Combining ENERGY STAR's Brand Recognition with ResStock Modeling to Create a Go-To Heat Pump Savings Estimator

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ABSTRACT

Thanks to the Inflation Reduction Act incentives for residential Air Source Heat Pumps (ASHPs), more people than ever will have the opportunity to cost-effectively decarbonize their HVAC system. However, the average consumer does not have an easily digestible and reputable source for understanding the potential impact that an ASHP could have on their energy bills. In this paper, we present the methodology behind the soon to be released ASHP Calculator tool created for the EPA which aims to fill this gap. This tool was created by running novel simulations using NREL's ResStock framework to estimate the impact of space heating electrification and heating system efficiency improvements for single-family homes in 15 climate zones across the US. Utilizing the probability distributions from ResStock to downselect housing characteristics, archetype EnergyPlus models were generated for each potential combination of a simplified set of user inputs including vintage, square footage, climate zone, and heating/cooling system fuel and type. Electricity and fuel impacts for installing ENERGY STAR base tier and cold climate ASHPs, both with electric and existing fuel backups, were then quantified by upgrading the HVAC systems within the models. A monthly utility bill calibration feature was also integrated into the analysis framework, allowing for the heating, cooling, and non-weather sensitive end use loads from simulation to be tailored to real-world consumption. Through this tool, EPA aims to provide a nationally recognized resource that can be leveraged by both homeowners and contractors to help accelerate transformation in the HVAC market.

Introduction

In order to meet the ambitious decarbonization goals set-forth at the federal, regional, and local levels, we will need to significantly reduce our consumption of carbon-intensive, on-site fossil fuels in the existing residential building stock (Berrill 2022). In many instances, one of the best ways a residential customer can reduce fossil fuel usage in their home is by installing a high efficiency Air Source Heat Pump (ASHP). ASHPs utilize the same refrigeration cycle as air conditioners or refrigerators, but are bi-directional, allowing for the same equipment to provide cooling in the summer and heating in the winter. Since residential ASHPs are powered by electricity, customers switching from a fuel furnace or boiler to an ASHP will reduce or eliminate their on-site fuel use and increase their electrical use, which will translate into lower and lower emissions over time with a decarbonizing grid.

Due to a variety of factors, including energy rates and home characteristics, it can be difficult to develop tools that help customers understand how installing an ASHP will impact energy usage and calculate potential bill savings. Factors like home age, square footage, climate, and electric and fuel rates will all play a role in determining economic results, and therefore the financial merit associated with installing an ASHP. These factors also make it difficult for homeowners to evaluate the benefits of an ASHP. Tools geared towards contractors may be technically challenging for a homeowner, while simpler tools may only provide a cursory solution. A 2023 study found that contrary to other advanced efficiency technology, heat pumps are evenly distributed throughout all levels of household income, including customers earning less than $30,000 annually (Davis 2024). However, the energy burden for low-income households is three times higher than that of non-low-income customers (US DOE 2024). This disparity highlights the importance for customers to understand associated energy costs and savings of owning a heat pump prior to installation.

As sales of ASHPs and other efficient electric appliances grow, the EPA identified the need for customers to be able to predict energy costs when switching out heating and cooling systems. While some utilities and key stakeholder groups have attempted to tackle this problem for specific regions, there is not an existing tool that can be reliably used throughout the entire country. The lack of a readily available tool has prevented customers from being able to access this type of information when exploring the idea of installing an ASHP. The EPA's ENERGY STAR program sought out to develop this tool prior to the Inflation Reduction Act incentives coming to market as this will likely trigger an unprecedented level of curiosity in the marketplace for heat pumps. This resource, coupled with ENERGY STAR resources that help educate consumers about the benefits of ASHPs, will provide customers with a comprehensive suite of materials that help them make an informed decision as to whether an ASHP is the right choice for them. The tool can also assist contractors or local organizations in explaining the potential benefits of heat pumps to end use customers.

Through comprehensive modeling of thousands of home types in different climate zones across the country using ResStock, an easy-to-use Microsoft Excel-based calculator was developed that gives customers reliable information on what homeowners can expect when installing a heat pump. Due to ENERGY STAR's recognition as a trusted resource among consumers for energy efficient products, we believe this tool can serve as a one-stop shop for customers throughout the country to understand how installing an ASHP could potentially provide financial benefits.

The EPA and ENERGY STAR

ENERGY STAR is a government-backed symbol of energy efficiency administered by the US Environmental Protection Agency (EPA). Launched in 1992, the EPA's ENERGY STAR program has helped American families and businesses to avoid more than $500 billion in energy costs and achieved 4 billion metric tons of Greenhouse Gas (GHG) reductions (US EPA 2024a). It is a trusted resource that works with thousands of organizations, including nearly 40 percent of Fortune 500 companies, to deliver energy efficiency solutions to protect the climate, improve air quality, and protect public health. The ENERGY STAR label provides consumers a way to easily identify efficient products. Nearly 90 percent of American households recognize the ENERGY STAR label, and among recent purchasers, nearly 60 percent say the label influenced their choice (US EPA 2022). The EPA's ENERGY STAR program works with its partners to identify and overcome common market barriers that prevent widespread adoption of energy efficient products, including informational barriers, financial barriers, technical barriers, and structural barriers. The development of this tool helps to address informational and financial barriers that may prevent customers from purchasing efficient ASHPs.

The Inflation Reduction Act provides a unique opportunity for ENERGY STAR to continue to expand its reach to consumers. In order for customers to qualify for rebates through the Home Electrification and Appliance Rebate (HEAR) program, ENERGY STAR certification is required for heat pumps, heat pump water heaters, heat pump clothes dryers, insulation, air sealing and ventilation, and electric stoves, cooktops, ranges, and ovens. The EPA's ENERGY STAR program has used this opportunity to engage with State Energy Offices and develop a suite of resources both for program administrators and implementers and for customers to gain a better understanding of efficient technologies and their associated rebate programs. For instance, earlier this year the EPA launched a Home Savings tool that will allow customers to input their location and income to better understand the rebates and tax credits available to them (US EPA 2024b). The heat pump calculator fits well into this growing suite of tools to assist customers in making informed decisions on efficient home upgrades.

Existing Work/Tools

Despite industry consensus around the importance of estimating energy costs when evaluating heat pump upgrades, a consumer friendly, holistic tool that is applicable to all areas of the country is not yet available. Most existing calculators or tools are location-specific and may not include features such as bill calibration, which adjust modeled energy use to more accurately reflect a user's unique energy consumption patterns. The most comprehensive and prominent example of an existing tool is the Cold Climate Air Source Heat Pump Product Sizing tool provided by Northeast Energy Efficiency Partnerships (NEEP). This tool was created for industry members to adequately size models of heat pumps to meet either heating or cooling demands for individual homes, specializing in cold climate heat pumps (NEEP 2024). This tool was developed to be contractor-facing and requires a level of HVAC system knowledge surrounding heat pumps to be effectively used. The tool provides outputs such as percent of heating and cooling load served, performance at various temperatures, and system capacity, but does not calculate associated energy costs. The tool is also only available for use based on weather stations in the Northeast.

Additional examples of current tools can be found on utility websites. New Hampshire Electric Co-op offers their customers a tool to input their current fuel use and view estimated energy costs, including cost savings, with the installation of a heat pump (New Hampshire Electric Co-op 2024). This calculator is specific to New Hampshire and does not allow for inputs such as home size or age. Efficiency Maine also offers a tool to compare home heating costs across different technologies and fuel types (Efficiency Maine 2024). The product of this calculation is a chart that provides the heating costs for sixteen different heating technologies. Both these tools are location specific and have several building specific assumptions baked in. This may not represent different home types, even in the relevant jurisdictions.

A group of researchers and analysts created a calculator for the installation of ductless mini split heat pumps in Alaska using Python (Analysis North, The Cold Climate Housing Research Center, and Arctic Energy Systems 2024). The tool allows for over twenty inputs to tailor the results and takes the cost of the upgrade equipment into account for quantifying financial outputs. The calculator provides a rate of return on the total cost of the heat pump, and annual fuel savings and electricity increases, among other products. It also provides monthly cost estimates. This tool, while very comprehensive, is only applicable for mini-splits and is only offered for Alaska locations.

One common factor among the tools referenced above is that they only provide results for a particular location, so a potential user in a different region could not use the same tool to estimate ASHP savings. Additionally, some of these tools are either too complex for an average consumer or may lack the level of detail required to accurately model impacts that encompass the different prominent archetypes of homes in a jurisdiction. The ENERGY STAR calculator seeks to fill the gap of a reputable, user-friendly tool that consumers can leverage to understand the potential benefits of an ASHP upgrade. As further described in the next section, the tool takes the form of an Excel-based calculator, in which users can input key parameters about their home such as heating fuel type, location, and size, as well as information about their monthly energy bill consumption. The tool then outputs a series of graphs and charts that summarize the anticipated energy consumption and energy bill impacts of installing different types of ENERGY STAR ASHPs which are tailored to the home characteristics and utility bill consumption input by the user.

Methodology

Microsoft Excel was selected as the current platform for the tool because it is widely utilized and has a relatively low barrier to entry. In the tool, the user enters 8 building specific inputs for parameters such as home vintage, heating fuel type, and square footage. Each unique input combination is mapped to a row in a back-end database of energy modeling simulation results of archetype building models. This database of models was created by leveraging NREL's ResStock framework to generate a corresponding archetype building energy model for each of the input combinations (NREL 2023a). ResStock generates building energy models in OpenStudio, which utilizes the EnergyPlus simulation engine, using conditional probability distributions for buildings characteristics such as insulation levels, infiltration rates, and HVAC system efficiency. Ultimately this enables ResStock to generate samples of building models which accurately represent the US housing stock. The analysis was set up so that the archetype models used represent the most likely combination of the building characteristics for each of the user input combinations (e.g., 1,500-2,499 sq. ft. homes built before 1940 in Massachusetts typically have an infiltration rate of 15% ACH50). Utilizing the ResStock framework makes the creation of the archetype building model process simple and scalable. The process for setting up this database of results, as well as the post-processing needed for layering in features such as the utility bill calibration, is described in the following subsections. NREL has conducted calibration of ResStock results (at an aggregate level) against real utility data to ensure it aligns with real world energy consumption of homes – this provides the level of accuracy required for this exercise.

Generating the Energy Impact Database

ResStock exists in two distinct forms, an analysis framework and published datasets created with that analysis framework. The published public datasets contain results for two million representative building models across the country that can be used to estimate the potential impact of common energy efficiency, electrification, and decarbonization measures. While these datasets can be used for a variety of applications, the team decided to use the ResStock framework and underlying codebase to create unique building models representative of different archetype homes in 15 ASHRAE climate zones in the US. This was done due to the desire for each archetype home to comprise the most likely building characteristics for a given set of user inputs. The ResStock framework utilizes 147 different building characteristics to fully specify a model, and so, even with a database of tens of thousands of models for each state, each unique combination of the 147 desired characteristics would not be in the published data sets. **Error! Reference source not found.** shows how a typical ResStock workflow running archetype building models works, and each step is discussed below.

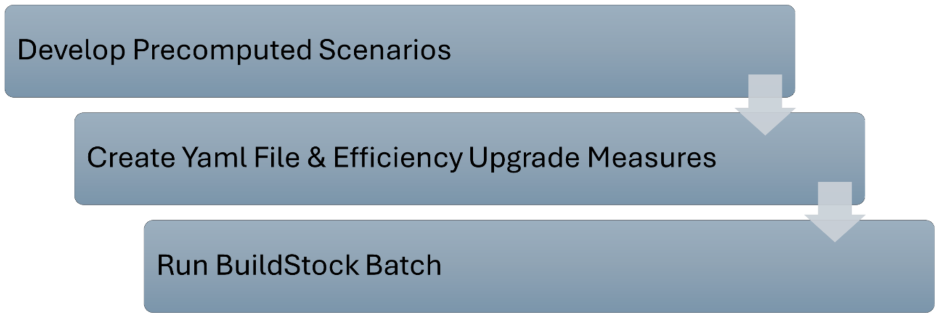


Figure 1. Typical ResStock Workflow

Develop Precomputed Scenarios

The creation of the database of ResStock simulation runs began with the establishment of the total number of entries required in the database. This was determined by mapping out all of the different input parameters and desired choice levels. The team settled on the input parameters and levels shown in Table 1. The current version of the tool is applicable to single-family homes with ducted and non-ducted heating systems. As such, homes with wood-fired heating and other uncommon heating systems are not included. The 8 inputs shown in the table were selected as an appropriate balance for the level of effort required and the accuracy of the tool results.

Each unique combination of these characteristics was used to generate 2,376 unique building models per climate zone[1], totaling up to 35,640 distinct building energy models to represent homes in the 15 climate zones. As previously noted, the ResStock framework uses 147 characteristics to fully specify building inputs. Once the desired building characteristic combination is specified, an OpenStudio workflow is used to translate these characteristics into the thousands of inputs required for a full EnergyPlus model for simulation (NREL 2023a). The building characteristics selected for inputs are 8 of the 147 characteristics that ResStock uses to specify a building.

Table 1. Fixed building characteristics across 15 climate zones

Building Characteristic	Options
Geometry Building Type RECS	Single-Family Detached
Geometry Floor Area Bin (sq. ft.)	0-1499, 1500-2499, 2500-3999, 4000+
Vintage	<1940, 1940s, 1950s, 1960s, 1970s, 1980s, 1990s, 2000s, 2010s
HVAC Heating Distribution System	Ducted, Non-Ducted

[1] It is not a simple multiplication of all items in the table since some scenarios were restricted. For example, homes were assuming to not have two different fuel supplies. This would restrict combinations like natural gas space heating and fuel oil water heater. Also, ducted homes cannot have MSHPs.

HVAC Heating Type and Fuel	Electric ASHP, Natural Gas Furnace, Propane Furnace, Fuel Oil Furnace, Electric Furnace, Electric Resistance Baseboard, Electric MSHP, Natural Gas Boiler, Propane Boiler, Fuel Oil Boiler, Electric Boiler
HVAC Cooling Type	None, Heat Pump, Central AC, Room AC
Water Heater Fuel	Electricity, Natural Gas, Propane, Fuel Oil
IECC Climate Zone	1A, 2A, 2B, 3A, 3B, 4A, 4B, 4C, 5A, 5B, 5C, 6A, 6B, 7A, 7B

Once these 8 inputs are defined for each of the distinct building archetype scenarios, all the other 139 building characteristics are selected to be the most likely value based on ResStock's probability distributions. To do this, the team created an oversampled (1 million buildings) building stock of the US using ResStock. A python script queried the oversampled dataset to identify the most likely values for the unique building characteristics for the 35,640 building models developed. This process resulted in the precomputed scenario csv file, which contains all required data in the correct format. After specifying the building characteristic combinations for each simulation run required, the next step was to generate and simulate the models to produce energy use estimates.

Create Yaml File & Efficiency Measure Upgrades

The next step was to define the efficiency measures (known as "upgrades" within BuildStock framework) in the Yaml file. The Yaml file (also known as the project file) is the primary input for BuildStock Batch and is used for basic inputs such as references to the correct inputs and weather files, as well as any upgrades that are applied. These upgrade cases can be defined to a certain subset of defined buildings in the precomputed models or can be applied to all buildings. The flexibility of assigning a measure to a subset of buildings is especially useful for measures like air sealing, where the upgrade condition can be assigned only to buildings that have higher infiltration rates. For this study, four[2] upgrade measures were applied to all homes representing retrofitting HVAC systems with ASHPs/MSHPs at various efficiency levels. Ducted homes got ducted-ASHP as a replacement and non-ducted homes got MSHPs as a replacement. Both types of heat pumps were simulated with the same efficiency levels and are modelled with both electric and fuel backup systems.

- ENERGY STAR Base Tier ASHP (SEER 16, 9.2 HSPF)[3]
- ENERGY STAR Cold-Climate ASHP (SEER 16, 9.5 HSPF)
- ENERGY STAR Most Efficient Base Tier ASHP (SEER 18, 9.7 HSPF)
- ENERGY STAR Most Efficient Cold-Climate ASHP (SEER 16, 10 HSPF)

Run BuildStock Batch

NREL provides a tool called BuildStock Batch which allows users to run thousands of building models at once. BuildStock Batch is built on top of ResStock, and leverages Amazon Web Services (AWS) (NREL 2023b). Once the precomputed csv file and upgrade measures specified in the Yaml file was loaded, the BuildStock framework was executed to run the baseline and upgrade case building models on AWS servers over the cloud. Once results are produced, the results are then summarized into monthly consumption by end-use.

[2] Effectively, there are 16 upgrade cases, but only 4 distinct efficient heat pump ef systems.
[3] Note that while equipment manufactured today has metrics of SEER2 and HSPF2, ResStock utilizes the prior metrics of SEER and HSPF.

Tool Setup & Functionality

The consolidated ResStock results for all 35,640 energy models, along with their ASHP upgrades, were consolidated in a spreadsheet and imported into Excel. This back-end database was mapped to a user-friendly front-end designed for a wide audience with various levels of understanding regarding buildings. One example of simplifying inputs was that the user is asked for zip code, and climate zone is determined automatically because most users are unlikely to know their climate zone. The input section of the user interface is shown in Figure 2, which corresponds to instructions on a README tab in the tool.

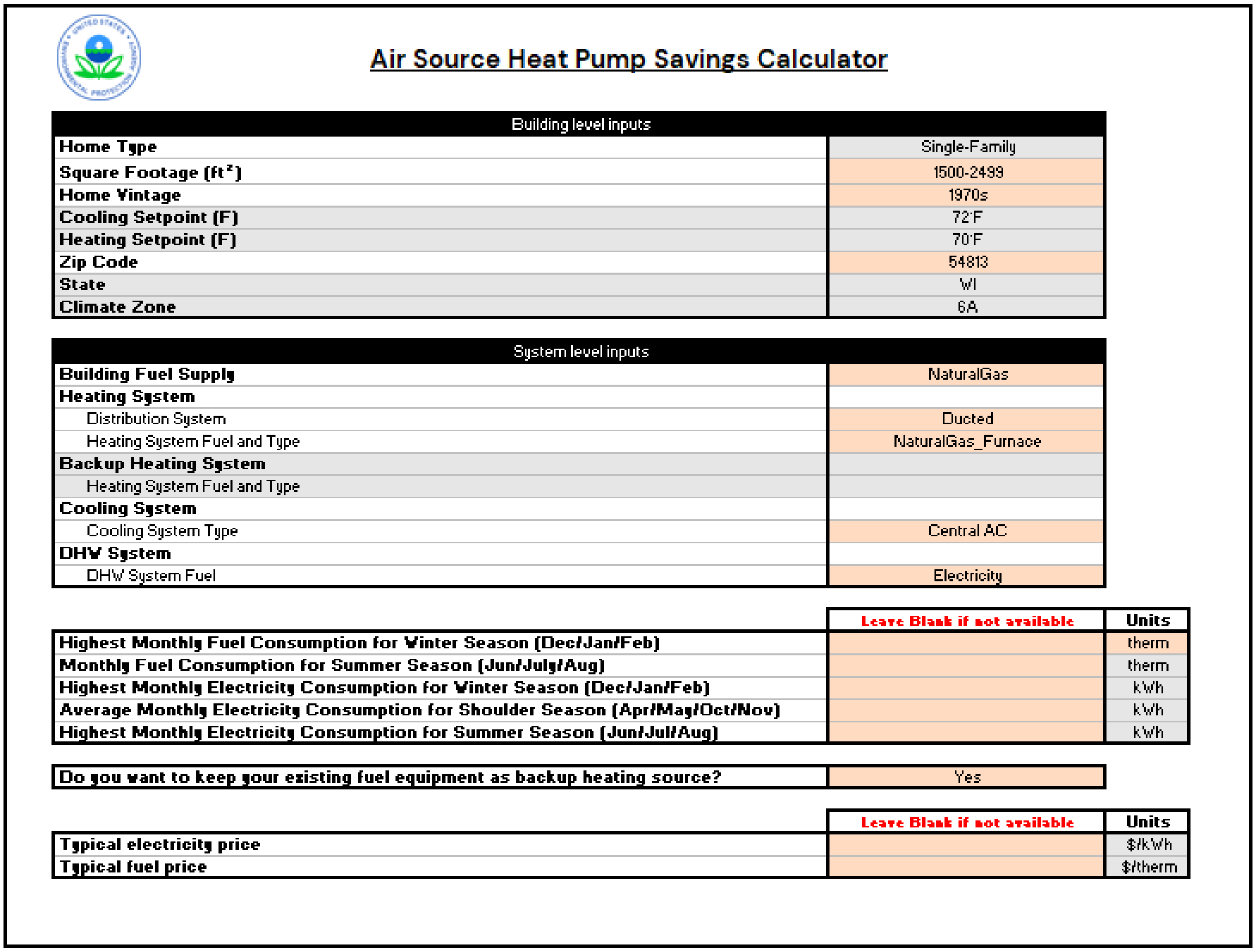
Figure 3 shows graphs included in the user input screen which illustrate the building’s baseline energy consumption that will be used in the calculations of energy and bill impacts. These graphs provide a greater level of transparency and a means of establishing trust for more technical users.

The inputs for the tool, as shown in Figure 2, are divided into two categories: Building Level and System Level.

Building Level User Inputs. Building Level user inputs are independent of any other field. This means that these inputs do not impact any of the other building inputs directly. These include:

- **Home size (ft^2)** – 0-1,499, 1,500-2,499, 2,500-3,999, 4,000+
- **Home vintage** – <1940, 1940s, 1950s, 1960s, 1970s, 1980s, 1990s, 2000s, 2010s
- **Zip Code**

One simplifying assumption is that the homes would have one primary heating system which would be replaced with an ASHP/MSHP with electric or fuel supplemental system.



Air Source Heat Pump Savings Calculator

Building level inputs	
Home Type	Single-Family
Square Footage (ft²)	1500-2499
Home Vintage	1970s
Cooling Setpoint (F)	72°F
Heating Setpoint (F)	70°F
Zip Code	54813
State	WI
Climate Zone	6A

System level inputs	
Building Fuel Supply	NaturalGas
Heating System	
Distribution System	Ducted
Heating System Fuel and Type	NaturalGas_Furnace
Backup Heating System	
Heating System Fuel and Type	
Cooling System	
Cooling System Type	Central AC
DHW System	
DHW System Fuel	Electricity

	Leave Blank if not available	Units
Highest Monthly Fuel Consumption for Winter Season (Dec/Jan/Feb)		therm
Monthly Fuel Consumption for Summer Season (Jun/July/Aug)		therm
Highest Monthly Electricity Consumption for Winter Season (Dec/Jan/Feb)		kWh
Average Monthly Electricity Consumption for Shoulder Season (Apr/May/Oct/Nov)		kWh
Highest Monthly Electricity Consumption for Summer Season (Jun/Jul/Aug)		kWh

Do you want to keep your existing fuel equipment as backup heating source?	Yes

	Leave Blank if not available	Units
Typical electricity price		$/kWh
Typical fuel price		$/therm

Figure 2. User inputs for the ENERGY STAR ASHP Savings Calculator

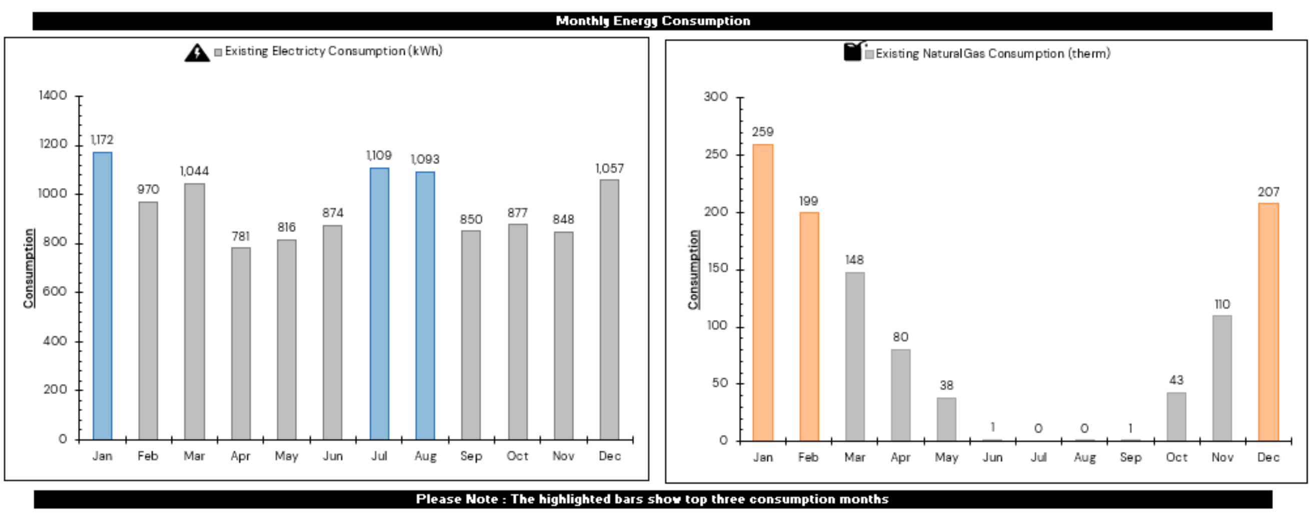


Figure 3. Estimated baseline energy consumption projections shown to the user.

System Level User Inputs. System Level user inputs are dependent on prior selections. These selections are explained below:

- **Building Fuel Supply** – Natural Gas, Propane, Fuel Oil, None (Electricity only)
- **Heating Distribution System** – Ducted, Non-Ducted
- **Heating System Type** – This field is dependent on Building Fuel Supply and Distribution System fields. For example, if the user selects Natural Gas and Ducted, the only available Heating System options will be Natural Gas Furnace, Air Source Heat Pump, and Electric Furnace.
- **Backup Heating System** – This field only gets triggered when the heating system is an Air Source Heat Pump or Mini-Split Heat Pump and would only have options of electric backup and/or a furnace/boiler with fuel type that matches Building Fuel Supply.
- **Cooling System** – This field is dependent on the Heating System, for example, if the user selects Air Source Heat Pump, the only available option will be Ducted Heat Pump for cooling. For all other Heating System scenarios, the available options are Central AC, Room AC and None.
- **DHW (Domestic Hot Water) System** – This field is dependent on Building Fuel Supply, where if the building has a fuel connection, it will give the user an option to choose between the fuel water heater or an electric one.
- **Existing Fuel Equipment as Backup** – This field gets triggered only if the Heating System or Backup Heating System is a fuel furnace/boiler. In all other cases, it is N/A.

The restrictions described above impact the total number of models that needed to be created using ResStock. If any of the above conditions are not met, the tool returns an error and highlights the fields that need correction.

Utility Rates and Bill Calibration

The tool was populated with back-end assumed electricity, natural gas and delivered fuel rates specific to each state, but an input is also available to enter user-specific energy rates. The ratio between electricity and fuel rates is one of the biggest factors for determining the economics of electrification, and so additional emphasis may be placed on this input in the version of the user interface that is ultimately released.

While the large number of user input parameters were to allow the tool to make a reasonably accurate estimate of the baseline energy consumption for a given home, inevitably there will be homes that deviate far from the average home modeled consumption. Factors such as thermostat setpoints, significant deviation from typical envelope performance (e.g., the home has undergone an efficiency retrofit), and resident behavior can easily cause significant shifts in energy for what appear to be similar homes. This is why Figure 3 shows an optional section in the user inputs that asks for users' peak and non-peak months' utility (i.e., electricity and fuel) bills. These inputs help normalize the energy usage of the model to the user's building energy consumption.

The energy load shape for both electricity and fuel would vary drastically between homes across climate zones and with different HVAC systems, and it is necessary to ensure that any erroneous utility bill inputs do not translate through the tool. To address this, ICF developed a parameter-estimation optimization technique to calibrate the estimated monthly electricity consumption using utility bill inputs. The algorithm requires inputting the highest monthly electricity consumption in winter months and summer months, as well as the average monthly electricity consumption in shoulder months. Then, scaling factors were developed to align the monthly electricity consumption for heating and cooling with the relevant bill inputs. Finally, a minimization algorithm was executed to estimate the optimum scaling factor for non-weather sensitive electricity consumption that yields the smallest absolute error between the predicted peak monthly consumptions from the simulations and the respective bill inputs. This algorithm is robust to errors in utility bill data, and preserves the shapes of the heating, cooling, and non-weather sensitive loads from the ResStock modeling.

Cold-Climate Heat Pump Modeling

As explained in previous sections, ResStock creates building inputs for OpenStudio to develop a model. OpenStudio then uses the EnergyPlus modeling engine to create and run the model. ResStock v3.2.0 was used to run the building simulations, and unlike older versions, the current versions of ResStock have a cold-climate heat pump as an "upgrade" measure. ResStock has two important characteristics that distinguish the performance between a base tier heat pump and a cold-climate heat pump:

- Heat pump heating capacity retention fraction: Expressed between 0-1, the higher value indicating the percent of heat pump capacity retained at "heat pump heating capacity retention temperature". For cold-climate heat pumps, the default is 0.7.
- Heat pump heating capacity retention temperature: Default value for this is 5, and it is expressed in degree Fahrenheit units.

These two conditions also agree with the criteria defined by ENERGY STAR to qualify a heat pump as the cold-climate variant.

Supplementary Heating Systems

As previously noted, a total of 4 upgrade cases were included in the tool, with each of those upgrade cases having one scenario with electric backup and another with fuel backup. This was intended to cover all arrays of HVAC system possibilities for the user to assess energy consumption and utility bill impacts resulting from the heat pump upgrades.

Switchover temperature is one key criterion that impacts the energy consumption of electricity/fuel and consequently (and more importantly in certain cases) the utility bills. This is why industry professionals (e.g., program administrators, installers) across North America were consulted to assign a temperature to each combination of heat pump and supplementary heating system at which the supplementary heating system becomes the primary source of heat, as shown in Table 2.

For ducted homes, electric backup supplementary heating systems provide additional capacity for the residual heating load that the heat pump is unable to provide until the point that the heat pump cannot operate, below which the heat pump shuts off and the electric backup system provides capacity for the entire heating load. However, we defined a temperature above which the heat pump supplemental heating system does not get activated, as shown in Table 2 as well. This restricts the amount of time heating will be called for from the supplemental systems. Whereas for the ducted fuel backup system, the backup is only activated at the compressor lockout temperature since the heat pump and fuel backup system cannot operate concurrently. This is because the temperature at which a furnace conditions the air for delivery into conditioned space is much higher compared to the temperatures at which heat pump delivers the air. This is why the fuel backup systems have a higher compressor cutoff temperature, to ensure the entire heating load of the building is being met under all conditions. The higher compressor cutoff temperature for fuel backup systems (especially with natural gas backup systems, since it is cheaper per unit of energy compared to electricity in most of North America) is also influenced by favorable customer utility bill economics at lower temperatures when the heat pump is less efficient.

For non-ducted homes, the control logic is identical to ducted systems when electric supplemental heating is present. When there is fuel supplemental heating, the only difference is that both the fuel supplemental heating and the heat pump can work together since the delivery systems are separate. This is why only the compressor lockout temperature is defined, as shown in Table 2.

Table 2. Supplemental Heating System Control Logic

Heat Pump Type	Supplementary Heating System	Compressor Lockout Temperature	Heat Pump Backup Lockout Temperature
Base Tier ASHP	Electric Backup (includes electric resistive coils and electric furnaces)		40°F (4°C)
Base Tier ASHP	Fuel Backup (includes natural gas/propane/fuel oil furnaces)	25°F (-4°C)	25°F (-4°C)
Cold-Climate ASHP	Electric Backup (includes electric resistive coils and electric furnaces)		30°F (-1°C)
Cold-Climate ASHP	Fuel Backup (includes natural gas/propane/fuel oil furnaces)	5°F (-15°C)	5°F (-15°C)
Base Tier MSHP	Electric Backup (includes electric resistive coils and electric boiler)	5°F (-15°C)	
Base Tier MSHP	Fuel Backup (includes natural gas/propane/fuel oil boilers)	5°F (-15°C)	
Cold-Climate MSHP	Electric Backup (includes electric resistive coils and electric boiler)	-13°F (-25°C)	
Cold-Climate MSHP	Fuel Backup (includes natural gas/propane/fuel oil boilers)	-13°F (-25°C)	

Results

In order to effectively communicate energy and bill impacts to tool users, a series of graphs was formulated which allow for quick and easy comparison of the existing HVAC system with each of the four upgrade cases examined. Note that the user selects whether they want to keep their existing fossil-fuel based system as backup, so the results either include electric backup or fuel backup heating for all upgrade cases. Figure 4 and Figure 5 show example energy consumption and savings results with ENERGY STAR heat pumps for a single-family home in Minnesota, with electric and fuel backup systems, respectively.

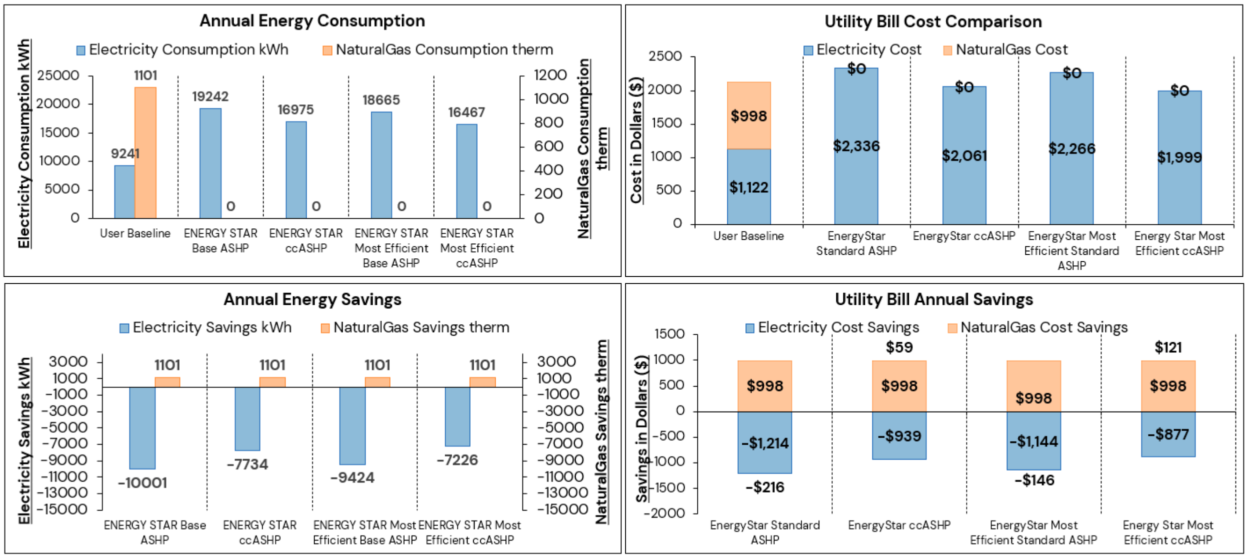


Figure 4. Energy and utility bill impacts for a sample home in Minneapolis, Minnesota (CZ6) from installing an ENERGY STAR heat pump with electric backup[4]

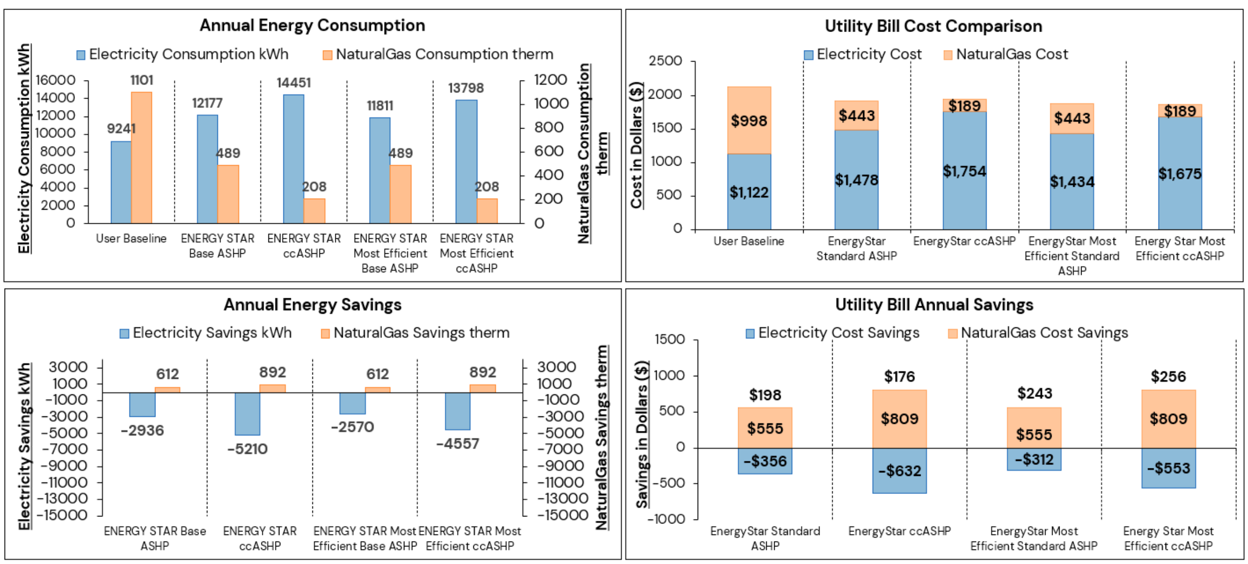


Figure 5. Energy and utility bill impacts for a sample home in Minneapolis, Minnesota (CZ6) from installing an ENERGY STAR heat pump with natural gas backup[5]

The figures illustrate a few key findings for this particular scenario. First, Figure 4 illustrates savings only for cold climate ASHPS due to the cold climate of Minnesota; meaning this homeowner would benefit from a ccASHP if an electric backup system is selected. Second, Figure 5 shows greater savings if the homeowner kept their existing natural gas furnace as the backup system, irrespective of which ENERGY STAR category heat pump is being installed.

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[4] This is for 1500-2499 square feet, 1970s home with heating provided by a natural gas furnace (prior to heat pump replacement), cooling with a central AC and water heating with an electric water heater, in Minneapolis, MN.
[5] This is for 1500-2499 square feet, 1970s home with heating provided by a natural gas furnace (prior to heat pump replacement), cooling with a central AC and water heating with an electric water heater, in Minneapolis, MN.

The economics to an individual home of full or partial electrification are highly dependent on electricity and natural gas rates. This difference in annual bill impacts is a consideration to be balanced with lifetime Greenhouse Gas (GHG) emissions reductions. The capability to also report GHG impacts is a feature that is currently under development for the tool and will likely be included prior to the first release.

Another set of example result explores the variation in energy consumption and bill impacts across climate zones, as can be seen in Figure 6. This figure shows the same home in terms of user input selections other than zip code (i.e., climate zone), across 4 climate zones.

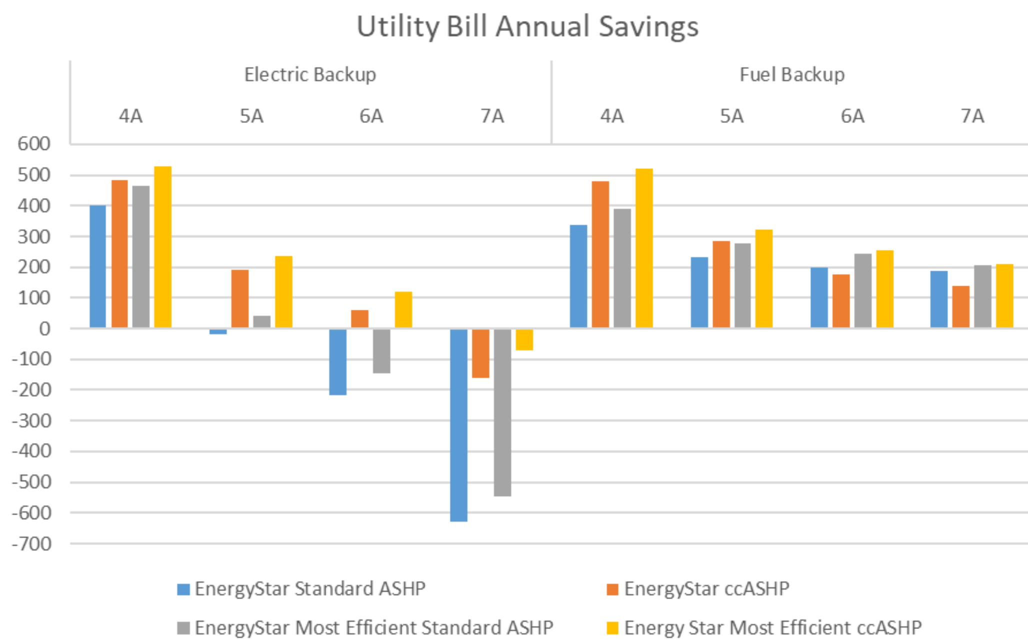

Figure 6. Comparison of Utility bill savings from ENERGY STAR ASHPs across 4 climate zones, with electric and fuel supplementary heating systems

While the weather data for the location / climate zones are important factors in determining the potential savings from a home, it is also important to note that creating archetype models using ResStock ensures that homes in each of these climate zones are representative of the most common level of efficiency characteristics that are typical in the concerned climate zones. Building characteristics like wall and roof insulation, window type and air infiltration levels contribute significantly to the building's heating and cooling loads. Hence, the results generated through this framework ensure that all of the building characteristics that may be different between climate zones (as well as vintage and size of the home) are taken into account, and the savings are not just a derivative of ASHP installation in identical homes in different climate zones, but they represent the most likely home for a given input combination in the individual climate zone.

This is evident in comparing the results of different climate zones, where the projected natural gas savings from replacing the furnace would be lower in some colder climate zones (CZ5) as compared to the savings from the warmer climate zone (CZ4). This is a result of the most likely air infiltration levels being higher in climate zone 4, along with other noticeable differences in efficiency parameter levels. While this will certainly not be the case for all homes, it emphasizes the impact that weatherization measures can have and reiterates the value of adding the utility bill calibration feature to tailor the estimates to real data if possible.

Conclusion

Through the ASHP Savings Calculator tool discussed in this paper, the EPA seeks to establish a go-to resource for providing users with reliable, accurate estimates of energy and utility cost impacts from installing an air-source heat pump. By considering both input effort and level of detail, the calculator strikes a balance in accuracy and usability. Through 8 simple building parameters, the tool provides users with an initial estimate of potential ASHP savings. Through 3-5 additional utility bill inputs, the estimate can be tailored to the actual consumption of the home. This tool leverages the credibility, reputation, and brand recognition of ENERGY STAR, and the prominent position that the ENERGY STAR brand has been given as part of the Inflation Reduction Act to provide simple and trusted results.

The convenience of one national resource, coupled with the easy-to-use interface and robust back-end building energy modeling makes this tool unique among other solutions available in the industry. The framework used to develop this tool is scalable and has the capability to eventually encompass archetypes for all homes in the US. Another benefit of using this framework is that since NREL updates the ResStock tool periodically, improvements like additional measures and updated probability distributions of building characteristics can be easily integrated into subsequent versions of the tool. This will help to prevent the tool from aging out of relevance, and hopefully allow it to grow into a well-established resource within the industry to support the clean energy transition for years to come.

Future Work

One key missing feature of the tool is the calculation of GHG emissions impacts. This is actively under development for the tool and will likely pull in emissions factors from a reputable national source such as NREL's Cambium tool (NREL 2023c).

In addition, the current analysis and tool development was focused on single-family homes. The following stage of this work would include multi-family homes as well. This addition will help expand the applicability of the tool, and allow the calculator to cover the vast majority of residential buildings (US EIA 2024). In addition, the EPA is exploring the potential of adding additional measures to the tool, such as water heating and envelope improvements. The inclusion of these measures would assist a consumer interested in understanding the benefits of other energy efficiency upgrades and the potential benefits of a multi-measure approach to home upgrades. For example, it could be particularly beneficial for a homeowner to understand the benefits of home envelope improvements when considering an ASHP.

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