Electrification of HVAC Systems

Better Buildings Low Carbon Pilot
Peer Exchange Call
October 28, 2021

Agenda & Housekeeping

1. Introduction & Polls
2. Presentation from NREL
3. Q&A

Be respectful of our speakers and remain muted until Q&A

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Today's Presenters

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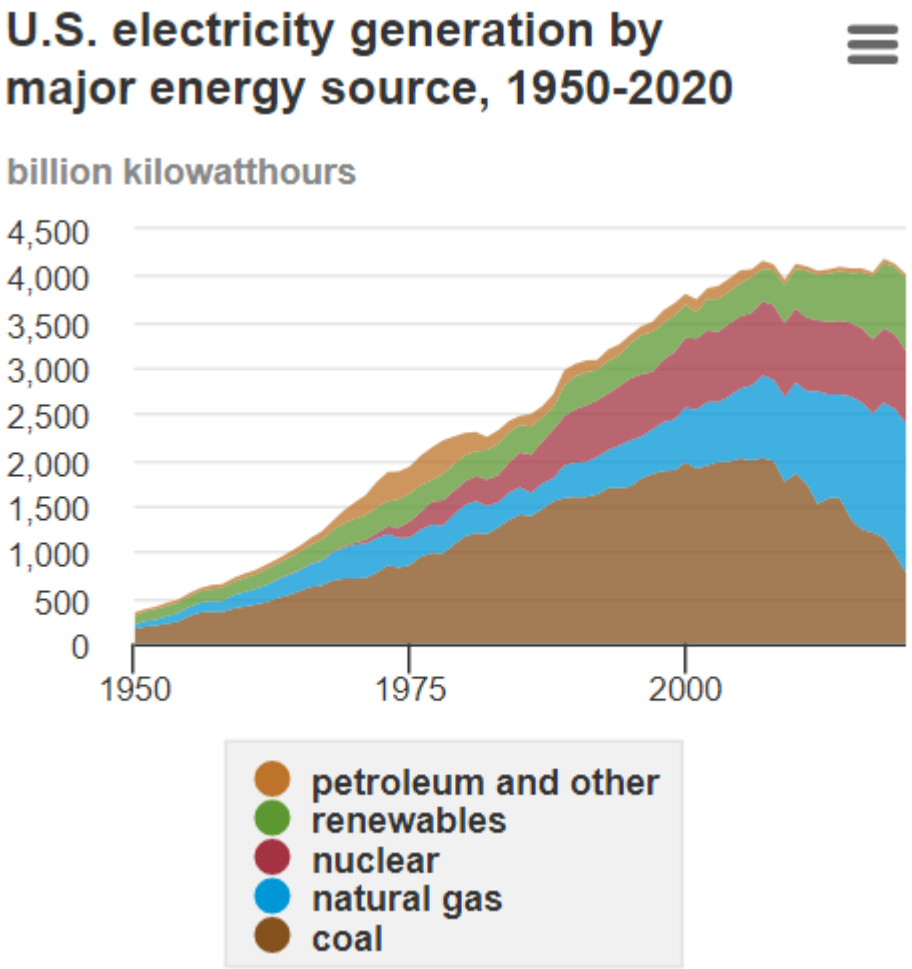
The Electrical Grid is Always Changing

- Renewables could exceed natural gas generation by 2030*
- Renewable percentage will increase as efficiency improves and consumption goes down



* EIA Annual Energy Outlook 2021

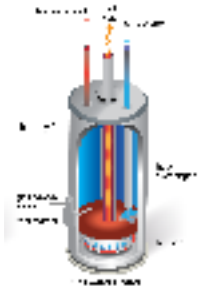
Source: Energy Information Administration, *Electricity generation, capacity, and sales in the United States*

Electrification

Gas Hot Water Heater

1.74 unit of gas in

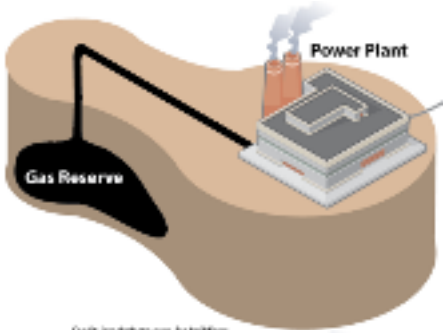
1.6 unit of gas in



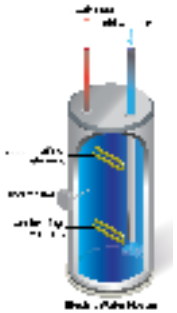
1 unit of hot water out

Electric (Resist) Hot Water Heater

1.87 unit of gas in



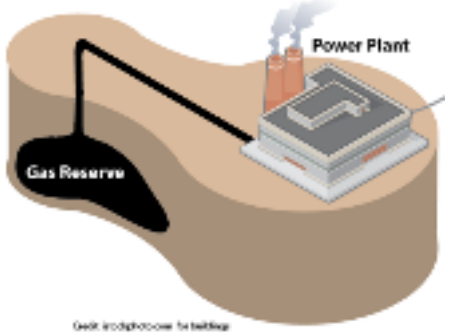
1.02 unit of electricity in



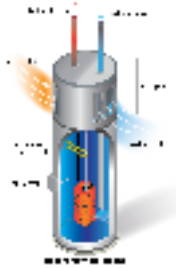
1 unit of hot water out

Heat Pump Hot Water Heater

0.61 unit of gas in



0.33 unit of electricity in



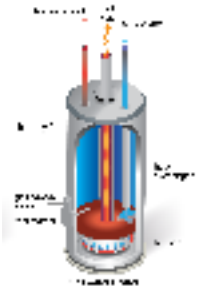
1 unit of hot water out

Energy Flows—Moving towards renewable energy

Gas Hot Water Heater

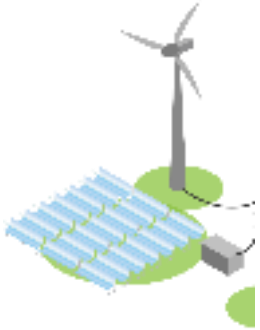
?

1.6 unit of gas in

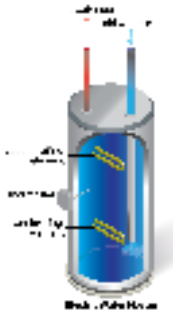


1 unit of hot water out

Electric (Resist) Hot Water Heater



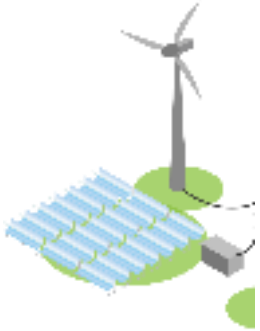
1.02 unit of electricity in



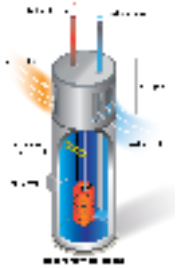
1 unit of hot water out

Heat Pump Hot Water Heater

PV Systems (1/3 the size)



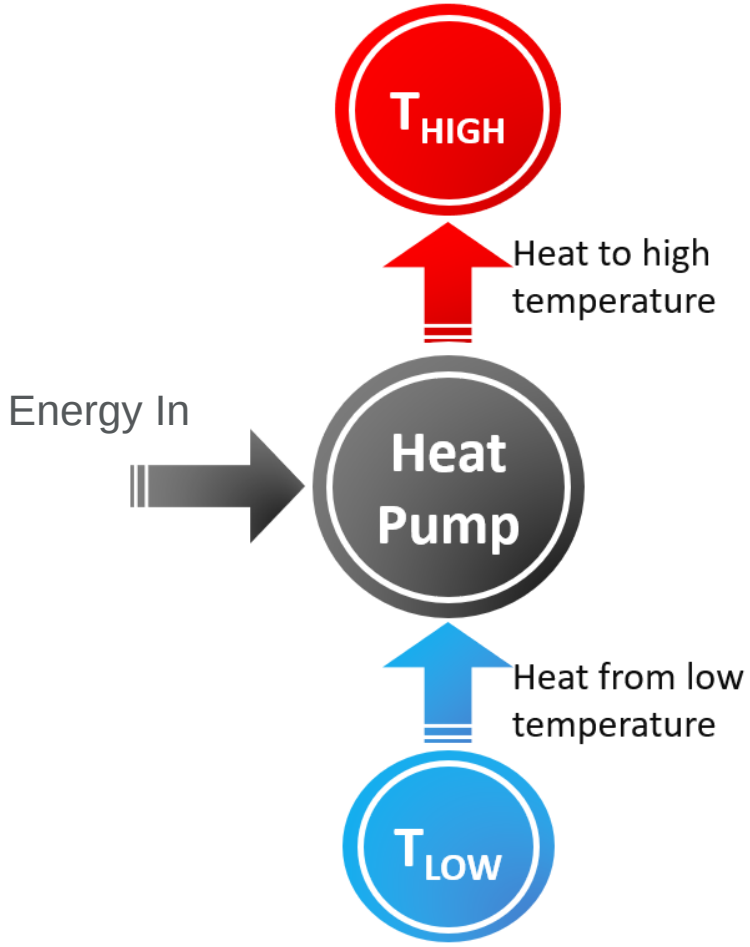
0.33 unit of electricity in



1 unit of hot water out

How do heat pumps work?

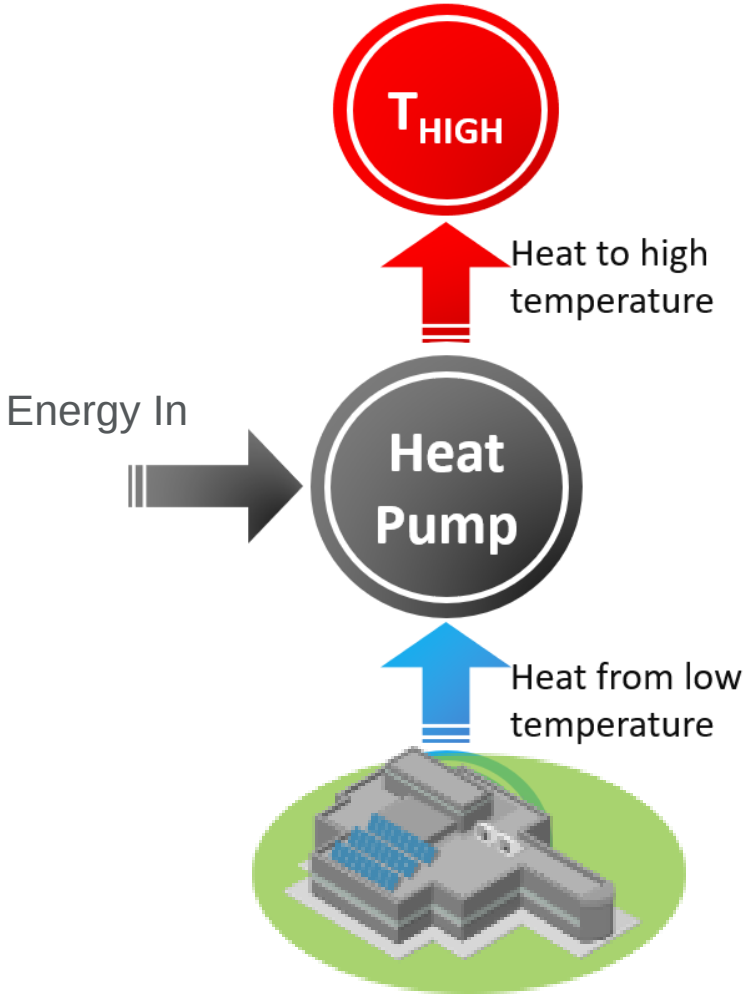
Heat Pump Basics



Graphic Source: NREL

- Heat pumps move heat from a cold temperature location to a warm temperature location using energy (often electricity) to move a refrigerant
- The refrigerant absorbs heat and evaporates, the refrigerant gas is compressed, and releases the heat when it condenses
- Because the heat pump is a closed loop no refrigerant is added or lost from the system.

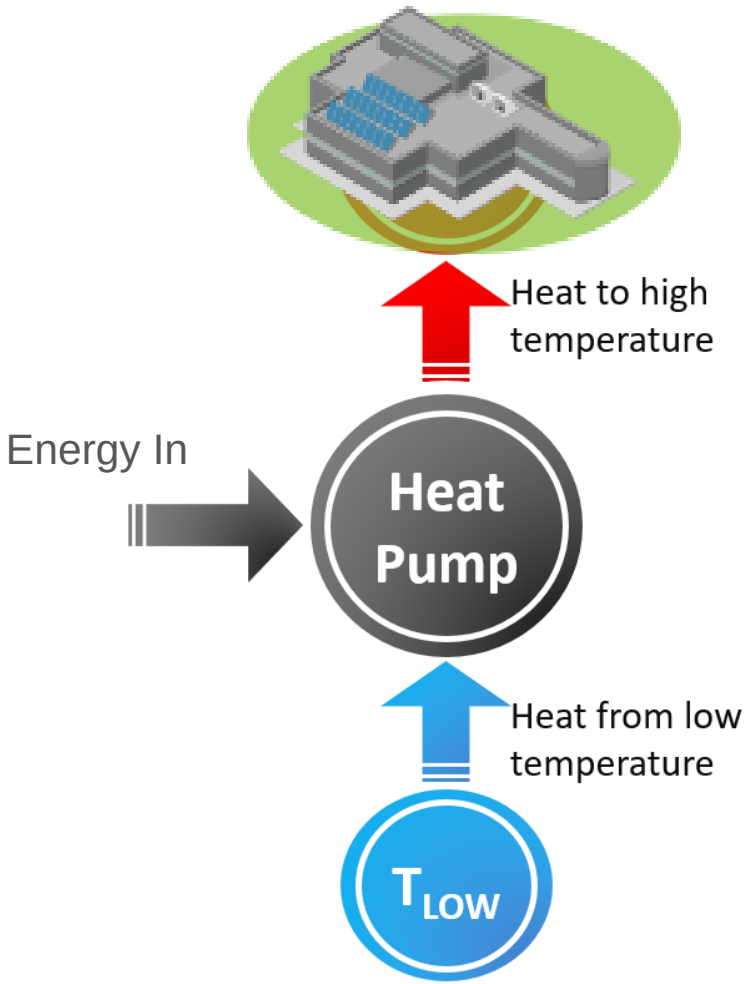
Heat Pump Basics



Graphic source: NREL

- Air-conditioning mode
  - Heat pump pulls heat from the building to make it cooler and pumps that heat to the warmer outdoors

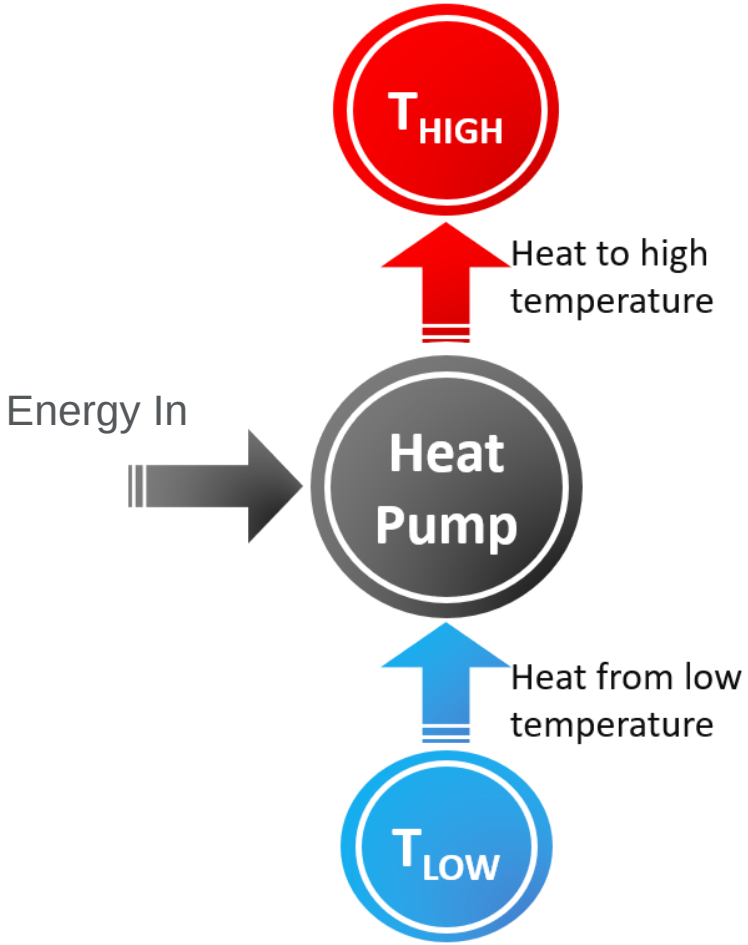
Heat Pump Basics



Graphic source: NREL

- Heat pumps move heat from a cold temperature location to a warm temperature location.
- Heating mode
  - Heat pump pulls heat from the outdoors and puts it into the building

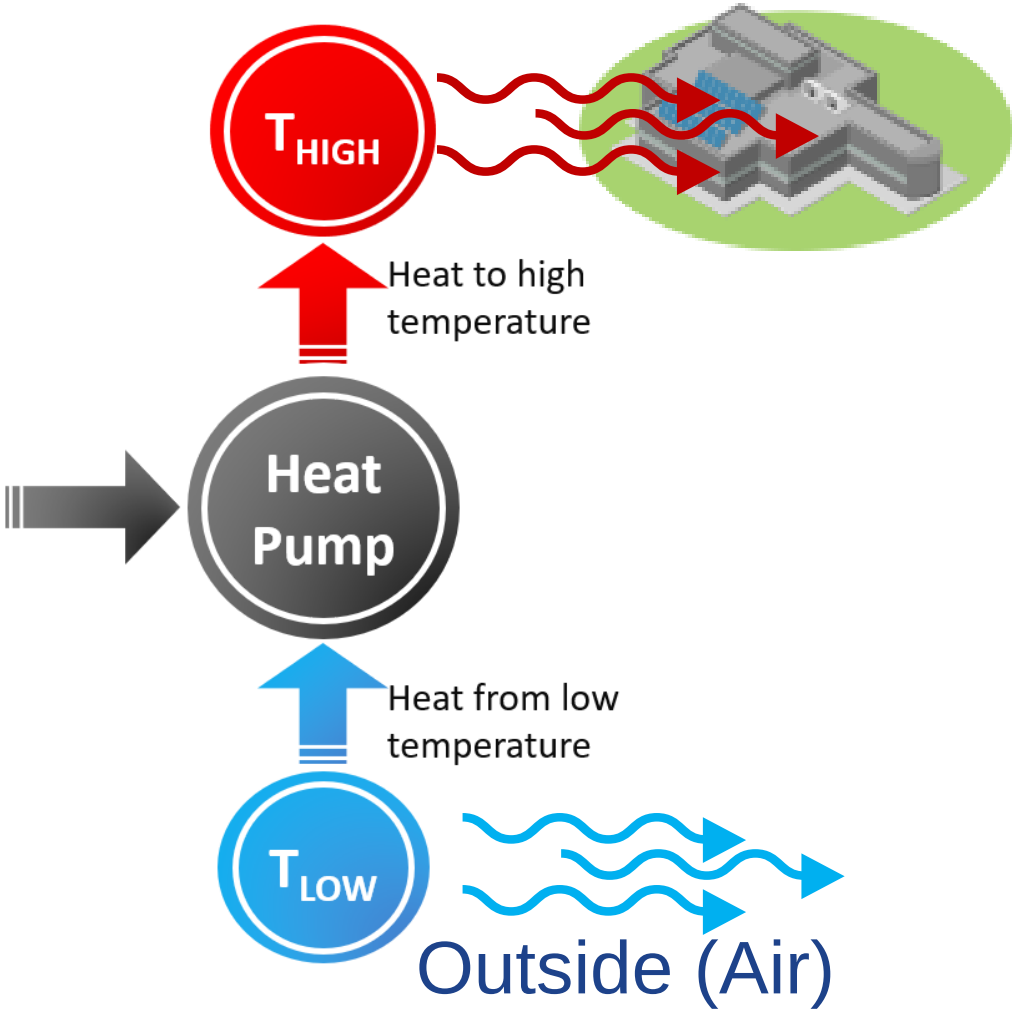
Heat Pump Basics



Graphic source: NREL

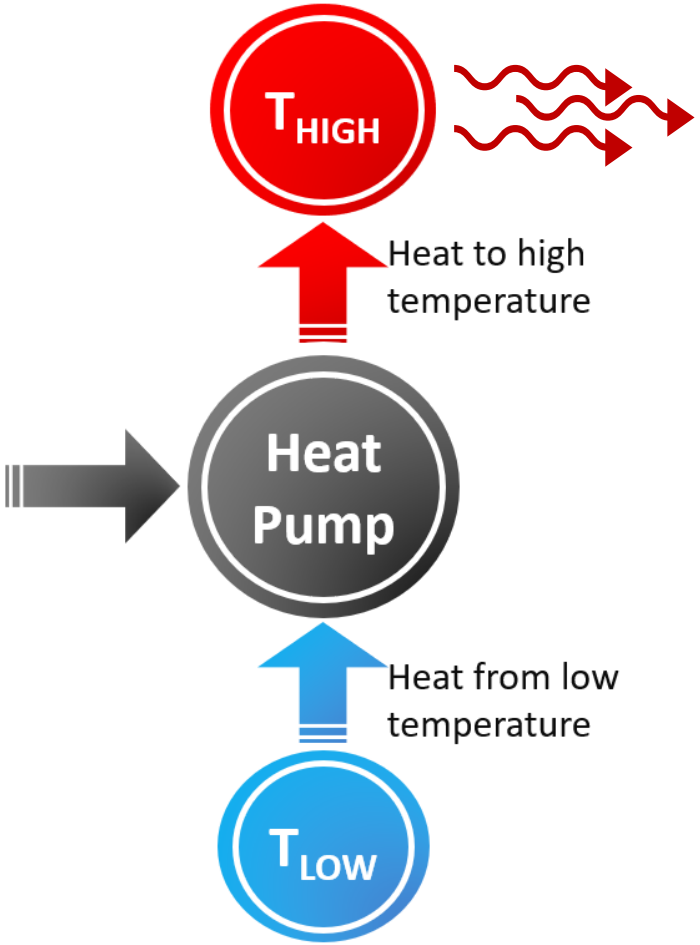
- The smaller the temperature difference from low to high, the easier it is to move the heat
  - If it's cold outside, heating mode is harder
  - But many heat pumps still work when temperatures are very low
- Ground source heat pumps
  - Take advantage of warmer (than the outdoor air) winter ground temperatures and cooler summer ground temperatures
  - Minimizes the effort to "pump" the heat
- Typically, it is 2 to 5 times more efficient to move heat than to generate it (such as with electric resistance heaters)

Types – Air Source Heat Pumps (in Heating Mode)



- Pull heat from the air—less efficient as the air becomes cooler
  - Heat pumps are rated down to 17°F. Need to ask how much colder a particular heat pump will operate
  - Cold climate heat pumps can work to -20°F which is sufficient for many US Climates
- System types:
  - Ducted Air-source heat pumps (ASHP)
  - Mini-splits (ductless or multi-head)

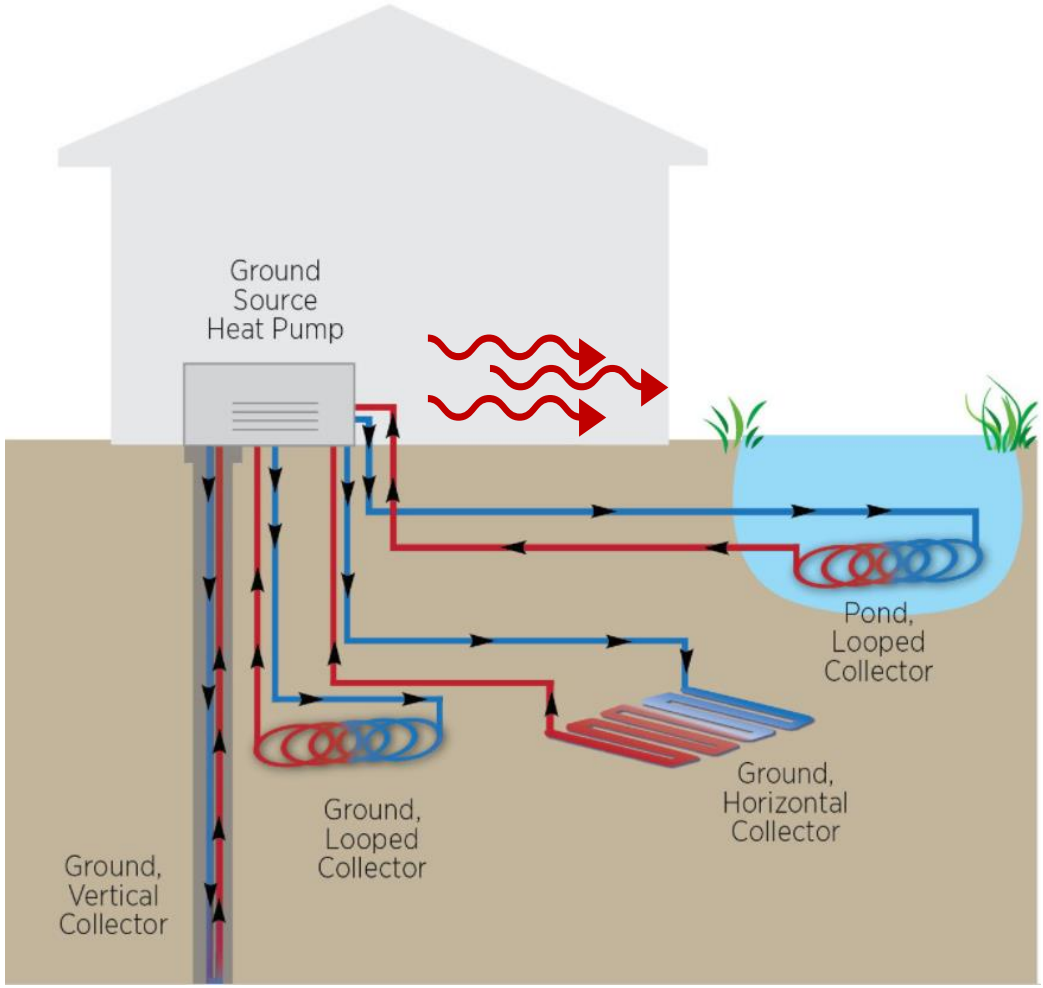
Types – Water to Water Heat Pump: Ground Source Heat Pumps (in Heating Mode)



Water to/from wells or ground loops

- Pull heat from the ground using water loops
  - Ground tends to maintain a more consistent year-round temperature than the air, which allows the heat pump to work more efficiently
  - Note that this is different than naturally hot water from geothermal sources (like 'Old Faithful')

Types – Water to Water Heat Pump: Ground Source Heat Pumps (in Heating Mode)



Source: PNNL
https://basc.pnnl.gov/resource-guides/geothermal-heat-pumps

- Pull heat from the ground using water loops
  - Ground tends to maintain a more consistent year-round temperature than the air, which allows the heat pump to work more efficiently
  - Note that this is different than naturally hot water from geothermal sources (like 'Old Faithful')

Planning for Heat Pumps

When replacing:	Consider:	Notes
Rooftop units (RTU) and gas heating equipment	Heat pump RTUs	use natural gas for back-up heating (*dual-fuel heat pump* RTU) to address all climates
Hot water boilers for space heating	Heat pump chiller	heating is the primary function and chilled water is the by-product
Domestic hot water	Heat pump water heaters (HPWH)	3-4x more efficient than electric resistance; commercial systems becoming more common
Chillers	Heat recovery chiller	Allows the use of condenser loops as heat source when chiller is running

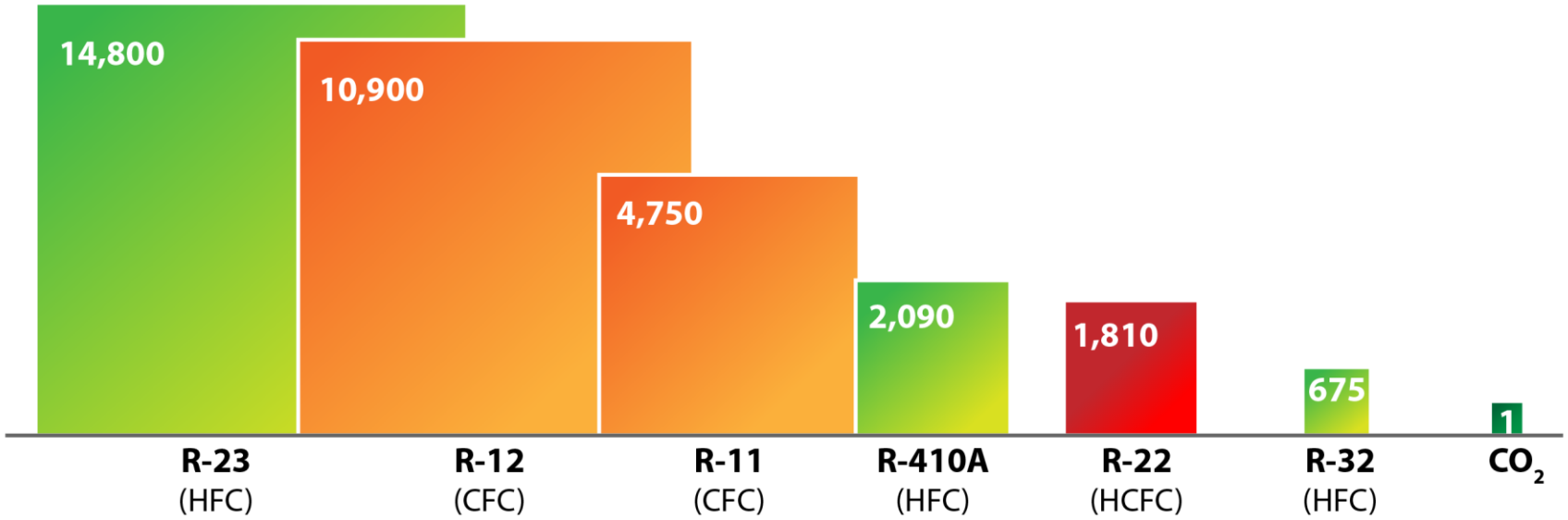
“Moving” towards electrification…

For building design and renovation, make the building “heat pump” ready:

1. **Provide electrical service** (or at least panel sizes, conduit)
2. **Lower supply temperatures** (larger heating coils, 120°F to 130°F hydronic systems, move away from steam)
3. **Energy storage** (which can benefit the cooling side demands and serve as back-up)
4. **Consider hybrid systems** (leave existing gas/oil equipment in place as peaking)—strive for an 80/20 rule

Refrigerant and Global Warming Potential

- HFCs have zero ozone-depletion potential (ODP) but high global warming potential (GWP)
- Low GWP alternatives
  - Alternative refrigerants are not direct drop-in replacements and may have restrictions
  - High efficiency systems using CO_2 are commercially available today in heat pump water heating applications
  - R-32 and R-290 are approved for use in room/window AC/Heat pumps and PTAC/PTHP systems in the U.S.
  - Several major HVAC manufacturers will offer products using low flammability refrigerants (e.g., R-454B, R-32)



Reference Slides

Product Solutions – New Construction or Deep Retrofit

- Variable Refrigerant Flow (VRF)
  - Refrigerant piping throughout the building can make retrofit a challenge, but if adding cooling where none existed (i.e. no ductwork), this may be easier than adding ductwork
  - Less than 40 tons
- Water-source heat pumps (WSHP)
  - Share a common condenser loop, heat recovery within the system between zones in heating mode and zones in cooling mode
  - Less than 25 tons
- Air-source Heat Pump (ASHP)
  - In low temp hot water systems (90°F -120°F), ASHP can be sole heating source

Roof Top Units

Current:

Gas heating with A/C

Photo Source: DOE Better Buildings

Electrified Pathway:

- RTU heat pumps currently operate to 17°F up to 10-ish tons.
- Above 10 tons, limited availability.
- Use gas furnace with heat pump for colder temperatures. Operate when below the design temperature of the heat pump…. Or increase loop temperature with gas if needed for meeting loads. "Dual fuel heat pump"
- Need bigger units to meet heating loads—use variable speed or multiple circuits to maintain humidity levels on cooling
- Install heat pumps with no electrical resistance back up if the lowest temperatures are above 20°F.
- Ground source minimizes impact from cold outdoor ambient

Planning:

- Size electrical for future RTU assuming COP=1.75 for heating at design temperature
- Design curb weight for larger size and today's (and tomorrow's) high efficiency RTU. Allow for flexibility for RTU size/location.

Other HVAC Types

Current:

Gas heating with A/C

Ductless Heat Pump Outdoor Unit

Photo source: PNNL Building America Solutions Center

Electrified Pathway:

- Up to 5 tons, install cold weather residential heat pumps good to -15°F.
- Some cold weather mini-split or VRF systems good to -15°F.
- Caution on controls and field installed refrigeration lines
- Ground source minimizes impact from cold outdoor ambient

Planning:

- Residential equipment available today for smaller applications

Hydronic Systems

Current:

Chillers and gas/oil boilers

R32 heat pump chiller

Photo source: Daikin

Electrified Pathway:

- Heat recovery chillers available in all size ranges—depends on how much recovery and at what temperature
- Sewer water heat recovery (not dependent on OA)
- Use building exhaust as an air supply for heat pumps (form of ventilation heat recovery)
- Some heat pump chillers available—need to size for heating load accounting for defrost cycles (ideally have multiple units--3) up to 70 tons each
- Hot and cold-water storage tanks help with capacity sizing—can include the loop water volume.
- Ground source minimizes impact from cold outdoor ambient

Planning:

- Size electrical for future hydronic heat pumps that can produce hot water with COP=1.75 for heating at design temperature
- Plan for storage tanks—install today to help with resilience and demand/load shifting

Domestic/Service Hot Water

Current:

Gas/oil boilers or electric resistance with recirculation loops

Photo Source: CHPWHS for Hospital and Clinical Settings, PG&E Training

Electrified Pathway:

- Evaluate point of use electric resistance—good for small remote loads. Recirculation loops can often use 30 to 50% of the load plus the pumping energy.
- Heat pumps for gas replacement are becoming available starting with smaller scale or units “ganged” together. Sizing and configuration must be carefully considered (gas is very forgiving).
- Potentially good to -15°F
- Ground source minimizes impact from cold outdoor ambient

Planning:

- Minimize loads
- Distribute hot water systems without recirculation—potentially smaller pipe sizes
- Design space and air for future tanks/heat pumps

Resources

- Getting Started Guide: HVAC and Water Heating Decarbonization (DOE Better Buildings Guide)
- YouTube Series: DOE Solar Decathlon: Building Science Education - Heat Pumps

Selected Decarbonization Resources

Title	Topic Areas	Case Studies	Notes
Thermal Electrification of Large Buildings in the Commonwealth (A Better City/Cadmus, 2020)	• Large multifamily and commercial buildings • Space heating and water heating	Yes, several real-world case studies	The report provides an overview of heating electrification options in Massachusetts, with several case studies for new construction and retrofits, including boiler systems.
Zero Carbon Commercial and Multi-Family Construction (Redwood Energy, 2019)	• Two reports, one for large commercial and one for multi-family (mostly new construction) • Space heating, water heating, cooking, and transportation electrification	Yes, several real-world case studies	The guide contains examples of large new commercial and multifamily developments that have avoided fossil fuel use in favor of all electric designs and provides examples for specific all-electric technologies.
Heat Pump Retrofit Strategies for Multifamily Buildings (NRDC, 2019)	• Residential multi-family, both small and large (may have applicability for some commercial as well) • Space heating and water heating, both in-unit and central	Yes, for several prototypical retrofit projects	The report examines heating electrification options for multifamily buildings, with a particular focus on technology options for existing buildings with central steam and hot water systems.

Q&A and Discussion

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Introductions

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Reach out to us with any questions!

Thank you!