OpenStudio-HPXML Documentation

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Apr 28, 2020

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Introduction

The OpenStudio-HPXML repository consists of residential OpenStudio measures that handle HPXML files.

1.1 Measures

This repository contains two OpenStudio measures:

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.

1.2 License

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Getting Started

2.1 Setup

To get started:

1. Download OpenStudio 3.0.0 and install the Command Line Interface/EnergyPlus components, or use the nrel/openstudio docker image.

2. Download the latest release for these OpenStudio measures.

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 Parametric Analysis Tool).

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` 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` file.

See the *SimulationOutputReport Measure* section for a description of all available outputs available.

HPXMLtoOpenStudio Measure

The HPXMLtoOpenStudio measure 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 Capabilities

The following building features/technologies are available for modeling via the HPXMLtoOpenStudio measure:

- Enclosure
    - Attics (Vented, Unvented, Conditioned)
    - Foundations (Slab, Unconditioned Basement, Conditioned Basement, Vented Crawlspace, Unvented Crawlspace, Ambient)
    - Garages
    - Windows & Overhangs
    - Skylights
    - Doors
- HVAC
    - Heating Systems (Electric Resistance, Furnaces, Wall Furnaces, Stoves, Boilers, Portable Heaters)
    - Cooling Systems (Central Air Conditioners, Room Air Conditioners, Evaporative Coolers)
    - Heat Pumps (Air Source, Mini Split, Ground Source, Dual-Fuel)
    - Setpoints
    - Ducts
- Water Heating
    - Water Heaters (Storage, Tankless, Heat Pump, Indirect, Tankless Coil)

- – Solar Hot Water

    - – Desuperheater

    - – Hot Water Distribution (Standard, Recirculation)

    - – Drain Water Heat Recovery

    - – Hot Water Fixtures

- • Ventilation

    - – Mechanical Ventilation (Exhaust, Supply, Balanced, ERV, HRV, CFIS)

    - – Kitchen/Bathroom Fans

    - – Whole House Fan

- • Photovoltaics

- • Appliances (Clothes Washer/Dryer, Dishwasher, Refrigerator, Cooking Range/Oven)

- • Dehumidifier

- • Lighting

- • Ceiling Fans

- • Plug Loads

3.2 EnergyPlus Use Case for 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, an EnergyPlus Use Case for HPXML has been developed that specifies the HPXML elements or enumeration choices required to run the measure.

Software developers should use the EnergyPlus Use Case (found at `HPXMLtoOpenStudio/resources/ EPvalidator.rb`, which defines sets of conditional XPath expressions) as well as the HPXML schema (HPXML.xsd) to construct valid HPXML files for EnergyPlus simulations.

The HPXML Toolbox website also provides several resources for software developers, including:

1. An interactive schema validator

2. A data dictionary

3. An implementation guide

3.2.1 Simulation Controls

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

The simulation controls currently offered are timestep, begin month, begin day of month, end month, and end day of month.

Timestep can be optionally provided as `Timestep`, where the value is in minutes and must be a divisor of 60. If not provided, the default value of 60 is used.

The simulation run period can be optionally specified with `BeginMonth`/`BeginDayOfMonth` and/or `EndMonth`/`EndDayOfMonth`. The `BeginMonth`/`BeginDayOfMonth` provided must occur before

`EndMonth`/`EndDayOfMonth` provided (e.g., a run period from 10/1 to 3/31 is invalid). If not provided, default values of January 1st and December 31st will be used.

3.2.2 Building Details

The building description is entered in HPXML's `/HPXML/Building/BuildingDetails`.

3.2.3 Building Summary

This section describes elements specified in HPXML's `BuildingSummary`. It is used for high-level building information including conditioned floor area, number of bedrooms, number of residents, number of conditioned floors, etc. Most occupancy assumptions are based on the number of bedrooms, while the number of residents is solely used to determine heat gains from the occupants themselves. Note that a walkout basement should be included in `NumberofConditionedFloorsAboveGrade`.

If `NumberofBathrooms` is not provided, it is calculated using the following equation based on the Building America House Simulation Protocols.

$$NumberofBathrooms = \frac{NumberofBedrooms}{2} + 0.5$$

Shading due to neighboring buildings can be defined inside an `Site/extension/Neighbors` element. Each `Neighbors/NeighborBuilding` element is required to have an `Azimuth` and `Distance` from the house. A `Height` is also optionally allowed; if not provided, the neighbor is assumed to be the same height as the house.

The local shelter coefficient can be entered as `Site/extension/ShelterCoefficient`. The shelter coefficient is defined by the AIM-2 infiltration model to account for nearby buildings, trees and obstructions. If not provided, the value of 0.5 will be assumed.

Shelter Coefficient	Description
1.0	No obstructions or local shielding
0.9	Light local shielding with few obstructions within two building heights
0.7	Local shielding with many large obstructions within two building heights
0.5	Heavily shielded, many large obstructions within one building height
0.3	Complete shielding with large buildings immediately adjacent

The terrain surrounding the building is assumed to be suburban.

3.2.4 Weather File

The `ClimateandRiskZones/WeatherStation` element specifies the EnergyPlus weather file (EPW) to be used in the simulation. The weather file can be entered in one of two ways:

1. Using `WeatherStation/WMO`, which must be one of the acceptable TMY3 WMO station numbers found in the `weather/data.csv` file. The full set of U.S. TMY3 weather files can be downloaded here.

2. Using `WeatherStation/extension/EPWFilePath`.

3.2.5 Enclosure

This section describes elements specified in HPXML's `Enclosure`.

All surfaces that bound different space types in the building (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.

The space types used in the HPXML building description are:

Space Type	Notes
living space	Above-grade conditioned floor area.
attic - vented	
attic - unvented	
basement - conditioned	Below-grade conditioned floor area.
basement - unconditioned	
crawlspace - vented	
crawlspace - unvented	
garage	
other housing unit	Used to specify adiabatic surfaces.

> **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.

Air Leakage

Building air leakage characterized by air changes per hour or cfm at 50 pascals pressure difference (ACH50 or CFM50) is entered at `Enclosure/AirInfiltration/AirInfiltrationMeasurement/BuildingAirLeakage/AirLeakage`. The `Enclosure/AirInfiltration/AirInfiltrationMeasurement` should be specified with `HousePressure='50'` and `BuildingAirLeakage/UnitofMeasure='ACH'` or `BuildingAirLeakage/UnitofMeasure='CFM'`.

In addition, the building's volume associated with the air leakage measurement can be provided in HPXML's `AirInfiltrationMeasurement/InfiltrationVolume`. If not provided, the infiltration volume is assumed to be equal to the conditioned building volume.

Vented Attics/Crawlspaces

The ventilation rate for vented attics (or crawlspaces) can be specified using an `Attic` (or `Foundation`) element. First, define the `AtticType` as `Attic[Vented='true']` (or `FoundationType` as `Crawlspace[Vented='true']`). Then use the `VentilationRate[UnitofMeasure='SLA']/Value` element to specify a specific leakage area (SLA). If these elements are not provided, default values of 1/300 for vented attics and 1/150 for vented crawlspaces will be used based on ANSI/RESNET/ICC 301-2019.

Roofs

Pitched or flat roof surfaces that are exposed to ambient conditions should be specified as an `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`.

Beyond the specification of typical heat transfer properties (insulation R-value, solar absorptance, emittance, etc.), note that roofs can be defined as having a radiant barrier.

Walls

Any wall that has no contact with the ground and bounds a space type should be specified as an `Enclosure/Walls/Wall`. Interior walls (for example, walls solely within the conditioned space of the building) are not required.

Walls are primarily defined by their `Insulation/AssemblyEffectiveRValue`. The choice of `WallType` has a secondary effect on heat transfer in that it informs the assumption of wall thermal mass.

Rim Joists

Rim joists, the perimeter of floor joists typically found between stories of a building or on top of a foundation wall, are specified as an `Enclosure//RimJoists/RimJoist`.

The `InteriorAdjacentTo` element should typically be "living space" for rim joists between stories of a building and "basement - conditioned", "basement - unconditioned", "crawlspace - vented", or "crawlspace - unvented" for rim joists on top of a foundation wall.

Foundation Walls

Any wall that is in contact with the ground should be specified as an `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 `Walls` and not `FoundationWalls`.

Exterior foundation walls (i.e., those that fall along the perimeter of the building's footprint) should use "ground" for `ExteriorAdjacentTo` and the appropriate space type (e.g., "basement - unconditioned") for `InteriorAdjacentTo`.

Interior foundation walls should be specified with two appropriate space types (e.g., "crawlspace - vented" and "garage", or "basement - unconditioned" and "crawlspace - unvented") for `InteriorAdjacentTo` and `ExteriorAdjacentTo`. Interior foundation walls should never use "ground" for `ExteriorAdjacentTo` even if the foundation wall has some contact with the ground due to the difference in below-grade depths of the two adjacent space types.

Foundations must include a `Height` as well as a `DepthBelowGrade`. For exterior foundation walls, the depth below grade is relative to the ground plane. For interior foundation walls, the depth below grade **should not** be thought of as relative to the ground plane, but rather as the depth 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.

Foundation wall insulation can be described in two ways:

Option 1. Both interior and exterior continuous insulation layers with `NominalRValue`, `extension/DistanceToTopOfInsulation`, and `extension/DistanceToBottomOfInsulation`. Insulation layers are particularly useful for describing foundation wall insulation that doesn't span the entire height (e.g., 4 ft of insulation for an 8 ft conditioned basement). If there is not insulation on the interior and/or exterior of the foundation wall, the continuous insulation layer must still be provided – with the nominal R-value, etc., set to zero. When insulation is specified with option 1, it is modeled with a concrete wall (whose `Thickness` is provided) as well as air film resistances as appropriate.

Option 2. An `AssemblyEffectiveRValue`. The assembly effective R-value should include the concrete wall and an interior air film resistance. The exterior air film resistance (for any above-grade exposure) or any soil thermal resistance should **not** be included.

Frame Floors

Any horizontal floor/ceiling surface that is not in contact with the ground (Slab) nor adjacent to ambient conditions above (Roof) should be specified as an `Enclosure/FrameFloors/FrameFloor`.

Frame floors are primarily defined by their `Insulation/AssemblyEffectiveRValue`.

Slabs

Any space type that borders the ground should include an `Enclosure/Slabs/Slab` surface with the appropriate `InteriorAdjacentTo`. This includes basements, crawlspaces (even when there are dirt floors – use zero for the `Thickness`), garages, and slab-on-grade foundations.

A primary input for a slab is its `ExposedPerimeter`. The exposed perimeter should include 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.

Vertical insulation adjacent to the slab can be described by a `PerimeterInsulation/Layer/NominalRValue` and a `PerimeterInsulationDepth`.

Horizontal insulation under the slab can be described by a `UnderSlabInsulation/Layer/NominalRValue`. The insulation can either have a fixed width (`UnderSlabInsulationWidth`) or can span the entire slab (`UnderSlabInsulationSpansEntireSlab`).

For foundation types without walls, the `DepthBelowGrade` element must be provided. For foundation types with walls, the `DepthBelowGrade` element is not used; instead the slab's position relative to grade is determined by the `FoundationWall/DepthBelowGrade` values.

Windows

Any window or glass door area should be specified as an `Enclosure/Windows/Window`.

Windows are defined by *full-assembly* NFRC `UFactor` and `SHGC`, as well as `Area`. Windows must reference a HPXML `Enclosures/Walls/Wall` element via the `AttachedToWall`. Windows must also have an `Azimuth` specified, even if the attached wall does not.

In addition, the summer/winter interior shading coefficients can be optionally entered as `InteriorShading/SummerShadingCoefficient` and `InteriorShading/WinterShadingCoefficient`. The summer interior shading coefficient must be less than or equal to the winter interior shading coefficient. Note that a value of 0.7 indicates a 30% reduction in solar gains (i.e., 30% shading). If not provided, default values of 0.70 for summer and 0.85 for winter will be used based on ANSI/RESNET/ICC 301-2019.

Overhangs (e.g., a roof eave) can optionally be defined for a window by specifying a `Window/Overhangs` element. Overhangs are defined by the vertical distance between the overhang and the top of the window (`DistanceToTopOfWindow`), and the vertical distance between the overhang and the bottom of the window (`DistanceToBottomOfWindow`). The difference between these two values equals the height of the window.

Finally, windows can be optionally described with `FractionOperable`. The input should solely reflect 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). If not provided, it is assumed that 67% of the windows are operable. The total open window area for natural ventilation is thus calculated using A) the fraction of windows that are operable, 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.

Skylights

Any skylight should be specified as an `Enclosure/Skylights/Skylight`.

Skylights are defined by *full-assembly* NFRC `UFactor` and `SHGC`, as well as `Area`. Skylights must reference a HPXML `Enclosures/Roofs/Roof` element via the `AttachedToRoof`. Skylights must also have an `Azimuth` specified, even if the attached roof does not.

Doors

Any opaque doors should be specified as an `Enclosure/Doors/Door`.

Doors are defined by `RValue` and `Area`. Doors must reference a HPXML `Enclosures/Walls/Wall` element via the `AttachedToWall`. Doors must also have an `Azimuth` specified, even if the attached wall does not.

3.2.6 Systems

This section describes elements specified in HPXML's `Systems`.

If any HVAC systems are entered that provide heating (or cooling), the sum of all their `FractionHeatLoadServed` (or `FractionCoolLoadServed`) values must be less than or equal to 1. For example, a room air conditioner might be specified with `FractionCoolLoadServed` equal to 0.3 if it serves 30% of the home's conditioned floor area.

If any water heating systems are entered, the sum of all their `FractionDHWLoadServed` values must be equal to 1.

Note: HVAC systems (Heating Systems, Cooling Systems, and Heat Pumps) can be autosized via ACCA Manual J/S by using -1 as the capacity. For a given system, all capacities must either be autosized or user-specified. For example, an air-to-air heat pump must have its heating capacity, cooling capacity, and backup heating capacity all autosized or user-specified.

Heating Systems

Each heating system (other than heat pumps) should be entered as a `Systems/HVAC/HVACPlant/HeatingSystem`. Inputs including `HeatingSystemType`, `HeatingCapacity`, and `FractionHeatLoadServed` must be provided.

Depending on the type of heating system specified, additional elements are required:

HeatingSystemType	DistributionSystem	HeatingSystemFuel	AnnualHeatingEfficiency
ElectricResistance		electricity	Percent
Furnace	AirDistribution or DSE	<any>	AFUE
WallFurnace		<any>	AFUE
Boiler	HydronicDistribution or DSE	<any>	AFUE
Stove		<any>	Percent
PortableHeater		<any>	Percent

If a non-electric heating system is specified, the `ElectricAuxiliaryEnergy` element may be provided if available.

Cooling Systems

Each cooling system (other than heat pumps) should be entered as a `Systems/HVAC/HVACPlant/CoolingSystem`. Inputs including `CoolingSystemType` and `FractionCoolLoadServed` must be provided. `CoolingCapacity` must also be provided for all systems other than evaporative coolers.

Depending on the type of cooling system specified, additional elements are required/available:

CoolingSys-temType	DistributionSystem	CoolingSys-temFuel	AnnualCoolingEffi-ciency	SensibleHeat-Fraction
central air conditioner	AirDistribution or DSE	electricity	SEER	(optional)
room air conditioner		electricity	EER	(optional)
evaporative cooler	AirDistribution or DSE (optional)	electricity		

Central air conditioners can also have the `CompressorType` specified; if not provided, it is assumed as follows:

- "single stage": SEER <= 15
- "two stage": 15 < SEER <= 21
- "variable speed": SEER > 21

Heat Pumps

Each heat pump should be entered as a `Systems/HVAC/HVACPlant/HeatPump`. Inputs including `HeatPumpType`, `CoolingCapacity`, `HeatingCapacity`, `FractionHeatLoadServed`, and `FractionCoolLoadServed` must be provided. Note that heat pumps are allowed to provide only heating (`FractionCoolLoadServed` = 0) or cooling (`FractionHeatLoadServed` = 0) if appropriate.

Depending on the type of heat pump specified, additional elements are required/available:

Heat-Pump-Type	DistributionSys-tem	Heat-Pump-Fuel	Annual-CoolingEffi-ciency	Annual-HeatingEffi-ciency	CoolingSensi-bleHeatFrac-tion	Heating-Capac-ity17F
air-to-air	AirDistribution or DSE	electric-ity	SEER	HSPF	(optional)	(optional)
mini-split	AirDistribution or DSE (optional)	electric-ity	SEER	HSPF	(optional)	(optional)
ground-to-air	AirDistribution or DSE	electric-ity	EER	COP	(optional)	

Air-to-air heat pumps can also have the `CompressorType` specified; if not provided, it is assumed as follows:

- "single stage": SEER <= 15
- "two stage": 15 < SEER <= 21
- "variable speed": SEER > 21

If the heat pump has backup heating, it can be specified with `BackupSystemFuel`, `BackupAnnualHeatingEfficiency`, and `BackupHeatingCapacity`. If the heat pump has a switchover temperature (e.g., dual-fuel heat pump) where the heat pump stops operating and the backup heating system starts running, it can be specified with `BackupHeatingSwitchoverTemperature`. If the `BackupHeatingSwitchoverTemperature` is not provided, the backup heating system will operate as needed when the heat pump has insufficient capacity.

Thermostat

A `Systems/HVAC/HVACControl` must be provided if any HVAC systems are specified. The heating setpoint (`SetpointTempHeatingSeason`) and cooling setpoint (`SetpointTempCoolingSeason`) are required elements.

If there is a heating setback, it is defined with:

- `SetbackTempHeatingSeason`: Temperature during heating setback
- `extension/SetbackStartHourHeating`: The start hour of the heating setback where 0=midnight and 12=noon
- `TotalSetbackHoursperWeekHeating`: The number of hours of heating setback per week

If there is a cooling setup, it is defined with:

- `SetupTempCoolingSeason`: Temperature during cooling setup
- `extension/SetupStartHourCooling`: The start hour of the cooling setup where 0=midnight and 12=noon
- `TotalSetupHoursperWeekCooling`: The number of hours of cooling setup per week

Finally, if there are sufficient ceiling fans present that result in a reduced cooling setpoint, this offset can be specified with `extension/CeilingFanSetpointTempCoolingSeasonOffset`.

HVAC Distribution

Each separate HVAC distribution system should be specified as a `Systems/HVAC/HVACDistribution`. There should be at most one heating system and one cooling system attached to a distribution system. See the sections on Heating Systems, Cooling Systems, and 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.

`AirDistribution` systems are defined by:

- Supply leakage to the outside in CFM25 or percent of airflow (`DuctLeakageMeasurement[DuctType='supply']/DuctLeakage/Value`)
- Optional return leakage to the outside in CFM25 or percent of airflow (`DuctLeakageMeasurement[DuctType='return']/DuctLeakage/Value`)
- Optional supply ducts (`Ducts[DuctType='supply']`)
- Optional return ducts (`Ducts[DuctType='return']`)

For each duct, `DuctInsulationRValue`, `DuctLocation`, and `DuctSurfaceArea` must be provided.

`HydronicDistribution` systems do not require any additional inputs.

`DSE` systems are defined by a `AnnualHeatingDistributionSystemEfficiency` and `AnnualCoolingDistributionSystemEfficiency` elements.

> **Warning:** Specifying a DSE for the HVAC distribution system will NOT be reflected in the raw EnergyPlus simulation outputs, but IS reflected by the SimulationOutputReport reporting measure.

Mechanical Ventilation

A single whole-house mechanical ventilation system may be specified as a `Systems/MechanicalVentilation/VentilationFans/VentilationFan` with `UsedForWholeBuildingVentilation='true'`. Inputs including `FanType`, `TestedFlowRate` (or `RatedFlowRate`), `HoursInOperation`, and `FanPower` must be provided.

Depending on the type of mechanical ventilation specified, additional elements are required:

FanType	SensibleRecoveryEfficiency	TotalRecoveryEfficiency	AttachedToHVACDistributionSystem
energy recovery ventilator	required	required	
heat recovery ventilator	required		
exhaust only			
supply only			
balanced			
central fan integrated supply (CFIS)			required

Note that AdjustedSensibleRecoveryEfficiency and AdjustedTotalRecoveryEfficiency can be provided instead.

In many situations, the rated flow rate should be the value derived from actual testing of the system. For a CFIS system, the rated flow rate should equal the amount of outdoor air provided to the distribution system.

Kitchen Fan

A kitchen range fan may be specified as a `Systems/MechanicalVentilation/VentilationFans/VentilationFan` with `FanLocation='kitchen'` and `UsedForLocalVentilation='true'`.

Additional fields may be provided per the table below. If not provided, default values will be assumed based on the Building America House Simulation Protocols.

Element Name	Default Value
RatedFlowRate [cfm]	100
HoursInOperation [hrs/day]	1
FanPower [W]	0.3 * RatedFlowRate
extension/StartHour [0-23]	18

Bathroom Fans

Bathroom fans may be specified as a `Systems/MechanicalVentilation/VentilationFans/VentilationFan` with `FanLocation='bath'` and `UsedForLocalVentilation='true'`.

Additional fields may be provided per the table below. If not provided, default values will be assumed based on the Building America House Simulation Protocols.

Element Name	Default Value
Quantity [#]	NumberofBathrooms
RatedFlowRate [cfm]	50
HoursInOperation [hrs/day]	1
FanPower [W]	0.3 * RatedFlowRate
extension/StartHour [0-23]	7

Whole House Fan

A single whole house fan may be specified as a `Systems/MechanicalVentilation/VentilationFans/VentilationFan` with `UsedForSeasonalCoolingLoadReduction='true'`. Required elements include `RatedFlowRate` and `FanPower`.

The whole house fan is assumed to operate during hours of favorable outdoor conditions. If available, it will take priority over natural ventilation.

Water Heaters

Each water heater should be entered as a `Systems/WaterHeating/WaterHeatingSystem`. Inputs including `WaterHeaterType` and `FractionDHWLoadServed` must be provided. The water heater `Location` can be optionally entered; if not provided, a default water heater location will be assumed based on IECC climate zone.

IECC Climate Zone	Default Water Heater Location
1-3, excluding 3A	Garage if present, else Living Space
3A, 4-8, unknown	Conditioned Basement if present, else Unconditioned Basement if present, else Living Space

The setpoint temperature may be provided as `HotWaterTemperature`; if not provided, 125°F is assumed.

Depending on the type of water heater specified, additional elements are required/available:

Water-HeaterType	UniformEnergyFactor or EnergyFactor	Fuel-Type	Tank-Volume	Heating-Capacity	Recovery-Efficiency	Uses-Desuperheater	WaterHeaterInsulation/Jacket/JacketRValue	Related-HVAC-System
storage water heater	required	<any>	<optional>	<optional>	<optional>	<optional>	<optional>	required if uses desuperheater
instantaneous water heater	required	<any>				<optional>		required if uses desuperheater
heat pump water heater	required	electricity	required			<optional>	<optional>	required if uses desuperheater
space-heating boiler with storage tank			required				<optional>	required
space-heating boiler with tankless coil								required

For storage water heaters, the tank volume in gallons, heating capacity in Btuh, and recovery efficiency can be optionally provided. If not provided, default values for the tank volume and heating capacity will be assumed based on Table 8 in the 2014 Building America House Simulation Protocols and a default recovery efficiency will be assumed depending on the fuel type, as shown in the table below. The equations for non-electric storage water heaters are based on the regression analysis of AHRI certified water heaters.

FuelType	RecoveryEfficiency
Electric	0.98
Non-electric, EF >= 0.75	$0.778114 \cdot EF + 0.276679$
Non-electric, EF < 0.75	$0.252117 \cdot EF + 0.607997$

For tankless water heaters, an annual energy derate due to cycling inefficiencies can be provided. If not provided, a value of 0.08 (8%) will be assumed.

For combi boiler systems, the `RelatedHVACSystem` must point to a `HeatingSystem` of type "Boiler". For combi boiler systems with a storage tank, the storage tank losses (deg-F/hr) can be entered as `StandbyLoss`; if not provided, a default value based on the AHRI Directory of Certified Product Performance will be calculated.

For water heaters that are connected to a desuperheater, the `RelatedHVACSystem` must either point to a `HeatPump` or a `CoolingSystem`.

Hot Water Distribution

A `Systems/WaterHeating/HotWaterDistribution` must be provided if any water heating systems are specified. Inputs including `SystemType` and `PipeInsulation/PipeRValue` must be provided.

For a `SystemType/Standard` (non-recirculating) system, the following element are used:

- `PipingLength`: Optional. Measured length of hot water piping from the hot water heater 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) If not provided, a default `PipingLength` will be calculated using the following equation from ANSI/RESNET/ICC 301-2019.

$$PipeL = 2.0 \cdot (\frac{CFA}{NCfl})^{0.5} + 10.0 \cdot NCfl + 5.0 \cdot bsmnt$$

Where, PipeL = piping length [ft], CFA = conditioned floor area [ft^2], 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.

For a `SystemType/Recirculation` system, the following elements are used:

- `ControlType`

- `RecirculationPipingLoopLength`: Optional. If not provided, the default value will be calculated by using the equation shown in the table below. Measured 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.

- `BranchPipingLoopLength`: Optional. If not provided, the default value will be assumed as shown in the table below. Measured 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.

- `PumpPower`: Optional. If not provided, the default value will be assumed as shown in the table below.

Element Name	Default Value
RecirculationPipingLoopLength [ft]	$2.0 \cdot (2.0 \cdot (\frac{CFA}{NCfl})^{0.5} + 10.0 \cdot NCfl + 5.0 \cdot bsmnt) - 20.0$
BranchPipingLoopLength [ft]	10
Pump Power [W]	50

In addition, a `HotWaterDistribution/DrainWaterHeatRecovery` (DWHR) may be specified. The DWHR system is defined by:

- `FacilitiesConnected`: 'one' if there are multiple showers and only one of them is connected to a DWHR; 'all' if there is one shower and it's connected to a DWHR or there are two or more showers connected to a DWHR

- `EqualFlow`: 'true' if the DWHR supplies pre-heated water to both the fixture cold water piping and the hot water heater potable supply piping

- `Efficiency`: As rated and labeled in accordance with CSA 55.1

Water Fixtures

Water fixtures should be entered as `Systems/WaterHeating/WaterFixture` elements. Each fixture must have `WaterFixtureType` and `LowFlow` elements provided. Fixtures should be specified as low flow if they are <= 2.0 gpm.

A `WaterHeating/extension/WaterFixturesUsageMultiplier` can also be optionally provided that scales hot water usage; if not provided, it is assumed to be 1.0.

Solar Thermal

A solar hot water system can be entered as a `Systems/SolarThermal/SolarThermalSystem`. The `SystemType` element must be 'hot water'.

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

If using simple inputs, the following elements are used:

- `SolarFraction`: Portion of total conventional hot water heating load (delivered energy and 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.

- `ConnectedTo`: Optional. If not specified, applies to all water heaters in the building. If specified, must point to a `WaterHeatingSystem`.

If using detailed inputs, the following elements are used:

- `CollectorArea`: in units of ft^2

- `CollectorLoopType`: 'liquid indirect' or 'liquid direct' or 'passive thermosyphon'

- `CollectorType`: 'single glazing black' or 'double glazing black' or 'evacuated tube' or 'integrated collector storage'

- `CollectorAzimuth`

- `CollectorTilt`

- `CollectorRatedOpticalEfficiency`: FRTA (y-intercept); see Directory of SRCC OG-100 Certified Solar Collector Ratings

- `CollectorRatedThermalLosses`: FRUL (slope, in units of Btu/hr-ft^2-R); see Directory of SRCC OG-100 Certified Solar Collector Ratings

- `StorageVolume`: Optional. If not provided, the default value in gallons will be calculated using the following equation

$$StorageVolume = 1.5 \cdot CollectorArea$$

- `ConnectedTo`: Must point to a `WaterHeatingSystem`. The connected water heater cannot be of type space-heating boiler or attached to a desuperheater.

Photovoltaics

Each solar electric (photovoltaic) system should be entered as a `Systems/Photovoltaics/PVSystem`. The following elements, some adopted from the PVWatts model, are required for each PV system:

- `Location`: 'ground' or 'roof' mounted

- `ModuleType`: 'standard', 'premium', or 'thin film'

- `Tracking`: 'fixed' or '1-axis' or '1-axis backtracked' or '2-axis'

- `ArrayAzimuth`

- `ArrayTilt`

- `MaxPowerOutput`

Inputs including `InverterEfficiency`, `SystemLossesFraction`, and `YearModulesManufactured` can be optionally entered. If `InverterEfficiency` is not provided, the default value of 0.96 is assumed.

`SystemLossesFraction` includes the effects of soiling, shading, snow, mismatch, wiring, degradation, etc. If neither `SystemLossesFraction` or `YearModulesManufactured` are provided, a default value of 0.14 will be used. If `SystemLossesFraction` is not provided but `YearModulesManufactured` is provided, `SystemLossesFraction` will be calculated using the following equation.

$$SystemLossesFraction = 1.0 - (1.0 - 0.14) \cdot (1.0 - (1.0 - 0.995^{(CurrentYear - YearModulesManufactured)}))$$

3.2.7 Appliances

This section describes elements specified in HPXML's `Appliances`.

Clothes Washer

An `Appliances/ClothesWasher` element can be specified; if not provided, a clothes washer will not be modeled. The `Location` can be optionally provided; if not provided, it is assumed to be in the living space.

Several EnergyGuide label inputs describing the efficiency of the appliance can be provided. If the complete set of efficiency inputs is not provided, the following default values representing a standard clothes washer from 2006 will be used.

Element Name	Default Value
IntegratedModifiedEnergyFactor [ft^3/kWh-cyc]	1.0
RatedAnnualkWh [kWh/yr]	400
LabelElectricRate [$/kWh]	0.12
LabelGasRate [$/therm]	1.09
LabelAnnualGasCost [$]	27.0
Capacity [ft^3]	3.0
LabelUsage [cyc/week]	6

If `ModifiedEnergyFactor` is provided instead of `IntegratedModifiedEnergyFactor`, it will be converted using the following equation based on the [Interpretation on ANSI/RESNET 301-2014 Clothes Washer IMEF](#).

$$IntegratedModifiedEnergyFactor = \frac{ModifiedEnergyFactor - 0.503}{0.95}$$

An `extension/UsageMultiplier` can also be optionally provided that scales energy and hot water usage; if not provided, it is assumed to be 1.0.

Clothes Dryer

An `Appliances/ClothesDryer` element can be specified; if not provided, a clothes dryer will not be modeled. The dryer's `FuelType` must be provided. The `Location` can be optionally provided; if not provided, it is assumed to be in the living space.

Several EnergyGuide label inputs describing the efficiency of the appliance can be provided. If the complete set of efficiency inputs is not provided, the following default values representing a standard clothes dryer from 2006 will be used.

Element Name	Default Value
CombinedEnergyFactor [lb/kWh]	3.01
ControlType	timer

If `EnergyFactor` is provided instead of `CombinedEnergyFactor`, it will be converted into `CombinedEnergyFactor` using the following equation based on the [Interpretation on ANSI/RESNET/ICC 301-2014 Clothes Dryer CEF](#).

$$CombinedEnergyFactor = \frac{EnergyFactor}{1.15}$$

An `extension/UsageMultiplier` can also be optionally provided that scales energy usage; if not provided, it is assumed to be 1.0.

Dishwasher

An `Appliances/Dishwasher` element can be specified; if not provided, a dishwasher will not be modeled. The dishwasher is assumed to be in the living space.

Several EnergyGuide label inputs describing the efficiency of the appliance can be provided. If the complete set of efficiency inputs is not provided, the following default values representing a standard dishwasher from 2006 will be used.

Element Name	Default Value
RatedAnnualkWh [kwh/yr]	467
LabelElectricRate [$/kWh]	0.12
LabelGasRate [$/therm]	1.09
LabelAnnualGasCost [$]	33.12
PlaceSettingCapacity [#]	12
LabelUsage [cyc/week]	4

If `EnergyFactor` is provided instead of `RatedAnnualkWh`, it will be converted into `RatedAnnualkWh` using the following equation based on ANSI/RESNET/ICC 301-2014.

$$RatedAnnualkWh = \frac{215.0}{EnergyFactor}$$

An `extension/UsageMultiplier` can also be optionally provided that scales energy and hot water usage; if not provided, it is assumed to be 1.0.

Refrigerator

An `Appliances/Refrigerator` element can be specified; if not provided, a refrigerator will not be modeled. The `Location` can be optionally provided; if not provided, it is assumed to be in the living space.

The efficiency of the refrigerator can be optionally entered as `RatedAnnualkWh` or `extension/AdjustedAnnualkWh`. If neither are provided, `RatedAnnualkWh` will be defaulted to represent a standard refrigerator from 2006 using the following equation based on ANSI/RESNET/ICC 301-2019.

$$RatedAnnualkWh = 637.0 + 18.0 \cdot Number of Bedrooms$$

An `extension/UsageMultiplier` can also be optionally provided that scales energy usage; if not provided, it is assumed to be 1.0.

Cooking Range/Oven

`Appliances/CookingRange` and `Appliances/Oven` elements can be specified; if not provided, a range/oven will not be modeled. The `FuelType` of the range must be provided. The cooking range and oven is assumed to be in the living space.

Inputs including `IsInduction` (for the cooking range) and `IsConvection` (for the oven) can be optionally provided. The following default values will be assumed unless a complete set of the optional variables is provided.

Element Name	Default Value
IsInduction	false
IsConvection	false

An `extension/UsageMultiplier` can also be optionally provided that scales energy usage; if not provided, it is assumed to be 1.0.

Dehumidifier

An `Appliance/Dehumidifier` element can be specified; if not provided, a dehumidifier will not be modeled. The `Capacity`, `DehumidistatSetpoint` (relative humidity as a fraction, 0-1), and `FractionDehumidificationLoadServed` (0-1) must be provided. The efficiency of the dehumidifier can either be entered as an `IntegratedEnergyFactor` or `EnergyFactor`.

3.2.8 Lighting

The building's lighting is described by six `Lighting/LightingGroup` elements, each of which is the combination of:

- `LightingGroup/ThirdPartyCertification`: 'ERI Tier I' (fluorescent) and 'ERI Tier II' (LEDs, outdoor lamps controlled by photocells, or indoor lamps controlled by motion sensor)

- `LightingGroup/Location`: 'interior', 'garage', and 'exterior'

The fraction of lamps of the given type in the given location are provided as the `LightingGroup/FractionofUnitsInLocation`. The fractions for a given location cannot sum to greater than 1. If the fractions sum to less than 1, the remainder is assumed to be incandescent lighting. Garage lighting values are ignored if the building has no garage.

To model a building without any lighting, all six `Lighting/LightingGroup` elements must be excluded.

A `Lighting/extension/UsageMultiplier` can also be optionally provided that scales energy usage; if not provided, it is assumed to be 1.0.

3.2.9 Ceiling Fans

Each ceiling fan (or set of identical ceiling fans) should be entered as a `Lighting/CeilingFan`. The `Airflow/Efficiency` (at medium speed) and `Quantity` can be provided, otherwise the following default assumptions are used from ANSI/RESNET/ICC 301-2019.

Element Name	Default Value
Airflow/Efficiency [cfm/W]	3000/42.6
Quantity [#]	NumberofBedrooms+1

In addition, a reduced cooling setpoint can be specified for summer months when ceiling fans are operating. See the Thermostat section for more information.

3.2.10 Plug Loads

Plug loads can be provided by entering `MiscLoads/PlugLoad` elements; if not provided, plug loads will not be modeled. Currently only plug loads specified with `PlugLoadType='other'` and `PlugLoadType='TV other'` are recognized. The annual energy consumption (`Load[Units='kWh/year']/Value`) can be provided, otherwise they will be calculated using the following equations from ANSI/RESNET/ICC 301-2019.

$$Television kWhs = 413.0 + 69.0 \cdot Number of Bedrooms$$

$$Other kWhs = 0.91 \cdot Conditioned Floor Area$$

An `extension/UsageMultiplier` can also be optionally provided that scales energy usage; if not provided, it is assumed to be 1.0.

3.3 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.

3.4 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.

SimulationOutputReport Measure

Documentation pending.

CHAPTER 5

Indices and tables

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