Electric Heat Pumps for Residential Heating in PA

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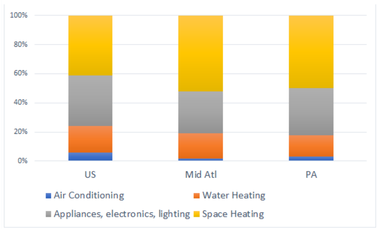
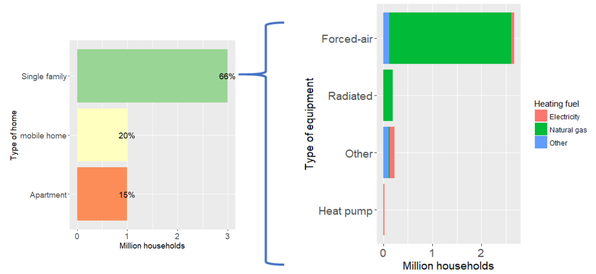
Introduction & Motivation

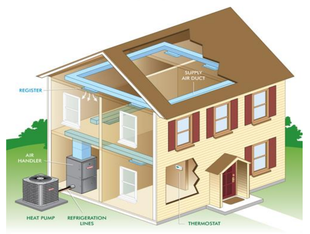


- 50% of energy consumed by the residential sector in Pennsylvania is used for space heating
- **Electric heat pumps are the most efficient heating and cooling system** available today
- Modern cold climate heat pumps can function near their max efficiency in extreme cold

Pennsylvania household by type of house, and heating system



- 2.5 million of Pennsylvania houses (66%) use central heating with natural gas
- This analysis targets **single family detached homes in PA with natural gas furnaces**
- Most single family homes in PA were built in 1970 or earlier; base model for analysis assumes poor/aging insulation and old, large windows.

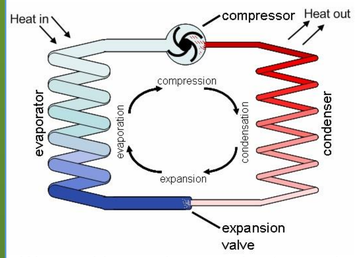


Modelling the average PA home:

- Single story
- 10 foot ceilings
- 6" fiberglass batting in attic, basement (R18)
- 4" Blown-in insulation in walls (R15)
- 20% of wall area is older windows (R1)
- "Leaky" house: 1 air exchange per hour
- **Estimated UA value 580 Btu/F-h**

In contrast, with DOE recommended retrofit insulation levels estimated UA value is 400 - 460 Btu/F-h

Heat Pump Calculations



- A heat pump works like an air-conditioner except that a reversing valve can change the direction of flow of the refrigerant, thus enabling **both a heating or cooling cycle.**
- **The refrigerant transfers heat** from one place to another as it goes through a complete cycle
- Heat pumps can be of different types depending on the source of heat (air source, geothermal, groundwater) and configuration (ducted or mini-split)

We consider an air source heat pump installation consisting of an outdoor condenser unit and an indoor air handler supplying heated air through the already existing ductwork. We size the heat pump based on the energy loss using the January HDDs in PA as this is the month of highest heating load

Energy Loss = Leakiness * Temp Demand

- Leakiness = U-Value * Area
- Temp Demand = HDDs (Temp Gradient * Duration)

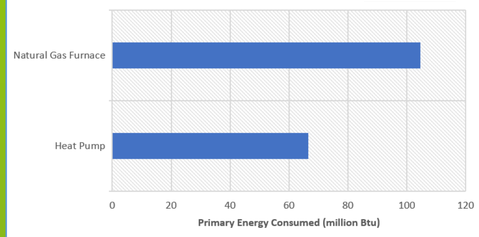
Monthly energy consumption for both heat pump and natural gas furnace is calculated using the system size, heat load and efficiency rating.

The energy consumption of the heat pump is given by its efficiency or Heating Season Performance Factor (HSPF). We assume a high efficiency heat pump with HSPF 13.

$$HSPF = H_s/1000\ P_w$$

- H_s = Heat Output (Btu)
- P_w = Electrical Power Consumed (kWh)

Results

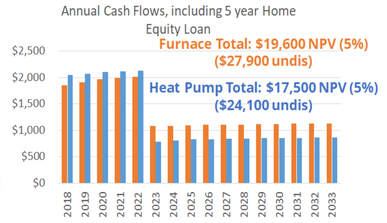


Primary Energy Consumption: Annual primary energy use for the average PA single family detached house, assuming a 33% efficient electrical grid (average efficiency of a coal plant)

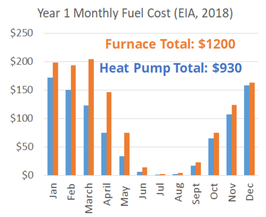
- Heat Pump : 66.6 million Btu
- Natural Gas Furnace: 104.6 million Btu

Financial Evaluation:

- The financial analysis assumes a **5 year home equity loan at a 5.45% APR**
- Fuel costs for electricity and natural gas in PA as well as the projected Mid-Atlantic fuel price changes are from obtained from EIA
- The higher capital cost of the heat pump ($5,900 compared to $4,200 for a new furnace), results in **higher cash flows during the lifetime of the loan**, but **lower overall costs and NPV of payments** due to the difference in energy prices.



- Gas prices have high seasonal variability compared to relatively stable electricity prices
- In 2018, the monthly fuel costs for heat pumps are projected to be 24% - 28% lower than the fuel costs for the furnace
- Over the 15 year period, the total cost of a new natural gas furnace is $21,830, 10% higher than the total cost of a heat pump ($19,558). With a discount rate of 5%, the NPV of these cashflows favors heat pumps slightly more as shown in figure



Sensitivity Analysis

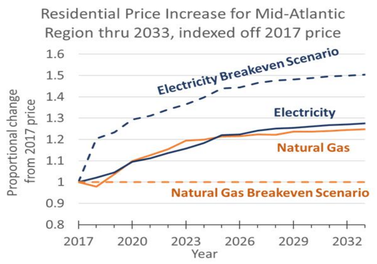
Model Assumption Changes	Furnace NPV	Heat Pump NPV	% diff.
Larger house (2000 sq ft)	$24,000	$20,700	-14%
Better insulation (DOE recommended insulation levels)	$15,600	$14,400	-7%
Warmer region (Philadelphia: 4700 HDDs/year)	$16,400	$15,200	-7%
Colder region (Bradford: 7700 HDDs/year)	$24,700	$20,900	-15%
Credit Card financing: 5 years, 11.99% APR	$20,300	$18,400	-9%
Lower efficiency heat pump (HSPF 10)	$19,600	$20,900	+7%

The sensitivity analysis compares the costs under various housing, financing, weather and preference assumptions. The only scenario that favors the gas furnace financially is a lower efficiency heat pump (HSPF 10).

Breakeven Scenarios (ceteris paribus):

- *Expensive heat pump*: An **$8,000** HSPF 13 heat pump
- *A very low time value of money,* i.e. a discount rate of 20%

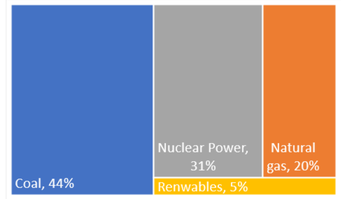
Finally, the dotted lines in the figure show how fuel prices would need to trend for breakeven scenarios (solid lines are 2017 AEO projection):



- Annual *natural gas prices remaining flat for 15 years*, or
- Annual *electricity prices increasing 18% more* per year than currently projected

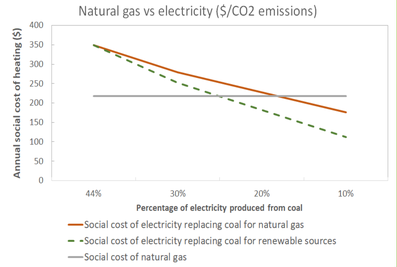
Environmental Impacts

The environmental impact of shifting from a natural gas central heating furnace to an electric heat pump is negative mainly because of the high percentage of coal in the grid mix



- **44% of coal in the electric generation mix** by Reliability First Corporation (RFC) region
- The total environmental impact might be an **increase of 10% in the Pennsylvania CO_2 emissions** from electricity consumption if all the target population switches to electric heat pumps

- The figure shows the annual social cost of heating a single home in Pennsylvania



- For comparable emissions to natural gas furnaces the **grid mix of coal would need to be reduced** from 44% to:
  - **26% if replaced by renewables,** or
  - **19% if replaced by natural gas**
- Heat pump savings can **be spent on carbon offsets** that make the technologies cost and emissions comparable

Limitations

- Heat pumps *can also meet cooling needs* during warmer months which is not considered in the financial analysis here
- *Incentives offered by utilities in some PA regions not included* as they are not universal
- General assumptions about housing stock - *variability of house size and insulation* will change the financial analysis

Highlights

This analysis compared replacing a natural gas furnace with an air source heat pump for single family detached homes in Pennsylvania, comparing costs and emissions

- Modern heat pumps can work up to -15˚F; furnaces can be easily replaced by air source condenser units, using the same ducts
- With current and projected prices for natural gas and electricity, annual heating costs were found to be **22-28% lower** for heat pumps.
- 15-year NPV with 5-yr home equity loan is **11% lower**:
  - Heat pump $17,500
  - Natural Gas Furnace: $19,600
- Heat Pumps are 40% more primary energy efficient than gas furnaces
- Reliability First Corporation (RFC) region which includes PA uses 44% coal, resulting in **more emissions for the heat pump**.
- Coal mix **of 26% if replaced by renewables and 19% if replaced by natural gas**, would result in comparable emissions.

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