Category 6 – Residential Heat Pump Plus Weatherization Retrofit Standard Simulation For Measure Packages (HP + Retrofit)

The standardized simulation savings approach outlined here can be used to determine savings for combined heat pump and envelope measure packages proposed for inclusion in residential retrofit programs. In addition to supporting the envelope measure packages established in Custom Measure Category 5. This new measure, Residential Heat Pump Plus Weatherization Retrofit Standard Simulation for Measure Packages (HP+Retrofit), supports adding both specific make and model cold climate air source heat pumps (ccASHP)and heat pump water heaters (HPWH) to a "selected" envelope package that is proposed for installation.

The three envelope improvement package options described in custom measure Category 5, are expanded to support additional building types, changes in the thermal boundaries for attics and basements, and low-e storm windows.

HPWH are included in the HP+Retrofit Measure and will interact with both existing fossil fuel heating and cooling equipment and ccASHP improvements. The ccASHP savings, included in the HP+Retrofit measure, use detailed heat pump performance data from the Northeast Energy Efficiency Partnerships (NEEP) Cold Climate Air Source Heat Pump List.[1451] Licensing of the NEEP database is an option that will reduce contractor effort and reduce data input error.

In order to support ccASHP savings, simplified input "Equivalent Block Load" calculations are integrated into the HP+Retrofit measure. These design load calculation methods have been compared to published ACCA Manual J Version 8[1452] standards and the primary difference is in the simplicity of the inputs. Additionally, the use of the standardized envelope performance established by the packages is leveraged to reduce the required inputs for most conditions.

The HP+Retrofit measure provides additional benefits by aligning with the data collection required by the DOE Home Energy Score. Testing verified that the HPXML generated by the HP+Retrofit measure can successfully generate a Home Energy Score via the Home Energy Score Application Programming Interface.

About Standardized Simulations

As in custom measure Category 5, savings in the standardized simulation is calculated using an open source, physics-based calculation method (OpenStudio/EnergyPlus)[1453] with simplified inputs, optimized to reduce input error and contractor data collection effort. The method offers a streamlined alternative to deemed and partially deemed savings calculations or whole house energy simulations. The simulation physics are transparent, and the underlying assumptions are explicitly defined,[1454] thereby providing consistency in the simulated savings for complex measure packages while eliminating the need for whole house modeling often required of contractors participating in residential home performance programs.

The standardized simulation is capable of supporting calculations for a wide range of energy conservation measures (ECMs) and standardized packages for the residential

[1451] https://neep.org/heating-electrification/ccashp-specification-product-list.

[1452] *Manual J Residential Load Calculation*, Arlington, VA. Air Conditioning Contractors Association.

[1453] The OpenStudio/EnergyPlus framework and the validation testing conducted by US Department of Energy and others is described in supplemental documentation for the *Custom Measure Category 6: Residential Heat Pump Plus Weatherization Retrofit Standard Simulation for Measure Packages, Chapter A: Third Party Validation for the Open Source Tools (EnergyPlus and OpenStudio*).

[1454] Further details are described in supplemental documentation for *Custom Measure Category 6: Residential Heat Pump Plus Weatherization Retrofit Standard Simulations for Measure Packages, Chapter B: Detailed Description for Transforming Standardized Program Data (HPRXML) into HPXML* <Link to DMM pending publication>

sector and can be readily expanded for application to commercial and multifamily buildings. The OpenStudio building performance simulation software runs on top of the EnergyPlus engine, where OpenStudio "Measures" are defined scripts that leverage the OpenStudio framework to automate performance simulation processes. The ECMs incorporated into standard measure packages can include complex measures such as heat pumps, controls, energy storage and other improvements.

These standardized simulation methods support a set of flexible and extensible residential retrofit measure packages that can be used by Program Administrators to readily incorporate heat pump plus envelope improvements into programs suitable for the residential sector. The packages are flexible in that the Program Administrator (PA) may select one or more energy efficiency improvements. They are also extensible in that energy efficiency and clean energy improvements can be added to the retrofit measure package. Realization rate studies have shown that calibrated energy models can improve savings prediction accuracy.[1455] Field studies of asset ratings, using similar standardized simulation methods and standard occupancy related inputs, also have shown strong correlations between predicted and actual usage.[1456]

Benefits of HP+Retrofit

The HP+Retrofit measure was developed to further support the integration of envelope improvements with the installation of ccASHP. It supports both expansion of the Category 5 package-based envelope load reduction measures and the whole building heat pump plus envelope measures that are a part of the statewide Clean Heating program. The benefits of the HP+Retrofit method are:

- Reduced cost of whole building heat pump retrofits through load reduction
- Improved ccASHP performance because of envelope load reduction which reduce cold drafts and sensitivity of thermal loads to outside air temperature and wind
- Expanded customer satisfaction with greater thermal comfort
- Better cost-effectiveness for ccASHP fuel conversion with the combination of ccASHP plus envelope measures
- Enhanced communication between ccASHP installers and envelope contractors, by providing a common tool for savings calculations, load calculations and data sharing within a PA energy efficiency program.

The HP+Retrofit measure also supports PA specific demand calculations and is suitable for use in supporting non pipes and non-wires alternatives where time and location-based impacts add value. The measure can also support peak demand management which result from residential building decarbonization efforts.

[1455] Jerone Gagliano et al., *NYSERDA Home Performance with Energy Star Realization Rate Attribution Study* (Ithaca, NY: 2015); Dana Nilsson et al., HPwES On Bill Recovery Impact Evaluation (Albany, NY: 2019).
[1456] David Roberts et al., *Assessment of the U.S. Department of Energy's Home Energy Scoring Too*l, (Golden, Colorado: July 2012); Brett Dillion et. al., *Standard for the Calculation and Labeling of the Energy Performance of Low-Rise Residential Buildings using an Energy Rating Index* (January 2016).

Relationship of the HP+Retrofit Measure to Custom Measure Category 5

The HP+Retrofit measure builds on the EnergyPlus based standardized simulation methods first introduced in custom measure Category 5. The same approaches to standardized simulation measure development and documentation are used in presenting custom measure 6. As a result, savings calculated in Category 5 envelope improvements will have very similar results when calculated in Category 6.

Comparisons of heating fuel savings for Category 6 in Albany and New York City weather locations were tested for parallels against several other modeling methods,[1457] including: EnergyPlus Category 5, EnergyPlus 6, EmpCalc, GJGNY, Simplified Engineering Calculation (SEC)60/70, and TREAT.

As shown in the figures below, the primary differences in savings between the EnergyPlus based methods result from enhancements to the newer versions of EnergyPlus and OpenStudio used in Category 6. These changes generally reduce savings. The updated versions of EnergyPlus and OpenStudio used are documented in *Supplemental Documentation Custom Measure Category 6: Residential Heat Pump Plus Weatherization Retrofit Standard Simulations for Measure Packages: Chapter A Third Party Validation for the Open Source Tools (EnergyPlus and OpenStudio).*

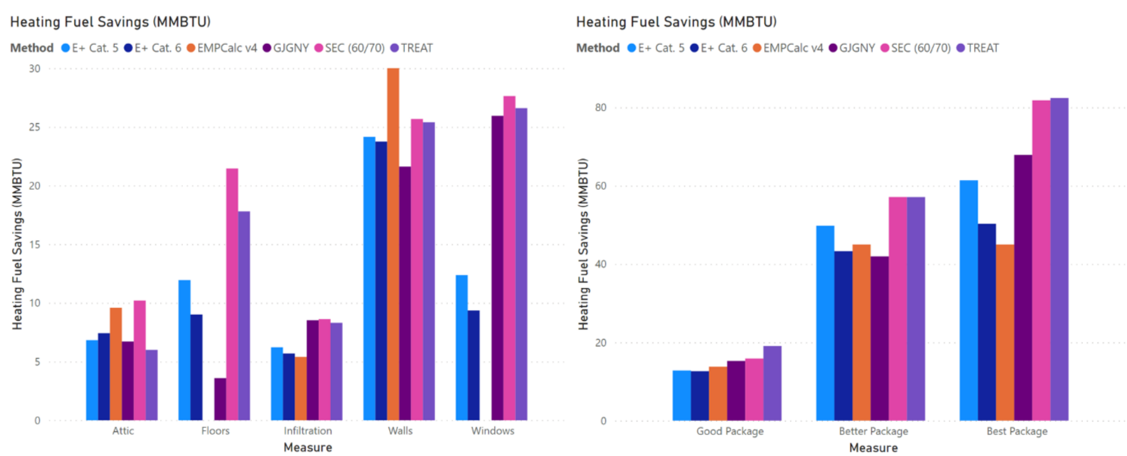


FIGURE: COMPARISON OF THE HP+RETROFIT TO CUSTOM MEASURE CATEGORY 5 SAVINGS RESULTS AND TO OTHER METHODS FOR NEW YORK CITY TMY3 WEATHER

1457 See modeling methods described in *Supplemental Documentation Custom Measure Category 5: Residential Retrofit Standard Simulations, Chapter C: Validation of Savings Results*.

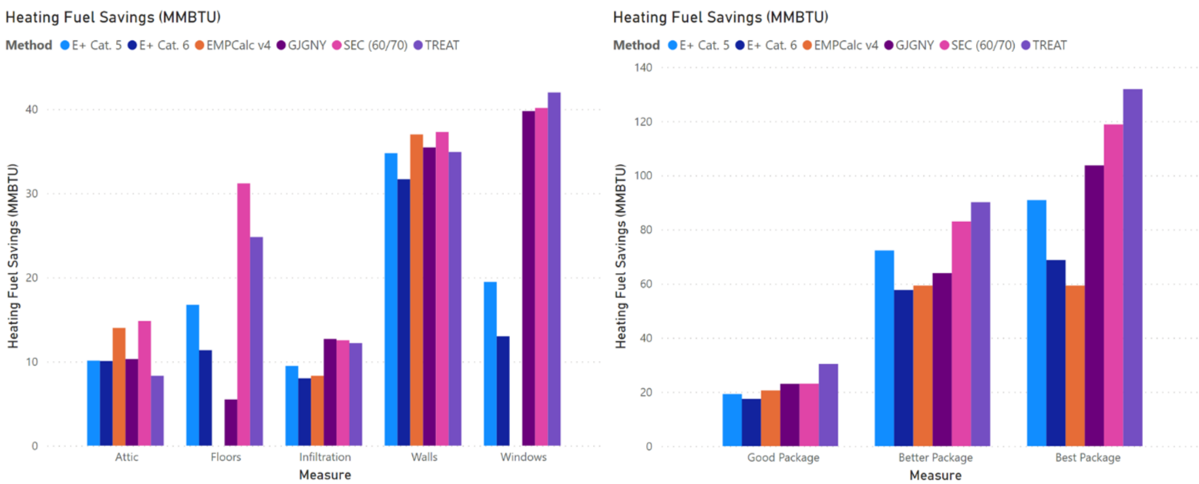


FIGURE: COMPARISON OF THE HP+RETROFIT MEASURE TO CUSTOM MEASURE CATEGORY 5 SAVINGS RESULTS AND OTHER METHODS FOR ALBANY TMY3 WEATHER

The drivers for developing Category 6 include the need to:

- Reduce the required number of user inputs as compared to whole building modeling methods
- Support the calculations of savings for make and model specific heat pumps in combination with envelope improvements
- Enable use of more detailed inputs which are required for accurate calculations of heating and cooling design and operating loads
- Expand to flexibly support more building types
- Provision of HPXML data which can be sent to the DOE Home Energy Score to generate a report to help embed the value of energy efficiency investments in the house real estate value.

The HP+Retrofit interface will allow envelope contractors to use default input values based on methods developed in Category 5, where detailed inputs are not required for envelope load reduction savings. For example, window inputs require a full inventory of windows for a load calculation and ccASHP installation savings calculation, but not for an envelope only installation savings calculation.

Below is a figure comparing inputs required for a colonial style house receiving three types of improvements. The figure compares savings calculation approaches: Category 5 – envelope only, Category 6 - HP+Retrofit, and ccASHP (no envelope improvements) deemed savings. The results indicate Category 6 approach cuts the inputs approximately in half.

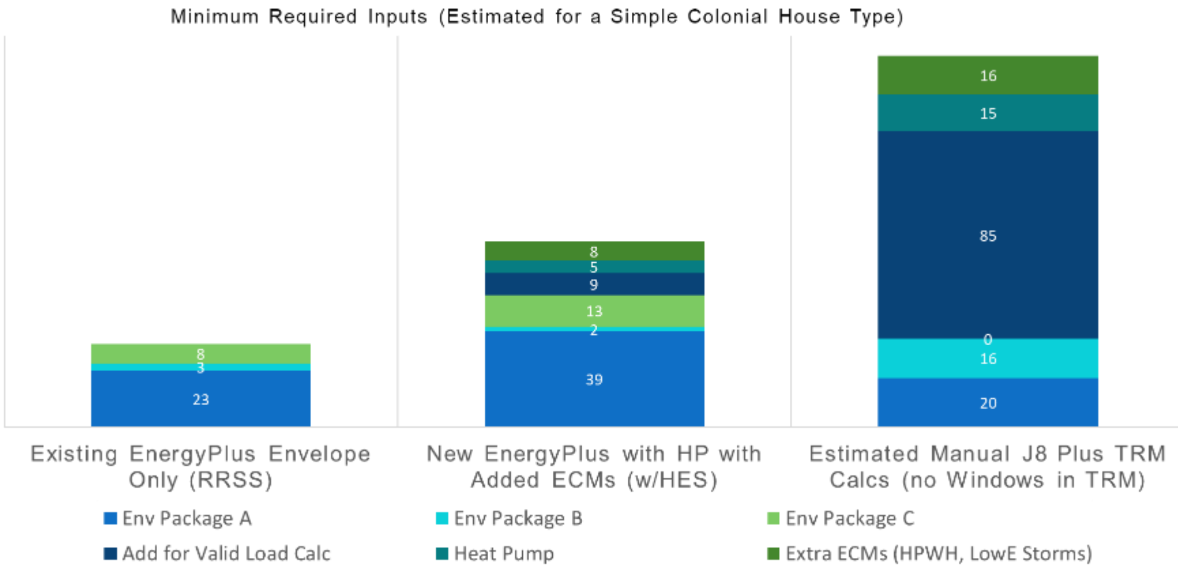


FIGURE : INPUT COMPARISON

Additional Functionality Supported by the HP+Retrofit Measure

The HP+Retrofit measure introduces new functionality to the standardized simulation to help heat pump plus weatherization retrofits more rapidly and successfully scale in New York State. These features include:

Integrated Block Load Calculation – Design load calculations used to size ccASHP equipment are integrated into the HP+Retrofit measure. These calculations are performed at a whole building or "block load" level. These calculations also provide feedback on the design load reductions from envelope packages and can be used to quality check the combined capacity of equipment proposed to be installed in the building. Design load considerations and the resulting equipment sizing decisions are a key aspect of enabling efficiency investments to support peak load management.

The equations used for these calculations are part of the NREL OpenStudio-HPXML workflow used by both the Category 5 and Category 6 standardized simulations. The methods used by these equations are a near duplicate of published ACCA Manual J version 8 methods. The figure below presents the relative heating load calculation results for an Albany location for both the Category 5 and Category 6 methods. The inputs in the HP+Retrofit measure were standardized and simplified to align with both envelope retrofit data collection and design load calculations. The simplified inputs were designed and tested to maintain an accuracy range of roughly 2,000 Btus/hr below and 4,000 Btus/hr above equivalent ACCA method results for heating design loads.[1458]

[1458] The simplification of inputs is expected to introduce limitations to the accuracy of the design load calculation method for some non-standard envelope configurations. These limitations are anticipated to be similar in type to those associated with the ACCA Manual J Simplified Block Load Calculation. These limitations will be explored and documented as part of field testing of the HP+Retrofit method.

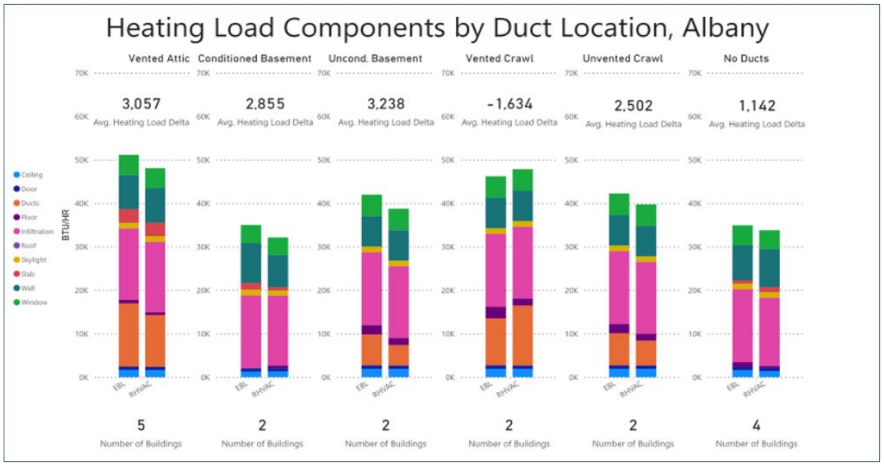


FIGURE: LOAD CALCULATION COMPARISON

Forms-Based Approach to Thermal Boundary Changes – A best practice for the installation of ducted retrofit ccASHP is to insulate the space containing the duct work, bringing the ducts inside the building envelope, and reducing duct losses. If the insulated space is well sealed, any duct leakage is moved from outside to inside the building envelope. The combination of these three effects (envelope insulation, reduction of duct heat transfer, and capturing duct leakage losses) provides a significant load reduction impact and as well as increased occupant satisfaction with ccASHP performance. The HP+Retrofit measure simplifies the calculation of the design load and annual energy effects by both envelope and ccASHP contractors.

Changing the location of the thermal boundary within a simulation generally requires developing two independent energy simulations, since the changes affect more than altering a surface characteristic between precondition and improvement condition. With Category 6, multiple simulations are produced from a single data file allowing different files to have different thermal boundary conditions as defined by the source “HPRXML” data file. Users will see this feature as a selection of the type of improvement to attics and basement/crawlspace. Each attic or basement/crawlspace improvement type has a different data collection requirement and is presented as a dynamic form for a contractor to fill out.

Integration of Detailed ccASHP Equipment Performance Specifications – The OpenStudio-HPXML workflow used by the HP+ Retrofit method contains assumptions about the performance of ccASHP that are extrapolated from a reduced set of inputs including HPSF, Rated Heating Capacity at 47°F, and Rated Heating Capacity at 17°F. The prescriptive ccASHP measure[1459] attempts to account for these variations, such as in COP performance, through a climate and equipment type look up tables. However, with the HP+Retrofit measure, specific detailed equipment performance, such as those available in the NEEP ccASHP Product Listing Database, are utilized – providing significant increases in accuracy of the performance of ccASHP equipment and backup energy use.

[1459] ccASHP Measure found in NY TRM v9.0, under Single and Multi-Family Residential Measures, Heating Ventilation and Air Conditioning (HVAC), Heat Pump – Air Source (ccASHP).

In developing the HP+Retrofit measure, the HPXML to OpenStudio measure was enhanced to support additional equipment specific metrics, including Minimum Capacity at 47°F, Maximum Capacity at 47°F, Maximum Capacity at 5°F, Maximum COP at 5°F, Minimum COP at 47°F. As a result of these updates, the savings calculations reward contractor equipment performance choices based on a more comprehensive set of ccASHP performance data. The resulting savings better represent both low temperature COP and capacity performance, as well as COP and capacity performance under low load conditions.[1460]

The selection of actual ccASHP equipment to serve a whole building load also typically requires the selection of multiple ccASHP systems. To account for this, the HP+Retrofit measure supports allocation of the whole building heating and cooling block loads to individual ccASHP systems. The individual ccASHP systems, which typically include variation in performance specifications, are run simultaneously in each EnergyPlus model generated by the HP+Retrofit method. The block load chosen by the contractor to each piece of equipment is allocated by the EnergyPlus simulation to each piece of equipment at each simulated time step. This approach improves the accuracy of peak electricity predictions.

Heat Pump Water Heater (HPWH) – The HPWH measure can be added to any of the three envelope packages and also to any heat pump(s) added to an envelope package. The HPWH measure is fully integrated with the EnergyPlus simulation and is not a stand-alone engineering calculation. Thus, the modeled HPWH operation is affecting the performance of the simulation at each time step. The location of the HPWH heater is an input (e.g., the basement) and thus the calculated savings from the chosen envelope package reflected in the performance of the HPWH. Category 6 standardizes hot water consumption schedules; and hot water consumption is scaled based on number of bedrooms.[1461]

Testing of New Features in the HP+Retrofit Measure

Design of Category 6 new features required additional testing against other simulations or load calculation tools beyond the testing conducted for the Category 5.

In general, the energy savings results of HP+Retrofit method are lower (more conservative) than those of TREAT for the corresponding test cases. The two primary contributing factors for this are the difference in load heat loss/gain algorithms, and the different timesteps used for calculating the HVAC energy. EnergyPlus is continuously being maintained and updated by the DOE with new features and improved algorithms.

[1460] Modifications to ccASHP modeling methods are described in *Supplemental Documentation Custom Measure Category 6:Residential Heat Pump Plus Weatherization Retrofit Standard Simulations for Measure Packages , Chapter C: Modifying HPXML-EnergyPlus Inputs to Use NEEP Data*. <Link to DMM pending publication>

[1461] Similar to the work done to enhance the information used to model ccASHP, assumptions about performance curves for HPWH could be made more equipment specific as part of a future revision of the HP+Retrofit measure.

TREAT's heat loss/gain algorithms come from the underlying SUNREL engine, last updated in 2002.

When compared to BEopt, the energy savings results of HP+Retrofit method are lower (more conservative) for the corresponding duct improvement test cases but are higher for the HPWH test cases. BEopt was last updated in 2018, and even though BEopt uses EnergyPlus as its underlying calculation engine, it is using EnergyPlus Ver 8.8, while the HP+Retrofit method uses the latest version of EnergyPlus, Ver 22.1. Additionally, the translation of key input variables to the native EnergyPlus inputs differs between BeOpt and the HPXML to OpenStudio workflow.

In areas where there were significant variances in results between Category 5 and Category 6 methods, additional investigation was conducted typically by evaluating performance at an hourly component level.   After minor improvements to the initial HP+Retrofit method, there is greater confidence in the Version 22.1.0 EnergyPlus results than in the other methods, and these variances were allowed to persist. As a result of testing new features in Category 6, further enhancements were made to the following calculation components.

Load Calculations – Test results for the load calculation in the HP+Retrofit method resulted in minor improvements by NREL to the calculations in OpenStudio which improved alignment to the ACCA Manual J Version 8 results. Much of the variance between methods in the tested results is due to the simplification of inputs. Example results are shown above in Figure: Load Calculation Comparison.

New Envelope Features – Generally, insulating unconditioned spaces to change the thermal envelope boundary requires a robust simulation for comparison. Differences in ground coupling and in the handling of floating temperatures in unconditioned spaces were the primary source of savings variation.

Where there were significant variances in results between methods, additional investigation was conducted typically by evaluating performance at an hourly component level.   After minor improvements to the initial HP+Retrofit method, there is greater confidence in the Version 22.1.0 EnergyPlus results than in the other methods, and these variances were allowed to persist.

Windows – The wide variation in EnergyPlus generated window savings results compared to other methods, including the TREAT simulation, was first noted in the testing for custom measure Category 5. A detailed investigation of this improvement, done in coordination with NREL, increased confidence in the conservative windows improvement (Package 3) savings results in the EnergyPlus based methods. See Figures: Comparison of Custom Measure Category 5 savings results to other methods including HP+Retrofit for Albany/New York City, above TMY3 weather, above. These Figures show that the annual energy savings for windows are reduced from custom measure Category 5 to the HP+Retrofit method.

The performance accuracy of windows in the EnergyPlus and OpenStudio platforms continues to be enhanced by DOE and methods leveraging these tools benefit from this continued federal investment. This EnergyPlus enhancement has reduced annual energy savings from windows. Load reduction savings (changes in equipment design load) are based on the industry standard load calculation method in the HPXML to OpenStudio measure and not affected by these changes to EnergyPlus.

Duct Improvements – These tests examined the impact of changes to duct insulation and leakage in various types of unconditioned spaces. BEopt was used as the comparison simulation for these runs. Results between BEopt and the HP+Retrofit method were similar except when evaluating duct leakage changes to insulated ducts located in an unconditioned basement. The EnergyPlus results were more conservative in this case, with reasons similar to those stated above. These differences in savings are due to different duct leakage heat gain/loss to the space algorithms and different abstraction of the duct leakage input.

HPWH – Test results for HPWH savings scenarios were generated, using the BEopt v2.8.0 software. Testing confirmed that HPWH location correctly impacts HVAC interactivity and space temperature depression, when located in unconditioned areas. Savings differences identified between HP+Retrofit and BEopt are likely due to due improvement in how the floating space temperature of unconditioned basements are handled, as well as differences in the HPWH models between versions of OpenStudio and EnergyPlus.

ccASHP – Supplemental Documentation Custom Measure Category 6: Residential Heat Pump Plus Weatherization Retrofit Standard Simulations for Measure Packages , Chapter C: Modifying HPXML-EnergyPlus Inputs to Use NEEP Data details extensive testing of the ccASHP modeling capabilities of the OpenStudio-HPXML v1.4.0 workflow. Modifications to the workflow were made to allow specific ccASHP systems to be modeled, using performance parameters extracted from the NEEP ccASHP Product List.

Description of the HP+Retrofit Measure Packages

This section describes the flexible and extensible residential HP+Retrofit packages developed using the standardized simulation.

Three packages are presented by order of priority based on the estimated load reduction and savings impact realized from the package installation in the climate zone as identified by building zip code and mapped to the appropriate NREL TMY3 weather file.[1462] By standardizing the package offered to the consumer, the contractor's customer acquisition costs are reduced and customer choices are driven to those with the greatest impact. The package improvements are intended to be implemented in a tiered approach to achieve the highest reduction in the home's heating and cooling loads thereby making the home ready for clean heating solutions aligned with electrification goals in New York.

[1462] The standardized simulation method may be updated to reflect the most current weather long-term average weather data. used by the NY TRM.

The simulation methods are both flexible and extensible enabling custom packages to satisfy policy goals specific to given NYS regions.

The three standard packages and the minimum requirements for each measure included in a specific package are presented in the Table HP+Retrofit, shown below.

- **Package 1**: attic insulation improvement (gable wall roof deck or attic floor), and basement rim joist seal and insulate
- **Package 2**: exterior above grade wall insulation, foundation ceiling insulation, foundation wall insulation, garage wall / ceiling insulation, cantilevered surface insulation, and all measures included in Package 1
- **Package 3**: ENERGY STAR windows (or equivalent) and all measures included in Package 2

Savings from one of the three standard packages may be interactively combined with the installation of one or more ccASHP system(s). Category 6 utilizes the HEAT PUMP – AIR SOURCE (ccASHP) measure description.

Savings from one of the three standard packages may be interactively combined with the installation of a HPWH. Category 6 utilizes the HEAT PUMP WATER HEATER (HPWH) – AIR SOURCE measure description.

Table HP+Retrofit Measure Packages

Measure Category	Measure	Package 1	Package 2	Package 3	Compliance Efficiency
Load Reduction Packages					
Insulation - Opaque Shell	**Attic Floor Insulation**	X	X	X	See Insulation – Opaque Shell Prescriptive Measure[1463]
	Attic Gable Wall or Attic Roof Deck Insulation	X	X	X	
	Knee Walls (Cape Cods)	X	X	X	
	Slope Ceiling (Cape Cods)	X	X	X	
	Rim Joist, spray foam	X	X	X	
	Duct insulation (external to envelope)	X	X	X	
	Wall cavity insulation		X	X	
Air Leakage Sealing	**Air Leakage Improvement**	X	X	X	See Air Leakage Sealing Prescriptive Measure [1464]
	Attic Hatch Sealing and insulation and pull down-stairs	X	X	X	
Insulation - Opaque Shell	**Insulate Foundation Ceiling**		X	X	See Insulation – Opaque Shell Prescriptive Measure[1463]
	Insulate Basement Wall		X	X	
	Insulate Crawlspace Wall		X	X	
	Insulate Garage Wall / Ceiling or Cantilever Surface		X	X	
Window – Low-E Storm	**Install Low-E Storm Window**			X	See Window – Low E Storm Prescriptive Measure[1465]
Window	**Replace Windows**			X	See Window – Low E Storm Prescriptive Measure[1466]
Optional Extensions to Load Reduction Packages					
Cold Climate Heat Pump(s)	**Install ccASHP system(s)**	x	x	x	See Heat Pump – Air Source (ccASHP) Prescriptive Measure[1467]
HPWH	**Install HPWH**	x	x	x	See Heat Pump Water Heater (HPWH) – Air Source Prescriptive Measure [1468]

Coincidence Factor (CF)

The EnergyPlus simulations produce project specific hourly simulation results for 49 weather files across New York State that can be utilized to generate time and location based peak impacts across a range of definitions of peak including both gas and electric fuels. This allows peak definitions to be set at the program level and calculated after each simulation run. Peak impacts should be based on other approved definitions of peak.

[1463]Measure in NY TRM v9.0, under Single and Multi-Family Residential Measures, Building Shell, Insulation – Opaque Shell.
[1464] Measure in NY TRM v9.0, under Single and Multi-Family Residential Measures, Building Shell, Insulation – Opaque Shell.
[1465]Measure in NY TRM v9.0, under Single and Multi-Family Residential Measures, Building Shell, Window - Low-E Storm.
[1466] Measure in NY TRM v9.0, under Single and Multi-Family Residential Measures, Building Shell, Window.
[1467] Measure in NY TRM v9.0, under Single and Multi-Family Residential Measures, Heating Ventilation and Air Conditioning (HVAC), Heat Pump – Air Source (ccASHP).
[1468] Measure in NY TRM v9.0, under Single and Multi-Family Residential Measures, Domestic Hot Water, Heat Pump Water Heater (HPWH) – Air Source.

Baseline efficiencies

The baseline condition is a building's existing condition, inclusive of housing type, vintage, housing characteristics, and estimated air leakage (or actual blower door test value).

Compliance efficiencies

For envelope improvements , the compliance condition is a residential opaque building shell with increased insulation meeting or exceeding the levels described in the Table HP+Retrofit Measure Packages, above.

Opaque shell insulation improvements performed under this measure shall be installed such that all altered envelope components comply with all federal, state, local and municipal codes and standards applicable to alterations to existing buildings, including but not limited to SectionR503.1 of ECCCNYS 2020[1469] requiring all existing ceiling, wall, and floor cavities exposed during construction to be filled with insulation. Thermal envelope components not altered as part of this measure (e.g., continuous insulation in wood-framed buildings) are not required to meet code for compliance.

For ccASHP improvements, the compliance condition is the same as used for the ccASHP prescriptive measure.[1470]

For HPWH improvements, the compliance condition is the same as used for the HPWH prescriptive measure.[1471]

HP+*Retrofit Measure Package Inputs*

The standardized simulations include simplification and optimization of inputs. Analysis of the influence of various inputs on savings is used to focus data collection on the inputs that influence savings the most, defaulting or abstracting other inputs.

These input simplifications, along with conservative assumptions on preconditions in the buildings, are key to managing the variability in results. Packages, described in Table HP+Retrofit Measure Packages (above), drive the definition of the standardized program data model (aka, Heat Pump Ready eXtensible Markup Language HPRXML).

Method for the Calculation

The HP+Retrofit calculation method builds on the EnergyPlus based methods introduced custom measure Category 5. The HP+Retrofit method also transforms a program defined XML data structure into the HPXML data standard for processing by the open source OpenStudio and EnergyPlus tools. The data collection requirement for HP+Retrofit is

[1469] ECCCNYS 2020, Section R503 Building Thermal Envelope.
[1470] Measure in NY TRM v9.0, under Single and Multi-Family Residential Measures, Heating Ventilation and Air Conditioning (HVAC), Heat Pump – Air Source (ccASHP).
[1471] Measure in NY TRM v9.0, under Single and Multi-Family Residential Measures, Domestic Hot Water, Heat Pump Water Heater (HPWH) – Air Source.

larger than in Category 5, driven by the need to be more accurate in the calculation of heat pump system design capacity and loads. As noted in the *Supplemental Documentation Custom Measure Category 6: Residential Heat Pump Plus Weatherization Retrofit Standard Simulations for Measure Packages , Chapters A and C*, the HPXML to OpenStudio measure has also been adjusted in targeted fashion to improve the ability of the HP+Retrofit measure to predict the performance of different contractor selected heat pumps, using equipment specific performance data available in the NEEP Cold Climate Air Source Heat Pump Database.

Operating Hours

Operating hours are the occupancy assumptions of the standardized simulation, including thermostat schedule.

Operation hours for heating and cooling equipment are not fixed Equivalent Full Load Hours (EFLH). Equipment run times are flexible and determined by the load in the Category 6 simulation. Changes in load, such as in the measures being submitted, affect the equipment run times.

Effective Useful Life

Standardized simulation results are at the whole building per fuel level. The standardized Package 1, Package 2, and Package 3 for different buildings will contain different mixes of measures based on the requirements of each building. In Table Estimated Average Measure Impacts, the estimated average improvements per measure for each package are presented. Also included are an estimate of the expected savings contributed from each measure on an average home.

Table Estimated Average Measure Impacts

Residential Retrofit Measure	**Estimated Area (ft^2)**	**Estimated Average Existing Condition**	**Estimated Average Improved Condition**	**Units**
Air Leakage	NA	3200	2400	CFM50
Attic Insulation	800	11	49	R Value
Rim Joist Insulation	130	5	19	R Value
Duct Insulation	50	2	23	R Value
Wall Insulation	1200	5	14	R Value
Floor Insulation	500	7	24	R Value
Window Replacement	200	0.556	0.270	U Value
ccASHP	NA	NA	NA	NA
Heat Pump Water Heater	NA	NA	NA	NA

These percentages are used to create a Composite Weighted Package Life, presented in Table Calculation of Composite Weighed Package Life, below. HP+Retrofit added equipment options to the basic envelope load reduction packages. These options are treated separate measure packages, with the measure life of the installed equipment affecting the composite measure life of the package type as shown below in Table – Weighted Composite Package Life for Equipment Options.

Table Calculation of Composite Weighed Package Life

Package	Measure	Measure Life from TRM in Years (See NY TRM Appendix P)	Estimated Average % Contribution per Measure to Package 1	Estimated Average % Contribution per Measure to Package 2	Estimated Average % Contribution per Measure to Package 3	Estimated Composite Weighted Package Life (Years)
Package 1	Air Sealing	15	37%	16%	14%	20.3
Package 1	Attic Insulation	25	36%	16%	13%	
Package 1	Rim Joist Insulation	25	12%	5%	5%	
Package 1	Duct Insulation	18	15%	6%	5%	
Package 2	Wall Insulation	25		43%	37%	22.9
Package 2	Floor Insulation	25		14%	12%	
Package 3	Replacement Windows	20			14%	22.5

Table – Weighted Composite Package Life for Equipment Options

Package Option	Measure	Measure Life from TRM in Years (See NY TRM Appendix P)	Estimated Average % Added Savings Contribution to Package	Envelope Package Measure Life (see above)	Adjusted Measure Life for Equipment Enhanced Package
Package 1 Plus ccASHP	ccASHP	15	50%	20.3	16.2
Package 1 Plus HPWH	HPWH	10	10%		
Package 2 Plus ccASHP	ccASHP	15	40%	22.9	18.7
Package 2 Plus HPWH	HPWH	10	8%		

Package 3 Plus ccASHP	ccASHP	15	35%	22.5	19
Package 3 Plus HPWH	HPWH	10	7%		

Ancillary Fossil Fuel Savings Impact
Ancillary savings impacts are implicitly captured in the simulation.

Ancillary Electric Savings Impact
Ancillary savings impacts are implicitly captured in the simulation.

Additional Outputs from the HP+Retrofit Measure

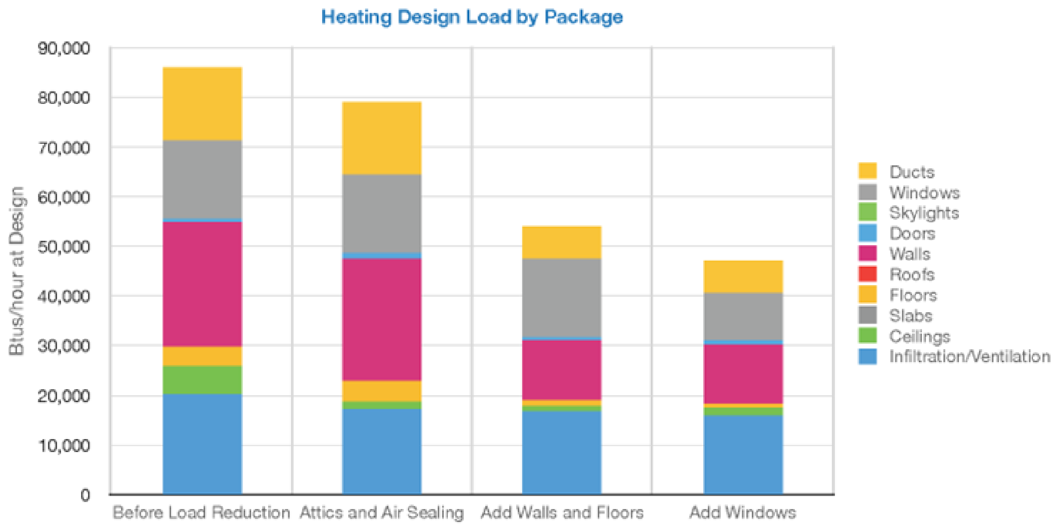
The HPXML to OpenStudio measure and the hourly EnergyPlus simulations produced by this measure produce outputs beyond annual savings that can be used to support energy efficiency program delivery.

The block heating and cooling design load calculation method within the HPXML to OpenStudio method is used to produce a heating and cooling load calculation for the base building and each of the three envelope packages. Cold climate heat pump sizing in New York State is dominated by heating loads so development of reports using this data have focused on heating loads. In contrast to most heating and cooling load calculation tools, which assume the load is fixed and the contractor is interested in comparing equipment, the HP+Retrofit measure can show the design loads for the base building and each of the three envelope packages. The OpenStudio to HPXML measure also includes the component load calculations allowing for the generation of design load analysis reports such as in Figure: Example Heating Design Load Report showing Component Level Envelope Loads by Package, below. Note that while design load impacts were part of the output from the Category 5 measure, these impacts were only accurate on relative basis, not absolute, and therefore the absolute design loads impacts were not made available to contractors in the application of the Category 5 measure.

Heating Design Load Report

Project Name: Jones House
Address: Albany, NY
Conditioned SF: 2000

Weather Location: Albany, NY
Heating Design Temp: 3 F
Cooling Design Temp: 88 F



Component	Size	Units	Before Load Reduction	Attics and Air Sealing	Add Walls and Floors	Add Windows
Infiltration/Ventilation	2800	Initial CFM 50	20094	17281	16577	15874
CFM50 % Reduction				14%	18%	21%
Ceilings	1000	Sq Ft	5719	1457	1457	1457
Slabs	0	Sq Ft	0	0	0	0
Floors	1000	Sq Ft	4072	4072	932	932
Roofs	3110	Sq Ft	0	0	0	0
Walls	2592	Sq Ft	24759	24759	11811	11811
Doors	49	Sq Ft	954	954	954	954
Skylights	0	Sq Ft	0	0	0	0
Windows	500	Sq Ft	15816	15816	15816	9738
Subtotal			71414	64339	47547	40766
Ducts	555	Sq Ft	14671	14525	6437	6309
Total (Btus/hr)			86085	78864	53984	47075

Heat Pump Load Reduction by Package (tons)		Attics and Air Sealing	Add Walls and Floors	Add Windows
	Ductless	0.6	2.0	2.6
	With Duct Losses	0.6	2.7	3.3

FIGURE: EXAMPLE HEATING DESIGN LOAD REPORT SHOWING COMPONENT LEVEL ENVELOPE LOADS BY PACKAGE

The Figure above shows the heating design load and load reduction impact of each package at the whole building and component level, both with and without ducts. This type of report supports improved contractor installation design decision-making by providing information on the impacts of the load reduction packages on equipment selection and sizing. This information can also support accelerated quality assurance review of contractor submitted load calculations.

The allocation of loads to individual specific ccASHP offers another opportunity to provide information to support contractor installation design decision making and program installation quality assurance. The block load calculation in the HP+Retrofit method sets a cap on the total load that can be allocated to installed ccASHP equipment. The EnergyPlus calculation allows for the hourly level detection of low load operation as measured by the minimum capacity of the specified equipment at that temperature. This information can be used by contractors and programs to help understand the potential impacts of too much load below minimum equipment capacity.

Additionally, the hourly simulation results, while not a part of the delivered output due to processing speed and bandwidth constraints, can be cost effectively queried at the EnergyPlus server to produce time, location, and technology dependent peak load impacts results based on a utility defined definition of peak. See the *Coincidence Factor* section above. These results allow the HP+Retrofit to be used to directly produce customized peak load outputs to support non pipes and non wires alternatives.

Change Management for Standardized Simulations

The centralized cloud-based calculations support cost effective and timely change management. A change to the method can be implemented in a central location, affecting all subsequent calculations. These can be done on an annual or semiannual basis. The HP+ Retrofit method utilizes an automated validation framework that supports analysis and reporting on the changes in the savings for both packages and individual measures within packages. Updates to these reports are a part of the approval process for any subsequent improvements to the calculations.

The credentialed savings method of the standardized simulation is subject to change management similar to other custom measures. Changes to the calculation methods will be evaluated and submitted for approval to DPS before being deployed to the centralized server. The cloud-based, centralized server implementation of the standardized simulation reduces the cost of deploying changes to the calculation method when compared to calculations distributed across many different users.

Changes could include upgrades to the EnergyPlus and OpenStudio software, adding new ECMs to the packages, changes to the HPRXML to HPXML transform based on program experience and evaluation results.

Summary of Variables and Data Sources

The variables used in the calculation are described in *Supplemental Documentation Custom Measure Category 6: Residential Heat Pump Plus Weatherization Retrofit Standard Simulations for Measure Packages*, *Chapter B: Detailed Description for Transforming Standardized Program Data (HPRXML) into HPXML.* Chapter B contains the details for transforming the program data input file (HPRXML) into the HPXML data standard that is read by the NREL OpenStudio to EnergyPlus measure. *Supplemental Documentation Custom Measure Category 6: Residential Heat Pump Plus Weatherization Retrofit Standard Simulations for Measure Packages , Chapters A: Third Party Validation for the Open-Source Tools (EnergyPlus and OpenStudio)*, contains documentation on the testing that these tools undergo.

Data collection is from contractors and can include remote data collection. The dynamic nature of the data collection increases the complexity of data collection table below. In practice users will not fill out the entire data table, just the sections dictated by their choice of improvement types. The nature of these choices is more fully documented in the sets of data tables A through J. The tables map contractor data collection for either (Cape Cod) or (Colonial / Ranch Homes) to subsequent Tables A through J, based on the type of Attic Improvement and type of Foundation improvement. Homes with Slab-on-Grade foundations need only collect the “Common” data and Attic Improvement data.

Table Data Collection for **Cape Cod** Homes

<table>
<tr><th>Existing Attic Type
→
Improved Attic Type</th><th>Existing Foundation Type
→
Improved Foundation Type</th><th>Common Project Data Collection</th><th>Attic Improvement Data Collection</th><th>Foundation Improvement Data Collection</th></tr>
<tr><td>Vented
→
Vented</td><td>Warm Unconditioned Basement
→
Warm Unconditioned Basement</td><td rowspan="6">Table A</td><td rowspan="6">Table D</td><td rowspan="3">Table B</td></tr>
<tr><td>Vented
→
Vented</td><td>Cold Unconditioned Basement
→
Cold Unconditioned Basement</td></tr>
<tr><td>Vented
→
Vented</td><td>Conditioned Basement
→
Conditioned Basement</td></tr>
<tr><td>Vented
→
Vented</td><td>Vented Crawlspace
→
Vented Crawlspace</td><td rowspan="3">Table C</td></tr>
<tr><td>Vented
→
Vented</td><td>Vented Crawlspace
→
Unvented Crawlspace</td></tr>
<tr><td>Vented
→
Vented</td><td>Unvented Crawlspace
→
Unvented Crawlspace</td></tr>
<tr><td>Vented → Unvented
OR
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→
Warm Unconditioned Basement</td><td rowspan="6">Table A</td><td rowspan="6">Table E</td><td rowspan="3">Table B</td></tr>
<tr><td>Vented → Unvented
OR
Unvented → Unvented</td><td>Cold Unconditioned Basement
→
Cold Unconditioned Basement</td></tr>
<tr><td>Vented → Unvented
OR
Unvented → Unvented</td><td>Conditioned Basement
→
Conditioned Basement</td></tr>
<tr><td>Vented → Unvented
OR
Unvented → Unvented</td><td>Vented Crawlspace
→
Vented Crawlspace</td><td rowspan="3">Table C</td></tr>
<tr><td>Vented → Unvented
OR
Unvented → Unvented</td><td>Vented Crawlspace
→
Unvented Crawlspace</td></tr>
<tr><td>Vented → Unvented
OR
Unvented → Unvented</td><td>Unvented Crawlspace
→
Unvented Crawlspace</td></tr>
</table>

Table Data Collection for **Colonial** or **Ranch** Homes

<table>
<tr><th>Existing Attic Type
→
Improved Attic Type</th><th>Existing Foundation Type
→
Improved Foundation Type</th><th>Common Project Data Collection</th><th>Attic Improvement Data Collection</th><th>Foundation Improvement Data Collection</th></tr>
<tr><td>Vented
→
Vented</td><td>Warm Unconditioned Basement
→
Warm Unconditioned Basement</td><td rowspan="6">Table A</td><td rowspan="6">Table D</td><td rowspan="3">Table B</td></tr>
<tr><td>Vented
→
Vented</td><td>Cold Unconditioned Basement
→
Cold Unconditioned Basement</td></tr>
<tr><td>Vented
→
Vented</td><td>Conditioned Basement
→
Conditioned Basement</td></tr>
<tr><td>Vented
→
Vented</td><td>Vented Crawlspace
→
Vented Crawlspace</td><td rowspan="3">Table C</td></tr>
<tr><td>Vented
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Vented</td><td>Vented Crawlspace
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Unvented Crawlspace</td></tr>
<tr><td>Vented
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Vented</td><td>Unvented Crawlspace
→
Unvented Crawlspace</td></tr>
<tr><td>Vented → Unvented
OR
Unvented → Unvented</td><td>Warm Unconditioned Basement
→
Warm Unconditioned Basement</td><td rowspan="6">Table A</td><td rowspan="6">Table E</td><td rowspan="3">Table B</td></tr>
<tr><td>Vented → Unvented
OR
Unvented → Unvented</td><td>Cold Unconditioned Basement
→
Cold Unconditioned Basement</td></tr>
<tr><td>Vented → Unvented
OR
Unvented → Unvented</td><td>Conditioned Basement
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Conditioned Basement</td></tr>
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OR
Unvented → Unvented</td><td>Vented Crawlspace
→
Vented Crawlspace</td><td rowspan="3">Table C</td></tr>
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OR
Unvented → Unvented</td><td>Vented Crawlspace
→
Unvented Crawlspace</td></tr>
<tr><td>Vented → Unvented
OR
Unvented → Unvented</td><td>Unvented Crawlspace
→
Unvented Crawlspace</td></tr>
<tr><td>Conditioned
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Conditioned</td><td>Warm Unconditioned Basement
→
Warm Unconditioned Basement</td><td rowspan="5">Table A</td><td rowspan="5">Table F</td><td rowspan="3">Table BError! Reference source not found.</td></tr>
<tr><td>Conditioned
→
Conditioned</td><td>Cold Unconditioned Basement
→
Cold Unconditioned Basement</td></tr>
<tr><td>Conditioned
→
Conditioned</td><td>Conditioned Basement
→
Conditioned Basement</td></tr>
<tr><td>Conditioned
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Conditioned</td><td>Vented Crawlspace
→
Vented Crawlspace</td><td rowspan="2">Table C</td></tr>
<tr><td>Conditioned
→
Conditioned</td><td>Vented Crawlspace
→
Unvented Crawlspace</td></tr>
</table>

Conditioned → Conditioned	Unvented Crawlspace → Unvented Crawlspace			

Table A: Data Collection Common for **ALL** Projects
Table A describes the entire set of possible (64) common data elements collected, for all basement improvement or foundation improvement scenarios.

The actual number of common data points needed will depend on which package is selected for analysis. For example, if only Package 1 savings will be analyzed, only (42) common data points will be needed. If Package 2 savings will be analyzed, an additional (13) data points will be collected. If Package 3 savings will be analyzed, an additional (9) common data points will be collected.

Table A: Data Collection Common for **ALL** Projects

Input Type	**Variable Name (HPRXML)**	**Description**	**Values**	**Notes**
Assessment	zip	Zip	limited to 5 digits	5 digit Zip Code
Assessment	county	County	String	County name
Assessment	year_built	Year Built	2010 2000 1990 1980 1970 1960 1950 1940 1930 1920 1910	Selection represents the beginning of the decade in which the home was built
Assessment	number_bedrooms	Number of Bedrooms	Integer	
Assessment	num_floor_above_grade	Number of Floors Above Grade	Integer	Between 1 and 3
Assessment	floor_to_ceiling_height	Floor To Ceiling Height	Integer	Between 6 and 12
Assessment	cond_floor_area_above_grade	Cond Floor Area Above Grade	Integer	

Assessment	floor_area_below_grade	Floor Area Below Grade	Integer	Conditioned and Unconditioned floor area
Assessment	foundation_type	Foundation Type	slab on grade warm unconditioned basement cold unconditioned basement vented crawlspace unvented crawlspace conditioned basement	
Assessment	attic_type	Attic Type	vented attic unvented attic conditioned attic none	
Assessment	attached_garage	Attached Garage	true false	Attached garage present?
Assessment	orientation_front_of_home	Orientation Front of Home	north south east west	
Assessment	building_type	Building Type	Colonial Cape Cod Ranch	Select the type of the home
Assessment	type	Primary Heating System	cond boiler baseboard boiler baseboard boiler radiator elec baseboard central furnace wall furnace heat pump gchp mini split	Select the type of the primary heating system
Assessment	install_year	Primary Heating System Age	2010 2000 1990 1980 1970	Select the decade in which the primary heating system was installed

Assessment	heating_fuel	Primary Heating Fuel	electric natural gas lpg fuel oil	Select the fuel for the primary heating system Select the type of the home
Assessment	type	Primary Cooling Type	heat pump central furnace gchp mini split room none	Select the type of the primary cooling system
Assessment	install_year	Primary Cooling System Age	2010 2000 1990 1980 1970	Select the decade in which the primary cooling system was installed
Assessment	predominant_location	Distribution System Predominant Location	attic living space basement crawlspace not applicable	Location where most of the distribution systems is located
Assessment	insulation_state	Distribution System Insulation State	Full Partial None N/A	Air Distribution System Insulation level
Assessment	estimated_leakage	Distribution System Estimated Leakage	Extremely sealed Notably sealed Average sealed Partially sealed N/A	Air Distribution Leakage level
Assessment	thermostat_control_type	Thermostat Schedule	None Nightly and Weekday Nightly Only	Are most of the thermostats set up on a schedule?
Assessment	fuel_primary	Hot Water Fuel	electric natural gas lpg fuel oil	Select the decade in which the primary heating system was installed

Assessment	type	Type of existing hot water system	storage or boiler tankless hpwh	
Assessment	install_year	Age of existing hot water system	storage or boiler tankless hpwh	
Assessment	location	Hot Water System Location	conditioned space unconditioned space	
Assessment	nonenergystar_window_glazing	Non-EnergyStar Window Glazing Type	Single-pane Single-pane plus storm Double-pane	Characterization of Windows not meeting EnergyStar Criteria and not being replaced
Assessment	preimproved_window_glazing	Pre-Improved Window Glazing Type	Single-pane Single-pane plus storm Double-pane	Characterization of Windows being replaced
Assessment	full_assembly_area	Non-EnergyStar Window area facing front	Integer	Frame area plus glazing area
Assessment	full_assembly_area	Non-EnergyStar Window area facing back	Integer	Frame area plus glazing area
Assessment	full_assembly_area	Non-EnergyStar Window area facing left	Integer	Frame area plus glazing area
Assessment	full_assembly_area	Non-EnergyStar Window area facing right	Integer	Frame area plus glazing area
Assessment	full_assembly_area	Pre-Improved Window area facing front	Integer	Frame area plus glazing area
Assessment	full_assembly_area	Pre-Improved Window area facing back	Integer	Frame area plus glazing area

Assessment	full_assembly_area	Pre-Improved Window area facing left	Integer	Frame area plus glazing area
Assessment	full_assembly_area	Pre-Improved Window area facing right	Integer	Frame area plus glazing area
Assessment	stud_size	Stud size	2 x 4 2 x 6	Depth of wall stud cavity
Assessment	blower_door	Blower Door test in	Integer	Blower door test before improvement
Assessment	package_run_type	Use-case for generating savings	Load Reduction Saving Load Reduction Plus System	
Improvement Package 1	use_package_1_info		true false	Estimate savings for package 1 improvements
Improvement Package 1	rim_joist_insulation	Rim Joist Insulation Condition	None Partial Full	
Improvement Package 1	blower_door	Blower Door test out	Integer	Blower door test after improvement
Improvement Package 2	use_package_2_info		true false	Estimate savings for package 2 improvements
Improvement Package 2	blower_door	Blower Door test out	Integer	Blower door test after improvement
Improvement Package 2	net_area	Exterior above grade wall area that will be insulated	Integer	Total exterior above grade wall area less any penetrations
Improvement Package 2	net_area	Exterior above grade wall area that meets program requirements	Integer	Total exterior above grade wall

				area less any penetrations
Improvement Package 2	net_area	Exterior above grade wall area that does not meet program requirements	Integer	Total exterior above grade wall area less any penetrations
Improvement Package 2	attic_thermal_boundary_change	Attic thermal boundary change	true false	Do attic improvements change the thermal boundary?
Improvement Package 2	location_of_existing_attic_insulation	existing attic thermal boundary	attic_ceiling attic_walls	The existing attic thermal boundary
Improvement Package 2	location_of_improved_attic_insulation	new attic thermal boundary	foundation_ceiling foundation_walls	The new attic thermal boundary
Improvement Package 2	foundation_thermal_boundary_change	Foundation thermal boundary change	true false	Do Foundation Improvements change the thermal boundary?
Improvement Package 2	location_of_existing_foundation_insulation	The existing foundation thermal boundary	foundation_ceiling foundation_walls	The existing foundation thermal boundary
Improvement Package 2	location_of_improved_foundation_insulation	The new foundation thermal boundary	foundation_ceiling foundation_walls	The new foundation thermal boundary
Improvement Package 2	net_area	Garage Wall / Ceiling Area to be Improved	Integer	Garage Wall / Ceiling Area to be Improved
Improvement Package 2	net_area	Cantilever Surface Area to be Improved	Integer	Cantilever Surface Area to be Improved

Improvement Package 3	use_package_3_info		true false	Estimate savings for package 3 improvements
Improvement Package 3	blower_door	Blower Door test out	Integer	Blower door test after improvement
Improvement Package 3	storm_window_glass_type	Type of storm window	low_e none clear	
Improvement Package 3	full_assembly_area	Right Facing Window Area to be improved	Integer	
Improvement Package 3	full_assembly_area	Left Facing Window Area to be improved	Integer	
Improvement Package 3	full_assembly_area	Front Facing Window Area to be improved	Integer	
Improvement Package 3	full_assembly_area	Back Facing Window Area to be improved	Integer	
Improvement Package 3	shgc	Improved Window U-Value	Double	
Improvement Package 3	u_value	Improved Window SHGC	Double	

Table B, Table C, Table D, Table E, Table F describe the additional data needed for specific Attic Improvement and Foundation improvement scenarios.

Table B: Data Collection for All Basement Improvements

Existing Condition: "Warm" Unconditioned Basement **Improved Condition**: "Warm" Unconditioned Basement					
Input Type	Variable Name	SystemIdentifiers	Description	Value	Notes
Assessment	net_area	surface_type = FoundationCeiling performance_state = Total	Net Area	Integer	Enter the net area of surfaces between the foundation and living space.
Improvement Package 2	net_area	surface_type = BasementWall performance_state = Improved	Net Area	Integer	Enter the net area of Basement Wall surfaces to be insulated.
Improvement Package 2	net_area	surface_type = BasementWall performance_state = MeetsRequirements	Net Area	Integer	Enter the net area of Basement Wall surfaces already

					meeting compliance efficiency levels
Improvement Package 2	net_area	surface_type = BasementWall performance_state = WillNotMeetRequirements	Net Area	Integer	Enter the net area of Basement Wall surfaces that will not meet compliance efficiency levels
Improvement Package 2	assembly_rvalue	surface_type = BasementWall performance_state = WillNotMeetRequirements	Assembly R-Value	Double	Enter the efficiency level of Basement Wall surfaces that will not meet compliance efficiency levels
Existing Condition: "Cold" Unconditioned Basement **Improved Condition**: "Cold" Unconditioned Basement OR **Existing Condition**: Conditioned Basement **Improved Condition**: Conditioned Basement					
Assessment	net_area	surface_type = BasementWall performance_state = Total	Net Area	Integer	Enter the net area of Basement Wall surfaces.
Improvement Package 2	net_area	surface_type = FoundationCeiling performance_state = Improved	Net Area	Integer	Enter the net area of Foundation Ceiling surfaces to be insulated.
Improvement Package 2	net_area	surface_type = FoundationCeiling performance_state = MeetsRequirements	Net Area	Integer	Enter the net area of Foundation Ceiling surfaces already meeting compliance efficiency levels
Improvement Package 2	net_area	surface_type = FoundationCeiling performance_state = WillNotMeetRequirements	Net Area	Integer	Enter the net area of Foundation Ceiling surfaces that will not meet compliance efficiency levels
Improvement Package 2	assembly_rvalue	surface_type = FoundationCeiling performance_state = WillNotMeetRequirements	Assembly R-Value	Double	Enter the efficiency level of Foundation Ceiling surfaces that will not meet compliance efficiency levels

Table C: Data Collection for All Crawlspace Improvements

Existing Condition: Vented Crawlspace **Improved Condition**: Vented Crawlspace					
Input Type	Variable Name	SystemIdentifiers	Description	Value	Notes
Assessment	net_area	surface_type = CrawlspaceWall performance_state = Total	Net Area	Integer	Enter the net area of Crawlspace Wall surfaces.
Improvement Package 2	net_area	surface_type = FoundationCeiling performance_state = Improved	Net Area	Integer	Enter the net area of Foundation Ceiling surfaces to be insulated.
Improvement Package 2	net_area	surface_type = FoundationCeiling performance_state = MeetsRequirements	Net Area	Integer	Enter the net area of Foundation Ceiling surfaces already meeting

					compliance efficiency levels
Improvement Package 2	net_area	surface_type = FoundationCeiling performance_state = WillNotMeetRequirements	Net Area	Integer	Enter the net area of Foundation Ceiling surfaces that will not meet compliance efficiency levels
Improvement Package 2	assembly_rvalue	surface_type = FoundationCeiling performance_state = WillNotMeetRequirements	Assembly R-Value	Double	Enter the efficiency level of Foundation Ceiling surfaces that will not meet compliance efficiency levels
Existing Condition: (Unvented Crawlspace or Vented Crawlspace) **Improved Condition**: Unvented Crawlspace					
Assessment	net_area	surface_type = FoundationCeiling performance_state = Total	Net Area	Integer	Enter the net area of Foundation Ceiling surfaces.
Improvement Package 2	net_area	surface_type = CrawlspaceWall performance_state = Improved	Net Area	Integer	Enter the net area of Crawlspace Wall surfaces to be insulated.
Improvement Package 2	net_area	surface_type = CrawlspaceWall performance_state = MeetsRequirements	Net Area	Integer	Enter the net area of Crawlspace Wall surfaces already meeting compliance efficiency levels
Improvement Package 2	net_area	surface_type = CrawlspaceWall performance_state = WillNotMeetRequirements	Net Area	Integer	Enter the net area of Crawlspace Wall surfaces that will not meet compliance efficiency levels
Improvement Package 2	assembly_rvalue	surface_type = CrawlspaceWall performance_state = WillNotMeetRequirements	Assembly R-Value	Double	Enter the efficiency level of Crawlspace Wall surfaces that will not meet compliance efficiency levels

Table D: Data Collection for a Vented Attic remaining a Vented Attic

Building Type = Colonial or Ranch **Existing Condition**: Vented Attic **Improved Condition**: Vented Attic					
Input Type	Variable Name	SystemIdentifiers	Description	Value	Notes
Assessment	net_area	surface_type = AtticGableWall performance_state = Total	Net Area	Integer	Enter the net area of Attic Gable Wall surfaces.
Assessment	net_area	surface_type = AtticRoofDeck performance_state =	Net Area	Integer	Enter the net area of Attic Roof Deck surfaces.

		Total			
Improvement Package 1	net_area	surface_type = PrimaryAtticFloor performance_state = Improved	Net Area	Integer	Enter the net area of Attic Floor surfaces to be insulated.
Improvement Package 1	assembly_rvalue	surface_type = PrimaryAtticFloor performance_state = Improved	Assembly R-Value	Double	Enter the efficiency level of Primary Attic Floor surfaces that will be improved
Improvement Package 1	net_area	surface_type = SecondaryAtticFloor performance_state = Improved	Net Area	Integer	Enter the net area of Attic Floor surfaces to be insulated.
Improvement Package 1	assembly_rvalue	surface_type = SecondaryAtticFloor performance_state = Improved	Assembly R-Value	Double	Enter the efficiency level of Secondary Attic Floor surfaces that will be improved
Improvement Package 1	net_area	surface_type = AtticFloor performance_state = MeetsRequirements	Net Area	Integer	Enter the net area of Attic Floor surfaces already meeting compliance efficiency levels
Improvement Package 1	net_area	surface_type = AtticFloor performance_state = WillNotMeetRequirements	Net Area	Integer	Enter the net area of Attic Floor surfaces that will not meet compliance efficiency levels
Improvement Package 1	assembly_rvalue	surface_type = AtticFloor performance_state = WillNotMeetRequirements	Assembly R-Value	Double	Enter the efficiency level of Attic Floor surfaces that will not meet compliance efficiency levels
Building Type = Cape Cod **Existing Condition**: Vented Attic **Improved Condition**: Vented Attic					
Assessment	net_area	surface_type = AtticGableWalls performance_state = Total	Net Area	Integer	Enter the net area of Attic Gable Wall surfaces.
Assessment	net_area	surface_type = AtticRoofDeck performance_state = Total	Net Area	Integer	Enter the net area of Attic Roof Deck surfaces.
Improvement Package 1	net_area	surface_type = PrimaryAtticFloor performance_state = Improved	Net Area	Integer	Enter the net area of Attic Floor surfaces to be insulated.

Improvement Package 1	net_area	surface_type = SecondaryAtticFloor performance_state = Improved	Net Area	Integer	Enter the net area of Attic Floor surfaces to be insulated.
Improvement Package 1	net_area	surface_type = AtticFloor performance_state = MeetsRequirements	Net Area	Integer	Enter the net area of Attic Floor surfaces already meeting compliance efficiency levels
Improvement Package 1	net_area	surface_type = AtticFloor performance_state = WillNotMeetRequirements	Net Area	Integer	Enter the net area of Attic Floor surfaces that will not meet compliance efficiency levels
Improvement Package 1	assembly_rvalue	surface_type = AtticFloor performance_state = WillNotMeetRequirements	Assembly R-Value	Double	Enter the efficiency level of Attic Floor surfaces that will not meet compliance efficiency levels
Improvement Package 1	net_area	surface_type = KneeWalls performance_state = Improved	Net Area	Integer	Enter the net area of Knee Wall surfaces to be insulated.
Improvement Package 1	net_area	surface_type = KneeWalls performance_state = MeetsRequirements	Net Area	Integer	Enter the net area of Knee Wall surfaces already meeting compliance efficiency levels
Improvement Package 1	net_area	surface_type = KneeWalls performance_state = WillNotMeetRequirements	Net Area	Integer	Enter the net area of Knee Wall surfaces that will not meet compliance efficiency levels
Improvement Package 1	assembly_rvalue	surface_type = KneeWalls performance_state = WillNotMeetRequirements	Assembly R-Value	Double	Enter the efficiency level of Knee Wall surfaces that will not meet compliance efficiency levels
Improvement Package 1	net_area	surface_type = SlopeCeiling performance_state = Improved	Net Area	Integer	Enter the net area of Slope Ceiling surfaces to be insulated.
Improvement Package 1	net_area	surface_type = SlopeCeiling performance_state = MeetsRequirements	Net Area	Integer	Enter the net area of Slope Ceiling surfaces already meeting

					compliance efficiency levels
Improvement Package 1	net_area	surface_type = SlopeCeiling performance_state = WillNotMeetRequirements	Net Area	Integer	Enter the net area of Slope Ceiling surfaces that will not meet compliance efficiency levels
Improvement Package 1	assembly_rvalue	surface_type = SlopeCeiling performance_state = WillNotMeetRequirements	Assembly R-Value	Double	Enter the efficiency level of Slope Ceiling surfaces that will not meet compliance efficiency levels

Table E: Data Collection for an Unvented Attic remaining an Unvented Attic
OR
A Vented Attic becoming an Unvented Attic

Building Type = Colonial or Ranch **Existing Condition**: (Vented Attic OR Unvented Attic) **Improved Condition**: Unvented Attic					
Input Type	Variable Name	SystemIdentifiers	Description	Value	Notes
Assessment	net_area	surface_type = AtticFloor performance_state = Total	Net Area	Integer	Enter the net area of Attic Floor surfaces.
Improvement Package 1	net_area	surface_type = AtticGableWalls performance_state = Improved	Net Area	Integer	Enter the net area of Attic Gable Wall surfaces to be insulated.
Improvement Package 1	net_area	surface_type = AtticGableWalls performance_state = MeetsRequirements	Net Area	Integer	Enter the net area of Attic Gable Wall surfaces already meeting compliance efficiency levels
Improvement Package 1	net_area	surface_type = AtticGableWalls performance_state = WillNotMeetRequirements	Net Area	Integer	Enter the net area of Attic Gable Wall surfaces that will not meet compliance efficiency levels
Improvement Package 1	assembly_rvalue	surface_type = AtticGableWalls performance_state = WillNotMeetRequirements	Assembly R-Value	Double	Enter the efficiency level of Attic Gable Wall surfaces that will not meet compliance efficiency levels
Improvement Package 1	net_area	surface_type = AtticRoofDeck performance_state = Improved	Net Area	Integer	Enter the net area of Attic Roof Deck surfaces to be insulated.
Improvement Package 1	net_area	surface_type = AtticRoofDeck performance_state = MeetsRequirements	Net Area	Integer	Enter the net area of Attic Roof Deck surfaces already

					meeting compliance efficiency levels
Improvement Package 1	net_area	surface_type = AtticRoofDeck performance_state = WillNotMeetRequirements	Net Area	Integer	Enter the net area of Attic Roof Deck surfaces that will not meet compliance efficiency levels
Improvement Package 1	assembly_rvalue	surface_type = AtticRoofDeck performance_state = WillNotMeetRequirements	Assembly R-Value	Double	Enter the efficiency level of Attic Roof Deck surfaces that will not meet compliance efficiency levels
Building Type = Cape Cod **Existing Condition**: (Vented Attic OR Unvented Attic) **Improved Condition**: Unvented Attic					
Assessment	net_area	surface_type = KneeWall performance_state = Total	Net Area	Integer	Enter the net area of Knee Wall surfaces.
Assessment	net_area	surface_type = AtticFloor performance_state = Total	Net Area	Integer	Enter the net area of Attic Floor surfaces.
Improvement Package 1	net_area	surface_type = AtticRoofDeck performance_state = Improved	Net Area	Integer	Enter the net area of Attic Roof Deck surfaces to be insulated.
Improvement Package 1	net_area	surface_type = AtticRoofDeck performance_state = MeetsRequirements	Net Area	Integer	Enter the net area of Attic Roof Deck Wall surfaces already meeting compliance efficiency levels
Improvement Package 1	net_area	surface_type = AtticRoofDeck performance_state = WillNotMeetRequirements	Net Area	Integer	Enter the net area of Attic Roof Deck surfaces that will not meet compliance efficiency levels
Improvement Package 1	assembly_rvalue	surface_type = AtticRoofDeck performance_state = WillNotMeetRequirements	Assembly R-Value	Double	Enter the efficiency level of Attic Roof Deck surfaces that will not meet compliance efficiency levels
Improvement Package 1	net_area	surface_type = AtticGableWall performance_state = Improved	Net Area	Integer	Enter the net area of Attic Gable Wall surfaces to be insulated.
Improvement Package 1	net_area	surface_type = AtticGableWall performance_state = MeetsRequirements	Net Area	Integer	Enter the net area of Attic Gable Wall surfaces already meeting compliance efficiency levels
Improvement Package 1	net_area	surface_type = AtticGableWall performance_state = WillNotMeetRequirements	Net Area	Integer	Enter the net area of Attic Gable Wall surfaces that will not

					meet compliance efficiency levels
Improvement Package 1	assembly_rvalue	surface_type = AtticGableWall performance_state = WillNotMeetRequirements	Assembly R-Value	Double	Enter the efficiency level of Attic Gable Wall surfaces that will not meet compliance efficiency levels
Improvement Package 1	net_area	surface_type = SlopeCeiling performance_state = Improved	Net Area	Integer	Enter the net area of Slope Ceiling surfaces to be insulated.
Improvement Package 1	net_area	surface_type = SlopeCeiling performance_state = MeetsRequirements	Net Area	Integer	Enter the net area of Slope Ceiling surfaces already meeting compliance efficiency levels
Improvement Package 1	net_area	surface_type = SlopeCeiling performance_state = WillNotMeetRequirements	Net Area	Integer	Enter the net area of Slope Ceiling surfaces that will not meet compliance efficiency levels
Improvement Package 1	assembly_rvalue	surface_type = SlopeCeiling performance_state = WillNotMeetRequirements	Assembly R-Value	Double	Enter the efficiency level of Slope Ceiling surfaces that will not meet compliance efficiency levels

Table F: Data Collection for a Conditioned Attic remaining a Conditioned Attic

Building Type = Colonial or Ranch **Existing Condition**: Conditioned Attic **Improved Condition**: Conditioned Attic					
Input Type	Variable Name	SystemIdentifiers	Description	Value	Notes
Improvement Package 1	net_area	surface_type = AtticRoofDeck performance_state = Improved	Net Area	Integer	Enter the net area of Attic Roof Deck surfaces to be insulated.
Improvement Package 1	net_area	surface_type = AtticRoofDeck performance_state = MeetsRequirements	Net Area	Integer	Enter the net area of Attic Roof Deck surfaces already meeting compliance efficiency levels
Improvement Package 1	net_area	surface_type = AtticRoofDeck performance_state = WillNotMeetRequirements	Net Area	Integer	Enter the net area of Attic Roof Deck surfaces that will not meet compliance efficiency levels
Improvement Package 1	assembly_rvalue	surface_type = AtticRoofDeck performance_state = WillNotMeetRequirements	Assembly R-Value	Double	Enter the efficiency level of Attic Roof Deck surfaces that will not meet compliance efficiency levels

Table G describes the data collection needed to evaluate an optional HPWH improvement.

Table G: Data Collection for a HPWH Improvement 1

Input Type	Variable Name	Description	Value	Notes
Improvement Package 1 Improvement Package 2 Improvement Package 3	uniform_energy_factor	HPWH UEF	Double	Provided by HPWH manufacturer
	tank_volume	HPWH Tank Volume	Double	Provided by HPWH manufacturer

ccASHPs listed in the NEEP ccASHP Product Performance database are optional improvements. Table H describes the data collection needed to evaluate the (whole house) ccASHP backup system and Table I describes ccASHP system improvements. "Whole House" ccASHP backup system information is entered once, while specific ccASHP information may be entered for more than one ccASHP system.

Table H: Data Collection for a ccASHP Backup System

Input Type	**Variable Name**	**Description**	**Value**	**Notes**
Improvement Package 1 Improvement Package 2 Improvement Package 3	trm_scenario	The NY TRM ccASHP measure scenario that best matches the application.	1c 1d 2h 3c 4d	
	heating_switchover_temp	If a dual-fuel system, the outside temperature which switches the ccASHP off and turns on the **backup** system	none -5 0 5 10 15 20 25	Units in °F
	system_available	should a ccASHP **backup** system be modeled?	true false	
	input_heating_capacity	ccASHP **backup** system input capacity (whole-house)	double	Units in Btu
	fuel	Primary fuel source used by ccASHP **backup** system	none electric natural_gas lpg fuel_oil	
	seasonal_efficiency	ccASHP **backup** system seasonal efficiency	Double	Value should be between 0 and 1.
	seasonal_efficiency	ccASHP **backup** system seasonal efficiency	Double	Value should be between 0 and 1.

Table I: Data Collection for ccASHP System(s)

Input Type	Variable Name	Description	Value	Notes
Improvement Package 1 Improvement Package 2 Improvement Package 3	name	Unique ccASHP name	String	
	seer	ccASHP Rated SEER	Double	Available in NEEP ccASHP product listing database based on AHRI #
	ducting_configuration	Ducting Configuration as tested for AHRI # listing	"Multizone All Non-ducted" "Packaged Terminal Heat Pump" "Singlezone Non-ducted, Ceiling Placement" "Singlezone Non-ducted, Floor Placement" "Singlezone Non-ducted Wall Placement" "Multizone All Ducted" "Singlezone Ducted, 'Compact Ducted'" "Singlezone Ducted, Centrally Ducted" "Multizone Mix of Non-ducted and Ducted"	
	min_clg_cap_95	Minimum NEEP Cooling Capacity @ 95°F	Double	
	rated_clg_cap_95	Rated NEEP Cooling Capacity @ 95°F	Double	
	max_clg_cap_95	Maximum NEEP Cooling Capacity @ 95°F	Double	
	min_htg_cap_47	Minimum NEEP Heating Capacity @ 47°F	Double	
	rated_htg_cap_47	Rated NEEP Heating Capacity @ 47°F	Double	
	max_htg_cap_47	Maximum NEEP Heating Capacity @ 47°F	Double	
	min_htg_cap_5	Minimum NEEP Heating Capacity @ 5°F	Double	
	min_clg_cop_95	Maximum NEEP Cooling COP @ 95°F	Double	
	max_clg_cop_95	Minimum NEEP Cooling COP @ 95°F	Double	
	min_htg_cop_47	Minimum NEEP Heating COP @ 47°F	Double	
	min_htg_cop_5	Minimum NEEP Heating COP @ 5°F	Double	

Each ccASHP system is assigned a proportion of the conditioned floor area. In addition, cooling and heating 'load allocation adjustments' can be used to weight the amount (proportion) of whole house heating or cooling load seen by each ccASHP system. Table J describes the data collection needed to describe the load allocation to a specific ccASHP.

Table J: Data Collection for Load Allocations of ccASHP System(s)

Input Type	Variable Name	Description	Value	Notes
Improvement Package 1 Improvement Package 2 Improvement Package 3	conditioned_sqft_served	CFA associated with the ccASHP system	Double	
	htg_load_allocation_adjustment	Adjustment Factor to account for non-uniform heating conditions	Double	
	clg_load_allocation_adjustment	Adjustment Factor to account for non-uniform cooling conditions	Double	
	predominant_location	Predominant location of ccASHP duct systems	attic living space basement crawlspace none	

Quality Assurance

Quality Assurance measures are designed to increase the speed and reduce the cost of review compared to typical custom measures. *Supplemental Documentation Custom Measure Category 6: Residential Heat Pump Plus Weatherization Retrofit Standard Simulations for Measure Packages, Chapter D: Quality Assurance Methods for Standardized Simulations* contains a list of automated data checks measures that will be administered to an HPRXML submitted by a program management tool. These checks can also be implemented with the program management tool. Results of the automated data checks can include triggering a manual review. The set of data checks can be expanded and statistics for identifying outliers can be established. Appropriate programmatic quality control measures are still required.

References

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2. Dillion et. al., *Standard for the Calculation and Labeling of the Energy Performance of Low-Rise Residential Buildings using an Energy Rating Index* (January 2016).

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4. Gagliano et al., *NYSERDA Home Performance with Energy Star Realization Rate Attribution Study* (Ithaca, NY: 2015).
5. Roberts et al., *Assessment of the U.S. Department of Energy's Home Energy Scoring Tool*, (Golden, Colorado: July 2012).
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Return to Table of Contents