OpenStudio-HPXML Documentation

NREL

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CHAPTER 1

Introduction

The OpenStudio-HPXML repository consists of a simple residential EnergyPlus-based workflow build on top of OpenStudio measures. The workflow operates using HPXML building description files.

The two OpenStudio measures used by the workflow are:

1. `HPXMLtoOpenStudio`: A measure that translates an HPXML file to an OpenStudio model.
2. `SimulationOutputReport`: A reporting measure that generates a variety of annual/timeseries outputs for a residential HPXML-based model.

1.1 Scope (Dwelling Units)

The OpenStudio-HPXML workflow is intended to be used to model individual residential dwelling units – either a single-family detached (SFD) building, or a single unit of a single-family attached (SFA) or multifamily (MF) building. This approach was taken because:

- It is required/desired for certain projects.
- It improves runtime speed by being able to simulate individual units in parallel (as opposed to simulating the entire building).
- It doesn't necessarily preclude the possibility of running a single integrated EnergyPlus simulation.

To model units of SFA/MF buildings, current capabilities include:

- Defining surfaces adjacent to generic SFA/MF spaces (e.g., "other housing unit" or "other multifamily buffer space").
- Locating various building components (e.g., ducts, water heaters, appliances) in these SFA/MF spaces.
- Defining shared systems (HVAC, water heating, mechanical ventilation, etc.) by approximating the energy use attributed to the unit.

Note that only the energy use attributed to each dwelling unit is calculated. Other OpenStudio capabilities should be used to supplement this workflow if the energy use of non-residential dwelling spaces (e.g., gyms, elevators, corridors, etc.) are of interest.

For situations where more complex, integrated modeling is required, it is possible to merge multiple OpenStudio models together into a single model, such that one could merge all residential OSMs together and potentially combine it with a commercial OSM. That capability is outside the scope of this project.

1.2 Accuracy vs Speed

The EnergyPlus simulation engine is like a Swiss army knife. There are often multiple models available for the same building technology with varying trade-offs between accuracy and speed. This workflow standardizes the use of EnergyPlus (e.g., the choice of models appropriate for residential buildings) to provide a fast and easy to use solution.

The workflow is continuously being evaluated for ways to reduce runtime without significant impact on accuracy. End-to-end simulations typically run in 3-10 seconds, depending on complexity, computer platform and speed, etc.

There are additional ways that software developers using this workflow can reduce runtime:

- Run on Linux/Mac platform, which is significantly faster than Windows.
- Run on computing environments with 1) fast CPUs, 2) sufficient memory, and 3) enough processors to allow all simulations to run in parallel.
- Limit requests for timeseries output (e.g., `--hourly`, `--daily`, `--timestep` arguments) and limit the number of output variables requested.
- Avoid using the `--add-component-loads` argument if heating/cooling component loads are not of interest.
- Use the `--skip-validation` argument if the HPXML input file has already been validated against the Schema & Schematron documents.

1.3 License

This project is available under a BSD-3-like license, which is a free, open-source, and permissive license. For more information, check out the license file.

CHAPTER 2

Getting Started

2.1 Setup

To get started:

1. Download OpenStudio 3.1.0 and install the Command Line Interface/EnergyPlus components, or use the nrel/openstudio docker image.
2. Download the latest release.

2.2 Running

To programatically run simulations, it's recommended to use the OpenStudio Command Line Interface. Two general approaches (basic and advanced) for running via the CLI are described below. The OpenStudio measures can also be run from user interfaces (e.g., the OpenStudio Application or OpenStudio Parametric Analysis Tool (PAT)).

Note: If the `openstudio` command is not found, it's because the executable is not in your PATH. Either add the executable to your PATH or point directly to the executable found in the openstudio-X.X.X/bin directory.

2.2.1 Basic Run

The simplest and fastest method is to call the OpenStudio CLI with the provided `workflow/run_simulation.rb` script.

For example: `openstudio workflow/run_simulation.rb -x workflow/sample_files/base.xml`

This will create a "run" directory with all input/output files. By default it will be found at the same location as the input HPXML file.

Run `openstudio workflow/run_simulation.rb -h` to see all available commands/arguments.

2.2.2 Advanced Run

If additional flexibility is desired (e.g., specifying individual measure arguments, including additional OpenStudio measures to run alongside this measure in a workflow, etc.), create an OpenStudio Workflow (OSW) file. The OSW is a JSON file that will specify all the OpenStudio measures (and their arguments) to be run sequentially. A template OSW that simply runs the HPXMLtoOpenStudio and SimulationOutputReport measures on the `workflow/sample_files/base.xml` file can be found at `workflow/template.osw`.

For example: `openstudio run -w workflow/template.osw`

This will create a "run" directory with all input/output files. By default it will be found at the same location as the OSW file.

2.2.3 Outputs

In addition to the standard EnergyPlus outputs found in the run directory, a variety of high-level annual outputs are conveniently reported in the resulting `run/results_annual.csv` (or `run/results_annual.json`) file.

Timeseries outputs can also be requested using either the Basic or Advanced approaches. When requested, timeseries outputs will be found in the `run/results_timeseries.csv` (or `run/results_timeseries.json`) file.

See *Workflow Outputs* for a description of all available outputs available.

CHAPTER 3

Workflow Inputs

OpenStudio-HPXML requires a building description in an HPXML file format. HPXML is an open data standard for collecting and transferring home energy data. Using HPXML files reduces the complexity and effort for software developers to leverage the EnergyPlus simulation engine.

3.1 Using HPXML

HPXML is an flexible and extensible format, where nearly all elements in the schema are optional and custom elements can be included. Because of this, a stricter set of requirements for the HPXML file have been developed for purposes of running EnergyPlus simulations.

HPXML files submitted to OpenStudio-HPXML should undergo a two step validation process:

1. Validation against the HPXML Schema

   The HPXML XSD Schema can be found at `HPXMLtoOpenStudio/resources/HPXML.xsd`. It should be used by the software developer to validate their HPXML file prior to running the simulation. XSD Schemas are used to validate what elements/attributes/enumerations are available, data types for elements/attributes, the number/order of children elements, etc.

   OpenStudio-HPXML **does not** validate the HPXML file against the XSD Schema and assumes the file submitted is valid. However, OpenStudio-HPXML does automatically check for valid data types (e.g., integer vs string), enumeration choices, and numeric values within min/max.

2. Validation using Schematron

   The Schematron document for the EnergyPlus use case can be found at `HPXMLtoOpenStudio/resources/EPvalidator.xml`. Schematron is a rule-based validation language, expressed in XML using XPath expressions, for validating the presence or absence of inputs in XML files. As opposed to an XSD Schema, a Schematron document validates constraints and requirements based on conditionals and other logical statements. For example, if an element is specified with a particular value, the applicable enumerations of another element may change.

   OpenStudio-HPXML **automatically validates** the HPXML file against the Schematron document and reports any validation errors, but software developers may find it beneficial to also integrate Schematron validation into their software.

Important: Usage of both validation approaches (XSD and Schematron) is recommended for developers actively working on creating HPXML files for EnergyPlus simulations:

- Validation against XSD for general correctness and usage of HPXML
- Validation against Schematron for understanding XML document requirements specific to running EnergyPlus

3.1.1 Input Defaults

A large number of elements in the HPXML file are optional and can be defaulted. Default values, equations, and logic are described throughout this documentation.

Defaults can also be seen in the `in.xml` file generated in the run directory, where additional fields are populated for inspection.

For example, suppose a HPXML file has a window defined as follows:

```
<Window>
  <SystemIdentifier id='Window'/>
  <Area>108.0</Area>
  <Azimuth>0</Azimuth>
  <UFactor>0.33</UFactor>
  <SHGC>0.45</SHGC>
  <AttachedToWall idref='Wall'/>
</Window>
```

In the `in.xml` file, the window would have additional elements like so:

```
<Window>
  <SystemIdentifier id='Window'/>
  <Area>108.0</Area>
  <Azimuth>0</Azimuth>
  <UFactor>0.33</UFactor>
  <SHGC>0.45</SHGC>
  <InteriorShading>
    <SystemIdentifier id='WindowInteriorShading'/>
    <SummerShadingCoefficient dataSource='software'>0.7</SummerShadingCoefficient>
    <WinterShadingCoefficient dataSource='software'>0.85</WinterShadingCoefficient>
  </InteriorShading>
  <FractionOperable dataSource='software'>0.67</FractionOperable>
  <AttachedToWall idref='Wall'/>
</Window>
```

Note: The OpenStudio-HPXML workflow generally treats missing elements differently than missing values. For example, if there is a `Window` with no `Overhangs` element defined, the window will be interpreted as having no overhangs and modeled this way. On the other hand, if there is a `Window` with no `FractionOperable` value defined, it is assumed that the operable property of the window is unknown and will be defaulted in the model according to *HPXML Windows*.

3.2 HPXML Software Info

High-level simulation inputs are entered in `/HPXML/SoftwareInfo`.

3.2.1 HPXML Simulation Control

EnergyPlus simulation controls are entered in `/HPXML/SoftwareInfo/extension/SimulationControl`.

Element	Type	Units	Constraints	Required	Default	Description
`Timestep`	integer	minutes	Divisor of 60	No	60 (1 hour)	Timestep
`BeginMonth`	integer		1 - 12[1]	No	1 (January)	Run period start date
`BeginDayOfMonth`	integer		1 - 31	No	1	Run period start date
`EndMonth`	integer		1 - 12	No	12 (December)	Run period end date
`EndDayOfMonth`	integer		1 - 31	No		Run period end date
`CalendarYear`	integer		> 1600	No	2007 (for TMY weather)[2]	Calendar year (for start day of week)
`DaylightSaving/Enabled`	boolean			No	true	Daylight savings enabled?

If daylight saving is enabled, additional information is specified in `DaylightSaving`.

Element	Type	Units	Constraints	Required	Default	Description
`BeginMonth` and `BeginDayOfMonth`	integer		1 - 12 and 1 - 31	No	EPW else 3/12 (March 12)[3]	Start date
`EndMonth` and `EndDayOfMonth`	integer		1 - 12 and 1 - 31	No	EPW else 11/5 (November 5)	End date

3.2.2 HPXML HVAC Sizing Control

HVAC equipment sizing controls are entered in `/HPXML/SoftwareInfo/extension/HVACSizingControl`.

Element	Type	Units	Constraints	Required	Default	Description
`AllowIncreasedFixedCapacities`	boolean			No	false	Logic for fixed capacity HVAC equipment[4]
`UseMaxLoadForHeatPumps`	boolean			No	true	Logic for autosized heat pumps[5]

[1] BeginMonth/BeginDayOfMonth date must occur before EndMonth/EndDayOfMonth date (e.g., a run period from 10/1 to 3/31 is invalid).

[2] CalendarYear only applies to TMY (Typical Meteorological Year) weather. For AMY (Actual Meteorological Year) weather, the AMY year will be used regardless of what is specified.

[3] Daylight savings dates will be defined according to the EPW weather file header; if not available, fallback default values listed above will be used.

[4] If AllowIncreasedFixedCapacities is true, the larger of user-specified fixed capacity and design load will be used (to reduce potential for unmet loads); otherwise user-specified fixed capacity is used.

[5] If UseMaxLoadForHeatPumps is true, autosized heat pumps are sized based on the maximum of heating/cooling design loads; otherwise sized per ACCA Manual J/S based on cooling design loads with some oversizing allowances for heating design loads.

3.3 HPXML Building Summary

High-level building summary information is entered in `/HPXML/Building/BuildingDetails/BuildingSummary`.

3.3.1 HPXML Site

Building site information is entered in `/HPXML/Building/BuildingDetails/BuildingSummary/Site`.

Element	Type	Units	Constraints	Required	Default	Notes
`SiteType`	string		See[6]	No	suburban	Terrain type for infiltration model
`ShieldingofHome`	string		See[7]	No	normal	Presence of nearby buildings, trees, obstructions for infiltration model
`extension/Neighbors`	element		>= 0	No	<none>	Presence of neighboring buildings for solar shading

For each neighboring building defined, additional information is entered in a `extension/Neighbors/NeighborBuilding`.

Element	Type	Units	Constraints	Required	Default	Notes
`Azimuth`	integer	deg	0 - 359	Yes		Direction of neighbors (clockwise from North)
`Distance`	double	ft	> 0	Yes		Distance of neighbor from the dwelling unit
`Height`	double	ft	> 0	No	See[8]	Height of neighbor

3.3.2 HPXML Building Occupancy

Building occupancy is entered in `/HPXML/Building/BuildingDetails/BuildingSummary/BuildingOccupancy`.

Element	Type	Units	Constraints	Required	Default	Notes
`NumberofResidents`	integer		>= 0	No	<number of bedrooms>	Number of occupants[9]

[6] SiteType choices are “rural”, “suburban”, or “urban”.
[7] ShieldingofHome choices are “normal”, “exposed”, or “well-shielded”.
[8] If Height not provided, assumed to be same height as the dwelling unit.
[9] NumberofResidents is only used for occupant heat gain. Most occupancy assumptions (e.g., usage of plug loads, appliances, hot water, etc.) are driven by the number of bedrooms, not number of occupants.

3.3.3 HPXML Building Construction

Building construction is entered in `/HPXML/Building/BuildingDetails/BuildingSummary/BuildingConstruction`.

Element	Type	Units	Constraints	Required	Default	Notes
`ResidentialFacilityType`	string		See[10]	Yes		Type of dwelling unit
`NumberofConditionedFloors`	double		> 0	Yes		Number of conditioned floors (including a basement)
`NumberofConditionedFloorsAboveGrade`	double		> 0, <= NumberofConditionedFloors	Yes		Number of conditioned floors above grade (including a walkout basement)
`NumberofBedrooms`	integer		> 0[11]	Yes		Number of bedrooms[12]
`NumberofBathrooms`	integer		> 0	No	See[13]	Number of bathrooms
`ConditionedFloorArea`	double	ft2	> 0	Yes		Floor area within conditioned space boundary
`ConditionedBuildingVolume` or `AverageCeilingHeight`	double	ft3 or ft	> 0	No	See[14]	Volume/ceiling height within conditioned space boundary
`extension/HasFlueOrChimney`	boolean			No	See[15]	Presence of flue or chimney for infiltration model

[10] ResidentialFacilityType choices are “single-family detached”, “single-family attached”, “apartment unit”, or “manufactured home”.

[11] NumberofBedrooms must also be <= (ConditionedFloorArea-120)/70.

[12] NumberofBedrooms is currently used to determine usage of plug loads, appliances, hot water, etc.

[13] If NumberofBathrooms not provided, calculated as NumberofBedrooms/2 + 0.5 based on the 2010 BAHSP.

[14] If neither ConditionedBuildingVolume nor AverageCeilingHeight provided, AverageCeilingHeight defaults to 8.0. If needed, additional defaulting is performed using the following relationship: ConditionedBuildingVolume = ConditionedFloorArea * AverageCeilingHeight.

[15] If HasFlueOrChimney not provided, assumed to be true if any of the following conditions are met:

- heating system is non-electric Furnace, Boiler, WallFurnace, FloorFurnace, Stove, PortableHeater, or FixedHeater and AFUE/Percent is less than 0.89,
- heating system is non-electric Fireplace, or
- water heater is non-electric with energy factor (or equivalent calculated from uniform energy factor) less than 0.63.

3.4 HPXML Weather Station

Weather information is entered in `/HPXML/Building/BuildingDetails/ClimateandRiskZones/WeatherStation`.

Element	Type	Units	Constraints	Required	Default	Notes
`SystemIdentifier`	id			Yes		Unique identifier
`Name`	string			Yes		Name of weather station
`extension/EPWFilePath`	string			Yes		Path to the EnergyPlus weather file (EPW)[16]

3.5 HPXML Enclosure

The dwelling unit's enclosure is entered in `/HPXML/Building/BuildingDetails/Enclosure`.

All surfaces that bound different space types of the dwelling unit (i.e., not just thermal boundary surfaces) must be specified in the HPXML file. For example, an attached garage would generally be defined by walls adjacent to conditioned space, walls adjacent to outdoors, a slab, and a roof or ceiling. For software tools that do not collect sufficient inputs for every required surface, the software developers will need to make assumptions about these surfaces or collect additional input.

Interior partition surfaces (e.g., walls between rooms inside conditioned space, or the floor between two conditioned stories) can be excluded.

For single-family attached (SFA) or multifamily (MF) buildings, surfaces between unconditioned space and the neighboring unit's same unconditioned space should set `InteriorAdjacentTo` and `ExteriorAdjacentTo` to the same value. For example, a foundation wall between the unit's vented crawlspace and the neighboring unit's vented crawlspace would use `InteriorAdjacentTo="crawlspace - vented"` and `ExteriorAdjacentTo="crawlspace - vented"`.

Warning: It is the software tool's responsibility to provide the appropriate building surfaces. While some error-checking is in place, it is not possible to know whether some surfaces are incorrectly missing.

Also note that wall and roof surfaces do not require an azimuth to be specified. Rather, only the windows/skylights themselves require an azimuth. Thus, software tools can choose to use a single wall (or roof) surface to represent multiple wall (or roof) surfaces for the entire building if all their other properties (construction type, interior/exterior adjacency, etc.) are identical.

3.5.1 HPXML Air Infiltration

Building air leakage is entered in `/HPXML/Building/BuildingDetails/Enclosure/AirInfiltration/AirInfiltrationMeasurement`.

[16] A full set of U.S. TMY3 weather files can be downloaded here.

Element	Type	Units	Constraints	Required	Default	Notes
SystemIdentifier	id			Yes		Unique identifier
BuildingAirLeakage/UnitofMeasure	string		See[17]	Yes		Units for air leakage
HousePressure	double	Pa	> 0	See[18]		House pressure with respect to outside[19]
BuildingAirLeakage/AirLeakage	double		> 0	Yes		Value for air leakage
InfiltrationVolume	double	ft3	> 0, >= ConditionedBuildingVolume	No	ConditionedBuildingVolume	Volume associated with infiltration measurement

3.5.2 HPXML Attics

If the dwelling unit has a vented attic, attic ventilation information can be optionally entered in /HPXML/Building/BuildingDetails/Enclosure/Attics/Attic[AtticType/Attic[Vented="true"]]/VentilationRate.

Element	Type	Units	Constraints	Required	Default	Notes
UnitofMeasure	string		See[20]	No	SLA	Units for ventilation rate
Value	double		> 0	No	1/300[21]	Value for ventilation rate

3.5.3 HPXML Foundations

If the dwelling unit has a vented crawlspace, crawlspace ventilation information can be optionally entered in /HPXML/Building/BuildingDetails/Enclosure/Foundations/Foundation[FoundationType/Crawlspace[Vented="true"]]/VentilationRate.

Element	Type	Units	Constraints	Required	Default	Notes
UnitofMeasure	string		See[22]	No	SLA	Units for ventilation rate
Value	double		> 0	No	1/150[23]	Value for ventilation rate

3.5.4 HPXML Roofs

Each pitched or flat roof surface that is exposed to ambient conditions is entered as an /HPXML/Building/BuildingDetails/Enclosure/Roofs/Roof.

For a multifamily building where the dwelling unit has another dwelling unit above it, the surface between the two dwelling units should be considered a FrameFloor and not a Roof.

[17] UnitofMeasure choices are "ACH" (air changes per hour at user-specified pressure), "CFM" (cubic feet per minute at user-specified pressure), or "ACHnatural" (natural air changes per hour).
[18] HousePressure only required if BuildingAirLeakage/UnitofMeasure is not "ACHnatural".
[19] HousePressure typical value is 50 Pa.
[20] UnitofMeasure choices are "SLA" (specific leakage area) or "ACHnatural" (natural air changes per hour).
[21] Value default based on ANSI/RESNET/ICC 301-2019.
[22] UnitofMeasure only choice is "SLA" (specific leakage area).
[23] Value default based on ANSI/RESNET/ICC 301-2019.

Element	Type	Units	Constraints	Required	Default	Notes
SystemIdentifier	id			Yes		Unique identifier
InteriorAdjacentTo	string		See[24]	Yes		Interior adjacent space type
Area	double	ft2	> 0	Yes		Gross area (including skylights)
Azimuth	integer	deg	0 - 359	No	See[25]	Azimuth (clockwise from North)
RoofType	string		See[26]	No	asphalt or fiberglass shingles	Roof type
SolarAbsorptance or RoofColor	double or string		0 - 1 or See[27]	Yes	See[28]	Solar absorptance or color
Emittance	double		0 - 1	No	0.90	Emittance
Pitch	integer	?:12	>= 0	Yes		Pitch
RadiantBarrier	boolean			No	false	Presence of radiant barrier
RadiantBarrierGrade	integer		1 - 3	See[29]		Radiant barrier installation grade
Insulation/SystemIdentifier	id			Yes		Unique identifier
Insulation/AssemblyEffectiveRValue	double	F-ft2-hr/Btu	> 0	Yes		Assembly R-value[30]

3.5.5 HPXML Rim Joists

Each rim joist surface (i.e., the perimeter of floor joists typically found between stories of a building or on top of a foundation wall) is entered as an `/HPXML/Building/BuildingDetails/Enclosure/RimJoists/RimJoist`.

[24] InteriorAdjacentTo choices are "attic - vented", "attic - unvented", "living space", or "garage". See *HPXML Locations* for descriptions.
[25] If Azimuth not provided, modeled as four surfaces of equal area facing every direction.
[26] RoofType choices are "asphalt or fiberglass shingles", "wood shingles or shakes", "slate or tile shingles", or "metal surfacing".
[27] RoofColor choices are "light", "medium", "medium dark", "dark", or "reflective".
[28] If SolarAbsorptance not provided, defaults based on RoofColor/RoofType:
- **asphalt or fiberglass shingles**: dark=0.92, medium dark=0.89, medium=0.85, light=0.75, reflective=0.50
- **wood shingles or shakes**: dark=0.92, medium dark=0.89, medium=0.85, light=0.75, reflective=0.50
- **slate or tile shingles**: dark=0.90, medium dark=0.83, medium=0.75, light=0.60, reflective=0.30
- **metal surfacing**: dark=0.90, medium dark=0.83, medium=0.75, light=0.60, reflective=0.30

[29] RadiantBarrierGrade only required if RadiantBarrier is provided.
[30] AssemblyEffectiveRValue includes all material layers, interior/exterior air films, and insulation installation grade.

Element	Type	Units	Constraints	Required	Default	Notes
SystemIdentifier	id			Yes		Unique identifier
ExteriorAdjacentTo	string		See[31]	Yes		Exterior adjacent space type
InteriorAdjacentTo	string		See[32]	Yes		Interior adjacent space type
Area	double	ft2	> 0	Yes		Gross area
Azimuth	integer	deg	0 - 359	No	See[33]	Azimuth (clockwise from North)
Siding	string		See[34]	No	wood siding	Siding material
SolarAbsorptance or Color	double or string		0 - 1 or See[35]	Yes	See[36]	Solar absorptance or color
Emittance	double		0 - 1	No	0.90	Emittance
Insulation/SystemIdentifier	id			Yes		Unique identifier
Insulation/AssemblyEffectiveRValue	double	F-ft2-hr/Btu	> 0	Yes		Assembly R-value[37]

3.5.6 HPXML Walls

Each wall that has no contact with the ground and bounds a space type is entered as an `/HPXML/Building/BuildingDetails/Enclosure/Walls/Wall`.

[31] ExteriorAdjacentTo choices are "outside", "attic - vented", "attic - unvented", "basement - conditioned", "basement - unconditioned", "crawlspace - vented", "crawlspace - unvented", "garage", "other housing unit", "other heated space", "other multifamily buffer space", or "other non-freezing space". See *HPXML Locations* for descriptions.

[32] InteriorAdjacentTo choices are "living space", "attic - vented", "attic - unvented", "basement - conditioned", "basement - unconditioned", "crawlspace - vented", "crawlspace - unvented", or "garage". See *HPXML Locations* for descriptions.

[33] If Azimuth not provided, modeled as four surfaces of equal area facing every direction.

[34] Siding choices are "wood siding", "vinyl siding", "stucco", "fiber cement siding", "brick veneer", or "aluminum siding".

[35] Color choices are "light", "medium", "medium dark", "dark", or "reflective".

[36] If SolarAbsorptance not provided, defaults based on Color:

- **dark**: 0.95
- **medium dark**: 0.85
- **medium**: 0.70
- **light**: 0.50
- **reflective**: 0.30

[37] AssemblyEffectiveRValue includes all material layers, interior/exterior air films, and insulation installation grade.

Element	Type	Units	Constraints	Required	Default	Notes
SystemIdentifier	id			Yes		Unique identifier
ExteriorAdjacentTo	string		See[38]	Yes		Exterior adjacent space type
InteriorAdjacentTo	string		See[39]	Yes		Interior adjacent space type
WallType	element		1[40]	Yes		Wall type (for thermal mass)
Area	double	ft2	> 0	Yes		Gross area (including doors/windows)
Azimuth	integer	deg	0 - 359	No	See[41]	Azimuth (clockwise from North)
Siding	string		See[42]	No	wood siding	Siding material
SolarAbsorptance or Color	double or string		0 - 1 or See[43]	Yes	See[44]	Solar absorptance or color
Emittance	double		0 - 1	No	0.90	Emittance
Insulation/SystemIdentifier	id			Yes		Unique identifier
Insulation/AssemblyEffectiveRValue	double	F-ft2-hr/Btu	> 0	Yes		Assembly R-value[45]

3.5.7 HPXML Foundation Walls

Each wall that is in contact with the ground should be specified as an `/HPXML/Building/BuildingDetails/Enclosure/FoundationWalls/FoundationWall`.

Other walls (e.g., wood framed walls) that are connected to a below-grade space but have no contact with the ground should be specified as a `Wall` and not a `FoundationWall`.

[38] ExteriorAdjacentTo choices are "outside", "attic - vented", "attic - unvented", "basement - conditioned", "basement - unconditioned", "crawlspace - vented", "crawlspace - unvented", "garage", "other housing unit", "other heated space", "other multifamily buffer space", or "other non-freezing space". See *HPXML Locations* for descriptions.

[39] InteriorAdjacentTo choices are "living space", "attic - vented", "attic - unvented", "basement - conditioned", "basement - unconditioned", "crawlspace - vented", "crawlspace - unvented", or "garage". See *HPXML Locations* for descriptions.

[40] WallType child element choices are `WoodStud`, `DoubleWoodStud`, `ConcreteMasonryUnit`, `StructurallyInsulatedPanel`, `InsulatedConcreteForms`, `SteelFrame`, `SolidConcrete`, `StructuralBrick`, `StrawBale`, `Stone`, `LogWall`, or `Adobe`.

[41] If Azimuth not provided, modeled as four surfaces of equal area facing every direction.

[42] Siding choices are "wood siding", "vinyl siding", "stucco", "fiber cement siding", "brick veneer", or "aluminum siding".

[43] Color choices are "light", "medium", "medium dark", "dark", or "reflective".

[44] If SolarAbsorptance not provided, defaults based on Color:

- **dark**: 0.95
- **medium dark**: 0.85
- **medium**: 0.70
- **light**: 0.50
- **reflective**: 0.30

[45] AssemblyEffectiveRValue includes all material layers, interior/exterior air films, and insulation installation grade.

Element	Type	Units	Constraints	Required	Default	Notes
SystemIdentifier	id			Yes		Unique identifier
ExteriorAdjacentTo	string		See[46]	Yes		Exterior adjacent space type[47]
InteriorAdjacentTo	string		See[48]	Yes		Interior adjacent space type
Height	double	ft	> 0	Yes		Total height
Area	double	ft2	> 0	Yes		Gross area (including doors/windows)
Azimuth	integer	deg	0 - 359	No	See[49]	Azimuth (clockwise from North)
Thickness	double	inches	> 0	No	8.0	Thickness excluding interior framing
DepthBelowGrade	double	ft	0 - Height	Yes		Depth below grade[50]
Insulation/SystemIdentifier	id			Yes		Unique identifier
Insulation/Layer[InstallationType="continuous - interior"]	element		0 - 1	See[51]		Interior insulation layer
Insulation/Layer[InstallationType="continuous - exterior"]	element		0 - 1	See[52]		Exterior insulation layer
Insulation/AssemblyEffectiveRValue	double	F-ft2-hr/Btu	> 0	See[53]		Assembly R-value[54]

If insulation layers are provided, additional information is entered in each FoundationWall/Insulation/Layer.

[46] ExteriorAdjacentTo choices are “ground”, “basement - conditioned”, “basement - unconditioned”, “crawlspace - vented”, “crawlspace - unvented”, “garage”, “other housing unit”, “other heated space”, “other multifamily buffer space”, or “other non-freezing space”. See *HPXML Locations* for descriptions.

[47] InteriorAdjacentTo choices are “basement - conditioned”, “basement - unconditioned”, “crawlspace - vented”, “crawlspace - unvented”, or “garage”. See *HPXML Locations* for descriptions.

[48] Interior foundation walls (e.g., between basement and crawlspace) should **not** use “ground” even if the foundation wall has some contact with the ground due to the difference in below-grade depths of the two adjacent spaces.

[49] If Azimuth not provided, modeled as four surfaces of equal area facing every direction.

[50] For exterior foundation walls, depth below grade is relative to the ground plane. For interior foundation walls, depth below grade is the vertical span of foundation wall in contact with the ground. For example, an interior foundation wall between an 8 ft conditioned basement and a 3 ft crawlspace has a height of 8 ft and a depth below grade of 5 ft. Alternatively, an interior foundation wall between an 8 ft conditioned basement and an 8 ft unconditioned basement has a height of 8 ft and a depth below grade of 0 ft.

[51] Layer[InstallationType=”continuous - interior”] only required if AssemblyEffectiveRValue is not provided.

[52] Layer[InstallationType=”continuous - exterior”] only required if AssemblyEffectiveRValue is not provided.

[53] AssemblyEffectiveRValue only required if Layer elements are not provided.

[54] AssemblyEffectiveRValue includes all material layers, interior air film, and insulation installation grade. R-value should **not** include exterior air film (for any above-grade exposure) or any soil thermal resistance.

Element	Type	Units	Constraints	Required	Default	Notes
NominalRValue	double	F-ft2-hr/Btu	>= 0	Yes		R-value of the foundation wall insulation; use zero if no insulation
extension/DistanceToTopOfInsulation	double	ft	>= 0	Yes		Vertical distance from top of foundation wall to top of insulation
extension/DistanceToBottomOfInsulation	double	ft	DistanceToTopOfInsulation - Height	Yes		Vertical distance from top of foundation wall to bottom of insulation

3.5.8 HPXML Frame Floors

Each horizontal floor/ceiling surface that is not in contact with the ground (Slab) nor adjacent to ambient conditions above (Roof) is entered as an /HPXML/Building/BuildingDetails/Enclosure/FrameFloors/FrameFloor.

Element	Type	Units	Constraints	Required	Default	Notes
SystemIdentifier	id			Yes		Unique identifier
ExteriorAdjacentTo	string		See[55]	Yes		Exterior adjacent space type
InteriorAdjacentTo	string		See[56]	Yes		Interior adjacent space type
Area	double	ft2	> 0	Yes		Gross area
Insulation/SystemIdentifier	id			Yes		Unique identifier
Insulation/AssemblyEffectiveRValue	double	F-ft2-hr/Btu	> 0	Yes		Assembly R-value[57]

For frame floors adjacent to "other housing unit", "other heated space", "other multifamily buffer space", or "other non-freezing space", additional information is entered in FrameFloor.

Element	Type	Units	Constraints	Required	Default	Notes
extension/OtherSpaceAboveOrBelow	string		See[58]	Yes		Specifies if above/below the MF space type

[55] ExteriorAdjacentTo choices are "outside", "attic - vented", "attic - unvented", "basement - conditioned", "basement - unconditioned", "crawlspace - vented", "crawlspace - unvented", "garage", "other housing unit", "other heated space", "other multifamily buffer space", or "other non-freezing space". See *HPXML Locations* for descriptions.

[56] InteriorAdjacentTo choices are "living space", "attic - vented", "attic - unvented", "basement - conditioned", "basement - unconditioned", "crawlspace - vented", "crawlspace - unvented", or "garage". See *HPXML Locations* for descriptions.

[57] AssemblyEffectiveRValue includes all material layers, interior/exterior air films, and insulation installation grade.

[58] OtherSpaceAboveOrBelow choices are "above" or "below".

3.5.9 HPXML Slabs

Each space type that borders the ground (i.e., basements, crawlspaces, garages, and slab-on-grade foundations) should have a slab entered as an `/HPXML/Building/BuildingDetails/Enclosure/Slabs/Slab`.

Element	Type	Units	Constraints	Required	Default	Notes
`SystemIdentifier`	id			Yes		Unique identifier
`InteriorAdjacentTo`	string		See[59]	Yes		Interior adjacent space type
`Area`	double	ft2	> 0	Yes		Gross area
`Thickness`	double	inches	>= 0	No	See[60]	Thickness[61]
`ExposedPerimeter`	double	ft	>= 0	Yes		Perimeter exposed to ambient conditions[62]
`PerimeterInsulationDepth`	double	ft	>= 0	Yes		Depth from grade to bottom of vertical insulation
`UnderSlabInsulationWidth`	double	ft	>= 0	See[63]		Width from slab edge inward of horizontal insulation
`UnderSlabInsulationSpansEntireSlab`	boolean			See[64]		Whether horizontal insulation spans entire slab
`DepthBelowGrade`	double	ft	>= 0	See[65]		Depth from the top of the slab surface to grade
`PerimeterInsulation/SystemIdentifier`	id			Yes		Unique identifier
`PerimeterInsulation/Layer/NominalRValue`	double	F-ft2-hr/Btu	>= 0	Yes		R-value of vertical insulation
`UnderSlabInsulation/SystemIdentifier`	id			Yes		Unique identifier
`UnderSlabInsulation/Layer/NominalRValue`	double	F-ft2-hr/Btu	>= 0	Yes		R-value of horizontal insulation
`extension/CarpetFraction`	double	frac	0 - 1	No	See[66]	Fraction of slab covered by carpet
`extension/CarpetRValue`	double	F-ft2-hr/Btu	>= 0	No	See[67]	Carpet R-value

3.5.10 HPXML Windows

Each window or glass door area is entered as an `/HPXML/Building/BuildingDetails/Enclosure/Windows/Window`.

[59] InteriorAdjacentTo choices are "living space", "basement - conditioned", "basement - unconditioned", "crawlspace - vented", "crawlspace - unvented", or "garage". See *HPXML Locations* for descriptions.

[60] If Thickness not provided, defaults to 0 when adjacent to crawlspace and 4 inches for all other cases.

[61] For a crawlspace with a dirt floor, enter a thickness of zero.

[62] ExposedPerimeter includes any slab length that falls along the perimeter of the building's footprint (i.e., is exposed to ambient conditions). So a basement slab edge adjacent to a garage or crawlspace, for example, should not be included.

[63] UnderSlabInsulationWidth only required if UnderSlabInsulationSpansEntireSlab=true is not provided.

[64] UnderSlabInsulationSpansEntireSlab=true only required if UnderSlabInsulationWidth is not provided.

[65] DepthBelowGrade only required if the attached foundation has no `FoundationWalls`. For foundation types with walls, the the slab's position relative to grade is determined by the `FoundationWall/DepthBelowGrade` value.

[66] If CarpetFraction not provided, defaults to 0.8 when adjacent to conditioned space, otherwise 0.0.

[67] If CarpetRValue not provided, defaults to 2.0 when adjacent to conditioned space, otherwise 0.0.

Element	Type	Units	Constraints	Required	Default	Notes
SystemIdentifier	id			Yes		Unique identifier
Area	double	ft2	> 0	Yes		Total area
Azimuth	integer	deg	0 - 359	Yes		Azimuth (clockwise from North)
UFactor	double	Btu/F-ft2-hr	> 0	Yes		Full-assembly NFRC U-factor
SHGC	double		0 - 1	Yes		Full-assembly NFRC solar heat gain coefficient
ExteriorShading/SummerShadingCoefficient	double	frac	0 - 1	No	1.00	Exterior summer shading coefficient (1=transparent, 0=opaque)
ExteriorShading/WinterShadingCoefficient	double	frac	0 - 1	No	1.00	Exterior winter shading coefficient (1=transparent, 0=opaque)
InteriorShading/SummerShadingCoefficient	double	frac	0 - 1	No	0.70[68]	Interior summer shading coefficient (1=transparent, 0=opaque)
InteriorShading/WinterShadingCoefficient	double	frac	0 - 1	No	0.85[69]	Interior winter shading coefficient (1=transparent, 0=opaque)
Overhangs	element		0 - 1	No	<none>	Presence of overhangs (including roof eaves)
FractionOperable	double	frac	0 - 1	No	0.67	Operable fraction[70]
AttachedToWall	idref		See[71]	Yes		ID of attached wall

If overhangs are specified, additional information is entered in Overhangs.

Element	Type	Units	Constraints	Required	Default	Notes
Depth	double	inches	>= 0	Yes		Depth of overhang
DistanceToTopOfWindow	double	ft	>= 0	Yes		Vertical distance from overhang to top of window
DistanceToBottomOfWindow	double	ft	> DistanceToTopOfWindow	Yes		Vertical distance from overhang to bottom of window[72]

3.5.11 HPXML Skylights

Each skylight is entered as an /HPXML/Building/BuildingDetails/Enclosure/Skylights/Skylight.

[68] InteriorShading/SummerShadingCoefficient default value indicates 30% reduction in solar heat gain, based on ANSI/RESNET/ICC 301-2019.

[69] InteriorShading/WinterShadingCoefficient default value indicates 15% reduction in solar heat gain, based on ANSI/RESNET/ICC 301-2019.

[70] FractionOperable reflects whether the windows are operable (can be opened), not how they are used by the occupants. If a Window represents a single window, the value should be 0 or 1. If a Window represents multiple windows (e.g., 4), the value should be between 0 and 1 (e.g., 0, 0.25, 0.5, 0.75, or 1). The total open window area for natural ventilation is calculated using A) the operable fraction, B) the assumption that 50% of the area of operable windows can be open, and C) the assumption that 20% of that openable area is actually opened by occupants whenever outdoor conditions are favorable for cooling.

[71] AttachedToWall must reference a Wall or FoundationWall.

[72] The difference between DistanceToBottomOfWindow and DistanceToTopOfWindow defines the height of the window.

Element	Type	Units	Constraints	Required	Default	Notes
SystemIdentifier	id			Yes		Unique identifier
Area	double	ft2	> 0	Yes		Total area
Azimuth	integer	deg	0 - 359	Yes		Azimuth (clockwise from North)
UFactor	double	Btu/F-ft2-hr	> 0	Yes		Full-assembly NFRC U-factor
SHGC	double		0 - 1	Yes		Full-assembly NFRC solar heat gain coefficient
ExteriorShading/SummerShadingCoefficient	double	frac	0 - 1	No	1.00	Exterior summer shading coefficient (1=transparent, 0=opaque)
ExteriorShading/WinterShadingCoefficient	double	frac	0 - 1	No	1.00	Exterior winter shading coefficient (1=transparent, 0=opaque)
InteriorShading/SummerShadingCoefficient	double	frac	0 - 1	No	1.00	Interior summer shading coefficient (1=transparent, 0=opaque)
InteriorShading/WinterShadingCoefficient	double	frac	0 - 1	No	1.00	Interior winter shading coefficient (1=transparent, 0=opaque)
AttachedToRoof	idref		See[73]	Yes		ID of attached roof

3.5.12 HPXML Doors

Each opaque door is entered as an /HPXML/Building/BuildingDetails/Enclosure/Doors/Door.

Element	Type	Units	Constraints	Required	Default	Notes
SystemIdentifier	id			Yes		Unique identifier
AttachedToWall	idref		See[74]	Yes		ID of attached wall
Area	double	ft2	> 0	Yes		Total area
Azimuth	integer	deg	0 - 359	Yes		Azimuth (clockwise from North)
RValue	double	F-ft2-hr/Btu	> 0	Yes		R-value

3.6 HPXML Systems

The dwelling unit's systems are entered in /HPXML/Building/BuildingDetails/Systems.

3.6.1 HPXML Heating Systems

Each heating system (other than a heat pump) is entered as an /HPXML/Building/BuildingDetails/Systems/HVAC/HVACPlant/HeatingSystem.

[73] AttachedToRoof must reference a Roof.
[74] AttachedToWall must reference a Wall or FoundationWall.

Element	Type	Units	Constraints	Required	Default	Notes
SystemIdentifier	id			Yes		Unique identifier
HeatingSystemType	element		1[75]	Yes		Type of heating system
HeatingSystemFuel	string		See[76]	Yes		Fuel type
HeatingCapacity	double	Btu/hr	>= 0	No	autosized	Input heating capacity
FractionHeatLoadServed	double	frac	0 - 1[77]	Yes		Fraction of heating load served

Electric Resistance

If electric resistance heating is specified, additional information is entered in HeatingSystem.

Element	Type	Units	Constraints	Required	Default	Notes
AnnualHeatingEfficiency[Units="Percent"]/Value	double	frac	0 - 1	Yes		Efficiency

Furnace

If a furnace is specified, additional information is entered in HeatingSystem.

Element	Type	Units	Constraints	Required	Default	Notes
DistributionSystem	idref		See[78]	Yes		ID of attached distribution system
AnnualHeatingEfficiency[Units="AFUE"]/Value	double	frac	0 - 1	Yes		Rated efficiency
extension/FanPowerWattsPerCFM	double	W/cfm	>= 0	No	See[79]	Fan power[80]
extension/AirflowDefectRatio	double	frac	> -1	No	0.0	Deviation between design/installed airflows[81]

[75] HeatingSystemType child element choices are ElectricResistance, Furnace, WallFurnace, FloorFurnace, Boiler, Stove, PortableHeater, FixedHeater, or Fireplace.

[76] HeatingSystemFuel choices are "electricity", "natural gas", "fuel oil", "fuel oil 1", "fuel oil 2", "fuel oil 4", "fuel oil 5/6", "diesel", "propane", "kerosene", "coal", "coke", "bituminous coal", "wood", or "wood pellets". For ElectricResistance, "electricity" is required.

[77] The sum of all FractionHeatLoadServed (across both HeatingSystems and HeatPumps) must be less than or equal to 1.

[78] HVACDistribution type must be AirDistribution (type: "regular velocity" or "gravity") or DSE.

[79] If FanPowerWattsPerCFM not provided, defaulted to 0 W/cfm if gravity distribution system, else 0.5 W/cfm if AFUE <= 0.9, else 0.375 W/cfm.

[80] If there is a cooling system attached to the DistributionSystem, the heating and cooling systems cannot have different values for FanPowerWattsPerCFM.

[81] AirflowDefectRatio is defined as (InstalledAirflow - DesignAirflow) / DesignAirflow; a value of zero means no airflow defect. See ANSI/RESNET/ACCA 310-2020 Standard for Grading the Installation of HVAC Systems for more information.

Wall/Floor Furnace

If a wall furnace or floor furnace is specified, additional information is entered in `HeatingSystem`.

Element	Type	Units	Constraints	Required	Default	Notes
`AnnualHeatingEfficiency[Units="AFUE"]/Value`	double	frac	0 - 1	Yes		Rated efficiency
`extension/FanPowerWatts`	double	W	>= 0	No	0	Fan power

Boiler

If a boiler is specified, additional information is entered in `HeatingSystem`.

Element	Type	Units	Constraints	Required	Default	Notes
`IsSharedSystem`	boolean			No	false	Whether it serves multiple dwelling units
`DistributionSystem`	idref		See[82]	Yes		ID of attached distribution system
`AnnualHeatingEfficiency[Units="AFUE"]/Value`	double	frac	0 - 1	Yes		Rated efficiency

If an in-unit boiler if specified, additional information is entered in `HeatingSystem`.

Element	Type	Units	Constraints	Required	Default	Notes
`ElectricAuxiliaryEnergy`	double	kWh/yr	>= 0	No	See[83]	Electric auxiliary energy

If instead a shared boiler is specified, additional information is entered in `HeatingSystem`.

Element	Type	Units	Constraints	Required	Default	Notes
`NumberofUnitsServed`	integer		> 1	Yes		Number of dwelling units served
`ElectricAuxiliaryEnergy` or `extension/SharedLoopWatts`	double	kWh/yr or W	>= 0	No	See[84]	Electric auxiliary energy or shared loop power
`ElectricAuxiliaryEnergy` or `extension/FanCoilWatts`	double	kWh/yr or W	>= 0	No[85]		Electric auxiliary energy or fan coil power

[82] For in-unit boilers, HVACDistribution type must be HydronicDistribution (type: "radiator", "baseboard", "radiant floor", "radiant ceiling", or "water loop") or DSE. For shared boilers, HVACDistribution type must be HydronicDistribution (type: "radiator", "baseboard", "radiant floor", "radiant ceiling", or "water loop") or AirDistribution (type: "fan coil"). If the shared boiler has "water loop" distribution, a *Water-Loop-to-Air Heat Pump* must also be specified.

[83] If ElectricAuxiliaryEnergy not provided, defaults as follows:

- **Oil boiler**: 330 kWh/yr
- **Gas boiler**: 170 kWh/yr

Stove

If a stove is specified, additional information is entered in `HeatingSystem`.

Element	Type	Units	Constraints	Required	Default	Notes
`AnnualHeatingEfficiency[Units="Percent"]/Value`	double	frac	0 - 1	Yes		Efficiency
`extension/FanPowerWatts`	double	W	>= 0	No	40	Fan power

Portable/Fixed Heater

If a portable heater or fixed heater is specified, additional information is entered in `HeatingSystem`.

Element	Type	Units	Constraints	Required	Default	Notes
`AnnualHeatingEfficiency[Units="Percent"]/Value`	double	frac	0 - 1	Yes		Efficiency
`extension/FanPowerWatts`	double	W	>= 0	No	0	Fan power

Fireplace

If a fireplace is specified, additional information is entered in `HeatingSystem`.

Element	Type	Units	Constraints	Required	Default	Notes
`AnnualHeatingEfficiency[Units="Percent"]/Value`	double	frac	0 - 1	Yes		Efficiency
`extension/FanPowerWatts`	double	W	>= 0	No	0	Fan power

3.6.2 HPXML Cooling Systems

Each cooling system (other than a heat pump) is entered as an `/HPXML/Building/BuildingDetails/Systems/HVAC/HVACPlant/CoolingSystem`.

[84] If ElectricAuxiliaryEnergy nor SharedLoopWatts provided, defaults as follows:
- **Shared boiler w/ baseboard**: 220 kWh/yr
- **Shared boiler w/ water loop heat pump**: 265 kWh/yr
- **Shared boiler w/ fan coil**: 438 kWh/yr

[85] FanCoilWatts only used if boiler connected to fan coil and SharedLoopWatts provided.

Element	Type	Units	Constraints	Required	Default	Notes
SystemIdentifier	id			Yes		Unique identifier
CoolingSystemType	string		See[86]	Yes		Type of cooling system
CoolingSystemFuel	string		See[87]	Yes		Fuel type
FractionCoolLoadServed	double	frac	0 - 1[88]	Yes		Fraction of cooling load served

Central Air Conditioner

If a central air conditioner is specified, additional information is entered in CoolingSystem.

Element	Type	Units	Constraints	Required	Default	Notes
DistributionSystem	idref		See[89]	Yes		ID of attached distribution system
AnnualCoolingEfficiency[Units='SEER']/Value	double	Btu/Wh	> 0	Yes		Rated efficiency
CoolingCapacity	double	Btu/hr	>= 0	No	auto-sized	Cooling capacity
SensibleHeatFraction	double	frac	0 - 1	No		Sensible heat fraction
CompressorType	string		See[90]	No	See[91]	Type of compressor
extension/FanPowerWattsPerCFM	double	W/cfm	>= 0	No	See[92]	Fan power[93]
extension/AirflowDefectRatio	double	frac	> -1	No	0.0	Deviation between design/installed airflows[94]
extension/ChargeDefectRatio	double	frac	> -1	No	0.0	Deviation between design/installed charges[95]

Room Air Conditioner

If a room air conditioner is specified, additional information is entered in CoolingSystem.

[86] CoolingSystemType choices are "central air conditioner", "room air conditioner", "evaporative cooler", "mini-split", "chiller", or "cooling tower".
[87] CoolingSystemFuel only choice is "electricity".
[88] The sum of all FractionCoolLoadServed (across both CoolingSystems and HeatPumps) must be less than or equal to 1.
[89] HVACDistribution type must be AirDistribution (type: "regular velocity") or DSE.
[90] CompressorType choices are "single stage", "two stage", or "variable speed".
[91] If CompressorType not provided, defaults to "single stage" if SEER <= 15, else "two stage" if SEER <= 21, else "variable speed".
[92] If FanPowerWattsPerCFM not provided, defaults to using attached furnace W/cfm if available, else 0.5 W/cfm if SEER <= 13.5, else 0.375 W/cfm.
[93] If there is a heating system attached to the DistributionSystem, the heating and cooling systems cannot have different values for FanPowerWattsPerCFM.
[94] AirflowDefectRatio is defined as (InstalledAirflow - DesignAirflow) / DesignAirflow; a value of zero means no airflow defect. See ANSI/RESNET/ACCA 310-2020 Standard for Grading the Installation of HVAC Systems for more information.
[95] ChargeDefectRatio is defined as (InstalledCharge - DesignCharge) / DesignCharge; a value of zero means no refrigerant charge defect. See ANSI/RESNET/ACCA 310-2020 Standard for Grading the Installation of HVAC Systems for more information.

Element	Type	Units	Constraints	Required	Default	Notes
AnnualCoolingEfficiency[Units="EER"]/Value	double	Btu/Wh	> 0	Yes		Rated efficiency
CoolingCapacity	double	Btu/hr	>= 0	No	autosized	Cooling capacity
SensibleHeatFraction	double	frac	0 - 1	No		Sensible heat fraction

Evaporative Cooler

If an evaporative cooler is specified, additional information is entered in CoolingSystem.

Element	Type	Units	Constraints	Required	Default	Notes
DistributionSystem	idref		See[96]	No		ID of attached distribution system
CoolingCapacity	double	Btu/hr	>= 0	No	autosized	Cooling capacity

Mini-Split

If a mini-split is specified, additional information is entered in CoolingSystem.

Element	Type	Units	Constraints	Required	Default	Notes
DistributionSystem	idref		See[97]	No		ID of attached distribution system
AnnualCoolingEfficiency[Units="SEER"]/Value	double	Btu/Wh	> 0	Yes		Rated cooling efficiency
CoolingCapacity	double	Btu/hr	>= 0	No	autosized	Cooling capacity
SensibleHeatFraction	double	frac	0 - 1	No		Sensible heat fraction
extension/ChargeDefectRatio	double	frac	> -1	No	0.0	Deviation between design/installed charges[98]

If a ducted mini-split is specified (i.e., a DistributionSystem has been entered), additional information is entered in CoolingSystem.

[96] If provided, HVACDistribution type must be AirDistribution (type: "regular velocity") or DSE.

[97] If provided, HVACDistribution type must be AirDistribution (type: "regular velocity") or DSE.

[98] ChargeDefectRatio is defined as (InstalledCharge - DesignCharge) / DesignCharge; a value of zero means no refrigerant charge defect. See ANSI/RESNET/ACCA 310-2020 Standard for Grading the Installation of HVAC Systems for more information.

Element	Type	Units	Constraints	Required	Default	Notes
extension/FanPowerWattsPerCFM	double	W/cfm	>= 0	No	0.18	Fan power
extension/AirflowDefectRatio	double	frac	> -1	No	0.0	Deviation between design/installed airflows[99]

Chiller

If a chiller is specified, additional information is entered in CoolingSystem.

Element	Type	Units	Constraints	Required	Default	Notes
IsSharedSystem	boolean		true	Yes		Whether it serves multiple dwelling units
DistributionSystem	idref		See[100]	Yes		ID of attached distribution system
NumberofUnitsServed	integer		> 1	Yes		Number of dwelling units served
CoolingCapacity	double	Btu/hr	>= 0	Yes		Total cooling capacity
AnnualCoolingEfficiency[Units="kW/ton"]/Value	double	kW/ton	> 0	Yes		Rated efficiency
extension/SharedLoopWatts	double	W	>= 0	Yes		Pumping and fan power serving the system
extension/FanCoilWatts	double	W	>= 0	See[101]		Fan coil power

Note: Chillers are modeled as central air conditioners with a SEER equivalent using the equation from ANSI/RESNET/ICC 301-2019.

Cooling Tower

If a cooling tower is specified, additional information is entered in CoolingSystem.

[99] AirflowDefectRatio is defined as (InstalledAirflow - DesignAirflow) / DesignAirflow; a value of zero means no airflow defect. See ANSI/RESNET/ACCA 310-2020 Standard for Grading the Installation of HVAC Systems for more information.

[100] HVACDistribution type must be HydronicDistribution (type: "radiator", "baseboard", "radiant floor", "radiant ceiling", or "water loop") or AirDistribution (type: "fan coil"). If the chiller has "water loop" distribution, a *Water-Loop-to-Air Heat Pump* must also be specified.

[101] FanCoilWatts only required if chiller connected to fan coil.

Element	Type	Units	Constraints	Required	Default	Notes
IsSharedSystem	boolean		true	Yes		Whether it serves multiple dwelling units
DistributionSystem	idref		See[102]	Yes		ID of attached distribution system
NumberofUnitsServed	integer		> 1	Yes		Number of dwelling units served
extension/SharedLoopWatts	double	W	>= 0	Yes		Pumping and fan power serving the system

Note: Cooling towers w/ water loop heat pumps are modeled as central air conditioners with a SEER equivalent using the equation from ANSI/RESNET/ICC 301-2019.

3.6.3 HPXML Heat Pumps

Each heat pump is entered as an /HPXML/Building/BuildingDetails/Systems/HVAC/HVACPlant/HeatPump.

Element	Type	Units	Constraints	Required	Default	Notes
SystemIdentifier	id			Yes		Unique identifier
HeatPumpType	string		See[103]	Yes		Type of heat pump
HeatPumpFuel	string		See[104]	Yes		Fuel type
BackupSystemFuel	string		See[105]	No		Fuel type of backup heating, if present

If a backup system fuel is provided, additional information is entered in HeatPump.

Element	Type	Units	Constraints	Required	Default	Notes
BackupAnnualHeatingEfficiency[Units="Percent" or Units="AFUE"]/Value	double	frac	0 - 1	Yes		Backup heating efficiency
BackupHeatingCapacity	double	Btu/hr	>= 0	No	autosized	Backup heating capacity
BackupHeatingSwitchoverTemperature	double	F		No	<none>	Backup heating switchover temperature[106]

[102] HVACDistribution type must be HydronicDistribution (type: "water loop"). A *Water-Loop-to-Air Heat Pump* must also be specified.
[103] HeatPumpType choices are "air-to-air", "mini-split", "ground-to-air", or "water-loop-to-air".
[104] HeatPumpFuel only choice is "electricity".
[105] BackupSystemFuel choices are "electricity", "natural gas", "fuel oil", "fuel oil 1", "fuel oil 2", "fuel oil 4", "fuel oil 5/6", "diesel", "propane", "kerosene", "coal", "coke", "bituminous coal", "wood", or "wood pellets".
[106] Provide BackupHeatingSwitchoverTemperature for, e.g., a dual-fuel heat pump, in which there is a discrete outdoor temperature when the heat pump stops operating and the backup heating system starts operating. If not provided, the backup heating system will operate as needed when the heat pump has insufficient capacity.

Air-to-Air Heat Pump

If an air-to-air heat pump is specified, additional information is entered in `HeatPump`.

Element	Type	Units	Constraints	Required	Default	Notes
`DistributionSystem`	idref		See[107]	Yes		ID of attached distribution system
`CompressorType`	string		See[108]	No	See[109]	Type of compressor
`HeatingCapacity`	double	Btu/hr	>= 0	No	autosized	Heating capacity (excluding any backup heating)
`HeatingCapacity17F`	double	Btu/hr	>= 0	No		Heating capacity at 17F, if available
`CoolingCapacity`	double	Btu/hr	>= 0	No	autosized	Cooling capacity
`CoolingSensibleHeatFraction`	double	frac	0 - 1	No		Sensible heat fraction
`FractionHeatLoadServed`	double	frac	0 - 1[110]	Yes		Fraction of heating load served
`FractionCoolLoadServed`	double	frac	0 - 1[111]	Yes		Fraction of cooling load served
`AnnualCoolingEfficiency[Units="SEER"]/Value`	double	Btu/Wh	> 0	Yes		Rated cooling efficiency
`AnnualHeatingEfficiency[Units="HSPF"]/Value`	double	Btu/Wh	> 0	Yes		Rated heating efficiency
`extension/FanPowerWattsPerCFM`	double	W/cfm	>= 0	No	See[112]	Fan power
`extension/AirflowDefectRatio`	double	frac	> -1	No	0.0	Deviation between design/installed airflows[113]
`extension/ChargeDefectRatio`	double	frac	> -1	No	0.0	Deviation between design/installed charges[114]

Mini-Split Heat Pump

If a mini-split heat pump is specified, additional information is entered in `HeatPump`.

[107] HVACDistribution type must be AirDistribution (type: "regular velocity") or DSE.
[108] CompressorType choices are "single stage", "two stage", or "variable speed".
[109] If CompressorType not provided, defaults to "single stage" if SEER <= 15, else "two stage" if SEER <= 21, else "variable speed".
[110] The sum of all `FractionHeatLoadServed` (across both HeatingSystems and HeatPumps) must be less than or equal to 1.
[111] The sum of all `FractionCoolLoadServed` (across both CoolingSystems and HeatPumps) must be less than or equal to 1.
[112] If FanPowerWattsPerCFM not provided, defaulted to 0.5 W/cfm if HSPF <= 8.75, else 0.375 W/cfm.
[113] AirflowDefectRatio is defined as (InstalledAirflow - DesignAirflow) / DesignAirflow; a value of zero means no airflow defect. See ANSI/RESNET/ACCA 310-2020 Standard for Grading the Installation of HVAC Systems for more information.
[114] ChargeDefectRatio is defined as (InstalledCharge - DesignCharge) / DesignCharge; a value of zero means no refrigerant charge defect. See ANSI/RESNET/ACCA 310-2020 Standard for Grading the Installation of HVAC Systems for more information.

Element	Type	Units	Constraints	Required	Default	Notes
DistributionSystem	idref		See[115]	No		ID of attached distribution system, if present
HeatingCapacity	double	Btu/hr	>= 0	No	autosized	Heating capacity (excluding any backup heating)
HeatingCapacity17F	double	Btu/hr	>= 0	No		Heating capacity at 17F, if available
CoolingCapacity	double	Btu/hr	>= 0	No	autosized	Cooling capacity
CoolingSensibleHeatFraction	double	frac	0 - 1	No		Sensible heat fraction
FractionHeatLoadServed	double	frac	0 - 1[116]	Yes		Fraction of heating load served
FractionCoolLoadServed	double	frac	0 - 1[117]	Yes		Fraction of cooling load served
AnnualCoolingEfficiency[Units="SEER",Value]	double	Btu/Wh	> 0	Yes		Rated cooling efficiency
AnnualHeatingEfficiency[Units="HSPF",Value]	double	Btu/Wh	> 0	Yes		Rated heating efficiency
extension/ChargeDefectRatio	double	frac	> -1	No	0.0	Deviation between design/installed charges[118]

If a ducted mini-split is specified (i.e., a DistributionSystem has been entered), additional information is entered in HeatPump.

Element	Type	Units	Constraints	Required	Default	Notes
extension/FanPowerWattsPerCFM	double	W/cfm	>= 0	No	0.18	Fan power
extension/AirflowDefectRatio	double	frac	> -1	No	0.0	Deviation between design/installed airflows[119]

Ground-to-Air Heat Pump

If a ground-to-air heat pump is specified, additional information is entered in HeatPump.

[115] If provided, HVACDistribution type must be AirDistribution (type: "regular velocity") or DSE.
[116] The sum of all FractionHeatLoadServed (across both HeatingSystems and HeatPumps) must be less than or equal to 1.
[117] The sum of all FractionCoolLoadServed (across both CoolingSystems and HeatPumps) must be less than or equal to 1.
[118] ChargeDefectRatio is defined as (InstalledCharge - DesignCharge) / DesignCharge; a value of zero means no refrigerant charge defect. See ANSI/RESNET/ACCA 310-2020 Standard for Grading the Installation of HVAC Systems for more information.
[119] AirflowDefectRatio is defined as (InstalledAirflow - DesignAirflow) / DesignAirflow; a value of zero means no airflow defect. See ANSI/RESNET/ACCA 310-2020 Standard for Grading the Installation of HVAC Systems for more information.

Element	Type	Units	Constraints	Required	Default	Notes
IsSharedSystem	boolean			No	false	Whether it has a shared hydronic circulation loop[120]
DistributionSystem	idref		See[121]	Yes		ID of attached distribution system
HeatingCapacity	double	Btu/hr	>= 0	No	autosized	Heating capacity (excluding any backup heating)
CoolingCapacity	double	Btu/hr	>= 0	No	autosized	Cooling capacity
CoolingSensibleHeatFraction	double	frac	0 - 1	No		Sensible heat fraction
FractionHeatLoadServed	double	frac	0 - 1[122]	Yes		Fraction of heating load served
FractionCoolLoadServed	double	frac	0 - 1[123]	Yes		Fraction of cooling load served
AnnualCoolingEfficiency[Units="EER"]/Value	double	Btu/Wh	> 0	Yes		Rated cooling efficiency
AnnualHeatingEfficiency[Units="COP"]/Value	double	W/W	> 0	Yes		Rated heating efficiency
NumberofUnitsServed	integer		> 0	See[124]		Number of dwelling units served
extension/PumpPowerWattsPerTon	double	W/ton	>= 0	No	See[125]	Pump power[126]
extension/SharedLoopWatts	double	W	>= 0	See[127]		Shared pump power[128]
extension/FanPowerWattsPerCFM	double	W/cfm	>= 0	No	See[129]	Fan power
extension/AirflowDefectRatio	double	frac	> -1	No	0.0	Deviation between design/installed airflows[130]
extension/ChargeDefectRatio	double	frac	0.0[131]	No	0.0	Deviation between design/installed charges[132]

Water-Loop-to-Air Heat Pump

If a water-loop-to-air heat pump is specified, additional information is entered in HeatPump.

[120] IsSharedSystem should be true if the SFA/MF building has multiple ground source heat pumps connected to a shared hydronic circulation loop.
[121] HVACDistribution type must be AirDistribution (type: "regular velocity") or DSE.
[122] The sum of all FractionHeatLoadServed (across both HeatingSystems and HeatPumps) must be less than or equal to 1.
[123] The sum of all FractionCoolLoadServed (across both CoolingSystems and HeatPumps) must be less than or equal to 1.
[124] NumberofUnitsServed only required if IsSharedSystem is true, in which case it must be > 1.
[125] If PumpPowerWattsPerTon not provided, defaults to 30 W/ton per ANSI/RESNET/ICC 301-2019 for a closed loop system.
[126] Pump power is calculated using PumpPowerWattsPerTon and the cooling capacity in tons, unless the system only provides heating, in which case the heating capacity in tons is used instead. Any pump power that is shared by multiple dwelling units should be included in SharedLoopWatts, *not* PumpPowerWattsPerTon, so that shared loop pump power attributed to the dwelling unit is calculated.
[127] SharedLoopWatts only required if IsSharedSystem is true.
[128] Shared loop pump power attributed to the dwelling unit is calculated as SharedLoopWatts / NumberofUnitsServed.
[129] If FanPowerWattsPerCFM not provided, defaulted to 0.5 W/cfm if COP <= 8.75/3.2, else 0.375 W/cfm.
[130] AirflowDefectRatio is defined as (InstalledAirflow - DesignAirflow) / DesignAirflow; a value of zero means no airflow defect. See ANSI/RESNET/ACCA 310-2020 Standard for Grading the Installation of HVAC Systems for more information.
[131] ChargeDefectRatio currently constrained to zero for ground-to-air heat pumps due to an EnergyPlus limitation; this constraint will be relaxed in the future.
[132] ChargeDefectRatio is defined as (InstalledCharge - DesignCharge) / DesignCharge; a value of zero means no refrigerant charge defect. See ANSI/RESNET/ACCA 310-2020 Standard for Grading the Installation of HVAC Systems for more information.

Element	Type	Units	Constraints	Required	Default	Notes
DistributionSystem	idref		See[133]	Yes		ID of attached distribution system
HeatingCapacity	double	Btu/hr	> 0	No	autosized	Heating capacity
CoolingCapacity	double	Btu/hr	> 0	See[134]		Cooling capacity
AnnualCoolingEfficiency[Units="SEER"]/Value	double	Btu/Wh	> 0	See[135]		Rated cooling efficiency
AnnualHeatingEfficiency[Units="COP"]/Value	double	W/W	> 0	See[136]		Rated heating efficiency

Note: If a water loop heat pump is specified, there must be at least one shared heating system (i.e., *Boiler*) and/or one shared cooling system (i.e., *Chiller* or *Cooling Tower*) specified with water loop distribution.

3.6.4 HPXML HVAC Control

If any HVAC systems are specified, a single thermostat is entered as a /HPXML/Building/BuildingDetails/Systems/HVAC/HVACControl.

Element	Type	Units	Constraints	Required	Default	Notes
SystemIdentifier	id			Yes		Unique identifier
extension/CeilingFanSetpointTempCoolingSeasonOffset	double	F	>= 0	No	0	Cooling setpoint temperature offset[137]

Thermostat setpoints are additionally entered using either simple inputs or detailed inputs.

Simple Inputs

To define simple thermostat setpoints, additional information is entered in HVACControl.

Element	Type	Units	Constraints	Required	Default	Notes
SetpointTempHeatingSeason	double	F		Yes		Heating setpoint temperature
SetpointTempCoolingSeason	double	F		Yes		Cooling setpoint temperature

If there is a heating temperature setback, additional information is entered in HVACControl.

[133] HVACDistribution type must be AirDistribution (type: "regular velocity") or DSE.
[134] CoolingCapacity required if there is a shared chiller or cooling tower with water loop distribution.
[135] AnnualCoolingEfficiency required if there is a shared chiller or cooling tower with water loop distribution.
[136] AnnualHeatingEfficiency required if there is a shared boiler with water loop distribution.
[137] CeilingFanSetpointTempCoolingSeasonOffset should only be used if there are sufficient ceiling fans present to warrant a reduced cooling setpoint.

Element	Type	Units	Constraints	Required	Default	Notes
SetbackTempHeatingSeason	double	F		Yes		Heating setback temperature
TotalSetbackHoursperWeekHeating	integer	hrs/week	> 0	Yes		Hours/week of heating temperature setback
extension/SetbackStartHourHeating	integer		0 - 23	No	23 (11pm)	Daily setback start hour

If there is a cooling temperature setup, additional information is entered in HVACControl.

Element	Type	Units	Constraints	Required	Default	Notes
SetupTempCoolingSeason	double	F		Yes		Cooling setup temperature
TotalSetupHoursperWeekCooling	integer	hrs/week	> 0	Yes		Hours/week of cooling temperature setup
extension/SetupStartHourCooling	integer		0 - 23	No	9 (9am)	Daily setup start hour

Detailed Inputs

To define detailed thermostat setpoints, additional information is entered in HVACControl.

Element	Type	Units	Constraints	Required	Default	Notes
extension/WeekdaySetpointTempsHeatingSeason	array	F		Yes		24 comma-separated weekday heating setpoints
extension/WeekendSetpointTempsHeatingSeason	array	F		Yes		24 comma-separated weekend heating setpoints
extension/WeekdaySetpointTempsCoolingSeason	array	F		Yes		24 comma-separated weekday cooling setpoints
extension/WeekendSetpointTempsCoolingSeason	array	F		Yes		24 comma-separated weekend cooling setpoints

3.6.5 HPXML HVAC Distribution

Each separate HVAC distribution system is entered as a /HPXML/Building/BuildingDetails/Systems/HVAC/HVACDistribution.

Element	Type	Units	Constraints	Required	Default	Notes
SystemIdentifier	id			Yes		Unique identifier
DistributionSystemType	element		1[138]	Yes		Type of distribution system
ConditionedFloorAreaServed	double	ft2	> 0	See[139]		Conditioned floor area served

Note: There should be at most one heating system and one cooling system attached to a distribution system. See *HPXML Heating Systems*, *HPXML Cooling Systems*, and *HPXML Heat Pumps* for information on which DistributionSystemType is allowed for which HVAC system. Also note that some HVAC systems (e.g., room air conditioners) are not allowed to be attached to a distribution system.

Air Distribution

To define an air distribution system, additional information is entered in `HVACDistribution/DistributionSystemType/AirDistribution`.

Element	Type	Units	Constraints	Required	Default	Notes
`AirDistributionType`	string		See[140]	Yes		Type of air distribution
`DuctLeakageMeasurement[DuctType="supply"]`	element		1	See[141]		Supply duct leakage value
`DuctLeakageMeasurement[DuctType="return"]`	element		1	See[142]		Return duct leakage value
`Ducts`	element		>= 0	No		Supply/return ducts[143]
`NumberofReturnRegisters`	integer		>= 0	No	See[144]	Number of return registers

Additional information is entered in each `DuctLeakageMeasurement`.

Element	Type	Units	Constraints	Required	Default	Notes
`DuctLeakage/Units`	string		See[145]	Yes		Duct leakage units
`DuctLeakage/Value`	double		>= 0[146]	Yes		Duct leakage value[147]
`DuctLeakage/TotalOrToOutside`	string		See[148]	Yes		Type of duct leakage (outside conditioned space vs total)

Additional information is entered in each `Ducts`.

[138] DistributionSystemType child element choices are `AirDistribution`, `HydronicDistribution`, or `Other=DSE`.
[139] ConditionedFloorAreaServed required only when DistributionSystemType is AirDistribution and `AirDistribution/Ducts` are present.
[140] AirDistributionType choices are "regular velocity", "gravity", or "fan coil" and are further restricted based on attached HVAC system type (e.g., only "regular velocity" or "gravity" for a furnace, only "fan coil" for a shared boiler, etc.).
[141] Supply duct leakage required if AirDistributionType is "regular velocity" or "gravity" and optional if AirDistributionType is "fan coil".
[142] Return duct leakage required if AirDistributionType is "regular velocity" or "gravity" and optional if AirDistributionType is "fan coil".
[143] Provide a Ducts element for each supply duct and each return duct.
[144] If NumberofReturnRegisters not provided and `AirDistribution/Ducts` are present, defaults to one return register per conditioned floor per ASHRAE Standard 152, rounded up to the nearest integer if needed.
[145] Units choices are "CFM25" or "Percent".
[146] Value also must be < 1 if Units is Percent.
[147] If the HVAC system has no return ducts (e.g., a ducted evaporative cooler), use zero for the Value.
[148] TotalOrToOutside only choice is "to outside".

Element	Type	Units	Constraints	Required	Default	Notes
DuctInsulationRValue	double	F-ft2-hr/Btu	>= 0	Yes		R-value of duct insulation[149]
DuctSurfaceArea	double	ft2	>= 0	See[150]	See[151]	Duct surface area
DuctLocation	string		See[152]	See[153]	See[154]	Duct location

Hydronic Distribution

To define a hydronic distribution system, additional information is entered in `HVACDistribution/DistributionSystemType/HydronicDistribution`.

Element	Type	Units	Constraints	Required	Default	Notes
HydronicDistributionType	string		See[155]	Yes		Type of hydronic distribution system

Distribution System Efficiency (DSE)

Warning: A simplified DSE model is provided for flexibility, but it is **strongly** recommended to use one of the other detailed distribution system types for better accuracy. Also note that when specifying a DSE system, its effect is reflected in the *Workflow Outputs* but is **not** reflected in the raw EnergyPlus simulation outputs.

To define a DSE system, additional information is entered in `HVACDistribution`.

Element	Type	Units	Constraints	Required	Default	Notes
AnnualHeatingDistributionSystemEfficiency	double		0-1	Yes		Seasonal distribution system efficiency for heating
AnnualCoolingDistributionSystemEfficiency	double		0-1	Yes		Seasonal distribution system efficiency for cooling

DSE values can be calculated from ASHRAE Standard 152.

[149] DuctInsulationRValue should not include air films (i.e., use 0 for an uninsulated duct).

[150] DuctSurfaceArea and DuctLocation are either both required or both disallowed.

[151] If DuctSurfaceArea not provided, duct areas will be calculated based on ASHRAE Standard 152:

- **Primary supply ducts**: 0.27 * F_out * ConditionedFloorAreaServed
- **Secondary supply ducts**: 0.27 * (1 - F_out) * ConditionedFloorAreaServed
- **Primary return ducts**: b_r * F_out * ConditionedFloorAreaServed
- **Secondary return ducts**: b_r * (1 - F_out) * ConditionedFloorAreaServed

where F_out is 1.0 when NumberofConditionedFloorsAboveGrade <= 1 and 0.75 when NumberofConditionedFloorsAboveGrade > 1, and b_r is 0.05 * NumberofReturnRegisters with a maximum value of 0.25.

[152] DuctLocation choices are "living space", "basement - conditioned", "basement - unconditioned", "crawlspace - unvented", "crawlspace - vented", "attic - unvented", "attic - vented", "garage", "outside", "exterior wall", "under slab", "roof deck", "other housing unit", "other heated space", "other multifamily buffer space", or "other non-freezing space". See *HPXML Locations* for descriptions.

[153] DuctLocation and DuctSurfaceArea are either both required or both disallowed.

[154] If DuctLocation not provided, defaults to the first present space type: "basement - conditioned", "basement - unconditioned", "crawlspace - vented", "crawlspace - unvented", "attic - vented", "attic - unvented", "garage", or "living space". Any secondary ducts (i.e., when NumberofConditionedFloorsAboveGrade > 1) will always be located in "living space".

[155] HydronicDistributionType choices are "radiator", "baseboard", "radiant floor", or "radiant ceiling".

3.6.6 HPXML Whole Ventilation Fan

Each mechanical ventilation system that provides ventilation to the whole dwelling unit is entered as a `/HPXML/Building/BuildingDetails/Systems/MechanicalVentilation/VentilationFans/VentilationFan`. If not entered, the simulation will not include mechanical ventilation.

Element	Type	Units	Constraints	Required	Default	Notes
`SystemIdentifier`	id			Yes		Unique identifier
`UsedForWholeBuildingVentilation`	boolean		true	Yes		Must be set to true
`IsSharedSystem`	boolean		See[156]	No	false	Whether it serves multiple dwelling units
`FanType`	string		See[157]	Yes		Type of ventilation system
`TestedFlowRate` or `RatedFlowRate`	double	cfm	>= 0	Yes		Flow rate[158]
`HoursInOperation`	double	hrs/day	0 - 24	No	See[159]	Hours per day of operation
`FanPower`	double	W	>= 0	Yes		Fan power

Exhaust/Supply Only

If a supply only or exhaust only system is specified, no additional information is entered.

Balanced

If a balanced system is specified, no additional information is entered.

Heat Recovery Ventilator

If a heat recovery ventilator system is specified, additional information is entered in `VentilationFan`.

Element	Type	Units	Constraints	Required	Default	Notes
`SensibleRecoveryEfficiency` or `AdjustedSensibleRecoveryEfficiency`	double	frac	0 - 1	Yes		(Adjusted) Sensible recovery efficiency

Energy Recovery Ventilator

If an energy recovery ventilator system is specified, additional information is entered in `VentilationFan`.

[156] For central fan integrated supply systems, IsSharedSystem must be false.
[157] FanType choices are "energy recovery ventilator", "heat recovery ventilator", "exhaust only", "supply only", "balanced", or "central fan integrated supply".
[158] For a central fan integrated supply system, the flow rate should equal the amount of outdoor air provided to the distribution system.
[159] If HoursInOperation not provided, defaults to 24 (i.e., running continuously) for all system types other than central fan integrated supply (CFIS), and 8.0 (i.e., running intermittently) for CFIS systems.

Element	Type	Units	Constraints	Required	Default	Notes
TotalRecoveryEfficiency or AdjustedTotalRecoveryEfficiency	double	frac	0 - 1	Yes		(Adjusted) Total recovery efficiency
SensibleRecoveryEfficiency or AdjustedSensibleRecoveryEfficiency	double	frac	0 - 1	Yes		(Adjusted) Sensible recovery efficiency

Central Fan Integrated Supply

If a central fan integrated supply system is specified, additional information is entered in VentilationFan.

Element	Type	Units	Constraints	Required	Default	Notes
AttachedToHVACDistributionSystem	idref		See[160]	Yes		ID of attached distribution system

Shared System

If the specified system is a shared system (i.e., serving multiple dwelling units), additional information is entered in VentilationFan.

Element	Type	Units	Constraints	Required	Default	Notes
FractionRecirculation	double	frac	0 - 1	Yes		Fraction of supply air that is recirculated[161]
extension/InUnitFlowRate	double	cfm	>= 0[162]	Yes		Flow rate delivered to the dwelling unit
extension/PreHeating	element		0 - 1	No	<none>	Supply air preconditioned by heating equipment?[163]
extension/PreCooling	element		0 - 1	No	<none>	Supply air preconditioned by cooling equipment?[164]

If pre-heating is specified, additional information is entered in extension/PreHeating.

Element	Type	Units	Constraints	Required	Default	Notes
Fuel	string		See[165]	Yes		Pre-heating equipment fuel type
AnnualHeatingEfficiency[Units="W/W"]/Value	double	W/W	> 0	Yes		Pre-heating equipment annual COP
FractionVentilationHeatLoadServed	double	frac	0 - 1	Yes		Fraction of ventilation heating load served by pre-heating equipment

[160] HVACDistribution type cannot be HydronicDistribution.
[161] 1-FractionRecirculation is assumed to be the fraction of supply air that is provided from outside. The value must be 0 for exhaust only systems.
[162] InUnitFlowRate must also be < TestedFlowRate (or RatedFlowRate).
[163] PreHeating not allowed for exhaust only systems.
[164] PreCooling not allowed for exhaust only systems.

If pre-cooling is specified, additional information is entered in `extension/PreCooling`.

Element	Type	Units	Constraints	Required	Default	Notes
`Fuel`	string		See[166]	Yes		Pre-cooling equipment fuel type
`AnnualCoolingEfficiency[Units="W/W"]/Value`	double	W/W	> 0	Yes		Pre-cooling equipment annual COP
`FractionVentilationCoolLoadServed`	double	frac	0 - 1	Yes		Fraction of ventilation cooling load served by pre-cooling equipment

3.6.7 HPXML Local Ventilation Fan

Each kitchen range fan or bathroom fan that provides local ventilation is entered as a `/HPXML/Building/BuildingDetails/Systems/MechanicalVentilation/VentilationFans/VentilationFan`. If not entered, the simulation will not include kitchen/bathroom fans.

Element	Type	Units	Constraints	Required	Default	Notes
`SystemIdentifier`	id			Yes		Unique identifier
`UsedForLocalVentilatio`	boolean		true	Yes		Must be set to true
`Quantity`	integer		>= 0	No	See[167]	Number of identical fans
`RatedFlowRate`	double	cfm	>= 0	No	See[168]	Flow rate
`HoursInOperation`	double	hrs/day	0 - 24	No	See[169]	Hours per day of operation
`FanLocation`	string		See[170]	Yes		Location of the fan
`FanPower`	double	W	>= 0	No	See[171]	Fan power
`extension/StartHour`	integer		0 - 23	No	See[172]	Daily start hour of operation

3.6.8 HPXML Whole House Fan

Each whole house fan that provides cooling load reduction is entered as a `/HPXML/Building/BuildingDetails/Systems/MechanicalVentilation/VentilationFans/VentilationFan`. If not entered, the simulation will not include whole house fans.

[165] Fuel choices are "natural gas", "fuel oil", "fuel oil 1", "fuel oil 2", "fuel oil 4", "fuel oil 5/6", "diesel", "propane", "kerosene", "coal", "coke", "bituminous coal", "anthracite coal", "electricity", "wood", or "wood pellets".
[166] Fuel only choice is "electricity".
[167] If Quantity not provided, defaults to 1 for kitchen fans and NumberofBathrooms for bath fans based on the 2010 BAHSP.
[168] If RatedFlowRate not provided, defaults to 100 cfm for kitchen fans and 50 cfm for bath fans based on the 2010 BAHSP.
[169] If HoursInOperation not provided, defaults to 1 based on the 2010 BAHSP.
[170] FanLocation choices are "kitchen" or "bath".
[171] If FanPower not provided, defaults to 0.3 W/cfm * RatedFlowRate based on the 2010 BAHSP.
[172] If StartHour not provided, defaults to 18 for kitchen fans and 7 for bath fans based on the 2010 BAHSP.

Element	Type	Units	Constraints	Required	Default	Notes
SystemIdentifier	id			Yes		Unique identifier
UsedForSeasonalCoolingLoadReduction	boolean		true	Yes		Must be set to true
RatedFlowRate	double	cfm	>= 0	Yes		Flow rate
FanPower	double	W	>= 0	Yes		Fan power

Note: The whole house fan is assumed to operate during hours of favorable outdoor conditions and will take priority over operable windows (natural ventilation).

3.6.9 HPXML Water Heating Systems

Each water heater is entered as a /HPXML/Building/BuildingDetails/Systems/WaterHeating/WaterHeatingSystem. If not entered, the simulation will not include water heating.

Element	Type	Units	Constraints	Required	Default	Notes
SystemIdentifier	id			Yes		Unique identifier
IsSharedSystem	boolean			No	false	Whether it serves multiple dwelling units or shared laundry room
WaterHeaterType	string		See[173]	Yes		Type of water heater
Location	string		See[174]	No	See[175]	Water heater location
FractionDHWLoadServed	double	frac	0 - 1[176]	Yes		Fraction of hot water load served[177]
HotWaterTemperature	double	F	> 0	No	125	Water heater setpoint
UsesDesuperheater	boolean			No	false	Presence of desuperheater?
NumberofUnitsServed	integer		> 0	See[178]		Number of dwelling units served directly or indirectly

[173] WaterHeaterType choices are "storage water heater", "instantaneous water heater", "heat pump water heater", "space-heating boiler with storage tank", or

Conventional Storage

If a conventional storage water heater is specified, additional information is entered in `WaterHeatingSystem`.

Element	Type	Units	Constraints	Required	Default	Notes
`FuelType`	string		See[179]	Yes		Fuel type
`TankVolume`	double	gal	> 0	No	See[180]	Tank volume
`HeatingCapacity`	double	Btuh	> 0	No	See[181]	Heating capacity
`UniformEnergyFactor` or `EnergyFactor`	double	frac	< 1	Yes		EnergyGuide label rated efficiency
`FirstHourRating`	double	gal/hr	> 0	See[182]		EnergyGuide label first hour rating
`RecoveryEfficiency`	double	frac	0 - 1	No	See[183]	Recovery efficiency
`WaterHeaterInsulation/Jacket/JacketRValue`	double	F-ft2-hr/Btu	>= 0	No	0	R-value of additional tank insulation wrap

Tankless

If an instantaneous tankless water heater is specified, additional information is entered in `WaterHeatingSystem`.

"space-heating boiler with tankless coil".

[174] Location choices are "living space", "basement - unconditioned", "basement - conditioned", "attic - unvented", "attic - vented", "garage", "crawlspace - unvented", "crawlspace - vented", "other exterior", "other housing unit", "other heated space", "other multifamily buffer space", or "other non-freezing space". See *HPXML Locations* for descriptions.

[175] If Location not provided, defaults to the first present space type:

- **IECC zones 1-3, excluding 3A**: "garage", "living space"
- **IECC zones 3A, 4-8, unknown**: "basement - conditioned", "basement - unconditioned", "living space"

[176] The sum of all `FractionDHWLoadServed` (across all WaterHeatingSystems) must equal to 1.

[177] FractionDHWLoadServed represents only the fraction of the hot water load associated with the hot water **fixtures**. Additional hot water load from clothes washers/dishwashers will be automatically assigned to the appropriate water heater(s).

[178] NumberofUnitsServed only required if IsSharedSystem is true, in which case it must be > 1.

[179] FuelType choices are "natural gas", "fuel oil", "fuel oil 1", "fuel oil 2", "fuel oil 4", "fuel oil 5/6", "diesel", "propane", "kerosene", "coal", "coke", "bituminous coal", "anthracite coal", "electricity", "wood", or "wood pellets".

[180] If TankVolume not provided, defaults based on Table 8 in the 2014 BAHSP.

[181] If HeatingCapacity not provided, defaults based on Table 8 in the 2014 BAHSP.

[182] FirstHourRating only required if UniformEnergyFactor provided.

[183] If RecoveryEfficiency not provided, defaults as follows based on a regression analysis of AHRI certified water heaters:

- **Electric**: 0.98
- **Non-electric, EnergyFactor < 0.75**: 0.252 * EnergyFactor + 0.608
- **Non-electric, EnergyFactor >= 0.75**: 0.561 * EnergyFactor + 0.439

Element	Type	Units	Constraints	Required	Default	Notes
FuelType	string		See[184]	Yes		Fuel type
PerformanceAdjustment	double	frac		No	See[185]	Multiplier on efficiency, typically to account for cycling
UniformEnergyFactor or EnergyFactor	double	frac	< 1	Yes		EnergyGuide label rated efficiency

Heat Pump

If a heat pump water heater is specified, additional information is entered in WaterHeatingSystem.

Element	Type	Units	Constraints	Required	Default	Notes
FuelType	string		See[186]	Yes		Fuel type
TankVolume	double	gal	> 0	Yes		Tank volume
UniformEnergyFactor or EnergyFactor	double	frac	> 1	Yes		EnergyGuide label rated efficiency
FirstHourRating	double	gal/hr	> 0	See[187]		EnergyGuide label first hour rating
WaterHeaterInsulation/Jacket/JacketRValue	double	F-ft2-hr/Btu	>= 0	No	0	R-value of additional tank insulation wrap

Combi Boiler w/ Storage

If a combination boiler w/ storage tank (sometimes referred to as an indirect water heater) is specified, additional information is entered in WaterHeatingSystem.

Element	Type	Units	Constraints	Required	Default	Notes
RelatedHVACSystem	idref		See[188]	Yes		ID of boiler
TankVolume	double	gal	> 0	Yes		Volume of the storage tank
WaterHeaterInsulation/Jacket/JacketRValue	double	F-ft2-hr/Btu	>= 0	No	0	R-value of additional storage tank insulation wrap
StandbyLoss	double	F/hr	> 0	No	See[189]	Storage tank standby losses

[184] FuelType choices are "natural gas", "fuel oil", "fuel oil 1", "fuel oil 2", "fuel oil 4", "fuel oil 5/6", "diesel", "propane", "kerosene", "coal", "coke", "bituminous coal", "anthracite coal", "electricity", "wood", or "wood pellets".
[185] If PerformanceAdjustment not provided, defaults to 0.94 (UEF) or 0.92 (EF) based on ANSI/RESNET/ICC 301-2019.
[186] FuelType only choice is "electricity".
[187] FirstHourRating only required if UniformEnergyFactor provided.
[188] RelatedHVACSystem must reference a HeatingSystem of type Boiler.
[189] If StandbyLoss not provided, defaults based on a regression analysis of AHRI Directory of Certified Product Performance.

Combi Boiler w/ Tankless Coil

If a combination boiler w/ tankless coil is specified, additional information is entered in `WaterHeatingSystem`.

Element	Type	Units	Constraints	Required	Default	Notes
`RelatedHVACSystem`	idref		See[190]	Yes		ID of boiler

Desuperheater

If the water heater uses a desuperheater, additional information is entered in `WaterHeatingSystem`.

Element	Type	Units	Constraints	Required	Default	Notes
`RelatedHVACSystem`	idref		See[191]	Yes		ID of heat pump or air conditioner

3.6.10 HPXML Hot Water Distribution

If any water heating systems are provided, a single hot water distribution system is entered as a `/HPXML/Building/BuildingDetails/Systems/WaterHeating/HotWaterDistribution`.

Element	Type	Units	Constraints	Required	Default	Notes
`SystemIdentifier`	id			Yes		Unique identifier
`SystemType`	element		1[192]	Yes		Type of in-unit distribution system serving the dwelling unit
`PipeInsulation/PipeRValue`	double	F-ft2-hr/Btu	>= 0	No	0.0	Pipe insulation R-value
`DrainWaterHeatRecovery`	element		0 - 1	No	<none>	Presence of drain water heat recovery device
`extension/SharedRecirculation`	element		0 - 1[193]	No	<none>	Presence of shared recirculation system serving multiple dwelling units

Note: In attached/multifamily buildings, only the hot water distribution system serving the dwelling unit should be defined. The hot water distribution associated with, e.g., a shared laundry room should not be defined.

Standard

If the in-unit distribution system is specified as standard, additional information is entered in `SystemType/Standard`.

[190] RelatedHVACSystem must reference a `HeatingSystem` (Boiler).
[191] RelatedHVACSystem must reference a `HeatPump` (air-to-air, mini-split, or ground-to-air) or `CoolingSystem` (central air conditioner or mini-split).
[192] SystemType child element choices are `Standard` and `Recirculation`.
[193] If SharedRecirculation is provided, SystemType must be `Standard`. This is because a stacked recirculation system (i.e., shared recirculation loop plus an additional in-unit recirculation system) is more likely to indicate input errors than reflect an actual real-world scenario.

Element	Type	Units	Constraints	Required	Default	Notes
PipingLength	double	ft	> 0	No	See[194]	Length of piping[195]

Recirculation

If the in-unit distribution system is specified as recirculation, additional information is entered in `SystemType/Recirculation`.

Element	Type	Units	Constraints	Required	Default	Notes
ControlType	string		See[196]	Yes		Recirculation control type
RecirculationPipingLoopLength	double	ft	> 0	No	See[197]	Recirculation piping loop length[198]
BranchPipingLoopLength	double	ft	> 0	No	10	Branch piping loop length[199]
PumpPower	double	W	>= 0	No	50[200]	Recirculation pump power

Shared Recirculation

If a shared recirculation system is specified, additional information is entered in `extension/SharedRecirculation`.

[194]

If PipingLength not provided, calculated using the following equation from ANSI/RESNET/ICC 301-2019:
PipeL = 2.0 * (CFA / NCfl)^0.5 + 10.0 * NCfl + 5.0 * Bsmnt
where
CFA = conditioned floor area [ft2],
NCfl = number of conditioned floor levels number of conditioned floor levels in the residence including conditioned basements,
Bsmnt = presence (1.0) or absence (0.0) of an unconditioned basement in the residence.

[195] PipingLength is the length of hot water piping from the hot water heater (or from a shared recirculation loop serving multiple dwelling units) to the farthest hot water fixture, measured longitudinally from plans, assuming the hot water piping does not run diagonally, plus 10 feet of piping for each floor level, plus 5 feet of piping for unconditioned basements (if any).

[196] ControlType choices are “manual demand control”, “presence sensor demand control”, “temperature”, “timer”, or “no control”.

[197]

If RecirculationPipingLoopLength not provided, calculated using the following equation from ANSI/RESNET/ICC 301-2019:
RecircPipeL = 2.0 * (2.0 * (CFA / NCfl)^0.5 + 10.0 * NCfl + 5.0 * Bsmnt) - 20.0
where
CFA = conditioned floor area [ft2],
NCfl = number of conditioned floor levels number of conditioned floor levels in the residence including conditioned basements,
Bsmnt = presence (1.0) or absence (0.0) of an unconditioned basement in the residence.

[198] RecirculationPipingLoopLength is the recirculation loop length including both supply and return sides, measured longitudinally from plans, assuming the hot water piping does not run diagonally, plus 20 feet of piping for each floor level greater than one plus 10 feet of piping for unconditioned basements.

[199] BranchPipingLoopLength is the length of the branch hot water piping from the recirculation loop to the farthest hot water fixture from the recirculation loop, measured longitudinally from plans, assuming the branch hot water piping does not run diagonally.

[200] PumpPower default based on ANSI/RESNET/ICC 301-2019.

Element	Type	Units	Constraints	Required	Default	Notes
NumberofUnitsServed	integer		> 1	Yes		Number of dwelling units served
PumpPower	double	W	>= 0	No	220[201]	Shared recirculation pump power
ControlType	string		See[202]	Yes		Shared recirculation control type

Drain Water Heat Recovery

If a drain water heat recovery (DWHR) device is specified, additional information is entered in DrainWaterHeatRecovery.

Element	Type	Units	Constraints	Required	Default	Notes
FacilitiesConnected	string		See[203]	Yes		Specifies which facilities are connected
EqualFlow	boolean			Yes		Specifies how the DHWR is configured[204]
Efficiency	double	frac	0 - 1	Yes		Efficiency according to CSA 55.1

3.6.11 HPXML Water Fixtures

Each water fixture is entered as a /HPXML/Building/BuildingDetails/Systems/WaterHeating/WaterFixture.

Element	Type	Units	Constraints	Required	Default	Notes
SystemIdentifier	id			Yes		Unique identifier
WaterFixtureType	string		See[205]	Yes		Type of water fixture
LowFlow	boolean			Yes		Whether the fixture is considered low-flow[206]

In addition, a /HPXML/Building/BuildingDetails/Systems/WaterHeating/extension/WaterFixturesUsageMultiplier can be optionally provided that scales hot water usage. if not provided, it is assumed to be 1.0.

[201] PumpPower default based on ANSI/RESNET/ICC 301-2019.
[202] ControlType choices are "manual demand control", "presence sensor demand control", "timer", or "no control".
[203] FacilitiesConnected choices are "one" or "all". Use "one" if there are multiple showers and only one of them is connected to the DWHR. Use "all" if there is one shower and it's connected to the DWHR or there are two or more showers connected to the DWHR.
[204] EqualFlow should be true if the DWHR supplies pre-heated water to both the fixture cold water piping *and* the hot water heater potable supply piping.
[205] WaterFixtureType choices are "shower head" or "faucet".
[206] LowFlow should be true if the fixture's flow rate (gpm) is <= 2.0.

3.6.12 HPXML Solar Thermal

A single solar hot water system can be entered as a `/HPXML/Building/BuildingDetails/Systems/SolarThermal/SolarThermalSystem`. If not entered, the simulation will not include solar hot water.

Element	Type	Units	Constraints	Required	Default	Notes
`SystemIdentifier`	id			Yes		Unique identifier
`SystemType`	string		See[207]	Yes		Type of solar thermal system

Solar hot water systems can be described with either simple or detailed inputs.

Simple Inputs

To define a simple solar hot water system, additional information is entered in `SolarThermalSystem`.

Element	Type	Units	Constraints	Required	Default	Notes
`SolarFraction`	double	frac	0 - 1	Yes		Solar fraction[208]
`ConnectedTo`	idref		See[209]	No[210]	<none>	Connected water heater

Detailed Inputs

To define a detailed solar hot water system, additional information is entered in `SolarThermalSystem`.

Element	Type	Units	Constraints	Required	Default	Notes
`CollectorArea`	double	ft2	> 0	Yes		Area
`CollectorLoopType`	string		See[211]	Yes		Loop type
`CollectorType`	string		See[212]	Yes		System type
`CollectorAzimuth`	integer	deg	0 - 359	Yes		Azimuth (clockwise from North)
`CollectorTilt`	double	deg	0 - 90	Yes		Tilt relative to horizontal
`CollectorRatedOpticalEfficiency`	double	frac	0 - 1	Yes		Rated optical efficiency[213]
`CollectorRatedThermalLosses`	double	Btu/hr-ft2-R	> 0	Yes		Rated thermal losses[214]
`StorageVolume`	double	gal	> 0	No	See[215]	Hot water storage volume
`ConnectedTo`	idref		See[216]	Yes		Connected water heater

[207] SystemType only choice is "hot water".
[208] Portion of total conventional hot water heating load (delivered energy plus tank standby losses). Can be obtained from Directory of SRCC OG-300 Solar Water Heating System Ratings or NREL's System Advisor Model or equivalent.
[209] ConnectedTo must reference a `WaterHeatingSystem`. The referenced water heater cannot be a space-heating boiler nor attached to a desuperheater.
[210] If ConnectedTo not provided, solar fraction will apply to all water heaters in the building.

3.6.13 HPXML Photovoltaics

Each solar electric photovoltaic (PV) system is entered as a `/HPXML/Building/BuildingDetails/Systems/Photovoltaics/PVSystem`. If not entered, the simulation will not include photovoltaics.

Many of the inputs are adopted from the PVWatts model.

Element	Type	Units	Constraints	Required	Default	Notes
`SystemIdentifier`	id			Yes		Unique identifier
`IsSharedSystem`	boolean			No	false	Whether it serves multiple dwelling units
`Location`	string		See[217]	No	roof	Mounting location
`ModuleType`	string		See[218]	No	standard	Type of module
`Tracking`	string		See[219]	No	fixed	Type of tracking
`ArrayAzimuth`	integer	deg	0 - 359	Yes		Direction panels face (clockwise from North)
`ArrayTilt`	double	deg	0 - 90	Yes		Tilt relative to horizontal
`MaxPowerOutput`	double	W	>= 0	Yes		Peak power
`InverterEfficiency`	double	frac	0 - 1	No	0.96	Inverter efficiency
`SystemLossesFraction` or `YearModulesManufactured`	double or integer	frac or #	0 - 1 or > 1600	No	0.14	System losses[220]
`extension/NumberofBedroomsServed`	integer		> 1	See[221]		Number of bedrooms served

3.6.14 HPXML Generators

Each generator that provides on-site power is entered as a `/HPXML/Building/BuildingDetails/Systems/extension/Generators/Generator`. If not entered, the simulation will not include generators.

[211] CollectorLoopType choices are "liquid indirect", "liquid direct", or "passive thermosyphon".
[212] CollectorType choices are "single glazing black", "double glazing black", "evacuated tube", or "integrated collector storage".
[213] CollectorRatedOpticalEfficiency is FRTA (y-intercept) from the Directory of SRCC OG-100 Certified Solar Collector Ratings.
[214] CollectorRatedThermalLosses is FRUL (slope) from the Directory of SRCC OG-100 Certified Solar Collector Ratings.
[215] If StorageVolume not provided, calculated as 1.5 gal/ft2 * CollectorArea.
[216] ConnectedTo must reference a `WaterHeatingSystem` that is not of type space-heating boiler nor connected to a desuperheater.
[217] Location choices are "ground" or "roof" mounted.
[218] ModuleType choices are "standard", "premium", or "thin film".
[219] Tracking choices are "fixed", "1-axis", "1-axis backtracked", or "2-axis".
[220] System losses due to soiling, shading, snow, mismatch, wiring, degradation, etc. If YearModulesManufactured provided but not SystemLossesFraction, system losses calculated as: SystemLossesFraction = 1.0 - (1.0 - 0.14) * (1.0 - (1.0 - 0.995^(CurrentYear - YearModulesManufactured))).
[221] NumberofBedroomsServed only required if IsSharedSystem is true, in which case it must be > NumberofBedrooms. PV generation will be apportioned to the dwelling unit using its number of bedrooms divided by the total number of bedrooms served by the PV system.

Element	Type	Units	Constraints	Required	Default	Notes
SystemIdentifier	id			Yes		Unique identifier
IsSharedSystem	boolean			No	false	Whether it serves multiple dwelling units
FuelType	string		See[222]	Yes		Fuel type
AnnualConsumptionkBtu	double	kBtu/yr	> 0	Yes		Annual fuel consumed
AnnualOutputkWh	double	kWh/yr	> 0[223]	Yes		Annual electricity produced
NumberofBedroomsServed	integer		> 1	See[224]		Number of bedrooms served

Note: Generators will be modeled as operating continuously (24/7).

3.7 HPXML Appliances

Appliances entered in /HPXML/Building/BuildingDetails/Appliances.

3.7.1 HPXML Clothes Washer

A single clothes washer can be entered as a /HPXML/Building/BuildingDetails/Appliances/ClothesWasher. If not entered, the simulation will not include a clothes washer.

Element	Type	Units	Constraints	Required	Default	Notes
SystemIdentifier	id			Yes		Unique identifier
IsSharedAppliance	boolean			No	false	Whether it serves multiple dwelling units[225]
Location	string		See[226]	No	living space	Location
IntegratedModifiedEnergyFactor or ModifiedEnergyFactor	double	ft3/kWh/cyc	> 0	No	See[227]	EnergyGuide label efficiency[228]
AttachedToWaterHeatingSystem	idref		See[229]	See[230]		ID of attached water heater
extension/UsageMultiplier	double		>= 0	No	1.0	Multiplier on energy & hot water usage

[222] FuelType choices are “natural gas” or “propane”.

[223] AnnualOutputkWh must also be < AnnualConsumptionkBtu*3.412 (i.e., the generator must consume more energy than it produces).

[224] NumberofBedroomsServed only required if IsSharedSystem is true, in which case it must be > NumberofBedrooms. Annual consumption and annual production will be apportioned to the dwelling unit using its number of bedrooms divided by the total number of bedrooms served by the generator.

[225] For example, a clothes washer in a shared laundry room of a MF building.

[226] Location choices are “living space”, “basement - conditioned”, “basement - unconditioned”, “garage”, “other housing unit”, “other heated space”, “other multifamily buffer space”, or “other non-freezing space”. See *HPXML Locations* for descriptions.

[227] If neither IntegratedModifiedEnergyFactor nor ModifiedEnergyFactor provided, the following default values representing a standard clothes washer from 2006 will be used: IntegratedModifiedEnergyFactor = 1.0, RatedAnnualkWh = 400, LabelElectricRate = 0.12, LabelGasRate = 1.09, LabelAnnualGasCost =

If IntegratedModifiedEnergyFactor or ModifiedEnergyFactor is provided, a complete set of EnergyGuide label information is entered in `ClothesWasher`.

Element	Type	Units	Constraints	Required	Default	Notes
`RatedAnnualkWh`	double	kWh/yr	> 0	Yes		EnergyGuide label annual consumption
`LabelElectricRate`	double	$/kWh	> 0	Yes		EnergyGuide label electricity rate
`LabelGasRate`	double	$/therm	> 0	Yes		EnergyGuide label natural gas rate
`LabelAnnualGasCost`	double	$	> 0	Yes		EnergyGuide label annual gas cost
`LabelUsage`	double	cyc/wk	> 0	Yes		EnergyGuide label number of cycles
`Capacity`	double	ft3	> 0	Yes		Clothes dryer volume

Clothes washer energy use and hot water use is calculated per the Energy Rating Rated Home in ANSI/RESNET/ICC 301-2019 Addendum A.

3.7.2 HPXML Clothes Dryer

A single clothes dryer can be entered as a `/HPXML/Building/BuildingDetails/Appliances/ClothesDryer`. If not entered, the simulation will not include a clothes dryer.

Element	Type	Units	Constraints	Required	Default	Notes
`SystemIdentifier`	id			Yes		Unique identifier
`IsSharedAppliance`	boolean			No	false	Whether it serves multiple dwelling units[231]
`Location`	string		See[232]	No	living space	Location
`FuelType`	string		See[233]	Yes		Fuel type
`CombinedEnergyFactor` or `EnergyFactor`	double	lb/kWh	> 0	No	See[234]	EnergyGuide label efficiency[235]
`extension/UsageMultiplier`	double		>= 0	No	1.0	Multiplier on energy use
`extension/IsVented`	boolean			No	true	Whether dryer is vented
`extension/VentedFlowRate`	double	cfm	>= 0	See[236]	100[237]	Exhust flow rate during operation

27.0, LabelUsage = 6, Capacity = 3.0.

[228] If ModifiedEnergyFactor (MEF) provided instead of IntegratedModifiedEnergyFactor (IMEF), it will be converted using the Interpretation on ANSI/RESNET 301-2014 Clothes Washer IMEF: IMEF = (MEF - 0.503) / 0.95.

[229] AttachedToWaterHeatingSystem must reference a `WaterHeatingSystem`.

[230] AttachedToWaterHeatingSystem only required if IsSharedAppliance is true.

[231] For example, a clothes dryer in a shared laundry room of a MF building.

[232] Location choices are "living space", "basement - conditioned", "basement - unconditioned", "garage", "other housing unit", "other heated space", "other multifamily buffer space", or "other non-freezing space". See *HPXML Locations* for descriptions.

[233] FuelType choices are "natural gas", "fuel oil", "fuel oil 1", "fuel oil 2", "fuel oil 4", "fuel oil 5/6", "diesel", "propane", "kerosene", "coal", "coke", "bituminous coal", "anthracite coal", "electricity", "wood", or "wood pellets".

[234] If neither CombinedEnergyFactor nor EnergyFactor provided, the following default values representing a standard clothes dryer from 2006 will be used:

Clothes dryer energy use is calculated per the Energy Rating Rated Home in ANSI/RESNET/ICC 301-2019 Addendum A.

3.7.3 HPXML Dishwasher

A single dishwasher can be entered as a `/HPXML/Building/BuildingDetails/Appliances/Dishwasher`. If not entered, the simulation will not include a dishwasher.

Element	Type	Units	Constraints	Required	Default	Notes
`SystemIdentifier`	id			Yes		Unique identifier
`IsSharedAppliance`	boolean			No	false	Whether it serves multiple dwelling units[238]
`Location`	string		See[239]	No	living space	Location
`RatedAnnualkWh` or `EnergyFactor`	double	kWh/yr or #	> 0	No	See[240]	EnergyGuide label consumption/efficiency[241]
`AttachedToWaterHeatingSystem`	idref		See[242]	See[243]		ID of attached water heater
`extension/UsageMultiplier`	double		>= 0	No	1.0	Multiplier on energy & hot water usage

If the RatedAnnualkWh or EnergyFactor is provided, a complete set of EnergyGuide label information is entered in `Dishwasher`.

Element	Type	Units	Constraints	Required	Default	Notes
`LabelElectricRate`	double	$/kWh	> 0	Yes		EnergyGuide label electricity rate
`LabelGasRate`	double	$/therm	> 0	Yes		EnergyGuide label natural gas rate
`LabelAnnualGasCost`	double	$	> 0	Yes		EnergyGuide label annual gas cost
`LabelUsage`	double	cyc/wk	> 0	Yes		EnergyGuide label number of cycles
`PlaceSettingCapacity`	integer	#	> 0	Yes		Number of place settings

Dishwasher energy use and hot water use is calculated per the Energy Rating Rated Home in ANSI/RESNET/ICC 301-2019 Addendum A.

CombinedEnergyFactor = 3.01.

[235] If EnergyFactor (EF) provided instead of CombinedEnergyFactor (CEF), it will be converted using the following equation based on the Interpretation on ANSI/RESNET/ICC 301-2014 Clothes Dryer CEF: CEF = EF / 1.15.

[236] VentedFlowRate only required if IsVented is true.

[237] VentedFlowRate default based on the 2010 BAHSP.

[238] For example, a dishwasher in a shared mechanical room of a MF building.

[239] Location choices are "living space", "basement - conditioned", "basement - unconditioned", "garage", "other housing unit", "other heated space", "other multifamily buffer space", or "other non-freezing space". See *HPXML Locations* for descriptions.

[240] If neither RatedAnnualkWh nor EnergyFactor provided, the following default values representing a standard dishwasher from 2006 will be used: RatedAnnualkWh = 467, LabelElectricRate = 0.12, LabelGasRate = 1.09, LabelAnnualGasCost = 33.12, LabelUsage = 4, PlaceSettingCapacity = 12.

[241] If EnergyFactor (EF) provided instead of RatedAnnualkWh, it will be converted using the following equation based on ANSI/RESNET/ICC 301-2014: RatedAnnualkWh = 215.0 / EF.

[242] AttachedToWaterHeatingSystem must reference a `WaterHeatingSystem`.

[243] AttachedToWaterHeatingSystem only required if IsSharedAppliance is true.

3.7.4 HPXML Refrigerators

Each refrigerator can be entered as a `/HPXML/Building/BuildingDetails/Appliances/Refrigerator`. If not entered, the simulation will not include a refrigerator.

Element	Type	Units	Constraints	Required	Default	Notes
`SystemIdentifier`	id			Yes		Unique identifier
`Location`	string		See[244]	No	See[245]	Location
`RatedAnnualkWh` or `extension/AdjustedAnnualkWh`	double	kWh/yr	> 0	No	See[246]	Annual consumption
`PrimaryIndicator`	boolean			See[247]		Primary refrigerator?
`extension/UsageMultiplier`	double		>= 0	No	1.0	Multiplier on energy use
`extension/WeekdayScheduleFractions`	array			No	See[248]	24 comma-separated weekday fractions
`extension/WeekendScheduleFractions`	array			No		24 comma-separated weekend fractions
`extension/MonthlyScheduleMultipliers`	array			No	See[249]	12 comma-separated monthly multipliers

3.7.5 HPXML Freezers

Each standalone freezer can be entered as a `/HPXML/Building/BuildingDetails/Appliances/Freezer`. If not entered, the simulation will not include a standalone freezer.

Element	Type	Units	Constraints	Required	Default	Notes
`SystemIdentifier`	id			Yes		Unique identifier
`Location`	string		See[250]	No	See[251]	Location
`RatedAnnualkWh` or `extension/AdjustedAnnualkWh`	double	kWh/yr	> 0	No	319.8[252]	Annual consumption
`extension/UsageMultiplier`	double		>= 0	No	1.0	Multiplier on energy use
`extension/WeekdayScheduleFractions`	array			No	See[253]	24 comma-separated weekday fractions
`extension/WeekendScheduleFractions`	array			No		24 comma-separated weekend fractions
`extension/MonthlyScheduleMultipliers`	array			No	See[254]	12 comma-separated monthly multipliers

[244] Location choices are "living space", "basement - conditioned", "basement - unconditioned", "garage", "other housing unit", "other heated space", "other multifamily buffer space", or "other non-freezing space". See *HPXML Locations* for descriptions.

[245] If Location not provided and is the *primary* refrigerator, defaults to "living space". If Location not provided and is a *secondary* refrigerator, defaults to the first present space type: "garage", "basement - unconditioned", "basement - conditioned", or "living space".

[246] If neither RatedAnnualkWh nor AdjustedAnnualkWh provided, it will be defaulted to represent a standard refrigerator from 2006 using the following equation based on ANSI/RESNET/ICC 301-2019: RatedAnnualkWh = 637.0 + 18.0 * NumberofBedrooms.

[247] If multiple refrigerators are specified, there must be exactly one refrigerator described with PrimaryIndicator=true.

[248] If WeekdayScheduleFractions or WeekendScheduleFractions not provided, default values from Figure 16 of the 2010 BAHSP are used: "0.040, 0.039, 0.038, 0.037, 0.036, 0.036, 0.038, 0.040, 0.041, 0.041, 0.040, 0.040, 0.042, 0.042, 0.042, 0.041, 0.044, 0.048, 0.050, 0.048, 0.047, 0.046, 0.044, 0.041".

[249] If MonthlyScheduleMultipliers not provided, default values from Figure 24 of the 2010 BAHSP are used: "0.837, 0.835, 1.084, 1.084, 1.084, 1.096, 1.096, 1.096, 1.096, 1.096, 0.931, 0.925, 0.837".

3.7.6 HPXML Dehumidifier

Each dehumidifier can be entered as a `/HPXML/Building/BuildingDetails/Appliances/Dehumidifier`. If not entered, the simulation will not include a dehumidifier.

Element	Type	Units	Constraints	Required	Default	Notes
`SystemIdentifier`	id			Yes		Unique identifier
`Type`	string		See[255]	Yes		Type of dehumidifier
`Location`	string		See[256]	Yes		Location of dehumidifier
`Capacity`	double	pints/day	> 0	Yes		Dehumidification capacity
`IntegratedEnergyFactor` or `EnergyFactor`	double	liters/kWh	> 0	Yes		Rated efficiency
`DehumidistatSetpoint`	double	frac	0 - 1[257]	Yes		Relative humidity setpoint
`FractionDehumidificationLoadServed`	double	frac	0 - 1[258]	Yes		Fraction of dehumidification load served

Note: Dehumidifiers are currently modeled as located within conditioned space; the model is not suited for a dehumidifier in, e.g., a wet unconditioned basement or crawlspace. Therefore the dehumidifier Location is currently restricted to "living space".

3.7.7 HPXML Cooking Range/Oven

A single cooking range can be entered as a `/HPXML/Building/BuildingDetails/Appliances/CookingRange`. If not entered, the simulation will not include a cooking range/oven.

[250] Location choices are "living space", "basement - conditioned", "basement - unconditioned", "garage", "other housing unit", "other heated space", "other multifamily buffer space", or "other non-freezing space". See *HPXML Locations* for descriptions.

[251] If Location not provided, defaults to "garage" if present, otherwise "basement - unconditioned" if present, otherwise "basement - conditioned" if present, otherwise "living space".

[252] RatedAnnualkWh default based on the 2010 BAHSP.

[253] If WeekdayScheduleFractions or WeekendScheduleFractions not provided, default values from Figure 16 of the 2010 BAHSP are used: "0.040, 0.039, 0.038, 0.037, 0.036, 0.036, 0.038, 0.040, 0.041, 0.041, 0.040, 0.040, 0.042, 0.042, 0.042, 0.041, 0.044, 0.048, 0.050, 0.048, 0.047, 0.046, 0.044, 0.041".

[254] If MonthlyScheduleMultipliers not provided, default values from Figure 24 of the 2010 BAHSP are used: "0.837, 0.835, 1.084, 1.084, 1.084, 1.096, 1.096, 1.096, 1.096, 1.096, 0.931, 0.925, 0.837".

[255] Type choices are "portable" or "whole-home".

[256] Location only choice is "living space".

[257] If multiple dehumidifiers are entered, they must all have the same setpoint or an error will be generated.

[258] The sum of all `FractionDehumidificationLoadServed` (across all Dehumidifiers) must be less than or equal to 1.

Element	Type	Units	Constraints	Required	Default	Notes
SystemIdentifier	id			Yes		Unique identifier
Location	string		See[259]	No	living space	Location
FuelType	string		See[260]	Yes		Fuel type
IsInduction	boolean			No	false	Induction range?
extension/UsageMultiplier	double		>= 0	No	1.0	Multiplier on energy use
extension/WeekdayScheduleFractions	array			No	See[261]	24 comma-separated weekday fractions
extension/WeekendScheduleFractions	array			No		24 comma-separated weekend fractions
extension/MonthlyScheduleMultipliers	array			No	See[262]	12 comma-separated monthly multipliers

If a cooking range is specified, a single oven is also entered as a /HPXML/Building/BuildingDetails/Appliances/Oven.

Element	Type	Units	Constraints	Required	Default	Notes
SystemIdentifier	id			Yes		Unique identifier
IsConvection	boolean			No	false	Convection oven?

Cooking range/oven energy use is calculated per the Energy Rating Rated Home in ANSI/RESNET/ICC 301-2019.

3.8 HPXML Lighting & Ceiling Fans

Lighting and ceiling fans are entered in /HPXML/Building/BuildingDetails/Lighting.

3.8.1 HPXML Lighting

Nine /HPXML/Building/BuildingDetails/Lighting/LightingGroup elements must be provided, each of which is the combination of:

- LightingType: 'LightEmittingDiode', 'CompactFluorescent', and 'FluorescentTube'
- Location: 'interior', 'garage', and 'exterior'

Information is entered in each LightingGroup.

[259] Location choices are "living space", "basement - conditioned", "basement - unconditioned", "garage", "other housing unit", "other heated space", "other multifamily buffer space", or "other non-freezing space". See *HPXML Locations* for descriptions.

[260] FuelType choices are "natural gas", "fuel oil", "fuel oil 1", "fuel oil 2", "fuel oil 4", "fuel oil 5/6", "diesel", "propane", "kerosene", "coal", "coke", "bituminous coal", "anthracite coal", "electricity", "wood", or "wood pellets".

[261] If WeekdayScheduleFractions or WeekendScheduleFractions not provided, default values from Figure 22 of the 2010 BAHSP are used: "0.007, 0.007, 0.004, 0.004, 0.007, 0.011, 0.025, 0.042, 0.046, 0.048, 0.042, 0.050, 0.057, 0.046, 0.057, 0.044, 0.092, 0.150, 0.117, 0.060, 0.035, 0.025, 0.016, 0.011".

[262] If MonthlyScheduleMultipliers not provided, default values from Figure 24 of the 2010 BAHSP are used: "1.097, 1.097, 0.991, 0.987, 0.991, 0.890, 0.896, 0.896, 0.890, 1.085, 1.085, 1.097".

Element	Type	Units	Constraints	Required	Default	Notes
SystemIdentifier	id			Yes		Unique identifier
LightingType	element		1[263]	Yes		Lighting type
Location	string		See[264]	Yes		See[265]
FractionofUnitsInLocation	double	frac	0 - 1[266]	Yes		Fraction of light fixtures in the location with the specified lighting type

Additional information is entered in Lighting.

Element	Type	Units	Constraints	Required	Default	Notes
extension/InteriorUsageMultiplier	double		>= 0	No	1.0	Multiplier on interior lighting use
extension/GarageUsageMultiplier	double		>= 0	No	1.0	Multiplier on garage lighting use
extension/ExteriorUsageMultiplier	double		>= 0	No	1.0	Multiplier on exterior lighting use
extension/InteriorWeekdayScheduleFractions	array			No	See[267]	24 comma-separated interior weekday fractions
extension/InteriorWeekendScheduleFractions	array			No		24 comma-separated interior weekend fractions
extension/InteriorMonthlyScheduleMultipliers	array			No		12 comma-separated interior monthly multipliers
extension/GarageWeekdayScheduleFractions	array			No	See[268]	24 comma-separated garage weekday fractions
extension/GarageWeekendScheduleFractions	array			No		24 comma-separated garage weekend fractions
extension/GarageMonthlyScheduleMultipliers	array			No		12 comma-separated garage monthly multipliers
extension/ExteriorWeekdayScheduleFractions	array			No	See[269]	24 comma-separated exterior weekday fractions
extension/ExteriorWeekendScheduleFractions	array			No		24 comma-separated exterior weekend fractions
extension/ExteriorMonthlyScheduleMultipliers	array			No		12 comma-separated exterior monthly multipliers
extension/ExteriorHolidayLighting	element		0 - 1	No	<none>	Presence of additional holiday lighting?

If exterior holiday lighting is specified, additional information is entered in extension/ExteriorHolidayLighting.

[263] LightingType child element choices are LightEmittingDiode, CompactFluorescent, or FluorescentTube.
[264] Location choices are "interior", "garage", or "exterior".
[265] Garage lighting is ignored if the building has no garage specified elsewhere.
[266] The sum of FractionofUnitsInLocation for a given Location (e.g., interior) must be less than or equal to 1. If the fractions sum to less than 1, the remainder is assumed to be incandescent lighting.
[267] If *interior* schedule values not provided, they will be calculated using Lighting Calculation Option 2 (location-dependent lighting profile) of the 2010 BAHSP.
[268] If *garage* schedule values not provided, they will be defaulted using Appendix C Table 8 of the Title 24 2016 Res. ACM Manual.
[269] If *exterior* schedule values not provided, they will be defaulted using Appendix C Table 8 of the Title 24 2016 Res. ACM Manual.

Element	Type	Units	Constraints	Required	Default	Notes
`Load[Units="kWh/day"]/Value`	double	kWh/day	>= 0	No	See[270]	Holiday lighting energy use per day
`PeriodBeginMonth`	integer		1 - 12	No	11 (November)	Holiday lighting start date
`PeriodBeginDayOfMonth`	integer		1 - 31	No	24	Holiday lighting start date
`PeriodEndMonth`	integer		1 - 12	No	1 (January)	Holiday lighting end date
`PeriodEndDayOfMonth`	integer		1 - 31	No	6	Holiday lighting end date
`WeekdayScheduleFractions`	array			No	See[271]	24 comma-separated holiday weekday fractions
`WeekendScheduleFractions`	array			No		24 comma-separated holiday weekend fractions

Interior, exterior, and garage lighting energy use is calculated per the Energy Rating Rated Home in ANSI/RESNET/ICC 301-2019.

3.8.2 HPXML Ceiling Fans

Each ceiling fan is entered as a `/HPXML/Building/BuildingDetails/Lighting/CeilingFan`. If not entered, the simulation will not include a ceiling fan.

Element	Type	Units	Constraints	Required	Default	Notes
`SystemIdentifier`	id			Yes		Unique identifier
`Airflow[FanSpeed="medium"]/Efficiency`	double	cfm/W	> 0	No	See[272]	Efficiency at medium speed
`Quantity`	integer		> 0	No	See[273]	Number of similar ceiling fans

Ceiling fan energy use is calculated per the Energy Rating Rated Home in ANSI/RESNET/ICC 301-2019.

Note: A reduced cooling setpoint can be specified for summer months when ceiling fans are operating. See *HPXML HVAC Control* for more information.

[270] If Value not provided, defaults to 1.1 for single-family detached and 0.55 for others.
[271] If WeekdayScheduleFractions not provided, defaults to "0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0.008, 0.098, 0.168, 0.194, 0.284, 0.192, 0.037, 0.019".
[272] If Efficiency not provided, defaults to 3000 / 42.6 based on ANSI/RESNET/ICC 301-2019.
[273] If Quantity not provided, defaults to NumberofBedrooms + 1 based on ANSI/RESNET/ICC 301-2019.

3.9 HPXML Pools & Hot Tubs

3.9.1 HPXML Pools

A single pool can be entered as a `/HPXML/Building/BuildingDetails/Pools/Pool`. If not entered, the simulation will not include a pool.

Element	Type	Units	Constraints	Required	Default	Notes
`SystemIdentifier`	id			Yes		Unique identifier
`Type`	string		See[274]	Yes		Pool type

Pool Pump

If a pool is specified, a single pool pump can be entered as a `Pool/PoolPumps/PoolPump`. If not entered, the simulation will not include a pool heater.

Element	Type	Units	Constraints	Required	Default	Notes
`SystemIdentifier`	id			Yes		Unique identifier
`Type`	string		See[275]	Yes		Pool pump type
`Load[Units="kWh/year"]/Value`	double	kWh/yr	>= 0	No	See[276]	Pool pump energy use
`extension/UsageMultiplier`	double		>= 0	No	1.0	Multiplier on pool pump energy use
`extension/WeekdayScheduleFractions`	array			No	See[277]	24 comma-separated weekday fractions
`extension/WeekendScheduleFractions`	array			No		24 comma-separated weekend fractions
`extension/MonthlyScheduleMultipliers`	array			No	See[278]	12 comma-separated monthly multipliers

Pool Heater

If a pool is specified, a pool heater can be entered as a `Pool/Heater`. If not entered, the simulation will not include a pool heater.

[274] Type choices are "in ground", "on ground", "above ground", "other", "unknown", or "none". If "none" is entered, the simulation will not include a pool.
[275] Type choices are "single speed", "multi speed", "variable speed", "variable flow", "other", "unknown", or "none". If "none" is entered, the simulation will not include a pool pump.
[276] If Value not provided, defaults based on the 2010 BAHSP: 158.5 / 0.070 * (0.5 + 0.25 * NumberofBedrooms / 3 + 0.35 * ConditionedFloorArea / 1920).
[277] If WeekdayScheduleFractions or WeekendScheduleFractions not provided, default values from Figure 23 of the 2010 BAHSP are used: "0.003, 0.003, 0.003, 0.004, 0.008, 0.015, 0.026, 0.044, 0.084, 0.121, 0.127, 0.121, 0.120, 0.090, 0.075, 0.061, 0.037, 0.023, 0.013, 0.008, 0.004, 0.003, 0.003, 0.003".
[278] If MonthlyScheduleMultipliers not provided, default values from Figure 24 of the 2010 BAHSP are used: "1.154, 1.161, 1.013, 1.010, 1.013, 0.888, 0.883, 0.883, 0.888, 0.978, 0.974, 1.154".

Element	Type	Units	Constraints	Required	Default	Notes
SystemIdentifier	id			Yes		Unique identifier
Type	string		See[279]	Yes		Pool heater type
Load[Units="kWh/year" or Units="therm/year"]/Value	double	kWh/yr or therm/yr	>= 0	No	See[280]	Pool heater energy use
extension/UsageMultiplier	double		>= 0	No	1.0	Multiplier on pool heater energy use
extension/WeekdayScheduleFractions	array			No	See[281]	24 comma-separated weekday fractions
extension/WeekendScheduleFractions	array			No		24 comma-separated weekend fractions
extension/MonthlyScheduleMultipliers	array			No	See[282]	12 comma-separated monthly multipliers

3.9.2 HPXML Hot Tubs

A single hot tub can be entered as a /HPXML/Building/BuildingDetails/HotTubs/HotTub. If not entered, the simulation will not include a hot tub.

Element	Type	Units	Constraints	Required	Default	Notes
SystemIdentifier	id			Yes		Unique identifier
Type	string		See[283]	Yes		Hot tub type

Hot Tub Pump

If a hot tub is specified, a single hot tub pump can be entered as a HotTub/HotTubPumps/HotTubPump. If not entered, the simulation will not include a hot tub pump.

[279] Type choices are "none, "gas fired", "electric resistance", or "heat pump". If "none" is entered, the simulation will not include a pool heater.

[280] If Value not provided, defaults as follows:

- **gas fired**: 3.0 / 0.014 * (0.5 + 0.25 * NumberofBedrooms / 3 + 0.35 * ConditionedFloorArea / 1920) (based on the 2010 BAHSP)
- **electric resistance**: 8.3 / 0.004 * (0.5 + 0.25 * NumberofBedrooms / 3 + 0.35 * ConditionedFloorArea / 1920) (based on the 2010 BAHSP)
- **heat pump**: (electric resistance) / 5.0 (based on an average COP of 5 from Energy Saver)

[281] If WeekdayScheduleFractions or WeekendScheduleFractions not provided, default values from Figure 23 of the 2010 BAHSP are used: "0.003, 0.003, 0.003, 0.004, 0.008, 0.015, 0.026, 0.044, 0.084, 0.121, 0.127, 0.121, 0.120, 0.090, 0.075, 0.061, 0.037, 0.023, 0.013, 0.008, 0.004, 0.003, 0.003, 0.003".

[282] If MonthlyScheduleMultipliers not provided, default values from Figure 24 of the 2010 BAHSP are used: "1.154, 1.161, 1.013, 1.010, 1.013, 0.888, 0.883, 0.883, 0.888, 0.978, 0.974, 1.154".

[283] Type choices are "in ground", "on ground", "above ground", "other", "unknown", or "none". If "none" is entered, the simulation will not include a hot tub.

Element	Type	Units	Constraints	Required	Default	Notes
SystemIdentifier	id			Yes		Unique identifier
Type	string		See[284]	Yes		Hot tub pump type
Load[Units="kWh/year"]/Value	double	kWh/yr	>= 0	No	See[285]	Hot tub pump energy use
extension/UsageMultiplier	double		>= 0	No	1.0	Multiplier on hot tub pump energy use
extension/WeekdayScheduleFractions	array			No	See[286]	24 comma-separated weekday fractions
extension/WeekendScheduleFractions	array			No		24 comma-separated weekend fractions
extension/MonthlyScheduleMultipliers	array			No	See[287]	12 comma-separated monthly multipliers

Hot Tub Heater

If a hot tub is specified, a hot tub heater can be entered as a HotTub/Heater. If not entered, the simulation will not include a hot tub heater.

[284] Type choices are "single speed", "multi speed", "variable speed", "variable flow", "other", "unknown", or "none". If "none" is entered, the simulation will not include a hot tub pump.

[285] If Value not provided, defaults based on the 2010 BAHSP: 59.5 / 0.059 * (0.5 + 0.25 * NumberofBedrooms / 3 + 0.35 * ConditionedFloorArea / 1920).

[286] If WeekdayScheduleFractions or WeekendScheduleFractions not provided, default values from Figure 23 of the 2010 BAHSP are used: "0.024, 0.029, 0.024, 0.029, 0.047, 0.067, 0.057, 0.024, 0.024, 0.019, 0.015, 0.014, 0.014, 0.014, 0.024, 0.058, 0.126, 0.122, 0.068, 0.061, 0.051, 0.043, 0.024, 0.024".

[287] If MonthlyScheduleMultipliers not provided, default values from Figure 24 of the 2010 BAHSP are used: "0.921, 0.928, 0.921, 0.915, 0.921, 1.160, 1.158, 1.158, 1.160, 0.921, 0.915, 0.921".

Element	Type	Units	Constraints	Required	Default	Notes
SystemIdentifier	id			Yes		Unique identifier
Type	string		See[288]	Yes		Hot tub heater type
Load[Units="kWh/year" or Units="therm/year"]/Value	double	kWh/yr or therm/yr	>= 0	No	See[289]	Hot tub heater energy use
extension/UsageMultiplier	double		>= 0	No	1.0	Multiplier on hot tub heater energy use
extension/WeekdayScheduleFractions	array			No	See[290]	24 comma-separated weekday fractions
extension/WeekendScheduleFractions	array			No		24 comma-separated weekend fractions
extension/MonthlyScheduleMultipliers	array			No	See[291]	12 comma-separated monthly multipliers

3.10 HPXML Misc Loads

Miscellaneous loads are entered in /HPXML/Building/BuildingDetails/MiscLoads.

3.10.1 HPXML Plug Loads

Each type of plug load can be entered as a /HPXML/Building/BuildingDetails/MiscLoads/PlugLoad.

It is required to include miscellaneous plug loads (PlugLoadType="other"), which represents all residual plug loads not explicitly captured elsewhere. It is common to include television plug loads (PlugLoadType="TV other"), which represents all television energy use in the home. It is less common to include the other plug load types, as they are less frequently found in homes. If not entered, the simulation will not include that type of plug load.

[288] Type choices are "none, "gas fired", "electric resistance", or "heat pump". If "none" is entered, the simulation will not include a hot tub heater.

[289] If Value not provided, defaults as follows:

- **gas fired [therm/year]**: 0.87 / 0.011 * (0.5 + 0.25 * NumberofBedrooms / 3 + 0.35 * ConditionedFloorArea / 1920) (based on the 2010 BAHSP)
- **electric resistance [kWh/year]**: 49.0 / 0.048 * (0.5 + 0.25 * NumberofBedrooms / 3 + 0.35 * ConditionedFloorArea / 1920) (based on the 2010 BAHSP)
- **heat pump [kWh/year]** = (electric resistance) / 5.0 (based on an average COP of 5 from Energy Saver)

[290] If WeekdayScheduleFractions or WeekendScheduleFractions not provided, default values from Figure 23 of the 2010 BAHSP are used: "0.024, 0.029, 0.024, 0.029, 0.047, 0.067, 0.057, 0.024, 0.024, 0.019, 0.015, 0.014, 0.014, 0.014, 0.024, 0.058, 0.126, 0.122, 0.068, 0.061, 0.051, 0.043, 0.024, 0.024".

[291] If MonthlyScheduleMultipliers not provided, default values from Figure 24 of the 2010 BAHSP are used: "0.837, 0.835, 1.084, 1.084, 1.084, 1.096, 1.096, 1.096, 1.096, 0.931, 0.925, 0.837".

Element	Type	Units	Constraints	Required	Default	Notes
SystemIdentifier	id			Yes		Unique identifier
PlugLoadType	string		See[292]	Yes		Type of plug load
Load[Units="kWh/year"]/Value	double	kWh/yr	>= 0	No	See[293]	Annual electricity consumption
extension/FracSensible	double		0 - 1	No	See[294]	Fraction that is sensible heat gain to conditioned space[295]
extension/FracLatent	double		0 - 1	No	See[296]	Fraction that is latent heat gain to conditioned space
extension/UsageMultiplier	double		>= 0	No	1.0	Multiplier on electricity use
extension/WeekdayScheduleFractions	array			No	See[297]	24 comma-separated weekday fractions
extension/WeekendScheduleFractions	array			No	See[298]	24 comma-separated weekend fractions
extension/MonthlyScheduleMultipliers	array			No	See[299]	12 comma-separated monthly multipliers

[292] PlugLoadType choices are "other", "TV other", "well pump", or "electric vehicle charging".

[293] If Value not provided, defaults as:
- **other**: 0.91 * ConditionedFloorArea (based on ANSI/RESNET/ICC 301-2019)
- **TV other**: 413.0 + 69.0 * NumberofBedrooms (based on ANSI/RESNET/ICC 301-2019)
- **well pump**: 50.8 / 0.127 * (0.5 + 0.25 * NumberofBedrooms / 3 + 0.35 * ConditionedFloorArea / 1920) (based on the 2010 BAHSP)
- **electric vehicle charging**: 1666.67 (calculated using AnnualMiles * kWhPerMile / (ChargerEfficiency * BatteryEfficiency) where AnnualMiles=4500, kWhPerMile=0.3, ChargerEfficiency=0.9, and BatteryEfficiency=0.9)

[294] If FracSensible not provided, defaults as:
- **other**: 0.855
- **TV other**: 1.0
- **well pump**: 0.0
- **electric vehicle charging**: 0.0

[295] The remaining fraction (i.e., 1.0 - FracSensible - FracLatent) must be > 0 and is assumed to be heat gain outside conditioned space and thus lost.

[296] If FracLatent not provided, defaults as:
- **other**: 0.045
- **TV other**: 0.0
- **well pump**: 0.0
- **electric vehicle charging**: 0.0

[297] If WeekdayScheduleFractions not provided, defaults as:
- **other**: "0.035, 0.033, 0.032, 0.031, 0.032, 0.033, 0.037, 0.042, 0.043, 0.043, 0.043, 0.044, 0.045, 0.045, 0.044, 0.046, 0.048, 0.052, 0.053, 0.05, 0.047,

3.10.2 HPXML Fuel Loads

Each fuel load can be entered as a `/HPXML/Building/BuildingDetails/MiscLoads/FuelLoad`.

It is less common to include fuel load types, as they are less frequently found in homes. If not entered, the simulation will not include that type of fuel load.

0.045, 0.04, 0.036" (based on Figure 23 of the 2010 BAHSP)
- **TV other**: "0.037, 0.018, 0.009, 0.007, 0.011, 0.018, 0.029, 0.040, 0.049, 0.058, 0.065, 0.072, 0.076, 0.086, 0.091, 0.102, 0.127, 0.156, 0.210, 0.294, 0.363, 0.344, 0.208, 0.090" (based on the American Time Use Survey)
- **well pump**: "0.044, 0.023, 0.019, 0.015, 0.016, 0.018, 0.026, 0.033, 0.033, 0.032, 0.033, 0.033, 0.032, 0.032, 0.032, 0.033, 0.045, 0.057, 0.066, 0.076, 0.081, 0.086, 0.075, 0.065" (based on Figure 23 of the 2010 BAHSP)
- **electric vehicle charging**: "0.042, 0.042"

[298] If WeekdendScheduleFractions not provided, defaults as:
- **other**: "0.035, 0.033, 0.032, 0.031, 0.032, 0.033, 0.037, 0.042, 0.043, 0.043, 0.043, 0.044, 0.045, 0.045, 0.044, 0.046, 0.048, 0.052, 0.053, 0.05, 0.047, 0.045, 0.04, 0.036" (based on Figure 23 of the 2010 BAHSP)
- **TV other**: "0.044, 0.022, 0.012, 0.008, 0.011, 0.014, 0.024, 0.043, 0.071, 0.094, 0.112, 0.123, 0.132, 0.156, 0.178, 0.196, 0.206, 0.213, 0.251, 0.330, 0.388, 0.358, 0.226, 0.103" (based on the American Time Use Survey)
- **well pump**: "0.044, 0.023, 0.019, 0.015, 0.016, 0.018, 0.026, 0.033, 0.033, 0.032, 0.033, 0.033, 0.032, 0.032, 0.032, 0.033, 0.045, 0.057, 0.066, 0.076, 0.081, 0.086, 0.075, 0.065" (based on Figure 23 of the 2010 BAHSP)
- **electric vehicle charging**: "0.042, 0.042"

[299] If MonthlyScheduleMultipliers not provided, defaults as:
- **other**: "1.248, 1.257, 0.993, 0.989, 0.993, 0.827, 0.821, 0.821, 0.827, 0.99, 0.987, 1.248" (based on Figure 24 of the 2010 BAHSP)
- **TV other**: "1.137, 1.129, 0.961, 0.969, 0.961, 0.993, 0.996, 0.96, 0.993, 0.867, 0.86, 1.137" (based on the American Time Use Survey)
- **well pump**: "1.154, 1.161, 1.013, 1.010, 1.013, 0.888, 0.883, 0.883, 0.888, 0.978, 0.974, 1.154" (based on Figure 24 of the 2010 BAHSP)
- **electric vehicle charging**: "1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0"

Element	Type	Units	Constraints	Required	Default	Notes
SystemIdentifier	id			Yes		Unique identifier
FuelLoadType	string		See[300]	Yes		Type of fuel load
Load[Units="therm/year"]/Value	double	therm/yr	>= 0	No	See[301]	Annual fuel consumption
FuelType	string		See[302]	Yes		Fuel type
extension/FracSensible	double		0 - 1	No	See[303]	Fraction that is sensible heat gain to conditioned space[304]
extension/FracLatent	double		0 - 1	No	See[305]	Fraction that is latent heat gain to conditioned space
extension/UsageMultiplier	double		>= 0	No	1.0	Multiplier on fuel use
extension/WeekdayScheduleFractions	array			No	See[306]	24 comma-separated weekday fractions
extension/WeekendScheduleFractions	array			No		24 comma-separated weekend fractions
extension/MonthlyScheduleMultipliers	array			No	See[307]	12 comma-separated monthly multipliers

[300] FuelLoadType choices are "grill", "fireplace", or "lighting".

[301] If Value not provided, calculated as based on the 2010 BAHSP:
- **grill**: 0.87 / 0.029 * (0.5 + 0.25 * NumberofBedrooms / 3 + 0.35 * ConditionedFloorArea / 1920)
- **fireplace**: 1.95 / 0.032 * (0.5 + 0.25 * NumberofBedrooms / 3 + 0.35 * ConditionedFloorArea / 1920)
- **lighting**: 0.22 / 0.012 * (0.5 + 0.25 * NumberofBedrooms / 3 + 0.35 * ConditionedFloorArea / 1920)

[302] FuelType choices are "natural gas", "fuel oil", "fuel oil 1", "fuel oil 2", "fuel oil 4", "fuel oil 5/6", "diesel", "propane", "kerosene", "coal", "coke", "bituminous coal", "anthracite coal", "wood", or "wood pellets".

[303] If FracSensible not provided, defaults to 0.5 for fireplace and 0.0 for all other types.

[304] The remaining fraction (i.e., 1.0 - FracSensible - FracLatent) must be > 0 and is assumed to be heat gain outside conditioned space and thus lost.

[305] If FracLatent not provided, defaults to 0.1 for fireplace and 0.0 for all other types.

[306] If WeekdayScheduleFractions or WeekendScheduleFractions not provided, default values from Figure 23 of the 2010 BAHSP are used:
- **grill**: "0.004, 0.001, 0.001, 0.002, 0.007, 0.012, 0.029, 0.046, 0.044, 0.041, 0.044, 0.046, 0.042, 0.038, 0.049, 0.059, 0.110, 0.161, 0.115, 0.070, 0.044, 0.019, 0.013, 0.007";
- **fireplace**: "0.044, 0.023, 0.019, 0.015, 0.016, 0.018, 0.026, 0.033, 0.033, 0.032, 0.033, 0.033, 0.032, 0.032, 0.032, 0.033, 0.045, 0.057, 0.066, 0.076, 0.081, 0.086, 0.075, 0.065";
- **lighting**: "0.044, 0.023, 0.019, 0.015, 0.016, 0.018, 0.026, 0.033, 0.033, 0.032, 0.033, 0.033, 0.032, 0.032, 0.032, 0.033, 0.045, 0.057, 0.066, 0.076, 0.081, 0.086, 0.075, 0.065".

[307] If MonthlyScheduleMultipliers not provided, default values from Figure 24 of the 2010 BAHSP are used:
- **grill**: "1.097, 1.097, 0.991, 0.987, 0.991, 0.890, 0.896, 0.896, 0.890, 1.085, 1.085, 1.097";
- **fireplace**: "1.154, 1.161, 1.013, 1.010, 1.013, 0.888, 0.883, 0.883, 0.888, 0.978, 0.974, 1.154";
- **lighting**: "1.154, 1.161, 1.013, 1.010, 1.013, 0.888, 0.883, 0.883, 0.888, 0.978, 0.974, 1.154".

3.11 HPXML Locations

The various locations used in an HPXML file are defined as follows:

Value	Description	Temperature	Building Type
outside	Ambient environment	Weather data	Any
ground		EnergyPlus calculation	Any
living space	Above-grade conditioned floor area	EnergyPlus calculation	Any
attic - vented		EnergyPlus calculation	Any
attic - unvented		EnergyPlus calculation	Any
basement - conditioned	Below-grade conditioned floor area	EnergyPlus calculation	Any
basement - unconditioned		EnergyPlus calculation	Any
crawlspace - vented		EnergyPlus calculation	Any
crawlspace - unvented		EnergyPlus calculation	Any
garage	Single-family garage (not shared parking)	EnergyPlus calculation	Any
other housing unit	E.g., conditioned adjacent unit or conditioned corridor	Same as living space	SFA/MF only
other heated space	E.g., shared laundry/equipment space	Avg of living space/outside; min of 68F	SFA/MF only
other multifamily buffer space	E.g., enclosed unconditioned stairwell	Avg of living space/outside; min of 50F	SFA/MF only
other non-freezing space	E.g., shared parking garage ceiling	Floats with outside; minimum of 40F	SFA/MF only
other exterior	Water heater outside	Weather data	Any
exterior wall	Ducts in exterior wall	Avg of living space/outside	Any
under slab	Ducts under slab (ground)	EnergyPlus calculation	Any
roof deck	Ducts on roof deck (outside)	Weather data	Any

3.12 Validating & Debugging Errors

When running HPXML files, errors may occur because:

1. An HPXML file provided is invalid (either relative to the HPXML schema or the EnergyPlus Use Case).
2. An unexpected EnergyPlus simulation error occurred.

If an error occurs, first look in the run.log for details. If there are no errors in that log file, then the error may be in the EnergyPlus simulation – see eplusout.err.

Contact us if you can't figure out the cause of an error.

3.13 Sample Files

Dozens of sample HPXML files are included in the workflow/sample_files directory. The sample files help to illustrate how different building components are described in HPXML.

Each sample file generally makes one isolated change relative to the base HPXML (base.xml) building. For example, the base-dhw-dwhr.xml file adds a `DrainWaterHeatRecovery` element to the building.

You may find it useful to search through the files for certain HPXML elements or compare (diff) a sample file to the base.xml file.

CHAPTER 4

Workflow Outputs

OpenStudio-HPXML generates a number of workflow outputs:

File	Notes
results_annual.csv (or .json)	Summary annual outputs in either CSV or JSON formats. See *Annual Outputs*.
results_timeseries.csv (or .json)	Timeseries outputs in either CSV or JSON formats. See *Timeseries Outputs*. Only generated if requested.
in.idf	The EnergyPlus input file.
in.xml	HPXML file populated with defaulted values (e.g., autosized HVAC capacities); defaults use the `dataSource='software'` attribute.
in.osm	The OpenStudio model file. Only generated if the `debug` argument is used.
run.log	Errors/warnings generated by the OpenStudio-HPXML workflow.
eplusout.*	Minimal E+ files (e.g., sql output, error file, etc.). ALL output files can be generated using the `debug` argument.

4.1 Annual Outputs

OpenStudio-HPXML will always generate an annual output file called results_annual.csv (or results_annual.json), co-located with the EnergyPlus output. The file includes the following sections of output:

4.1.1 Annual Energy Consumption by Fuel Use

Current fuel uses are listed below.

Type	Notes
Fuel Use: Electricity: Total (MBtu)	
Fuel Use: Electricity: Net (MBtu)	Subtracts any power produced by PV or generators.
Fuel Use: Natural Gas: Total (MBtu)	
Fuel Use: Fuel Oil: Total (MBtu)	Includes "fuel oil", "fuel oil 1", "fuel oil 2", "fuel oil 4", "fuel oil 5/6", "kerosene", and "diesel"
Fuel Use: Propane: Total (MBtu)	
Fuel Use: Wood: Total (MBtu)	
Fuel Use: Wood Pellets: Total (MBtu)	
Fuel Use: Coal: Total (MBtu)	Includes "coal", "anthracite coal", "bituminous coal", and "coke".

4.1.2 Annual Energy Consumption By End Use

Current end uses are listed below.

Note that all end uses are mutually exclusive – the "Electricity: Heating" end use, for example, excludes energy reported in the "Electricity: Heating Fans/Pumps" end use. So the sum of all end uses for a given fuel (e.g., sum of all "End Use: Natural Gas: *") equal the above reported fuel use (e.g., "Fuel Use: Natural Gas: Total").

Type	Notes
End Use: Electricity: Heating (MBtu)	Excludes fans/pumps
End Use: Electricity: Heating Fans/Pumps (MBtu)	
End Use: Electricity: Cooling (MBtu)	Excludes fans/pumps
End Use: Electricity: Cooling Fans/Pumps (MBtu)	
End Use: Electricity: Hot Water (MBtu)	Excludes recirc pump and solar thermal pump
End Use: Electricity: Hot Water Recirc Pump (MBtu)	
End Use: Electricity: Hot Water Solar Thermal Pump (MBtu)	Non-zero only when using detailed (not simple) solar thermal inputs
End Use: Electricity: Lighting Interior (MBtu)	
End Use: Electricity: Lighting Garage (MBtu)	
End Use: Electricity: Lighting Exterior (MBtu)	
End Use: Electricity: Mech Vent (MBtu)	Excludes preheating/precooling
End Use: Electricity: Mech Vent Preheating (MBtu)	
End Use: Electricity: Mech Vent Precooling (MBtu)	
End Use: Electricity: Whole House Fan (MBtu)	
End Use: Electricity: Refrigerator (MBtu)	
End Use: Electricity: Freezer (MBtu)	
End Use: Electricity: Dehumidifier (MBtu)	
End Use: Electricity: Dishwasher (MBtu)	
End Use: Electricity: Clothes Washer (MBtu)	
End Use: Electricity: Clothes Dryer (MBtu)	
End Use: Electricity: Range/Oven (MBtu)	
End Use: Electricity: Ceiling Fan (MBtu)	
End Use: Electricity: Television (MBtu)	
End Use: Electricity: Plug Loads (MBtu)	Excludes independently reported plug loads (e.g., well pump)

Continued on next page

Table 1 – continued from previous page

Type	Notes
End Use: Electricity: Electric Vehicle Charging (MBtu)	
End Use: Electricity: Well Pump (MBtu)	
End Use: Electricity: Pool Heater (MBtu)	
End Use: Electricity: Pool Pump (MBtu)	
End Use: Electricity: Hot Tub Heater (MBtu)	
End Use: Electricity: Hot Tub Pump (MBtu)	
End Use: Electricity: PV (MBtu)	Negative value for any power produced
End Use: Electricity: Generator (MBtu)	Negative value for any power produced
End Use: Natural Gas: Heating (MBtu)	
End Use: Natural Gas: Hot Water (MBtu)	
End Use: Natural Gas: Clothes Dryer (MBtu)	
End Use: Natural Gas: Range/Oven (MBtu)	
End Use: Natural Gas: Mech Vent Preheating (MBtu)	
End Use: Natural Gas: Mech Vent Precooling (MBtu)	
End Use: Natural Gas: Pool Heater (MBtu)	
End Use: Natural Gas: Hot Tub Heater (MBtu)	
End Use: Natural Gas: Grill (MBtu)	
End Use: Natural Gas: Lighting (MBtu)	
End Use: Natural Gas: Fireplace (MBtu)	
End Use: Natural Gas: Generator (MBtu)	Positive value for any fuel consumed
End Use: Fuel Oil: Heating (MBtu)	
End Use: Fuel Oil: Hot Water (MBtu)	
End Use: Fuel Oil: Clothes Dryer (MBtu)	
End Use: Fuel Oil: Range/Oven (MBtu)	
End Use: Fuel Oil: Mech Vent Preheating (MBtu)	
End Use: Fuel Oil: Mech Vent Precooling (MBtu)	
End Use: Fuel Oil: Grill (MBtu)	
End Use: Fuel Oil: Lighting (MBtu)	
End Use: Fuel Oil: Fireplace (MBtu)	
End Use: Propane: Heating (MBtu)	
End Use: Propane: Hot Water (MBtu)	
End Use: Propane: Clothes Dryer (MBtu)	
End Use: Propane: Range/Oven (MBtu)	
End Use: Propane: Mech Vent Preheating (MBtu)	
End Use: Propane: Mech Vent Precooling (MBtu)	
End Use: Propane: Grill (MBtu)	
End Use: Propane: Lighting (MBtu)	
End Use: Propane: Fireplace (MBtu)	
End Use: Propane: Generator (MBtu)	Positive value for any fuel consumed
End Use: Wood Cord: Heating (MBtu)	
End Use: Wood Cord: Hot Water (MBtu)	
End Use: Wood Cord: Clothes Dryer (MBtu)	
End Use: Wood Cord: Range/Oven (MBtu)	
End Use: Wood Cord: Mech Vent Preheating (MBtu)	
End Use: Wood Cord: Mech Vent Precooling (MBtu)	
End Use: Wood Cord: Grill (MBtu)	
End Use: Wood Cord: Lighting (MBtu)	
End Use: Wood Cord: Fireplace (MBtu)	
End Use: Wood Pellets: Heating (MBtu)	

Continued on next page

Table 1 – continued from previous page

Type	Notes
End Use: Wood Pellets: Hot Water (MBtu)	
End Use: Wood Pellets: Clothes Dryer (MBtu)	
End Use: Wood Pellets: Range/Oven (MBtu)	
End Use: Wood Pellets: Mech Vent Preheating (MBtu)	
End Use: Wood Pellets: Mech Vent Precooling (MBtu)	
End Use: Wood Pellets: Grill (MBtu)	
End Use: Wood Pellets: Lighting (MBtu)	
End Use: Wood Pellets: Fireplace (MBtu)	
End Use: Coal: Heating (MBtu)	
End Use: Coal: Hot Water (MBtu)	
End Use: Coal: Clothes Dryer (MBtu)	
End Use: Coal: Range/Oven (MBtu)	
End Use: Coal: Mech Vent Preheating (MBtu)	
End Use: Coal: Mech Vent Precooling (MBtu)	
End Use: Coal: Grill (MBtu)	
End Use: Coal: Lighting (MBtu)	
End Use: Coal: Fireplace (MBtu)	

4.1.3 Annual Building Loads

Current annual building loads are listed below.

Type	Notes
Load: Heating (MBtu)	Includes HVAC distribution losses.
Load: Cooling (MBtu)	Includes HVAC distribution losses.
Load: Hot Water: Delivered (MBtu)	Includes contributions by desuperheaters or solar thermal systems.
Load: Hot Water: Tank Losses (MBtu)	
Load: Hot Water: Desuperheater (MBtu)	Load served by the desuperheater.
Load: Hot Water: Solar Thermal (MBtu)	Load served by the solar thermal system.

4.1.4 Annual Unmet Building Loads

Current annual unmet building loads are listed below.

Type	Notes
Unmet Load: Heating (MBtu)	
Unmet Load: Cooling (MBtu)	

These numbers reflect the amount of heating/cooling load that is not met by the HVAC system, indicating the degree to which the HVAC system is undersized. An HVAC system with sufficient capacity to perfectly maintain the thermostat setpoints will report an unmet load of zero.

Note that if a building has partial (or no) HVAC system, the unserved load will not be included in the unmet load outputs. For example, if a building has a room air conditioner that meets 33% of the cooling load, the remaining 67% of the load is not included in the unmet load. Rather, the unmet load is only the amount of load that the room AC *should* be serving but is not.

4.1.5 Peak Building Electricity

Current peak building electricity outputs are listed below.

Type	Notes
Peak Electricity: Winter Total (W)	Winter season defined by operation of the heating system.
Peak Electricity: Summer Total (W)	Summer season defined by operation of the cooling system.

4.1.6 Peak Building Loads

Current peak building loads are listed below.

Type	Notes
Peak Load: Heating (kBtu)	Includes HVAC distribution losses.
Peak Load: Cooling (kBtu)	Includes HVAC distribution losses.

4.1.7 Annual Component Building Loads

Note: This section is only available if the `--add-component-loads` argument is used. The argument is not used by default for faster performance.

Component loads represent the estimated contribution of different building components to the annual heating/cooling building loads. The sum of component loads for heating (or cooling) will roughly equal the annual heating (or cooling) building load reported above.

Current component loads disaggregated by Heating/Cooling are listed below.

Type	Notes
Component Load: *: Roofs (MBtu)	Heat gain/loss through HPXML `Roof` elements adjacent to conditioned space
Component Load: *: Ceilings (MBtu)	Heat gain/loss through HPXML `FrameFloor` elements (inferred to be ceilings) adjacent to conditioned space
Component Load: *: Walls (MBtu)	Heat gain/loss through HPXML `Wall` elements adjacent to conditioned space
Component Load: *: Rim Joists (MBtu)	Heat gain/loss through HPXML `RimJoist` elements adjacent to conditioned space
Component Load: *: Foundation Walls (MBtu)	Heat gain/loss through HPXML `FoundationWall` elements adjacent to conditioned space
Component Load: *: Doors (MBtu)	Heat gain/loss through HPXML `Door` elements adjacent to conditioned space
Component Load: *: Windows (MBtu)	Heat gain/loss through HPXML `Window` elements adjacent to conditioned space, including solar
Component Load: *: Skylights (MBtu)	Heat gain/loss through HPXML `Skylight` elements adjacent to conditioned space, including solar
Component Load: *: Floors (MBtu)	Heat gain/loss through HPXML `FrameFloor` elements (inferred to be floors) adjacent to conditioned space
Component Load: *: Slabs (MBtu)	Heat gain/loss through HPXML `Slab` elements adjacent to conditioned space
Component Load: *: Internal Mass (MBtu)	Heat gain/loss from internal mass (e.g., furniture, interior walls/floors) in conditioned space
Component Load: *: Infiltration (MBtu)	Heat gain/loss from airflow induced by stack and wind effects
Component Load: *: Natural Ventilation (MBtu)	Heat gain/loss from airflow through operable windows
Component Load: *: Mechanical Ventilation (MBtu)	Heat gain/loss from airflow/fan energy from mechanical ventilation systems (including clothes dryer exhaust)
Component Load: *: Whole House Fan (MBtu)	Heat gain/loss from airflow due to a whole house fan
Component Load: *: Ducts (MBtu)	Heat gain/loss from conduction and leakage losses through supply/return ducts outside conditioned space
Component Load: *: Internal Gains (MBtu)	Heat gain/loss from appliances, lighting, plug loads, water heater tank losses, etc. in the conditioned space

4.1.8 Annual Hot Water Uses

Current annual hot water uses are listed below.

Type	Notes
Hot Water: Clothes Washer (gal)	
Hot Water: Dishwasher (gal)	
Hot Water: Fixtures (gal)	Showers and faucets.
Hot Water: Distribution Waste (gal)	

4.2 Timeseries Outputs

OpenStudio-HPXML can optionally generate a timeseries output file. The timeseries output file is called results_timeseries.csv (or results_timeseries.json) and co-located with the EnergyPlus output.

Depending on the outputs requested, the file may include:

Type	Notes
Fuel Consumptions	Energy use for each fuel type (in kBtu for fossil fuels and kWh for electricity).
End Use Consumptions	Energy use for each end use type (in kBtu for fossil fuels and kWh for electricity).
Hot Water Uses	Water use for each end use type (in gallons).
Total Loads	Heating, cooling, and hot water loads (in kBtu) for the building.
Component Loads	Heating and cooling loads (in kBtu) disaggregated by component (e.g., Walls, Windows, Infiltration, Ducts, etc.).
Unmet Loads	Unmet heating and cooling loads (in kBtu) for the building.
Zone Temperatures	Average temperatures (in deg-F) for each space modeled (e.g., living space, attic, garage, basement, crawlspace, etc.).
Airflows	Airflow rates (in cfm) for infiltration, mechanical ventilation (including clothes dryer exhaust), natural ventilation, whole house fans.
Weather	Weather file data including outdoor temperatures, relative humidity, wind speed, and solar.

Timeseries outputs can be one of the following frequencies: hourly, daily, monthly, or timestep (i.e., equal to the simulation timestep, which defaults to an hour but can be sub-hourly).

Timestamps in the output use the end-of-hour (or end-of-day for daily frequency, etc.) convention. Most outputs will be summed over the hour (e.g., energy) but some will be averaged over the hour (e.g., temperatures, airflows).

CHAPTER 5

Indices and tables

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- search