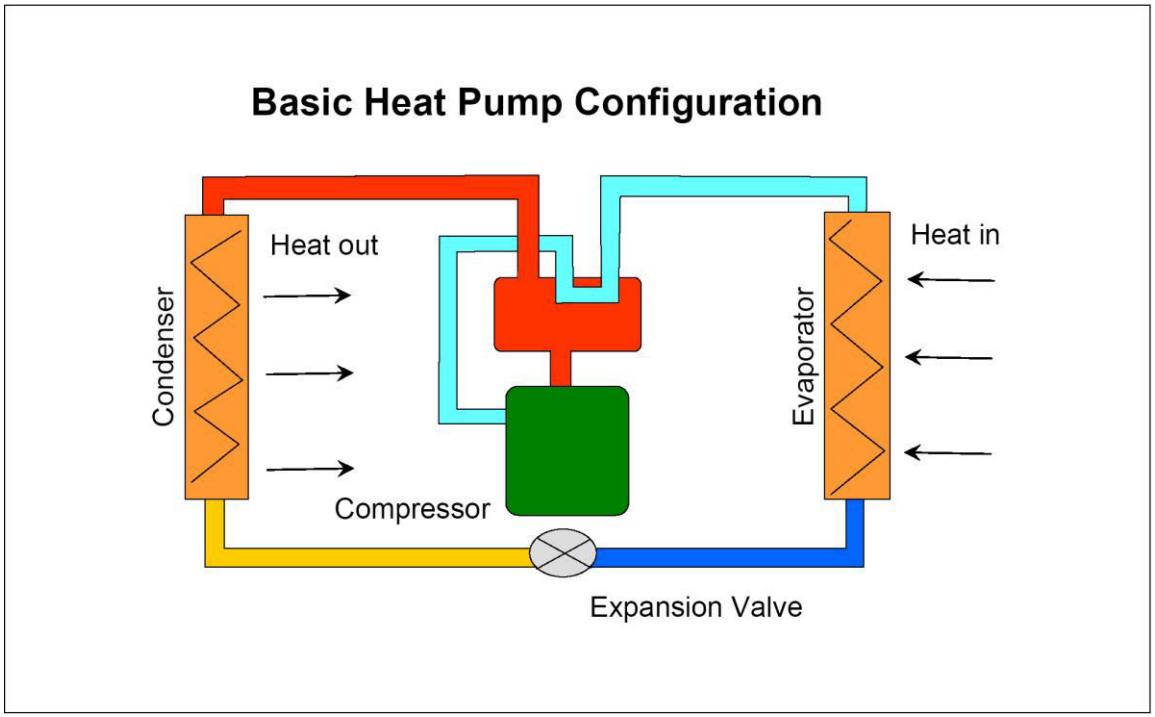
Exploring Climate Solutions *Renewable Thermal Technologies: Heat Pumps*



Joe Swift
Sabrish Menon
April 8, 2016

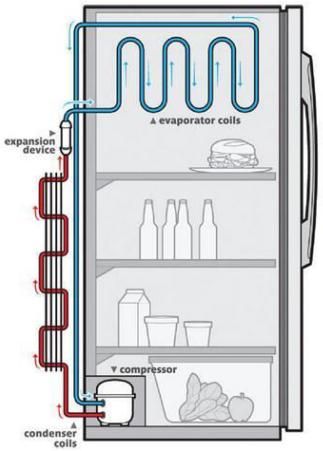
Types of Renewable Thermal Technologies

- Heat Pumps
  - Air Source Heat Pumps (heating, cooling)
  - Heat Pump Water Heaters (water)
  - Ground Source Heat Pumps (heating, cooling, water)
- Solar Thermal
- Biomass
- Biodiesel

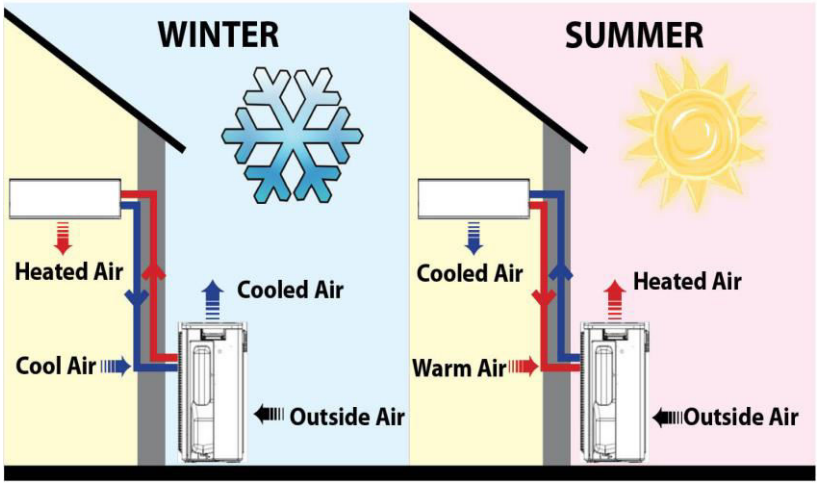
Today's presentation will focus on heat pumps

What is a heat pump and how does it work?

- The technology is fundamentally no different than that used in a refrigerator.
- The primary advantage of heat pumps is that it is using electricity to move heat versus converting electricity directly to heat. Thus they can be up to four+ times more efficient than electric heat because they take advantage of *"free"* thermal (heat) energy.
- Heat pumps do not utilize combustion, so no chimney or venting is required.
- One disadvantage of heat pumps is that their efficiency is a function of outdoor (or ground) temperature.
  - Heating capacity and efficiency is lower with lower source temperature.
  - Cooling capacity and efficiency is lower with higher source temperatures.

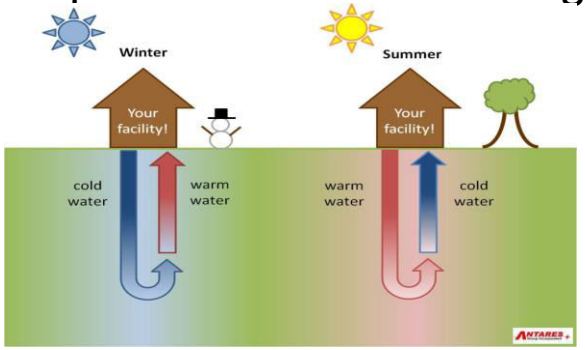


Both are refrigeration systems.

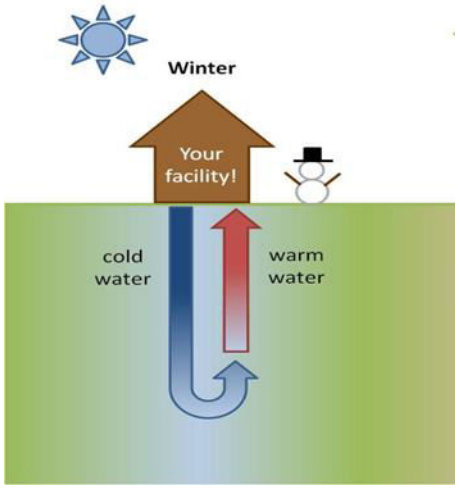


Ground Source Heat Pumps (aka “Geothermal Heat Pumps”)

- Typically use a large network of polyethylene pipes to extract or dissipate heat to and from the ground.
- Pipes can be horizontal (trenches) or vertical (drilled, most common in CT), or submerged in ponds (uncommon).
- Most are “closed loops” with food grade antifreeze.
- More efficient than air source heat pumps since the temperature of the ground is relatively stable (around 50 degrees F).
- Most expensive heat pump option (because of the ground coupling). Installed cost of approximately $9000 per ton (before incentives or tax credits). A typical residential system ranges from $36,000 to $45,000 (excluding tax credits and incentives)
- Typically are ducted, but some models can provide hot water for baseboard heating and/or provide domestic hot water.
- 30 percent tax credit through December 2016.



A Reconfigured Open Loop Ground Source Heat Pump!



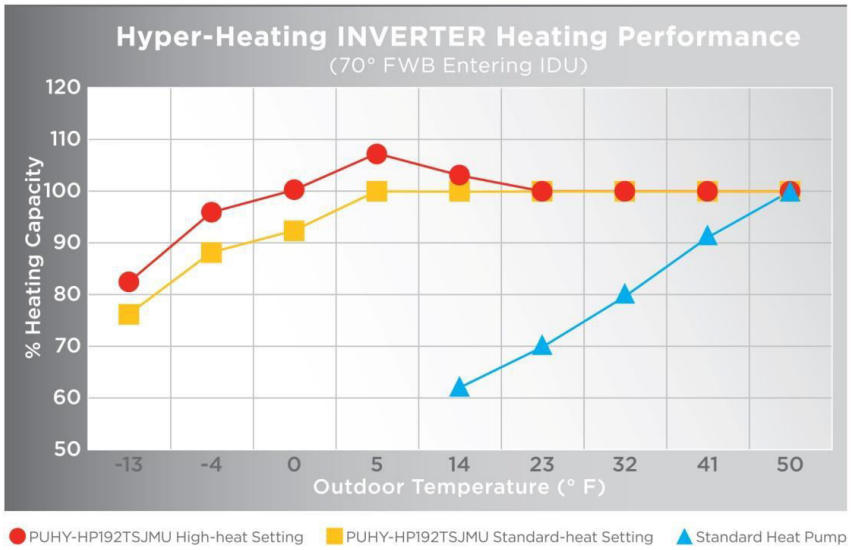
Why is this a ground source heat pump?

1. "Warm" water enters from the ground
2. Heat is removed from the water through a refrigeration process.
3. That heat is transferred to the surrounding air using a fan and coils (heat exchanger)
4. The resulting cold water runs down the drain and back to the earth.

Air Source Heat Pumps

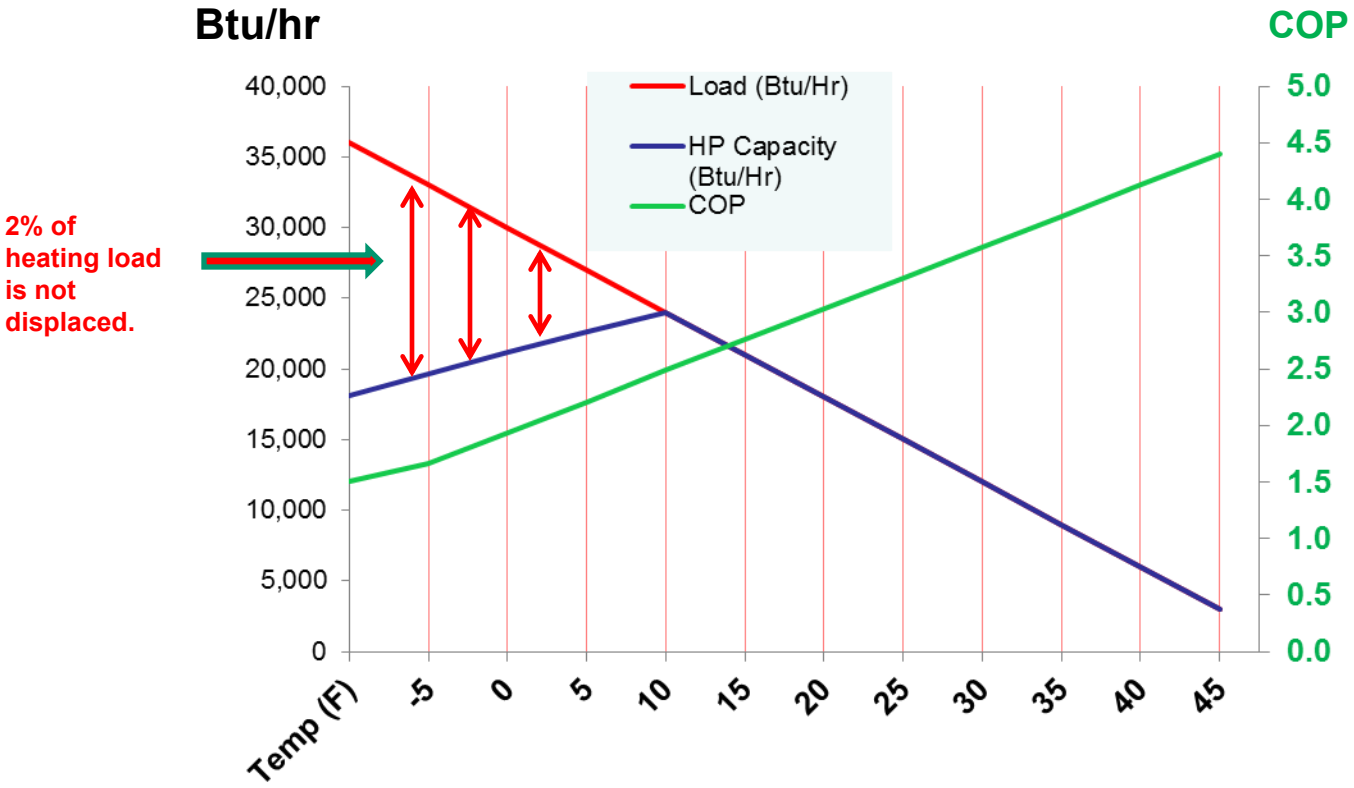
- Use the outdoor air as the heat sink and heat source.
  - Ducted heat pumps
  - Ductless heat pumps
  - Heat Pump Water Heaters
- Not as efficient as ground source heat pumps and work best in milder climates.
  - Heating performance (capacity and efficiency) drops as outdoor air temperature drops.
  - Cooling performance (capacity and efficiency) drops as outdoor temperature rises.
- New generation heat pumps are greatly improved: they will work and can provide value in very cold climates.

New Generation “Cold Climate” Ductless Heat Pumps



Greatly improved performance. However, supplemental heating may be required for low outdoor temperatures. However, most (sometimes all) of load can still be met. Shell upgrades can help eliminate the gap.

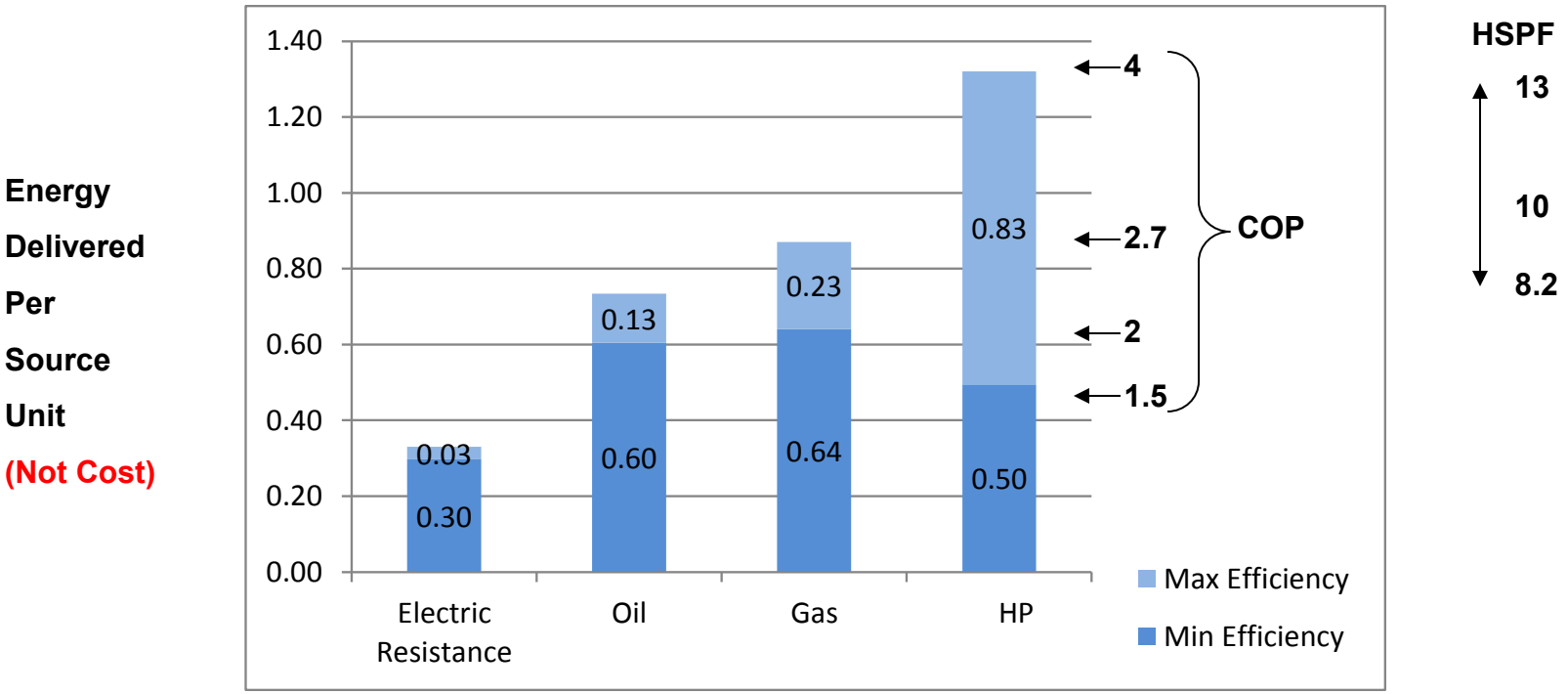
COP and Capacity Variable with Outdoor Air Temp



COP decreases with outdoor temperature. Supplemental heating typically required for DSHP at low outdoor temperatures. However, most (sometimes all) of load is covered with DSHP.

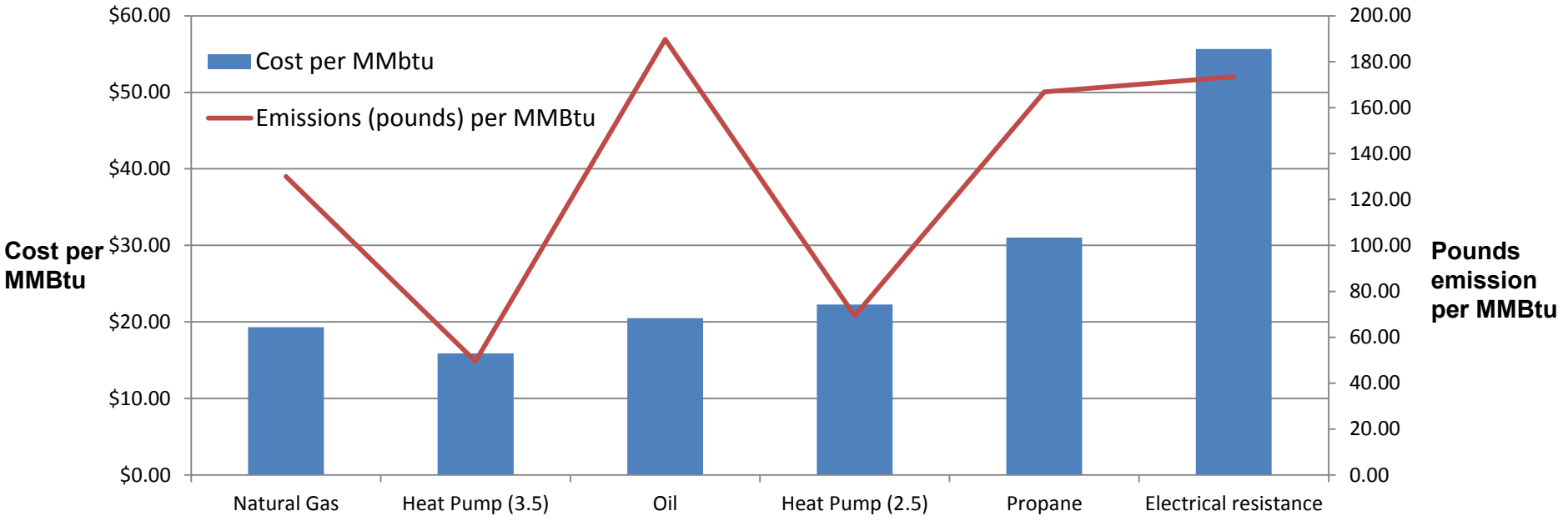
Example is based on typical Hartford weather data. At a balance point of 10 degrees, approximately 98 percent of the load can be displaced with a ductless heat pump.

COP Above 2.7 Provides Highest Energy Savings



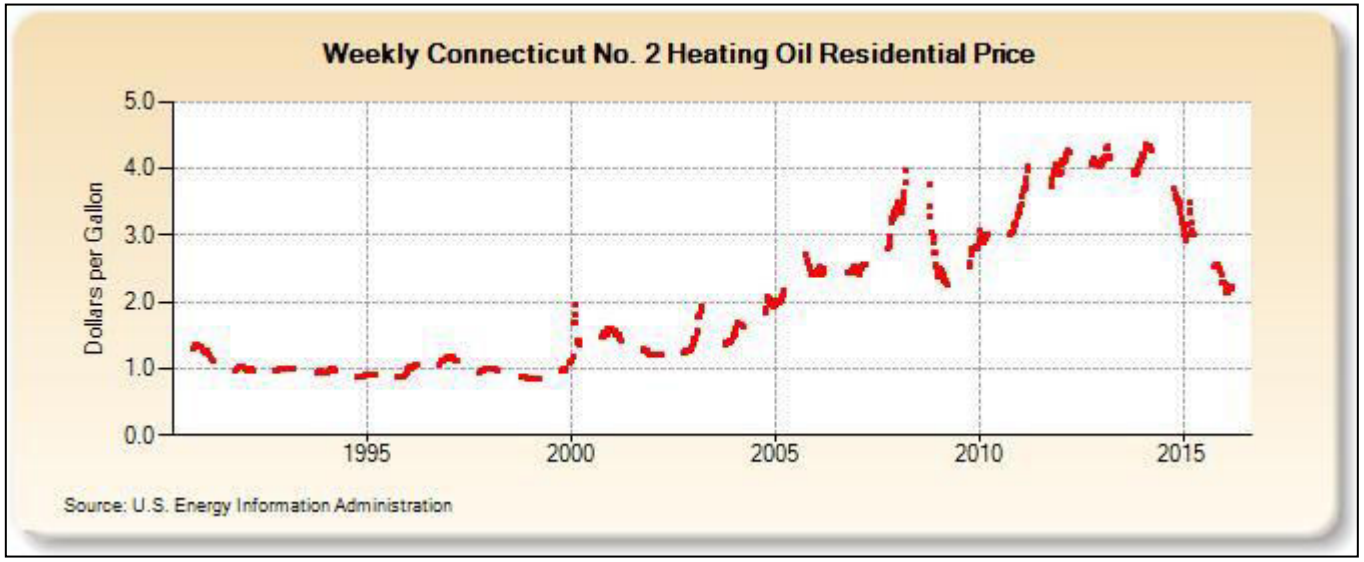
COP levels above 2.7 (GSHP) will provide opportunity for highest energy efficiency opportunity for all fuel types, but at the highest cost. COP levels between 2 and 2.7 (heat pump) may provide energy savings typically at a lower cost. COP levels below 1.5 will still provide energy significant savings over electric resistance.

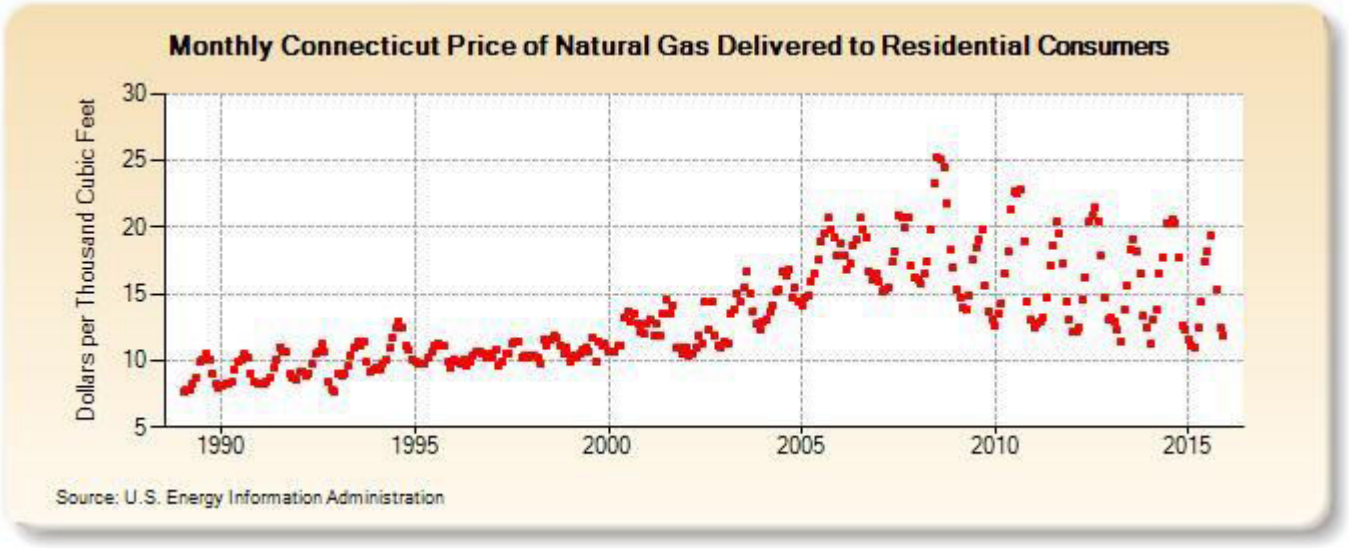
Customer Costs and Emissions (2016)



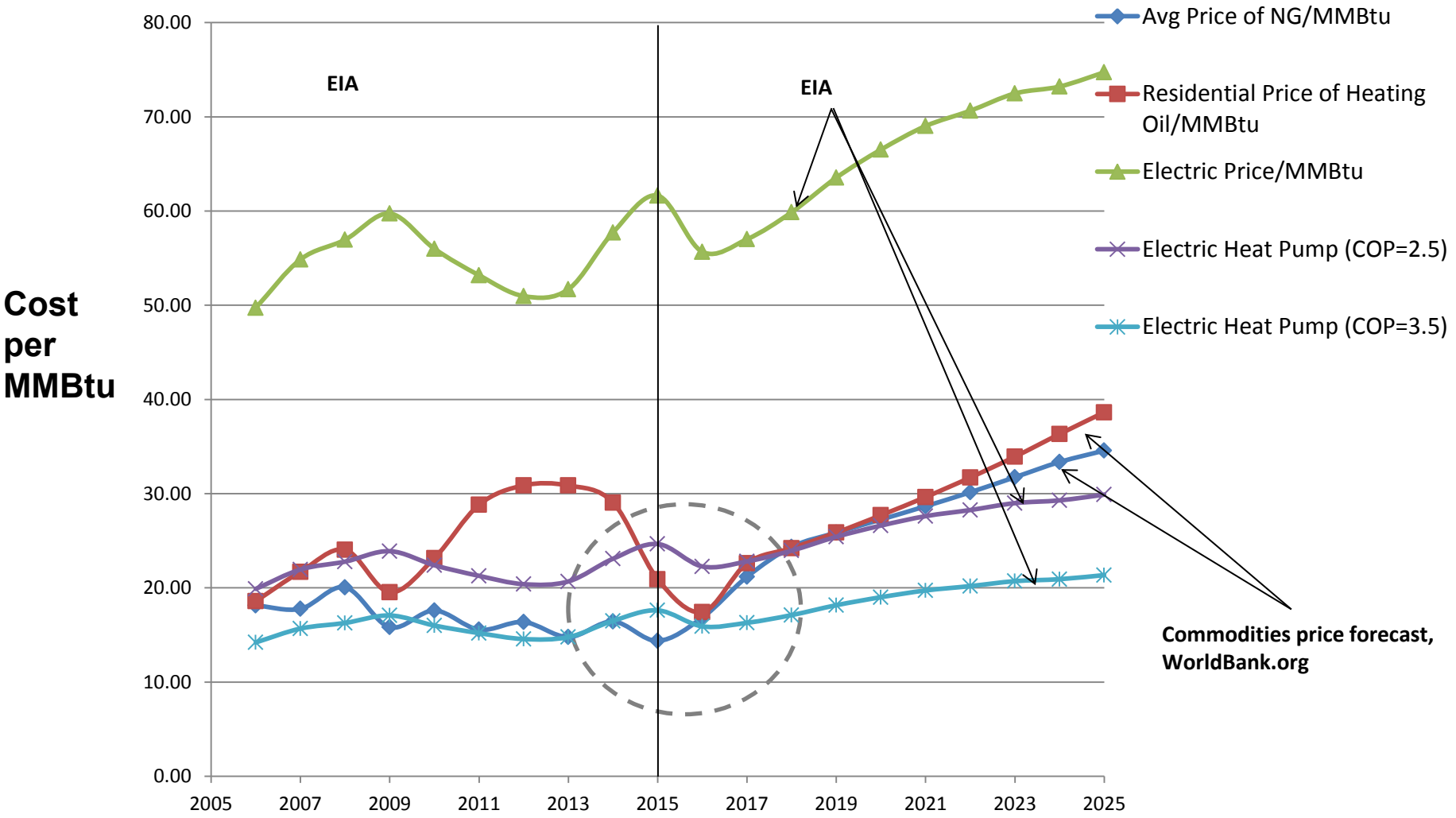
Fuel	Cost/Unit	Units	Efficiency
Oil	2.42	Gallon	0.85
Natural Gas	1.79	CCF	0.9
Propane	2.5	Gallon	0.9
Electrical resistance	0.19	kWh	1
Heat Pump	0.19	kWh	2.5
Heat Pump	0.19	kWh	3.5

The energy world is changing





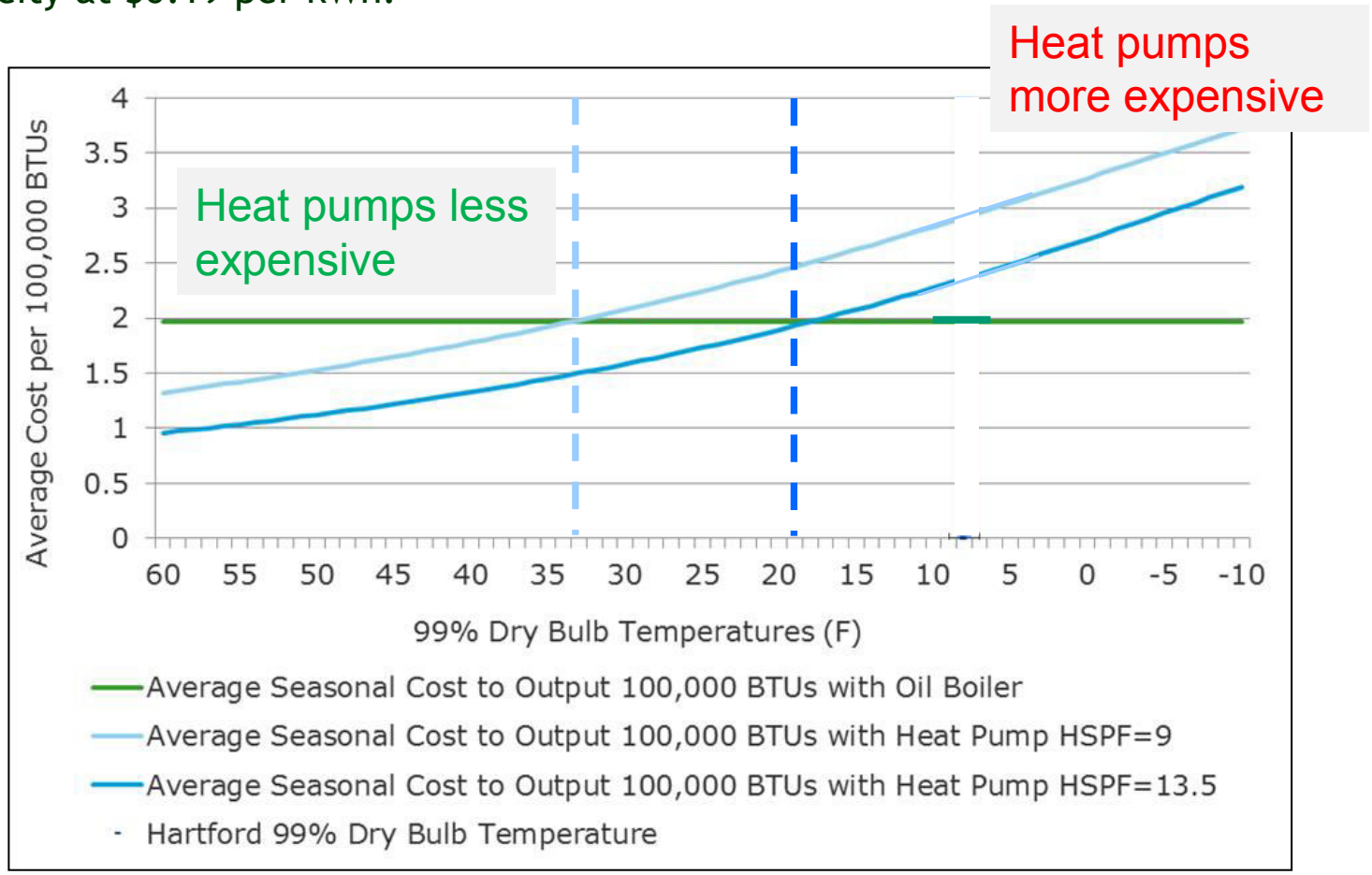
Historical and Forecasted



Heat Pump Operation cost versus temperature

Based on oil at $2.17 per gallon, and 80 percent efficiency.
Electricity at $0.19 per kWh.

EVERSOURCE ENERGY



Source:R113 Ductless Heat Pump Evaluation

Connecticut Energy Efficiency Board (EEB)

Prepared by DNV GL under subcontract to NMR Group, Inc.

March 13, 2016

Heat Pumps Should be Used Differently for Different Customers

Typical Home (supplemental heating opportunity)

Natural Gas Primary Heating	No
Oil Primary Heating	Maybe
Propane Primary Heating	Maybe
Electric Resistance Primary Heating	Yes

Low Load Home (DSHP primary heating opportunity)

DSHP or GSHP Primary Heating	Yes

Zero Energy Home in Massachusetts with two zone DSHP. Builder: Carter Scott, Transformations Inc.

Customers face a myriad of options!

EVERSOURCE ENERGY

Lower Cost

Lower Savings

Shorter payback

Oil Furnace, window AC, no natural gas.

+

= **Solution** (single DSHP)

+

= **Solution** (multi DSHP, electric baseboard)

= **Solution** (ducted ASHP)

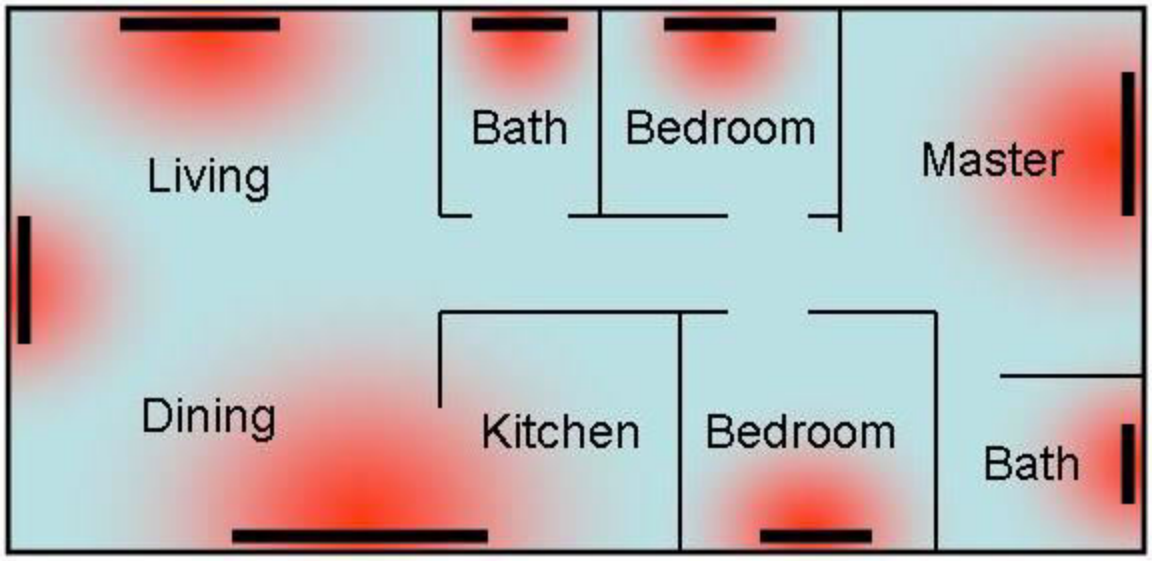
Higher Cost

High Savings

Longer payback

= **Solution** (GSHP)

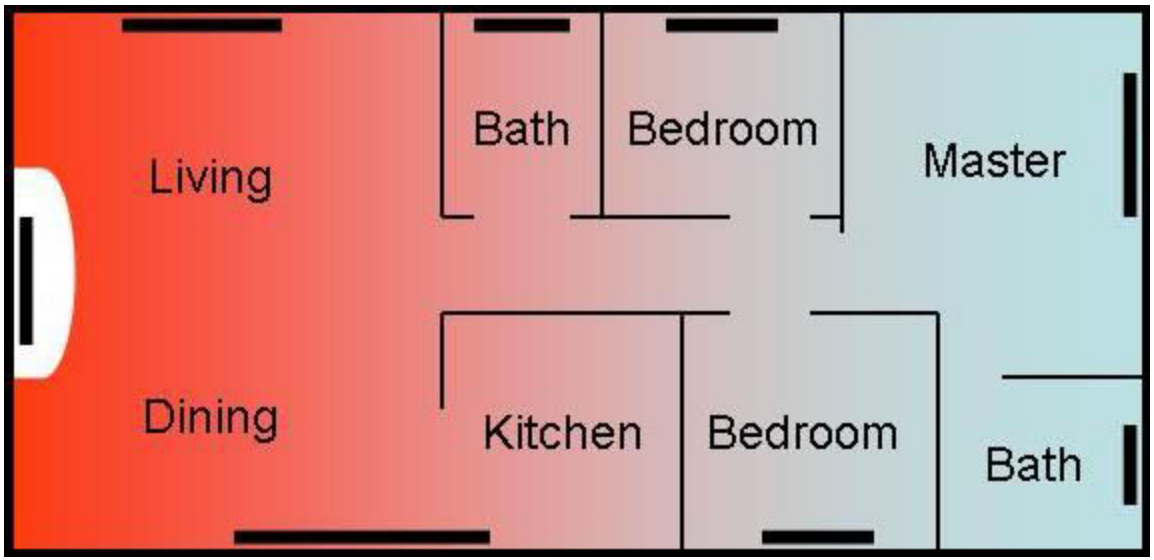
Replacement Theory (typical):



Typical home with baseboard or supplies for heating in each room

Displacement Theory:
Often used with DSHPs

Centrally located DSHP →

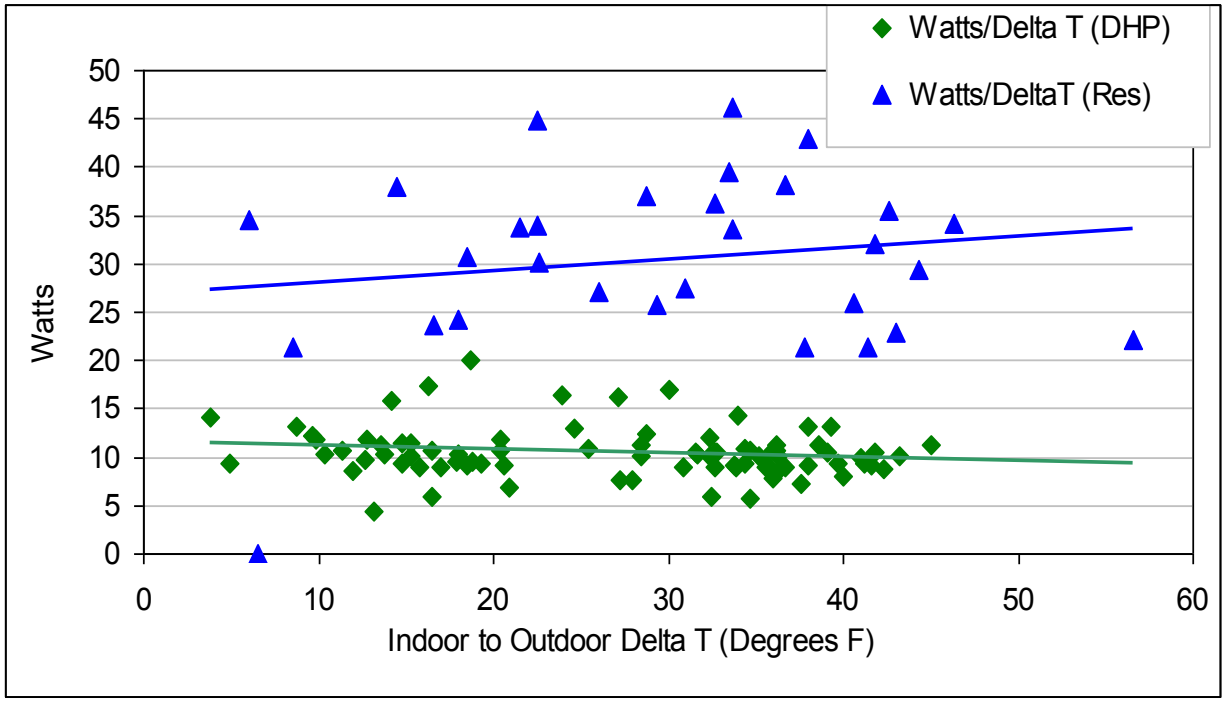


The same home after a DSHP is installed in a centrally located area

RESULTS – PERFORMANCE (Single DHP Test)

- Performance quantified as an effective seasonal COP (“Real COP”)
- Effective Seasonal COP using the watts per ΔT method is 2.9
- This method provides a more realistic snapshot of the actual equipment performance of a properly installed and well managed unit

POWER CONSUMPTION PER TEMPERATURE DIFFERENTIAL (ΔT)



Actual results based on properly designed and operated system.

Results vary based on size, efficiency, location of outdoor unit, temperature setting, air temperature.

Other tests have varied greatly with COPs estimated between roughly 1.5 and 3.0

GSHP Savings Potential is significant, but cost is higher.

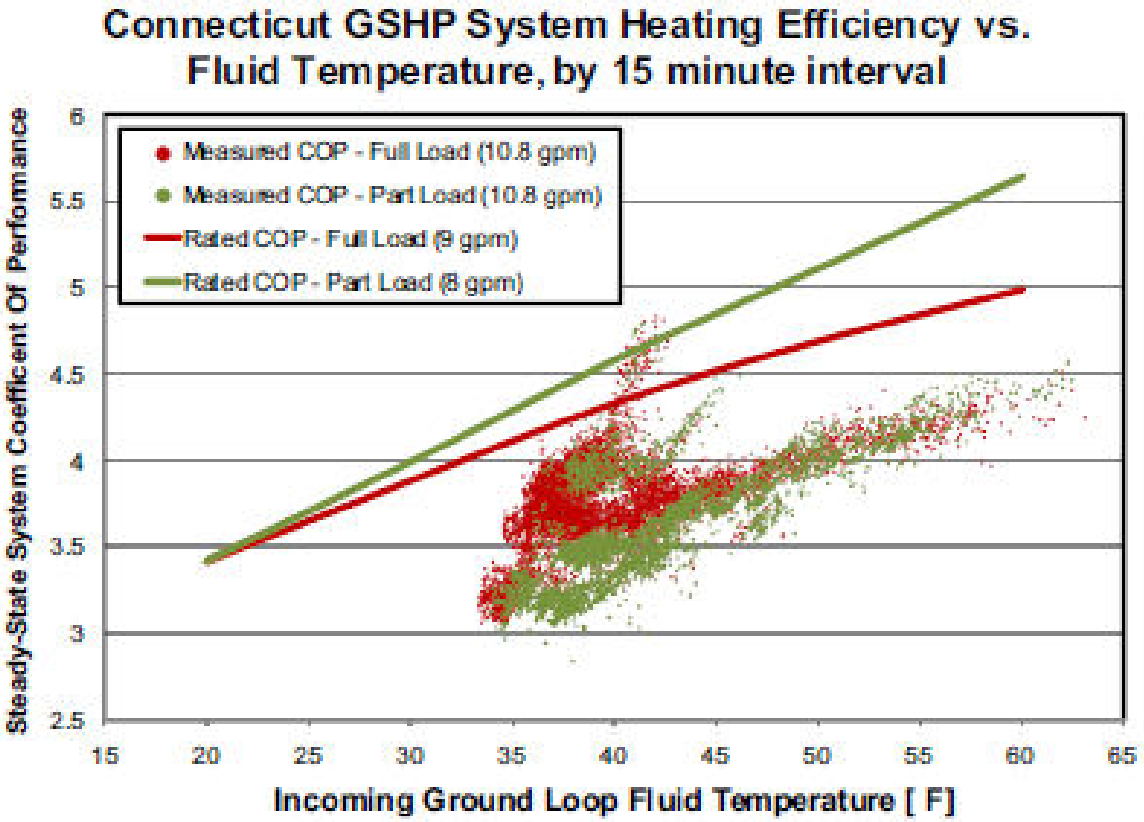


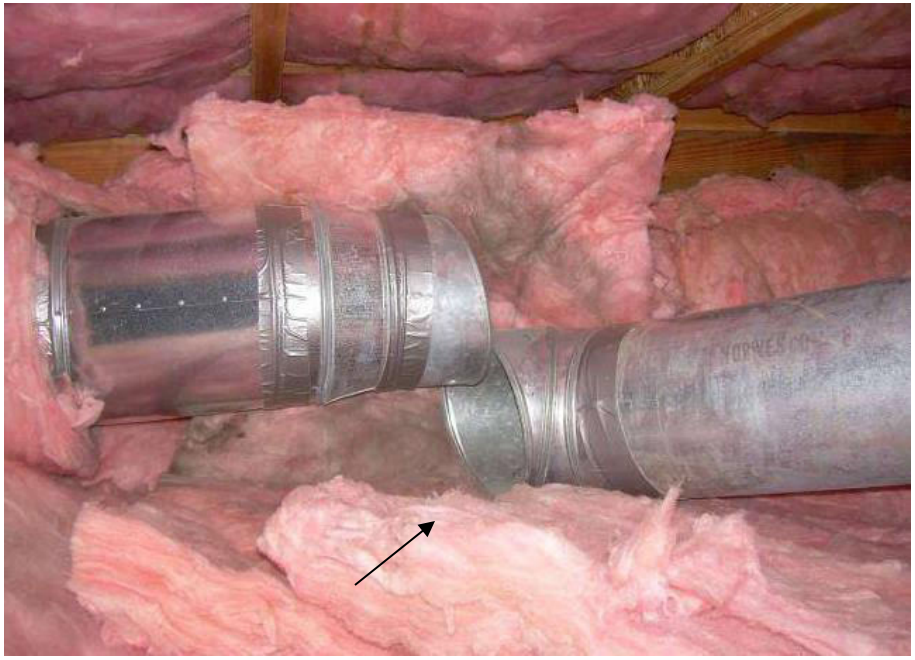
Figure 1. Steady state heating performance of Connecticut system from Nov. 2007 through Jan. 2010.

Residential Ground-Source Heat Pumps:
In-Field System Performance and Energy Modeling

Srikanth Puttagunta, Robb A. Aldrich, Douglas Owens, and Pallavi Mantha

Steven Winter Associates, Inc., Norwalk, CT

Ducts and envelope should not be overlooked in any HVAC system retrofit.

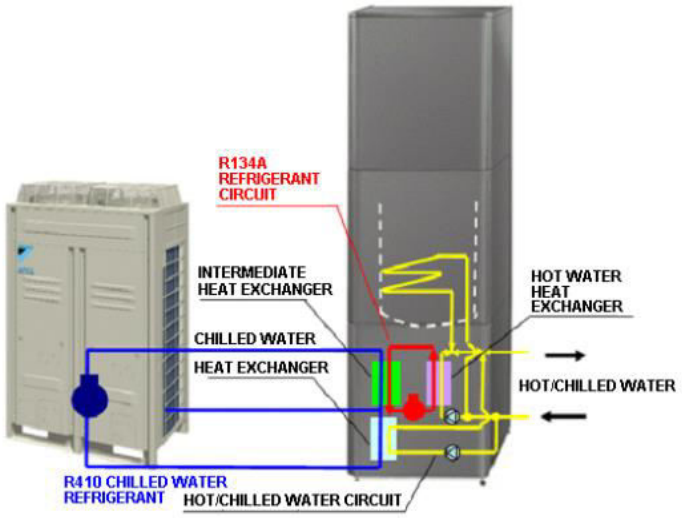


- DSHPs offer one solution because they do not waste energy heating or cooling unoccupied spaces which may provide additional opportunity for savings.
- Ducts likely need to be replaced for ducted heat pump options

Hot water should be considered in the decision making process.

Standalone

Integrated



- Heat Pump Water Heaters (HPWHs) pull heat from the surrounding & transfer it at a higher temperature into a tank to heat water
- They tend to cool and dehumidify the space that they are in.
- Heat pump water heater systems typically have higher initial costs than conventional storage water heaters but can be 2 to 3 times more efficient
- Heat pump water heaters may be a viable option for some customers, but are not a universal solution. You need sufficient space in an unconditioned basement (this climate)

Financing and Incentives:

EVERSOURCE ENERGY

- Ductless HP receive rebates of $300 per home
- ENERGY STAR Heat Pumps receive rebates of $250-$500
- ENERGY STAR Heat Pump Water Heaters receive up to $400 instant discount
- Geothermal Heat Pump systems receive rebates of $500-$1,500
- Financing of up to $15000, 10% down & 2.99% interest rate (3-10 years)
- SF homeowners may borrow up to $25,000 (10 years) below market rate & MF up to $3,500 per unit
- Low-or Zero interest rate (12 years) financing of $1,000-$25,000

Summary:

- Heat pump technology is a viable solution for many situations.
  - Newer generation heat pumps have improved dramatically.
- Current fuel prices have changed the landscape.
- Existing heating system can remain for retrofit situations (especially DHPs) and can be used in colder temperatures where heat pumps may not provide sufficient and/or cost effective heat.
- Proper design is critical
  - Case by case design (best fit for my home)
- Hot water needs may influence decision
- Shell upgrades should be a priority.
- Visit www.EnergizeCT.com for more information.

Questions?

Thank you

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