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• Mini-Split & Multi-Split
• Ground-Source Heat Pumps
• Single-Package Units
• Split-System Units

Commercial
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• **Variable Refrigerant Flow Multi-Splits**
• Split-System Units
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• Applied Air Conditioning Equipment, Chillers, etc.
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US Fraction of Heat Pumps in Total AC and HP Shipments, by Year

Percentage of air/ground source heat pumps

Source: US Census, 2017 Characteristics of New Housing, 2018
US Manufacturer’s Shipments of Unitary Central Air Conditioners, Unitary Heat Pumps, Oil and Natural Gas Furnaces

Source: AHRI

Source: AHRI
Geothermal HP Shipments

Sources: Shipments/installations through 2009 are based on data from the US Energy Information Administration (EIA). For 2010-2015 shipments were estimated based on Energy Star unit shipment and market penetration reports.
Central AC and ASHP Shipment

U.S. Manufacturers’ Shipments of Central Air Conditioners and Air-Source Heat Pumps by Size

Size (kBtu) & Size (kW)

Millions

1998 2003 2008 2013 2018

Sources: AHRI
Total installed costs and typical capacities

**Residential Space Heating**
- **Heat Pump Technologies**: Different cost ranges with typical capacities varying from 0 to 150 kBtu/h.
- **Other Technologies**: Cost ranges and typical capacities.

**Commercial Space Heating**
- **Heat Pump Technologies**: Cost and capacity details.
- **Other Technologies**: Cost and capacity details.

**Residential Water Heating**
- **Heat Pump Technologies**: Cost and capacity details.
- **Other Technologies**: Cost and capacity details.

**Commercial Water Heating**
- **Heat Pump Technologies**: Cost and capacity details.
- **Other Technologies**: Cost and capacity details.

Maintenance cost and average life

Financial Incentives for Heat Pumps

- Sales Tax Incentive Rebate Program
- Property Tax Incentive
- Personal Tax Deduction
- Personal Tax Credit
- PACE Financing
- Loan Program
- Leasing Program
- Industry Recruitment/Support
- Green Building Incentive
- Grant Program
- Corporate Tax Deduction
- Corporate Tax Credit
- Corporate Depreciation
- Bond Program
- Utility Rate Discount
- Performance-Based Incentive
- Other Incentive

Federal
State and Utilities

607 programs
143 programs
Regulatory Policies

- Renewables Portfolio Standard
- Public Benefits Fund
- Energy Standards for Public Buildings
- Energy Efficiency Resource Standard
- Solar/Wind Access Policy (includes geothermal access)
- Other Policy
- Green Power Purchasing
- Appliance/Equipment Efficiency Standards
- Building Energy Code

Federal
State and Utilities
DOE’s Partners for Heat Pump R&D

- National laboratories, academia, small businesses, manufacturers, and other industry stakeholders
  - To advance technology R&D and commercialization
- Standards and certifying bodies and technical organizations (e.g., ASHRAE, AHRI)
  - To help accelerate market acceptance

**R&D of heat pumping technologies**

- Heating, Ventilation, Air Conditioning/Water Heating/Appliances Sub-Program

**Partnering Programs within DOE’s Building Technology Office**

- Windows and Building Envelope Sub-Program
  - To reduce heating and cooling energy consumption
- Residential and Commercial Building Integration Programs
  - To bridge the gap from technology commercialization to broad market acceptance
- Building Codes and Appliance and Equipment Standards Programs
  - To identify equipment or appliances that require further R&D support
  - To facilitate development of appropriate codes and standards.
Refrigerant Policies

• The US has not signed-on to the Paris Accord / 2016 Kigali Agreement

• The US Environmental Protection Agency (EPA) is not currently pursuing further de-listing of HFCs through the Significant New Alternatives Policy (SNAP).

• Some states are considering legislating to reduce the use of HFCs in new HVAC equipment. California is the only state, so far, with laws in-place.
Efficiency Trends

• 1979 was first appearance of the Seasonal Energy Efficiency Ratio (SEER) for air conditioning equipment.

• Beginning in 1992, the US Department of Energy established minimum efficiency requirements for many classes of consumer products including air conditioners and heat pumps.

• Minimum 10 SEER for AC took effect Jan. 1992

• Minimum 13 SEER for AC took effect Jan. 2006

• Regional Minimums took effect in July 2016
  • 14 SEER for South and Southwest
  • 13 SEER for remainder of country
Advancing Technologies

- Proliferation of “communicating” controls (Internet of Things)
- New generation refrigerants with lower GWP
- Research supporting Codes and Standards for “A2L” refrigerants
- Incorporation of refrigerant and airflow modulation
- Improvement of HP low-temperature performance
Trends

• Development of AC made southern latitudes more habitable

• Population growth rate has been greatest in “sunbelt” states – good climate for heat pumps

• Research on improving heat pump performance for colder climates

• Transition to Lower GWP refrigerants and responding to higher efficiency minimums are challenging the US HVAC industry

• “Internet Generation” has different expectations about HVAC
Thank You!

Contact Info:

Melissa V. Lapsa
Oak Ridge National Laboratory
lapsamv@ornl.gov
Appendix. standard and efficiency


<table>
<thead>
<tr>
<th>Residential ASHP</th>
<th>Current Federal Minimum Efficiency Standards</th>
<th>Current ENERGY STAR Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min. SEER</td>
<td>Min. HSPF</td>
</tr>
<tr>
<td>Split-System</td>
<td>14</td>
<td>8.2</td>
</tr>
<tr>
<td>Single-Package</td>
<td>14</td>
<td>8</td>
</tr>
<tr>
<td>Small-Duct, High Velocity</td>
<td>12</td>
<td>7.2</td>
</tr>
<tr>
<td>Space-Constrained</td>
<td>12</td>
<td>7.4</td>
</tr>
</tbody>
</table>

Note:
- Units for SEER, HSPF and EER are in Btu/Wh (divide by 3.412 to get equivalent dimensionless values).
- For split-system air conditioners (cooling only), the minimum SEER increased to 14 in southern climate regions, while the 13 SEER standard established in 2006 remained effective in the north. Whereas, for split-system ASHPs, the minimum SEER increased to 14 and the minimum HSPF increased to 8.2 in all climate regions.

Table A-4. ENERGY STAR Criteria for Water-to-air Ground Source Heat Pumps

<table>
<thead>
<tr>
<th>Type</th>
<th>Heating COP</th>
<th>Cooling EER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Closed Loop</td>
<td>3.6</td>
<td>17.1</td>
</tr>
<tr>
<td>Open Loop</td>
<td>4.1</td>
<td>21.1</td>
</tr>
<tr>
<td>Direct Expansion</td>
<td>3.6</td>
<td>16</td>
</tr>
</tbody>
</table>
**Appendix.** standard and efficiency


<table>
<thead>
<tr>
<th>Volume Range</th>
<th>Draw Pattern</th>
<th>Federal Standard</th>
<th>Federal minimum UEF for typical sizes</th>
<th>ENERGY STAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 20 gal and ≤ 55 gal</td>
<td>Very Small</td>
<td>UEF=0.8808-(0.0008*Gal)</td>
<td>No models on the market</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>UEF=0.9254-(0.0003*Gal)</td>
<td>0.91 for a 27-gallon water heater</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>UEF=0.9307-(0.0002*Gal)</td>
<td>0.92 for a 36-gallon water heater</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>UEF=0.9349-(0.0001*Gal)</td>
<td>0.93 for a 45-gallon water heater</td>
<td>2.0</td>
</tr>
<tr>
<td>&gt; 55 gal and ≤ 120 gal</td>
<td>Very Small</td>
<td>UEF=1.9236-(0.0011*Gal)</td>
<td>No models on the market</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>UEF=2.0440-(0.0011*Gal)</td>
<td>No models on the market</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>UEF=2.1171-(0.0011*Gal)</td>
<td>2.03 for a 77-gallon water heater</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>UEF=2.2418-(0.0011*Gal)</td>
<td>2.15 for a 82-gallon water heater</td>
<td>2.2</td>
</tr>
</tbody>
</table>

**Notes:**

- Standards for residential electric storage WH also apply to integrated HPWH.
- Federal standards that came into effect in April 2015 effectively mandate heat pump technology for electric storage water heaters with storage volume > 55 gallons. Thus, the standards for the >55-gallon range and all ENERGY STAR levels are only achievable through heat pump technology.

<table>
<thead>
<tr>
<th>Cooling Capacity (kBtu/h)</th>
<th>Heating Type</th>
<th>Federal Standard Effective 1/1/2010</th>
<th>ENERGY STAR version 2.2 Effective 1/1/2011</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min. EER</td>
<td>Min. COP at 47°F</td>
</tr>
<tr>
<td>Small (≥ 65 and &lt; 135)</td>
<td>Electric resistance or none</td>
<td>11.0</td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td>Any other type</td>
<td>10.8</td>
<td>3.3</td>
</tr>
<tr>
<td>Large (≥ 135 and &lt; 240)</td>
<td>Electric resistance or none</td>
<td>10.6</td>
<td>3.2</td>
</tr>
<tr>
<td></td>
<td>Any other type</td>
<td>10.4</td>
<td>3.2</td>
</tr>
</tbody>
</table>

Note:
- This values in this table are for air-cooled commercial packaged rooftop heat pumps. There are different standards for many other types of commercial heat pumps.
- In 2018, the DOE-regulated metric switched from EER to IEER, and the minimum IEER for ASHPs with electric resistance or no heating system and any other type (e.g., heat pump) are set at 12.2 and 12.0, respectively, for small capacity systems and 11.6 and 11.4 for large capacity systems. They are effective until 2022.