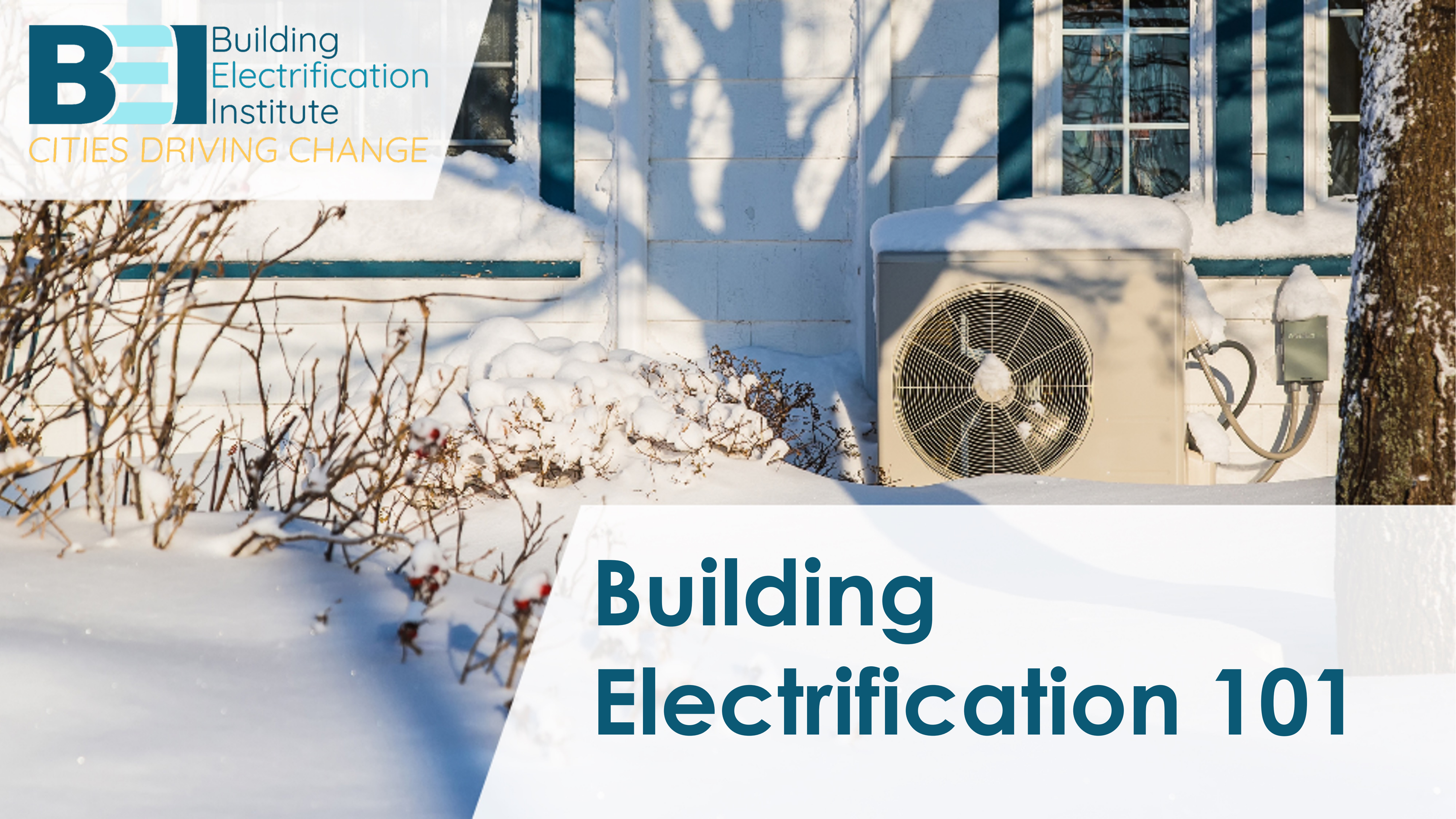
Building Electrification Institute

CITIES DRIVING CHANGE



Building Electrification 101

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What is Building Electrification?

- Building electrification includes **converting fossil fuel building systems to high-efficiency electric equipment**, which can use increasingly renewable power.
- It also includes **converting inefficient electric heating technologies** to high-efficiency electric technologies.

Fossil fuel technologies: furnace, gas hot water heater, gas range

Heat pump technologies: Heat pump water heater, mini-split, ducted heat pump

What are Building Electrification Technologies?

Primary building electrification technologies

Space heating and cooling

Air source heat pumps

Hot water heating

Heat pump water heater

Cooking

Electric cooktops

Other complementary technologies

Energy efficiency

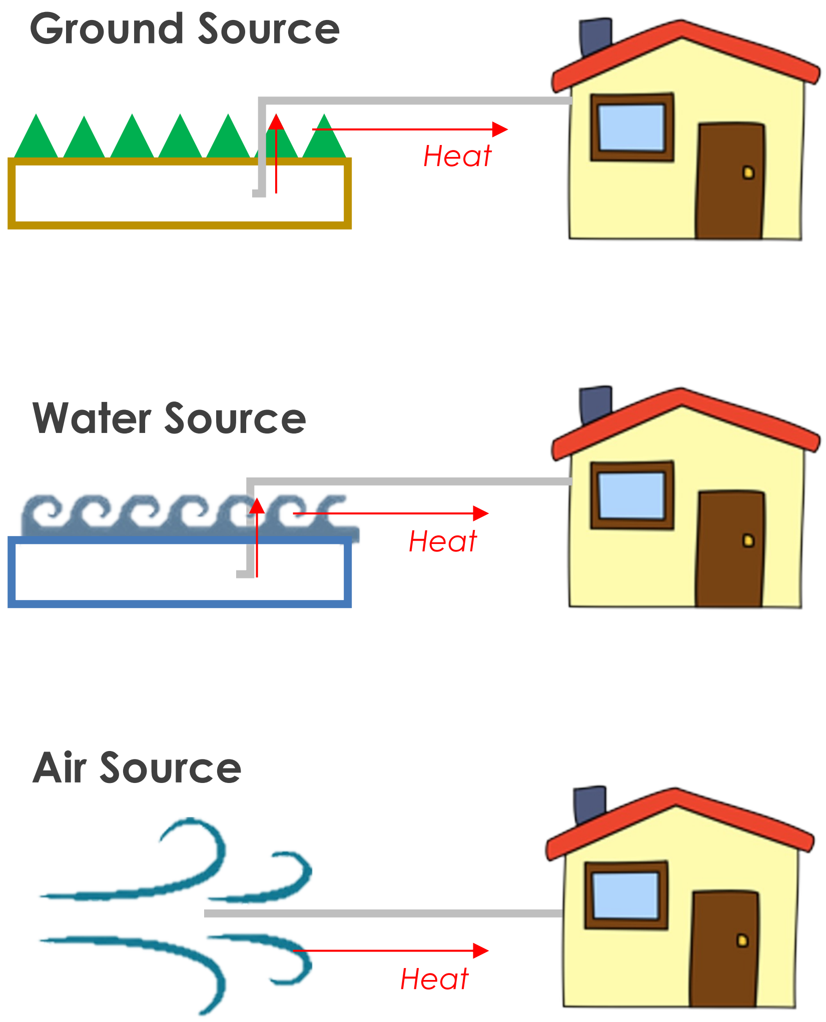
On-site Solar PV

Smart controls

Ground source heat pumps

What is a Heat Pump?

- **Heat pumps use electricity to pump heat from outside into an indoor space.**
  - There is heat in the outdoor air, water, and the ground, even in the winter.
  - Heat pumps transfer heat rather than create it, which makes them operate at very high efficiencies.
- **Heat pumps are not a new technology.**
  - Refrigerators use a similar process to transfer heat.
  - About 12 million heat pumps are already installed in U.S. homes.
  - Heat pumps have 80%+ HVAC market share in Asia.

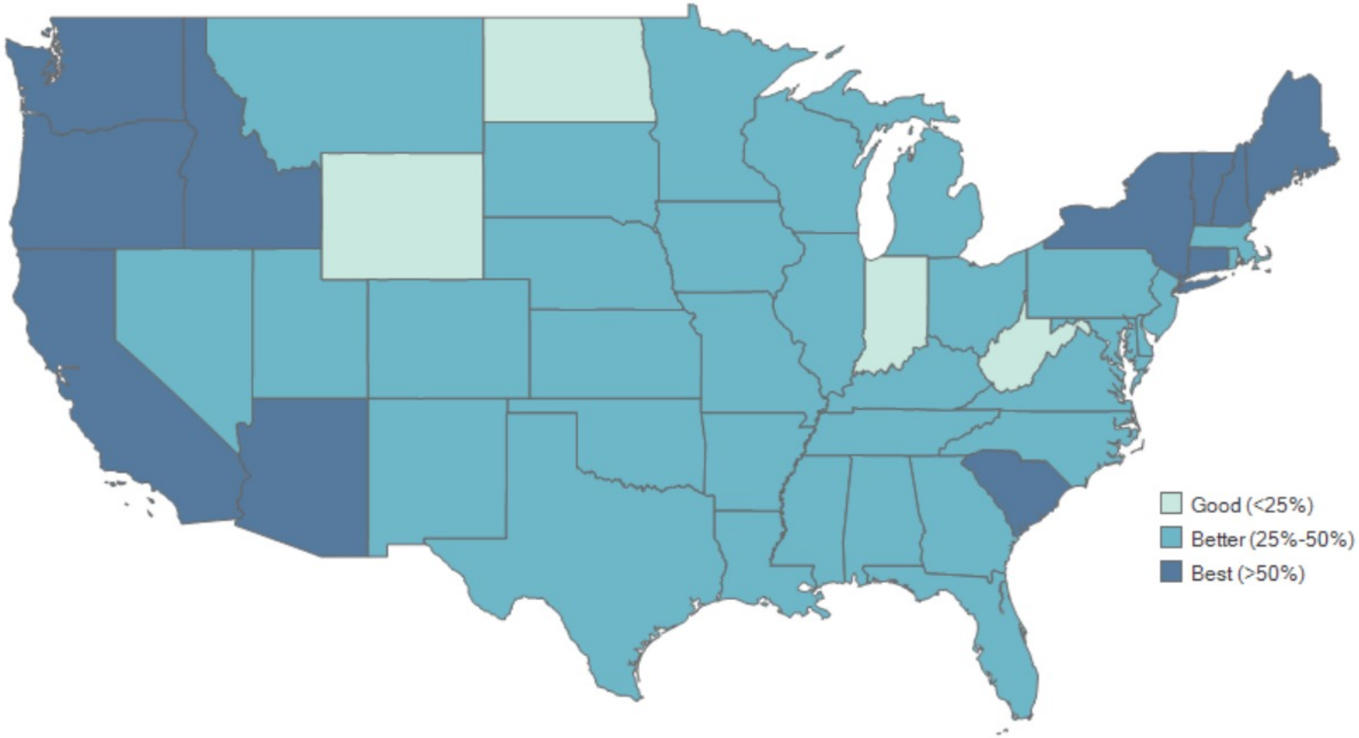


Sources: (1) EIA, *Residential Energy Consumption Survey, Space Heating*, 2015; (2) Mitsubishi Electric, *32 Years of Leadership in Providing Unique Solutions for the HVAC Market*, 2005/2007.

How Does a Heat Pump Reduce GHG Emissions?

- **Heat pumps can achieve efficiencies of well over 200%.**
  - Cold climate air source heat pumps can operate at between 200-300% efficiency even in very cold temperatures.
- **Heat pumps also use electricity, which across the U.S. is becoming increasingly clean and renewable.**
  - Heat pumps reduce GHG emissions in every state in the U.S. today except for Wyoming.*
  - Emissions will be reduced further as the grid becomes increasingly powered by renewables.

Average Household GHG Reduction from Replacing Gas Space and Water Heating with Heat Pumps over Lifetime of the Appliance



Sources: (3) RMI, *Emissions Impact by State, Heat pumps vs. Gas Furnace*; (4) Sierra Club, *New Analysis: Heat Pumps Slow Climate Change in Every Corner of the Country*, 2021.
*Note: Results in Utah are pending policy change.

Where Are We Now?

- **About 12% of homes in the U.S. currently use heat pumps for heating.**
- **In the U.S., heat pumps are more prevalent:**
  - In new construction
  - In milder and/or more humid climates
  - To provide supplemental heating and/or cooling
- **Heating and hot water systems are only replaced every 10-30 years.**
  - Existing equipment may be replaced only 1-2 times before 2050.
  - Replacements typically happen at the time of equipment failure.

Source: (1) EIA, *Residential Energy Consumption Survey, Space Heating*, 2015.

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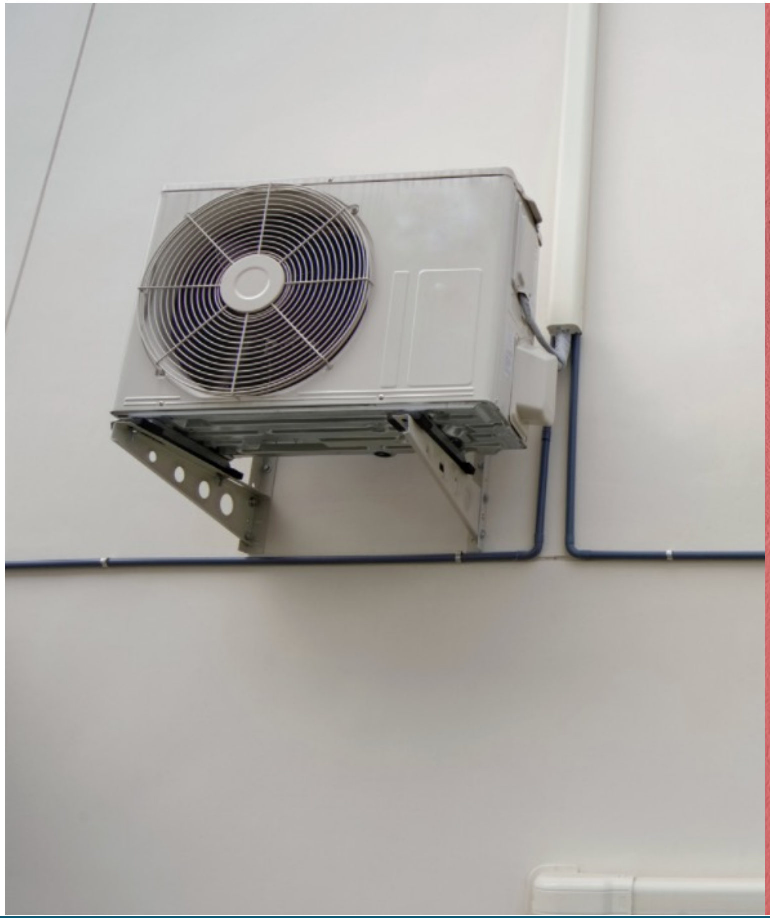
Air Source Heat Pumps | What are they?

- **Air source heat pumps transfer heat from the outside air into a building to provide heating** and do the reverse to provide cooling.

- Compared to ground and water source heat pumps, air source heat pumps are:
  - Less expensive
  - Often more appropriate in dense urban environments

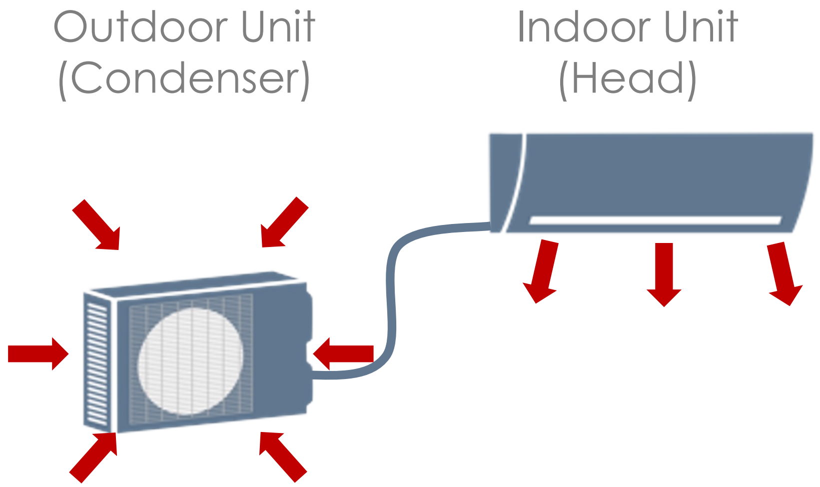
Outdoor Unit (Condenser)



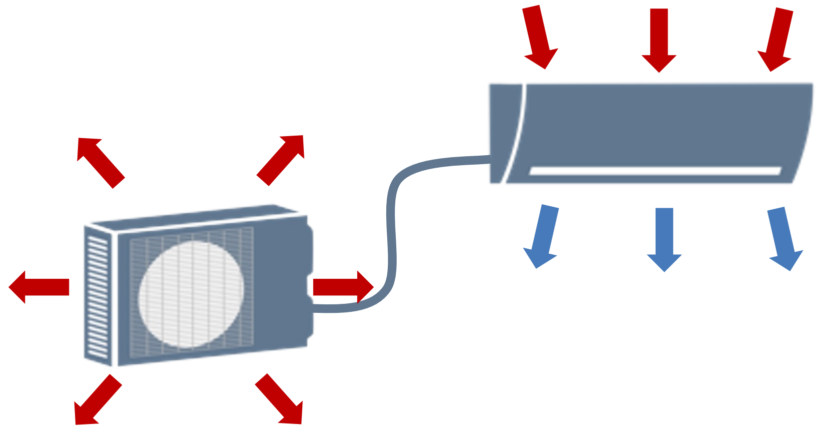
Indoor Unit (Head)

Air Source Heat Pumps | How do they work?

Two modes of operation:



Winter: Absorbs heat from outdoor air and moves it indoors to provide heating



Summer: Absorbs heat from indoors and moves it outdoors to provide cooling (like an air conditioner)

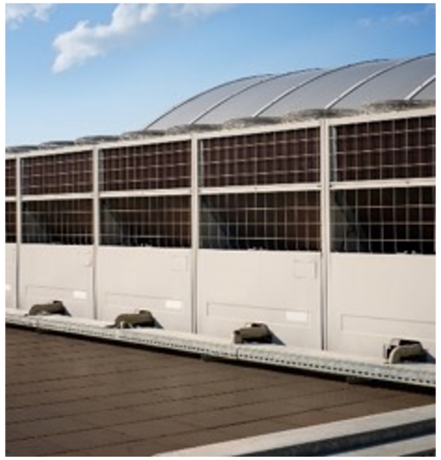
Air Source Heat Pumps | Available Options

- **Centrally Ducted Heat Pumps:** Outdoor unit connects to a building's existing ductwork, similar to a furnace or central air conditioner.
- **Ductless Heat Pumps:** Outdoor unit connects to individual indoor units; sometimes also referred to as a ductless "mini-split."
- **Variable Refrigerant Flow (VRF):** Large systems that can provide simultaneous heating and cooling; sometimes also referred to as Variable Refrigerant Volume (VRV).
- **Packaged Terminal Heat Pumps:** Outdoor and indoor units that are installed together; applications generally found in multifamily buildings and hotels.

Centrally Ducted Heat Pump

Ductless Mini-split

Variable Refrigerant Flow (VRF)



Packaged Terminal Heat Pump

Air Source Heat Pumps | Benefits

- **Energy reduction**
- GHG emissions reduction
- Improved comfort
- High flexibility
- Improved air quality
- Potential cost savings

Fossil fuel furnaces

~80% efficient

Electric Resistance

~100% efficient

Air Source Heat Pumps

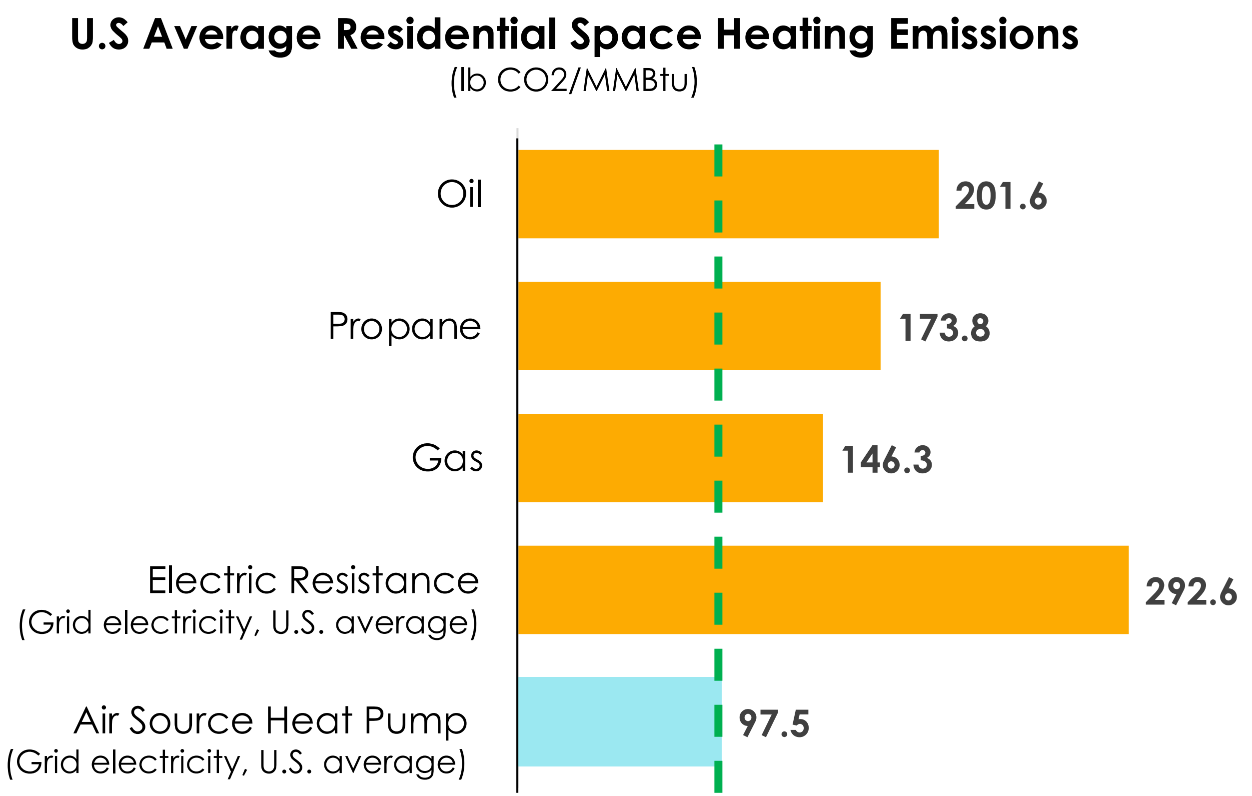
~300-400% efficient

- ASHPs require significantly less energy to provide the same amount of heat.
- They can be over 100% efficient because they transfer heat instead of generating it.

Air Source Heat Pumps | Benefits

- Energy reduction
- **GHG emissions reduction**
- Improved comfort
- High flexibility
- Improved air quality
- Potential cost savings

On average, ASHPs emit significantly less GHG emissions than oil, propane, gas, and electric resistance heating systems in the U.S.



Source: BEI Internal Analysis
Assumptions: US eGrid emission factors; AFUE of 80% for fossil fuel, COP of 3 for ASHP, no duct losses assumed.

Air Source Heat Pumps | Benefits

- Energy reduction
- GHG emissions reduction
- **Improved comfort**
- High flexibility
- Improved air quality
- Potential cost savings

- Provides both heating and cooling
- Zoning allows for different temperatures in different rooms
- Dehumidifies indoor air

Air Source Heat Pumps | Benefits

- Energy reduction
- GHG emissions reduction
- Improved comfort
- **High flexibility**
- Improved indoor air quality
- Potential cost savings

Location: Can use ducts or be mounted on the floor or ceiling

Space coverage: Could heat and cool a few rooms or a whole building

Air Source Heat Pumps | Benefits

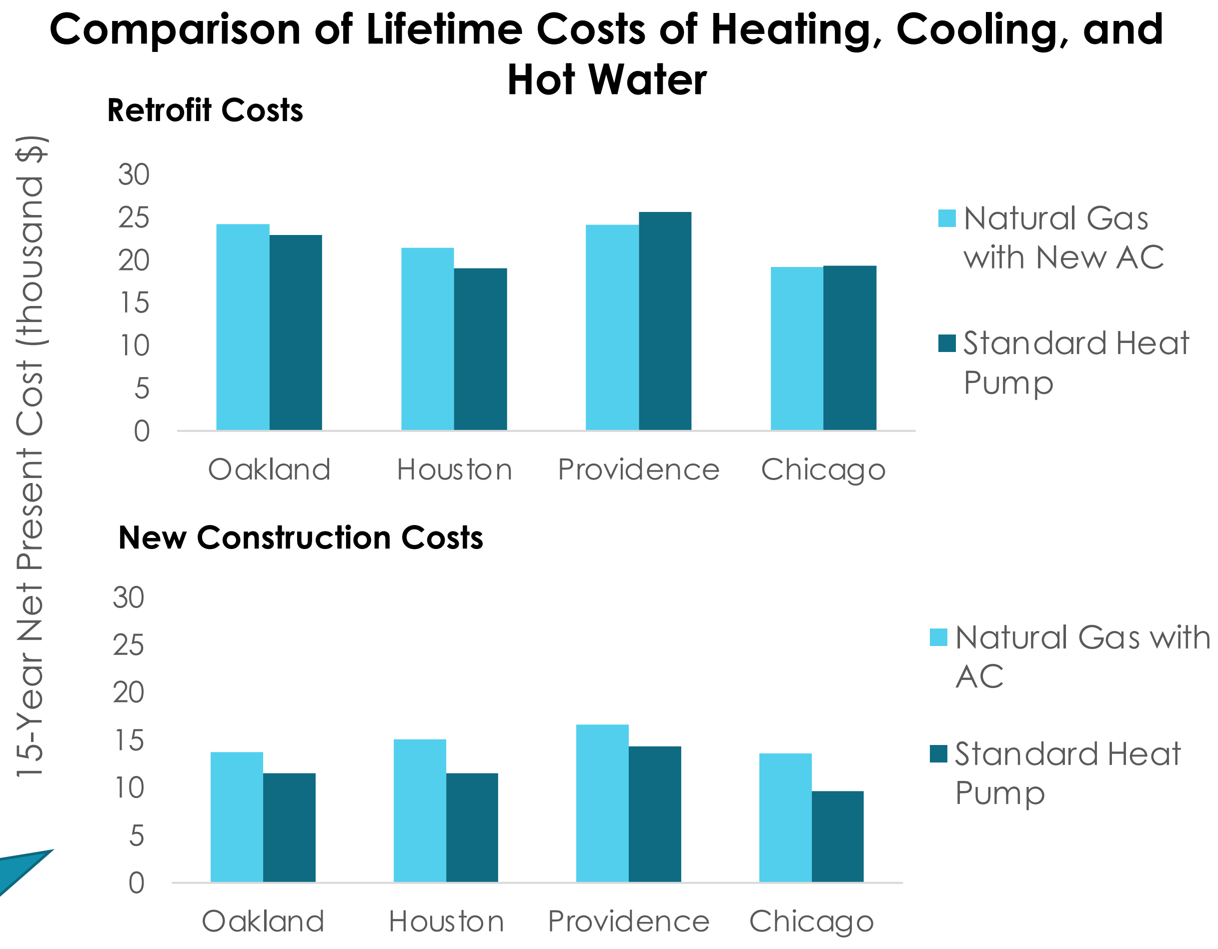
- Energy reduction
- GHG emissions reduction
- Improved comfort
- High flexibility
- **Improved air quality**
- Potential cost savings

ASHPs reduce NOx, carbon monoxide, and other indoor and outdoor air pollutants from fossil fuel combustion

Air Source Heat Pumps | Benefits

- Energy reduction
- GHG emissions reduction
- Improved comfort
- High flexibility
- Improved air quality
- **Potential cost savings**

In California, building new single family homes all-electric saves $1,500 to $6,000 in construction, and $4,000-10,000 on utility bills for homeowners over 20 years.



Air Source Heat Pumps | Common Concerns

Costs

- **Installation costs for ASHPs are often higher than fossil fuel systems,** such as furnaces or boilers.
  - Installation costs can range from $3,000-$5,000 or more per zone (or room).
  - Costs can also vary widely based on building layout, specific technologies, and labor costs.
  - Other upgrades may also be needed, such as insulation or electrical panel capacity, particularly in older homes.
- **Heat pumps may not always lead to energy savings compared to gas systems,** which is dependent on the local climate and utility rates.

Source: (7) Navigant, *Ductless Mini-Split Heat Pump Cost Study*. 2018.

Air Source Heat Pumps | Common Concerns

System Performance

- **Heating efficiency can drop in very cold temperatures, although performance has improved significantly** in recent years.
    - Cold climate ASHPs can now provide heat at high efficiencies down to -13°F.
    - In some cases, integration with the existing system for backup heat may still be a good option for the coldest climates.
- **Contractors must be trained** to perform high quality installations.
- **Heat pumps should be run continuously to achieve high efficiencies**, unlike furnaces or boilers.

Air Source Heat Pumps | Common Concerns

Refrigerant Leakage

- **Refrigerants are fluids found in many technologies,** including refrigerators and air conditioners.
- **If they leak, refrigerants have high global warming potential (GWP)** and can contribute significantly to climate change.
- **Preventing leaks requires proper maintenance and disposal of systems**. Longer lines of refrigerants (such as in VRFs) have a higher risk of leakage.
- Advancements under the Montreal Protocol will result in lower GWP refrigerants by 2050.

GHG Emissions from Mixed Fuel and All-electric Home in Sacramento

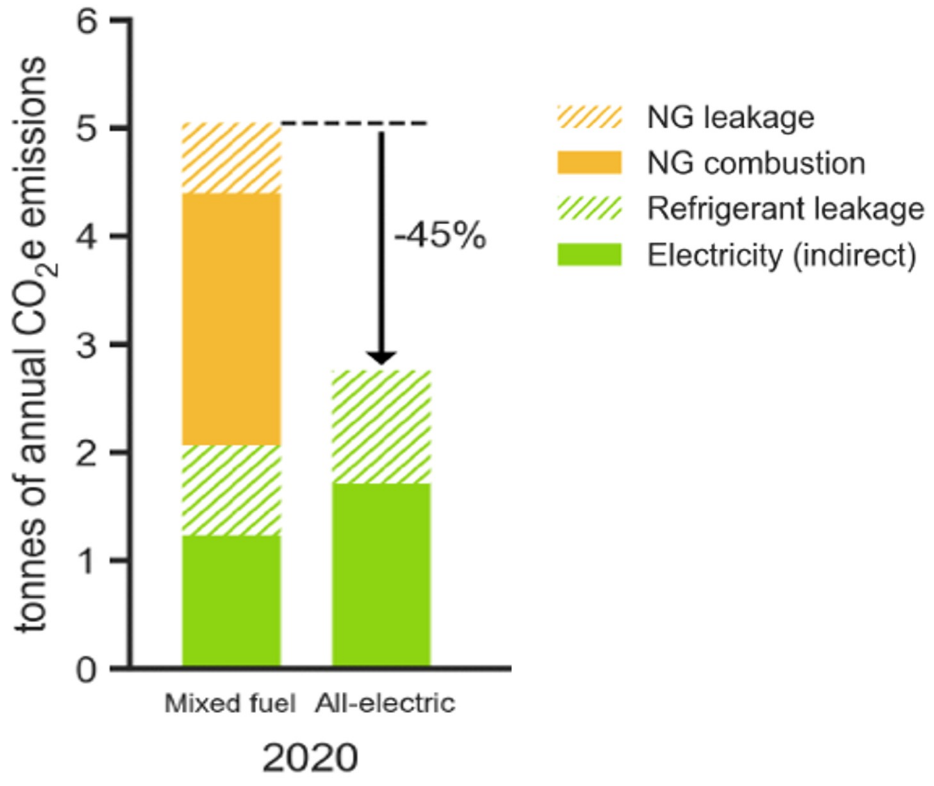


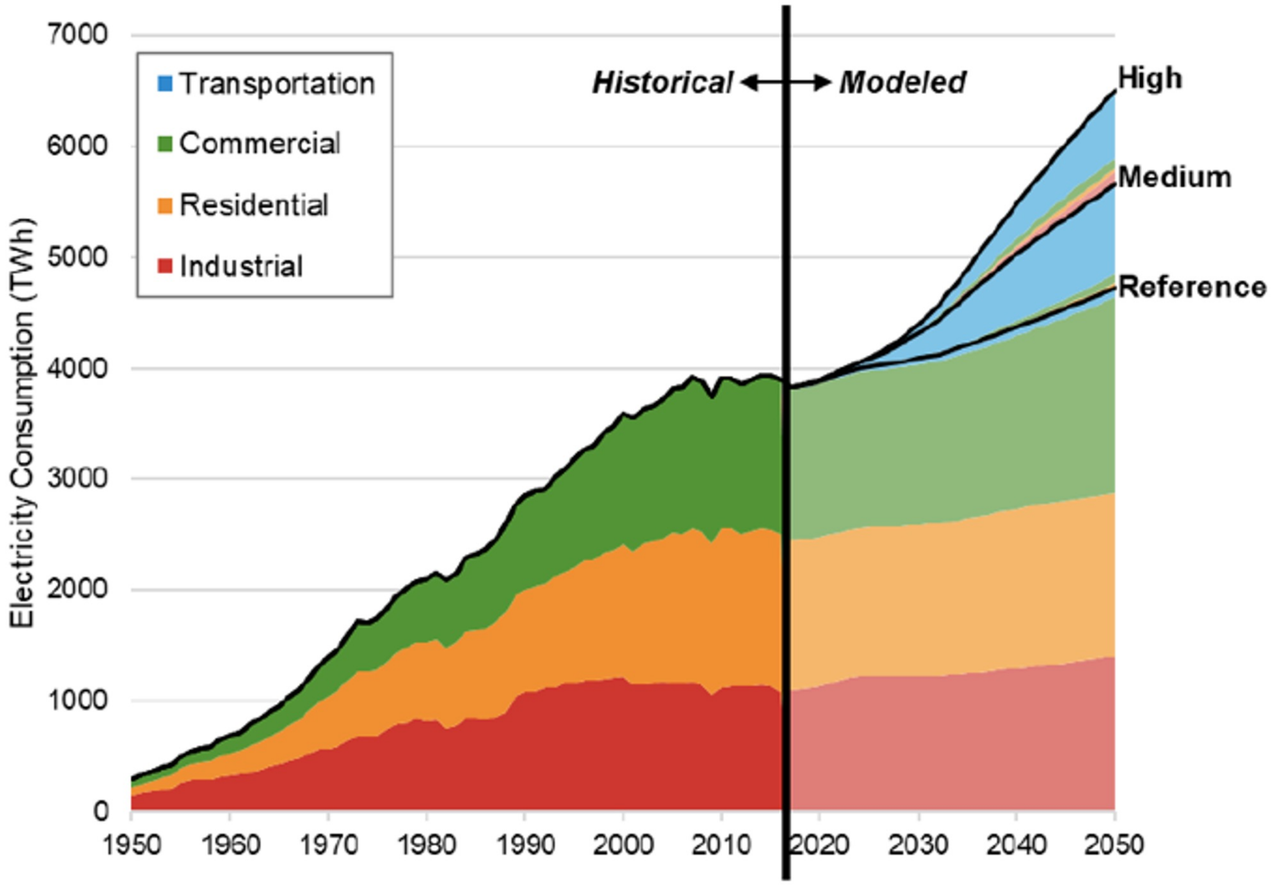
Chart Source: (8) E3, *Residential Building Electrification in California*, 2018

Air Source Heat Pumps | Common Concerns

Energy Infrastructure

- **Electrification will lead to more electric consumption** and potentially higher peak loads to manage, but most of the increase is from electrified transportation rather than buildings.
- **Heat pumps combined with energy storage could provide more flexible loads** and help manage energy infrastructure and peak loads.
- With high levels of electrification, **there are open questions about how to manage the operations and costs of the remaining gas infrastructure.**

Historical and Projected Annual Electricity Consumption



Source: (9) National Renewable Energy Laboratory, *Electrification Futures Study*, 2018

Air Source Heat Pumps | Common Concerns

Applications in Large Building Retrofits

- ASHPs may require a substantial increase in electrical load.
- Ductless ASHPs and VRFs may also require new or retrofitted ventilation systems.

In multifamily buildings:

- Space needed for outdoor units (patios, wall mounted, rooftop)
- Smaller living spaces require smaller ASHPs and/or engineered solutions to distribute heat

In commercial buildings:

- Limited cold climate options available to support commercial building cooling loads

Image Source: ACHR News.

Air Source Heat Pumps | Installation

Installation Best Practices

- Work with installers and electricians that have certification from manufacturers or other third parties.
- Weatherize homes first in colder climates.
- Add on-site solar or other renewable energy generation to reduce costs and GHG emissions.
- Evaluate replacement vs. displacement options.

Replacement	Displacement
Serves as the sole source of heating and cooling	Supplements existing system, displacing fossil fuel heating
Costs more to install	Lower first cost
May not be suitable in particularly cold areas	Requires maintaining a backup heating system

Getting The Most Out of Your Heat Pump

Your cold-climate heat pump can save a lot on heating and cooling costs. Whether your heat pump is ductless or centrally ducted, this new technology is different than the conventional heating and air conditioning systems that you're probaly used to. These tips will help you get the best comfort and the most savings for years to come.

Ductless Users! Maximize the use of your heat pump

If you have ductless indoor units, use them to heat as much of your house as possible in order to increase your savings!

Set the ductless heat pump thermostat for comfort

- Don't worry too much about the specific numbers.
- You may find it comfortable to set it higher in colder weather; that's OK!
- It's also OK to overheat one room a bit, to help heat more of the house.

If you are keeping your existing heating system as a backup, use it only when needed:

- Turn the thermostat for your existing heating system down 5-10 degrees lower than the usual setting to make the ductless heat pump your primary heating source.
- When the weather is very cold, you may need to turn up your backup slightly.
- Try to keep the doors open to rooms without the ductless unit, allowing the heat pump's heat to circulate as much as possible.

Settings are the Key to Great Heat Pump Performance

Use these settings, whether your heat pump is ducted or ductless, to maximize savings and improve your comfort:

Pro Tip! *If your central heat is oil or propane, you can expect your electric bill to increase significantly in cold weather. But you will save more in the long run with reduced fuel costs: keep running the heat pump as much as possible to minimize your backup system operation.*

Set it and Forget it

- Avoid frequently adjusting the thermostat; try to keep indoor settings steady.
- It's fine to adjust temperatures up and down as needed for comfort (e.g. turn it down at night if you like it a bit cooler).
- However, *unlike conventional heating systems, deep setbacks of cold-climate heat pumps may cost you energy and money!*
- Avoid turning heat pump unit(s) "on" and "off" to control the temperature.
- "Set it and forget it" is effective when air conditioning, too.

Pro tip! *In humid summer climates, the "dry" setting (when available), may provide better comfort at less cost than "cool". You may need to set the temperature higher to avoid over-cooling.*

Use the "heat" or "cool" setting on the thermostat or control, rather than "auto"

- Set the unit to "off" when outside temperature is mild and no heat or air conditioning is needed

Set the indoor fan speed to "auto" or automatic, so the fan runs only as needed. *Avoid settings that run the fan constantly.*

For ductless heat pumps, keep the air vanes open to allow air to flow freely through the unit.

Source: (10) NEEP, ASHP Installer and Consumer Resources

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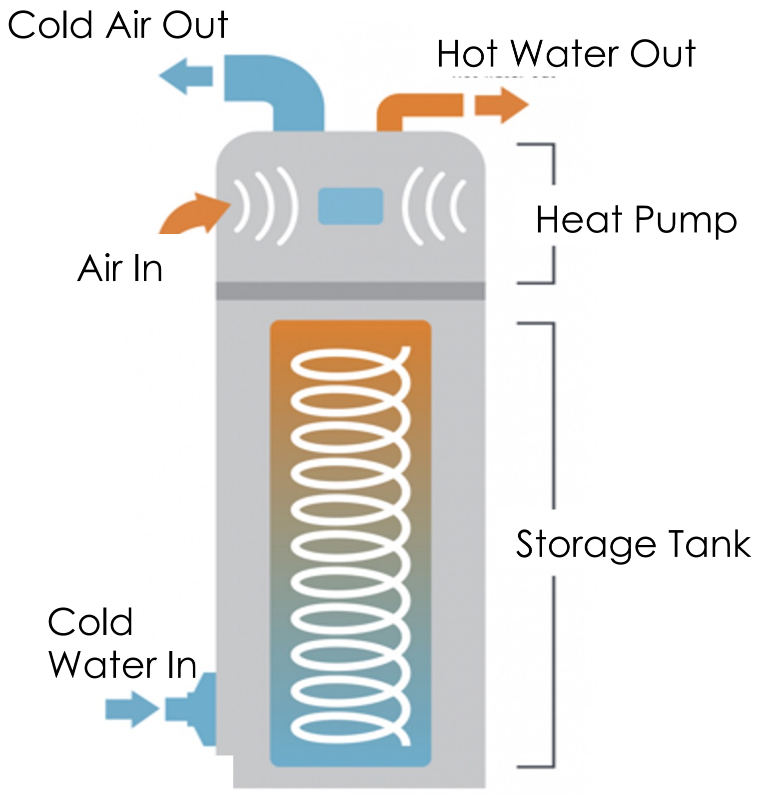
Heat Pump Water Heaters | How do they work?

- **Heat pump water heaters transfer heat from the indoor or outdoor air into a storage tank to heat water.**

- The technology may also use backup electric resistance heating for periods of high demand.

How it works:

Hybrid Heat Pump Water Heater



Source: (11) The Environmental Center, *Heat Pump Water Heaters*

Heat Pump Water Heaters | Available Options

- **Integrated heat pump water heater:** Most heat pump water heaters have all their components in a single tank, and typically transfer indoor heat into the tank.
- **Split heat pump water heater:** A limited number of models use an outdoor unit to absorb heat from the air and transfer the heat into an indoor water storage tank.
- **Commercial-scale:** Larger scale systems are typically split systems that use outdoor air to serve large commercial and multifamily buildings.
  - Note: Many commercial-scale models are not currently well-suited for cold climates.

Hybrid Heat Pump Water Heater

Split Heat Pump Water Heater

Commercial Scale Heat Pump Water Heater

Heat Pump Water Heaters | Benefits

- **Energy savings**
- GHG emissions reduction
- Dehumidification
- Grid reliability benefits

Oil Water Heater

~60% efficient

Gas Water Heaters

~65% efficient

Electric Water Heater

~90% efficient

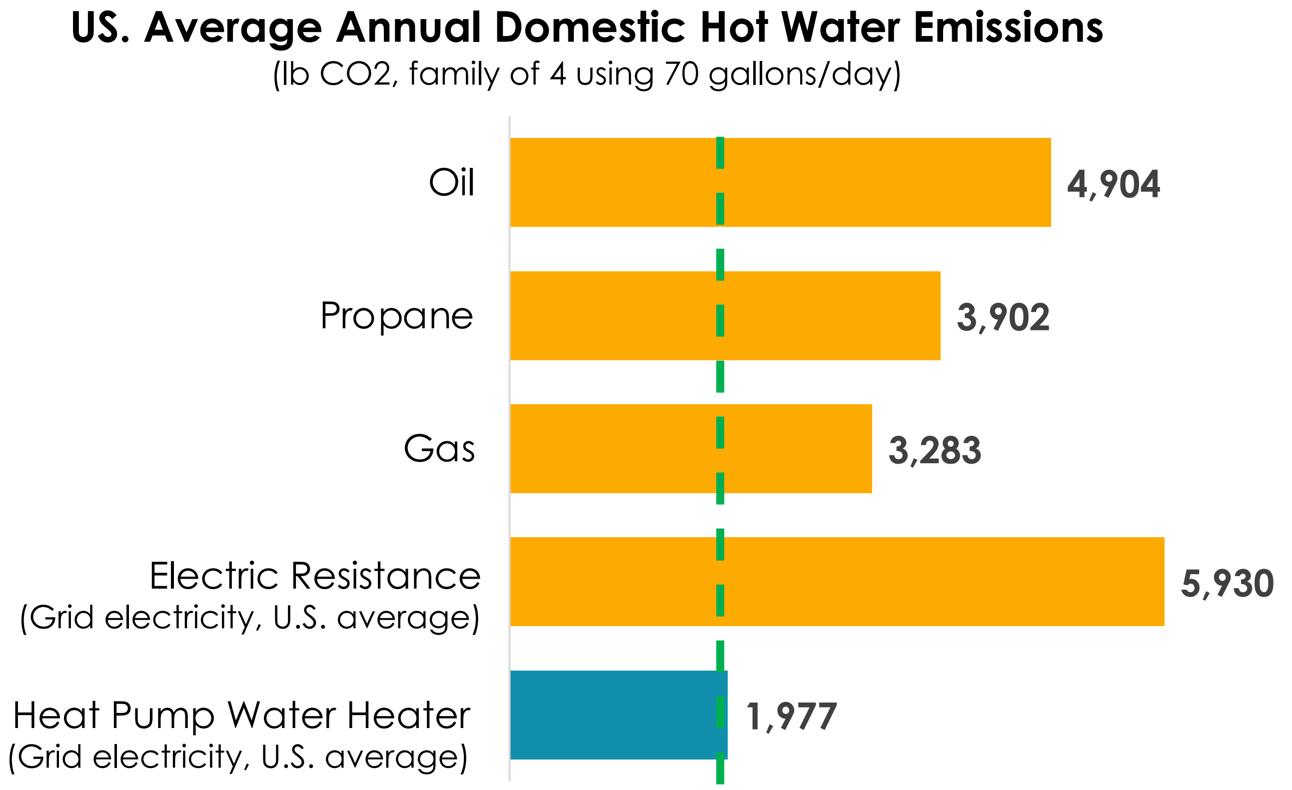
Heat Pump Water Heater

~300% efficient

- HPWHs require significantly less energy to provide the same amount of hot water.
- They can be over 100% efficient because they transfer heat instead of generating it.

Heat Pump Water Heaters | Benefits

- Energy savings
- **GHG emissions reduction**
- Dehumidification
- Grid reliability benefits



On average, HPWHs emit significantly less GHG emissions than oil, propane, gas, and electric resistance water heating systems in the U.S.

Source: Internal BEI Analysis

Assumptions: US eGrid emission factors); AFUE of 65% for propane and natural gas, AFUE of 60% for oil, UEF of 90% for electric resistance, COP of 3 for HPWH

Heat Pump Water Heaters | Benefits

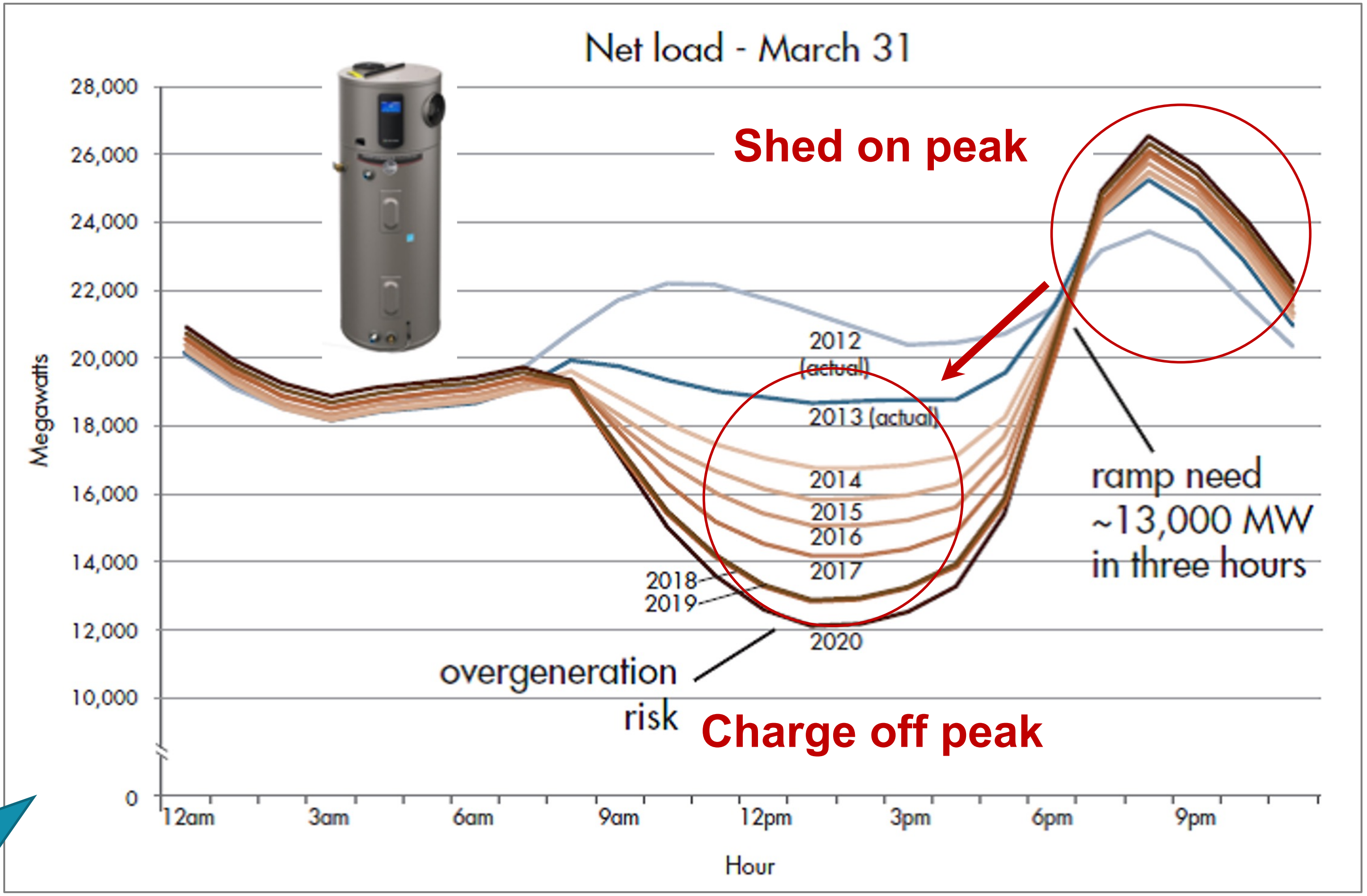
- Energy savings
- GHG emissions reduction
- **Dehumidification**
- Grid reliability benefits

- Often placed in basements or garages where they can dehumidify indoor air

Heat Pump Water Heaters | Benefits

- Energy savings
- GHG emissions reduction
- Dehumidification
- **Grid reliability benefits**

HPWHs can shift electric loads by storing thermal energy in the water tank and make use of cleaner and cheaper electricity at different times of the day.



Source: (12) NRDC and Ecotope, HPWH Demand Flexibility Study, 2018

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Heat Pump Water Heaters | Common Concerns

- **Cools space:** Integrated HPWHs extract heat from indoor air, which reduces the cooling load in summer, but can increase the heating load in winter.
- **Noise:** Louder than a typical gas water heater (noise is similar to a refrigerator).
- **Slower recovery:** HPWHs take longer to re-heat water compared to other water heaters.
- **Space considerations:** Integrated HPWHs cannot be placed in small closets due to insufficient airflow.
- **Cost:** HPWHs cost more to install compared to typical electric or fossil fuel water heaters, and may also cost more to operate than gas water heaters, depending on electric rates.
- **Limited multifamily applications:** Multifamily buildings will require on-site design and engineering to install HPWHs successfully.

Heat Pump Water Heaters | Installation

Installation Best Practices

- **The space matters**
  - Some HPWHs can be taller than other water heaters
  - A drain is required for condensation generated by the unit
  - Must be located in an area where the intake and exhaust air from the unit does not blow onto the living space and cause discomfort
  - Hybrid HPWHs need space for airflow to maximize efficiency
- **Insulate piping and improve installation first**
  - Hot water may take a long time to reach the faucet, which is often an issue with water distribution rather than the heating source.

Sources: (13) Eversource, *Guidelines for Integrated, Heat Pump Water Heaters in Multifamily Buildings*, 2018; (14) U.S. Department of Energy, *Measure Guideline: Heat Pump Water Heaters in New and Existing Homes*, 2012.

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- What is Building Electrification?
- **Building Electrification Technologies**
    - Air source heat pumps
    - Heat pump water heaters
    - **Complementary technologies and strategies**

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Complementary Technologies | Induction Stovetops

- **What is it?**
  - Stove tops that use electricity to directly heat pots and pans through a magnetic current, rather than a heat source.
- **Benefits**
  - Boils quickly and provides precise temperature control
  - Emits no indoor air pollutants from fossil fuel combustion
  - Reduces risk of fires and burns
- **Drawbacks**
  - Some pots and pans do not work with induction.
  - More expensive than conventional stovetops

Complementary Technologies | Energy Efficiency

- **What is it?**
  - Measures to reduce energy use from equipment and appliances.
  - Includes weatherization/insulation, heating distribution improvements, LEDs, low-flow fixtures, etc.
- **Benefits**
  - Saves operational costs and improves comfort.
  - Can reduce heating or cooling loads, resulting in a smaller heat pump and lower costs.
- **Drawbacks**
  - May add cost and time to an electrification project.

Complementary Technologies | On-site Solar PV

- **What is it?**
  - Solar panels that can be installed on or near a building to generate carbon-free electricity.
- **Benefits**
  - Reduce GHG emissions.
  - Can reduce electric peak demands.
  - Can offset electricity costs for heat pumps, depending on local net energy metering rules.
  - Technology and leasing improvements have brought installation costs down.
- **Drawbacks**
  - Some buildings may lack sufficient rooftop area.
  - Energy generation decreases without sunlight.

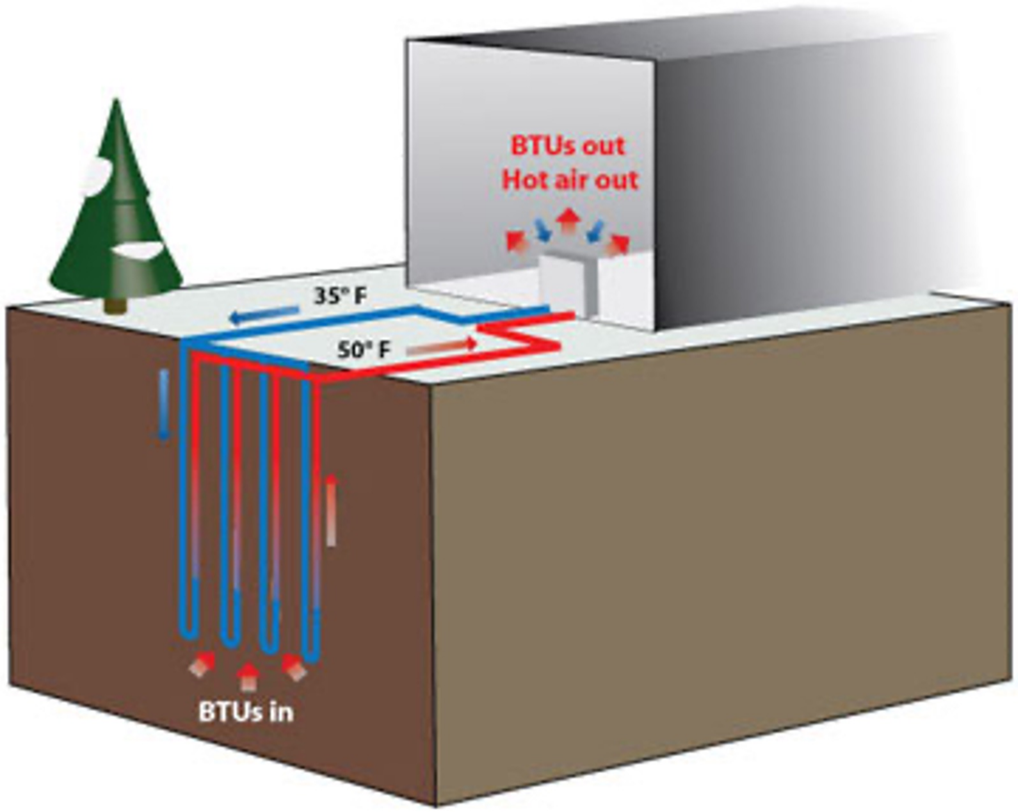
Image Source: Energy Sage

Complementary Technologies | Smart Controls

- **What is it?**
  - Automate operations to maximize energy use and cost savings.
  - Helps manage backup heating systems.
  - Can help owners take advantage of time-of-use electric rates
  - Grid-enabled controls can also help manage grid impacts.
- **Benefits**
  - Can provide cost savings to the building owner.
  - Can reduce electric peak demands.
- **Drawbacks**
  - Technology advancements are needed for better backup system integration.

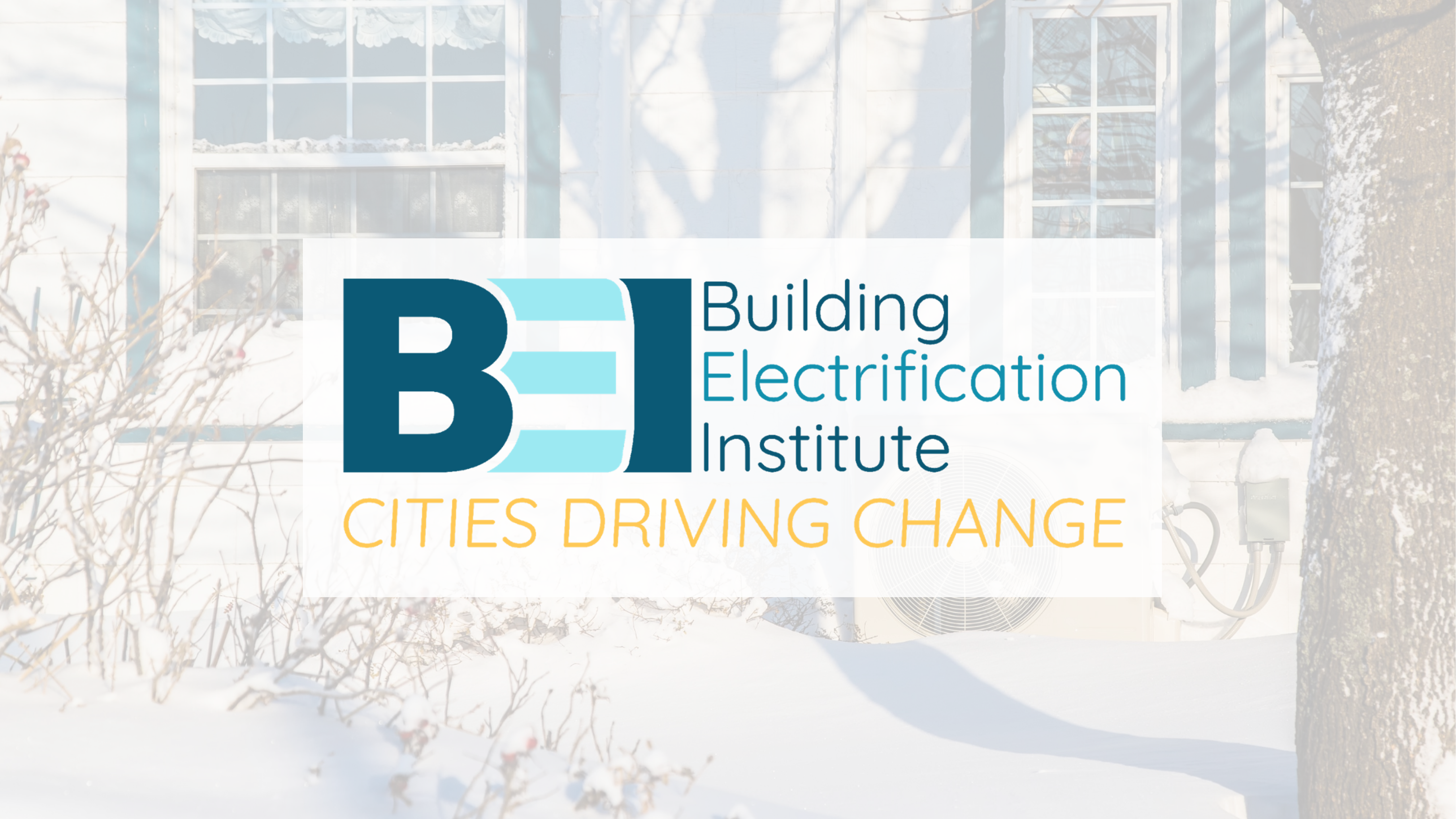
Complementary Technologies | Ground Source (Geothermal) Heat Pumps

- **What is it?**
  - Heat pumps that transfer heat from the ground instead of the air.
- **Benefits**
  - Can provide whole building heating, cooling, and hot water at highest efficiencies.
  - Often work well in district/campus applications.
- **Drawbacks**
  - Typically very high cost to install.
  - Particularly challenging to install in dense, urban environments.



Sources

1. EIA, *Residential Energy Consumption Survey, Space Heating*, 2015. https://www.eia.gov/consumption/residential/data/2015/
2. Mitsubishi Electric, *32 Years of Leadership in Providing Unique Solutions for the HVAC Market*, 2005/2007. https://www.energystar.gov/sites/default/files/asset/document/Mitsubishi-Doppel.pdf
3. RMI, *Emissions Impact by State, Heat pumps vs. Gas Furnace*. https://rmi.org/its-time-to-incentivize-residential-heat-pumps/
4. Sierra Club, *New Analysis: Heat Pumps Slow Climate Change in Every Corner of the Country*, 2021. https://www.sierraclub.org/articles/2020/04/new-analysis-heat-pumps-slow-climate-change-every-corner-country
5. Synapse Energy Economics, *Decarbonization of Heating Energy Use in California Buildings*, 2018. http://www.synapse-energy.com/sites/default/files/Decarbonization-Heating-CA-Buildings-17-092-1.pdf
6. RMI, *The Economics of Electrifying Buildings*, 2018. https://rmi.org/insight/the-economics-of-electrifying-buildings/
7. Navigant, *Ductless Mini-Split Heat Pump Cost Study*, 2018. https://ma-eeac.org/wp-content/uploads/RES28_Assembled_Report_2018-10-05.pdf
8. E3, Residential Building Electrification in California, 2018. https://www.ethree.com/wp-content/uploads/2019/04/E3_Residential_Building_Electrification_in_California_April_2019.pdf.
9. NREL, *Electrification Futures Study*, 2018. https://www.nrel.gov/analysis/electrification-futures.html
10. NEEP, *ASHP Installer and Consumer Resources*. https://neep.org/high-performance-air-source-heat-pumps/air-source-heat-pump-installer-and-consumer-resources
11. The Environmental Center, *Heat Pump Water Heaters*. https://envirocenter.org/programs/the-energy-challenge/save-energy-at-home/heat-pump-water-heaters/
12. NRDC and Ecotope, *HPWH Demand Flexibility Study*, 2018. https://www.aceee.org/sites/default/files/pdf/conferences/hwf/2018/2a-delforge.pdf.
13. Eversource, Guidelines for Integrated, Heat Pump Water Heaters in Multifamily Buildings, 2018. https://energizect.com/sites/default/files/Eversource-IHPWH%20Guidelines-1118-FIN.pdf.
14. U.S. Department of Energy, *Measure Guideline: Heat Pump Water Heaters in New and Existing Homes*, 2012. https://www.nrel.gov/docs/fy12osti/53184.pdf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