (gas heat)</td>
<td>2.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HP Units</td>
<td>1.75</td>
<td></td>
</tr>
</tbody>
</table>

Average Savings across all sites: 515 Wh/h/hp
## ARC Measure Costs

<table>
<thead>
<tr>
<th>RTU Capacity (tons)</th>
<th>Supply Fan Size (hp)</th>
<th>Controller ($)</th>
<th>Controller Labor ($)</th>
<th>Total ($)</th>
<th>$/hp</th>
<th>$/ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤5</td>
<td>1</td>
<td>2,200</td>
<td>750</td>
<td>2,950</td>
<td>2,950</td>
<td>1,180</td>
</tr>
<tr>
<td>&gt; 5 and ≤ 10</td>
<td>2</td>
<td>2,600</td>
<td>750</td>
<td>3,350</td>
<td>1,675</td>
<td>447</td>
</tr>
<tr>
<td>&gt; 10 and ≤ 15</td>
<td>3</td>
<td>3,500</td>
<td>750</td>
<td>4,250</td>
<td>1,417</td>
<td>340</td>
</tr>
<tr>
<td>&gt; 15 and ≤ 20</td>
<td>5</td>
<td>4,000</td>
<td>750</td>
<td>4,750</td>
<td>950</td>
<td>271</td>
</tr>
<tr>
<td>&gt; 20 and ≤ 25</td>
<td>7.5</td>
<td>4,142</td>
<td>750</td>
<td>4,892</td>
<td>652</td>
<td>217</td>
</tr>
</tbody>
</table>
## Initial, High Level Technical Potential Estimate

<table>
<thead>
<tr>
<th>Size Category</th>
<th>Regional Units</th>
<th>Regional Hours (millions)</th>
<th>Savings (kWh/hr)</th>
<th>Regional Tech Savings (aMW)</th>
<th>Cost Per Unit ($)</th>
<th>Total Cost (million $)</th>
<th>Levelized Cost ($/MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10</td>
<td>74,200</td>
<td>303</td>
<td>1.00</td>
<td>35</td>
<td>3,150</td>
<td>234</td>
<td>69</td>
</tr>
<tr>
<td>10-15</td>
<td>25,300</td>
<td>113</td>
<td>1.80</td>
<td>23</td>
<td>4,250</td>
<td>108</td>
<td>47</td>
</tr>
<tr>
<td>&gt;15</td>
<td>25,200</td>
<td>135</td>
<td>4.20</td>
<td>65</td>
<td>4,821</td>
<td>121</td>
<td>19</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>124,700</strong></td>
<td><strong>552</strong></td>
<td><strong>123</strong></td>
<td></td>
<td><strong>463</strong></td>
<td><strong>39</strong></td>
<td></td>
</tr>
</tbody>
</table>

Gray cells are data from CBSA, red text are data from PNNL report
Levelized cost of PNNL test sites is $24.32/MWh
Saturation and Applicability

- Single-zone, ducted systems, RTU and HP, constant speed fans
- 85% achievability
- Possibly use only the fan energy portion (91%)
  - The other 9% is climate dependent
  - However, PNW has high share of electric heat, so recommend keeping it
- Achievable potential: 104 aMW
  - Final number will change slightly as applicability and saturations are applied in more detail (e.g., building type)
Questions

- Use 100% or 91%?
  - The PNNL study found that 91% of the savings is from fan energy
  - The remainder is from economizer, heating, and cooling savings
    - These are more climate-dependent savings and we don’t have enough data to disaggregate these

- Measure life – 15 years?
Next Steps

- Finalize workbooks
- New construction? Covered by codes
- Consider “Catalyst lite”?  
  - Half the cost
  - Only fan controls
  - Primarily applies to smaller systems
- Incorporate comments and reviewer feedback
Supplemental Slides