An Examination of the US Residential Heating Market

Background, Behavior, Policy, and Prospective Companies

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Executive Summary

This paper outlines the US residential space heating market and highlights thirteen disruptive companies whose products decarbonize some link in the space heating supply chain. The goal of the paper is to provide Energy Impact Partners (EIP) with a strong understanding of market trends, regional switching costs, customer behaviors, and policy incentives. Additionally, we present an investment landscape of disruptive companies from which EIP may choose to pursue specific investment objectives.

The US residential space heating market may be thought of as a mix of space heating fuel sources, such as natural gas and electricity, and a mix of space heating technologies, such as Furnaces and Heat Pumps. Four major trends stick out. First, Furnaces dominate the technology landscape as the most popular heating technology. Second, natural gas and electricity are the two main fuel types used for space heating, with 51% of households using natural gas and 37% of households using electricity. Third, the mixes of fuel and equipment have changed since 2001 largely due to higher population growth in southern regions where electricity and Heat Pumps provide space heating for most homes. Fourth, according to utility executives interviewed the mix of fuel and technology will not change drastically over the next ten years.

Payback periods calculated are often long, greater than 10 years, making the switch to less carbon intensive fuel sources or less energy intensive technologies less appealing to the average homeowner. Furthermore, customer behavior hinders the switch to decarbonizing technologies because most individuals do not view space heating equipment as aspirational purchases and will only replace equipment upon failure – which often happens during the winter – forcing them to seek out the quickest fix rather than shop around for an alternative option, even if that option can save money through lower operating costs.

Several federal and state incentives exist to motivate homeowners to decarbonize their space heating system. More details are provided in Chapter 7.

Ultimately, the paper concludes with four insights for EIP with regards to investing in space heating startups. These insights revolve around the projected energy and technology mix, where innovation occurs in the space heating supply chain, customer behavior in purchasing decisions, and the importance of government policy for a startup's success.

Acknowledgements

This project was a challenge to say the least. Working on this project on a part-time basis over nine months while managing schoolwork, recruiting, and internships tested our project management, client engagement, and teamwork skills. We would like to first and foremost thank Andy Lubershane for his expertise and guidance on this engagement and Dr. Lauren Bigelow for her support and direction throughout the project. We would also like to thank Fandi Shen for her contribution and dedication to the project, and we wish her the best of luck on her journey forward.

We also received a lot of great perspectives on the US space heating market and feedback regarding our thesis from a range of executives across the industry. To that end, we would like to thank all those we interviewed throughout the project who allowed us to create a more well-rounded report. Additionally, we would like to thank the SEAS Administration for shepherding us through our project plan and keeping us accountable to one another.

We would also like to thank each other for executing on this project and taking over Munger Residence Halls to complete this requirement. Well done and Go Blue!

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Chapter 1: Project Background

Problem Statement

Currently, heating production is responsible for 50% of global final energy consumption (Eisentraut, A., & Brown, A., 2014). With fossil fuels providing around 75% of this energy, heating becomes an important contributor to global greenhouse gas emissions and has historically been a difficult source of emissions to address. 65% of American household energy is used for space heating, water heating, and air conditioning (EIA, 2009). For many countries, including the US, tackling the decarbonization of heat is essential for the success of combating climate change. Considering the enormous emerging technologies and supportive policies, there are a range of investment opportunities in the field of space heating decarbonization. Our client, Energy Impact Partners (EIP), would like to identify venture investment opportunities as well as better understand the market landscape of this space. To that end, our team researched new technologies in the field of space heating decarbonization and provided a baseline evaluation of their potential to be future investment opportunities for EIP. This analysis will help contribute to the challenge of tackling heating-related emissions while also creating value for EIP's customers and stakeholders.

Background on Energy Impact Partners

Energy Impact Partners is the world's largest strategic venture investment firm focused exclusively on energy. They have raised a $500 million fund targeting early-to-mid stage equity investments in innovative companies who will impact the future of the electric and gas utility industry. Their limited partners – the investors in the fund – are a global coalition of utilities seeking to increase the efficiency, sustainability, and value of their industry. EIP adopts a collaborative approach to energy innovation, bringing incumbents, capital and entrepreneurs together to shape the future of energy.

Project Objectives and Scope

The primary goal of the project is to map out potential venture capital investments for EIP in the field of space heating decarbonization. Our mapping and analysis will help inform EIP's future venture capital investments in the space. Given the goal, our team aims to meet the following objectives:

1) Conduct a market overview of current space heating systems

2) Provide an economic analysis of EIP selected technology switching costs in the Northeast and Southeast regions
3) Identify innovative technologies that can reduce the carbon intensity of space heating
4) Explain the key barriers of switching technologies or adopting new technologies
5) Understand the policy landscape in both the USA and EU for space heating
6) Provide a baseline level analysis of these innovative technologies from which EIP may or may not choose to research in greater detail, after extensive due diligence.

Project Output

In support of identifying and evaluating venture investment opportunities related to space heating decarbonization, our team completed a project plan that comprised of a number of deliverables. The interim deliverables encompassed all work products that supported the creation of the final deliverable. The final deliverable is what will be handed and presented to the client.

- Final report
- Pitch-Deck - PowerPoint presentation detailing

  (1) Technological solutions that tackle space heating decarbonization

  (2) The viability of these technologies and their position within the market

  (3) Incumbent and investible solution-providers deploying these technologies

  (4) Recommendations on how EIP should move forward when investing in this space.
- Presentation - Present findings to EIP stakeholders on-site in EIP’s Council Day meeting in San Francisco

Chapter 2: Methodology

Literature Review

Given that heating decarbonization itself is a "new frontier" area of interest within EIP, we anticipated that literature exclusively relating to the topic would be difficult to source, if not impossible to source. Moreover, our team reviewed reports published by think tanks and research institutes to collect the newest information about the technology landscape, industry trends, and current policies. We also extracted information from data provided by open-source government websites such as the U.S. Energy Information Administration (EIA). The chart below demonstrates the way in which our literature review will take shape.

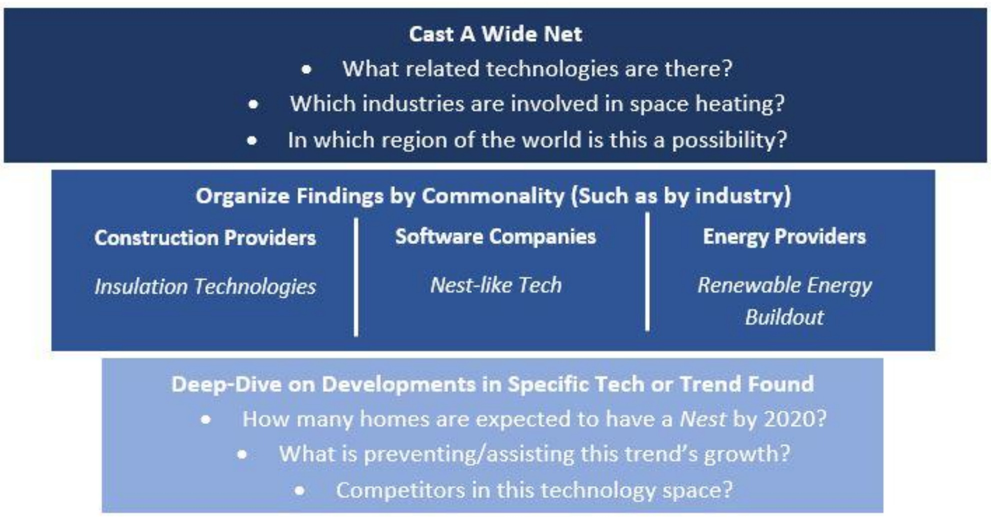


Figure 1 Literature review process of the project

Interviews

In addition to literature and reports, we also connected with start-up technology companies and utilities to gain first-hand data and insights from interviews. All interviews were facilitated by EIP. Because EIP maintains relationships with some of the world's most well-known companies in the energy space, having them facilitate interviews was a requirement of the project. Given the importance of the information collected during interviews, the team followed a set procedure to ensure the utmost accuracy of each interview session. The procedure included:

- An audio recording of each session
- A designated "interviewer" who was responsible for facilitating the conversation
- A designated "note taker" who was responsible for transcribing the interview

- The drafting of an interview template, listing questions and providing structure, to be sent to the interviewee prior to the interview session

Considering the different interest demands of start-up technology companies and utilities, we designed two question lists for them (See Appendix D and Appendix F). For start-up technology companies, we were more interested in getting information about their product, marketing and customer acquisition, competition, traction, economics, and financials, all of which helped to evaluate their investment potentials. For utilities, we focused more on their insights about space heating market forecasts and their opinions about customer behaviors and regulations, which helped us to better understand the feasibility of deployment better.

IRB Process

Our team has followed the IRB process at the University of Michigan to ensure that our project complies with the human subject review procedures.

Analysis

Analysis was conducted on payback periods in the northeast and southeast regions of the United States, from one old heating technology to a variety of new heating technologies outlined in Chapter 4. Each scenario was setup in the same manner and followed the same procedure to arrive at two payback periods. One payback period assumed that there was a preemptive switch from the fuel oil system to a new system. In other words, a scenario in which the homeowner installs a new system without his or her old system having failed. The second payback period assumed that the technology switch occurs upon the fuel oil system's failure. There are five steps in total, each shown below:

1) Calculate the cost of switching from an old technology to another technology
2) Calculate the annual operating costs of all systems in question
3) Calculate the annual fuel savings each new system provides
4) Calculate the payback period for a preemptive installation or an installation at failure

Analysis was also conducted on the list of disruptive companies in the space heating market that we uncovered. The analysis looked at the following characteristics of each company to determine its "investability."

1) Qualitative factors such management experience and composure during phone calls
2) Product development stage
3) Baseline company characteristics such as total funding raised to date, competitors, and other factors listed in Figure 36

Chapter 3: Market Overview of Space Heating Technology

Overview of Energy Feedstocks Used in Space Heating

Background

Space heating equipment is powered by a variety of fuel sources throughout the United States, varying considerably by climate region. Most northern and mid-Atlantic states strongly favor natural gas as the primary heating fuel energy source. The Mountain North and North Central areas, which include states such as Idaho, Minnesota, and North Dakota have the greatest number of users of natural gas, on a percentage basis, of all regions. This may be due to a variety of factors but as a commodity product, the price of natural gas is what largely informs consumer decisions and these states trend towards the lowest residential natural gas prices in the country (See Figure 2). Natural gas dominance declines somewhat in the Middle Atlantic region and more so in the New England states because of a long-standing competition from fuel oil.

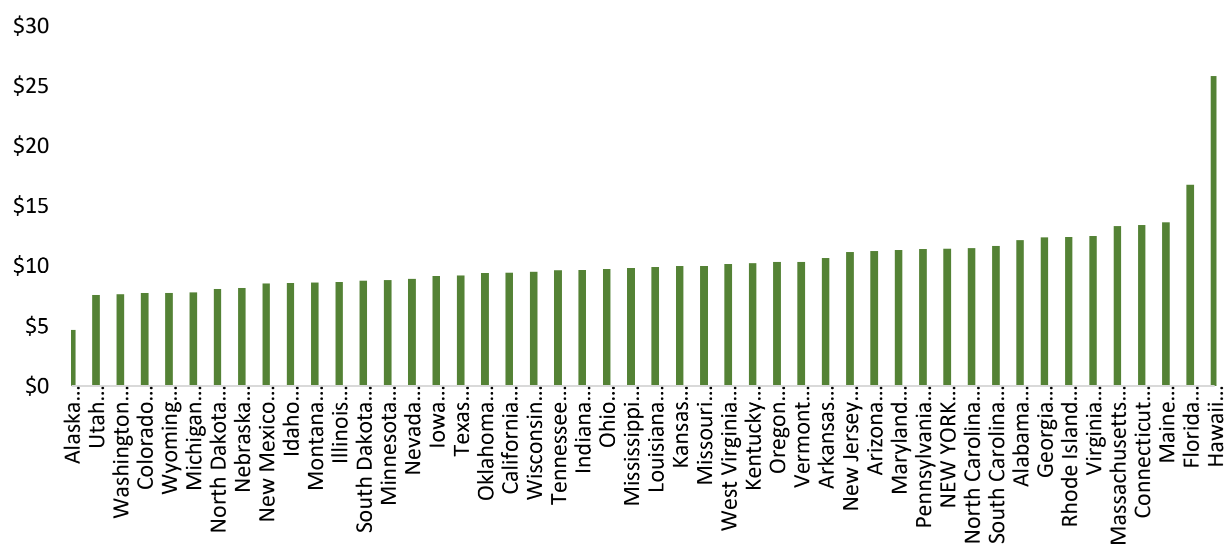


Figure 2 Average Price ($ / 1,000 Cubic Feet) of Natural Gas by State (Residential)

The Northeast residential infrastructure was largely expanded following WWII under the “Cheap fuel hypothesis” in which it was believed that U.S. petroleum would dominate into perpetuity, thus keeping fuel oil prices low. However, the price of fuel oil has not followed such naïve thinking. Between 2000 and 2013, the price of fuel oil increased from roughly $1.50 per gallon to over $4.00 per gallon. Today, the price per gallon is hovering around $3.00, showcasing that not only is fuel oil expensive but the price is extremely volatile compared to other energy options (See Figure 3). Due to these factors, natural gas has made inroads in the Northeast, but New England's natural gas pipelines can't transport enough gas into the region during periods of cold weather to provide both residential heating customers and power plants. As pipeline capacity is maxed out, the price of natural gas spikes (Clemente, 2016). So, fuel oil still makes sense for some New England consumers.

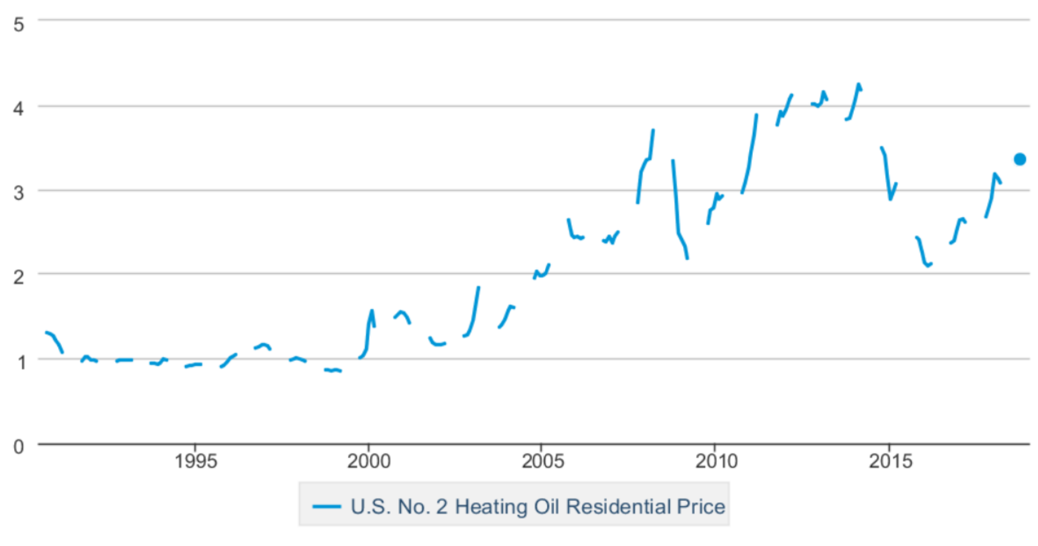


Figure 3 U.S. No. 2 Heating Oil Residential Price ($ / gallon)[1]

In the U.S. South, which includes states from Texas in the west to Florida in the east, electricity is the dominant fuel source for residential space heating. Low heating degree days (See Figure 4) and inexpensive electricity for the region (See Figure 5) have resulted in electricity as the most popular space heating energy source. A heating degree day (HDD) compares the mean outdoor temperatures recorded for a location to a standard temperature of usually 65° Fahrenheit in the USA. The more extreme the outside temperature, the higher the number of degree days. A high number of degree days generally results in higher levels of energy use for space heating or cooling. For example, a day with a mean temperature of 40°F has 25 HDD (EIA, 2018). According to EIA, “The cost of generating electricity is the largest component of the price of electricity,” (See Figure 6) southern states simply generate electricity from cheaper sources, such as nuclear and coal (Bade, 2015).

[1] US Energy Information Administration (EIA)

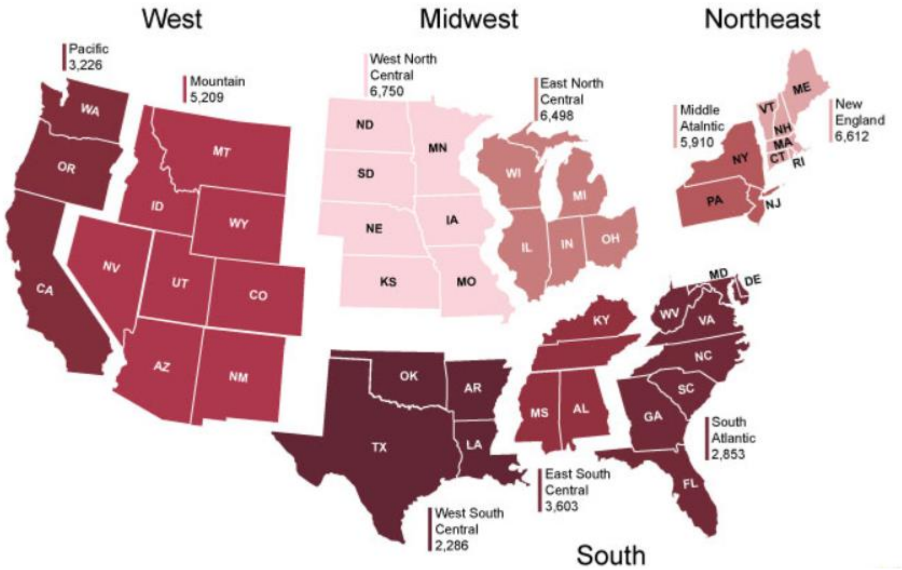


Figure 4 Heating Degree Days by Census Region in the U.S.[2]

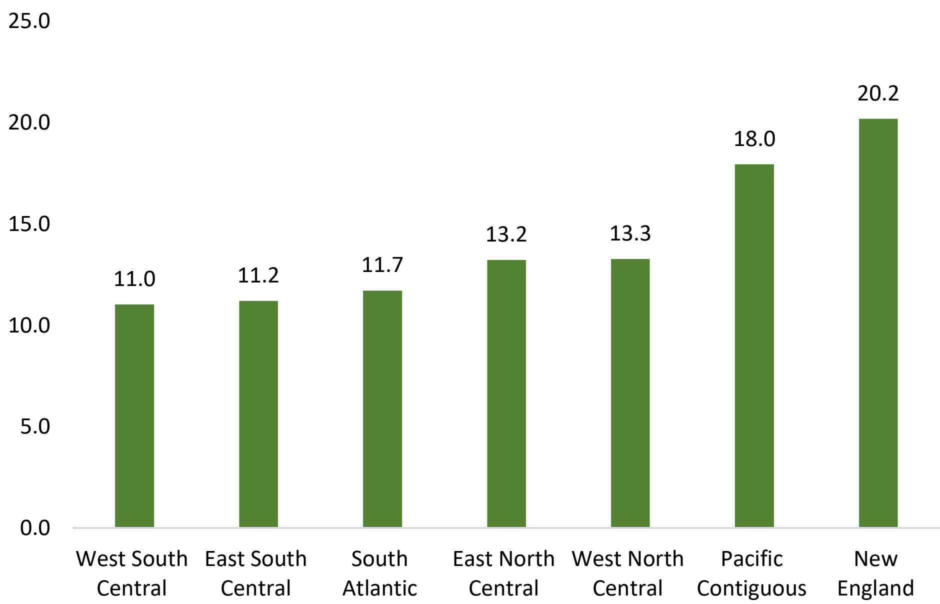


Figure 5 Average Price (Cents / Kilowatt-hour) of Electricity to Residential Customers by Region (2018)[3]

[2] US Energy Information Administration (EIA)
[3] US Energy Information Administration (EIA)

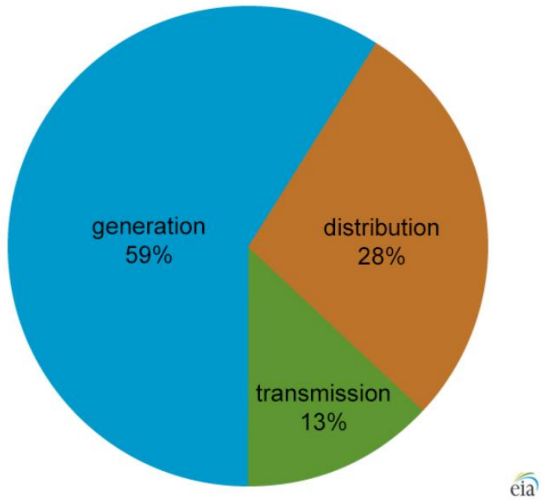


Figure 6 Major Components of the U.S. Average Price of Electricity, 2017[4]

These regional heating fuel preferences may be viewed in the below map of the continental United States, which was assembled with 2015 data from EIA. The key insights gained from this graphic are the following:

- Natural gas and electricity are the two dominant fuel types
- Natural gas tends to be more prevalent in colder climate regions
- Electricity tends to be more prevalent in warmer climate regions
- Fuel oil is contained to the Mid-Atlantic and Northeast
- Other fuel types, such as wood, make up small percentages of the total mix

The evolution of the mix of space heating fuel types did change drastically throughout the 20th century, essentially mirroring the broader U.S. energy mix (See Figure 8), in which coal replaced wood, and was itself replaced by a mix of oil, gas, and nuclear power. However, over the past decade, the mix of space heating fuels has not changed significantly (See Figure 9).

[4] US Energy Information Administration (EIA)

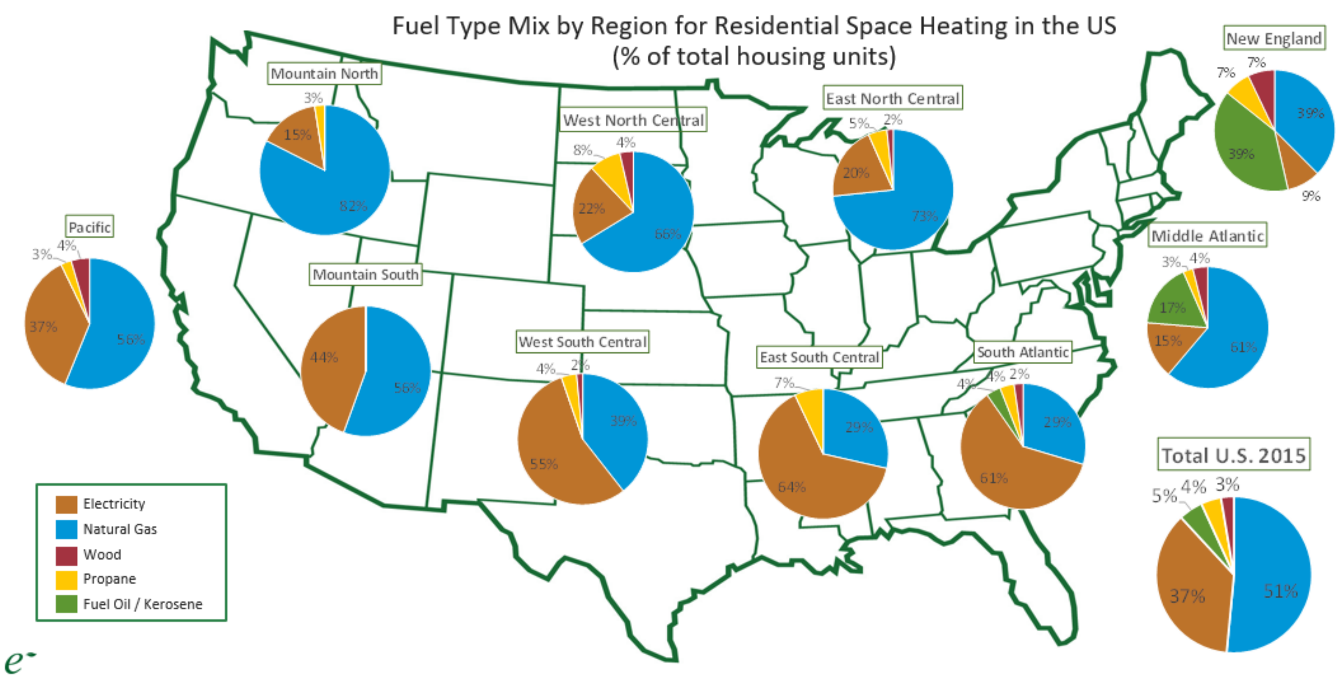


Figure 7 Fuel Type Mix by Region for Residential Space Heating in the U.S. (% of total housing units)[5]

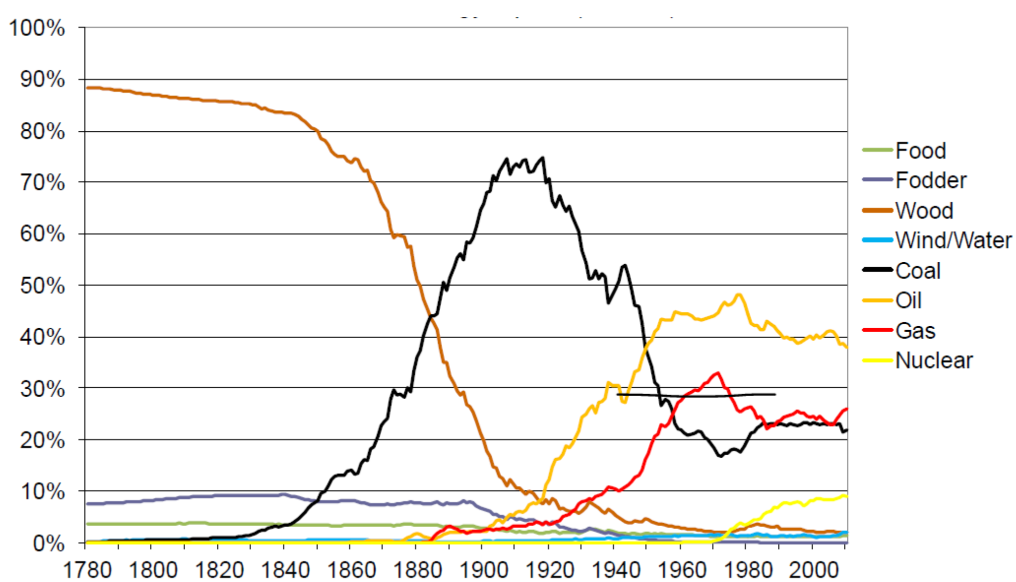


Figure 8 Energy Inputs (Shares) from 1780 to 2010)[6]

[5] US Energy Information Administration (EIA)
[6] U.S. Energy Transitions 1780–2010, Peter A. O'connor

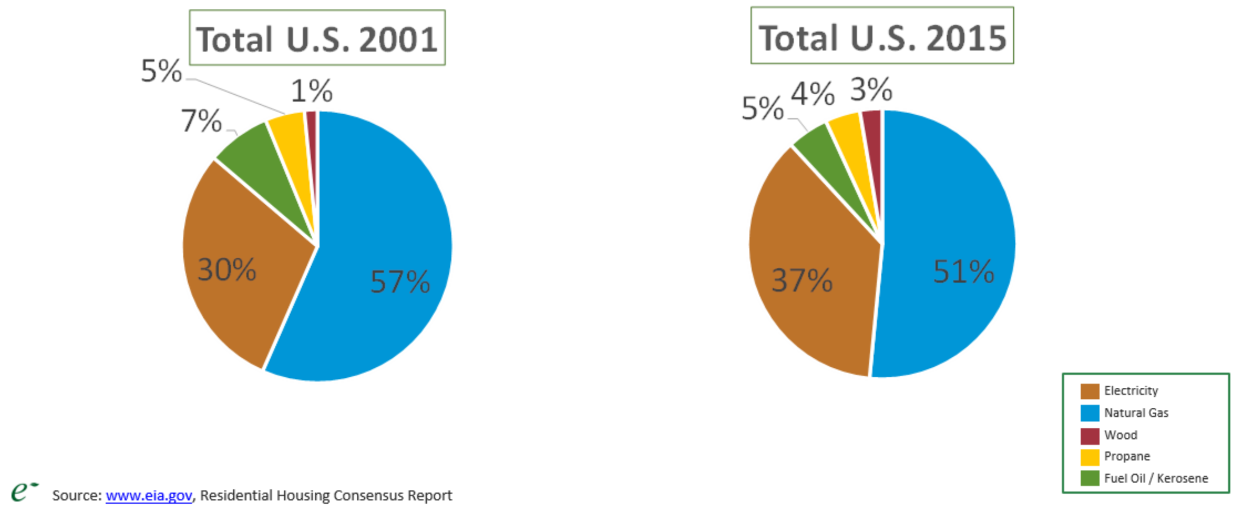


Figure 9 Fuel Type Mix for Residential Space Heating in the U.S. (% of total housing units)[7]

The percentage of homes heated by electricity has increased from roughly 30% to 37%, while the percentage of homes heated by natural gas has decreased from 57% to 51%. The leading cause of this change in fuel type is best explained by geographic preferences of U.S. citizens. Between 2000 and 2015, new housing construction in the cold/very cold climate zones of the U.S. grew on average by roughly 25%. During that same time period, new housing construction in the hot-humid and mixed-humid climate zones (See Figure 10) of the U.S. grew on average by roughly 50% (See Figure 11). The U.S. population has been shifting south and west for about 60 years, and this data shows that this movement should continue in the future (Millsap, 2018).

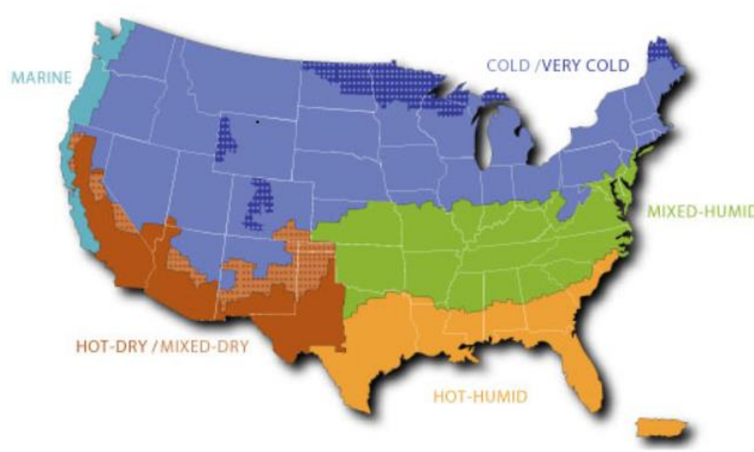
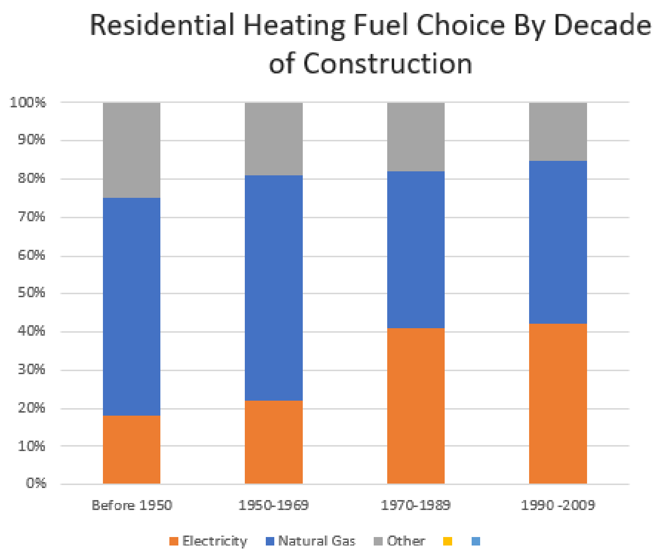


Figure 10 Climate Zones in the U.S.

[7] US Energy Information Administration (EIA) 2015 Residential Energy Consumption Survey



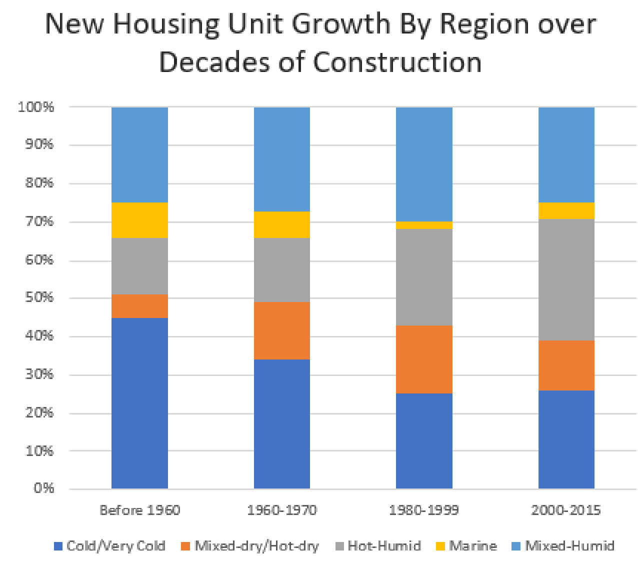


Figure 11 Residential Heating Fuel Choice by Decade of Construction (left); New Housing Unit Growth by Region over Decade of Construction (right)[8]

Provision Technology

There are a range of space heating technologies that are used throughout the United States to meet residential space heating needs. The most prevalent technologies are central Furnaces, Heat Pumps, steam or hot water systems, and built-in electric units. Other far less prevalent, main-source heating technologies include portable electric heaters, wood stoves, and fireplaces. As with heating fuels, the variety in heating technologies varies mainly by climate region (See Figure 12). For example, natural gas Furnaces are very popular in cold/very cold climates where heating degree days are high and natural gas prices are low. In hot-humid states though, where electricity is cheaper and heating degree days are less, electric Furnaces and electric Heat Pumps reign supreme.

Please note: Descriptions for the functionality of different space heating technology have been pulled directly from source material for the purpose of simplicity and conciseness. This source material has been cited for reference.

[8] US Energy Information Administration (EIA) 2015 Residential Energy Consumption Survey

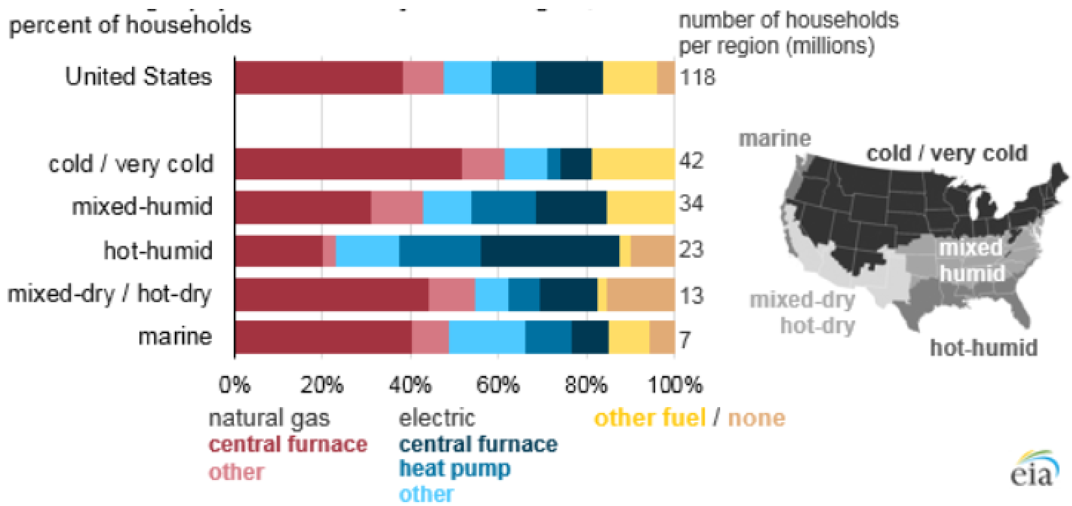
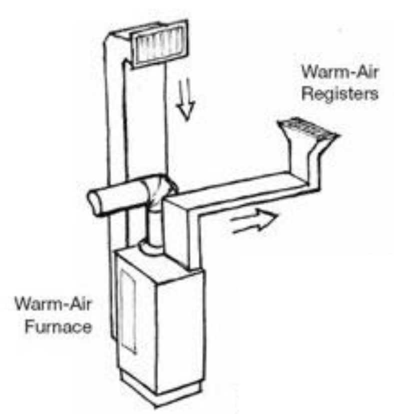


Figure 12 Main Heating Equipment Choice by Climate Region, 2015[9]

A brief description of each major technology's operation and mix in the U.S. heating market follows below:

Central Furnace

How does it work



Smarter House reports: "A Furnace works by blowing heated air through ducts in the house that deliver the warm air to rooms. Furnaces can be powered by electricity, natural gas, or fuel oil. Inside a gas- or oil-fired Furnace, the fuel is mixed with air and burned. The flames heat a metal heat exchanger where the heat is transferred to the air. Air is pushed through the heat exchanger by the Furnace fan and then forced through the ductwork downstream of the heat exchanger. Combustion bi-products are vented out of the building through a flue pipe" (Smarter House, 2015).

Historic Mix Change

Central Furnaces make up at least 50% of all residential space heating technology in each major region (Northwest, South, etc.) of the United States. Between 2001 and 2015, central Furnaces have declined from roughly 65% of the market to 61% (See Figure 13), due mainly to an expansion

[9] US Energy Information Administration (EIA) 2015 Residential Energy Consumption Survey

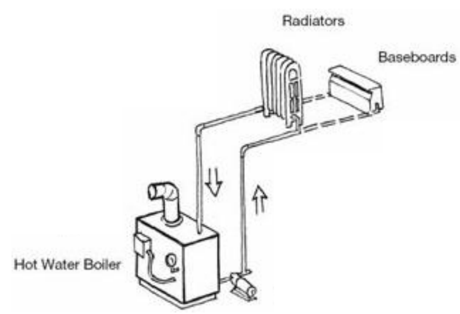
in southern homes that were built with Heat Pumps. Overall though, natural gas Furnaces are the most common main space heating equipment used in every climate region except the hot-humid region of the Southeast, where heating needs are lower and electric Furnaces are more prevalent.

Projected Growth

Total Furnace market revenue is projected to grow at a 5.4% CAGR until 2024 (See Figure 15). Quick heating capability, ease of installation and access to replacement parts given its large market penetration today, and high energy efficiency models will drive this growth (Grand View Research, 2016). Additionally, electric Furnaces do not give off harmful emissions and will be popular among a more environmentally conscientious population.

Boiler

How does it work?



Smarter House reports: “Boilers are special-purpose water heaters. While Furnaces carry heat in warm air, Boiler systems distribute the heat in hot water, which gives up heat as it passes through radiators or other devices in rooms throughout the house. The cooler water then returns to the Boiler to be reheated. Residential Boilers generally use natural gas, electricity, or heating oil for fuel. In steam Boilers, which are much less common than water Boilers, the water is boiled and steam carries heat through the house, condensing to water in the radiators as it cools. Oil and natural gas are commonly used in steam systems. Instead of a fan and duct system, a Boiler uses a pump to circulate hot water through pipes alone (radiant heating) or to radiators” (Smarter House, 2015).

Mix

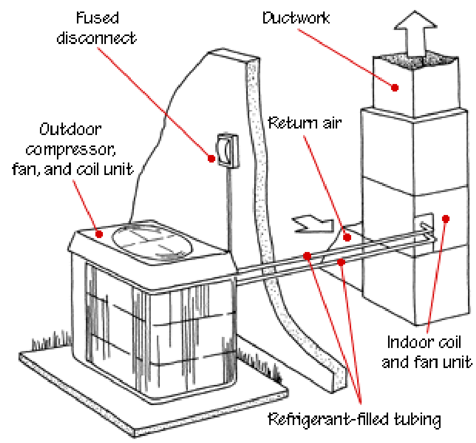
Between 2001 and 2015, the percentage of Boilers used for residential heating in the United States fell from 12% to 8% (See Figure 13), due to southbound population shifts and natural gas technology alternatives, such as natural gas Furnaces in the Northeast region. The majority of Boiler systems are found in New England and the Mid-Atlantic, where they run off of fuel oil.

Projected Growth

The total market revenue generated from the sale of Boilers is expected to grow at a CAGR of 5.6% from 2016 to 2024 (Grand View Research, 2016). The major benefits of a Boiler system include quiet operation, no blowing of dust and allergens within the home, potentially evenly distributed heating that exceeds the even distribution of forced-air systems (Shavitz, 2018). Since many of the homes in the Mid-Atlantic and Northeast were constructed to support Boiler systems either through a heat distribution network to a radiator or radiant heat pipes, Boilers can retain their stronghold in these regions. Growth may come from retrofits or older fuel oil systems to newer natural gas systems or from new construction, performed by contractors who are more comfortable installing Boiler systems.

Heat Pumps (Air Source)

How does it work?



Smarter House reports: “Heat Pumps are two-way air conditioners. During the summer, an air conditioner works by moving heat from the cool indoors to the warmer outdoors. In winter, the Heat Pump reverses this methodology by taking heat from the cold outdoors, using an electrical system, and pumping that heat into the house. Most Heat Pumps use forced warm-air delivery systems (ducting) to move heat throughout the home. Because electricity in a Heat Pump is used to move heat rather than to generate it, the Heat Pump can deliver more energy than it consumes” (Smarter House, 2015).

Mix

Between 2001 and 2015, the percentage of Heat Pumps for residential space heating grew from 9% to 12% (See Figure 13), due mainly to population growth in southern climates where space heaters are favored for the dual serving purpose as air conditioners and heaters. In fact, Heat Pump penetration in new housing units has grown extensively since 2000 (See Figure 14).

Projected Growth

Although the major deployment of Heat Pumps has historically occurred in the U.S. South historically, Heat Pump technology is becoming viable in colder parts of the country, such as in Vermont where $800 incentives are available for qualifying homeowners (Lapsa et al., 2017). Nevertheless, such state programs are in their infancy and the majority of growth will come from a combination of increased houses built in the South, a warmer climate lessening the need for heating only systems in northern climates, and the view among younger generations that space cooling is a requirement for new homes (Lapsa et al., 2017). The Heat Pump market size is projected to grow at a CAGR of 6% from 2016 to 2025, outpacing the growth of Furnaces and Boilers (See Figure 15).

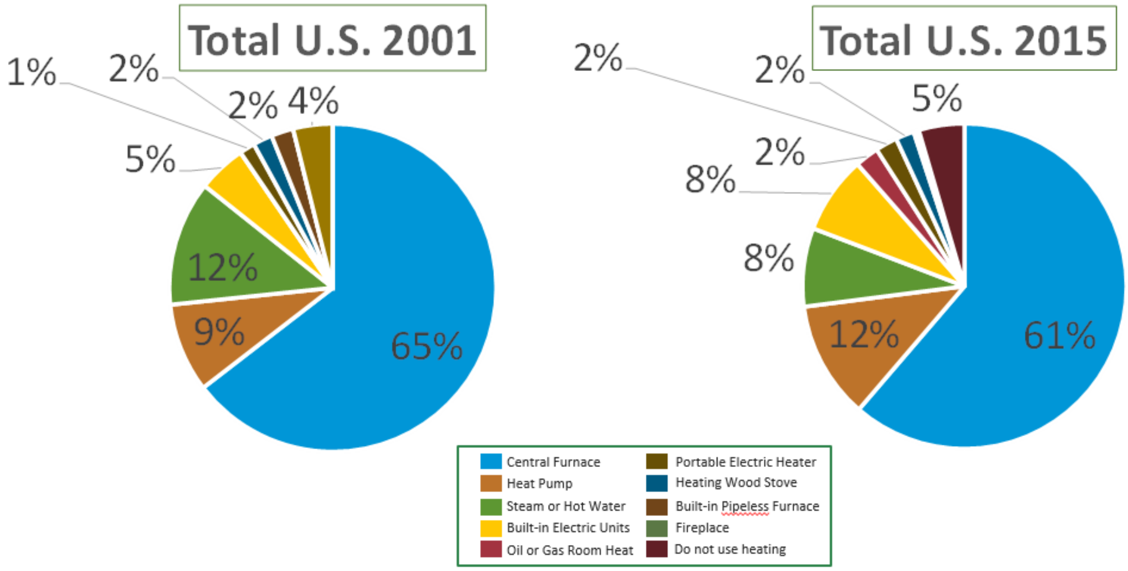


Figure 13 Space Heating Technology Mix 2001 & 2015[10]

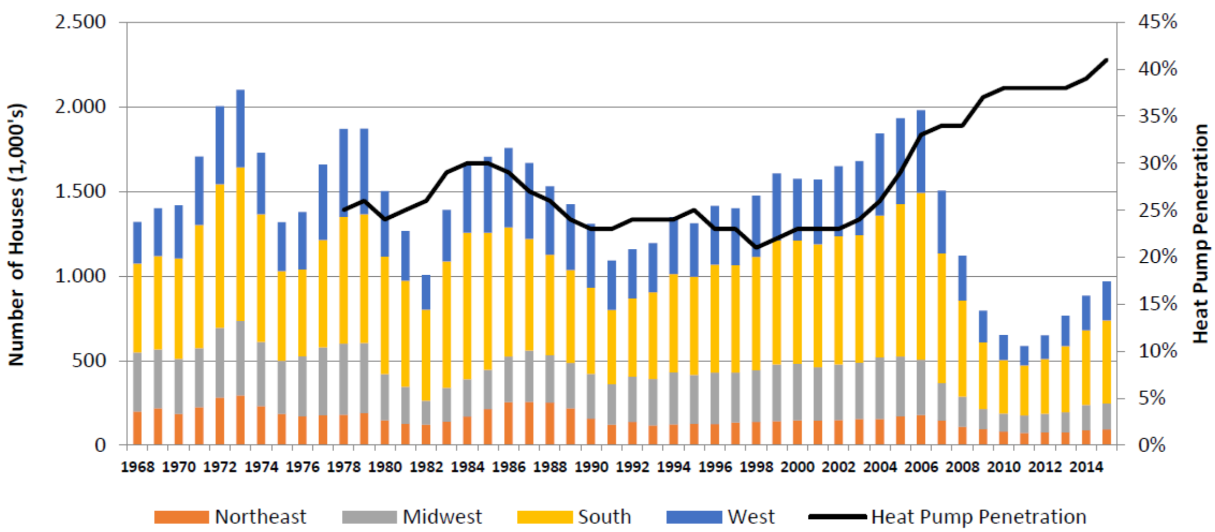


Figure 14 U.S. New Housing Units Completed and Heat Pump Penetration into New Housing Market[11]

[10] US Energy Information Administration (EIA) 2015 Residential Energy Consumption Survey
[11] Lapsa et al. 2017

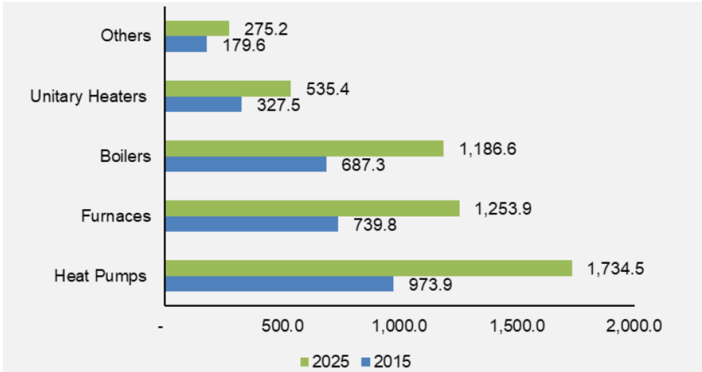


Figure 15 Grand View Research Market Revenue Estimates[12]

These regional heating technology preferences may be viewed in the below map of the continental United States, which was assembled with 2015 data from EIA (See Figure 16). The key insights gained from this graphic are the following:

- Central Furnaces are the most prevalent space heating technology in all regions
- Heat Pumps are sizeable in southern states with warmer climates
- Steam and hot water Boiler systems are only found in northern, colder climates with the majority concentrated in New England and the Mid-Atlantic

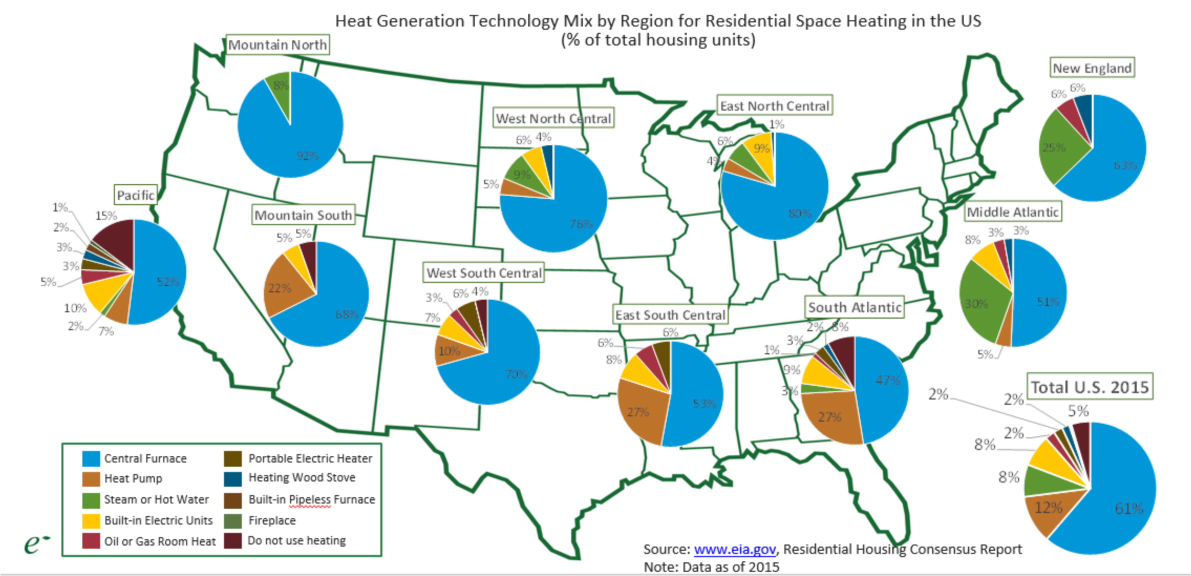


Figure 16 Heating Generation Technology Mix by Region for Residential Space Heating in the U.S. (% of total housing units)[13]

[12] Grand View Research Report

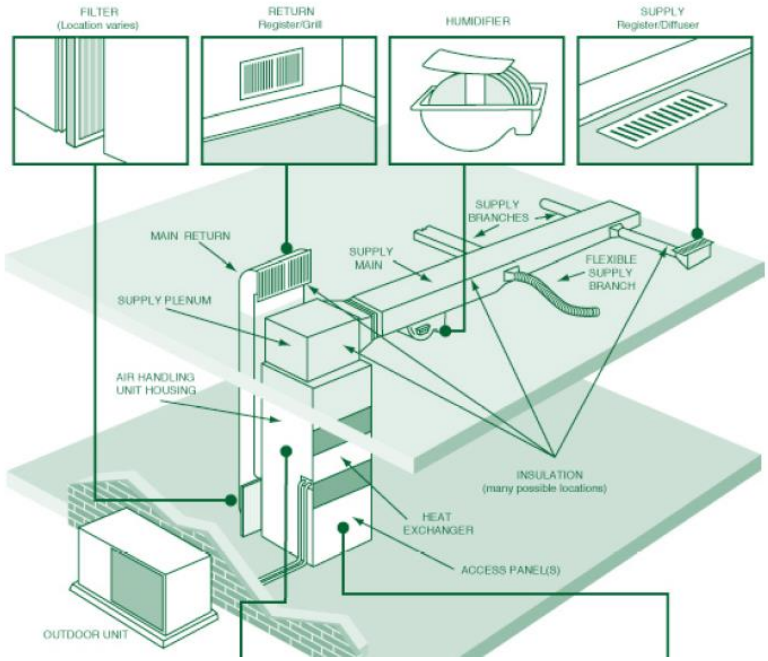
[13] US Energy Information Administration (EIA) 2015 Residential Energy Consumption Survey

Distribution Technology

Distribution technology refers to the equipment that transports and ultimately delivers heat to the home. The major distribution technologies are forced air heating ducts, steam and hot water radiators, radiant floor heating, and electric or hydronic baseboard heating. Descriptions of each technology and their popularity in the U.S. market are outlined below:

Forced Air Heating Ducts and Vents

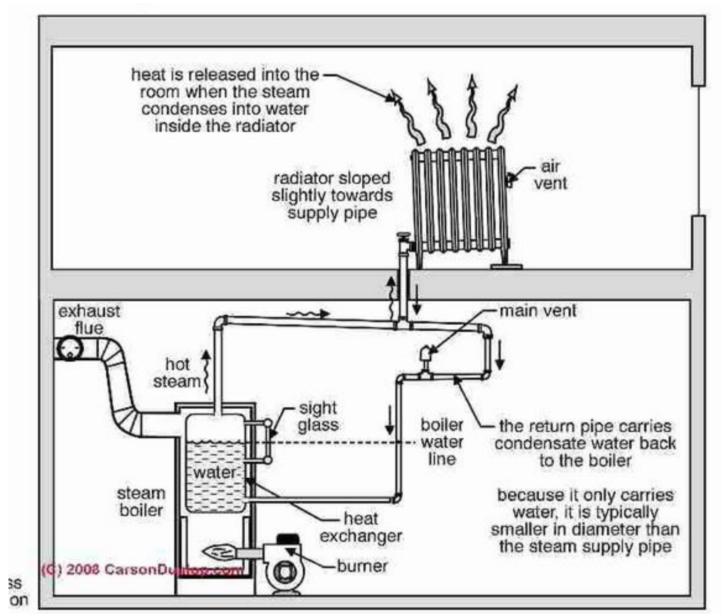
A forced air heating system is any heating process that heats air and disperses it throughout the house using a pathway of ducts/vents in the walls or floor. Some of the major benefits of forced



air heating systems include prompt heating times as air heated directly and then circulated via an electric fan ensures rapid heat delivery (Carney Plumbing, 2018). Evenly heated rooms are another benefit as the air exiting the vent will circulate through the room. A third benefit of a duct and vent system is that it can be used for both heating and cooling. Major drawbacks of the system include the potential for massive heat loss through poorly sealed ductwork and poorer indoor air quality due to the spread of allergens (Carney Plumbing, 2018). The Energy Star program believes that in “a typical house…about 20 to 30 percent of the air that moves through the duct system is lost due to leaks, holes, and poorly connected ducts (Energy Star, 2018).” Even the most vigilant homeowners may be unaware that their system is wasting such amounts of heat, unless they are subscribed to an energy use report through their utility or a third party. Forced air systems are the most popular distribution system for new construction. About 89% of homes built since 2000 have a main space heating system that includes central ducts; for homes built before 1940, that number is just 30% (See Figure 17).

Figure 17 Increase in central air conditioning in newer homes (% of homes)[14]

Steam or Hot Water Radiator



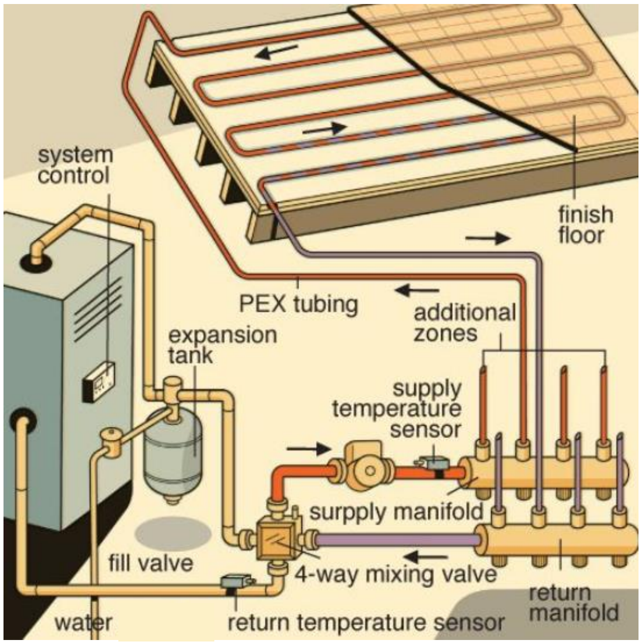
A steam heating system uses a Boiler, which turns water into steam that then travels through a network of pipes to radiators placed throughout the home. The steam cools in the radiator, condenses into water, and that condensed water is returned to the Boiler to be converted into steam once again. In a hot water system, the Boiler heats water, which is pumped to the radiators in the home via a circulation pump. The hot water in the system will continually circulate so long as the Boiler is on. The major pros of a steam or hot water radiator system include the ease of turning on and off to only heat the rooms desired, and quieter operation when running efficiently since there is no blower fan. The major cons of steam and hot water radiators include the potential for severe water damage due to improperly sealed pipes, variable

[14] US Energy Information Administration (EIA) 2009 Residential Energy Consumption Survey. Note: A central AC system refers to a forced air system, which may be used for both air conditioning and heating.

room temperature as there is no circulation of hot air, and the reduction of usable space as area around the radiator must be maintained clear. (AHS, 2018) Between 6 to 11 percent of American homes have radiators installed (Lasky, 2013).

Radiant Heating

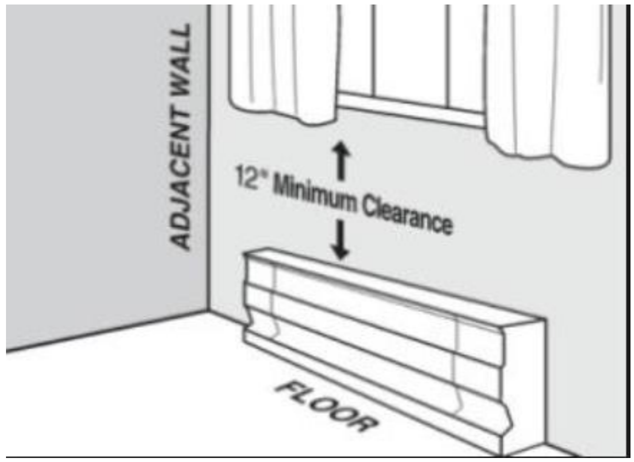
Radiant heating systems supply heat directly to the floor, walls, or ceiling where the heating tubes and/or panels are installed. The entire system works because of radiant heat transfer, which is the delivery of heat from a hot surface to people and objects in the room. There are three types of systems: air-heated radiant floors, electric radiant floors, and hydronic radiant floors. Given the poor heat retention of air and the expensive operating cost of electricity in colder climates, only hydronic radiant heat is truly viable (Scientific American, 2018). Hydronic systems pump heated



water from a Boiler through tubing laid in a pattern under the floor. As the floor warms, radiant heat is absorbed by individuals and objects in the room. The key advantages of radiant heating are the potential to be more efficient than forced-air systems since there is no heat loss through ducting, the system does not spread allergens through the air, and heat is evenly dispersed rather than stemming from a single corner of the room from a radiator. In fact, radiant systems transmit heat on average some 15 percent more efficiently than conventional radiators (Scientific American, 2018). Certain drawbacks include potential water damage as with any hot water system and invasive and expensive repairs given the need to remove the home flooring. Fewer than 10% of homes in the United States are heated by a radiant system (Franco, 2018).

Baseboards

Home Advisor reports: “Baseboard heating refers to either electric baseboard heaters or hot water (hydronic) baseboard heaters. Electric baseboards are individual units that heat a home room-by-room, requiring no central heating system or the installation of ducts. Cables inside the heating unit warm the air and fans may push the air out of the unit. Hydronic baseboard heaters do require a central Boiler to pump hot water through the baseboard and into each room of the home where they are installed” (Home Advisor, 2018). The impact of hydronic baseboards is similar to that of a radiant heat system but with a much lower installation cost. One of the major incentives for baseboard installation over other systems is lower cost.



Additionally, individual room temperature control is possible either via a thermostat or by adjusting the baseboard itself. Downsides of baseboards include quantity of heat delivered as they are smaller systems, high operating costs for electric systems in colder climates, and reduced usable square feet as a clear zone must be maintained around the units for safety. Approximately 10% of homes in the United states use baseboard heating (See Figure 16).

Demand Efficiency Technology

Thermostat

There are four categories of thermostats based upon the features that are possessed: Smart Thermostats, Programmable Thermostats, Non-Programmable Thermostats, and Manual Thermostats. Smart thermostats came into the U.S. lexicon with the introduction of the Nest Smart Thermostat in 2011. These pieces of equipment are characterized by their WiFi connections so that they may be controlled using mobile phones or in newer models their voice recognition feature, allowing individuals to easily control room temperature without lifting a finger Additionally, smart thermostats can learn behavior, schedules, and preferences of owners, thus programing itself for maximum energy savings (Home Edit, 2018). Lastly, these

thermostats can help to improve energy-saving behavior by sending monthly reports of energy usage. 13% of U.S. internet connected households owned a smart thermostat at the end of 2017

(Parks & Associates, 2018) and by 2020 this percentage is expected to grow to roughly 34% (~40 million) of internet connected households (John, 2017). Programable thermostats enable the user to program different daytime and nighttime temperature settings or create temperature settings by various days and times of the week. Programmable thermostats are essentially non-smart, electronic thermostats. Mechanical thermostats operate though the triggering of metal bars that heat up or cool down. The major drawback of mechanical thermostats is a slow response time that causes uncomfortable temperature variations around operator set temperature points. Current space heating thermostat behavior varies widely (See Figure 18).

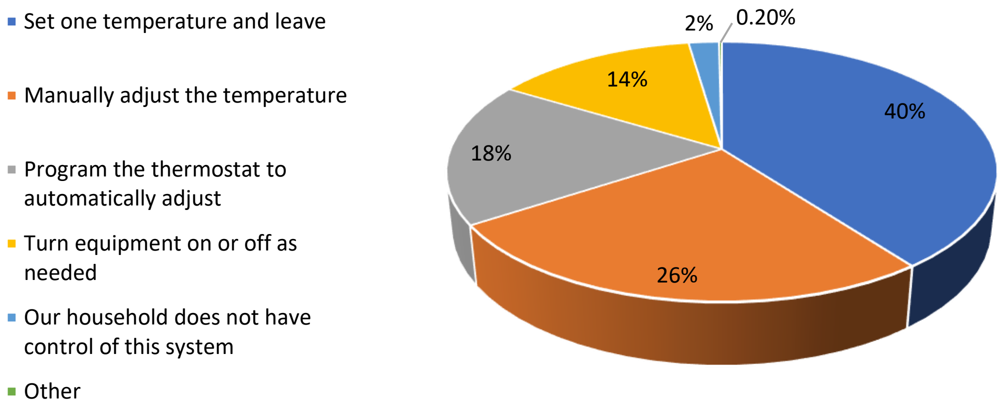


Figure 18 Heating Thermostat Behavior[15]

Thermostatic Radiator Valves (TRV)

A TRV adjusts the flow of water or steam into a radiator depending on how it is set. Only Radiators explains: "A thermostatic valve head goes on top of the valve body and as the room temperature changes, the valve head expands, adjusting a pin in the valve body so that it opens or closes, thus regulating the flow of water or steam" (Only Radiators, 2018). Increasing room temperature causes the pin to close, while decreasing room temperature cause the pin to open. Smart radiator valves, such as the one created by Natatmo, provide many of the same features found in smart thermostats.

[15] US Energy Information Administration (EIA) 2015 Residential Energy Consumption Survey

Chapter 4: Switching costs in the NE and SE regions

Region Background: Northeast

EIP was interested in knowing what the payback periods from switching heating technologies looks like for two primary regions that it believes are set for disruption of the space heating sector. The first region is the Northeast/Mid-Atlantic where a considerable percentage of homes still use fuel oil. As shown in Table 1, while fuel oil is less carbon intensive than coal, the US Census Bureau estimated that only 127,000 households used coal as a primary heating fuel in 2015, or about 0.1% of American homes (Ackerly, 2017). On the other hand, there are roughly 5.7 million homes in the USA that use fuel oil, making fuel oil's carbon footprint significant with regards to the space heating sector. Additionally, given growing concern among consumers about their household emissions and given the aggressive emissions targets of many Northeast states – New York, New Hampshire, Vermont, Maine, Rhode Island, and Connecticut all have emissions reductions targets in the short and long term (See Figure 19) – converting fuel oil systems to natural gas or ideally electricity may be required to meet these targets.

Table 1 Pounds of CO2 emitted per million BTUs of energy for various fuels (EIA)

Coal (anthracite)	228.6
Coal (bituminous)	205.7
Coal (lignite)	215.4
Coal (subbituminous)	214.3
Diesel fuel and heating oil	161.3
Gasoline (without ethanol)	157.2
Propane	139.0
Natural gas	117.0

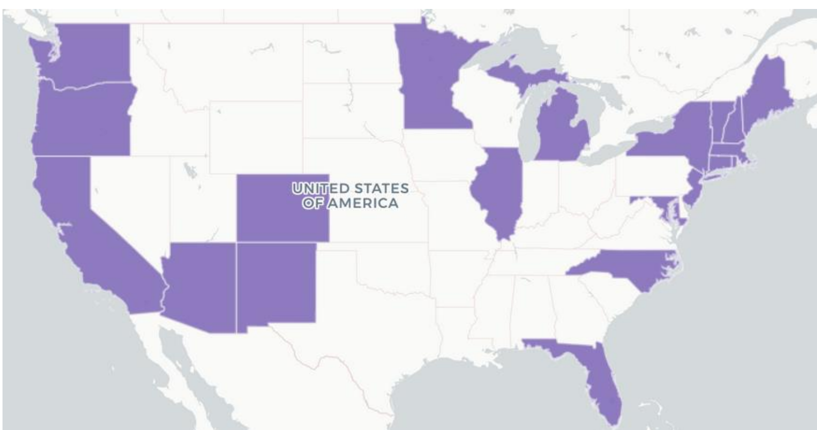


Figure 19 Map of the United States showing states that have enacted emissions reductions targets[16]

[16] The Northeast region has pledged a variety of reduction levels by 2020 and by 2050. New York, for example, has pledged to reduce emissions by 80% below 1990 levels by 2050. However, the state has since introduced an interim goal of 40% below 1990 levels by 2030 with the hope of making the 2050 goal more realistic.

Payback Background: Northeast

The two main heating technologies in the Northeast and Mid-Atlantic regions are Furnaces (63% in the Northeast and 51% in the Mid-Atlantic) and Steam or Hot Water Boilers (25% in the Northeast and 30% in the Mid-Atlantic). Our study focused on the technology whose switch would have the greatest impact due to possessing greater market share, namely Furnaces. Additionally, given that our study is meant to be an introduction to switching cost economics and that our data on labor, equipment, and other associated costs come from a variety of web sources, our team found that Furnace to Furnace and Furnace to Heat Pump conversion costs are more readily available than Boiler to Furnace and Boiler to Heat Pump conversion costs. The main reason for this difference in available data has to do with the compatibility of heat distribution systems. Fuel oil Furnaces used forced air / duct systems, is a heat distribution system that is compatible with electric and natural gas Furnaces, as well as Heat Pumps. Boilers, as discussed previously, use hot water or steam piping systems, a distribution platform that neither Furnaces nor Heat Pumps can connect to. Therefore, retrofitting from a Boiler to a Furnace or Heat Pump would have to include the installation of a forced air system as well, which is prohibitively expense. A homeowner could switch from a Boiler to a ductless Heat Pump, which provide zone heat (single room heat, much like window AC units provide air for one room), however each room in the house would need its own ductless Heat Pump, making this option prohibitively expensive for most. Thus, we looked at four scenarios:

1) Fuel Oil Furnace to Electric Furnace
2) Fuel Oil Furnace to Natural Gas Furnace
3) Fuel Oil Furnace to Air Source Heat Pump
4) Fuel Oil Furnace to Ground Source Heat Pump

Payback Methodology: Northeast and Southeast

Each scenario was setup in the same manner and followed the same procedure to arrive at two payback periods. One payback period assumed that there was a preemptive switch from the fuel oil system to a new system. In other words, a scenario in which the homeowner installs a new system without his or her old system having failed. The second payback period assumed that the technology switch occurs upon the fuel oil system's failure. There are five steps in total (See Figure 20) and each step is explained in greater detail, following the below figure.

	Low	High	Average
Switching Cost: Fuel Oil Furnace to Heat Pump			
Cost to Remove Heating Oil Tank	$500	$3,000	$1,750
Cost to Remove Heating Oil Furnace	100	300	200
Cost of New Heat Pump w/ Installation	4,965	8,260	6,770
Total Switching Cost	$5,565	$11,560	$8,720
Annual Operating Costs			
Oil Furnaces			
80% AFUE Furnace (federal minimum)	$1,414		
95% AFUE Furnace	$1,190		
Electric Heat Pumps			
8.2 HSPF	$1,118		
8.5 HSPF	$1,079		
10.3 HSPF	$890		
Annual Fuel Savings			
Equipment Change			
80% AFUE Furnace to 8.2 HSPF	$295		
80% AFUE Furnace to 8.5 HSPF	$335		
80% AFUE Furnace to 10.3 HSPF	$523		
95% AFUE Furnace to 10.3 HSPF	$300		
Payback Period - Preemptive Replacement			
80% AFUE Furnace to 8.2 HSPF			
80% AFUE Furnace to 8.5 HSPF			
80% AFUE Furnace to 10.3 HSPF			
95% AFUE Furnace to 10.3 HSPF			
Payback Period at Replacement			
80% AFUE Furnace to 8.2 HSPF			
80% AFUE Furnace to 8.5 HSPF			
80% AFUE Furnace to 10.3 HSPF			
95% AFUE Furnace to 10.3 HSPF			

Figure 20 The steps followed to arrive at the payback periods[17]

1) *Calculate the cost of switching from an old technology to another technology*

The numeric information to complete step 1 came from homeadvisor.com, houselogic.com, and costhelper.com. These websites are partnered with contractors nationwide to assist them in sourcing a plethora of home projects, including HVAC installations and repairs. In exchange, project information is shared with Home Advisor, Cost Helper, and House Logic so that they may provide the best cost information to online visitors. Our switching cost models look at three cases: a low case that is inexpensive, a high case that is most expensive, and an average case. These cases relate to the equipment efficiency standards described further in step 2. For all switching scenarios, the cost of removing the fuel oil tank creates large variation between the three cases. A surface tank may be removed for as little as $500 but removal of a buried tank may cost around $3,000. Law requires the removal of unused fuel oil tanks. Also, in each switching scenario, the installation cost of the new heating equipment is often greater than the equipment sticker price alone. Phone calls with various HVAC contactors confirmed that this situation is realistic as

[17] These payback periods are under the scenario of switching from a fuel oil Furnace of either 80% or 95% AFUE to a Heat Pump of varying HSPF (Heating Seasonal Performance Factor) efficiency.

installation can take many hours, if not a few days, and is not a simple process of "plugging in" a new system. The equipment costs of electric and natural gas Furnaces, and Heat Pumps were sourced from tables from homeadvisor.com (See Appendix B). We did not include the cost reductions that can come from a variety of rebates available to customers, except for the geothermal case which has a 30% federal rebate in place. Rebates may be offered by states, townships, the federal government, or HVAC companies themselves. This level of detail would be incredibly difficult to include in our model, given the variety, and so is beyond the scope of our analysis. Additionally, as the more "do-it-yourself" population can attest, HVAC retrofit projects may be rife with unforeseen costs, none of which we could confidently include in our analysis. Therefore, the switching costs arrived at may be viewed as what would happen under the most ideal installation circumstances, thus serving as baseline numbers from which further analysis could be conducted.

2) *Calculate the annual operating costs of all systems in question*

Annual operating costs of the systems used in the analysis were sourced from the U.S. Energy Information Administration (EIA) (See Appendix C). EIA provides regional consumption, price, and expenditure information for space heating going back seven years. Our analysis used the historic five-year average of consumption data to calculate annual operating costs. The historic five-year average of fuel oil consumption for space heating in the Northeast region was 499 gallons per home per heating season. Our team assumed that an 80% AFUE fuel oil Furnace (the federally mandated minimum efficiency) was the equipment used in consuming these 499 gallons. We then converted the 499 gallons to 55,309,144 British Thermal Units (BTUs) to know what the average home heat demand is. An 80% AFUE fuel oil Furnace producing 55,309,144 BTUs acted as our baseline heat demand, which all replacement equipment would have to meet. We kept this heat demand number constant and then converted it back into the appropriate fuel energy (cubic feet of natural gas or kWh of electricity) of the new equipment. For Furnaces, we then divided this converted heat demand number by the efficiency standard of the corresponding equipment to arrive at the total consumption in either cubic feet of natural gas or kWh of electricity. Air Source Heat Pump calculations were more complicated due to the Heating Seasonal Performance Factor (HSPF) efficiency calculation of *HSPF = # BTUs outputted / 1000/ # of kWh inputted*. Ground Source Heat Pump fuel consumption was calculated using the equation of *Coefficient of Performance (COP) = kWh outputted / kWh inputted*. Lastly, the total consumption number was multiplied by the average price per unit that was sourced from the EIA table mentioned before to arrive at an annual operating cost (See Table 2).

Table 2 The Process of Calculating the fuel consumption for the new technology[18]

	Equipment	Efficiency	Fuel Consumed	Fuel Converted to Hea	Fuel Converted to Heat (BTUs)	$ paid per year
Baseline	Oil Furnace	80%	499 fuel oil gallons	399 fuel oil gallons	55,309,144 BTUs	$1,414
	Oil Furnace	95%	420 fuel oil gallons	399 fuel oil gallons	55,309,144 BTUs	$1,190
	NG Furnace	80%	66,670 cubic feet	53,336 cubic feet	55,309,144 BTUs	$728
	NG Furnace	85%	62,748 cubic feet	53,336 cubic feet	55,309,144 BTUs	$685
	NG Furnace	95%	56,143 cubic feet	53,336 cubic feet	55,309,144 BTUs	$613

3) Calculate the annual fuel savings each new system provides

Calculating the annual fuel savings of each new system was straightforward. We subtracted the annual operating cost of the new equipment from the fuel oil equipment to arrive at a fuel savings number. We looked at switching from an 80% AFUE fuel oil Furnace to three efficiency ranges of new equipment. For example, in the case above we switched from an 80% AFUE fuel oil Furnace to either an 8.2,8.5, or 10.3 HSPF Heat Pump. Additionally, we switched from a 95% AFUE fuel oil Furnace to a 10.3 HSPF Heat Pump. We assumed that an average household may switch to a system less efficient, as efficient, or more efficient than the current system. Additionally, a 95% AFUE Furnace is high efficiency and so we assumed that those households would only realistically consider switching to another high efficiency system, such as a 10.3 HSPF Heat Pump.

4 & 5) Calculate the payback period for a preemptive installation or an installation at failure

The payback period for a preemptive installation was calculated by dividing the total cost of the new equipment by the annual fuel savings calculated in step 3 above. For example, the upfront cost of the most inexpensive Heat Pump (8.2 HSPF) is $5,565 and this Heat Pump requires less energy to produce the same amount of BTU heat, resulting in annual energy savings of $295. Dividing $5,565 by $295 results in a payback period of approximately 19 years. The payback period for an installation upon failure of the old equipment was shorter than a preemptive installation because the homeowner can deduct the cost of a new fuel oil (Northeast) or natural gas (Southeast) Furnace from the total cost of a new heating system. The incremental cost of a new system over the old system is what matters in the mind of the homeowner if his or her system is replaced upon failure. Therefore, the value to be regained through fuel savings is less, thus lowering the payback period.

[18] The baseline case of an 80% AFUE oil Furnace producing 55 million BTUs was held constant across all technologies and then converted into the appropriate value of fuel consumed according to new equipment efficiency. This fuel consumption was then multiplied by the appropriate price per unit to arrive at an annual operating cost.

Payback Results: Northeast

Fuel Oil Furnace to Electric Furnace

Although the hardware costs of electric Furnaces are cheaper than those of fuel oil Furnaces, the cost of electricity in the Northeast region makes operating an electric Furnace prohibitively expensive. For all cases studied, the annual fuel savings were negative when switching to an electric Furnace (See Table 3). Therefore, there is no payback period for this case, as there is no way to recoup the initial investment through future fuel savings.

Table 3 Annual fuel savings when switching from a fuel oil Furnace to an electric Furnace

Annual Fuel Savings	
Equipment Change	
80% AFUE to 80% AFUE	($1,946)
80% AFUE to 85% AFUE	($1,748)
80% AFUE to 95% AFUE	($1,415)
95% AFUE to 95% AFUE	($1,639)

Fuel Oil Furnace to Natural Gas Furnace

Natural gas Furnace costs were assumed to be $4,600 on the low end, $7,535 on average, and $11,200 on the high end. Despite this expensive average equipment cost, the annual fuel savings were positive due to the inexpensive price of natural gas for the region. The scenario with the smallest annual savings was a 95% AFUE to a 95% AFUE system, creating $577 in fuel savings per year. The greatest annual savings came from an 80% AFUE to a 95% AFUE system, creating $801 in fuel savings per year. The payback results for a preemptive replacement and replacement at failure are shown in the figures below.

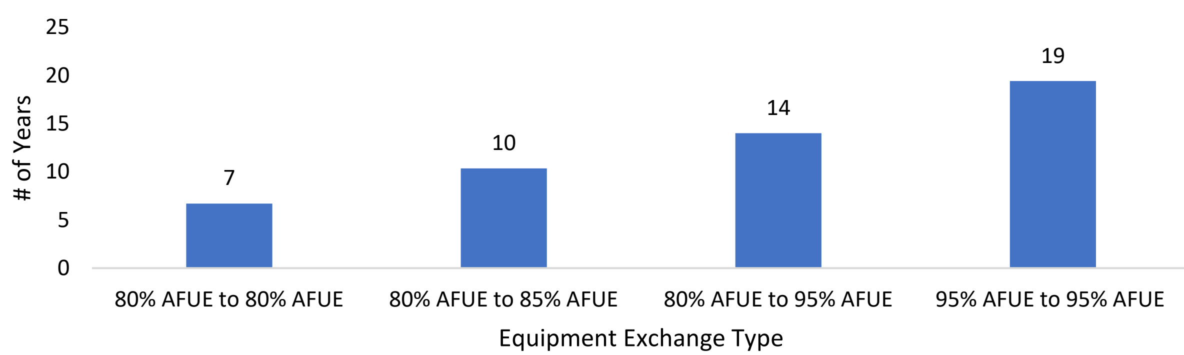


Figure 21 Oil Furnace to natural gas Furnace payback: Preemptive replacement.

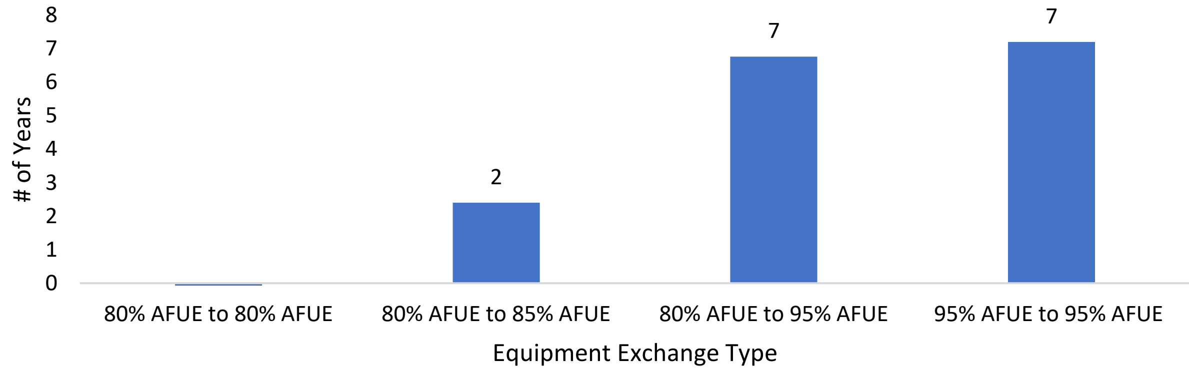


Figure 22 Oil Furnace to natural gas Furnace payback: Equipment failure

Preemptive installation results in payback years that would be unattractive to most homeowners, with seven years as the minimum payback from switching from an 80% AFUE to an 80% AFUE system. Switching from a high efficiency fuel oil Furnace to a high efficiency natural gas Furnace is the least attractive, with a payback period of 19 years. Therefore, preemptive installations are unlikely to happen frequently. Exceptions could be individuals who are committed to living in their homes for several decades or individuals who are compelled to switch for environmental rather than economic reasons. Installation at time of failure results in payback years that are significantly less. An 80% AFUE to 80% AFUE pays back immediately because natural gas Furnaces of this efficiency are cheaper than their fuel oil counterparts. Higher upfront costs of the highest efficiency natural gas systems result in payback periods of seven years.

Fuel Oil Furnace to Air Source Heat Pump

Heat Pump equipment costs were calculated to be $5,565 on the low end, $8,720 on average, and $11,560 on the high end, with better HSPF efficiency commanding a price premium. These high initial equipment costs were offset by between $295 to $523 in annual fuel savings. The greatest fuel savings came from switching from an 80% AFUE fuel oil Furnace to a 10.3 HSPF Heat Pump, while the smallest fuel savings came from switching from the same Furnace but to an 8.2 HSPF Heat Pump. The payback results for a preemptive replacement and replacement at failure are shown in the figures below.

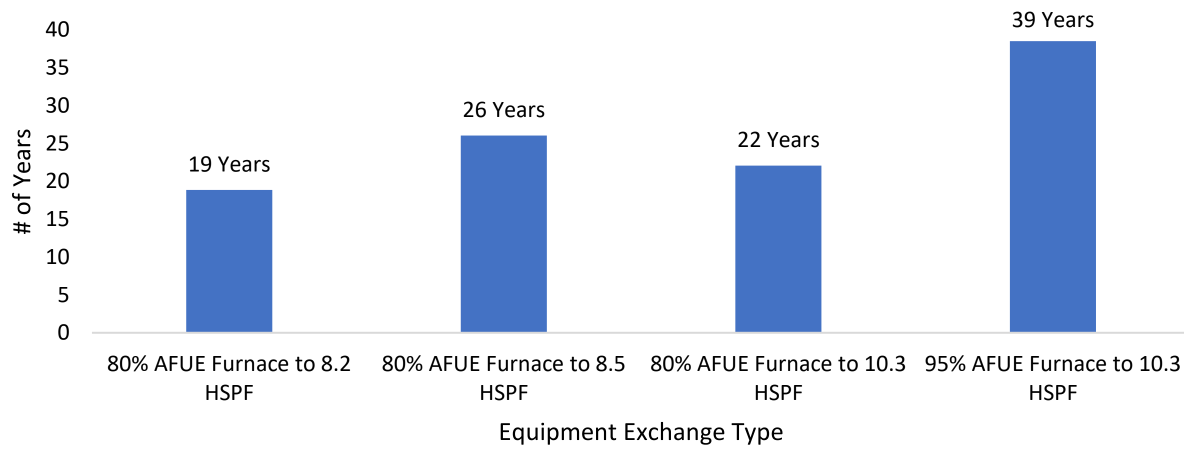


Figure 23 Oil Furnace to Heat Pump payback: Preemptive replacement

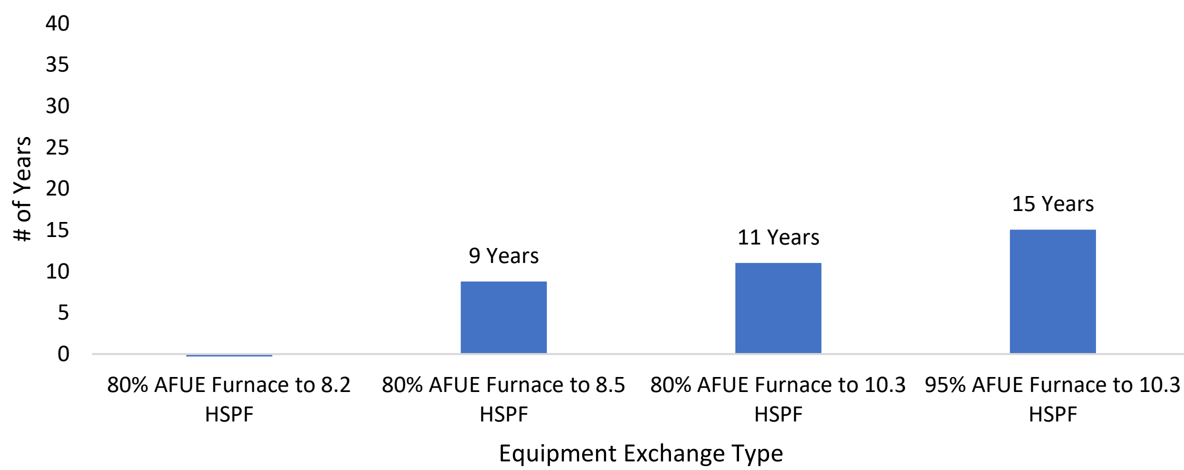


Figure 24 Oil Furnace to Heat Pump payback: Equipment failure

The preemptive replacement payback years are incredibly high across all technology switching scenarios, with a minimum payback period of 19 years between the two least efficient systems. Therefore, we conclude that the preemptive installation of a Heat Pump would rarely occur except in those instances previously mentioned for natural gas Furnaces. Payback years for replacements after equipment failure are considerably shorter but only the 80% AFUE to 8.2 HSPF is immediate. Other switching scenarios' paybacks range between 9 and 15 years. Cold-climate Heat Pumps would further shorten these paybacks because of greater efficiency; however, cold-climate Heat Pumps are not yet installed on a large scale and have not been included in our study.

Fuel Oil Furnace to Ground Source Heat Pump

Ground source Heat Pump total installation costs were calculated to be $13,300 on the low end, $21,050 on average, and $28,800 on the high end. Similar to the ancillary costs that were assumed for switching to a natural gas Furnace (the costs of digging a gas line and installing the gas line) in the Northeast, a ground source Heat Pump installation comes with a bounty of extra costs. There is often a home energy audit to see if a ground source Heat Pump makes sense for the home, the cost of a soil composition study, excavation costs that we estimated can be as high as $10,000, and ground tubing installation costs (See Table 4). However, to offset these high upfront costs there does exist a simple to understand federal government rebate of 30% for ground source Heat Pumps installed before 12/31/2019. We assumed that all homeowners would take advantage of at least this one rebate and so included it in this analysis, thus lowering total installation costs to $9,310 on the low end, $14,735 on average, and $20,160 on the high end.

Table 4 Approximate major costs for ground source Heat Pump installation

Switching Cost: Fuel Oil Furnace to Ground Source Heat Pump	Low	High	Average
Home Energy Audit	300	500	400
Cost to Remove Heating Oil Tank	$500	$3,000	$1,750
Cost to Remove Heating Oil Furnace	100	300	200
Cost of new GS Heat Pump including installation	5,000	10,000	7,500
Federal 30% Rebate	-3,990	-8,640	-6,315
Soil Composition Study	800	1,800	1,300
Cost to Excavate ground	5,000	10,000	7,500
Cost of ground tubing	1,600	3,200	2,400
Total Switching Cost After Rebate	$9,310	$20,160	$14,735
Total Switching Cost Before Rebate	13,300	28,800	21,050

The payback results for a preemptive replacement and replacement at failure are shown in the figures below.

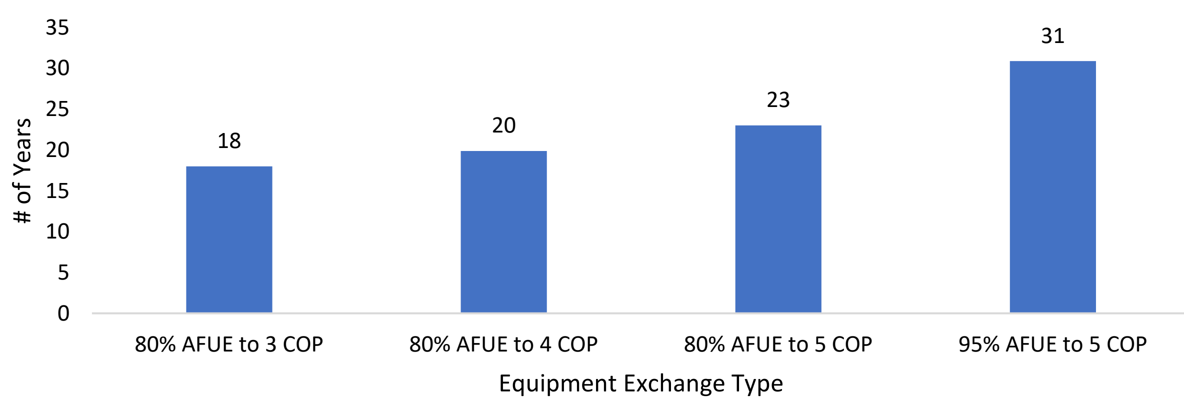


Figure 25 Oil Furnace to ground source Heat Pump payback: Preemptive replacement

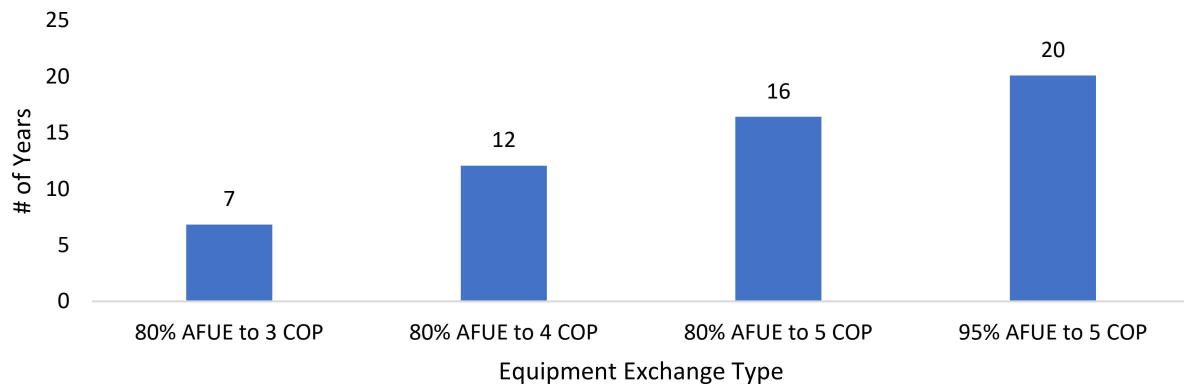


Figure 26 Oil Furnace to ground source Heat Pump payback: Equipment failure

The fuel savings created by a ground source Heat Pump are greater than those created by an air source Heat Pump, leading to shorter payback periods following preemptive replacement. Annual fuel savings for the ground source Heat Pumps range from $500 to $900 while the range for air source Heat Pumps is $300 to $500. Nevertheless, the preemptive installation payback period is at least 18 years, making this an unattractive option for most homeowners. While the payback periods for installation at time of failure are shorter, only the 80% AFUE to 3 COP option is under 10 years. The combination of high electricity prices and high upfront costs are responsible for these results, despite ground source Heat Pump efficiency (COP) of 300%, 400%, and 500% used in our analysis.

Study by American Council for an Energy-Efficient Economy

The ACEE performed a state-level payback analysis on switching from fuel oil Furnaces to air source Heat Pumps in July 2018 that supports the results of our own analysis (Figure 27). As shown in the Northeast segment of the figure, paybacks range from under 10 years to well over 20 years depending on the Heat Pump system purchased, the fuel oil Furnace replaced, and the geographic location of the installation. These estimates confirm of our own estimates.

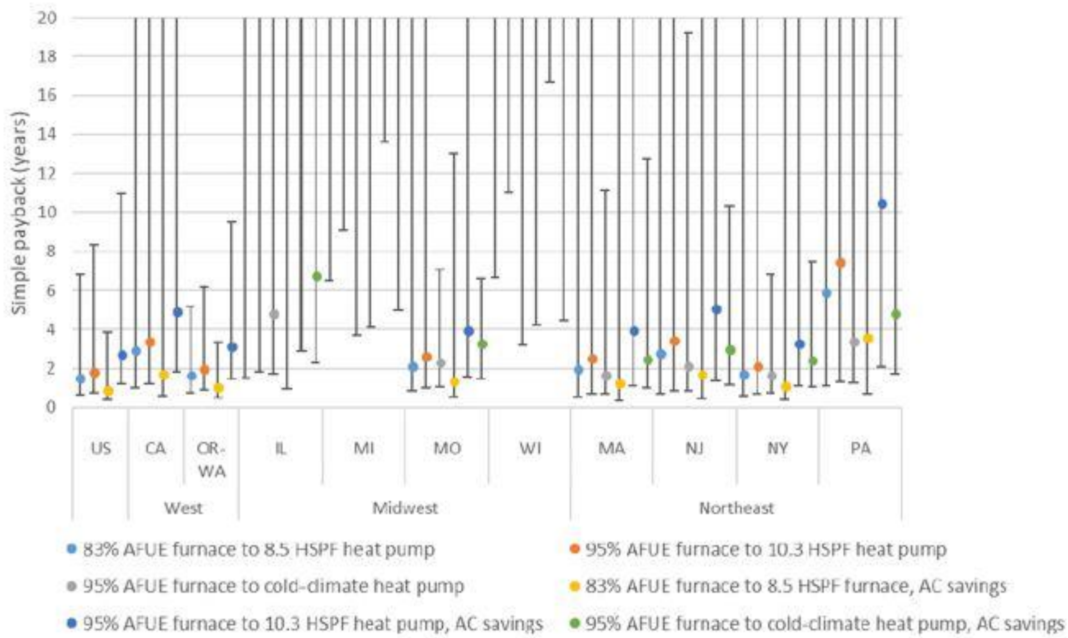


Figure 27 Payback periods from switching from fuel oil Furnace to air source Heat Pump[19]

Region Background: Southeast

The second region is the southeast where a considerable percentage of homes still use natural gas Furnaces for space heating. However, the southeast region also has the cheapest electricity prices of all regions in the United States, perhaps making the switch from natural gas a more viable option, especially if switching to a more efficient electrical system.

Payback Background: Southeast

The main heating technology in the Southeast region is a central Furnace. Our study focused on switching from a natural gas Furnace to an electric Furnace, electric air source Heat Pump, and electric ground source Heat Pump. Thus, we looked at three scenarios:

1) Natural Gas Furnace to Electric Furnace
2) Natural Gas Furnace to Air Source Heat Pump
3) Natural Gas Furnace to Ground Source Heat Pump

[19] ACEE, July 2018

Payback Results: Southeast

The payback results of each or the above scenarios were not conducive to getting natural gas Furnace owners to switch to an electric technology source because there either were no annual operating savings, or the annual operating savings were so small, that paybacks exceeded multiple decades in each scenario. Using EIA, 5-year data we calculated the average amount of natural gas consumed by an average home in the Southeast region to be 45 million cubic feet (Mcf) per heating season. Using an 80% AFUE natural gas Furnace as our baseline equipment, that 45 Mcf of natural gas provides 37,730,208 BTUs of heat to the home at a cost of $505 per year. Even though the cost of electricity in the southeast region is cheaper than in the northeast region, ~11 cents per kWh versus ~16 cents per kWh, lower heating demand and low natural gas prices are tough to overcome with electric technology options, as shown in the below figures of each scenario.

Table 5 Natural Gas Furnace to Electric Furnace: $ paid per year

	Equipment	Efficiency	Fuel Consumed	Fuel Converted to Heat	Fuel Converted to Heat (BTUs)	$ paid per year
Baseline	NG Furnace	80%	45 million cubic feet	36 million cubic feet	37,730,208 BTUs	$505
	NG Furnace	95%	38 million cubic feet	36 million cubic feet	37,730,208 BTUs	$425
	Electric Furnace	80%	13,823 kWh	11,058 kWh	37,730,208 BTUs	$1,529
	Electric Furnace	85%	13,010 kWh	11,058 kWh	37,730,208 BTUs	$1,439
	Electric Furnace	95%	11,640 kWh	11,058 kWh	37,730,208 BTUs	$1,287

Table 6 Natural Gas Furnace to Air Source Heat Pump: $ paid per year

	Equipment	Efficiency	Fuel Consumed	Fuel Converted to Heat	Fuel Converted to Heat (BTUs)	$ paid per year
Baseline	NG Furnace	80%	45 million cubic feet	36 million cubic feet	37,730,208 BTUs	$505
	NG Furnace	95%	38 million cubic feet	36 million cubic feet	37,730,208 BTUs	$425
	Heat Pump	8.2 HSPF	4,601 kWh		37,730,208 BTUs	$509
	Heat Pump	8.5 HSPF	4,439 kWh		37,730,208 BTUs	$491
	Heat Pump	10.3 HSPF	3,663 kWh		37,730,208 BTUs	$405

Table 7 Natural Gas Furnace to Ground Source Heat Pump: $ paid per year

	Equipment	Efficiency	Fuel Consumed	Fuel Converted to Heat	Fuel Converted to Heat (BTUs)	$ paid per year
Baseline	Oil Furnace	80%	45 million cubic feet	36 million cubic feet	37,730,208 BTUs	$505
	Oil Furnace	95%	38 million cubic feet	36 million cubic feet	37,730,208 BTUs	$425
	GS Heat Pump	3 COP	3,686 kWh	11,058 kWh	37,730,208 BTUs	$408
	GS Heat Pump	4 COP	2,765 kWh	11,058 kWh	37,730,208 BTUs	$306
	GS Heat Pump	5 COP	2,212 kWh	11,058 kWh	37,730,208 BTUs	$245

Ground source Heat Pumps provide the greatest efficiency in our analysis and therefore provide the greatest savings relative to electric Furnaces and electric air source Heat Pumps. However, the minimum payback scenario is still 34 years.

Chapter 5: Decarbonizing Technology

Renewable Technology

Increasing the adoption of renewable energy technology shows promise in decarbonizing residential space heating. For the purpose of this study, we define renewable energy technology as equipment that provisions heat directly for residential housing using renewable energy or carbon neutral sources. Renewable energy sources encompass solar and geothermal energy, while carbon neutral sources include energy derived from burning wood biomass.

This technology shows promise because it can provision heat without the use of fossil fuels, thereby reducing carbon emissions produced. Numerous studies from both academic and governmental sources confirm these benefits. For example, in the case of geothermal energy, the DOE reports that, "geothermal ground-source Heat Pumps systems save roughly, "33-65 percent in energy use compared with baseline HVAC systems and cut CO2 emissions by 25-65 percent" (DOE, 2015). Furthermore, if all US housing stock were to leverage geothermal energy for space heating and cooling, the US could, "eliminate 270 million metric tons of CO2 emissions (a 45.3% reduction) and save more than $50 billion in energy (a 48.2% savings); and reduce 216 gigawatts in summer peak electrical demand (a 56.1% reduction)" (DOE, 2015).

The adoption of this technology is predicated upon building and homeowners fundamentally changing their energy feedstock and heat provisioning technology. For example, solar thermal technology requires homeowners not only to install solar thermal coils on their roof, but also to install a solar energy controller and Boiler to transform this energy into heat. From there, an existing or new radiator system would need to be paired with this technology.

To that end, this section will explain how ground-source Heat Pumps, solar thermal heating, and biomass heating fundamentally work.

Geothermal Ground-source Heat Pumps (GHP)

Geothermal GHP systems work by transferring the ground's natural heat (54 degrees) into a building through a Heat Pump. This system is dependent on three components:

Earth Connection Loop:

GHP systems leverage the Earth's ground heat by running a series of connected pipes in a closed loop system from a building and into the ground. This loop travels from the building to at least ten feet below the Earth's surface. From there, these pipes are filled with water or an anti-freeze mixture that circulates through the loop to absorb the ground's heat and transfer it to the building.

Heat Pump:

The Heat Pump removes heat within the fluid, which was generated from the Earth's ground temperature. The pump then concentrates this heat and pumps it throughout the building as hot air.

Heat Distribution:

Conventional ductwork is needed to move hot air throughout the building.

Figure 28 details the process of geothermal GHP systems:

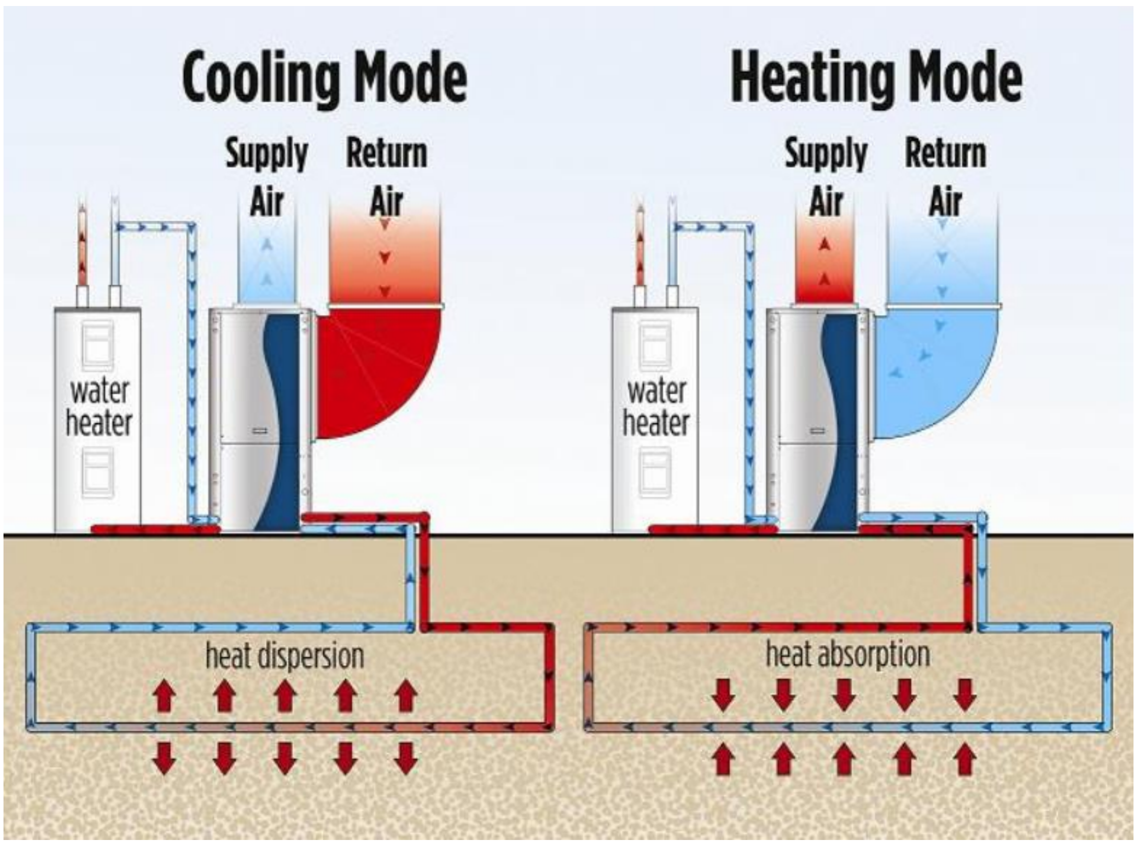


Figure 28 The process of geothermal GHP systems[20]

Solar Thermal Heating Systems

There are two types of solar space heating systems: hydronic and air systems. Hydronic systems heat water through solar-heated coils and leverage a radiator system to distribute heat, while air systems power ambient air through soil coils and pump that air throughout a building.

[20] Energy Environmental

Hydronic Systems:

Hydronic Systems are made up of three key components: solar collectors, a solar storage tank, and a radiant heating distribution system. Solar collectors encompass an array of pipes installed on the roof of a building that circulate a liquid solution (generally corn glycol) within them. This solution absorbs heat from the sun and is then sent and circulated through a solar storage tank. The solar storage tank contains water, which is heating to up to 135 - 175 degrees. This water is then distributed via a radiator distribution system within the building. See Figure 29 for more details on how solar hydronic systems work. Please note that this system can be reconfigured to heat a home's water supply.

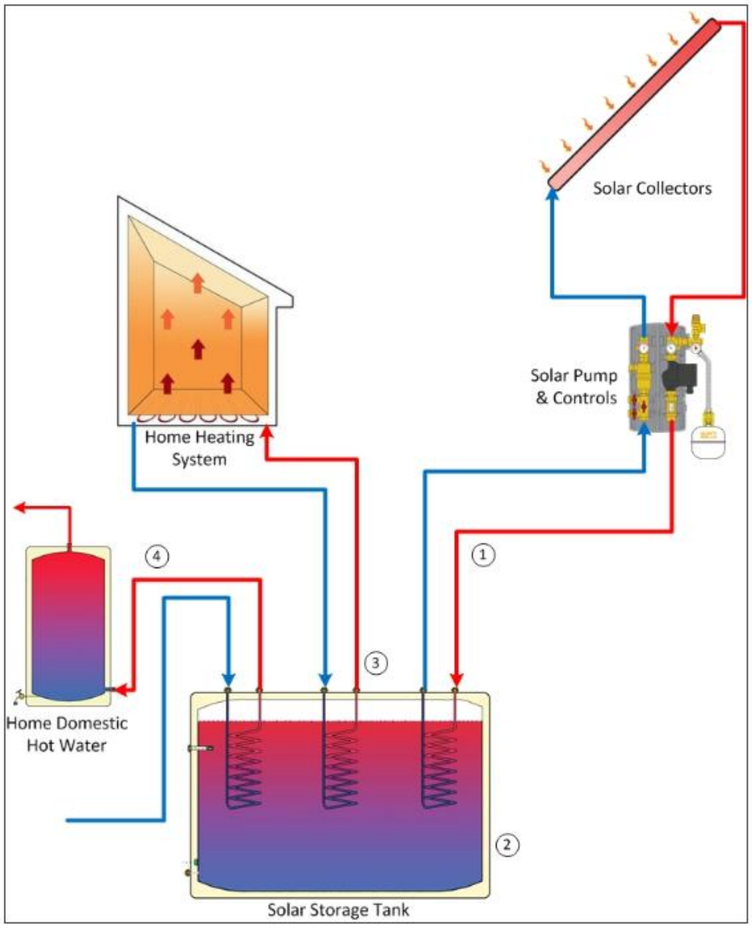


Figure 29 The working process of solar hydronic systems[21]

[21] Solar Panels Plus, 2014

Air Systems:

Solar air systems rely on three components to heat a building: a solar collector, a fan, and a ductwork distribution system. Ambient air travels through vertical tubes placed alongside a building (generally the southside to attract more sunlight). The sun heats these tubes and the air within them. From there, a fan distributes this heated air through a forced-air ductwork system. Please see Figure 30 to see how solar air systems function in more detail:

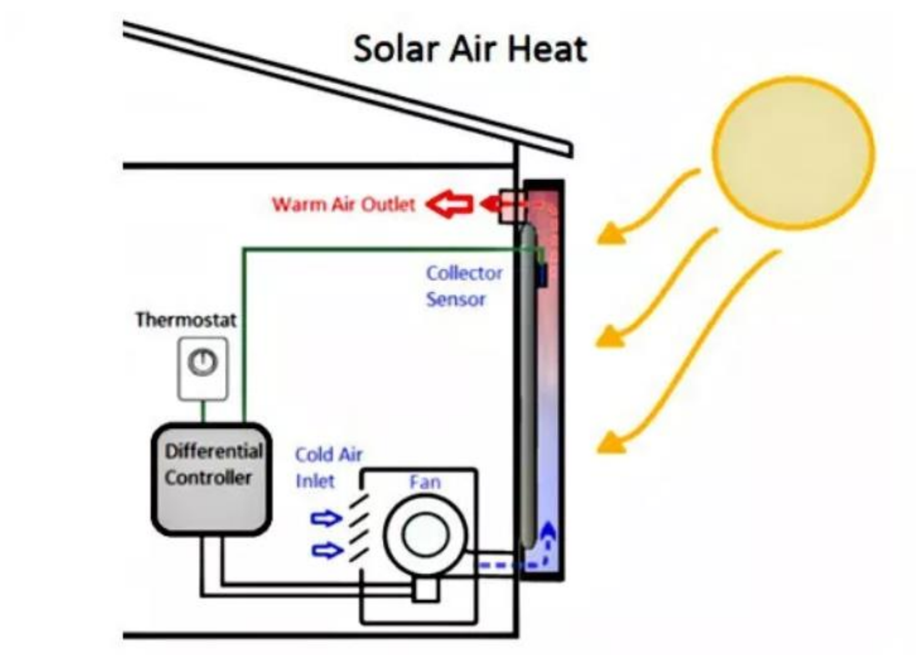


Figure 30 The process of solar air systems[22]

Wood Biomass Systems

Wood biomass systems work like traditional Furnaces or Boilers but use compressed wood pellets as an energy feedstock to generate heat. This process is considered less carbon intensive than fossil fuel usage since forests, which sequester carbon, are continuously farmed for wood. For wood biomass systems, wood is harvested, compressed, and sometimes treated to make it ready for use and increase its burning efficiency. From there, wood pellets are fed into a hopper, which provides a continuous supply of wood for heating. The wood is then burned, and the heat generated from combustion is used to heat water, which is distributed throughout the home through a radiant system. Figure 31 provides more detail on this process:

[22] Abdelhamid, 2015

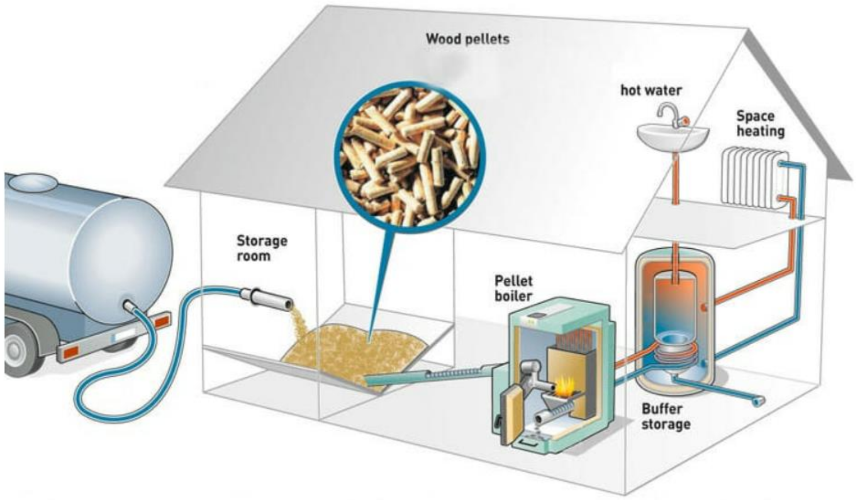


Figure 31 The process of wood biomass system[23]

Electrification of Heat

Another pathway to decarbonizing the space heating market is through electrification, which we define as the usage of space heating provision equipment that solely runs on electricity. Today, this type of technology encompasses Heat Pumps, Furnaces, and baseboards. Please see the Market Overview chapter to learn more about how Heat Pumps and Furnaces function and the current trends associated with their growth and development.

It is important to note however that the adoption of electric source heating only indirectly reduces the carbon intensity of space heating. For there to be carbon reduction, homeowners must source their electricity from renewable energy sources. Homeowners could overcome this challenge by running an electric Heat Pump on a home solar array or by working with their utility to source renewable electricity from the grid. In both cases, the play for EIP is not the renewable energy itself; rather, the electric heat appliance.

Promoting electrification as an indirect means of carbon reduction may prove promising when considering macro and micro trends associated with renewable energy development. From a microeconomic perspective, increased demand for home electricity-use can increase the financial benefit and reduce the payback period of residential renewable energy systems (i.e. solar photovoltaics), which may increase their adoption nationwide. Likewise, from a macroeconomic perspective, electricity generated from renewable energy is increasing as a total share of energy produced across the United States. Supporting technology that can realize the benefits of this trend only increases the impact of renewable energy development.

[23] Herschel Infrared Heaters, 2018

Increased Efficiency of Fossil Fuel-Based Heating Technologies

While transitioning the space heating market to renewable energy may show promise, most of the country still relies on natural gas to run its heat provisioning technology. One way to reduce the carbon impact of these fuels is to increase the efficiency of heating and cooling provision technology. Increased efficiency has largely been accomplished in two ways: (1) increased federal and state standards and (2) ENERGY STAR certification. In the case of standards, the federal government has slowly increased efficiency standards for the whole industry over time, while states have followed suit with their own regulation. The Policy Landscape chapter of this report details the history and current trends of minimum efficiency stands. In the case of ENERGY STAR, this program certifies and labels high efficiency products to allow consumers to make educated purchasing decisions when buying new appliances.

To that end, EIP has the opportunity to invest in companies that provide technology that may meet expected increased energy efficiency standards or may be differentiated as an ENERGY STAR product.

Efficient Usage of Heat

A more immediate path to decarbonization is reducing the amount of heat demanded within a building. There are numerous technologies on the market to assist consumers to become more efficient with their heating energy usage. For the purpose of this study, we define these technologies as hardware tools that increase the efficiency of distributing or regulating space heat. This may include smart heating vents, smart thermostats, etc. An example of this technology in the context of distributing heat is that of EcoVent. This company has a created a smart home system that controls the climate of individual rooms by remotely opening and closing heating/cooling vents for target temperatures (Ecovent, 2018). This technology has the opportunity to significantly reduce the amount of energy used in buildings by giving consumers the power to only select rooms they want heated, thereby increasing the overall efficiency of the distribution system. Another example of efficient demand regulation is the product launched by Radiator Labs. This company has created smart covers that encase radiators to regulate the heat emitted from them. By regulating the heat based on consumer settings, this technology prevents rooms from overheating and consumers opening windows for comfort. The result is lower energy costs for buildings, more comfort, and less emissions (Radiator Labs, 2018).

Chapter 6: Barriers to Adopting New Technology

Homeowners and builders face a range of barriers when it comes to adopting decarbonizing space heating technology. Our team identified three key barriers:

1. **Customer Awareness** – Are consumers even aware of options to decarbonize their space heating?
2. **Project Timeliness** – When given the ability for customers to change their heating system, how does the immediacy of needing heat factor into customers' preferences?
3. **Location & Infrastructure-Specific Challenges** – How does a customers' existing heating system coupled with their location dictate what new options customers could switch to?

Customer Awareness

Many industry experts contend that most consumers are not aware of low carbon space heating technologies; and if they do, they possess a negative perspective of it. According to NYSERDA, New York State's Energy Efficiency Authority, lack of awareness is primarily due to the long lifespan of a consumers' heating system coupled with federal, state, and utility incentives for increasing fossil fuel system efficiency rather than renewable energy adoption. Another key factor NYSERDA outlines is the fact that consumers have poor confidence in new technology's functionality (NYSERDA, 2017). Renewable energy systems like solar thermal or geothermal technology came out in the late 1970's, and early adopters of the technology often had problems, which created the idea that this technology is simply not ready for residential use. Since then, the renewable energy industry has not been able to counter this idea in the space heating market and has only been able to target consumers that are environmentally minded or possess huge heating bills.

To that end, industry reports contend that customer awareness and perception is a huge issue. In the case of geothermal adoption, MarketWatch reports that, "lack of consumer awareness or confidence in the benefits of geothermal Heat Pumps [acts] as a major challenge in the overall acceptance of this technology" (Marketwatch, 2018).

Project Timeliness

Another barrier to adoption is the timeliness of installing a new heating system. Switching to a new heating system is often conducted under three different scenarios: (1) a builder installing a system under new home construction, (2) a homeowner replacing a heating system after the existing system's failure, and (3) a homeowner switching heat systems in a planned fashion before existing system failure. Within the US market, most new heating systems are installed under scenario 1 and 2 conditions. These conditions, however, aren't conducive to the adoption of new space heating technology. In the case of a new homebuilder installing a new system, these builders are incentivized to install systems that don't increase their capital costs, thereby increasing the cost of the home. Likewise, in the case of a homeowner replacing a system after a failure, these customers prioritize the timeliness of installing a new heating system. A utility executive articulated this mindset perfectly:

The key dynamic to understand here is that retrofits typically happen upon failure, not like elected early switch out. Usually your Furnace fails in the middle of the night and you are trying to get something in the next day. So, some guy tries to sell you on switching from oil or gas to Heat Pumps, and you say, 'interesting, now put in an oil system in the next two hours because I'm freezing'.

The biggest challenge, however, is getting homeowners to preemptively retrofit their systems before failure. Today, the only homeowners who possess this mindset are eco-warriors that are ideologically driven to reduce fossil-fuel consumption or are those that have such high energy costs they are actively looking for cheaper heating systems. These two customer segments make-up a marginal portion of the US space heating market given low electricity prices in the South and low gas prices in the US. This issue is made more difficult when coupled with the high capital costs of renewable space heating technology.

Outside of these two groups, both the private and public sector organizations are trying to incentivize new equipment purchases. From a private sector perspective, some companies are trying to aid this decision-making process through smart sensors on existing Furnaces and Boilers. These sensors can pick up on the health of the heating system and warn homeowners of the need to switch, thereby giving homeowners more time and autonomy to make heating decisions. From a public sector perspective, utilities and state governments are running community awareness campaigns and providing homeowners with a host of rebates and tax incentives to reduce the capital costs of making a switch.

Location & Infrastructure-specific Challenges

Two additional variables that complicate decarbonizing space heating adoption is the location and infrastructure of the homes themselves. Some heating technology is climate dependent and often requires hybrid solutions if it is installed outside its target locale. This is evident with electric Heat Pumps which are not as efficient in colder climates but are very popular in southern climates given the South’s limited number of heating degree days. A utility executive put it aptly during an interview:

Think of it more as a goldilocks problem: The South is too hot to even care about how switching to a Heat Pump; the far North is too cold to use a Heat Pump; but the swath between Virginia and Pennsylvania extending west is goldilocks zone for Heat Pumps.

So, the propensity of getting consumers to adopt specific technology is largely limited to where these consumers live.

Compounding the problem of home location is the home’s existing heating infrastructure. A home’s heating distribution system or access to certain energy feedstocks limits the retrofit options available to homeowners. For example, when trying to switch to electric Heat Pumps, homeowners generally require a Furnace system and forced air ductwork. If the home does not have this distribution system, the homeowner may need to make structural changes to the home, which increases the transaction costs of switching, thereby decreasing the likelihood of adoption. Likewise, access to energy may limit the retrofit options available. In the case of switching to a natural gas-based system, some homes do not have access to municipal-provided piped natural gas infrastructure. Gaining access to natural gas pipes over 100 feet away is often prohibitively expensive, forcing homeowners to consider off-grid systems such as wood, oil, or geothermal technology. A homeowner’s decision to switch heating systems is often home-specific given these two variables and should not be discounted by investors.

Chapter 7: Policy Landscape

US Federal Policies

The federal government uses several mechanisms to increase the efficiency of existing heating technology and promote the adoption of renewable energy across the US space heating market.

Product Efficiency Standards (Furnace, Boiler, Heat Pump)

Background

The US Department of Energy (DOE) mandates that all heating appliances must meet minimum efficiency standards to conserve energy and reduce greenhouse gas emissions. These standards nudge the industry to create more efficient and cost-effective appliances for the public.

These standards are appliance-specific and are calculated through efficiency metrics. For Boilers and Furnaces, the efficiency is measured through the appliance's "Annual Fuel Utilization Efficiency"; while for Heat Pumps, efficiency is measured through "Heating Seasonal Performance Factor". Formulas for each metric are provided in the figure below:

$$\text{AFUE} = \frac{\text{Amount of Heat Produced (BTU)}}{\text{Amount of Heat Inputted (BTU)}} \qquad \text{HSPF} = \frac{\text{Heat Output over Heating Season (BTU)}}{\text{Total Electricity Used}}$$

Standards are set through the DOE's rule-making process in partnership with the appliance industry and non-governmental organizations (NGOs). The table below details appliance-specific standards:

Table 8 Detailed Appliance-specific standards

Provision Technology	Efficiency Metric	Minimum Efficiency Standard	Data of Standard
Boilers	AFUE	84%	2015
Furnaces	AFUE	80%	2015
Heat Pump	HSPF	8.0	2015

Standard Trends

Minimum efficiency standards have slowly increased over time since their introduction in the 1980's. The pace of increasing minimum efficiency standards varies depending on the appliance. Also, the implementation of these standards generally occurs several years after their adoption. Additionally, the appliance and fossil fuel industries have effectively worked to delay the rule-making process or roll-back regulation through litigation and lawsuits.

Case Study on Furnace Efficiency Standards

These trends are clearly identified through the adoption and implementation of Furnace efficiency standards. The first Furnace efficiency standard was created in 1987 and was set for implementation in 1992. Since then, the DOE has worked to increase these standards two more times both in 2007 and 2011. The 2007 standard set minimum efficiency at 80% nationally, while the 2011 standard increased efficiency at various levels at a regional level ranging from 80% - 90%. The appliance and fossil fuel industry, however, worked to roll-back these regulations by suing the DOE. A 2011 lawsuit withdrew the 3rd federal standard, which allowed the 2007 standards to be implemented in 2015. In 2016, the DOE completed a proposed rule on Furnaces, Boilers, and Heat Pumps; however, the proposed rule has not been finalized and will not be implemented until 2021.

Effect of Standards

Minimum efficiency standards have been shown to effectively move the appliance industry toward more efficient products, incentivize consumers to switch to more efficient provision technology, and reduce carbon emissions. This is evident through the Appliance Standards Awareness Project's (ASAP) analysis of national energy savings due to current efficiency standards across a range of products. For example, the ASAP predicts that the most recent Boiler efficiency standards will save US consumers 0.16 quads of energy, 9.3 million metric tons of carbon emissions, and $350 million dollars (discounted at 7 percent) through 2050 (ASAP, 2015).

Furthermore, future minimum efficiency standards will begin to hit a ceiling of effectiveness when considering that the proposed efficiency targets are approaching 90 to 95 percent.

Implications for EIP

Federal minimum efficiency standards can help create a market for high efficiency provision technology as the industry can no longer sell low-cost, low-efficiency products. Additionally, these standards may cause the cost of fossil fuel-based heat provisioning technology to increase, thereby incentivizing consumers to switch to other, more renewable provisioning technology. For example, the DOE projected that in response to the proposed 2015 gas Furnace efficiency standards, 9 percent of consumers with gas Furnaces may switch to electric heating equipment, mostly Heat Pumps and some electric resistance heat (ASAP, 2015). These trends could help boost the product economics of new investible technology.

However, the development of new standards moves at such a slow pace that EIP should not rely on standards creation when analyzing investment opportunities. Efficiency standards can help slowly nudge the space heating market, but they will not fundamentally change market dynamics.

Product Emissions Standards (Wood Heat)

Background

The Environmental Protection Agency (EPA) regulates the emissions for wood residential heating through the Clean Air Act. Smoke released from wood heaters contains particulate pollution that includes carbon monoxide, volatile organic compounds, and air toxics such as benzene (EPA, 2015). According to the EPA, at a national level, "residential wood combustion accounts for 44 percent of total stationary and mobile polycyclic organic matter (POM) emissions, nearly 25 percent of all area source air toxic cancer risks and 15 percent of noncancer respiratory effects" (EPA, 2015).

Since 1988, the EPA has set emissions standards for wood heaters; and in 2015, the EPA issued an updated rule to strengthen these standards. The updated rule does the following:

- Increases emissions standards for existing wood heater technology
- Creates an emission standard for new, unregulated wood heater technology

Like the DOE efficiency standards, EPA's new standards will be implemented in 2 years (2020) to allow for the wood stove and heating manufacturers to limit the emission of their products.

Impact of Standards

Volatile organic compound emissions from residential wood heating are expected to drop by 70 percent (or about 8,300 tons/year) over a 20-year time period. In addition, the EPA calculates that while this new regulation will cost consumers and the industry $46 million annually, the net benefit to society will yield about $5 billion annually in increased efficiency, health, and environmental savings (EPA, 2015).

Implications for EIP

As with the efficiency standards, these new standards could help increase the competitiveness of more efficient wood heat provisioning products and may shift consumers to consider more renewable substitutes. However, the total impact of these standards will be minimal when considering investment opportunities in the wood heating space.

Product Certification (ENERGY STAR)

The EPA and DOE jointly manage a voluntary product certification program called ENERGY STAR with the mission of providing, "simple, credible, and unbiased information that consumers and businesses rely on to make well-informed decisions" (DOE, 2018). In the context of space heating, this program certifies products that meet energy efficiency standards above the federal minimum standard. For example, ENERGY STAR certified gas Furnaces must meet a 90 percent AFUE standard when sold in the southern US and a 95 percent when sold in the in northern US compared to the current federal minimum of 80 percent.

The main appeal of ENERGY STAR products is their cost-effectiveness relative to low-efficiency products. The DOE Federal Energy Management Program conducted a study of cost-savings of residential Furnaces and found cost savings between $1,200 and $1,500 dollars over their life-span. The table below details the program's calculations:

Table 9 Lifetime Savings for Efficient Residential Furnace Models

Performance	Best Available	ENERGY STAR	Less Efficient
AFUE	97.5%	95.0%	80.0%
Output Capacity	70,000 Btu/h	70,000 Btu/h	70,000 Btu/h
Annual Energy Use	648 therm	665 therm	770 therm
Annual Energy Cost	$441	$452	$524
Lifetime Energy Cost (20 years)	$7,665	$7,867	$9,108
Lifetime Cost Savings	**$1,443**	**$1,241**	======

The main strength of ENERGY STAR is the certification's scale and brand awareness. Over 40 percent of the Fortune 500 companies work to certify their products as Energy Star (DOE, 2018), while "78 percent of households that recognized the label and purchased an ENERGY STAR-labeled product were likely to recommend ENERGY STAR to a friend" (DOE, 2018). Together, these factors result in a large fraction of US consumers purchasing ENERGY STAR products. For the Furnace market alone, ENERGY STAR certified Furnaces accounted for roughly 41 percent of all Furnace sales between 2010 and 2013 (Navigant Consulting, 2015).

Implications for EIP

The strong brand awareness associated with the ENERGY STAR certification among consumers is a great marketing tool for high efficiency products. Investing in technologies that can take advantage of the ENERGY STAR brand may help drive sales across the US.

Loan Financing Assistance

The federal government also assists consumers with financing the cost of home energy efficiency projects through energy efficiency mortgage assistance. The goal behind these programs is to give homeowners access to capital by using their mortgages as additional lines of credit. These lines of credit carry reduced risk as the energy savings from the improvements should cover the cost of an increased mortgage payment. Table 10 illustrates an example of the economics behind an energy efficient home mortgage:

Table 10 Sample Comparison of Homeowner Costs

	Older Existing Home	Same Home with $10,000 Energy Improvements
Home Price	$200,000	$210,000
Mortgage Amount (96% of Price)	$192,000	$201,600
Monthly Payment ** (30-year mortgage at 5.5%, rounded)	$1,090	$1,145
Monthly Energy Bills (Electric, Gas)	$186	$110
Monthly Cost of Homeownership	$1,276	$1,255
Monthly Savings	n/a	$21
Home Comfort During Hot or Cold Weather	- - -	+++

Different agencies, including the Department for Housing and Urban Development (HUD), Department of Agriculture (USDA), and the DOE, have programs that assist homeowners to gain access to capital that can fund energy efficiency improvements. Below are the different programs by agency:

HUD Financing Programs:

1) Rehabilitation Mortgage Assistance

HUD reports: “this mortgage product allows homebuyers and homeowners to finance both the purchase of a house and the cost of its rehabilitation through a single mortgage or to finance (or refinance) the rehabilitation of their existing home (HUD, 2014). The program is effective in upgrading the efficiency of existing housing stock. Thermal efficiency activities that are eligible for financing under the program include:

- Installation of renewable energy systems
- Installation of efficient HVAC and/or other appliances
- Installation of sealing ducts and other insulation

2) Energy Efficient Mortgage Program

This program enables homeowners and homebuyers to finance the cost of energy efficiency investments through a federally financed loan or refinance transaction. To qualify for these loans, homeowners must prove that the energy efficiency investment is cost effective. Put another way, the savings generated from the energy efficiency improvements must cover the capital investment required over the estimated useful life of the improvements. To prove an investment is cost-effective, HUD requires borrowers to get a home energy system audit, which outlines eligible energy improvements and details a cost-benefit analysis. With this audit, the borrower can receive access to financing.

One benefit of these loans is that they are guaranteed to increase the appraised value of the home by the amount borrowed because the investments are cost-effective. However, given these benefits, energy efficient mortgages have gained limited traction as they account for fewer than 1 percent of all home loans. (Tedeschi, 2006).

3) Case Study: Efficiency Maine Offers PowerSaver Loans

Many states have been able to offer federally-supported home energy efficiency loans. Efficiency Maine, the state of Maine's independent administrator of energy efficiency programs, works with the Federal Housing Administration (FHA) to offer PowerSaver loans for single family homes. These loans are attractive because they are low-interest (4.99%) and long-term (15 to 20-year duration) and fund a variety of energy efficiency upgrades including solar thermal, wood pellet stoves, high efficiency Boilers and Furnaces, and geothermal installations. As of 2014, Efficiency Maine has offered over $1.7 million in PowerSaver loans to 150 homeowners with an average loan amount of $20,600 per household. Most of these loans generate consumer energy saving of about 50% and have a payback period of less than 10 years. To source these loans, Efficiency Maine has also created a network of over 500 energy professionals to advise and contract with local homeowners (USDA, 2014).

Implication for EIP

Home energy efficiency financing support can help increase the adoption of new space heating technologies by providing customers with access to capital. These programs are essential in creating demand for space heating technology that would otherwise be inaccessible to customers due to the high capital costs. However, the programs don’t adjust the project economics associated with installing these technologies. These programs only provide customers with a means to engage with them.

Federal Tax Credits

The federal government offers a variety of tax credits to reduce the capital costs associated with implementing renewable energy and energy efficiency home projects. These tax credits were renewed through The Bipartisan Budget Act of 2018 and is set to expire in 2021. These include:

Residential Renewable Energy Tax Credit

The homeowner may claim a credit of up to 30% of the cost of installing a solar electric, solar water heating, geothermal, wind energy, or fuel cell system on his or her property (DOE, 2018). Below is a table detailing the tax credit awarded depending on time of installation:

Table 11 Detailed Tax Credit Awarded by Time of Installation

Technology	Systems in Service by 12/31/2019	System in Service after 12/31/2019 and before 01/01/2021	Systems in Service after 12/31/2020 and before 01/01/2022
Solar Electric Solar Water Heating Geothermal Heat Pump	30%	26%	22%

Residential Energy Property Tax Credit

Homeowners received a tax credit when purchasing ENERGY STAR appliances. The tax credit cover 10% of the cost of the product up to $500. The tax credit covers appliances such as Heat Pumps, Boilers, water heaters, and biomass stoves (Energy Star, 2018).

Energy-Efficient New Homes Tax Credit for Home Builders

Home builders can have a $2,000 credit when building a new home (site-built or manufactured) its construction is certified to reduce heating and cooling energy consumption by 50% relative to the International Energy Conservation Code (IECC) 2006 and meet minimum efficiency standards established by the DOE (DOE, 2018).

US State Policy

States use similar policies to incentivize a less a carbon-intensive space heating landscape within their markets. These policies include:

- **Renewable Energy Portfolio Standards –** Regulation created by each state that requires utilities to increase production of renewable energy sources such as wind, solar, and geothermal.
- **Building Codes –** Standards for home builders and home owners when building and maintaining housing stock.
- **Tax Incentives and Rebates –** Financing incentives to help increase investment of renewable energy and energy efficiency projects.

Each state sets different standards and offers various financial incentives for space heating decarbonization projects. This paper will look at the most progressive states across the country – California, Massachusetts, and New York – to show where the country is trending toward aggressive decarbonization policy.

California

Renewable Energy Portfolio Standards

California's electric utilities are obligated to source 50% of their electric generation through renewable energy by 2050. This standard, however, does not include any regulation regarding residential space heating uses across the state.

Building Codes

California's Title 24 building code stipulates that, effective 2020, all new housing stock under three stories tall must be outfitted with a solar PV array, which is sized equal to the home's projected electricity use. This standard is climate-region specific across California; and in the event that a home is suitable for a solar array, the home must have access to community solar or be outfitted with additional energy efficiency technology. Greentech Media reports that this standard will, "reduce home energy use by 53 percent compared to the current code, saving Californians $1.7 billion in energy costs over the next 30 years." Currently, under Title 24 building codes, all new housing stock must be "solar ready", which means the rooftop of the home must have access to sunlight for rooftop solar. Additionally, California has mandates that all new housing stock have net-zero energy use by 2020, meaning that the building must produce as much energy as it consumes.

Given these aggressive standards, NGOs, such as the Sierra Club, are already pushing the state to regulate energy use outside of electric generation. According to Greentech Media:

The Sierra Club submitted a letter to the CEC this week, including 5,858 digital signatures from members and supporters, calling for the Commission to reduce the reliance on gas in the next building standards update... 'California now burns as much gas in our buildings as we do in our power plants,' the letter states. 'While we have programs to increase the use of renewable energy and reduce our reliance on gas plants, we do not have policies in place to replace gas use in buildings with available high-efficiency electric technologies that can be powered by clean energy.' (Greentech Media, 2018).

Tax Incentives and Rebates

California offers a myriad of financial incentives to subsidize renewable energy investment. For space heating, the California Solar Initiative Thermal Program offers rebates of up to $4,300 dollars for homeowners to implement solar thermal water heating systems. Many counties and utilities offer local rebates and incentives based on the output of your renewable energy system.

Massachusetts

Alternative Energy Portfolio Standards

Massachusetts includes the production of renewable thermal energy to meet its Alternative Energy Portfolio Standard (APS), which requires the state to source 5 percent of its energy through alternative energy by 2020. Eligible technologies include efficient biomass, geothermal, and solar thermal technologies. To meet this requirement, utilities can purchase alternative energy credits, which measure heat output through a conversion to one megawatt-hour of electricity.

Building Codes

Massachusetts requires counties to comply with a base energy code or opt into a "stretch code". The stretch code is performance-based and requires new residential construction to achieve a Home Energy Rating System (HERS) rating score of 55 or more. Over 70% percent of all Massachusetts counties have opted into this performance standard.

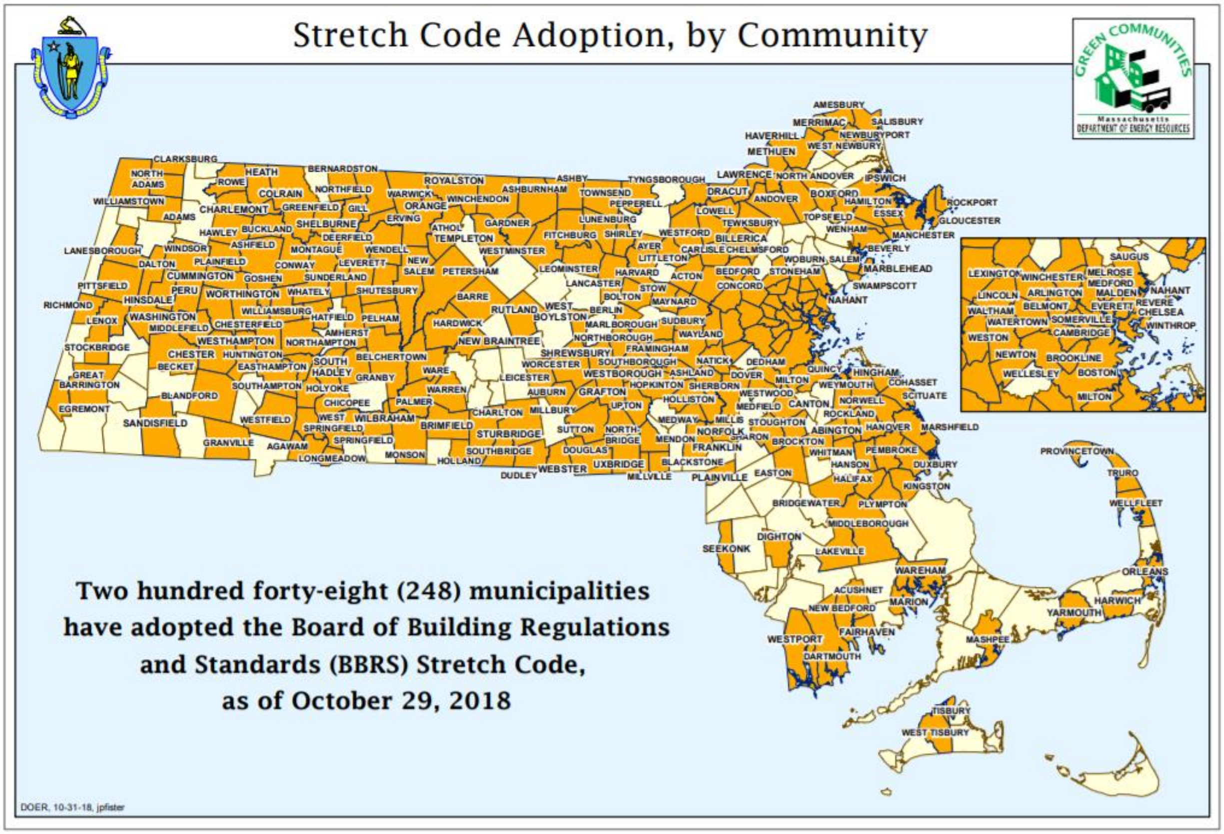


Figure 32 Stretch Code Adoption, by Community

Tax Incentives and Rebates

Home Energy Market Value Performance Program (Home MVP)

This program assists homeowners through every stage of an energy efficiency home improvement. The program accomplishes this by:

- Connecting customers with approved contractors, who will conduct a home energy audit and explain what home improvements are subsidized by the state.
- Financing home improvement projects through zero interest loans for up to seven years through MassSave HEAT Loans.
- Subsidizing the capital investment through other MassSave and Massachusetts Clean Energy Center rebates.

Eligible Projects for the Home MVP program include:

- Solar Thermal
- Cold Climate Heat Pumps

- Modern Wood Heating
- Geothermal Energy Systems
- Air and Duct Sealing
- Insulation
- Electric Heating/Cooling
- Improved Controls (such as wireless thermostats and more efficient distribution systems)
- High Performance Windows
- Mechanical Ventilation

Mass Save Rebates:

The Mass Save Program offers a variety of rebates for all different types of home energy efficiency improvements:

Table 12 Rebates offered by the Mass Save Program

Improvement	**Rebate**
Electric Heating & Cooling	Up to $500
Early Heating & Cooling	Up to $3,250
Gas Heating Equipment	Up to $1,600
Electric Heat Pump	Up to $750
Wireless & Programmable Thermostats	Up to $125

Mass Clean Energy Center (MassCEC)

This State program has committed $48 million through 2020 to making renewable heating and cooling projects more cost effective. MassCEC offers the following financial incentives:

Table 13 Rebates offered by the MassCEC

Improvement	**Rebate**
Air Source Heat Pumps	Up to $2000
Modern Wood Heating	Up to $12,000
Ground-Source Heat Pump	Up to $10,000
Solar Hot Water	Up to $3,500

New York

Reduction Goal

New York State has set a goal of generation of 185 trillion BTUs of end-use energy savings below the 2025 energy-use forecast. These saving are equivalent to saving the energy consumed by 1.8 million New York homes.

Tax Incentives and Rebates

- **Solar Hot Water Initiative –** New York State provides a 25% tax credit for the installation of solar hot water systems in residential homes
- **Ground Source Heat Pump Initiative –**The New York State offers a ground source Heat Pump rebate of up to $15,000.
- **Renewable Heat New York** – New York State provides financial incentives toward installation costs for high-efficiency, low emission wood heating systems for homeowners not currently using natural gas.
- **Clean Heating and Cooling Communities** – New York works to incentivize whole communities to adopt clean heating and cooling technologies through this program. It works by engaging communities with at least 40,000 residents and conducting consumer awareness campaigns. From there, communities can negotiate rates collectively, select installers competitively, and decrease upfront costs by enrolling in a local campaign.

Chapter 8: Investment Landscape of Disruptive Companies

Introduction & Company List

With a better understanding of the space heating market in mind, our team embarked on the task of finding disruptive companies whose products and services improved one of the four links in the space heating supply chain, namely heating fuel source, heat generation technology, heat distribution technology, and consumer demand technology. We utilized a range of databases, including Crunchbase, Factset, and Dealbook to find potential investments. A list of the thirteen companies that we found most compelling follows below in alphabetical order along with product descriptions:

Table 14 The Disruptive Company List

CaSA .energy	CaSA designs and manufactures residential energy management equipment to provide intelligent control over a home's electricity use while providing grid operator-level software solutions to shape and control demand.
DANDELION	Originally conceived at X, Alphabet's innovation lab, Dandelion is now an independent company offering geothermal heating and cooling systems to homeowners, starting in the Northeastern US.
ecovent	Ecovent is a whole home, Digital Zoning system that delivers room-by-room temperature control through "smart vent" hardware and smart phone software controlled by the homeowner.
FLAIR	Flair is a manufacturer of a smart home thermostat and smart vent that pair with the company's proprietary software to allow greater temperature control by the homeowner.
Greenwood	Greenwood manufactures a wood gasification Boiler that burns fuel so completely it leaves no smoke, creosote or ash. Management describes the product as "the Cadillac" of wood Boilers.

Helios Products LLC	Helios manufactures solar thermal heating collectors which are made from translucent, specially colored plastics that yield twice as much energy and are made from less expensive materials compared with competitive products.
HIVE	Hive manufactures a variety of smart home products, including a smart thermostat that may be controlled from the homeowner's smartphone to improve heat demand and reduce heat waste.
KEEN™ home	Keen Smart Vents™ adjust airflow to over-conditioned rooms and redirect this airflow to rooms that need it most. Temp Sensors and a "Smart Bridge" allow the Keen Home smartphone app to set schedules, set specific room temperatures, and control compatible thermostats.
LifeWhere	LifeWhere provides predictive analytics for home utilities. "LifePulse" technology attaches to machines in the home, constantly monitoring utility health. Service providers are alerted to a problem before it happens, and homeowners have a home health dashboard.
powerley	Powerley provides a real-time window into energy usage for homes and their connected appliances. For consumers, the company provides smart thermostats and phone software. For utilities, the company provides a management portal. The system also monitors appliance heath.
Radiator Labs	Manufactures "The Cozy", a smart insulating enclosure that is installed over existing radiators, with no contact to plumbing or steam components. The system redistributes steam flow transferring wasted heat from overheated rooms to colder rooms and gives tenants control.

tado°	Tado manufactures a smart thermostat, smart radiator valve, and phone application to control these hardware systems, thus improving homeowner control over space heating.
ThermoLift	ThermoLift manufactures a cold-climate Heat Pump that combines heating, cooling, and hot water delivery into a single appliance utilizing a proven thermodynamic cycle to improve system efficiency. The result is a 30-50% reduction in HVAC costs, reductions in GHG emissions, and elimination of hydrochlorofluorocarbon refrigerants.

Potential Disruptions to the Space Heating Supply Chain

The below image (See Figure 33) highlights where these companies fall along the space heating supply chain. When determining where to place these companies, our team looked at the major products or services that they offered since some companies may fall between two supply chain categories. For example, Flair manufactures smart vents that improve the efficiency of the heat distribution network; however, the company also develops a software that allows homeowners to

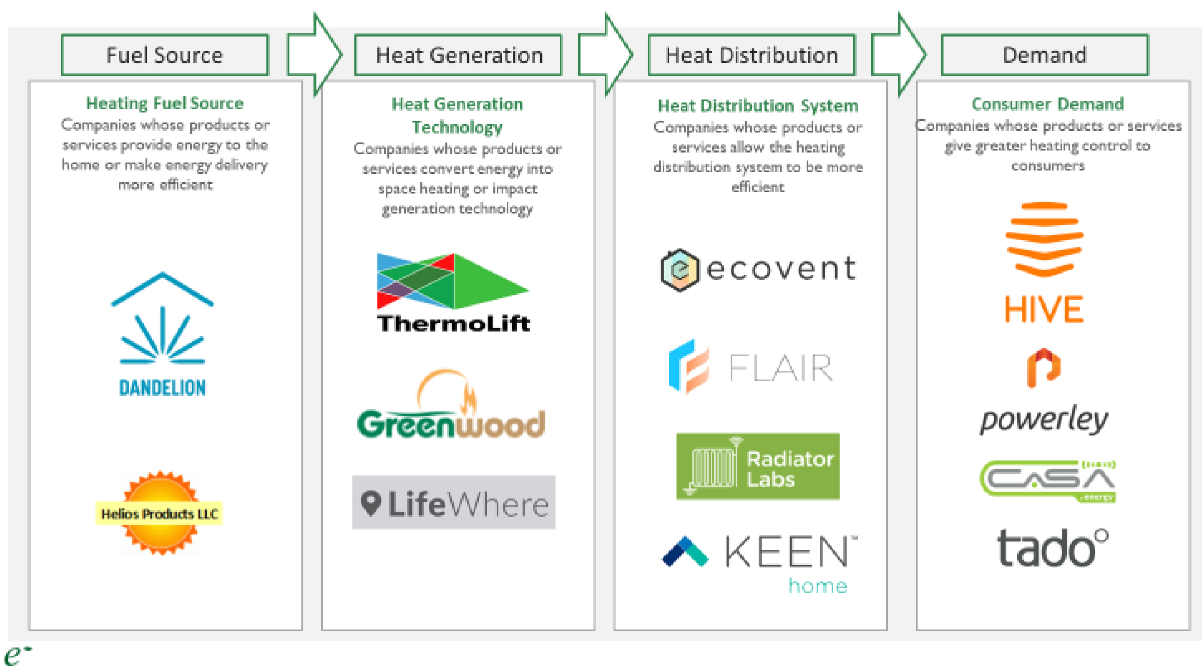


Figure 33 Major Categories of Investable Companies Along the Space Heating Supply Chain

better control their demand needs. Flair has been placed in the Heat Distribution category given that its hardware directly alters a home's forced are ventilation system.

A key takeaway from Figure 33 is that most companies – 8 out of the 13 – impact either the heat distribution system or the consumer's demand and control ability. As the minimum efficiencies proposed by federal regulations for AFUE, HSPF, and COP are already quite high (80% AFUE for Furnaces for example) and the range of Energy Star efficiencies are over 90%, most entrepreneurs have concentrated on later links in the supply chain where greater impacts would be felt due to outdated, analog driven hardware. Additionally, novel heat generation and fuel source technologies may be less prevalent because the development costs are often higher for products in these spaces. Heat Pumps have dozens of components and need to be tested against critical failures to prevent loss of life scenarios once the product goes to market. An automated vent flap, on the other hand, has fewer parts and does not need to combust any fuel, making safety testing less time consuming.

Development Stage of Companies

Our team also estimated where each of the thirteen companies falls along a development scale (See Figure 35) to allow EIP to better determine which of the companies to invest in. EIP usually invests in later stage funding rounds that may be described as "growth capital" or "expansion capital". This type of financing would usually fall in the second or third step as shown in the graphic to the left (See Figure 34). Earlier investors that provide equity capital while the company is moving through the "Valley of Death", a phrase to describe the time period when a startup is generating no revenue and burning cash to research an idea, develop a business plan, and build a prototype, are assuming a huge amount of risk as roughly 75% of venture-backed startups fail (Henry, 2017). EIP's investment strategy is relatively less risky since by the second or third funding rounds, the startup has already made early sales and may have recurring revenues, indicating that the market approves of the product. Nevertheless,

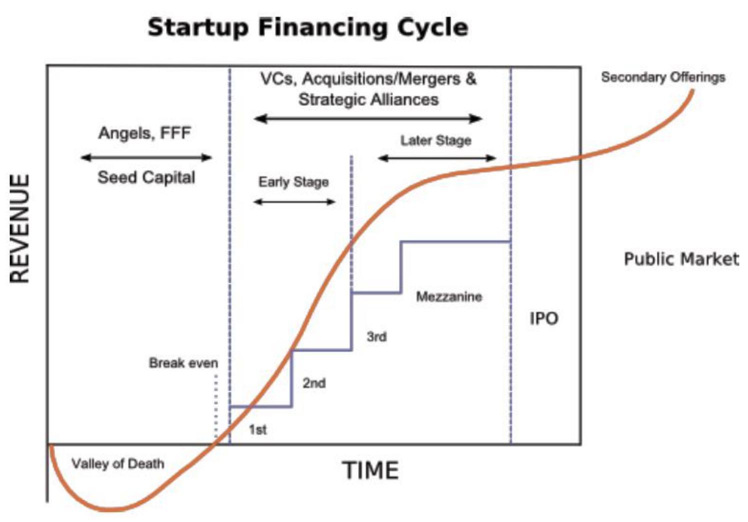


Figure 34 Startup Financing Cycle

the startup could still fail even after consecutive years of recurring revenue or positive operating income (revenues less fixed and variable costs) due to a plethora of internal or external factors.

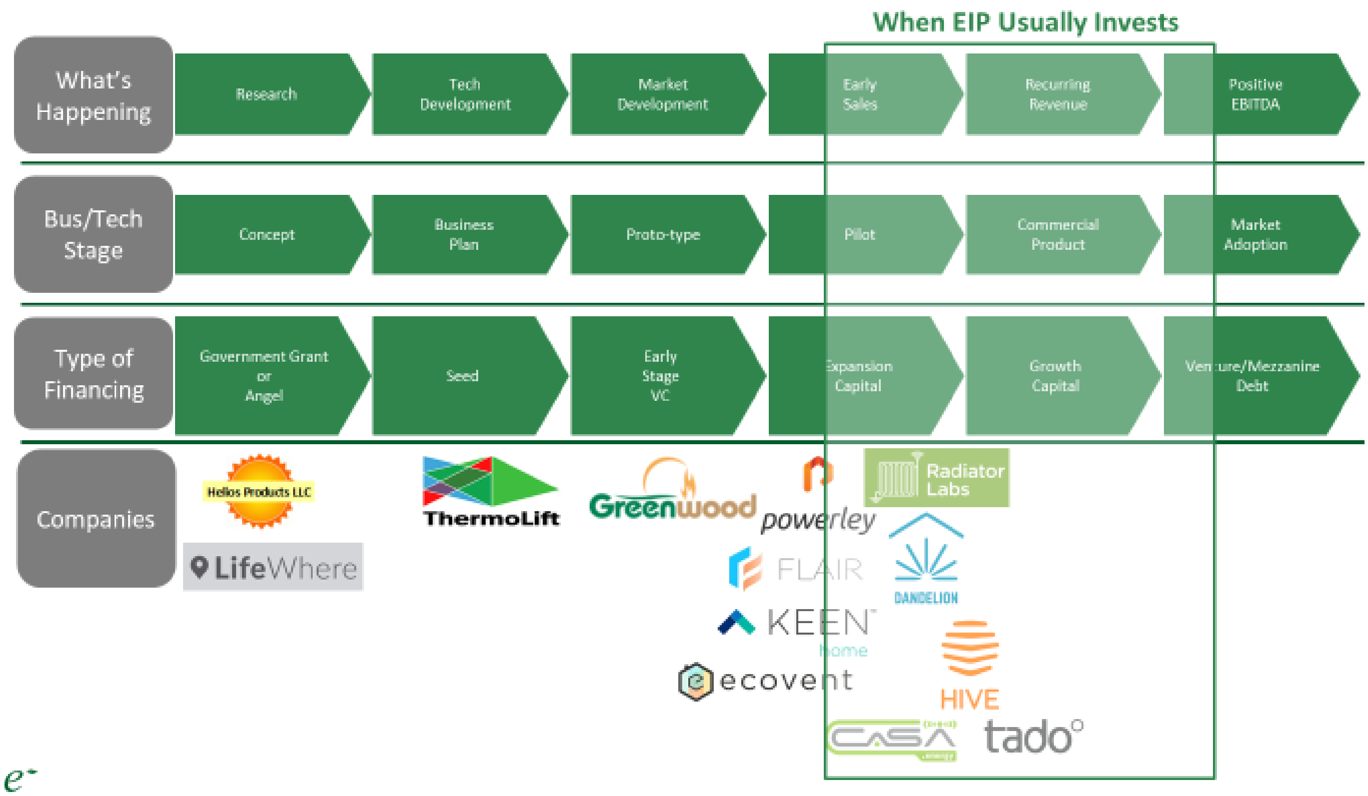


Figure 35 Investable Companies' Development Stages

Assisting EIP's Investment Rationale

For the companies that fall roughly within EIP's usual stage for investment, our team created an investment rational matrix (See Figure 36) to accompany the above company descriptions, which will better assist EIP in selecting potential investments. The goal of this exercise was to provide an introduction of these companies to EIP, who could conduct further research and outreach if so desired. An explanation of why each column category was chosen follows the below graphic.

Company	Total Funding To Date	Most Recent Revenue or Units	Size of U.S. Target Market	Partnerships	Direct Competitors	Product Pricing	Payback
powerley	NA	$2 million	U.S. Housing Market ~118 million	DTE Energy AEP Ohio	Whisker Labs Sense Nexi	NA	NA
FLAIR	$1 million	NA	U.S. Homes with Central A/C ~86.6 million	Nest Ecobee Amazon Alexa	Keen Home Ecovent	Smart Vent $69 Flair Puck $99	~ 1 – 3 years
Radiator Labs	$3.2 million	$1.5 million $6 million projected for '19	U.S. Homes with radiators ~8.3 million	Rudin Real Estate	Thermostatic Radiator Valves	Cozy $500 Subscription $24/yr	~4-6 years NG ~2-4 years Oil
KEEN home	$9.5 million	$3.7 million	U.S. Homes with Central A/C ~86.6 million	Nest Ecobee Iris by Lowes	Flair Ecovent	Smart Vent $130 Temp Sensor $40 Smart Bridge $50	~ 1 – 3 years
ecovent	$9.8 million	$1 million in pre orders	U.S. Homes with Central A/C ~86.6 million	Sensi	Flair Keen Home	Smart Vent $170 Smart Bridge $300 Temp Sensor $170	~ 1 – 3 years
DANDELION	$6.5 million	$8 million	U.S. Single Family Detached Homes ~73.9 million	NA	Trane Carrier Bosch Contract Installers	Geothermal $19,000	~7-20 years
HIVE	$5.4 million	NA	U.S. Homes with Central A/C ~86.6 million	Amazon Alexa Google Assistant	Nest Ecobee Sensi	Thermostat $180	~1 – 3 years
CASA	$1.2 million	$ 1 million	U.S. Housing Market ~118 million	Giant CANMET	Nest Ecobee Sensi	Thermostat $75	~ 1 – 3 years
tado°	$109.3 million	$150 million	U.S Homes with Central A/C & Radiators ~94 million	Google Assistant Amazon Alexa Enet Smarthome	Netatmo Nest Hive	Thermostat $173 Radiator Valve $75	~1 – 3 years

Figure 36 Investable Companies' Baseline Characteristics

Total Funding to Date

The amount of capital raised gauges overall company legitimacy and credibility in the eyes of investors. Startups must explain what they plan to do with the money from a fundraising round and so higher levels of funding can indicate attributes such as a more defined business plan, manufacturing schedule, or attractive realized sales.

Most Recent Revenue or Units Sold

Higher sales can be translated to greater market acceptance of the product. Greater market acceptance provides confidence to investors that the product will last for years to come.

Size of U.S. Target Market

How large can the company grow in the United States? Understanding the market size allows investors to set realistic growth expectations for startups and set future valuations.

Partnerships

Similar to the legitimacy that is created by customers buying products and increasing a startup's revenue, partnerships convey legitimacy farther up the supply chain. Purchase orders with retailers or supply contracts with suppliers both convey third party belief that the company can move its inventory or services.

Direct Competitors

How unique is the product or service? Understanding who else is providing the same product or service can shed insight into how protected the company's future sales are from competitor poaching. Asked another way, are the barriers to entry high or low in this space?

Product Pricing

Is this a commodity product or an aspirational purchase? Lower prices can convey a greater target market potential on the plus side or cheap equipment on the downside that will not retain customers. Aspirational purchases will have higher prices and thus move less quantity of product in the short term.

Payback Period

The space heating technology that we are investigating improves the efficiency of the home heating system. Therefore, customers can expect to spend less per year with these systems than more antiquated systems. Long-term paybacks may only be attractive to committed long-term homeowners, while shorter paybacks may reach a broader audience.

Determining which specific companies to invest in goes beyond the scope of this research project. The due diligence process that venture capital firms embark on requires direct communication of often confidential information with the companies being considered. While such baseline characteristics, as highlighted in the above table, do provide important information on gauging a company's legitimacy to date, they do not provide enough confidence to suggest a monetary commitment. A prime example of the importance of due diligence is showcased with Flair.

Flair vents are less expensive than those sold by Ecovent and Keen. Additionally, Flair vents are made from steel whereas those manufactured by Keen are plastic. Lastly, Flair is compatible with Nest, Alexa, and Ecobee while Ecovent can only pair with a Sensi thermostat. A review of these three attributes would point to Flair as the clear winner of the smart vent companies that we uncovered. However, a user review of Flair on the discussion forum website, Reddit.com, explained, "A couple of weeks ago I got a letter that a manufacturing issue would further delay my order…Almost no communication for a year, and then great communication - about more problems" (Reddit). Such a statement is a red flag to investors and highlights why investment recommendations cannot be made without deep company knowledge.

Chapter 9: Conclusion

Our team is proud to present this report to EIP as an educational guide to the US space heating market. EIP staff and partners will have gained a strong foundational knowledge of a variety of topics, such as equipment types, efficiency rates, and customer behaviors upon perusing its pages. We have provided the 4 key takeaways from this report for EIP to best understand the space heating market and to help inform future investment decisions.

Projected Energy & Technology Mix - The space heating energy mix and the space heating technology mix will not change significantly over the next 10 years but gradual growth in electric heating appliances will continue, as it has since 2001 (See Chapter 3). As has been referenced before in this report, the United States' population will grow most rapidly in Southern states that already heat with electricity, thus increasing electricity's share as a heating fuel type. Electric Heat Pumps will grow most rapidly over the next 5-10 years (See Chapter 3: Heat Pumps (Air Source)) but Furnaces (natural gas and electric) will still make up roughly 55% of the market. This assumption conservatively assumes that the -0.5% CAGR of Furnaces between 2001 and 2015 continues. Our conclusion is supported by utility partners:

> *As solar costs come down and as storage costs come…you are starting to produce a lot more electricity than maybe your needs are and if you can store that energy and use it for other purposes like space heating then things essentially start to become more cost effective. I think farther out than 10 years…we will be using more Heat Pumps, but I think the transition will take longer than 10 years. From forced air Furnaces to Heat Pumps.*

Innovation in the Supply Chain – The greatest number of disruptive companies will occur at the final link in the space heating supply chain, enhancing how consumers demand heat. Smart thermostats, smart ventilation grates, and smart radiator covers are examples of the technologies that will impact this space. These "add-on" products are non-invasive, relatively inexpensive, and easy-to-use in the eyes of millennials & Gen Xers who are now buying homes. Disruption of Fuel Source and Heat Generation Technology are in their infancy, with Dandelion Energy acting as the exception, not the rule. Our sentiments are supported by a managing director in a utility's VC arm and a utility executive:

> *Today the only way you can really control your heating systems is around your thermostat and thermostats are getting smarter…but there needs to be more in the home. And so, I think smart homes in general is where the growth will be… More IoT in the home essentially. I think that it will happen in the home. It has to because homes have a faster ability to change.*

Dandelion was going to bring in fracking related technologies for drilling for geothermal systems, but I don't think they've quite proven that system...the payback period is not that attractive.

Customer Behavior – The vast majority of customers switch from one provision technology to another provision technology at the time of their old equipment's failure, often when the equipment is needed most during winter. Such behavior greatly limits the inroads that renewable fuel source and more efficient heat generation technology can have as part of the retrofit market. Customers want an immediate fix to not freeze. Therefore, we believe that startups in the Fuel Source and Heat Generation links of the space heating supply chain must showcase how they plan to enter only the new home build market or how they might overcome this significant hurdle in the retrofit market, to be considered for investment. Our conclusion is supported by a market research analyst from Heating, Air-Conditioning, and Refrigeration International (HARDI) and a utility executive:

This stuff is not an aspirational purchase. Change is slow. People did not yank their treated lumber decks and replace with Trex. Space heating equipment is shopping for car tires – generally do it when you have to.

The key dynamic to understand here is that retrofits typically happen upon failure not like elected early switch out, usually your Furnace [breaks] in the middle of the night and you are trying to get something in the next day.

Government Policy – The payback periods for switching to new heat generation technologies are often long (See Chapter 4)**,** therefore government savings incentives, in the form of rebates, tax breaks, etc., must continue so that homeowners are financially motivated to decarbonize their home heating system, especially because space heating is not an aspirational purchase. Massachusetts, for example, offers a $750 rebate for Heat Pumps (See Chapter 7: US State Policy). Startups must understand how their product will take advantage of such incentives in order to be successful. If a startup cannot do so, they may be naïve in their understanding of customer behavior with regards to new heating equipment. Our conclusion is support by a utility executive:

These startups are going to have to have a really good policy regulatory game. In their business plan they are going to have to have a regulatory hack. It is the first question a VC should be asking, what is your regulatory play, how are you going to break the model and put it back together again that favors your technology and why will regulators believe it. If they can't answer that question, then they probably haven't thought very hard about the market they are going after.

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Appendices

Appendix A: Example of Payback Calculations (Oil to Geothermal)

Switching Cost: Fuel Oil Furnace to Ground Source Heat Pump	Low	High	Average
Home Energy Audit	300	500	400
Cost to Remove Heating Oil Tank	$500	$3,000	$1,750
Cost to Remove Heating Oil Furnace	100	300	200
Cost of new GS Heat Pump including installation	5,000	10,000	7,500
Federal 30% Rebate	-3,990	-8,640	-6,315
Soil Composition Study	800	1,800	1,300
Cost to Excavate ground	5,000	10,000	7,500
Cost of ground tubing	1,600	3,200	2,400
Total Switching Cost After Rebate	$9,310	$20,160	$14,735
Total Switching Cost Before Rebate	13,300	28,800	21,050
Annual Operating Costs			
Oil Furnaces			
80% AFUE Furnace (federal minimum)	$1,414		
95% AFUE Furnace	$1,190		
Natural Gas Furnaces			
80% AFUE Gas Furnace	$896		
85% AFUE Furnace	$672		
95% AFUE Gas Furnace	$538		
Annual Fuel Savings			
Equipment Change			
80% AFUE to 3 COP	$518		
80% AFUE to 4 COP	$742		
80% AFUE to 5 COP	$876		
95% AFUE to 5 COP	$653		
Payback Period - Preemptive Replacement			
80% AFUE to 3 COP	18		
80% AFUE to 4 COP	20		
80% AFUE to 5 COP	23		
95% AFUE to 5 COP	31		
Payback Period at Replacement			
80% AFUE to 3 COP	7		
80% AFUE to 4 COP	12		
80% AFUE to 5 COP	16		
95% AFUE to 5 COP	20		

	Equipment	Efficienc	Fuel Consumed	Fuel Converted to Heat	Fuel Converted to Heat (BTUs)	$ paid per year
Baseline	Oil Furnace	80%	499 fuel oil gallons	399 fuel oil gallons	55,309,144 BTUs	$1,414
	Oil Furnace	95%	420 fuel oil gallons	399 fuel oil gallons	55,309,144 BTUs	$1,190
	GS Heat Pump	3 COP	5,403 kWh	16,210 kWh	55,309,144 BTUs	$896
	GS Heat Pump	4 COP	4,053 kWh	16,210 kWh	55,309,144 BTUs	$672
	GS Heat Pump	5 COP	3,242 kWh	16,210 kWh	55,309,144 BTUs	$538

Average Cost of GS Heat Pump	
Cost comes from the price per ton	
Average price per ton	2,500
Average tons per home	3
Average GS heat pump cost	$7,500

Average Cost of Ground Looping (Horizontal)	
Average price per ton	800
Average tons per home	3
Average Cost of Ground Looping	$2,400

Appendix B: Average Prices for Space Heating Equipment

Gas Furnace Brand	Estimated Furnace Cost	Estimated Installation Cost
Payne	$680	$1,820
Goodman	$695	$1,860
Coleman	$780	$2,360
York	$785	$2,100
Heil	$860	$2,300
Amana	$897	$2,385
Nordyne	$925	$2,490
Bryant	$980	$2,570
Rheem	$1,100	$2,940
Carrier	$1,164	$3,095
Ruud	$1,185	$3,180
Trane	$1,275	$3,560
American Standard	$1,350	$3,620
Lennox	$1,410	$3,990
Average Cost	**$1,215**	**$2,370**

Electric Furnace Brand	Estimated Furnace Cost	Estimated Installation Cost
Goodman	$395	$1,657
Payne	$425	$1,720
Heil	$440	$1,590
Amana	$460	$1,720
Coleman	$480	$1,800
Rheem/Ruud	$520	$1,945
Bryant	$540	$1,800
York	$610	$2,050
Carrier	$753	$2,100
Trane	$1,130	$2,265
Lennox	$1,145	$2,420
American Standard	$1,165	$2,457
Average Furnace Cost	**$665**	**$1,950**

Oil Furnace Brand	Estimated Furnace Cost	Estimated Installation Cost
Armstrong	$1,360	$4,640
Ducane	$1,650	$5,415
Rheem	$1,660	$5,440
Olsen	$1,695	$5,475
Williamson	$1,750	$4,681
Miller	$1,850	$5,950
Carrier	$1,890	$6,050
Lennox	$1,950	$6,225
Thermo Pride	$2,260	$7,040
Trane	$2,300	$6,872
Average Furnace Cost	**$1,836**	**$5,780**

Prices for Purchasing and Installing 3-ton Heat Pump Units	
Brand	**System Installation**
Coleman	$4,965
Bryant	$5,810
Lennox	$6,305
American Standard	$7,590
Carrier	$7,690
Trane	$8,260
Average	**$6,770**

Appendix C: Average Consumer Prices and Expenditures for Heating Fuels During the Winter

Table WF01. Average Consumer Prices and Expenditures for Heating Fuels During the Winter

U.S. Energy Information Administration | Short-Term Energy Outlook - November 2018

	Winter of							Forecast	
Fuel / Region	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	% Change
Natural Gas									
Northeast									
Consumption (Mcf**)	56.2	64.7	71.7	72.2	57.4	61.6	65.2	65.5	0.5
Price ($/mcf)	12.20	11.71	11.52	10.80	10.18	10.70	11.39	11.10	-2.6
Expenditures ($)	686	757	826	780	584	659	743	727	-2.1
Midwest									
Consumption (Mcf)	61.2	73.5	84.2	79.1	63.6	64.8	73.9	73.2	-0.9
Price ($/mcf)	8.96	8.34	8.68	8.54	7.55	8.28	7.83	9.05	15.5
Expenditures ($)	549	614	731	676	480	536	579	663	14.5
South									
Consumption (Mcf)	40.4	46.6	52.7	50.9	40.3	37.9	45.6	47.2	3.5
Price ($/mcf)	11.41	10.67	10.71	10.75	10.72	12.04	11.27	11.04	-2.1
Expenditures ($)	461	497	564	547	432	457	514	521	1.3
West									
Consumption (Mcf)	48.0	47.4	45.2	40.1	44.7	45.6	43.7	45.3	3.6
Price ($/mcf)	9.34	9.13	9.96	10.71	9.92	10.68	10.24	10.90	6.4
Expenditures ($)	448	433	450	430	443	487	447	493	10.3
U.S. Average									
Consumption (Mcf)	51.7	58.4	63.9	60.7	51.8	52.9	57.5	58.0	1.0
Price ($/mcf)	10.23	9.71	9.95	9.89	9.28	10.06	9.82	10.31	4.9
Expenditures ($)	529	567	636	600	481	532	564	598	5.9
Heating Oil									
U.S. Average									
Consumption (gallons)	427.4	493.0	547.5	548.2	436.6	468.2	495.4	501.9	1.3
Price ($/gallon)	3.73	3.87	3.87	3.04	2.06	2.41	2.78	3.17	14.0
Expenditures ($)	1,594	1,910	2,121	1,668	900	1,128	1,376	1,589	15.5
Electricity									
Northeast									
Consumption (kWh***)	7,610	8,299	8,879	8,927	7,705	8,051	8,342	8,375	0.4
Price ($/kwh)	0.154	0.152	0.163	0.168	0.164	0.165	0.169	0.174	3.1
Expenditures ($)	1,173	1,264	1,448	1,501	1,263	1,325	1,406	1,456	3.5
Midwest									
Consumption (kWh)	9,132	10,344	11,363	10,816	9,365	9,479	10,384	10,312	-0.7
Price ($/kwh)	0.111	0.111	0.112	0.118	0.122	0.124	0.124	0.128	3.2
Expenditures ($)	1,009	1,152	1,275	1,274	1,138	1,173	1,286	1,318	2.5
South									
Consumption (kWh)	8,793	9,731	10,487	10,300	8,781	8,511	9,545	9,746	2.1
Price ($/kwh)	0.107	0.107	0.109	0.111	0.110	0.111	0.112	0.113	0.7
Expenditures ($)	938	1,037	1,140	1,141	967	948	1,069	1,099	2.8
West									
Consumption (kWh)	8,848	8,778	8,487	7,830	8,441	8,563	8,313	8,523	2.5
Price ($/kwh)	0.115	0.119	0.123	0.127	0.130	0.132	0.136	0.139	2.2
Expenditures ($)	1,015	1,041	1,045	993	1,095	1,129	1,127	1,181	4.8
U.S. Average									
Consumption (kWh)	8,470	9,193	9,728	9,417	8,456	8,420	9,046	9,186	1.5
Price ($/kwh)	0.116	0.117	0.120	0.123	0.124	0.125	0.126	0.129	1.8
Expenditures ($)	983	1,071	1,163	1,158	1,044	1,055	1,143	1,182	3.4

Appendix D: Start-up Company interview question list

Product

1. What is the value proposition of your product?
2. What differentiates your product from the competition?
3. What is the value proposition to the customer?

Marketing & Customer Acquisition

1. Who is your target customer?
2. How does the company plan to market the product to these customers?
3. What barriers do customers have in adopting your product?
4. Where do you see growth potential?
5. If they are B2C how flip to B2B and vice versa
6. Is there a geography that you prefer due to climate conditions and/or federal/state policy?

Competition

1. Who do you think to be your competitors and why?
2. What are your competitive advantages as a company?

Traction

1. What early traction has the company gotten? (Interest from distributor or
2. What are your sales to date? Revenue #s if possible!!! (annual 2017/2018 and recurring, if any)
3. What are your forecasted sales over the next 3/5 years?
4. What are your next big milestones over the next few years?
5. Where are you in the product development cycle?
6. Do you have any meaningful partnerships?

Economics (Weave into product discussion)

1. How do you price your product? What are the variables that come into it?
2. What savings would the customer get from using this? %s or #s
3. What is the payback period?

Financials

1. At what revenue stage and year do you think you will be profitable?
2. How much has been invested in the company to date?

3. Who are your investors?
4. When and how much was your most recent fundraising round?
5. Do you foresee a next round, and if so, when?

Intellectual property

1. What does your patent protection look like?
2. What is secured and what is provisional? (Ask during product discussion)

Appendix E: Examples of Company Information Sheet

Radiator Labs

Company Overview

- Aims to solve the overheating and discomfort issues found in all radiator heated buildings
- Target Geography: Climate zones 4.5 and above (New England, New York City, Chicago, Boston, Philadelphia, Pittsburg, DC)

Solution Offering

- "The Cozy": Fan turns on when it senses that the room temperature is below the desired set-point. When the set-point is satisfied, the fan turns off, which traps heat in thermal encasement. This results in a room that maintains temperature, with minimal variability.
- "The Cozy App": Adjusts the set-point and releases trapped hot air into the room as customer demands
- Payback periods: 4-6 years with natural gas; 2-4 years with heating oil; 1 year with district steam

Strategic Relevance

- Cost savings to building operators (average 25%) and greater comfort to building tenants by regulating heat distribution in a once unregulated system.
- Non-invasive: "Bolt-on" product that requires no retrofitting

Company Snapshot

Correspondence	Call with Marshall Cox (CEO)
Headquarters	Brooklyn, NY
Founded	2011
Employees	2-10 employees
Revenues	$ 1.5M to date, $ 6M projected over the next 6 months
Invested ($)	~$ 3M
Key Investors	Rudin Management Company, MetaProp NYC, Investors from 1776 Accelerator Program, Urban US Ventures
Burn Rate	
Key Customers / Partners	Rudin Management Company, National Grid
Last Round	Equity round of $1.5M in 2017 Convertible Note Bridge Loan of $400k in 2017
New Deal	Series A in fall 2018
Team	Marshall Cox, Founder and CEO John Kymissis, Co-Founder and Technical Advisor

CaSA .energy

Company Overview

- Connected adhoc Smart Appliances (CaSA)
- Canadian leader in residential energy load aggregation and control.
- Develops and manufactures its own line of consumer hardware for space heating, water heating, electric vehicle (EV) charging stations and provides OEM integration services
- Software focused

Solution Offering

- CALEO - The world's first Wi-Fi enabled line-voltage thermostat for baseboard heat.
- TRITON - A retrofit or factory-installed controller that converts a water heater into an energy storage device. Triton is exclusive to all Giant products in Canada and the US.
- OHME – EV charging solution that pairs with an ODBII module for state-of-charge information, ensuring demand is actively managed and cars are fully charged.

Strategic Relevance

- CALEO - While baseboard heat is typically a fraction of homes within an operator's jurisdiction, it usually accounts for a significant part of the peak demand.
- TRITON - With its impressive thermal mass and large inertia, the domestic electric water heater is the perfect battery for energy storage.
- OHME - EV sales continue to climb throughout North America and every household that welcomes one in its garage creates a new, high-draw load, usually aligned with evening peak demand.

Company Snapshot

Correspondence	Call with Martin Fassier
Headquarters	Beloeil, QC
Founded	2014
Employees	15 full-time
Revenues	2018 sales of $1m
Invested ($)	$1.2M from Giant Factories Inc. & $1.2M from others / owners
Key Investors	Giant Factories Inc. (>300 employees)
Burn Rate	
Key Customers / Partners	Giant Factories Inc., CanmetENERGY, BC Hydro, St. John Energy
Last Round	$1.2M from Giant Factories Inc.
New Deal	Seeking to raise $2m to launch large-scale commercialization effort with Giant Factories Inc.
Team	Martin Fassier (CEO), Catherine Chicoine (CFO), Patrick Pepin (COO), Louis-Pierre Morin (CTO), Mario Sergi (CIO)

Appendix F: Utility interview question list

Utility activity

1. What is your role in the company?
2. Does your company try to influence customer decisions about heating in any way? (via efficiency programs, rebates, etc.)
3. Any tension between gas and electric sides of the business?

Space Heating Forecasts

1. How do you think the space heating energy mix will change over the next 10 years?
2. What is driving this change?
3. How do you think the space heating technology mix will change over the next 10 years?
4. What is driving this change?
5. Is this change in technology mix stemming from new construction or retrofits?

Customer Behavior

1. What would cause customers to change from natural gas systems to electricity systems?
2. What is the biggest barrier for the installation of solar thermal and geothermal space heating systems?

Space Heating Distribution System

1. Where do you think the greatest disruption will occur along our space heating distribution chain (provide photo)?
2. What new space heating technology would be most attractive for your utility to invest in?

Regulations

1. Is there any regulation that you foresee that will fundamentally change the space heating market? We will want to look at federal and state level

Appendix G: Example of a Utility Interview Transcription

Utility activity

Your role?

Evergy is the parent company, that's the holding company for two operating companies that merged in June this year. 1 was Chem City Power and Light / Great Plains Energy and then the other was Westar Energy. I was previously part of the Great Plains team which had a small venture arm that is today GXP investments, that name is changing pretty soon to Evergy Ventures. Our fund is an LP in investments with EIP, that is our relationship with EIP. On the GXP Investment teams we only have 4 people on the team. Our check sizes are much smaller than EIP's, we write 3 to 5 million dollars and that generally winds up into a Series A or Series B type investment. We are very interested in similar deals that EIP is interested in. Later stage investments are more once and awhile.

Yes, I am an investment officer. We do not have a tiered structure. We all lead our own investments.

Basically, all energy is the area where we look to invest in. Our teams are almost identical to where EIP looks to invest in. So, Energy Storage, electric mobility, things around built environment, smart homes, smart cities, predictive analytics, predictive maintenance in the utility itself. A lot of things around renewables. So, very similar buckets to what EIP does.

We are in Missouri and Kansas. Parent company is very similar to DTE. We are a regulated monopoly.

Does your company try to influence customer decisions about heating in any way? (via efficiency programs, rebates, etc. etc.)

Yea so we are only an electric utility, so we are a 100% electric utility. We are highly motivated around electrification in general. So, that's through a combination of programs, energy efficiency programs and also through rebate programs for our customers to convert them over from oil and gas or other sources to some sort of electrified appliance.

Yes, we offer rebates to make switching costs less for customers and to make that switch easier.

No, we are trying to test things to alter customer behavior. We are in the midst of introducing sometime of use and demand charge type rates. We already have some today, but they are not stark in the sense that the difference between the time of use rate and regular rate is not that different, so we do not have that much adoption in these behavior changing plans. But were going to try and test a few different new rate plans to cause those pricing differences to be high enough to change behavior.

I don't know the day to day energy efficacy programs, so I am unsure which method of influence is most effective. Based on conversations that I've had, anecdotally, I think we're trying to implement user solutions from a technology standup to basically understand what the load looks like from a user level, being able to disaggregate the load then provide them with personalized messaging that would increase their likelihood to do those types of things (be more energy conscious). So that's in the works, but I don't think it has quite launched yet, but I know we are in the midst of more personalized recommendations for our customers.

Any tension between gas and electric sides of the business?

No, no discussion of including natural gas as part of the business.

Why is electricity so dominant in Southern States?

I don't have an answer to that question. I've not been here long enough to know an answer to that.

Space Heating Forecasts

How do you think the space heating energy mix will change over the next 10 years? What is driving this change?

I think so, that the mix of energy will change. As solar costs come down and as storage costs come down it would be, I mean you are starting to produce a lot more electricity than maybe your needs are and if you can store that energy and use it for other purposes then things essentially start to become more cost effective.

So, I would say instant water heaters, electrified water heaters are going to become more and more popular. Our penetration numbers are not high on the water heating side, but I think it will get higher as we can keep the costs low on the electricity side.

In Missouri and Kansas, the penetration of solar is really low but I anticipate those costs coming down over time with more penetration of solar and storage. So, the effective rate of electricity that the user pays is going to become lower of time.

Renewables will drive this change.

Kansas is the 2nd highest potential state for wind energy but only .5% of that capacity has been tapped. And that already represents you know 10s of Gigawatts of wind that's already online today but there's another 25 GWts of wind coming online and there's not many places for it to go to. And so, a good chunk of that is going to come tour customers.

So, with the right type of pricing and storage potential our customers are going to see a greater benefit from it.

How do you think the space heating technology mix will change over the next 10 years? What is driving this change?

The mix may not change as much that fast. It might change more slowly over a longer time as people are upgrading their equipment just because there is a lower cost of one fuel over another doesn't mean they are going to switch overnight. And these things have decent amount of lifetime left in them and so I think that is just a natural upgrade process and cycle that will make that shift happen in terms of which technologies will win out over time.

But I think that the mix is going to be pretty consistent here, it's not going to change dramatically over ten years.

Correct, I would not expect one to change from one technology to another within 10 years. A Furnace will be replaced by a Furnace, etc.

And I don't think that we are going to give incentives large enough to make that change easy. We will provide some incentives and rebates but not large enough for them to switch overnight.

Customer Behavior

What would cause customers to change from natural gas Heat Pumps to electricity Heat Pumps?

One would be if they start to think about solar and storage in their homes and if they're implementing renewables in the home itself and if they size the system larger, they may look at that calculation and say "I'm going to have excess electricity why don't I go ahead and start switching to more electrified appliances whether it's for heating or water purposes."

The other piece there in terms of what would cause this change is if we provided some sort of large rebate. Like I said I do not think our rebates are going to be material any time soon.

But I think those would be the two main drivers for them to change from natural gas to electricity Heat Pumps.

What is the biggest barrier for the installation of solar thermal and geothermal space heating systems?

1) Geothermal – I don't think Dandelion has proved the premise of a faster, cheaper geothermal install. I think installation of geothermal, the cost is very high, and the payback period is not that attractive. You end up tearing up your lawn quite a bit. So, install costs are still significant. Dandelion was going to bring in fracking related technologies for drilling for geothermal systems, but I don't think they've quite proven that system.

2) Solar Thermal – The barriers are going to be driven by the solar market in general and maybe also technology. I don't quite know how evolved the technology is on the solar thermal side.

Space Heating Distribution System

Where do you think the greatest disruption will occur along our space heating distribution chain?

What people want is comfort, and cheap comfort essentially, so any technology whether it is inside or outside needs to be solving for this problem.

And I think the other place where this might happen will be from increased digitization or technology applications around all of this. Today the only way you can really control your heating systems is around your thermostat and thermostats are getting smarter and smarter and that's good but there needs to be more in the home. And so, I think smart homes in general is a concept, the more penetration you have of that will allow for better control of systems in the home and for you to better find out where the inefficiencies might be to make it more comfortable for the user while at the same time reducing the cost to the user.

More IoT in the home essentially. And not just in the home but in the systems also. I think you will find more and more OEMs baking these technologies into their hardware when it ships out. So better integration across these systems and making sure that it's not a siloed solution but that it looks at all these different devices and appliances around the home and can orchestrate all of it is going to be the key to providing that comfort for the user.

What new space heating technology would be most attractive for your utility to invest in?

I don't know if there are any that we would invest in just yet, but we are watching.

IoT though, absolutely. We invested in Ecobee alongside EIP. So that was step 1. We are working with companies like Tendril, we are talking to a few other companies.

Software led hardware is exactly where we think the disruption will be.

Regulations

Is there any regulation that you foresee that will fundamentally change the space heating market? (We will want to look at federal and state level).

On the Missouri side, Missouri is ranked 37^{th} in the country for energy efficacy. Kansas is ranked dead last if I am not mistaken. We have really good programs on the Missouri side and we have no programs on the Kansas side.

On the Missouri side there is something called MEEIA (Missouri Energy Efficiency Investment Act) that was legislated, and we've been doing a tremendous amount of work on the energy efficiency of the DSM (demand side management) and demand side tools in general. The Missouri side continues to evolve and the third version of MEEIA will launch next year.

Kansas has nothing in the pipeline.

I am not familiar enough to know the answer to anything done federally.

I do not see regulation playing a large role. Given the current administration and the types of initiatives you see at the federal level it is hard for me to even imagine anything like that happening (subsidies given to solar industry) and also we have so much natural gas that it I think in general you are going to see more of a mix over time and maybe the mix will shift as different sources of supply come online and it will tilt towards more non-gas options. I just don't see how that type of regulation will come to bear any time soon. It's good that we had solar regulations in place, I don't think this administration would have done something like that. I think we just have to take what we've got and keep running with it.

Other

Ashwin is curious to see what others have said. Would love to see the outcomes of those calls.