Building Electrification Initiative
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.**
- It also includes **converting inefficient electric heating technologies** to high-efficiency 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

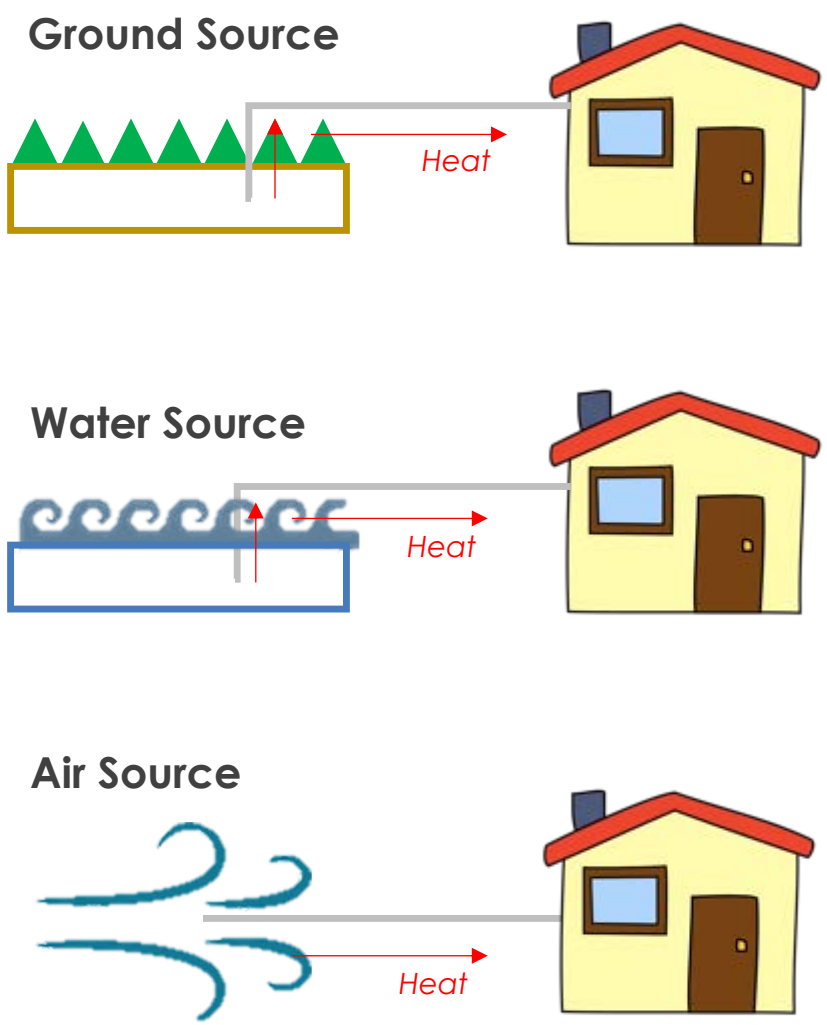
Smart controls

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, even in the winter.

- **Not a new technology!**
  - Refrigerators use a similar process
  - Nearly 12 million heat pumps are installed in U.S. homes.[16]
  - Heat pumps have 80%+ HVAC market share in Asia.[17]
  - Not electric resistance heating



Sources: EIA, Residential Energy Consumption Survey- Space Heating, 2015
Mitsubishi Electric, 32 Years of Leadership in Providing Unique Solutions for the HVAC Market, 2005/2007

Where are we now?

- **Only about 12% of homes in the U.S. currently use heat pumps for heating.**
- **More prevalent in:**
  - Milder and/or more humid climates
  - Supplemental heating and/or cooling
  - New construction
- **Heating and hot water systems are replaced only every 10 to 30 years.**
  - There may be only 1-2 changes for equipment replacement before 2050.
  - Replacements typically happen at the time of equipment failure.

Source: EIA, Residential Energy Consumption Survey- Space Heating, 2015

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Air Source Heat Pumps

- Air source heat pumps are **systems that provide heating and cooling by pumping heat from the outside air into a building.**

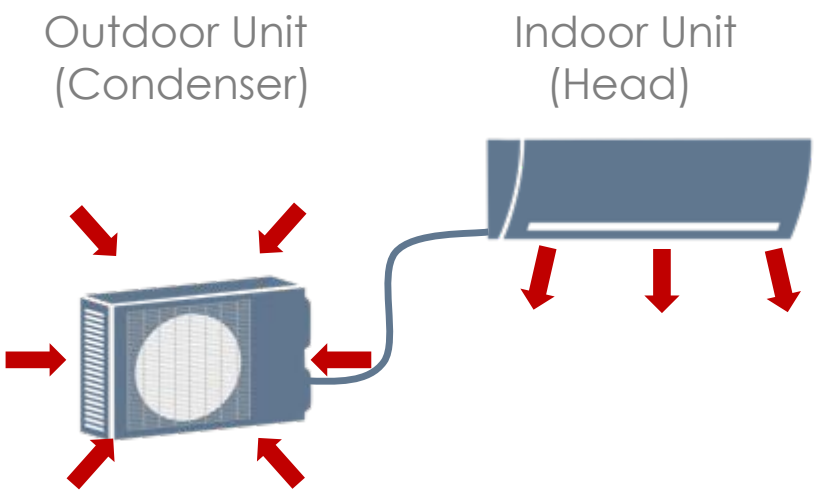
- Compared to ground source and water source heat pumps, air source heat pumps are:
  - Less expensive
  - Often more appropriate in dense urban environments

Outdoor Unit (Condenser)

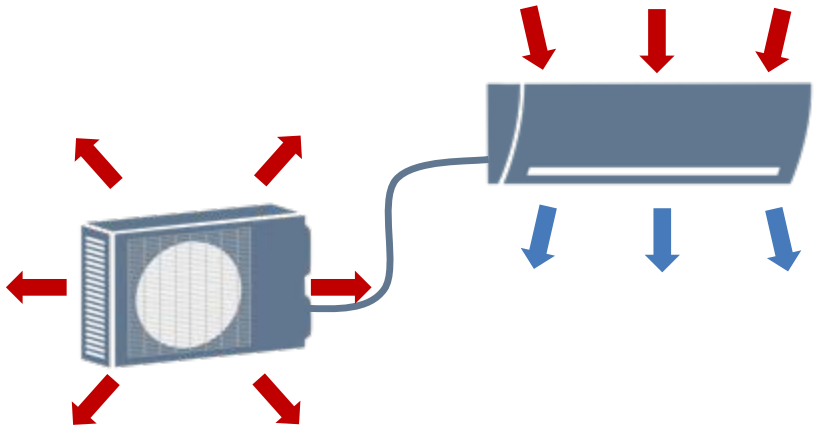
Indoor Unit (Head)

Air Source Heat Pumps | How does it work?

Two modes of operation:



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



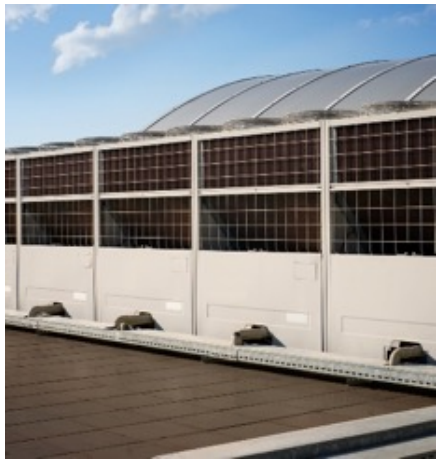
Summer: Absorbs heat from indoors and moves it outdoors to provide cooling (like an air conditioner)

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 "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 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 indoor air quality
- Cost savings (sometimes)

Fossil fuel furnaces
~80% efficient

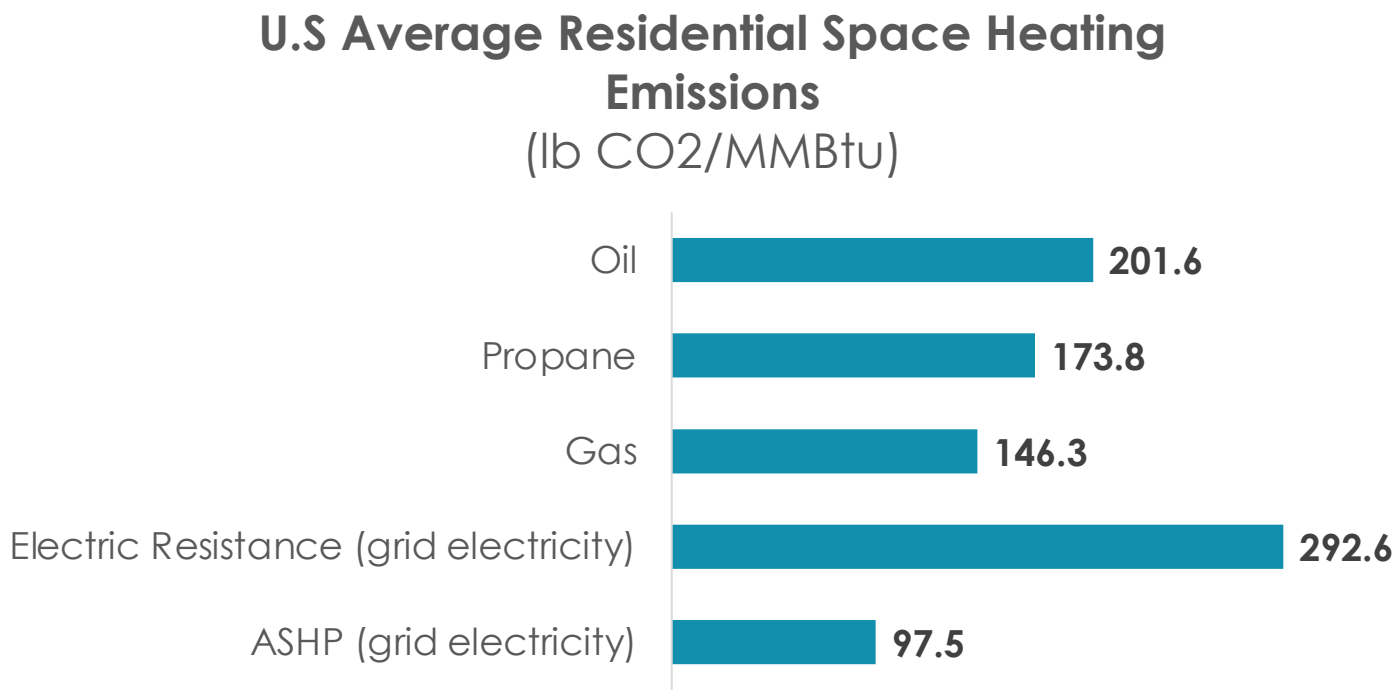
Electric Resistance
~100% efficient

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 indoor air quality
- Cost savings (sometimes)



Source: Building Electrification Institute
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 indoor air quality
- Cost savings (sometimes)

- Provides both heating and cooling
- Zoning and control over individual indoor units
- Dehumidifies indoor air

Air Source Heat Pumps | Benefits

- Energy reduction
- GHG emissions reduction
- Improved comfort
- **High flexibility**
- Improved indoor air quality
- Cost savings (sometimes)

- Can be installed with ducts or mounted in the floor or ceiling
- Could heat and cool just a few rooms or a whole building

Air Source Heat Pumps | Benefits

- Energy reduction
- GHG emissions reduction
- Improved comfort
- High flexibility
- **Improved indoor air quality**
- Cost savings (sometimes)

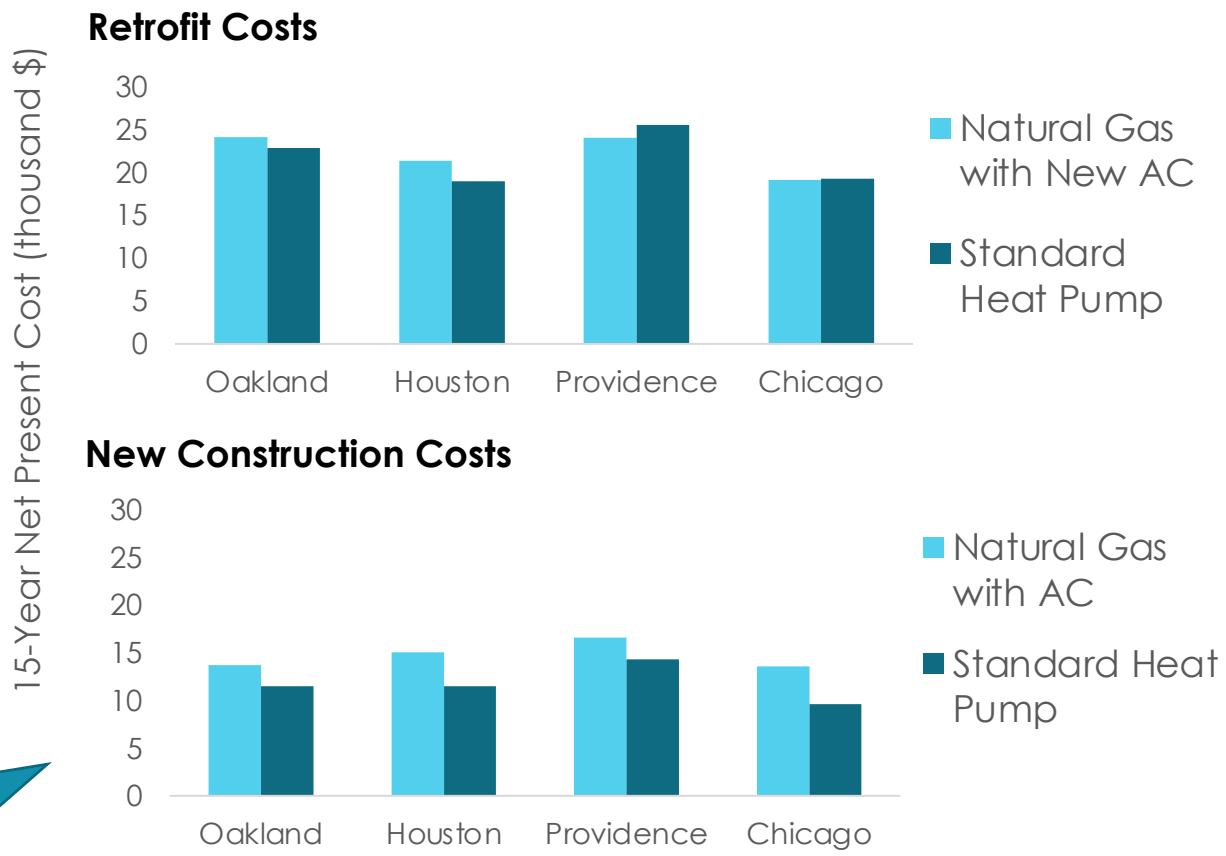
- Reduces NOx, carbon monoxide, and other indoor air pollutants from fossil fuel combustion

Air Source Heat Pumps | Benefits

- Energy reduction
- GHG emissions reduction
- Improved comfort
- High flexibility
- Improved indoor air quality
- **Cost savings (sometimes)**

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.

Comparison of Costs of Heating, Cooling, and Hot Water



Source: Rocky Mountain Institute, "Economics of Electrifying Buildings", 2018

Source: Ductless Mini-Split Heat Pump Cost Study. Navigant, 2018. Synapse Energy Economics, "Decarbonization of Heating Energy Use in California Buildings", 2018

Air Source Heat Pumps | Common Concerns

Cost

- Installation costs are often higher than conventional systems (gas furnace, boiler, hot water tank)
    - Ductless installs: $3,600-$5,200 per zone (room)
    - Wide variation based on technology, labor costs, and need for other upgrades.
    - Older homes may need to upgrade electrical capacity.
- In some cases, heat pumps can also have higher operating costs compared to gas systems.

Source: Ductless Mini-Split Heat Pump Cost Study. Navigant, 2018. Synapse Energy Economics, "Decarbonization of Heating Energy Use in California Buildings", 2018

Air Source Heat Pumps | Common Concerns

System Performance

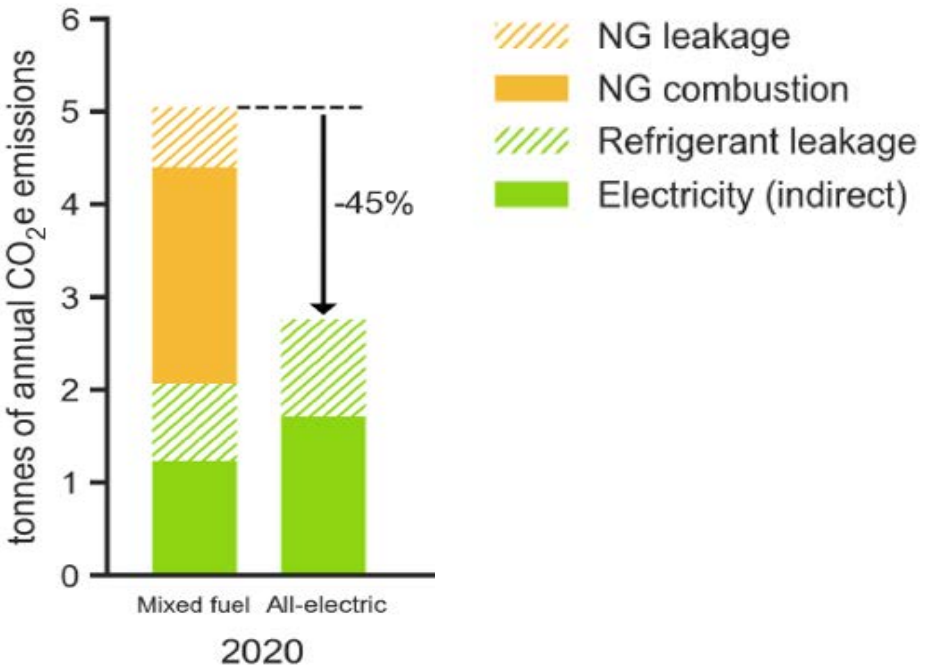
- Heating output and efficiency drop in very cold temperatures.
  - New models provide heat at high efficiencies down to -13°F.
- Integration with existing heating system to provide backup heat may be needed in very cold climates.
  - Necessary controls are under development.
- Heat pumps should be run continuously to achieve high efficiencies (unlike furnaces).
- Contractors must be trained to perform high quality installations.

Air Source Heat Pumps | Common Concerns

Refrigerant leakage

- Refrigerants are found in many technologies, including refrigerators and air conditioners.
- Refrigerants have high global warming potential (GWP) if they leak.
- Preventing leaks requires proper maintenance and disposal of systems.
  - Longer lines of refrigerants, such as in VRFs, tend to result in more 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



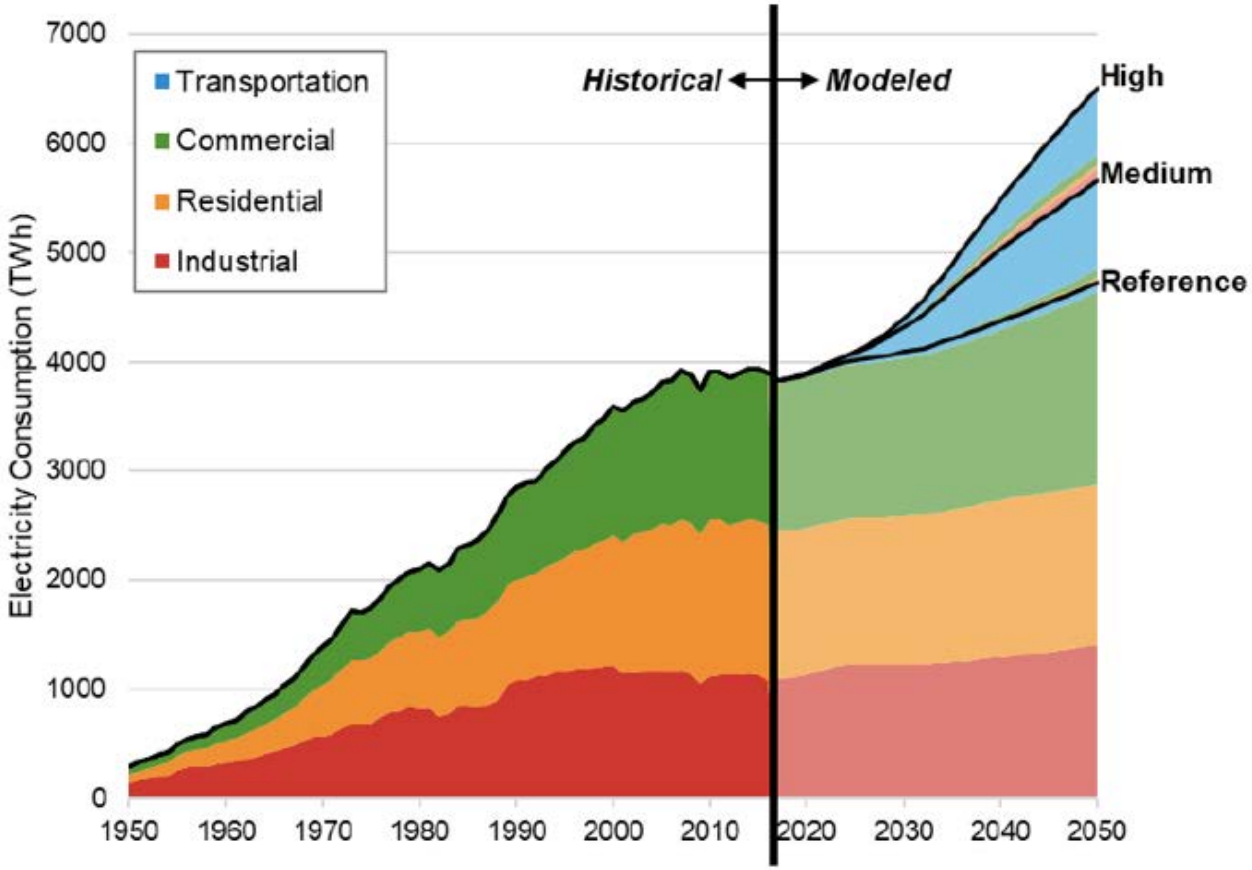
Source: E3, "Residential Building Electrification in California," 2018

Air Source Heat Pumps | Common Concerns

Energy Infrastructure

- There is potential higher electric consumption and peak loads with greater electrification.
  - Majority expected to come from electrified transportation (EVs).
- Heat pumps combined with storage could be used for grid management to provide flexible loads.
- Accelerated depreciation of gas pipelines and infrastructure may be necessary with high levels of building electrification.

Historical and Projected Annual Electricity Consumption



Source: National Renewable Energy Laboratory, "Electrification Futures Study," 2018

Air Source Heat Pumps | Common Concerns

Applications for Large Building Retrofits

- May require substantial increase in electrical load
- Ductless ASHPs and VRFs may 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

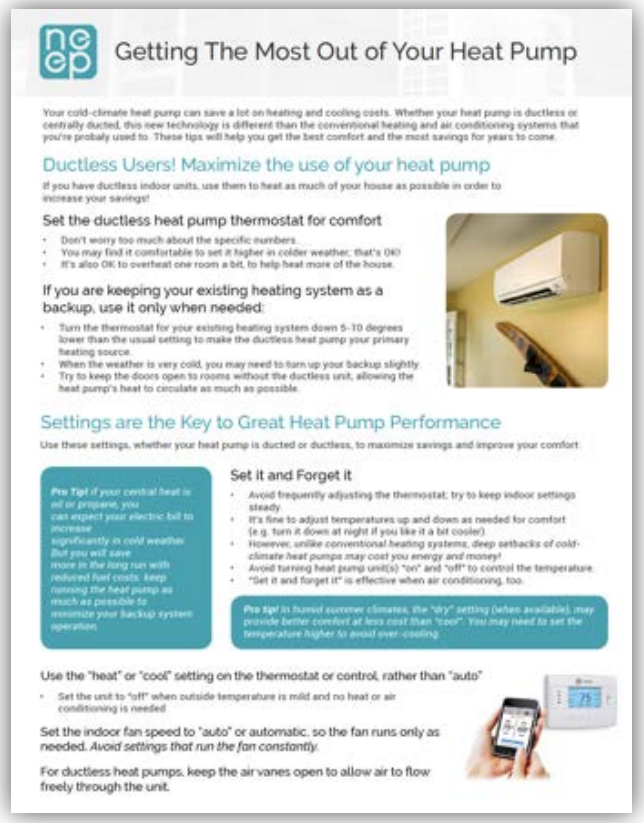
Image Source: ACHR News, "Mini Splits a Legit Fit in Maritime Climate", May 2015

Air Source Heat Pumps | Installation

Installation Best Practices

- Work with installers and electrifications 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.

Resource: NEEP ASHP Installer and Consumer Guides and Videos

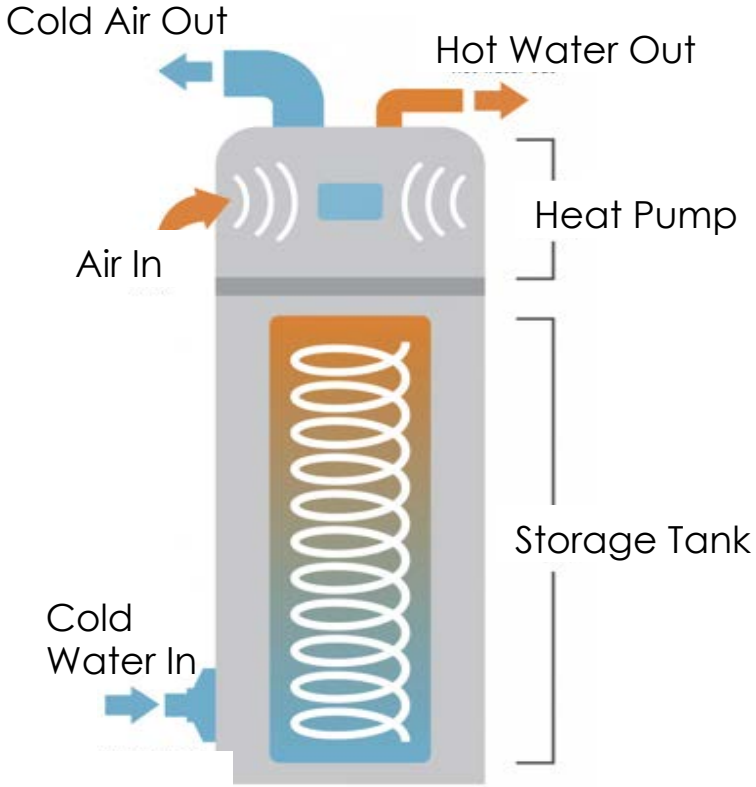
Heat Pump Water Heaters

- Heat pump water heaters are similar to air source heat pumps but produce hot water.

- **Heat pump water heaters transfer heat from indoor or outdoor air into a storage tank to heat water.**
  - Uses backup electric resistance heating for periods of high demand

How it works:

Hybrid Heat Pump Water Heater



Source: The Environmental Center, Heat Pump Water Heaters FAQ

Heat Pump Water Heaters | Available Options

- **Integrated heat pump water heater:** Most heat pump water heaters have all 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 the air and transfer the heat into an indoor storage tank.
- **Commercial-scale:** Larger scale systems are typically split systems that use outdoor air to serve large commercial and multifamily buildings.
  - Most current models are not 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

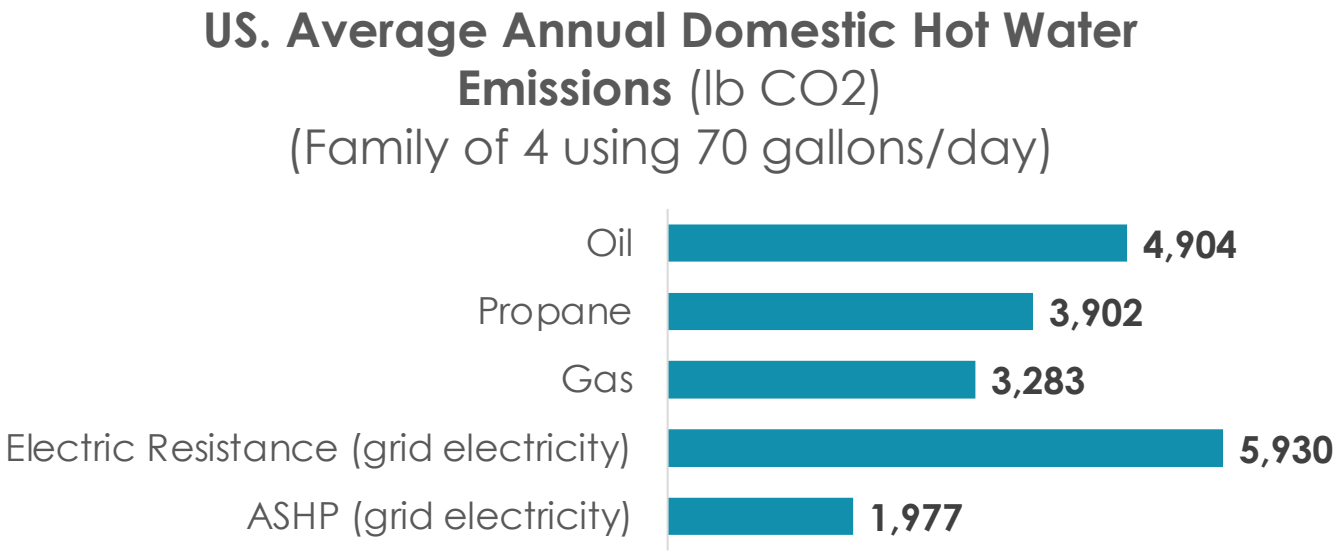
Heat Pump Water Heater

~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



Source: Building Electrification Institute
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

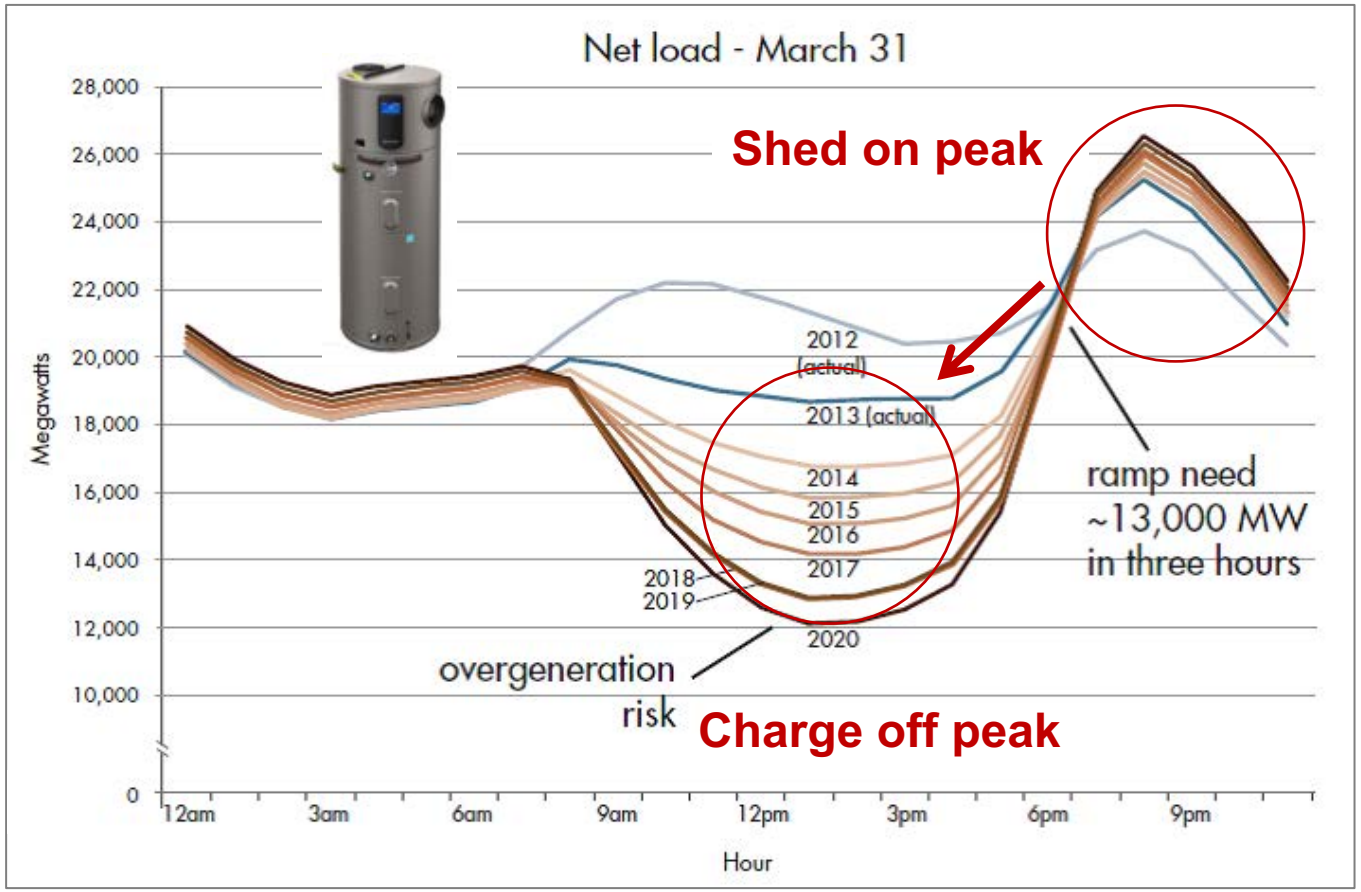
- Energy savings
- GHG emissions reduction
- **Dehumidification**
- Grid reliability benefits

› Often placed in basements

› De-humidifies indoor air

Heat Pump Water Heaters | Benefits

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



Source: NRDC and Ecotope study, ACEEE Aug. 2018

Heat Pump Water Heaters | Common Concerns

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

Heat Pump Water Heaters | Installation

Installation Best Practices

- **The space matters**
  - Hybrid heat pump water heaters need space for airflow to maximize efficiency
  - Can be taller than other water heaters
  - Requires a drain 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
- **Insulate piping and improve installation first**
  - Hot water taking a long time to reach the faucet is likely an issue with distribution rather than the heating source

NEEP Resource: Guidelines for Integrated, Heat Pump Water Heaters in Multifamily Buildings
NEEP Resource: Measure Guideline: Heat Pump Water Heaters in New and Existing Homes

Complementary Technologies | Induction Stovetops

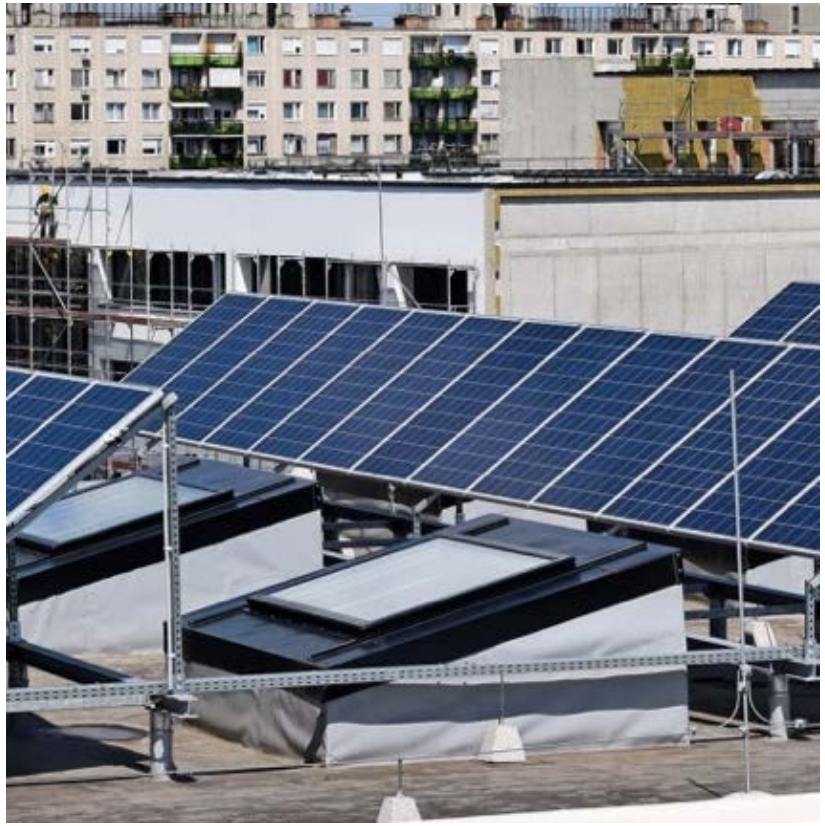
- **What is it?**
  - Stove tops that use electricity to directly heat pots and pans through a magnetic current
- **Benefits**
  - Boils quickly and provides precise temperature control
  - Emits no indoor air pollutants from fossil fuel combustion
  - Reduces risk from fires and burns
  - Paired with heat pumps, can result in an all-electric building that can eliminate gas usage and fees
- **Drawbacks**
  - Some pots and pans do not work on induction stovetops
  - More expensive than conventional stovetops

Complementary Technologies | Energy Efficiency

- **What is it?**
  - Measures to reduce energy use while maintaining similar services.
  - Includes weatherization, 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**
  - Sometimes difficult to motivate owners to install measures.

Complementary Technologies | On-site Solar PV

- **What is it?**
  - Renewable technology that can be installed on or near a building to generate carbon-free electricity.
- **Benefits**
  - Can off-set electricity cost for heat pumps
  - Reduce GHG emissions
  - Can reduce electric peak demands
  - Installation price of on-site PVs fallen by over 60% in last 10 years
- **Drawbacks**
  - Tall multifamily buildings may lack significant rooftop area for solar
  - Generation decreases when the sun goes down



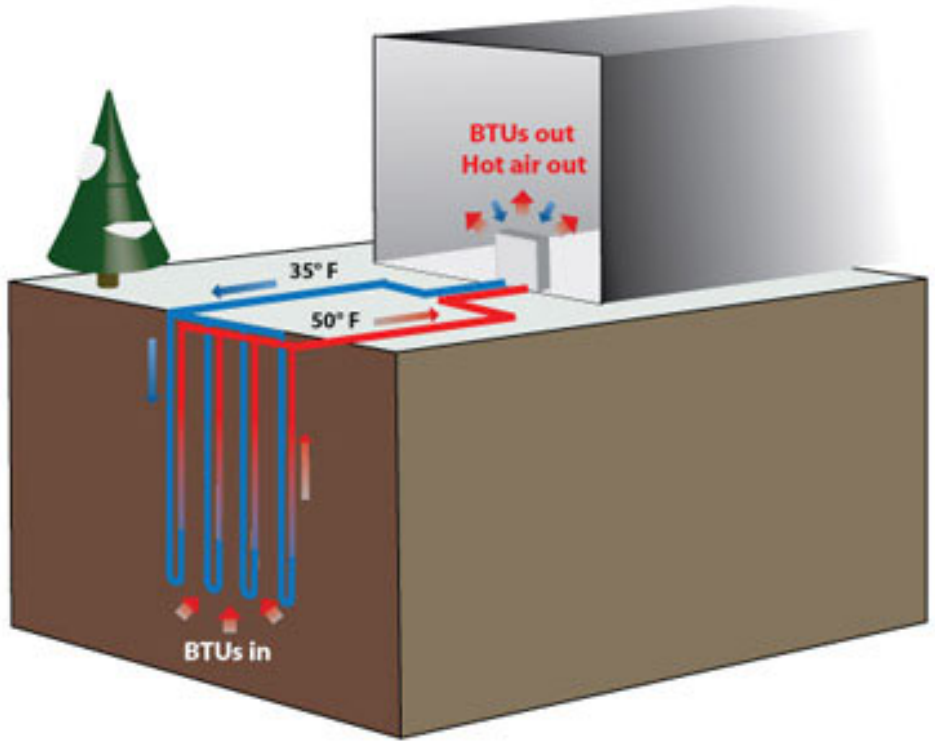
Source: Energy Sage, "How solar panel cost and efficiency have changed over time"

Complementary Technologies | Smart Controls

- **What is it?**
  - Automate operations to maximize savings, particularly with a backup heating system and time-of-use electric rates
  - Grid-enabled controls can also help manage grid impacts from new electric loads
- **Benefits**
  - Can provide cost savings to the building owner
  - Can reduce electric peak demands
- **Drawbacks**
  - Technology advancements needed

Complementary Technologies
Ground Source (Geothermal) Heat Pumps

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



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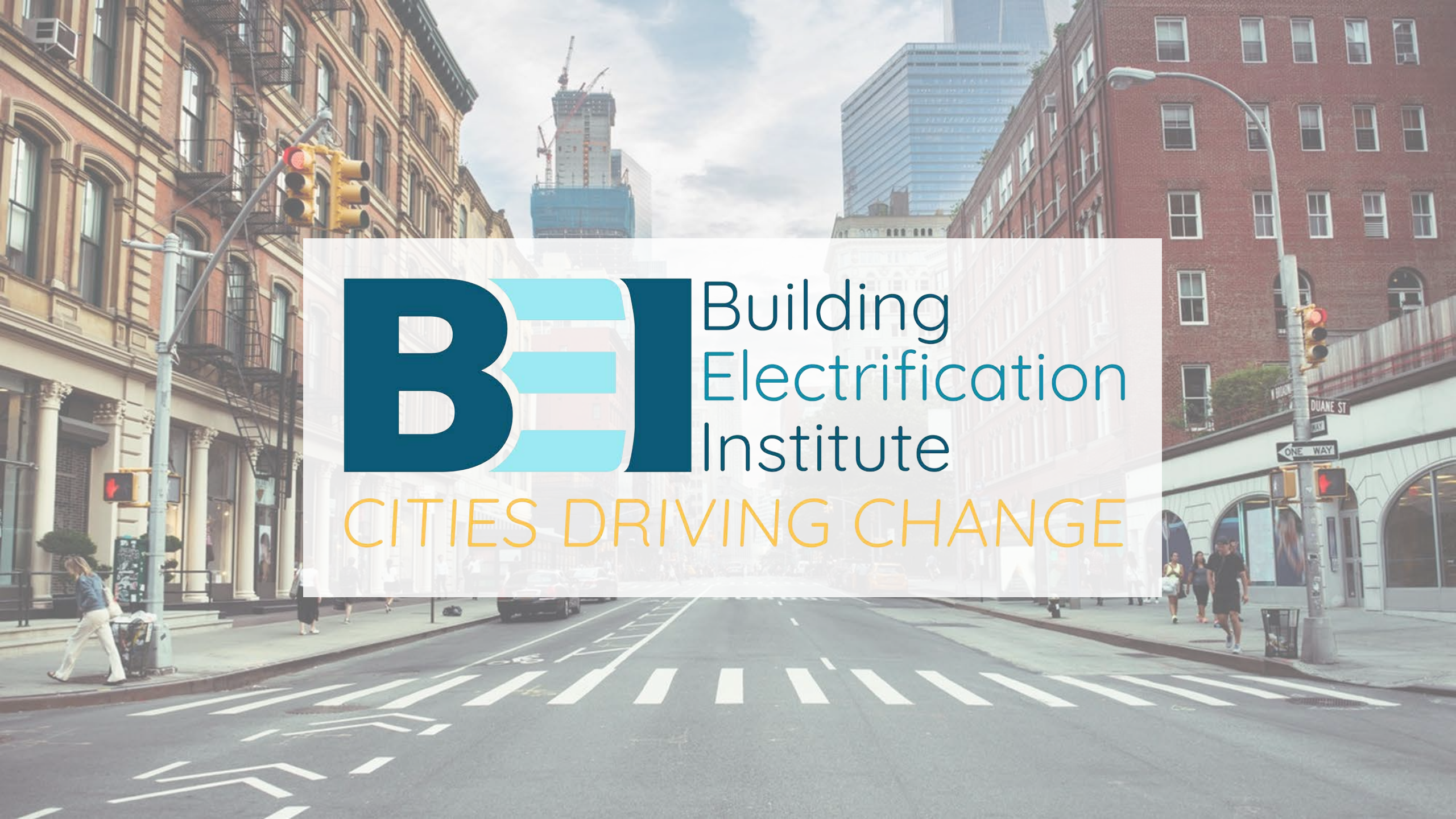

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