CATEGORY 5 – RESIDENTIAL RETROFIT STANDARDIZED SIMULATION FOR MEASURE PACKAGES

The standardized simulation savings approach outlined here can be used to determine savings for residential retrofit measure packages proposed for inclusion in residential retrofit programs to reduce heating and cooling loads to prepare homes for electrification. Savings are calculated using a standardized simulation that is an open source, physics-based calculation method 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 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 uses an OpenStudio/EnergyPlus framework[1438] and is capable of supporting calculations for a wide range of energy conservation measures (ECMs) and standardized packages for the residential sector, and could be readily expanded for application to commercial and multifamily buildings. The OpenStudio

[1438] 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 5: Residential Retrofit Standard Simulations for Measure Packages, Chapter A: Third Party Validation for the Open Source Tools (EnergyPlus and OpenStudio*). <Link to DMM pending publication>

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 PAs to readily incorporate envelope improvements into weatherization programs suitable for the residential sector. Packages are flexible in that the PA may select one or more energy efficiency improvements and 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.[1439] 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.[1440]

Standardized Simulation Benefits

Standardized simulations have a number of advantages over the typical partially deemed calculations and whole house modeling, and leverage the underlying physics models to address complex measures such as:

- Packages: Groups, or packages of measures interact with each other within the physics of the simulation. For example, envelope measures combine to change the reference temperature in the building.
- Floors: Floors above unconditioned spaces are not exposed to the outdoor temperature. Calculating the temperature of this unconditioned space is complicated. Uninsulated floors also reduce cooling load.
- Windows: Improvements to window U-Value also reduces the transmission of solar gain into the building. This solar gain varies with the direction of the window.
- Complex Technologies: Technologies where performance varies with temperature (e.g., heat pumps) or with changes in schedule can be represented accurately.
- Fuel conversions: Load reductions resulting from implementation of residential retrofit measure packages may include fuel conversion retrofits that are readily accounted for by standardized simulation methods.

The standardized simulation allows for a wider range of inputs, relative to the limitations of tables of variables, thereby increasing accuracy. Notable impacts:

[1439] 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).
[1440] 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).

- Expansion in the number of weather files available, from 7 to 49, offering improvements in accuracy of up to 10% for building locations outside of the seven urban areas currently in the TRM.
- Operation hours for heating and cooling equipment are not fixed Equivalent Full Load Hours. Equipment run times are flexible and determined by the load in the simulation.
- Thermostat settings can be adjusted to more closely reflect occupant operation of equipment. This can help reduce overestimation of savings.

The standard simulation provides improved metrics, including:

- Time and location dependent peak impacts, for both electricity and gas, using program defined flexible definitions of peak periods.
- Building design load reduction due to the weatherization measure packages using an Equivalent Block Design Load method

Description of the Residential Retrofit Measure Packages

This section describes the flexible and extensible residential retrofit measure 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.[1441] By standardizing the package offered to the consumer, the contractor may reduce customer acquisition costs while driving consumer choice of 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.
The simulation methods are both flexible and extensible enabling custom packages to satisfy policy goals specific to given regions.

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

- **Package 1**: attic air sealing and insulation, basement rim joist seal and insulate
- **Package 2**: wall insulation, floor insulation, and all measures included in Package 1
- **Package 3**: ENERGYSTAR windows (or equivalent) and all measures included in Package 2

[1441] The standardized simulation method may be updated to reflect the most current weather long-term average weather data used by the NY TRM.

Measure Category	Measure	Package 1	Package 2	Package 3	Compliance Efficiency
Air Leakage Sealing	**Air leakage improvement**	X	X	X	Ensure air leakage paths between the attic and living space are sealed, leakage paths between basement rim joist and outside are sealed and the final air leakage rate (ACH50) is measured with a blower door.
	Attic hatch sealing and insulation and pull-down stairs	X	X	X	R-20/R-13
Blown in cellulose attic insulation	**Attic insulation**	X	X	X	R-49
Insulation, Opaque shell	**Duct insulation (external to envelope)**	X	X	X	R-12
	Rim joist, spray foam	X	X	X	R-14
	Knee walls (Cape Cods)	X	X	X	R-15
	Wall cavity insulation		X	X	R-14
Window	**Window replacement**			X	U-Factor: 0.28 SHGC: 0.32

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69.[1442]

Baseline efficiencies

[1442] Based on BG&E 'Development of Residential Load Profile for Central Air Conditioners and Heat Pumps' research, the Maryland Peak Definition coincidence factor is 0.69. This study is not publicly available, but is referenced by M. M. Straub, Using Available Information for Efficient Evaluation of Demand-Side Management. Programs, Electricity Journal, September 2011 and supported by research conducted by Cadmus on behalf of the RM Management Committee.

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

The compliance condition is a residential opaque building shell with increased insulation meeting or exceeding the Package 1, Package 2, and Package 3 described in the table 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[1443] 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.

Residential 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 the standardized simulation 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 the table above, combined with the sensitivity analysis,[1444] drive the definition of the standardized program data model (aka, Heat Pump Ready eXtensible Markup Language HPRXML).

Method for Calculation: Transforming Program Data (HPRXML) into HPXML

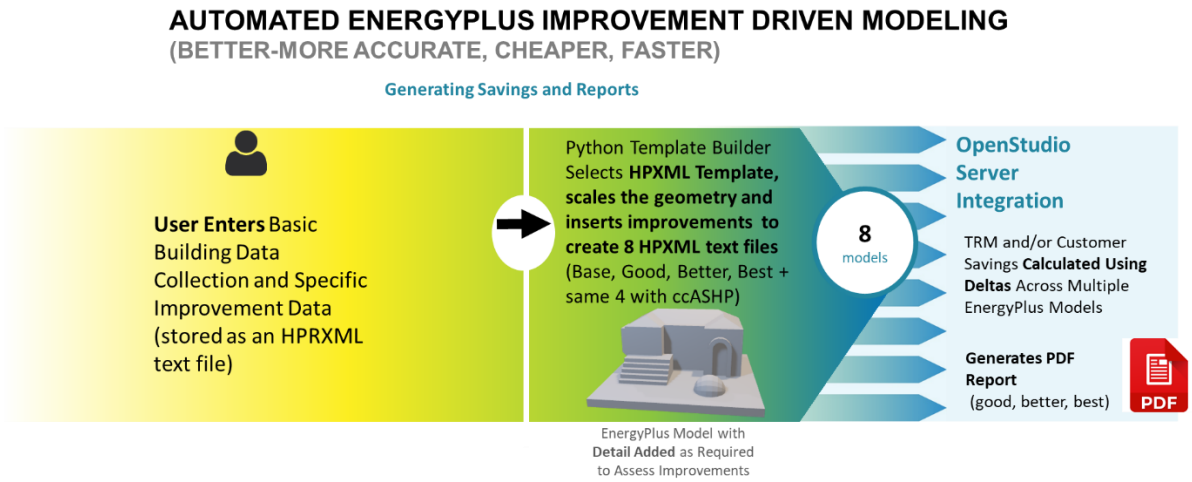
The standardized simulation data collection and inputs have been simplified significantly over that generally required for energy modeling tools and leverages the BPI-2100-S-2013 Standard for Home Performance-Related Data Transfer (Home Performance XML). The HPRXML is transformed to HPXML and is aligned with the US Department of Energy Home Energy Score data set to provide a future option to generate a post retrofit Home Energy Score, albeit with current credentialing requirements. The US DOE has conducted a considerable amount of field validation on this data model as a front end for

[1443] ECCCNYS 2020, Section R503 Building Thermal Envelope.

[1444] The sensitivity analysis is described in supplemental documentation for *the Custom Measure Category 5: Residential Retrofit Standard Simulations for Measure Packages, Chapter C: Validation of Savings Results.* <Link to DMM pending publication>

a simulation.[1445] Additionally, the HPRXML data taxonomy was aligned with Home Energy Score where possible.

The transformation of the HPRXML data model into HPXML uses an approach called "Improvement Driven Modeling" (see figure below). This approach leverages the fact that the energy savings is primarily driven by the change in the model. Detailed data collection efforts are focused on defining the specifications of the changes to the building. The building itself is generalized as a box, defined by primary characteristics.



The HPXML files generated by the method are fed into the open source OpenStudio-HPXML Measure[1446] developed by the National Renewable Energy Lab (NREL). OpenStudio is "middleware" software, also developed by NREL, built to simplify the process of working with the EnergyPlus simulation engine. OpenStudio Measures are scripts, or interpreted programs, that leverage the OpenStudio Application Programming Interface to manage the simulation processes. The OpenStudio-HPXML Measure is called to run the EnergyPlus simulations using the building descriptions in corresponding HPXML files.[1447]

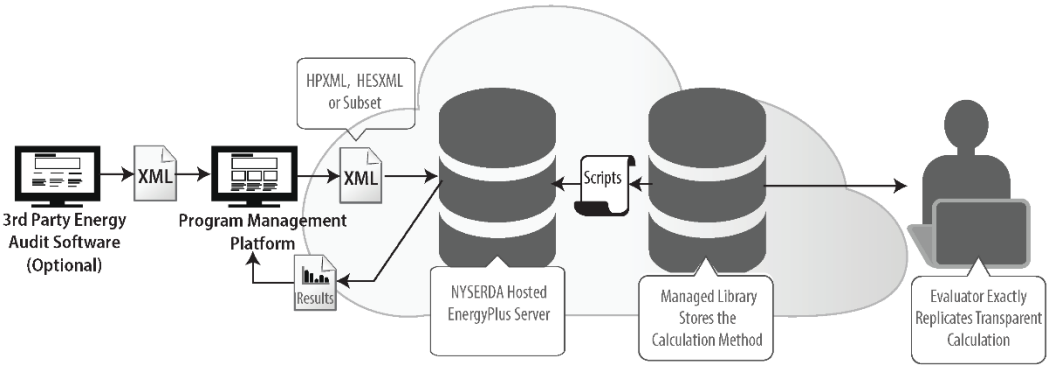
Total electricity end use, total natural gas or other fuel end use, peak electric and gas demand, zone sensible heating load, and zone sensible cooling load are pulled from the results for each simulation. The process returns a CSV file with the result for each run in a row of the CSV file.
To calculate savings, the values for performance metrics across improvement packages are subtracted by the program management software from those for the base (pre-improvement) building energy model.

[1445] 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 5: Residential Retrofit Standard Simulations for Measure Packages, Chapter A: Third Party Validation for the Open Source Tools (EnergyPlus and OpenStudio).* <Link to DMM pending publication>
[1446] https://github.com/NREL/OpenStudio-HPXML
[1447] More information about this Measure can be found here: https://openstudio-hpxml.readthedocs.io/en/latest/

The formulas, assumptions, and tables supporting the transformation from HPRXML into HPXML are provided in supplemental documentation for the *Custom Measure 5: Residential Retrofit Standard Simulations for Measure Packages, Chapter B: Detailed Description for Transforming Standardized Program Data (HPRXML) into HPXML*.

Managing Workflows

The standardized simulation is maintained by transparently transforming the program data into the HPXML data standard before processing by the OpenStudio/EnergyPlus simulation framework. An open source OpenStudio "measure" or script processes the HPXML file producing an EnergyPlus simulation run for each HPXML file it processes. This approach allows the calculations of the standardized simulation to be replicated on a local computer as shown in the figure below.[1448]



The standardized simulation is deployed on a central cloud server. Access to the server is through an online Application Programming Interface (API). Data files in a standard format (HPRXML) are sent by a program administration platform to the cloud server and processed into different HPXML files representing the existing building, including any required baseline values and the Package 1, Package 2, and Package 3 files.

Detailed Extract Transform Load Workflow Description

The Residential Retrofit Standardized Simulation for Measure Packages uses a transparent *extract-transform-load (ETL) workflow* to support standardized EnergyPlus simulation savings estimation for Package 1, Package 2, and Package 3 improvements in single-family detached residences. This is a data industry standard approach to managing the transformation of data with algorithms. The following describes the processes associated with each stage of this workflow.

[1448] Support for replicating the generation of an EnergyPlus simulation using the OpenStudio "measure" is provided in supplemental documentation for the *Custom Measure Category 5: Residential Retrofit Standard Simulations for Measure Packages, Chapter G: Methods for Third Party Review of the Residential Retrofit Standard Simulations for Measure Packages Savings Method*.

Extract

Data extraction is the first stage of an ETL workflow. Data is collected using a program management platform that validates contractor entries according to a set of tests described in supplemental documentation for the *Custom Measure 5: Residential Retrofit Standard Simulations for Measure Packages, Chapter D: Quality Assurance Methods for Standardized Simulations*. Data is extracted from the Program Management platform in XML format. The building level XML data file that is passed into the next stage of this workflow is called a Heat Pump Ready XML (HPRXML).[1449] The calculation related inputs to the HPRXML file are described in the Summary of Data Source and Variables section below. HPRXML contains a combination of building description and improvement description. When the HPRXML is processed into HPXML the detailed descriptions of the improvements are embedded in the package HPXML files. Improvements are added in stages to create packages with increasing savings depth.

Transform

The extracted HPRXML is read for transformation. The goal of this step is to convert a HPRXML into Home Performance XML files (HPXML). These HPXMLs represent the:

- Base Building: The building as it currently exists.
- Package 1, Package 2, and Package 3 Packages: Improvements from corresponding packages within the extracted HPRXML are used to create the improved buildings.

Documentation for the full transform is described in supplemental documentation for the *Custom Measure Category 5: Residential Retrofit Standard Simulations for Measure Packages, Chapter B: Detailed Description for Transforming Standardized Program Data (HPRXML) into HPXML*. HPXML files generated can be downloaded and inspected, and the changes in the HPXML data compared to transforms described in the documentation. The files can then be run in the OpenStudio/EnergyPlus framework, generating the same results as the cloud-based simulation. This provides full transparency on the calculation method.

To support multiple envelope designs and HVAC types, there are individual XML templates for each primary building component. See tables below for examples. Combining the templates that match the envelope design and HVAC type for an inspected home creates a base building HPXML. Three building styles, five foundation types, and eight HVAC systems are supported (see Table Supported Envelope Designs and HVAC Types). All buildings are modeled with vented attics. Contractors can select the closest type for buildings outside of the three primary types supported.

[1449] Further details are described in supplemental documentation for the *Custom Measure Category 5: Residential Retrofit Standard Simulations for Measure Packages, Chapter B: Detailed Description for Transforming Standardized Program Data (HPRXML) into HPXML*.

Table: Supported Envelope Designs and HVAC Types

Building Component	Enumeration
Style	Ranch, Colonial, Cape Cod
Foundation Type	Slab, Conditioned Basement, Unconditioned Basement, Vented Crawl Space, Unvented Crawl Space
Heating Systems	Condensing and Non-Condensing Furnaces, Wall Furnaces, Condensing and Non-Condensing Boilers, Electric Baseboards
Cooling Systems	Room Air Conditioners, Central Air Conditioners
Heat Pumps	Air Source Heat Pumps, Ductless Mini-Splits, Ground Source Heat Pumps

Table Data Transform Abstractions

HPRXML Inputs	Abstracted HPXML Specifications
Construction Era	Attic Floor R-Value
Building Style, Number of Stories, Conditioned Floor Area	Roof Pitch, Roof Area, Attic Gable Area, Cape Cod Knee Wall Area, Cape Cod Knee Roof Area, Above Grade Wall Area, Window Area, Rim Joist Area, Attic Floor/ Slab / Floor above Foundation Area, Foundation Wall Area, Hot Water Piping Length, Supply and Return Duct Areas
Foundation Type	Conditioned Building Volume, Foundation Wall Area

Load

During this stage, the HPXML files are fed into the OpenStudio-HPXML Measure. The OpenStudio-HPXML Measure will run the residential EnergyPlus simulations using the building descriptions in corresponding HPXML files.[1450]

Total electricity end use, total natural gas or additional fuel end use, peak electric demand, ,peak gas demand, zone sensible heating load, and zone sensible cooling load are pulled from the results for each simulation. Before calculating savings, the HPXML file results are grouped into categories. To calculate savings in each group, the values for performance metrics across improvement packages are subtracted from those for the corresponding base building.

Operating Hours

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

[1450] More information about this Measure can be found here: https://openstudio-hpxml.readthedocs.io/en/latest/

Operation hours for heating and cooling equipment are not fixed Equivalent Full Load Hours. Equipment run times are flexible and determined by the load in the in the 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. Table Estimated Average Measure Impacts, below, contains the estimated average improvements per measure for each package and an estimate of the expected savings contribution from that measure on an average home.

Residential Retrofit Measure	**Estimated Area**	**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

Table Estimated Average Measure Impacts

These percentages are used to create a Composite Weighted Package Life, presented in Table Calculation of Composite Weighed Package Life, below.

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	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 2	Wall Insulation	25		43%	37%	22.9
Package 2	Floor Insulation	25		14%	12%	
Package 3	Replacement Windows	20			14%	22.5

Table Calculation of Composite Weighed Package Life

Ancillary Fossil Fuel Savings Impact

Ancillary savings impacts are implicitly captured in the simulation.

Ancillary Electric Savings Impact

*A*ncillary savings impacts are implicitly captured in the simulation.

Additional Outputs from the Residential Retrofit Measure Packages

The OpenStudio/EnergyPlus based method provides additional metrics beyond annual savings and demand impacts that may be of high value to programs.

- **Manual J "Equivalent" Heating and Cooling Loads** The EnergyPlus / OpenStudio workflow also outputs "Whole House" Peak Heating and Cooling loads calculated using an approach which mimics Manual J8 AE. When modeled HVAC equipment is indicated as 'auto-sized', these capacities are used to set the auto-sized capacity values. The "Manual J8 AE Equivalent" method estimates the peak heating and cooling load contributions of windows, doors, walls, roofs, floors and infiltration/ventilation components and occupant related internal gains that are described within an HPXML file.
- **Time and Location Dependent Peak Demand** The EnergyPlus / OpenStudio workflow generates several data outputs that supports the estimation of location specific values of Peak Demand. A machine learning algorithm (also used by the DOE Asset Score Tool) has been used to map one of 49 different TMY3 Weather files to each of the 1,753 New York Zip Codes. For each HPXML file and associated simulation run, a maximum value of the whole building electricity meter is reported, along with the paired 10-minute time stamp of occurrence. In addition, the simulation provides the peak value (and time of peak) of all electricity end-uses, such as electric heating or electric cooling. Finally, the workflow also produces time series outputs for whole building electricity, which

can be post processed to estimate values associated with a coincident system peak.

- **Gas Peak Heating Load** The EnergyPlus / OpenStudio workflow can use the same techniques available for estimating Peak Electrical Demand impacts that are described above, for Natural Gas. For each HPXML file and associated simulation, both the time of peak and magnitude of peak Natural Gas, for both whole building usage and the heating end-use, can be generated.
- **Customer Facing Interacted Fuel Conversion Calculations** The standardized simulation supports the calculation of interacted savings, such as the conversion from existing equipment to heat pumps, without any envelope improvements, and in combination with each of the measure packages.

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 Residential Retrofit Standard Simulations for Measure Packages 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 results of the validation are described in supplemental documentation for the *Custom Measure 5: Residential Retrofit Standard Simulations for Measure Packages, Chapter C: Validation of Savings Results.*

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 for the *Custom Measure Category 5: Residential 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 for the Custom Measure Category 5: Residential Retrofit Standard Simulations for Measure Packages,*

Chapter 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 contractor entered fields are described in the table below.

Input Type	Variable Name	Description	Values	Notes
Assessment	YearBuilt	Estimated Construction Era	2010 2000 1990 1980 1970 1960 1950 1940 1930 1920 1900	Select the decade range the main part of the house was constructed.
Assessment	FloorArea	Conditioned Floor Area	Integer	Enter the total conditioned floor area of the house
Assessment	BuildingType	Building Type	Cape Cod Colonial Ranch	Select the type of the home
Assessment	NumberStories	Number of Stories	Integer	Enter a value between 1 and 3
Assessment	StoryHeight	Average Story height (ft)	Integer	Enter a value between 6 and 12
Assessment	Bedrooms	Number of Bedrooms	Integer	Enter value between 1 and 10
Assessment	FoundationType	Foundation Type	Conditioned Basement Slab on Grade Unconditioned Basement Unvented Crawlspace Vented Crawlspace	Enter the predominant foundation type in the house
Assessment	WallInsulation_Depth	Depth of wall cavity	2x4 2x6	Select the wall cavity depth based on framing members of the wall

Input Type	Variable Name	Description	Values	Notes
Assessment	RimJoistInsulation	Rim/Band Insulation level	None	Select the level of existing insulation for the rim joist/band
			Partial	
			Full	
Assessment	BlowerDoorIn	Blower Door CFM50	Integer	Enter the Existing air leakage in CFM50
Assessment	EstimatedAirLeakage	Estimated Air Leakage	Measured	Enter estimated air leakage if friable asbestos is present in the home or measured leakage if available
			Very Leaky	
			Leaky	
			Average	
			Fairly Tight	
			Tight	
Assessment	WindowGlazing	Window Glazing Type	Single-pane, clear	Select the predominant glazing type for existing windows
			Single-pane, tinted	
			Double-pane, clear	
			Double-pane, tinted	
			Double-pane, insulating low-E	
			Double-pane, insulating low-E, argon gas fill	
			Double-pane, solar-control low-E	
			Double-pane, solar-control low-E, argon gas fill	
			Triple-pane, insulating low-E, argon gas fill	
Assessment	PrimaryHeatingFuel	Primary Heating Fuel	Electric	Select the fuel for the primary heating system
			Natural Gas	
			LPG (Propane)	
			Fuel Oil	

Input Type	Variable Name	Description	Values	Notes
Assessment	PrimaryHeatingSystem	Primary Heating Type	Heat Pump	Select the type of the primary heating system
			Boiler	
			Condensing boiler	
			Baseboard	
			Condensing furnace	
			Central furnace	
			Ground Coupled Heat Pump	
			Ductless mini split heat pump	
			Wall furnace	
Assessment	PrimaryHeatingSystemAge	Primary Heating System Age	2010	Select the decade in which the primary heating system was installed
			2000	
			1990	
			1980	
			1970	
Assessment	CoolingEquipmentType	Primary Cooling Type	Heat Pump	Select the type of the primary cooling system
			Central furnace	
			Ground Coupled Heat Pump	
			Ductless mini split heat pump	
			Room	
			None	
Assessment	CoolingSystemYear	Primary Cooling System Age	2010	Select the decade in which the primary cooling system was installed
			2000	
			1990	
			1980	
			1970	
Assessment	HotWaterFuel	Hot Water Fuel	Electricity	Select the fuel used to provide hot water
			Natural Gas	
			LPG (Propane)	
			Fuel Oil	
			Wood	
			Wood Pellets	

Input Type	Variable Name	Description	Values	Notes
Assessment	ThemostatSchedule	Thermostat Schedule	None Nightly and Weekday Nightly Only	Are most of the thermostats set up on a schedule?
Assessment	ElectricityUse	Annual Electricity Cost ($)	Decimal	Enter the annual electricity use in USD ($)
Assessment	OtherFuel1	Other Fuel 1	None Natural Gas LPG (Propane) Fuel Oil Wood Wood Pellets	If there is another fuel in the house for other purpose, select from the list
Assessment	OtherFuelUse1	Annual Other Fuel 1 Cost ($)	Decimal	Enter the annual use in USD ($) for the other fuel
Assessment	OtherFuel2	Other Fuel 2	None Natural Gas LPG (Propane) Fuel Oil Wood Wood Pellets	If there is another fuel in the house for other purpose, select from the list
Assessment	OtherFuelUse2	Annual Other Fuel 2 Cost ($)	Decimal	Enter the annual use in USD ($) for the 2nd other fuel
Improvement Package 1	BlowerDoorOut	Improved Blower Door CFM50	Integer	Enter the improved air leakage in CFM50
Improvement Package 1	PrimaryAttic_ImprovedArea	Primary Attic Improved Area	Integer	Enter the area in sq. ft. of the improved attic floor, else enter the area in sq.ft of the roof. Enter 0 if no improvement is needed
Improvement Package 1	PrimaryAttic_ImprovedRValue	Primary Attic Improved R-Value	Integer	Enter the improved attic R-Value of either floor or roof, depending on what is insulated

Input Type	Variable Name	Description	Values	Notes
Improvement Package 1	SecondaryAttic_ImprovedArea	Secondary Attic Improved Area	String	If insulating attic floor, Enter the area in sq. ft. of the improved attic floor, else enter the area in sq.ft of the roof. Enter 0 if no improvement is needed.
Improvement Package 1	SecondaryAttic_ImprovedRValue	Secondary Attic Improved R-Value	Integer	Enter the improved attic R-Value of either floor or roof, depending on what is insulated
Improvement Package 2	BlowerDoorOut	Improved Blower Door CFM50	Integer	Enter the improved air leakage in CFM50
Improvement Package 2	ExposedFloor_Area	Improved Floor Area	Integer	Enter the area in sq.ft. of the improved floor insulation. Enter 0 if no improvement is needed.
Improvement Package 2	WallInsulation_Area	Improved Wall Area	Integer	Enter the area in sq. ft. of the improved wall insulation. Enter 0 if no improvement is needed.
Improvement Package 3	BlowerDoorOut	Improved Blower Door CFM50	Integer	Enter the improved air leakage in CFM50
Improvement Package 3	WindowArea_North	Window Improved Area - North (Sq Ft)	Integer	Enter the area in sq.ft. of improved windows on the North side of the house. Enter 0 if no improvement is needed.
Improvement Package 3	WindowArea_East	Window Improved Area - East (Sq Ft)	Integer	Enter the area in sq.ft. of improved windows on the East side of the house. Enter 0 if no improvement is needed.

Input Type	Variable Name	Description	Values	Notes
Improvement Package 3	WindowArea_South	Window Improved Area - South (Sq Ft)	Integer	Enter the area in sq.ft. of improved windows on the South side of the house. Enter 0 if no improvement is needed.
Improvement Package 3	WindowArea_West	Window Improved Area - West (Sq Ft)	Integer	Enter the area in sq.ft. of improved windows on the West side of the house. Enter 0 if no improvement is needed.
Improvement Package 3	Window_ImprovedUValue	Window New U-Value (Predominant)	Integer	Enter the predominant improved U-Value
Improvement Package 3	Window_ImprovedSHGC	Window New SHGC (Predominant)	Integer	Enter the predominant improved Solar Heat Gain Coefficient

Quality Assurance and Quality Control Procedures

Quality Assurance measures are designed to increase the speed and reduce the cost of review compared to typical custom measures. Supplemental documentation for the *Custom Measure Category 5: Residential Retrofit Standard Simulations for Measure Packages, Chapter D: Quality Assurance Methods for Standardized Simulations* contains a list of automated data checks measures that will administered by a program management tool before sending a program XML file to the EnergyPlus calculation server. 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.