



ASHRAE 90.1 App G PRM and LEED User Guide

DesignBuilder v7.3



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1. Introduction to DesignBuilder ASHRAE 90.1 and LEED

The DesignBuilder ASHRAE 90.1 and LEED modelling tool largely automates the baseline building creation from the proposed building and helps you to provide documentation for LEED credits EAp2 and EAc1. The assessment is based on the ASHRAE 90.1 Standard Appendix G Performance Rating Method (App G PRM).

As DesignBuilder only currently uses ASHRAE 90.1 App G PRM for LEED models, unless otherwise stated, the terms ASHRAE 90.1 App G PRM (or in short App G PRM) or simply ASHRAE 90.1 mean the same in this document.

This LEED Modelling Guide generally focuses only on LEED-specific functionality. It is assumed that the modeller has sufficient experience and knowledge of DesignBuilder regarding creation of the actual (Proposed) building model, which is typically created prior to the baseline building. More general (non-LEED specific) DesignBuilder information can be accessed from the [DesignBuilder Help](#) system.

The DesignBuilder App G PRM modelling tool is tightly integrated into the EnergyPlus modelling environment in the software. An App G PRM model looks very much like a standard DesignBuilder EnergyPlus model, but it includes various extra functionality that specifically meet ASHRAE 90.1 App G PRM requirements.

To use DesignBuilder LEED you will need the following licence modules:

- LEED
- Simulation,
- HVAC and
- Cost (for utility tariff).

These can be purchased most conveniently and cost-effectively through the [Engineering Essentials](#) package.

By following ASHRAE 90.1 App G PRM definitions, the DesignBuilder LEED tool generates data for LEED EAc1 and earns points based on energy cost saving from the proposed building over the baseline building. The baseline building can be automatically generated from the proposed building using two simple wizards.

2. Why DesignBuilder ASHRAE 90.1?

The DesignBuilder ASHREA 90.1 and LEED modelling tool is based on the following:

- LEED approved EnergyPlus simulation engine (refer to Clause G2.2 Simulation Program in ASHRAE 90.1 Standard 2007).
- The tool meets the Appendix G Performance Rating Method requirements of the ASHRAE 90.1 2007' 2010, 2013 or 2016 standards.
- A wide range of pre-configured templates and libraries to speed up model definition.
- To automate the baseline building generation the proposed model should be created first. The baseline building can be created first if required, but this is not the recommended workflow.
- DesignBuilder LEED includes two separate wizards. One baseline building wizard that deals with geometry and other non-HVAC related data, and a baseline HVAC wizard that sets up the HVAC system. Some further manual checks and changes to the baseline HVAC system are usually required.
- The proposed and baseline building models are stored and manipulated in a single project file, which provides an easy data check and more secure model quality.
- In cases where four rotated baseline building simulations are required, they are run simultaneously in parallel using DesignBuilder's Simulation Manager to speed up the simulations.
- DesignBuilder provides an output comparing proposed and aggregated baseline building results.

- A link to the LEED v4 and LEED v4.1 data processing tool is provided to speed up the generation of LEED submission documentation, i.e. LEED v4 and v4.1 Minimum Energy Performance Calculator (MEPC) report.

3. DesignBuilder ASHRAE 90.1 and LEED Workflow

Figure 1 illustrates the workflow of a DesignBuilder LEED modelling project.

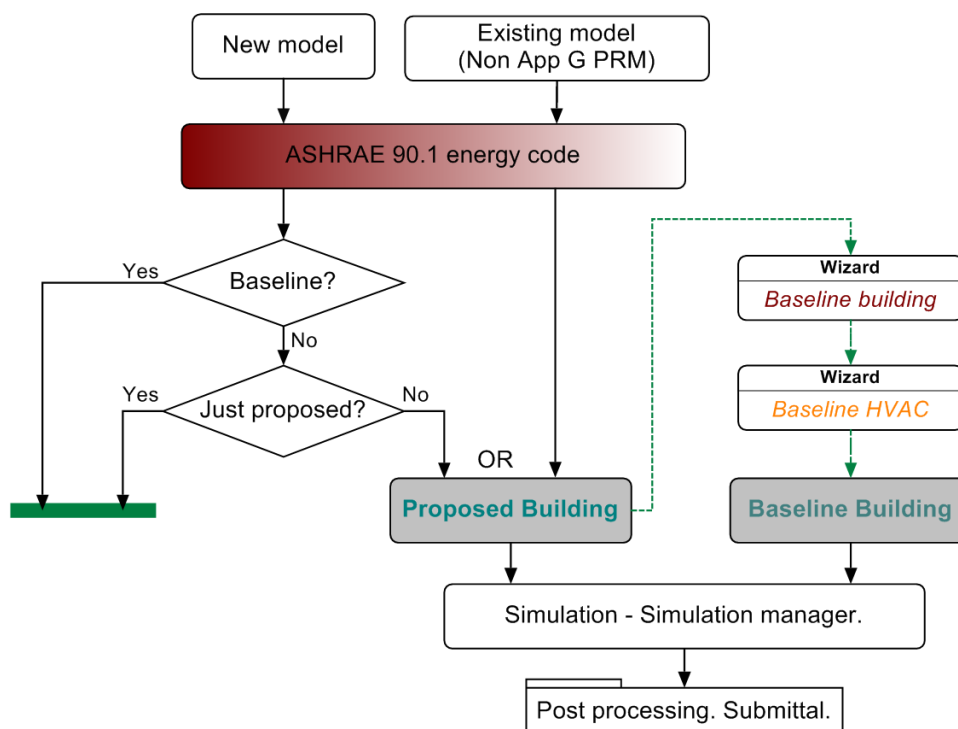


Figure 1 DesignBuilder LEED module structure and flowchart

The usual workflow is to create the proposed building model first and then automatically create the corresponding baseline model from that. In this case, the two models are contained in the same dsb file. However, for cases where, for any reason, it is more convenient to use separate files for the two models DesignBuilder's LEED tool allows this. Figure 1 also shows that the proposed building can be created either from scratch or converted from a non-ASHRAE 90.1 model.

This document describes the step-by-step process of modelling a full LEED project from proposed to baseline within the same dsb file. It does not cover the process used for modelling the baseline and proposed buildings in separate files.

4. Create an ASHRAE 90.1 Project – Proposed Building

A new ASHRAE 90.1 project will typically be created via the “New file” command.

Alternatively, if you already have a model that you wish to convert to an ASHRAE 90.1 model, you can change the energy code for the model by editing data at site level. DesignBuilder currently supports the “ASHRAE 90.1-2007”, “ASHRAE 90.1-2010”, “ASHRAE 90.1-2013” and “ASHRAE 90.1-2016” codes and the appropriate selection can be made in an existing model by changing the “Mandatory energy code” on the “Region” tab at site

level (Figure 2). Selecting any one of four “ASHRAE 90.1” codes under US category enables the model to be an ASHRAE 90.1 App G PRM model, and enables the additional LEED functionality described in this document.

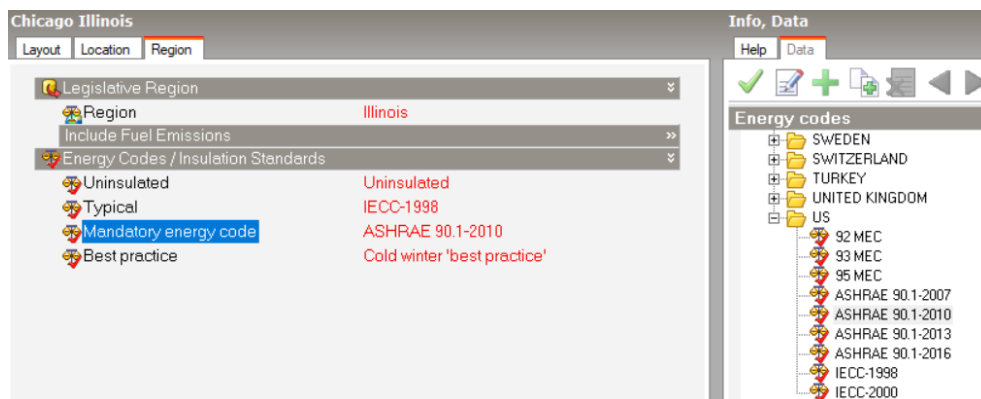


Figure 2 ASHRAE 90.1 energy code to enable App G PRM model functionality

4.1 Units and Currency (Program Options)

Prior to starting the ASHRAE 90.1 model, it is best to ensure the correct Program options are correctly set for your region. You can select either IP (imperial) or SI (metric) units and a wide range of common currencies including US dollars. Although units and currency can be changed at any time during any modelling process prior to simulations, DesignBuilder recommends making the appropriate selections in Program options before creating the model. To do this, use the Tools -> Program Options top menu option and choose the [International tab](#) (Figure 3).

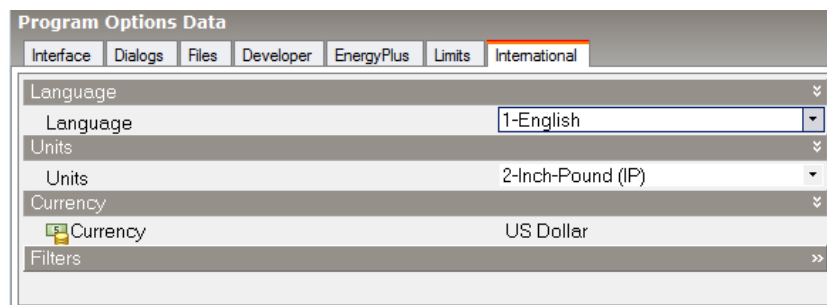


Figure 3 Options for choosing Units and currency (as well as interface language)

4.2 Proposed model setup for a new project

In the “New file” dialog input the Title and set the weather location. Keep the “Analysis type” as “1-EnergyPlus” (this is a requirement for ASHRAE 90.1 modelling in DesignBuilder), check the “ASHRAE 90.1 App G PRM” checkbox and select one of the ASHRAE 90.1 Standard options from the dropdown list (highlighted in Figure 4).

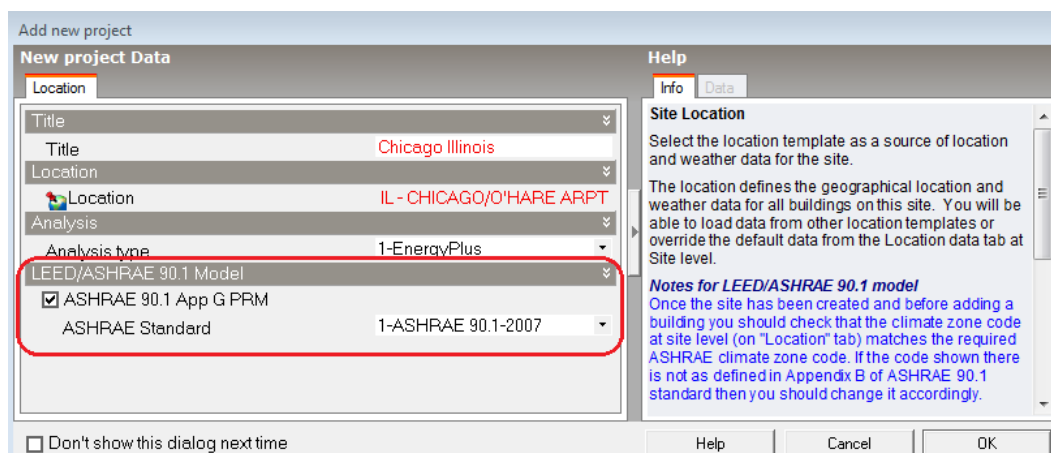


Figure 4 Add new LEED project

4.2.1 Location and ASHRAE climate zone

After a new project has been created, it is always possible to check or change the location, weather file, ASHRAE climate zone etc at site level on the “Location” tab (Figure 5).

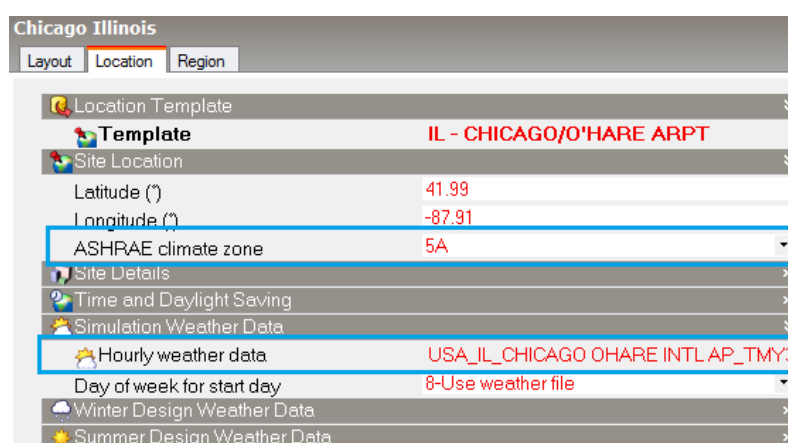


Figure 5 ASHRAE climate zone and simulation weather file

The climate zone setting in the model will affect the constructions and glazing selected when the baseline building is created using the baseline building wizard. It can also affect the selection of details in the baseline HVAC system. The ASHRAE climate zone shown on the interface is preloaded from the location template (Figure 6).

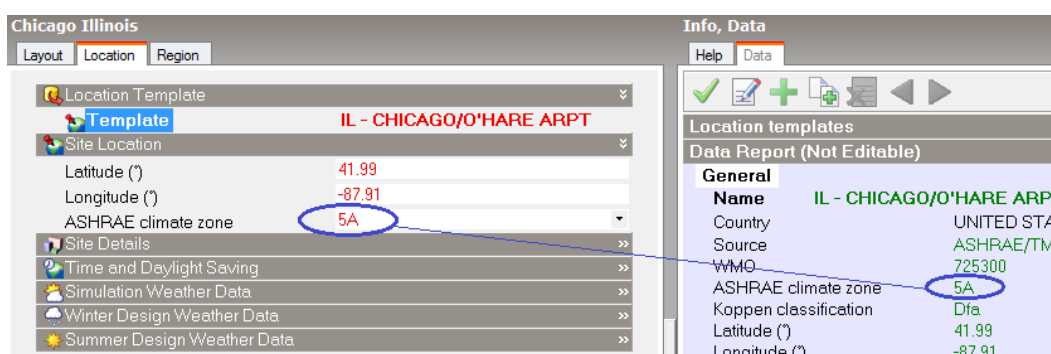


Figure 6 ASHRAE climate zone is preloaded from location template

In the unlikely event that the selected climate zone does not correspond with the climate zone specified by ASHRAE for the location, it should be changed manually. When making a change using the dropdown list, a message will alert the user of this change together with relevant baseline construction and glazing changes (Figure 7).

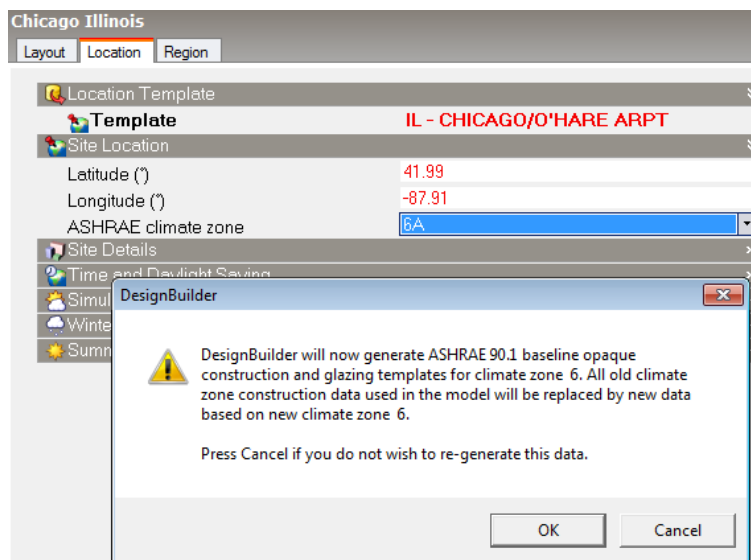


Figure 7 A confirmation message is shown when overriding the default climate zone

Note: Two new climate zones (0A and 0B) have been added to ASHRAE 90.1 2016, where 0A is for extremely hot humid climate while 0B extremely hot dry climate.

4.2.2 Add new building

A building can then be added into the empty project (site) using the “Add new building” command (Figure 8).

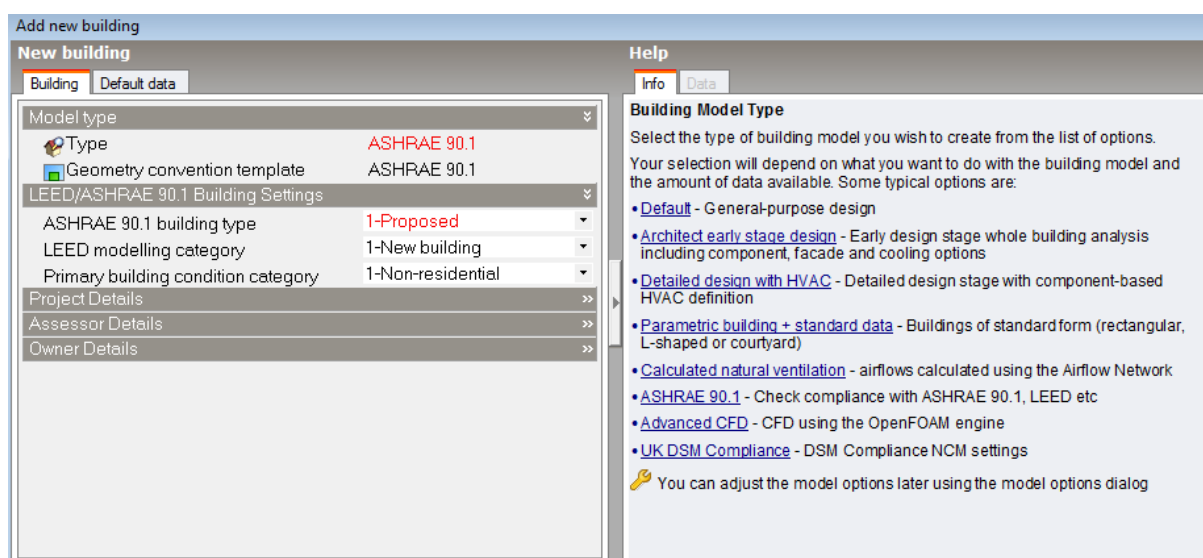


Figure 8 Add new building dialog

Although a baseline building could be modeled first, DesignBuilder recommends creating the proposed building first and then using the built-in wizards to generate the baseline building. This offers a much faster and more automated approach than manually creating the baseline model.

If the baseline building is created first, both baseline and proposed building models must be modeled manually, but this guide does not cover that workflow.

4.2.3 Model option - type

When the “Type” option under the “Model type” header is set to ASHRAE 90.1 there will be additional ASHRAE 90.1 model inputs visible. The “LEED/ASHRAE 90.1 Building Settings” options can be changed here or on the “Activity” tab later.

When the “ASHRAE 90.1” type is set DesignBuilder will load some appropriate model data settings such as detailed HVAC (a mandatory requirement for App G PRM models in DesignBuilder) and 6 time steps per hour for simulating the proposed and baseline building models.

4.2.4 Model option - Geometry convention

It is important for ASHRAE 90.1 App G PRM-based work that the proposed and baseline buildings have appropriately similar floor areas and zone volumes. The easiest way to ensure this is to use the “ASHRAE 90.1” geometry convention for both buildings (see Figure 9). Using this template, the block geometry is drawn to the outside face of the external walls giving the correct surface geometry and zone volumes for the simulation according to ASHRAE 90.1. This convention also “disconnects” the construction data from the building geometry so that the baseline building zone geometry will be correct even after loading the baseline constructions, which will often have a different thickness.

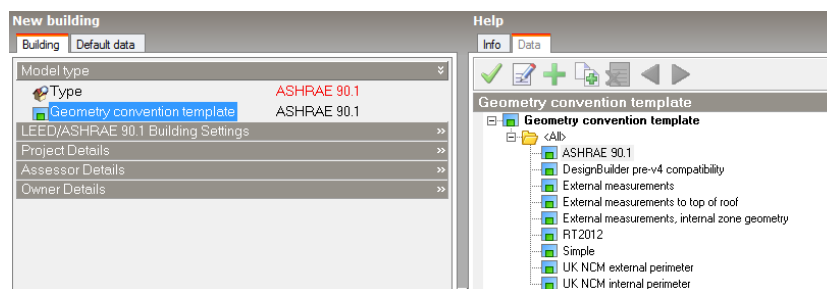


Figure 9 Use the ASHRAE 90.1 Geometry convention template

If you chose to use the “External measurements” template for example you will find that the baseline building surface areas, floor area and zone volumes are different after loading the baseline constructions because these generally have a different thickness to those selected for the proposed building. If you choose to use a geometry convention other than “ASHRAE 90.1” please refer to the Geometry conventions information in the Program Help and ensure you fully understand the implications of any alternative setting.

4.3 Modelling data

There is a library of pre-created ASHRAE 90.1 model data and schedules to choose from in DesignBuilder database. Schedules are capable of representing variations in occupancy, lighting power, miscellaneous equipment power, thermostat setpoints and HVAC system operations. These schedules should generally be the same for the proposed building and baseline buildings. As the ASHRAE 90.1 standard indicates, the schedules shall be typical of the proposed building type as determined by the designer and approved by the rating authority.

4.3.1 ASHRAE Activity Template

The ASHRAE 62.1 activity templates in DesignBuilder are appropriate for use in App G PRM modelling based on the building type or space type of the model. Typically, they use ASHRAE 62.1 occupancy densities, ASHRAE 62.1 outdoor fresh air rates and schedules from ASHRAE 90.1 User’s manual (Table G-E through Table G-O in

2007 user's manual). A screenshot of some ASHRAE 62.1 activity templates in DesignBuilder is shown in Figure 10.

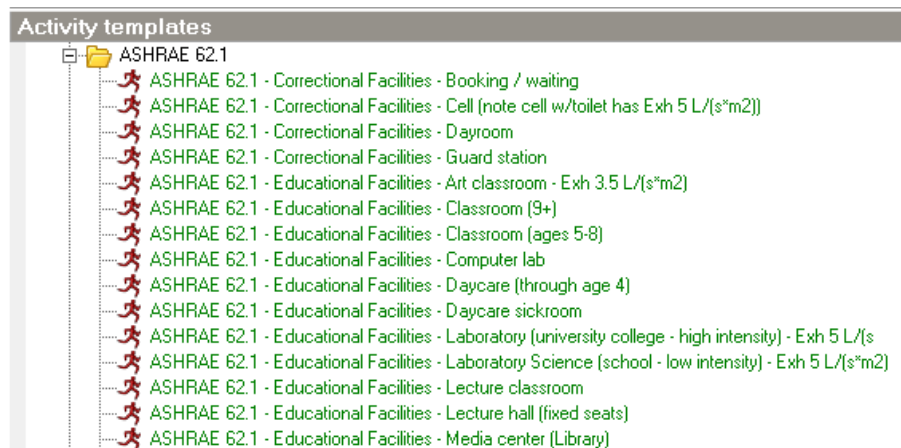


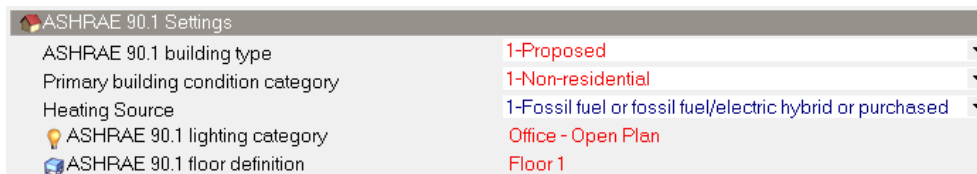
Figure 10 ASHRAE 62.1 activity templates ready for App G PRM use

4.3.2 ASHRAE 90.1 “Activity” tab settings

When the ASHRAE 90.1 model type is selected you will see additional “Activity” tab inputs specifically related to an ASHRAE 90.1 App G PRM model. Items shown on the “Activity” tab will differ according to the version of ASHRAE 90.1 Standard applied and the level the model is viewed at.

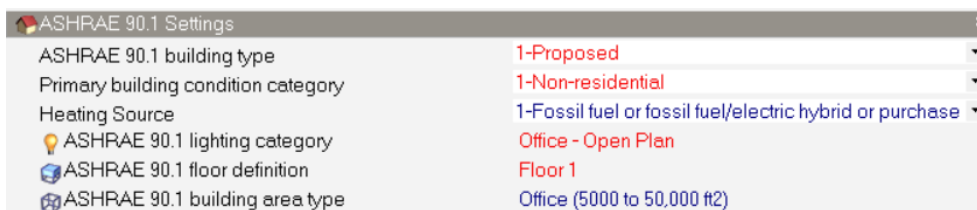
4.3.2.1 ASHRAE 90.1 Activity tab settings at Building Level

At the building level, the Activity tab shows the relevant ASHRAE 90.1 settings including the ASHRAE 90.1 building type, primary building condition category, heating source, ASHRAE 90.1 lighting category and ASHRAE 90.1 floor definition (Figure 11).



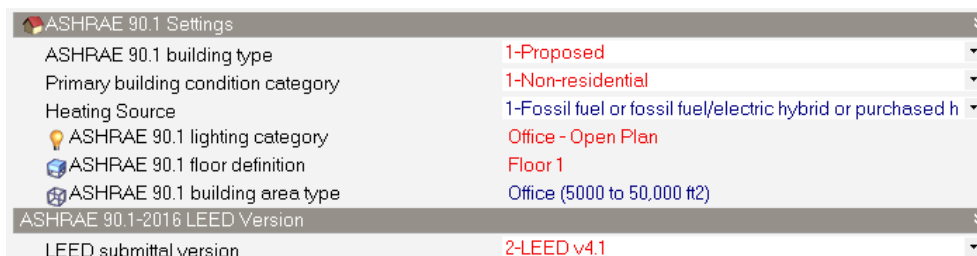
ASHRAE 90.1 Settings	
ASHRAE 90.1 building type	1-Proposed
Primary building condition category	1-Non-residential
Heating Source	1-Fossil fuel or fossil fuel/electric hybrid or purchased
ASHRAE 90.1 lighting category	Office - Open Plan
ASHRAE 90.1 floor definition	Floor 1

(a) Settings for ASHRAE 90.1-2007 and 2010



ASHRAE 90.1 Settings	
ASHRAE 90.1 building type	1-Proposed
Primary building condition category	1-Non-residential
Heating Source	1-Fossil fuel or fossil fuel/electric hybrid or purchase
ASHRAE 90.1 lighting category	Office - Open Plan
ASHRAE 90.1 floor definition	Floor 1
ASHRAE 90.1 building area type	Office (5000 to 50,000 ft2)

(b) Settings for ASHRAE 90.1-2013 and 2016



ASHRAE 90.1 Settings	
ASHRAE 90.1 building type	1-Proposed
Primary building condition category	1-Non-residential
Heating Source	1-Fossil fuel or fossil fuel/electric hybrid or purchased h
ASHRAE 90.1 lighting category	Office - Open Plan
ASHRAE 90.1 floor definition	Floor 1
ASHRAE 90.1 building area type	Office (5000 to 50,000 ft2)
ASHRAE 90.1-2016 LEED Version	
LEED submittal version	2-LEED v4.1

(c) LEED submittal version selection for ASHRAE 90.1-2016

Figure 11 ASHRAE 90.1 settings at building level

The “ASHRAE 90.1 building type” defines whether the building is 1-Proposed or 2-Baseline. DesignBuilder does not recommend switching between ASHRAE 90.1 building types unless you understand the risk and there is a need to do so.

The “Primary building condition category” can be either 1-Non-residential or 2-Residential, which is used to define primary building use. This is especially useful when modelling mixed use buildings because it controls constructions, HVAC selections etc according to its condition category.

The “Heating source” defines the building’s heating use as either electric or fossil fuel. This will affect the baseline model HVAC system selection (Table G3.1.1A and Table G3.1.1B in ASHRAE 90.1 Standard).

The “ASHRAE 90.1 lighting category”, “ASHRAE 90.1 floor definition” and “ASHRAE 90.1 building area type” inputs will be discussed in more detail below.

DesignBuilder version 7.3 supports LEED v4.1 Minimum Energy Performance Calculator (MEPC) generation, and this is only applicable for ASHRAE 90.1 – 2016. Figure 11 (c) indicates an additional “LEED submittal version” dropdown list when ASHRAE 90.1 – 2016 energy code is selected at the site level.

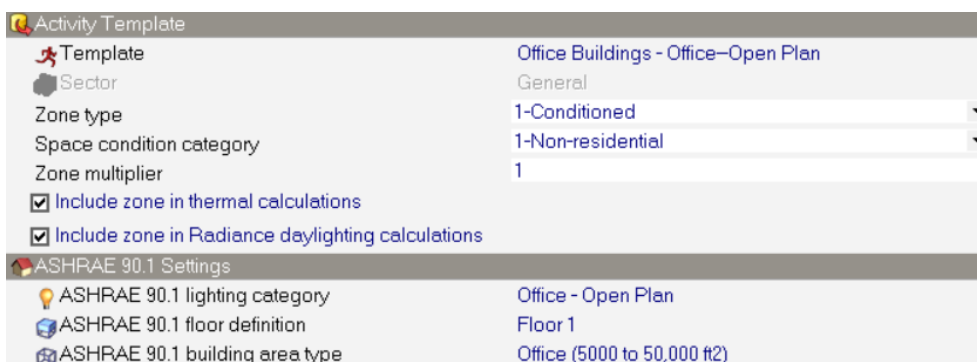
4.3.2.2 ASHRAE 90.1 settings on Activity tab at block and zone levels

The “ASHRAE 90.1 lighting category” and “ASHRAE 90.1 floor definition” inputs are available at block and zone levels. (Figure 12 ASHRAE 90.1 settings at zone level(a) and (b)). The “ASHRAE 90.1 building area type” item of 2013 and 2016 energy code is also shown at block and zone levels (Figure 12 ASHRAE 90.1 settings at zone level(b)).



Activity Template	
Template	Office Buildings - Office-Open Plan
Sector	General
Zone type	1-Conditioned
Space condition category	1-Non-residential
Zone multiplier	1
☒ Include zone in thermal calculations	
☒ Include zone in Radiance daylighting calculations	
ASHRAE 90.1 Settings	
ASHRAE 90.1 lighting category	Office - Open Plan
ASHRAE 90.1 floor definition	Floor 1

(a) Settings for ASHRAE 90.1-2007 and 2010



Activity Template	
Template	Office Buildings - Office-Open Plan
Sector	General
Zone type	1-Conditioned
Space condition category	1-Non-residential
Zone multiplier	1
☒ Include zone in thermal calculations	
☒ Include zone in Radiance daylighting calculations	
ASHRAE 90.1 Settings	
ASHRAE 90.1 lighting category	Office - Open Plan
ASHRAE 90.1 floor definition	Floor 1
ASHRAE 90.1 building area type	Office (5000 to 50,000 ft2)

(b) Settings for ASHRAE 90.1-2013 and 2016

Figure 12 ASHRAE 90.1 settings at zone level

Additional inputs at block/zone levels define whether the current zone is conditioned, unconditioned or semi-heated (Figure 12). You must also define whether the zone is conditioned, and set the "Space condition category"..

The non-residential or residential category denotes whether or not the zone falls under the building level primary building condition category. If it is the same at both zone and building level, the zone will fall into the primary condition category, otherwise the zone will fall into the non-predominant condition category.

The building area types shown in Figure 12 (b) will be further discussed in section 4.3.2.5 ASHRAE 90.1 building area type.

4.3.2.3 ASHRAE 90.1 Lighting Category

The available options for "ASHRAE 90.1 lighting category" are based on ASHRAE 90.1-2007 or 2010 Table 9.6.1 (Figure 13) or ASHRAE 90.1-2016 Table G3.7 (Figure 14). This affects lighting settings, especially lighting power density (LPD) after the baseline building has been created using the baseline building wizard.

TABLE 9.6.1 Lighting Power Densities Using the Space-by-Space Method

Common Space Types ^a	LPD, W/ft ²	Building-Specific Space Types	LPD, W/ft ²
Office—Enclosed	1.1	Gymnasium/Exercise Center	
Office—Open Plan	1.1	Playing Area	1.4
Conference/Meeting/Multipurpose	1.3	Exercise Area	0.9
Classroom/Lecture/Training	1.4	Courthouse/Police Station/Penitentiary	
For Penitentiary	1.3	Courtroom	1.9
Lobby	1.3	Confinement Cells	0.9
For Hotel	1.1	Judges' Chambers	1.3
For Performing Arts Theater	3.3	Fire Stations	
For Motion Picture Theater	1.1	Engine Room	0.8
Audience/Seating Area	0.9	Sleeping Quarters	0.3
For Gymnasium	0.4	Post Office—Sorting Area	1.2
For Exercise Center	0.3	Convention Center—Exhibit Space	1.3
For Convention Center	0.7	Library	
For Penitentiary	0.7	Card File and Cataloging	1.1
For Religious Buildings	1.7	Stacks	1.7

Figure 13 Lighting power densities using space-by-space method in ASHRAE 90.1-2007 (IP Edition)

Table G3.7 Performance Rating Method Lighting Power Density Allowances and Occupancy Sensor Reductions Using the Space-by-Space Method

Common Space Types ^a	Lighting Power Density, W/ft ²	Occupancy Sensor Reduction ^b
Audience Seating Area		
Auditorium	0.90	10%
Convention center	0.70	10%
Exercise center	0.30	10%
Gymnasium	0.40	10%
Motion picture theater	1.20	10%
Penitentiary	0.70	10%
Performing arts theater	2.60	10%
Religious facility	1.70	10%
In a sports arena	0.40	10%
Transportation facility	0.50	10%
All other audience seating area	0.90	10%
Atrium		
≤40 ft in height	0.0375 per foot in total height	10%
>40 ft in height	0.50 + 0.025 per foot in total height	10%
Banking Activity Area	1.50	10%

Figure 14 Lighting power density allowances using space-by-space method in ASHRAE 90.1 -2016 (IP Edition)

Users must ensure that the correct “ASHRAE 90.1 lighting category” is selected (Figure 15). If you are not able to find a perfectly matching record in the list, you could choose one that is closest to your application.

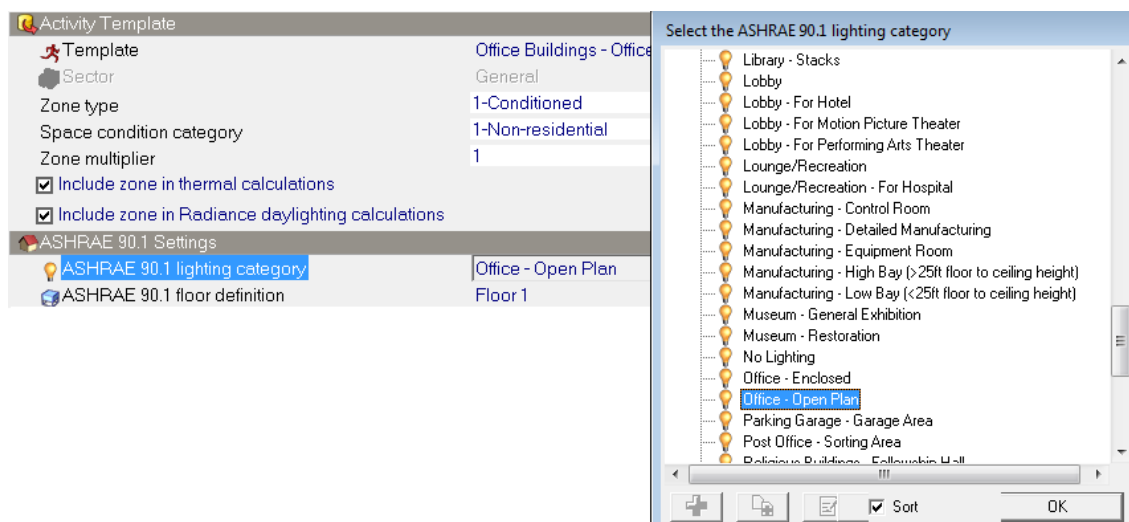


Figure 15 ASHRAE 90.1 lighting category in DesignBuilder

4.3.2.4 ASHRAE 90.1 floor definition

This gives an option for user defined floors to be included.

The ASHRAE 90.1 floors will be used in the HVAC wizard discussed in section 06.2.1.4 Systems #5 – #8 – each floor to have a separate HVAC system later.

4.3.2.5 ASHRAE 90.1 building area type

ASHRAE 90.1-2013 and 2016 Appendix G introduces building area types (Figure 16), which are used to determine vertical fenestration areas when the baseline building is configured (by percentage to the gross above-grade-wall areas).

Table G3.1.1-1 Baseline Building Vertical Fenestration Percentage of Gross Above-Grade-Wall Area

Building Area Types ^a	Baseline Building Gross Above-Grade-Wall Area
Grocery store	7%
Healthcare (outpatient)	21%
Hospital	27%
Hotel/motel (≤75 rooms)	24%
Hotel/motel (>75 rooms)	34%
Office (≤5000 ft ²)	19%
Office (5000 to 50,000 ft ²)	31%
Office (>50,000 ft ²)	40%
Restaurant (quick service)	34%
Restaurant (full service)	24%
Retail (stand alone)	11%
Retail (strip mall)	20%
School (primary)	22%
School (secondary and university)	22%
Warehouse (nonrefrigerated)	6%

a. In cases where both a general building area type and a specific building area type are listed, the specific building area type shall apply.

Figure 16 Baseline building window to wall ratio (WWR) defined by Building Area Types

DesignBuilder provides an option on the Activity tab to allow any of these building area types be selected (Figure 17).

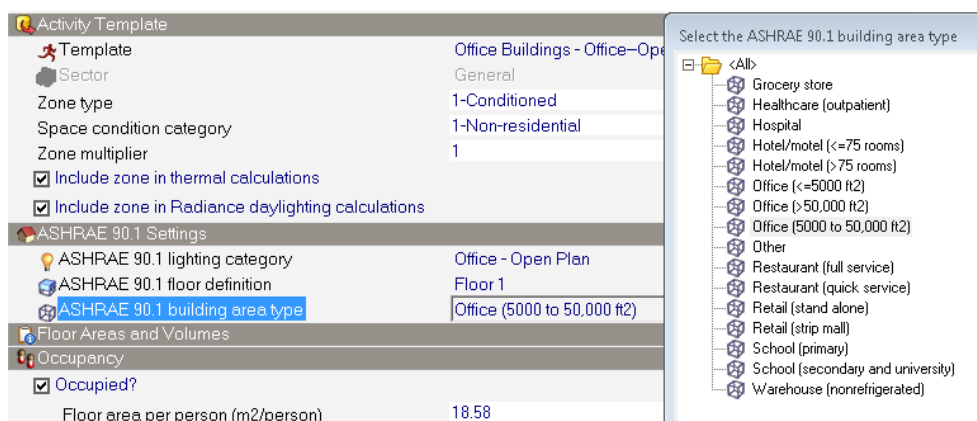


Figure 17 ASHRAE 90.1 building area type shown on Activity tab

In ASHRAE 90.1 2013 and 2016, for building area types included in Table G3.1.1-1 (Figure 16), vertical fenestration areas for new buildings and additions shall be as defined in Table G3.1.1-1 based on the area of gross above-grade walls that separate conditioned spaces and semi-heated spaces from the exterior. Where a building has multiple building area types, each type shall use the values in the table.

For building areas not shown in the table, vertical fenestration areas for new buildings and additions shall follow the rule as per ASHRAE 90.1 2007 or 2010, i.e. they equal window to wall ratios in the proposed design or 40% of gross above-grade wall area, whichever is smaller.

The DesignBuilder ASHRAE 90.1 building wizard handles this new feature for ASHRAE 90.1 2013 or 2016 models.

The use of ASHRAE 90.1 building area type will be further explained in Section 6.1.2.3 Baseline building vertical fenestration on building area types.

4.3.3 Equipment loads

DesignBuilder breaks down the equipment load inputs into different categories, i.e. computers, office equipment, miscellaneous, catering and process.

Computers and office equipment always use electricity as the fuel source, hence there is not a fuel type to choose from and subsequently there is not an end-use subcategory applied. They require gain density and associated operational schedule to be entered (Figure 18).

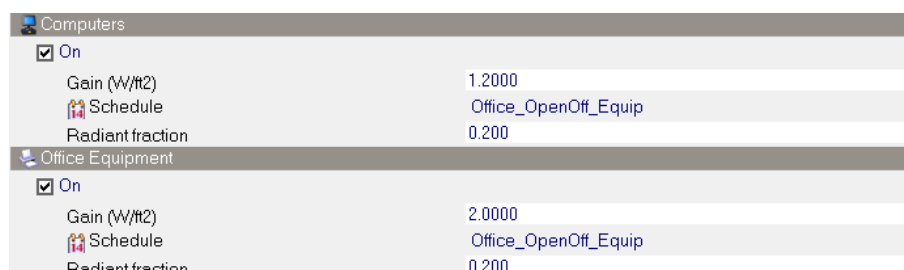
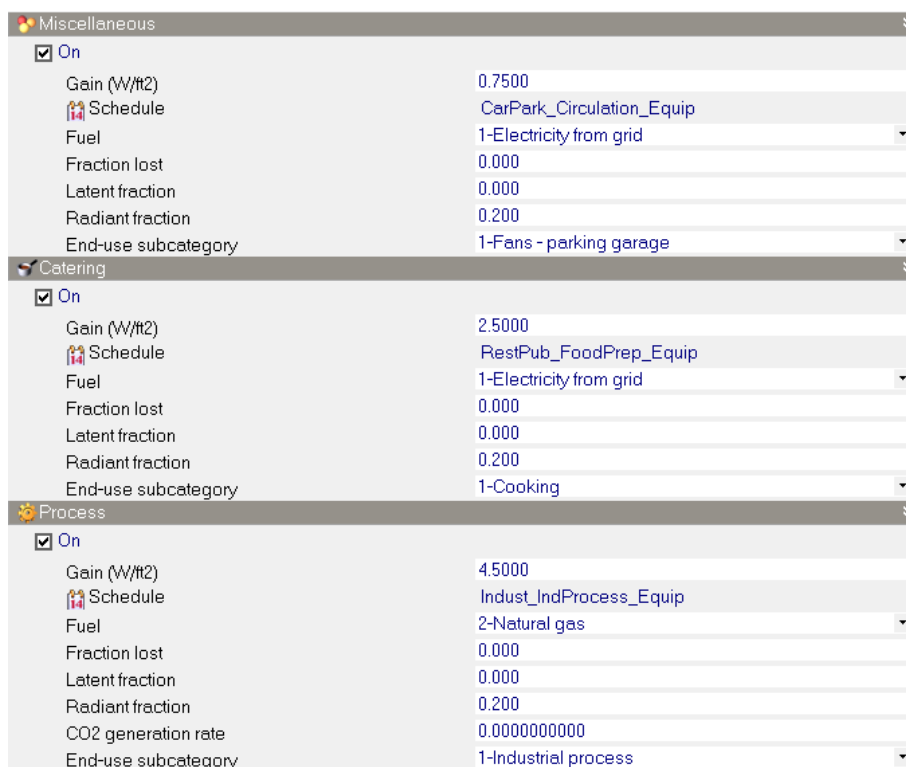


Figure 18 Computers and office equipment loads input on Activity tab

Miscellaneous, Catering and Process gains allow “Fans – Parking garage” and “Elevators and escalators” (under Miscellaneous load definition), “Cooking” (under Catering load definition) and “Industrial process” (under Process load definition) to define the end-use subcategory (Figure 19) for the input. These loads are reported in the LEED summary report after the simulation.



Miscellaneous	
☒ On	
Gain (W/ft2)	0.7500
Schedule	CarPark_Circulation_Equip
Fuel	1-Electricity from grid
Fraction lost	0.000
Latent fraction	0.000
Radiant fraction	0.200
End-use subcategory	1-Fans - parking garage
Catering	
☒ On	
Gain (W/ft2)	2.5000
Schedule	RestPub_FoodPrep_Equip
Fuel	1-Electricity from grid
Fraction lost	0.000
Latent fraction	0.000
Radiant fraction	0.200
End-use subcategory	1-Cooking
Process	
☒ On	
Gain (W/ft2)	4.5000
Schedule	Indust_IndProcess_Equip
Fuel	2-Natural gas
Fraction lost	0.000
Latent fraction	0.000
Radiant fraction	0.200
CO2 generation rate	0.0000000000
End-use subcategory	1-Industrial process

Figure 19 Other LEED required loads input on Activity tab

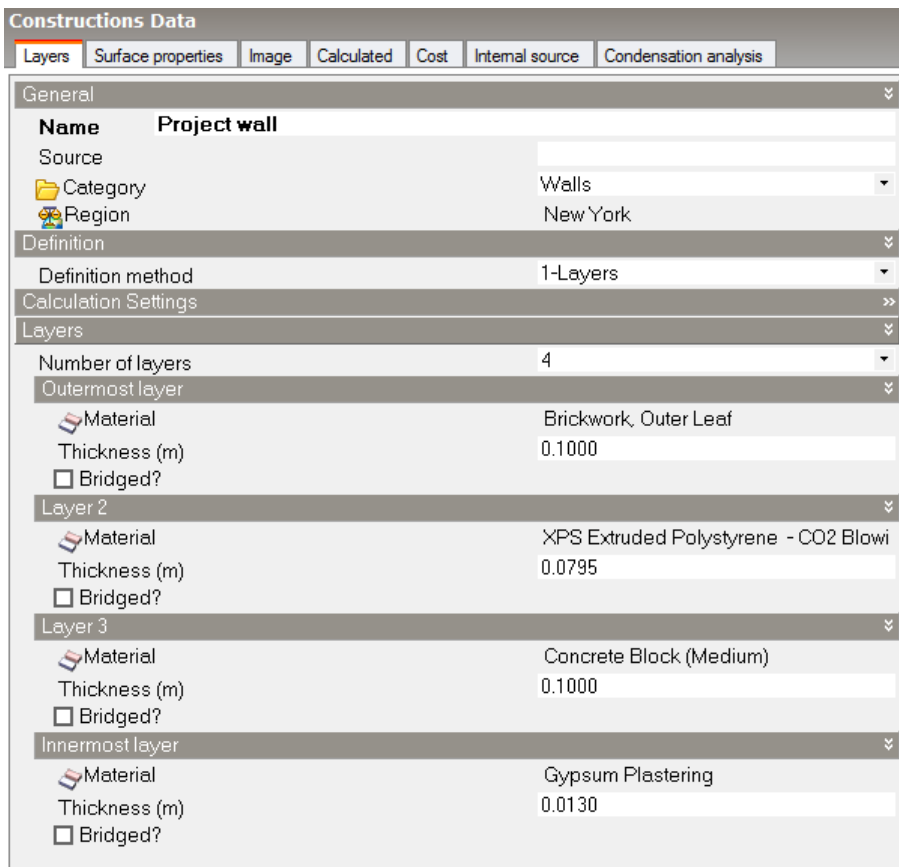
4.3.4 Opaque and Glazed constructions

Constructions and glazing should be modeled as shown on architectural drawings or as built for existing building envelopes. Local shading and window shading can be defined on the Openings tab.

When a site is created or when the climate zone is changed, the appropriate corresponding baseline construction and glazing templates are generated in DesignBuilder so that they can be assigned to the model when the baseline building is created. The ASHRAE 90.1 templates in the model could be copied and edited for use in the proposed building where appropriate.

4.3.4.1 Layer based constructions

DesignBuilder constructions are comprised of material layers (Figure 20) as required by EnergyPlus.



Constructions Data	
Layers Surface properties Image Calculated Cost Internal source Condensation analysis	
General	
Name	Project wall
Source	
Category	Walls
Region	New York
Definition	
Definition method	1-Layers
Calculation Settings	
Layers	
Number of layers	4
Outermost layer	
Material	Brickwork, Outer Leaf
Thickness (m)	0.1000
Bridged?	☐
Layer 2	
Material	XPS Extruded Polystyrene - CO2 Blown
Thickness (m)	0.0795
Bridged?	☐
Layer 3	
Material	Concrete Block (Medium)
Thickness (m)	0.1000
Bridged?	☐
Innermost layer	
Material	Gypsum Plastering
Thickness (m)	0.0130
Bridged?	☐

Figure 20 Opaque construction built up by layers

A list of baseline wall constructions for climate zone 5 (CZ5) is shown in Figure 21 as an example.

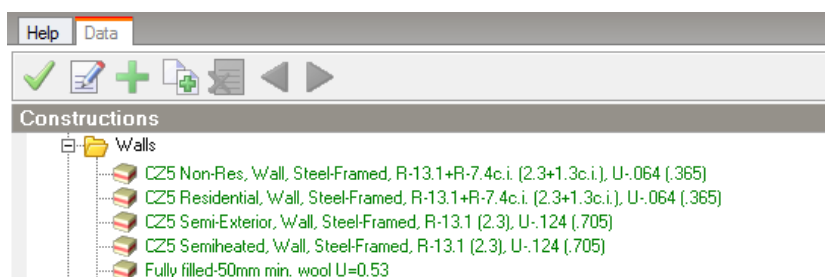


Figure 21 Baseline wall constructions

The terminology used in the ASHRAE 90.1 constructions list gives the climate zone, the description of the construction, insulation level(s) in IP units and the U-value in IP units and in brackets the values in SI units. For example, the construction:

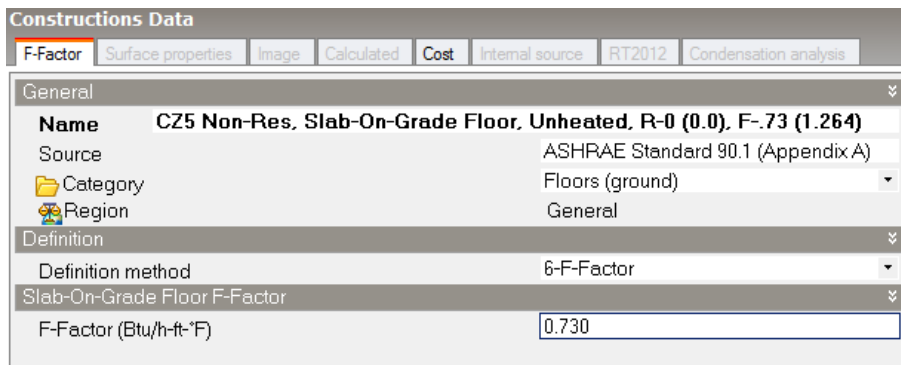
“CZ4 Non-Res, Wall, Steel-Framed, R-13.1+R-7.4 (2.3+1.3), U-.064 (.365)”

indicates a non-residential steel framed wall for climate zone 4 (CZ4) with internal insulation levels of two layers of minimum 13.1 and 7.4 ft²·°F/(Btu/hr) in IP units (2.3 and 1.3 m²·K/W in SI units) and a U-value of 0.064 Btu/hr·ft²·°F in IP units (0.365 W/m²·K in SI units).

4.3.4.2 F-factor and C-factor constructions

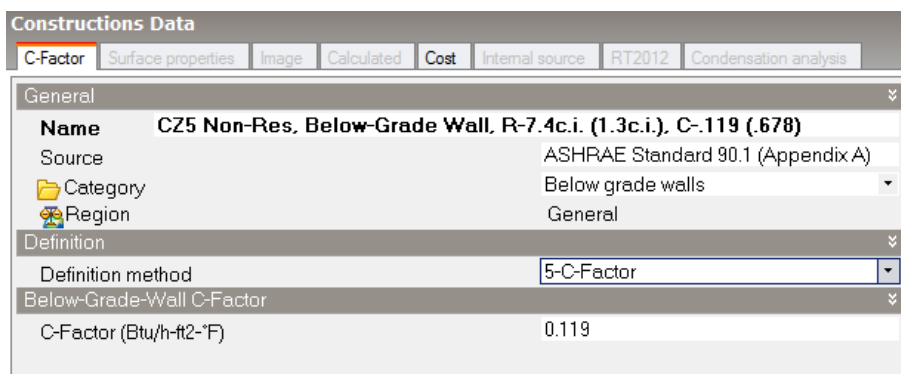
The ASHRAE 90.1 Standard requires two special opaque construction types: F-factor slab on grade ground floors (Figure 22), and C-factor below-grade walls (Figure 23). These differ from conventional layered constructions as

they do not use layers of materials but instead the overall thermal properties are defined as an F-factor (for slab on grade floors) or a C-factor (for below grade walls). EnergyPlus uses these factors to generate equivalent layered constructions. During the simulation these surfaces exchange heat with the FCFactor ground temperatures only (Figure 24).



Constructions Data	
F-Factor	
General	
Name	CZ5 Non-Res. Slab-On-Grade Floor, Unheated, R-0 (0.0), F-.73 (1.264)
Source	ASHRAE Standard 90.1 (Appendix A)
Category	Floors (ground)
Region	General
Definition	
Definition method	6-F-Factor
Slab-On-Grade Floor F-Factor	
F-Factor (Btu/h-ft²-F)	0.730

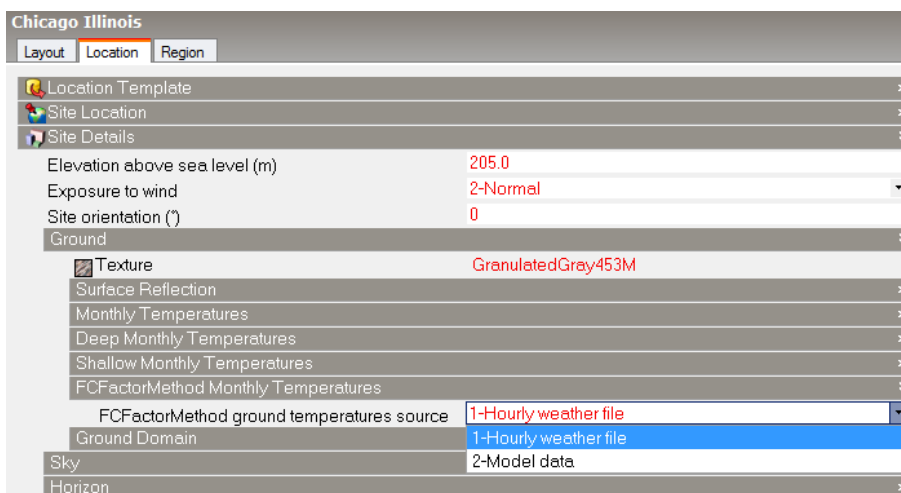
Figure 22 Slab on grade F-factor construction



Constructions Data	
C-Factor	
General	
Name	CZ5 Non-Res. Below-Grade Wall, R-7.4c.i. (1.3c.i.), C-.119 (.678)
Source	ASHRAE Standard 90.1 (Appendix A)
Category	Below grade walls
Region	General
Definition	
Definition method	5-C-Factor
Below-Grade-Wall C-Factor	
C-Factor (Btu/h-ft²-F)	0.119

Figure 23 Below grade wall C-factor construction

When running Heating or Cooling design calculations, if the “FCFactorMethod ground temperatures source data” at site level has “1-Hourly weather file” selected, the calculations will use the undisturbed ground temperature data contained within the weather file. This will be automatically downloaded (if not yet in your weather file folder on your computer) prior to the calculations. If “2-Model data” is selected, the Heating and Cooling design calculations do not require the weather file (Figure 24).



Chicago Illinois	
Location	
Location Template	
Site Location	
Site Details	
Elevation above sea level (m)	205.0
Exposure to wind	2-Normal
Site orientation (°)	0
Ground	
Texture	GranulatedGray453M
Surface Reflection	
Monthly Temperatures	
Deep Monthly Temperatures	
Shallow Monthly Temperatures	
FCFactorMethod Monthly Temperatures	
FCFactorMethod ground temperatures source	1-Hourly weather file
Ground Domain	1-Hourly weather file
Sky	2-Model data
Horizon	

Figure 24 FCFactorMethod ground temperature source at site level

4.3.4.3 Glazing constructions

The baseline glazing constructions (skylight for example) are stored in DesignBuilder's glazing database (Figure 25) ready for assigning in the model.

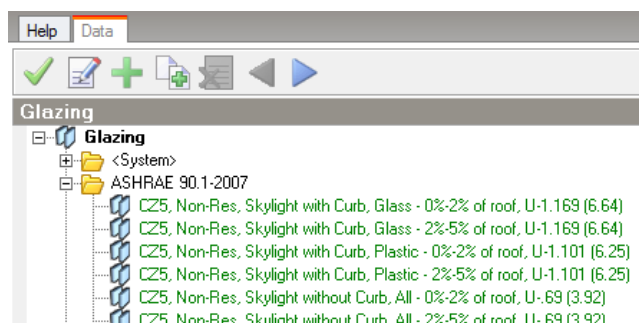


Figure 25 Baseline glazing constructions

Note: The Simple glazing definition type (WindowMaterial:SimpleGlazingSystem object in EnergyPlus) is used to model glazing in the baseline building model. The U-factor and other input values for this simple glazing type already include the effect of the frame, so the “Has a frame/dividers?” checkbox under the “Frame and Dividers” header on “Openings” tab should be left unchecked in the baseline building model.

4.3.5 Lighting

Lighting including lighting power density (LPD) should be input from the actual lighting or as designed for each zone (Figure 26).

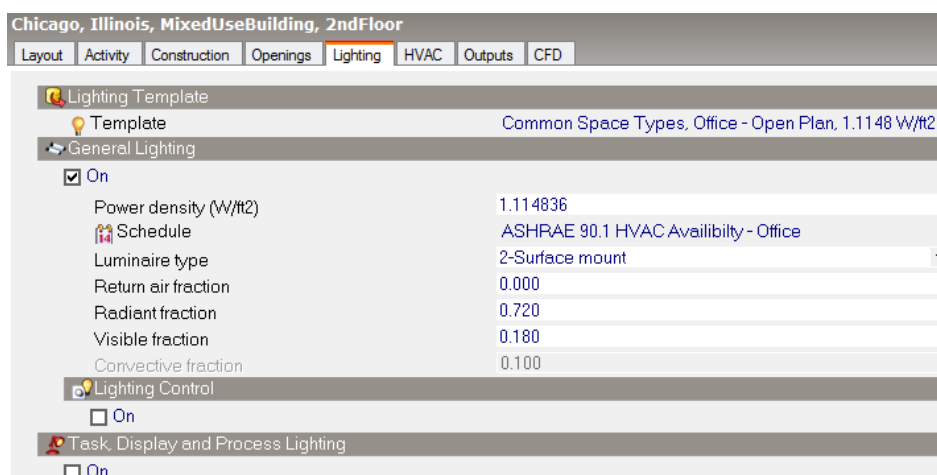


Figure 26 Lighting settings

For modelling the proposed building, DesignBuilder provides a set of predefined lighting templates (these are the ones used in the baseline building when it is generated) that can be used directly or copied and edited as required (Figure 27).

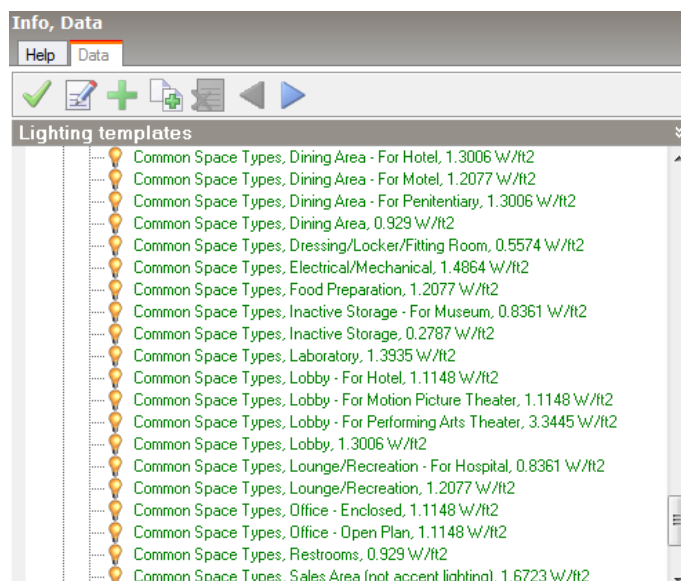


Figure 27 Predefined ASHRAE 90.1 lighting templates

Table G3.1-6 in ASHRAE 90.1 Standard indicates that credit may be taken for the use of automatic controls for daylight utilization. In DesignBuilder, automatic daylight control can be modeled in the proposed building using the Lighting Control settings (Figure 28).

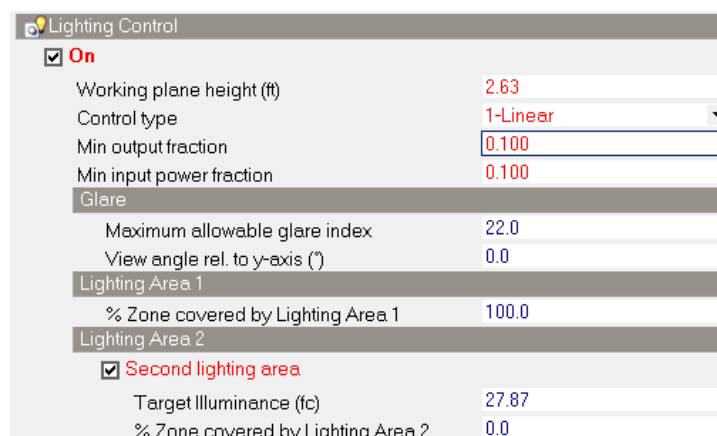


Figure 28 Automatic lighting control settings

4.3.5.1 Exterior lighting

The exterior lighting load is a simple input (total load) modified by a schedule and daylight override on the "Lighting" tab (Figure 29). This input is available at building level only.

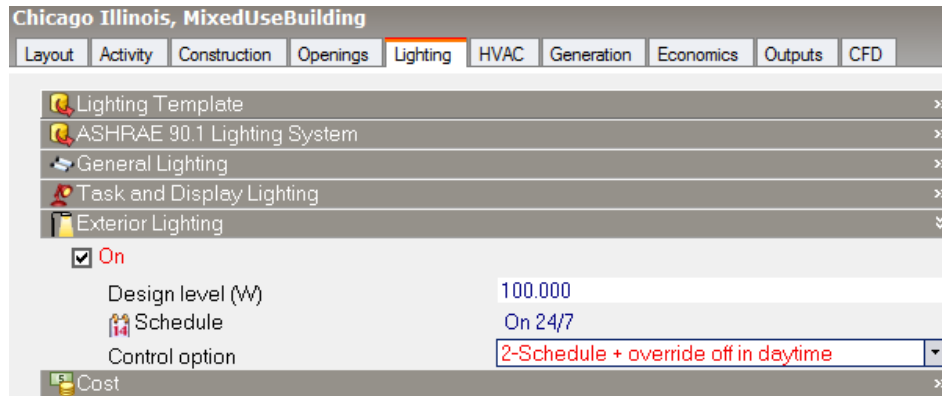


Figure 29 Exterior lighting input

EnergyPlus will report this exterior lighting consumption in output summary tables. Detailed input of exterior lighting zone selection and the lighting definition on tradable/nontradable surfaces are not allowed. Please see DesignBuilder LEED v4.1 Data Reporting User Guide for more details for how to report the exterior lighting in LEED MEPC.

4.3.6 Costs - Utility rates/Tariffs input

The “Economics” tab is available at building level only. Note that it is only visible when the Detailed HVAC model option is selected. It enables the model to use utility rates (tariffs) for calculating operational energy costs in electricity, gas or other energy sources (Figure 30). Up to 5 tariffs can be loaded into one building model.

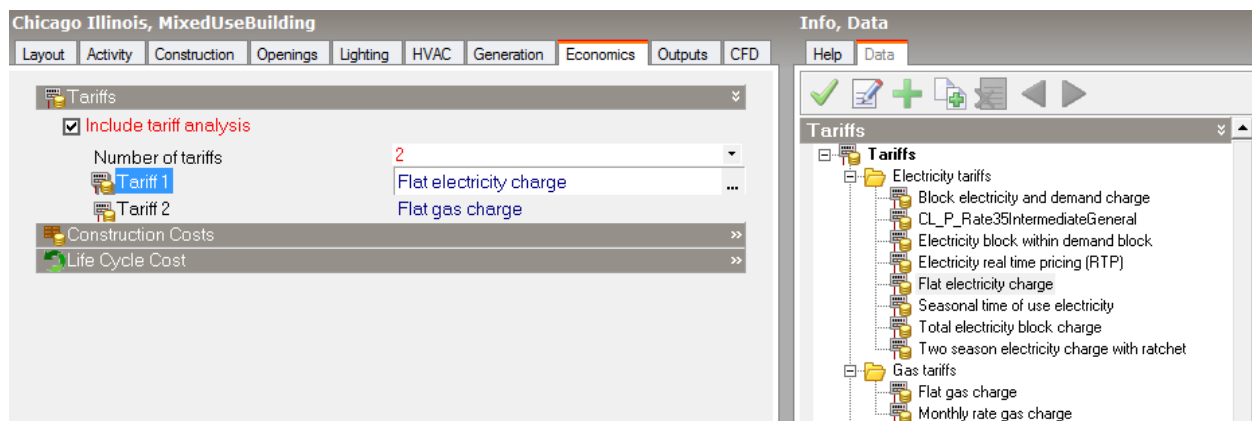


Figure 30 Utility rates (tariffs) input from Economics tab

As a minimum, data on the Tariff tab (Figure 31) and Charge tab (Figure 32) should be set up for utility cost calculations to work. On the Tariff tab, users need to input general tariff settings, such as the output meter used, schedules for defining seasonal or time of day charges, monthly service charge and minimum monthly charge etc.

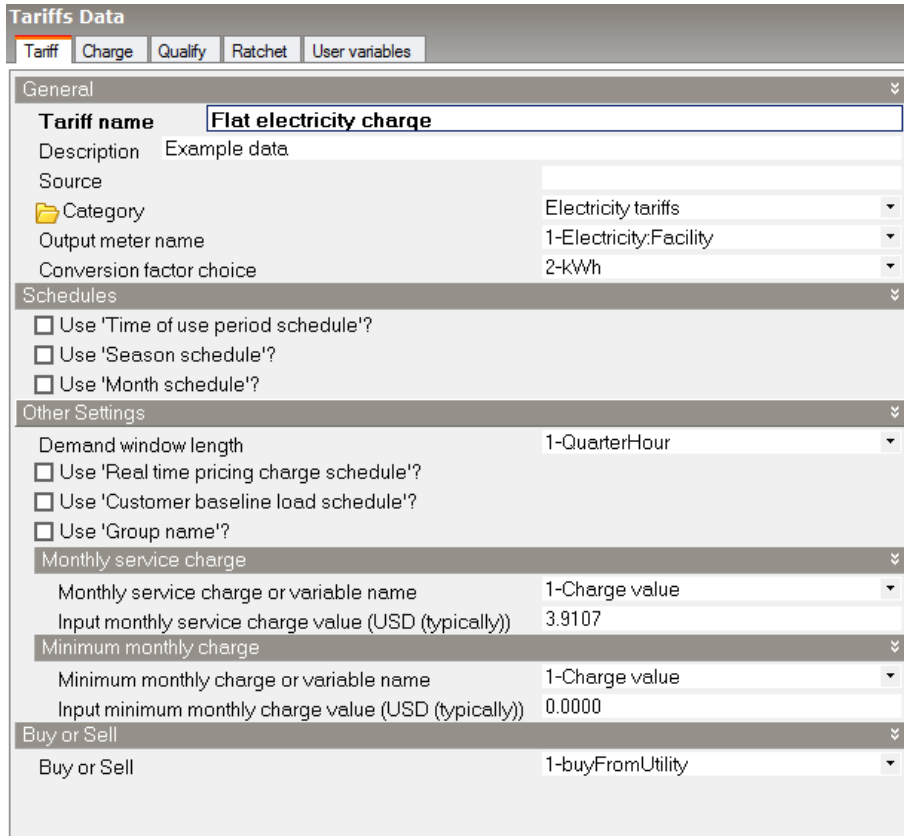


Figure 31 Tariff tab data input

The charge tab provides options to input simple or complex charges from the utility company (Figure 32). A maximum of 10 charges can be input as a combination of either the simple charge format or the block charge format, which provides more complex charge patterns. The charge can apply on both energy and demand readings depending on the source variable to be used.

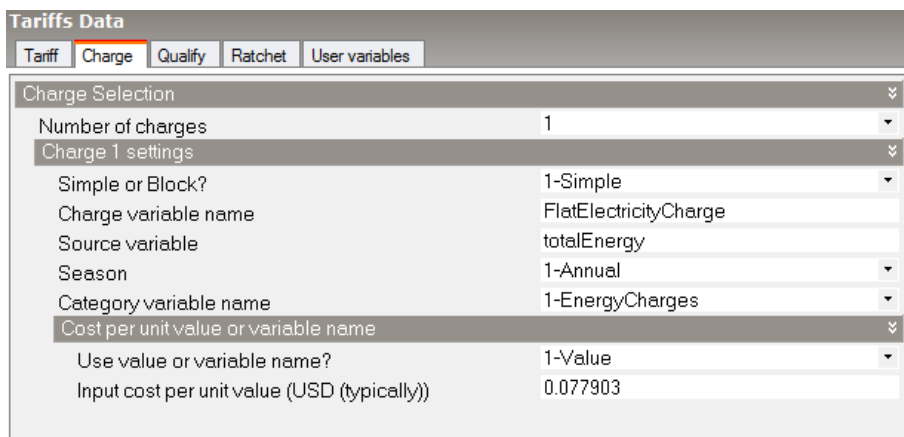


Figure 32 Charge tab data input

ASHRAE 90.1 indicates that annual energy costs shall be determined using either actual rates for purchased energy or state average energy prices published by DOE's Energy Information Administration (EIA) for commercial building customers. However, rates from different sources may not be mixed in the same project.

4.4 Detailed HVAC system

The HVAC system type and all related performance parameters in the proposed design, such as equipment capacities and efficiencies shall reflect the actual system type using actual component capacities and efficiencies where a complete HVAC system exists. For the system under design, the HVAC system shall be consistent with design documents. The ASHRAE 90.1 Standard section 6.4.1 defines the adjustment on equipment efficiencies from actual design conditions to the standard rating conditions.

4.4.1 Using HVAC templates or add loop/components tools

DesignBuilder's Detailed HVAC model option must be selected for LEED modelling to enable the HVAC requirements specified by ASHRAE 90.1 to be reflected in the model. DesignBuilder has a large range of pre-defined common HVAC system templates which can be used as a starting point for the proposed building model (Figure 33). Baseline systems #11, #12 and #13 were added for ASHRAE 90.1 2013 and 2016 modelling.

For example, a graphical layout of a "VAV Reheat, Water-cooled Chiller" system is illustrated in Figure 34, which includes a chilled water loop, a condenser loop a hot water loop, and an air loop that contains an air handling unit (AHU).

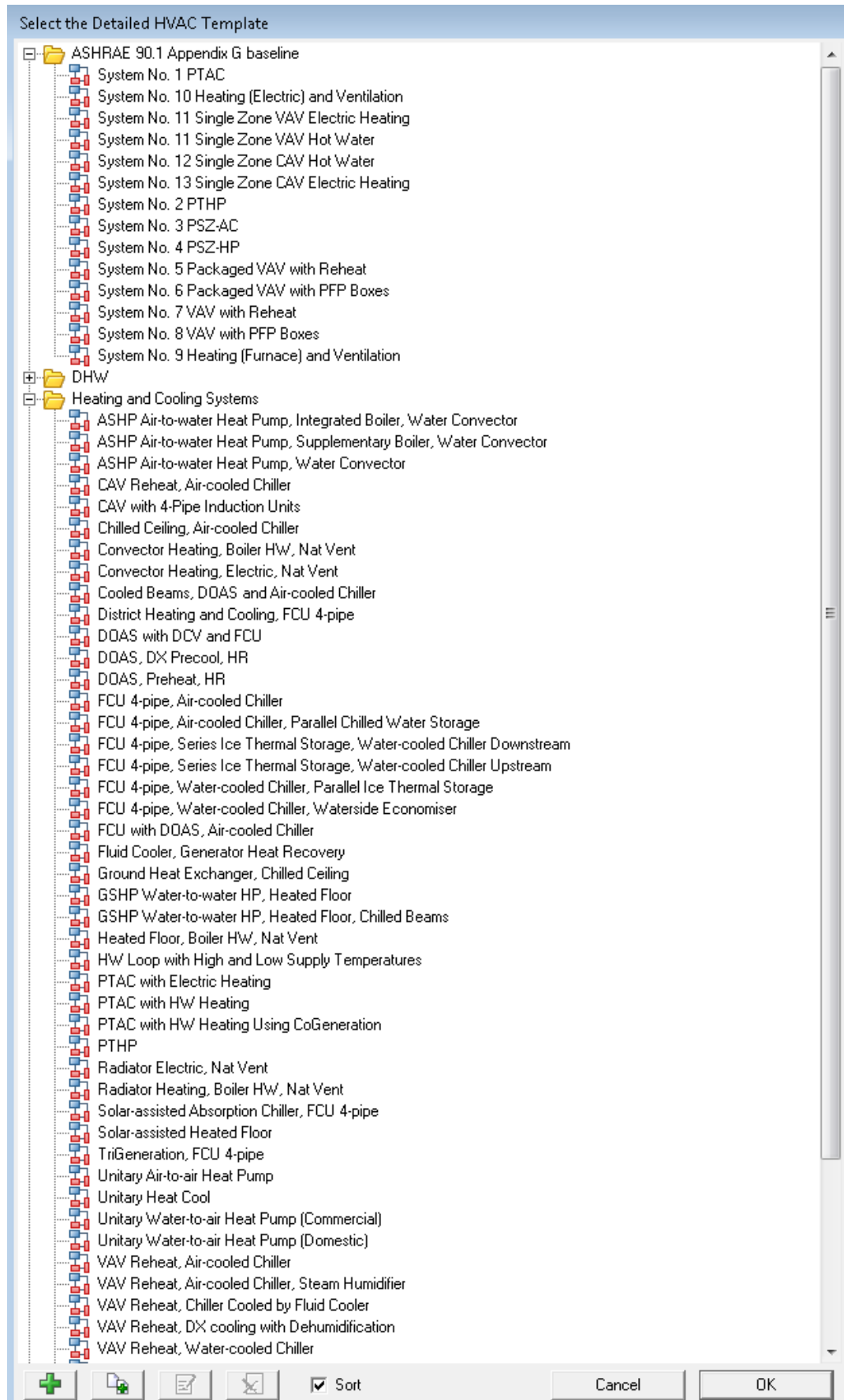


Figure 33 List of predefined detailed HVAC systems (templates) in DesignBuilder

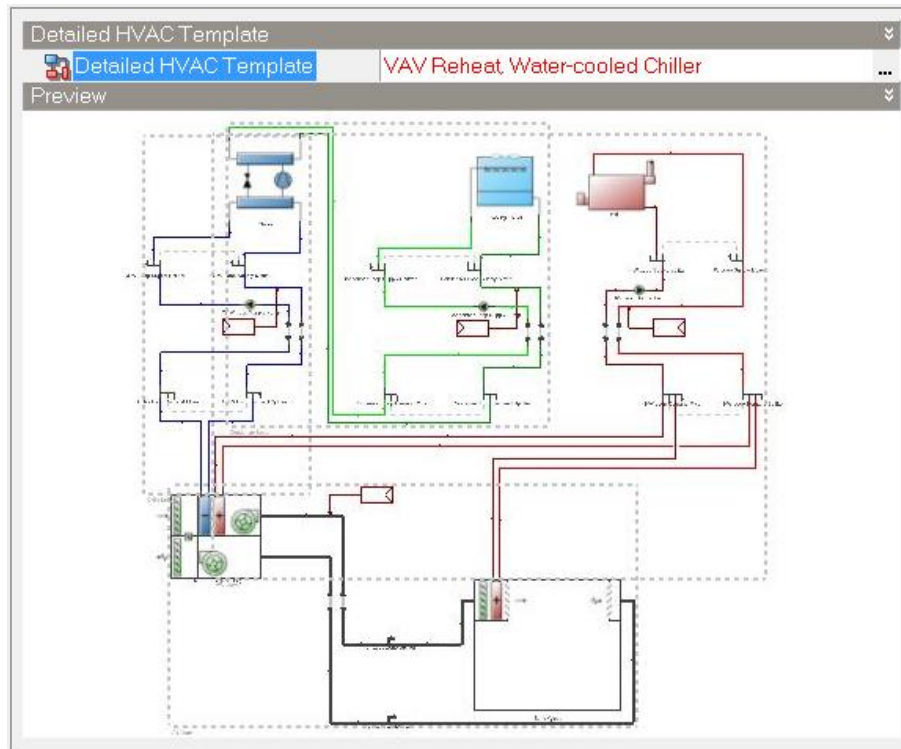


Figure 34 Graphical layout of detailed HVAC system

To set up the HVAC system exactly as required, including service hot water or SHW systems (called domestic hot water or DHW systems in DesignBuilder), users need to edit the Loop and component dialogs to define the performance characteristics and controls. Users can modify a pre-defined template to represent their design system or create a system from scratch by adding loops and components using the HVAC tools in DesignBuilder (Figure 35 and Figure 36).

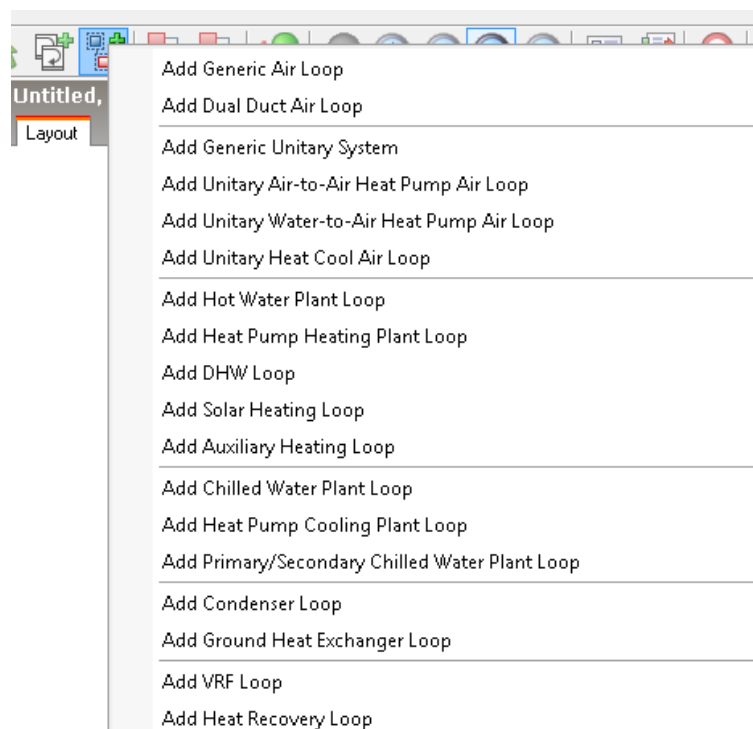


Figure 35 Add Loop function to help build up HVAC system manually

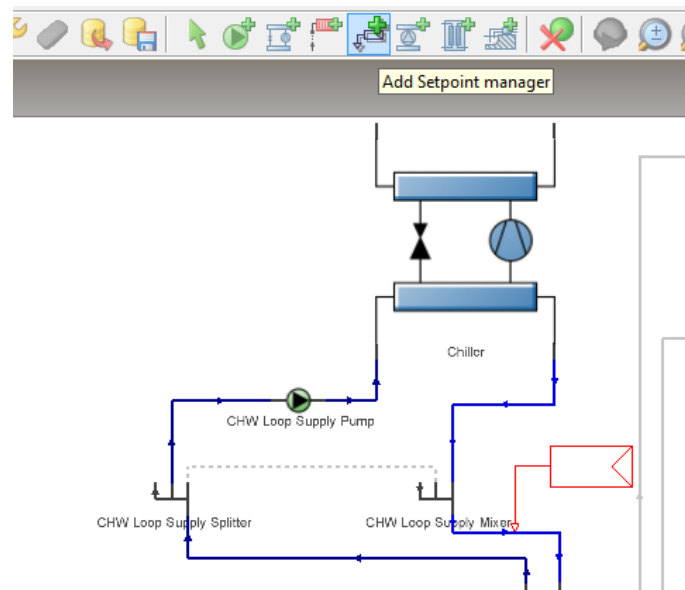


Figure 36 Add HVAC Component tool to help configure HVAC system manually

4.4.2 Variety of pre-configured HVAC systems including GSHP, VRF and Generic Unitary System

DesignBuilder Detailed HVAC template database contains a wide range of predefined HVAC systems (Figure 33) that are ready to be loaded into the model. In addition to common fan coil unit system and constant air or variable air systems, water-to-air and air-to-water heat pump systems are on the HVAC template list. Also, ground source heat pump (GSHP) systems and variable refrigerant flow (VRF) systems can be modeled in DesignBuilder, where the templates based on the typical use of these components are also pre-defined, which helps set up proposed HVAC systems quickly (Figure 37 and Figure 38 illustrate the layout of these two systems respectively as examples).

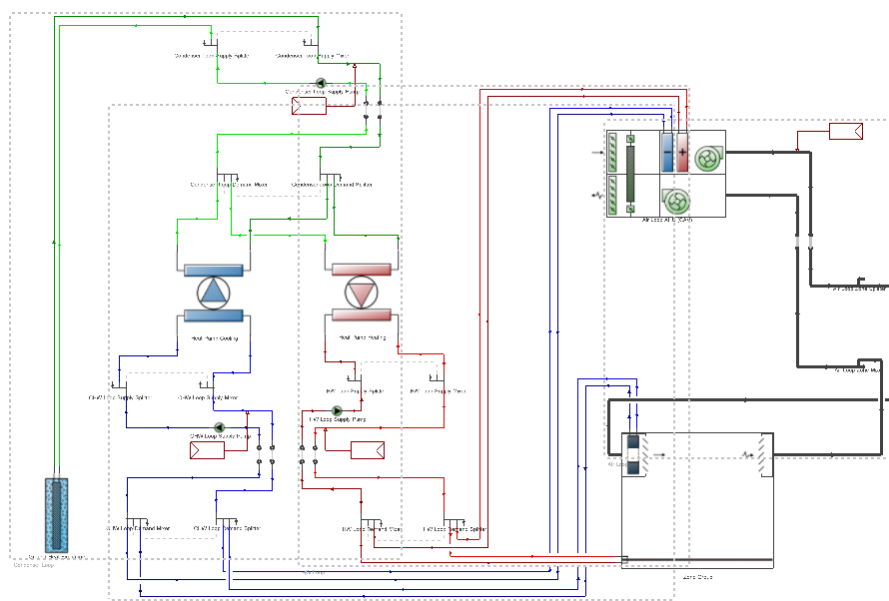


Figure 37 GSHP Water-to-water HP with heated floor and chilled beams

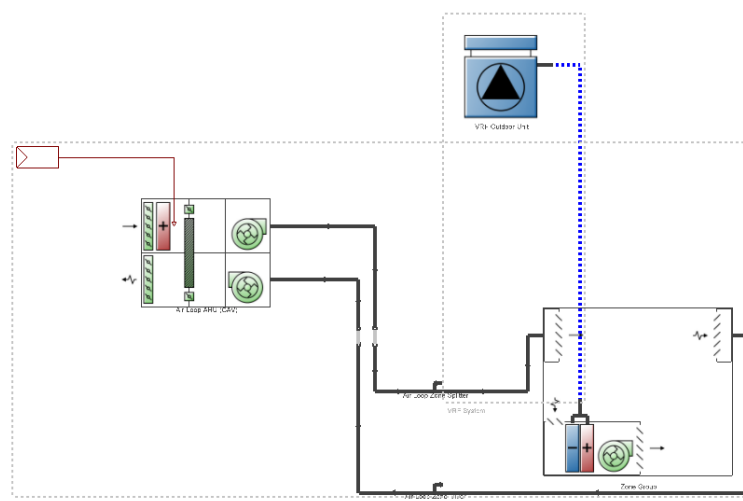


Figure 38 VRF with heat recovery and DOAS

Although a number of GSHP and VRF template data sets from different manufacturers are already incorporated into the GSHP and VRF database to speed up data entry, DesignBuilder also offers GSHP and VRF performance curve tools to help you generate performance curves for systems such as VRF and GSHP from manufacturer's catalogue data, where available.

If VRF is selected as part of the HVAC system for the proposed building, you need to use manufacturer performance data, if it is available, to derive the performance curves for the actual VRF unit (they are normally hard sized) rather than EnergyPlus example VRF model curves. In DesignBuilder version 7.3, you can also find a generic air loop unitary system (see Figure 39), which is a composite object that can accommodate all fan and coil types. It is ready to model ASHRAE 90.1 baseline system #11, which is designed to model the computer room HVAC system.

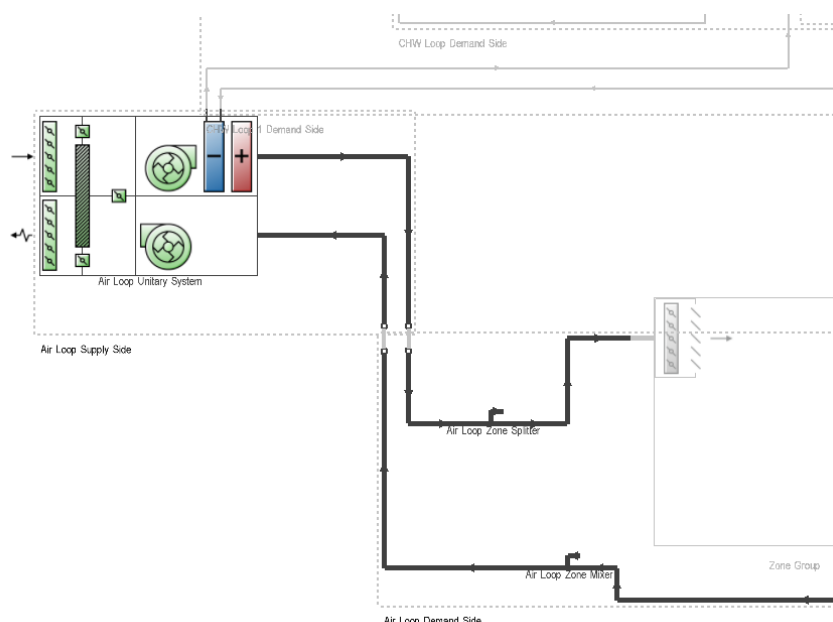


Figure 39 Generic Air Loop Unitary System

Since the proposed building is the modelling counterpart of the actual building that is to be certified, where the HVAC systems are already adopted or designated, the proposed model inputs should be consistent with the design documents. In addition to that, the modeler should apply 90.1 Standard mandatory provisions to the modeled HVAC systems and components.

4.4.3 Computer room System #11 for ASHRAE 90.1 2013 and 2016

Computer rooms in buildings with a total computer room peak cooling load >3,000,000Btu/h or a total computer room peak cooling load >600,000Btu/h where the baseline HVAC system type would otherwise be #7 or #8 should use System #11. All other computer rooms should use System #3 or #4.

System #11 is preconfigured in DesignBuilder as a Detailed HVAC template. As this is not included in the Baseline HVAC System Types defined in Table G3.1.1-3, you can load it to the model where the computer room meets one of the above room cooling load thresholds.

There are two different system types #11 differentiated by the heating source:

- System #11 Single Zone VAV Electric Heating
- System #11 Single Zone VAV Hot Water

When using one of these systems you will need to manually apply some specific configuration settings following requirements in G3.1.2.6.1 Computer Room Economizers, G3.1.3.9 Chilled-Water Supply Temperature Reset Exception 1, G3.1.3.10 Chilled-Water Pumps and G3.1.3.11 Heat Rejection.

5. Convert an Existing Model to App G PRM Model

It can sometimes be useful to use an existing model for LEED modelling and so DesignBuilder provides a mechanism to convert an existing model to ASHRAE 90.1 App G PRM format. The conversion process is as follows (Figure 40).

- (1) Navigate to site level.
- (2) Choose "Region" tab.
- (3) Click to select the "Mandatory energy code" item.
- (4) Choose the "ASHRAE 90.1-2007", "ASHRAE 90.1-2010", "ASHRAE 90.1-2013" or "ASHRAE 90.1-2016" energy code from the US category (alternatively, you can use browse mode to locate the right item and apply it; if this is a case, the step 5 below is omitted).
- (5) Click "Apply" button  or double click the selected energy code.

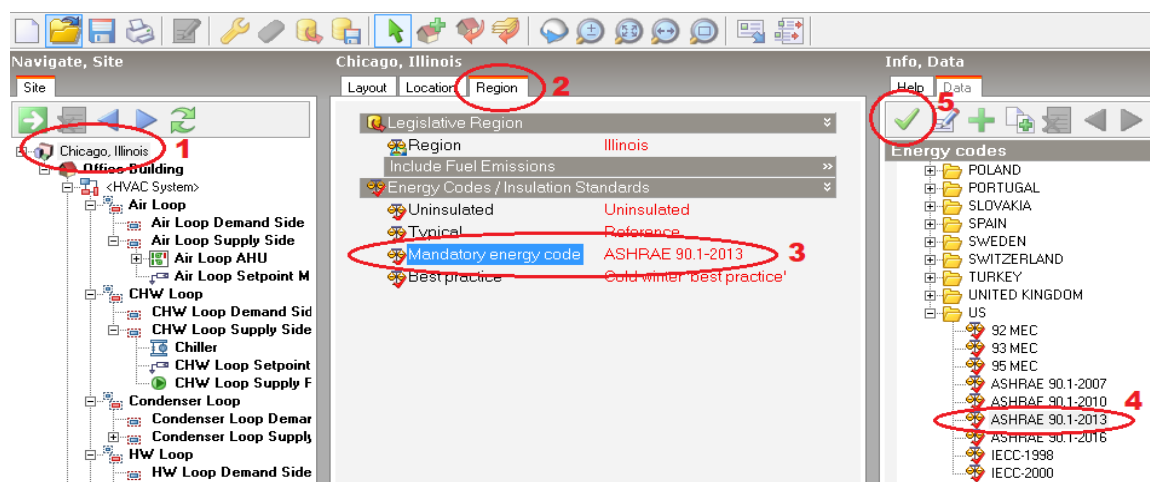


Figure 40 Convert an existing model to ASHRAE 90.1 model

Click "Yes" in response to the pop up message box (Figure 41) to confirm that you understand the impact of the conversion and are happy to continue, otherwise click "No" to keep the old energy code without converting.

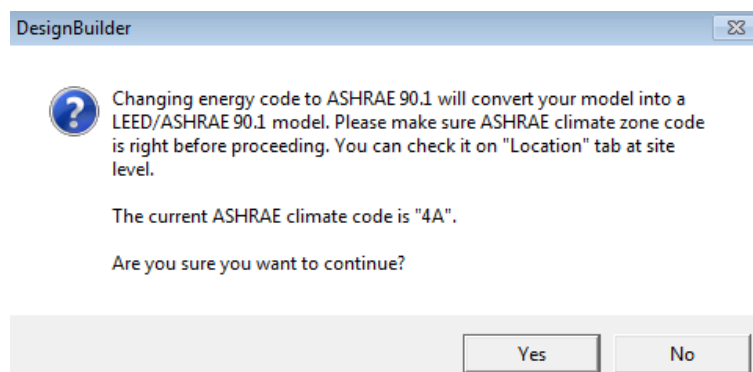


Figure 41 Prompt for confirmation of conversion

After the conversion the remaining steps of LEED modelling for the proposed building are the same as described in section 4. Create an ASHRAE 90.1 Project – Proposed Building above.

6. Create Baseline Building Model Using Wizards

Once the proposed building is complete, you are advised to use the built-in wizards to automatically generate the baseline building from the proposed building. DesignBuilder has two ASHRAE 90.1 baseline wizards to generate the baseline building model. The baseline building wizard deals with building fabric, geometry and other non-HVAC related data and the baseline HVAC wizard handles the baseline HVAC systems.

6.1 Create Baseline Building from Proposed Building using Baseline Building Wizard

This section demonstrates how to use DesignBuilder's ASHRAE 90.1 baseline building wizard step-by-step.

6.1.1 Access to the Wizard

When viewing the proposed building at building level the "Create Baseline Building" icon  is visible in the toolbar (Figure 42).

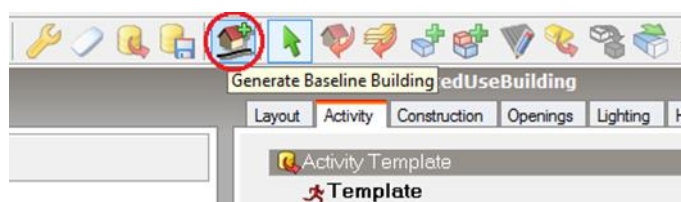


Figure 42 Baseline building wizard icon available at proposed building level

ASHRAE 90.1 covers buildings except low-rise residential buildings, e.g. dwellings with less than 4 floors. To ensure the modeled building fulfils ASHRAE 90.1 Standard definitions, DesignBuilder issues a warning message for low-rise residential buildings before the baseline building wizard runs (Figure 43). Normally, when this warning message is displayed, you should click "No" to close the message box and check the model and make any changes where appropriate. However, this is based on the number of floors estimated by the software. If it differs from the project designation due to the complexity of accurately defining floor numbers, you can click "Yes" to continue loading Baseline Building Wizard.

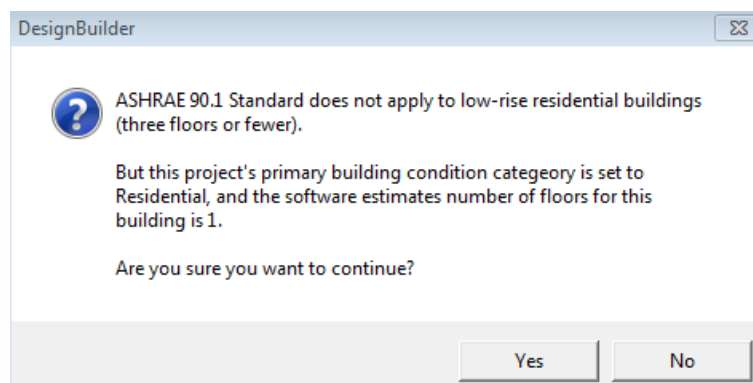


Figure 43 Exception of low-rise residential building

6.1.2 The Baseline Building Wizard

6.1.2.1 Run baseline building wizard

Clicking the “Create Baseline Building” icon opens the Baseline building wizard containing three pages of information gathered from the proposed building model (Figure 44). The summary data shown on the wizard is displayed to enable you to check the key details before creating the baseline.

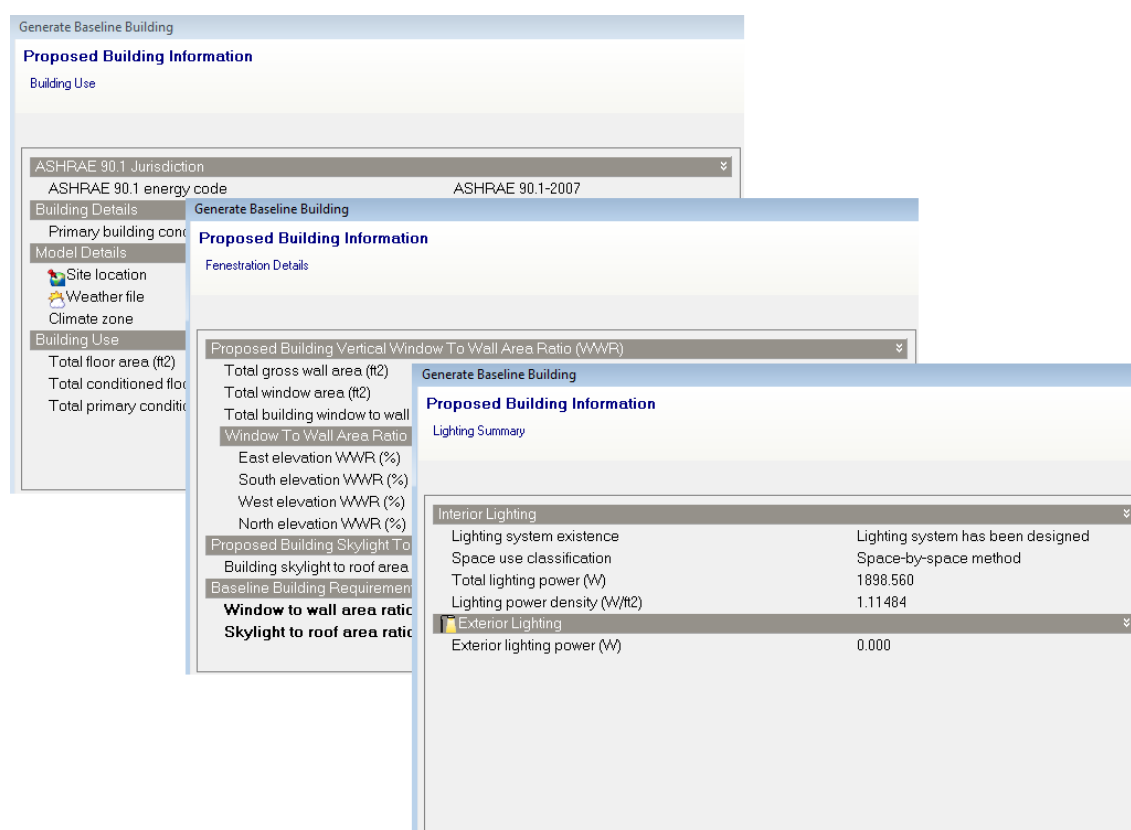


Figure 44 Baseline Building Wizard information displayed

The LEED submittal version is included on the Building Use summary page (see Figure 45 (a)). This data comes from the definition on Activity tab of the proposed building. ASHRAE 90.1 building area types are also summarised and displayed on the Fenestration Details page (Figure 45 (b)).

Generate Baseline Building

Proposed Building Information

Building Use

ASHRAE 90.1 Jurisdiction		«
ASHRAE 90.1 energy code	ASHRAE 90.1-2016	
Building Details		«
Primary building condition category	Non-residential	
Model Details		«
Site location	LONDON/GATWICK ARPT	
Weather file	GBR_LONDON_GATWICK_IWEC	
Climate zone	4A	
Building Use		«
Total floor area (m2)	254.850	
Total conditioned floor area (m2)	254.850	
Total primary conditioned floor area (m2)	254.850	
Alternative Baseline Building Generation		«
☐ Convert current proposed building to baseline		
ASHRAE 90.1-2016 LEED Version		«
LEED submittal version	LEED v4.1	

Cancel Help Back Next Finish

(a) Building use summary page

Generate Baseline Building

Proposed Building Information

Fenestration Details

Proposed Building Vertical Window To Wall Area Ratio (WWR)		«
Building Area Type and WWR		«
Office (5000 ft2 to 50000 ft2)	50.0%	
Retail (strip mall)	30.0%	
All other		«
Total other wall area (m2)	55.960	
Total other window area (m2)	13.990	
Total other WWR (%)	25.00	
Window To Wall Area Ratio (WWR) For Each Elevation		«
East elevation WWR (%)	37.50	
South elevation WWR (%)	50.00	
West elevation WWR (%)	40.00	
North elevation WWR (%)	27.50	
Proposed Building Skylight To Roof Area Ratio		«
Building skylight to roof area ratio (%)	0.00	
Baseline Building Requirements		«
Window to wall area ratio (%)	38.75	
Skylight to roof area ratio (%)	0.00	

Cancel Help Back Next Finish

(b) Fenestration details page

Figure 45 Baseline Building Wizard under ASHRAE 90.1-2016

If any of the summary information is incorrect you should cancel the wizard, edit the model and then re-run the wizard.

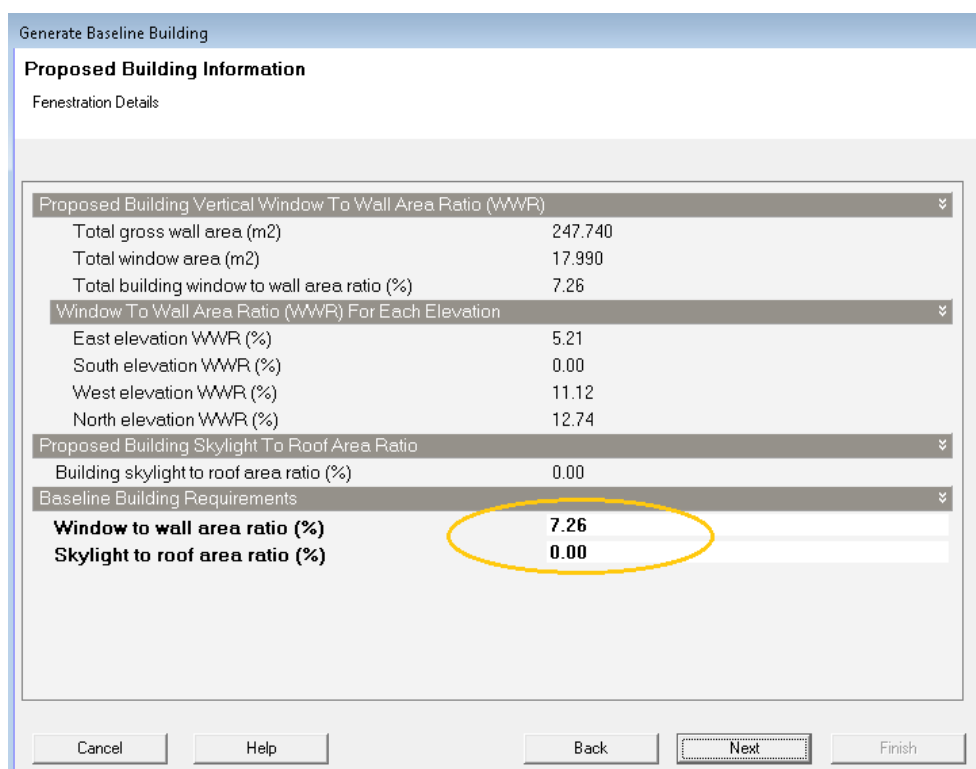
Of the information displayed on the wizard, perhaps the most important is the summary of the window to wall ratio and skylight to roof area ratio of the proposed building. This indicates the glazing ratios that will be used for the

baseline building in accordance with the criteria defined in Table G3.1 section 5 of ASHRAE 90.1 App G. The baseline building vertical fenestration and skylight window to surface ratios should follow the official rules:

- Vertical fenestration areas for new buildings and additions shall equal that in the proposed design or 40% of gross above-grade wall area, whichever is smaller, and shall be distributed on each face of the building in the same proportions as in the proposed design.
- Skylight area shall be equal to that in the proposed building design or 5% of the gross roof area that is part of the building envelope, whichever is smaller. If the skylight area of the proposed building design is greater than 5% of the gross roof area, baseline skylight area shall be decreased by an identical percentage in all roof components in which skylights are located to reach the 5% skylight-to-roof ratio. Skylight orientation and tilt shall be the same as in the proposed building design.
- If ASHRAE 90.1 building area types are used in the model (for ASHRAE 90.1 2013 and 2016 only), the WWR will follow the definition in section 4.3.2.5 ASHRAE 90.1 building area type.

6.1.2.2 Override input for window to wall area ratio and skylight to roof area ratio

In order to provide some flexibility for the input of window to wall ratio (WWR) or skylight to roof area ratio (SRR), for example to meet Canadian NECB project requirements, it is possible to hard-set the WWR or SRR in the LEED v4.0 Baseline Building wizard (Figure 46). **If you are intending to make such a change you must ensure that it is justified and you understand the consequences before doing so.**



Proposed Building Vertical Window To Wall Area Ratio (WWR)	
Total gross wall area (m2)	247.740
Total window area (m2)	17.990
Total building window to wall area ratio (%)	7.26

Window To Wall Area Ratio (WWR) For Each Elevation	
East elevation WWR (%)	5.21
South elevation WWR (%)	0.00
West elevation WWR (%)	11.12
North elevation WWR (%)	12.74

Proposed Building Skylight To Roof Area Ratio	
Building skylight to roof area ratio (%)	0.00

Baseline Building Requirements	
Window to wall area ratio (%)	7.26
Skylight to roof area ratio (%)	0.00

Figure 46 Window to wall area ratio and skylight to roof area ratio are allowed to change

If all data on the wizard is correct, click the “Finish” button (on final page) and the software will generate a baseline building so that both buildings are displayed in the model side by side (Figure 47).

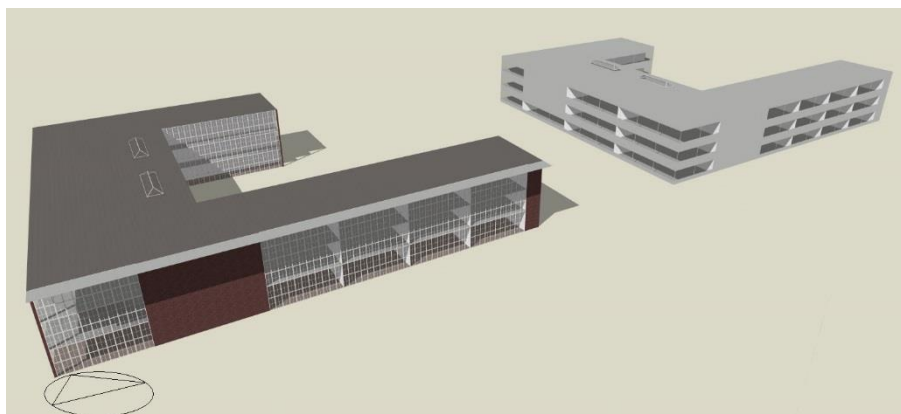
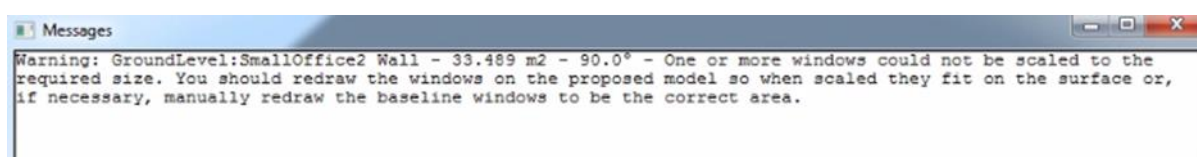


Figure 47 Baseline building generated from wizard sits with proposed building side by side

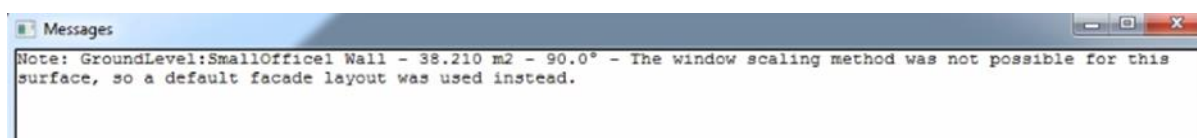
6.1.2.3 Baseline building vertical fenestration on building area types

For ASHRAE 90.1 2016, following WWR requirements defined in Table G3.1.1-1, in the generated baseline building the window sizes may need to be increased and/or new windows may need to be created for wall surfaces that do not contain a window in the original proposed building. However, in such cases, it is not always possible for the required windows to be created, usually due to obstructions from other objects on the same wall surface. The various cases and their corresponding solutions are summarized below with the associated warning and note messages.

- When windows on a surface cannot be scaled up to the required size due to an obstruction, such as a door or a vent, a warning is issued that says “One or more windows could not be scaled to the required size. You should redraw the windows on the proposed model so when scaled they fit on the surface or, if necessary, manually redraw the baseline windows to be the correct area”. DesignBuilder does not apply window scaling up or apply default facade method in this case, so the baseline surface layout stays the same as in the proposed building.



- When windows on a surface that contains no other opening types cannot be scaled up to the required size as they would need to overlap an edge, a note is issued to indicate the default facade method has been applied to this surface to generate appropriately sized windows.



- In the case of Zone 1 shown in Figure 48, only one wall contains windows, so when applying window scaling following the ASHRAE 90.1 WWR rules mentioned above, this wall would need the WWR to exceed 100% which of course is not possible.

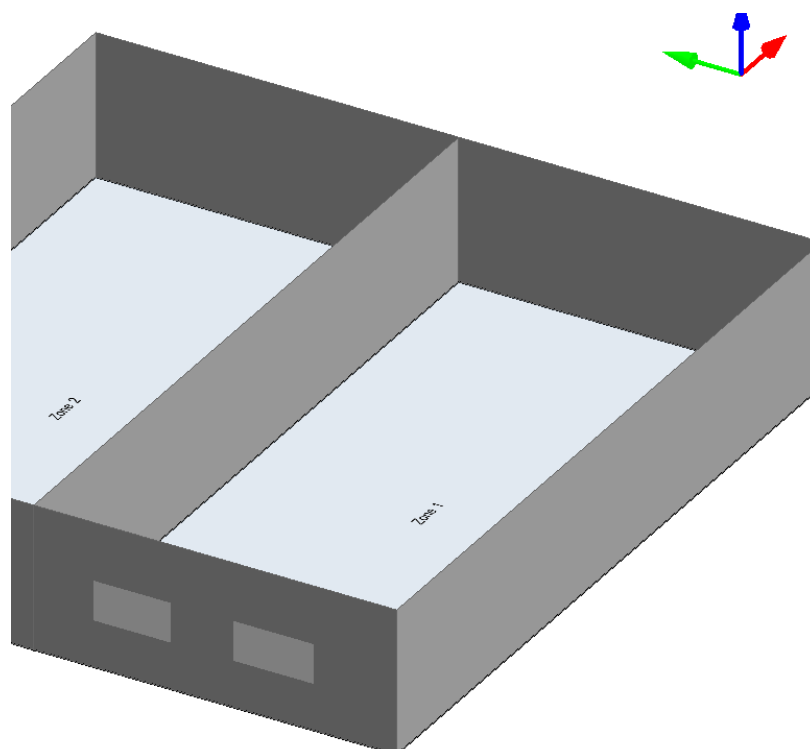
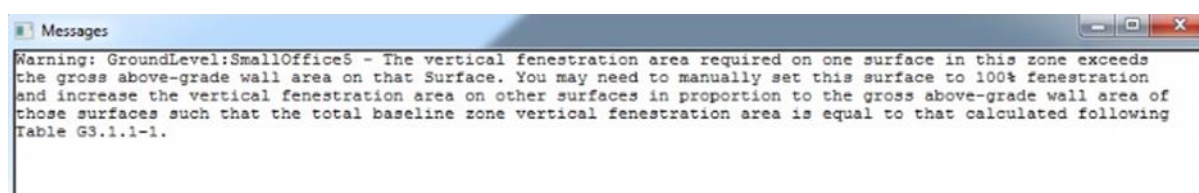


Figure 48 A zone with just one exterior wall containing windows

In this case, DesignBuilder displays a message that says “The vertical fenestration area required on one surface in this zone exceeds the gross above-grade wall area on that Surface. You may need to manually set this surface to 100% fenestration and increase the vertical fenestration area on other surfaces in proportion to the gross above-grade wall area of those surfaces such that the total baseline zone vertical fenestration area is equal to that calculated following Table G3.1.1-1”.



This requires you to manually increase the windows to occupy the whole surface of this wall and distribute the remaining opening area in an equal percentage across the other remaining walls, even if they did not have windows originally. This requirement will appear in ASHRAE 90.1 Standard 2022 version.

6.1.3 Checking the baseline building model

After the baseline building has been created, the data on the “Activity”, “Construction”, “Openings” and “Lighting” tabs should be checked to ensure that the automatic assignment has been carried out correctly, and any manual changes should be made as required. The appearance of the baseline building should also be checked in the Layout window.

Depending on the proposed building details, various changes in the baseline building relative to the proposed building will generally be seen:

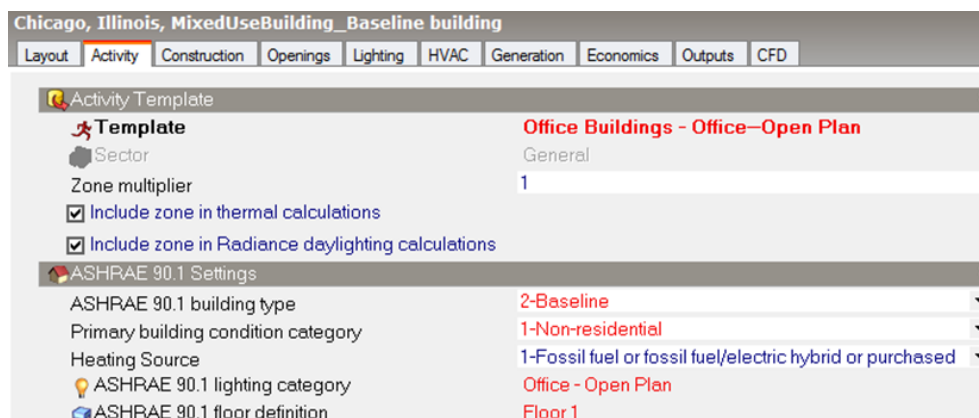
- Constructions/glazing will be assigned constructions with names starting CZ# (# denotes the climate zone number) in the construction's title/name.

- Lighting settings, especially LPD, will be set based on the proposed building's "ASHRAE 90.1 Lighting category" input on the Activity tab.
- The Window to wall ratio (WWR) will be either the ratio from the proposed building, or 40%, whichever is the smallest. For models that use ASHRAE 90.1 2013 or 2016, the WWR needs to be checked against the appropriate value for the building area type, if selected (i.e. if the "Other" building area type has not been selected for the zone).
- The skylight-to-roof area ratio will be either the ratio from the proposed building or 5%, whichever is the smallest.
- Window local shadings are removed.
- Standard component blocks with Level set to "1-Building" are removed.

Note: If significant changes need to be made to the proposed building after the baseline building has been created, it usually best to delete the baseline building, edit the proposed building and re-run the baseline generation wizard.

6.1.3.1 Activity and ASHRAE 90.1 settings

The Baseline Building "ASHRAE 90.1 building type" is shown as "2-Baseline" in the Activity tab at building level as shown in Figure 49, where differences between 2007/2010 and 2013/2016 versions can be seen.



Chicago, Illinois, MixedUseBuilding_Baseline building

Layout Activity Construction Openings Lighting HVAC Generation Economics Outputs CFD

Activity Template

Template Office Buildings - Office-Open Plan

Sector General

Zone multiplier 1

☒ Include zone in thermal calculations

☒ Include zone in Radiance daylighting calculations

ASHRAE 90.1 Settings

ASHRAE 90.1 building type 2-Baseline

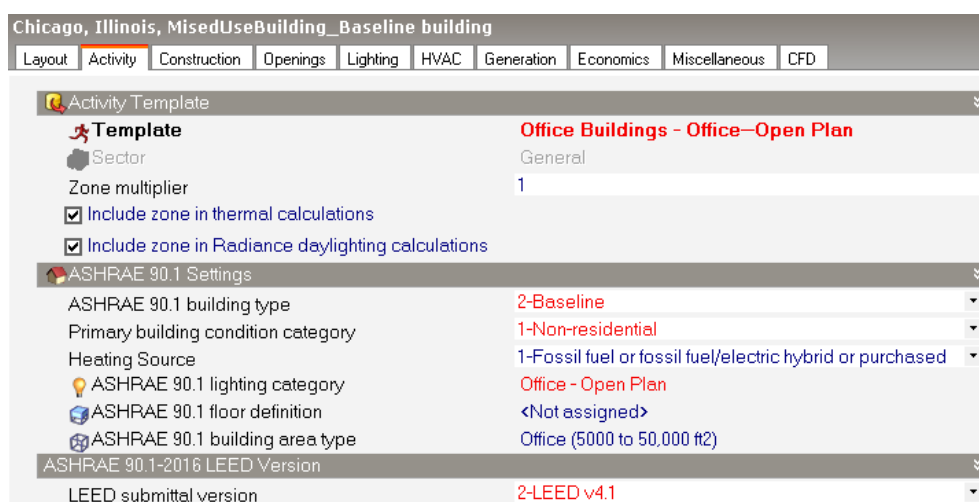
Primary building condition category 1-Non-residential

Heating Source 1-Fossil fuel or fossil fuel/electric hybrid or purchased

ASHRAE 90.1 lighting category Office - Open Plan

ASHRAE 90.1 floor definition Floor 1

(a) ASHRAE 90.1 2007 or 2010



Chicago, Illinois, MixedUseBuilding_Baseline building

Layout Activity Construction Openings Lighting HVAC Generation Economics Miscellaneous CFD

Activity Template

Template Office Buildings - Office-Open Plan

Sector General

Zone multiplier 1

☒ Include zone in thermal calculations

☒ Include zone in Radiance daylighting calculations

ASHRAE 90.1 Settings

ASHRAE 90.1 building type 2-Baseline

Primary building condition category 1-Non-residential

Heating Source 1-Fossil fuel or fossil fuel/electric hybrid or purchased

ASHRAE 90.1 lighting category Office - Open Plan

ASHRAE 90.1 floor definition <Not assigned>

ASHRAE 90.1 building area type Office (5000 to 50,000 ft2)

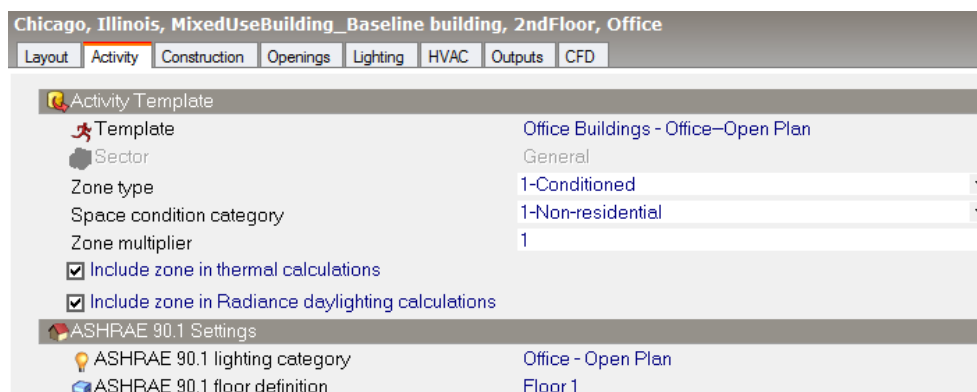
ASHRAE 90.1-2016 LEED Version

LEED submittal version 2-LEED v4.1

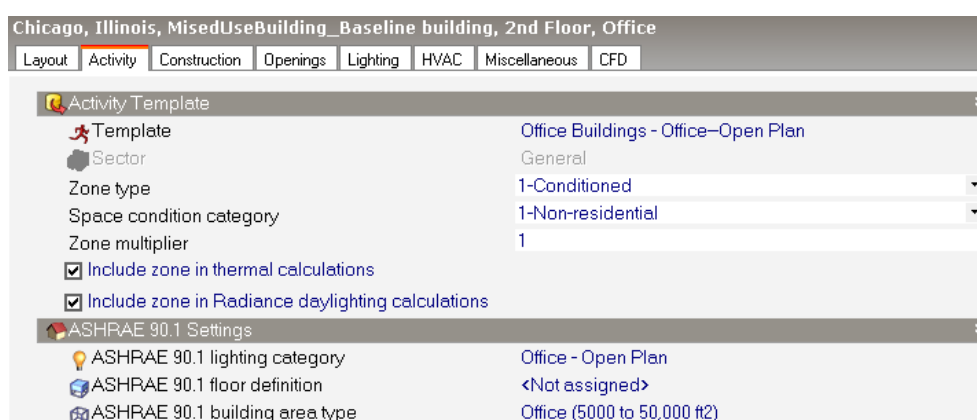
(b) ASHRAE 90.1 2013 or 2016

Figure 49 ASHRAE 90.1 settings on activity tab at building level of baseline building

At zone level of the baseline building (Figure 50 below) the data shown is similar to that of the proposed building (Figure 12).



(a) ASHRAE 90.1 2007 or 2010



(b) ASHRAE 90.1 2013 or 2016

Figure 50 Activity tab at zone level of baseline building

6.1.3.2 Opaque constructions

The Construction tab shows that the relevant baseline constructions following ASHRAE 90.1 Table G3.1-5 and Tables 5.5-1 through 5.5-8 have been applied in the model (Figure 51).

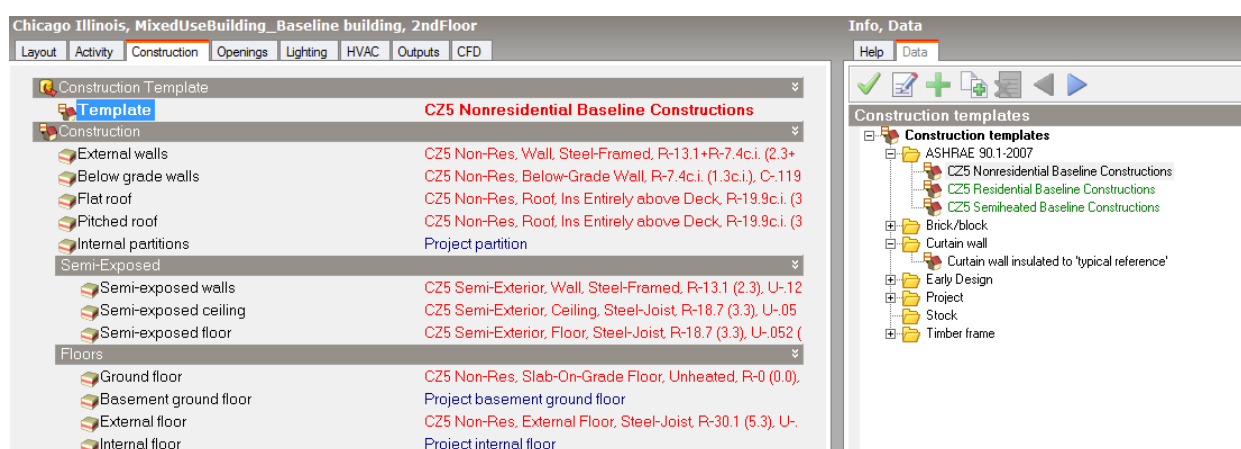


Figure 51 Opaque constructions

If the LEED submittal version is "2-LEED v4.1", i.e. the ASHRAE 90.1 – 2016 energy code is applied, the auto-assigned constructions will come from the ASHRAE 90.1 Standard 2016 Appendix G Table G3.4 (Figure 52).

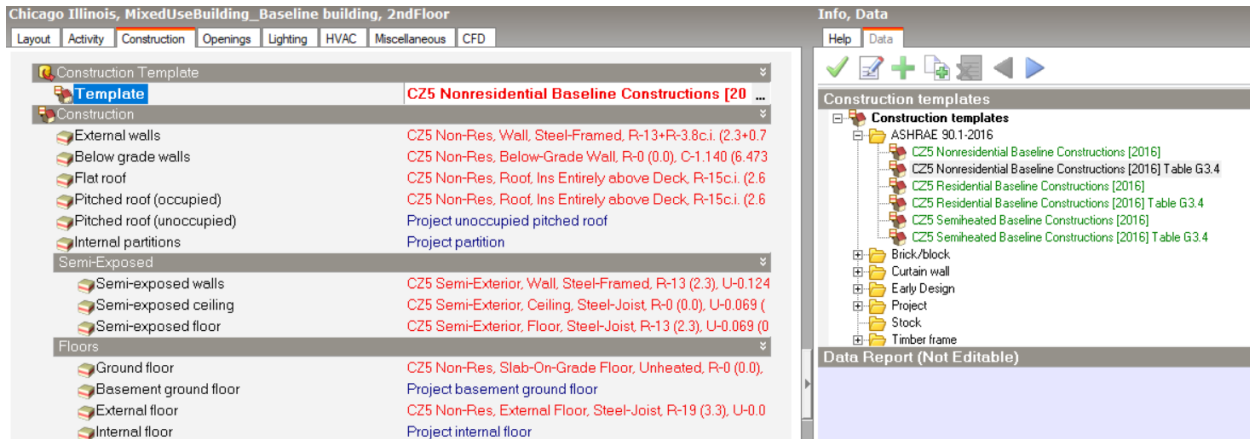


Figure 52 Baseline constructions consistent to ASHRAE 90.1 2016 Appendix G Table G3.4

Note: Constructions such as internal partitions that are not covered by ASHRAE 90.1 are modeled as per the proposed building.

ASHRAE 90.1 defines slab-on-grade floor, which needs to use F-factor construction, as the portion of a slab floor of the building envelope that is in contact with the ground and that is either above grade or is slightly below the grade (less than or equal to 24 inch, or 600 mm, below the final elevation of the nearest exterior grade). The F-factor represents the heat transfer through the floor, induced by a unit temperature difference between the outside and inside air temperature per linear length of the exposed perimeter of the floor. **F-Factor constructions should only be selected for Ground adjacent surfaces with exposed perimeter greater than zero.**

Basement ground floors were introduced into DesignBuilder for ASHRAE 90.1 models only to distinguish floors from slab-on-grade floors. They are normally outside the scope of slab-on-grade floor definition described in ASHRAE 90.1 and are not regulated by the 90.1 Standard. The baseline model takes the same construction for basement ground floors as that used in the proposed model, where a standard layered floor construction is normally used.

During the IDF generation process, if a ground floor surface is assigned an F-Factor ground floor construction, but its exposed perimeter is calculated as zero, the software will use the currently selected Basement ground floor construction instead. Furthermore, in this case, if the Basement ground floor has an F-Factor construction selected, a message is displayed advising the use of a layered ground floor construction instead of F-Factor construction (Figure 53).

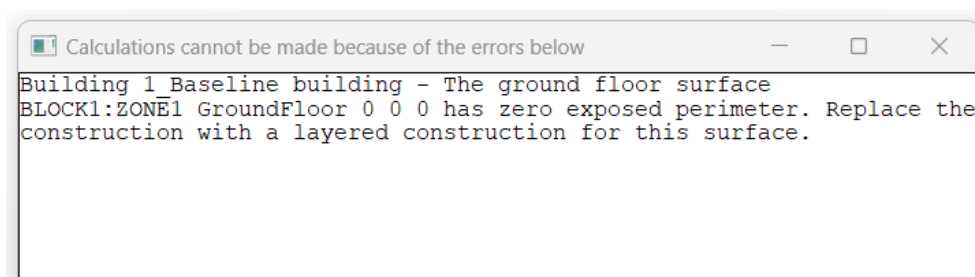


Figure 53 DesignBuilder error message when an F-Factor ground floor has zero exposed perimeter

6.1.3.3 Glazing constructions

The baseline glazing constructions are shown on the Openings tab (following ASHRAE 90.1 Table G3.1-5 and Tables 5.5-1 through 5.5-8 for 2007 and 2010 versions) (Figure 54).

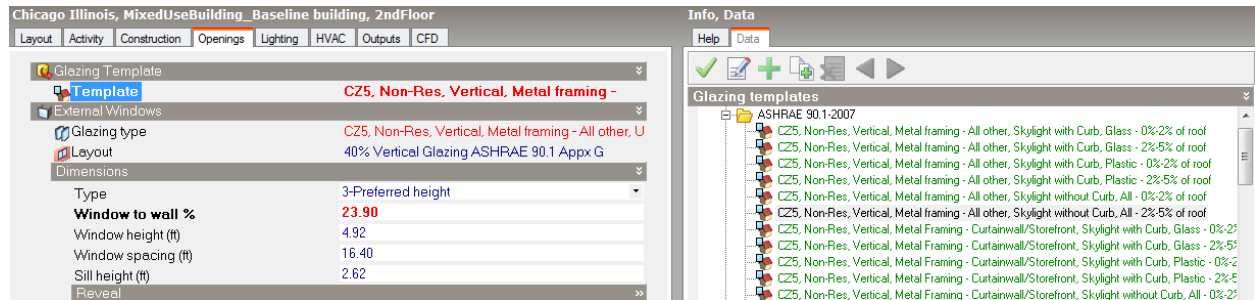


Figure 54 Glazing constructions

As for opaque constructions, if the LEED submittal version is “2-LEED v4.1”, i.e. ASHRAE 90.1 – 2016 energy code is applied, the auto-assigned glazing constructions will come from ASHRAE 90.1 Standard 2016 Appendix G Table G3.4 (Figure 55).

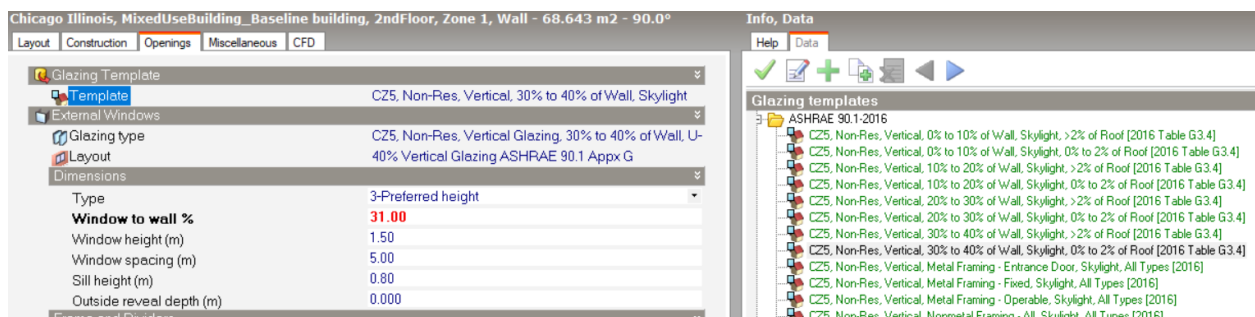


Figure 55 Baseline glazing consistent to ASHRAE 90.1 2016 Appendix G Table G3.4

For the projects located in climate zone 3, ASHRAE 90.1 2016 distinguishes baseline glazing for climate zone suffix A, B and C separately (Figure 56 and Figure 57).

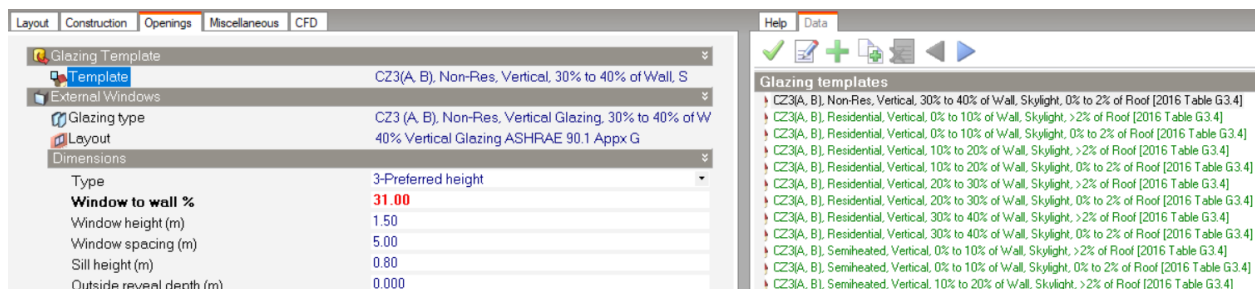


Figure 56 Climate Zone 3 A and B baseline glazing for ASHRAE 90.1 2016

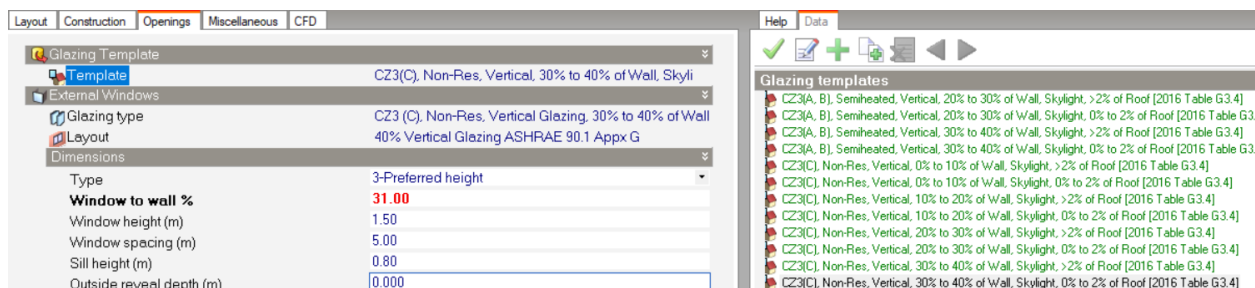


Figure 57 Climate Zone 3 C baseline glazing for ASHRAE 90.1 2016

6.1.3.4 Lighting

The baseline lighting power density is set on the Lighting tab based on the “ASHRAE 90.1 lighting category” selected on the “Activity” tab (an example of 2010 version template is shown in Figure 58).

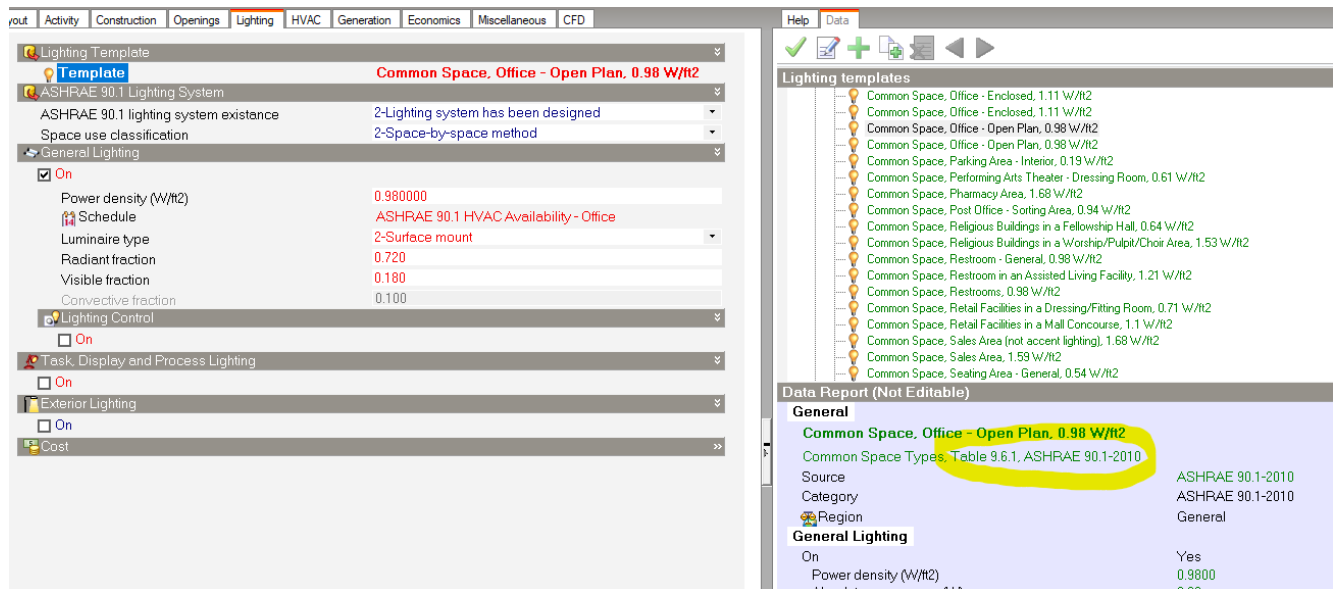


Figure 58 Lighting template and lighting power density (LPD) for 2010 version

However, for ASHRAE 90.1 2016 version, the auto-assigned lighting template is from Appendix Table G3.7 (Figure 59).

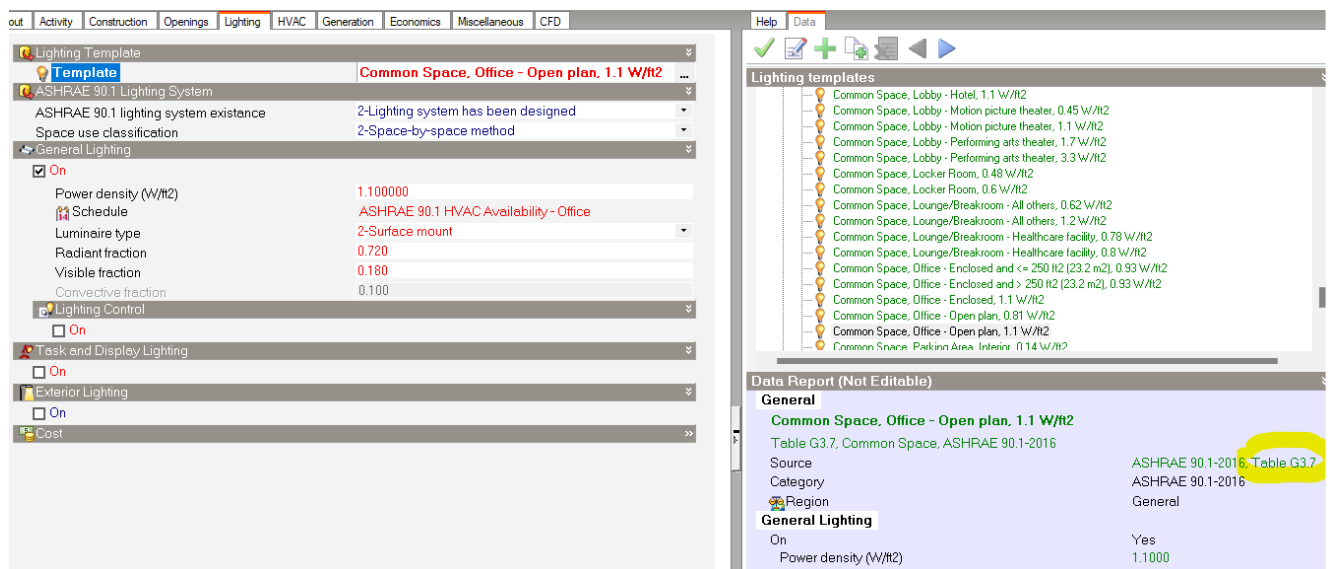


Figure 59 Lighting template and lighting power density (LPD) for 2016 version

6.1.3.5 Utility rates (tariffs)

The utility rates (tariffs) remain the same as those of the proposed building.

6.2 Set up baseline HVAC systems using baseline HVAC wizard

The Baseline HVAC system type is based on building use (residential or non-residential), number of floors, heating source etc. Eight different baseline HVAC systems (systems #1 through #8) can be chosen for ASHRAE 90.1 2007, with 2 more (#9 and #10) to choose from in the 2010 version, and a further three more (#11, #12 and #13)

are available for the 2013 and 2016 versions. For mixed-use buildings, additional information must be provided to define non-predominant systems based on the conditioned floor area.

DesignBuilder includes templates for all baseline HVAC systems, and the Baseline HVAC wizard helps you choose the appropriate HVAC template for primary conditioned zones. However, for non-predominant zones, you should select and add the system manually.

6.2.1 Run the Baseline HVAC wizard

The Baseline HVAC wizard opens automatically when navigating to the <HVAC System> node under the baseline building in the navigation panel for the first time. Otherwise, you can select the “Load HVAC template” toolbar icon if the wizard is not automatically displayed or you want to re-run the wizard (Figure 60).

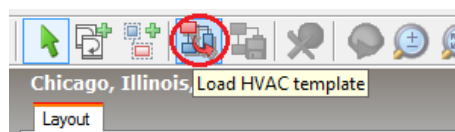


Figure 60 Baseline HVAC wizard is using Load HVAC template icon

6.2.1.1 General procedure

The wizard starts by summarizing the data that will be used to guide the HVAC system selection (see Figure 61 below).

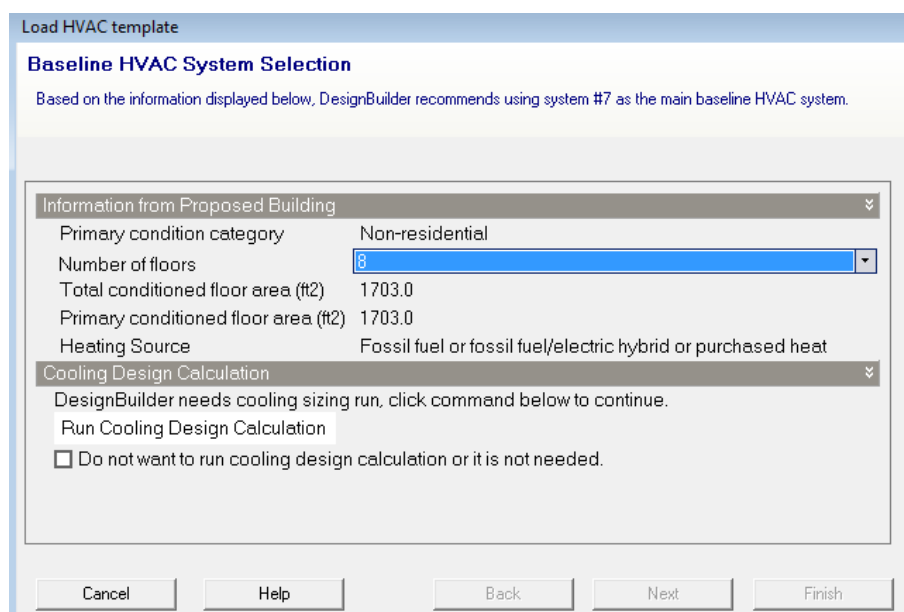


Figure 61 Baseline wizard has been called

At the top of the wizard, DesignBuilder recommends an HVAC system for use in the baseline building model. The recommendation is based on the information shown on this page. If system #7 or #8 is recommended, the wizard will show a cooling design calculation section if the cooling design calculation has not been run prior to calling the baseline HVAC wizard. The total peak cooling load results from the cooling design calculation will define how many chillers are needed for system #7 or #8 according to ASHRAE 90.1 2010 Appendix G Table G3.1.3.7. The Next button is greyed out so that you cannot continue until the cooling design calculation has been run.

If neither system #7 or #8 is recommended by DesignBuilder, or system #7 or #8 is recommended but the cooling design calculation has been run already, the cooling design calculation section will not show on HVAC wizard page (Figure 62).

Load HVAC template

Baseline HVAC System Selection

Based on the information displayed below, DesignBuilder recommends using system #7 as the main baseline HVAC system.

Information from Proposed Building	
Primary condition category	Non-residential
Number of floors	8
Total conditioned floor area (ft ²)	1703.0
Primary conditioned floor area (ft ²)	1703.0
Heating Source	Fossil fuel or fossil fuel/electric hybrid or purchased heat

Figure 62 Next button is enabled after cooling design calculation run

The number of floors shown on the page is an estimated figure based on the calculation using total building height dividing by a calculated average floor height from modeled building. This field is editable so you can change it to a number that matches the building design specifications of the project. Be aware that changes to this value will sometimes result in a change of HVAC system type.

The recommended HVAC system will preload and be previewed on the second wizard page (Figure 63). You can change the baseline HVAC system manually here should you need to.

HVAC Template Selection

DesignBuilder recommends using system #7 as main baseline HVAC system.
You can override this setting by choosing another system or press Cancel to create one from scratch.

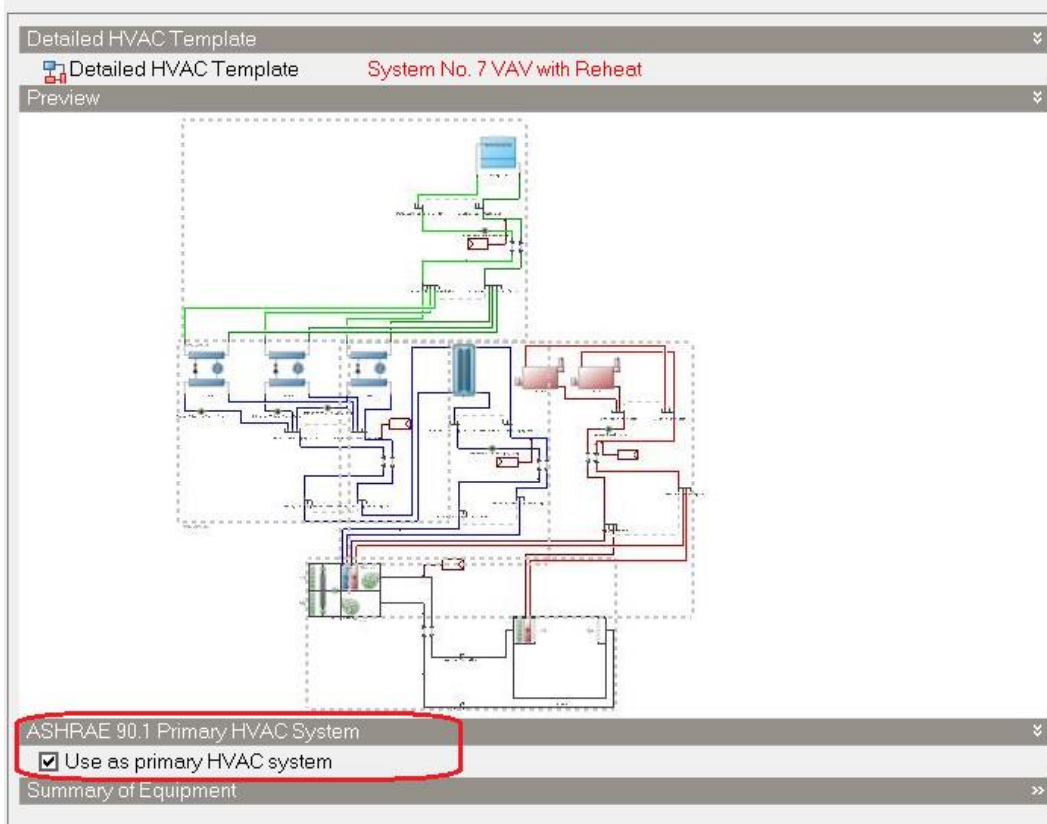


Figure 63 Second page of the wizard shows the system name and layout

The “Use as primary HVAC system” option on the baseline HVAC wizard is useful in helping process data for the DesignBuilder LEED MEPC reporting tool if you plan to use this tool after the simulations. The MEPC tool is described in a separate user guide which can be assessed online from a link in Section 8.3 Data reporting tool. After running the Baseline HVAC wizard, this primary HVAC system selection is stored and displayed on HVAC tab at building level (Figure 64).

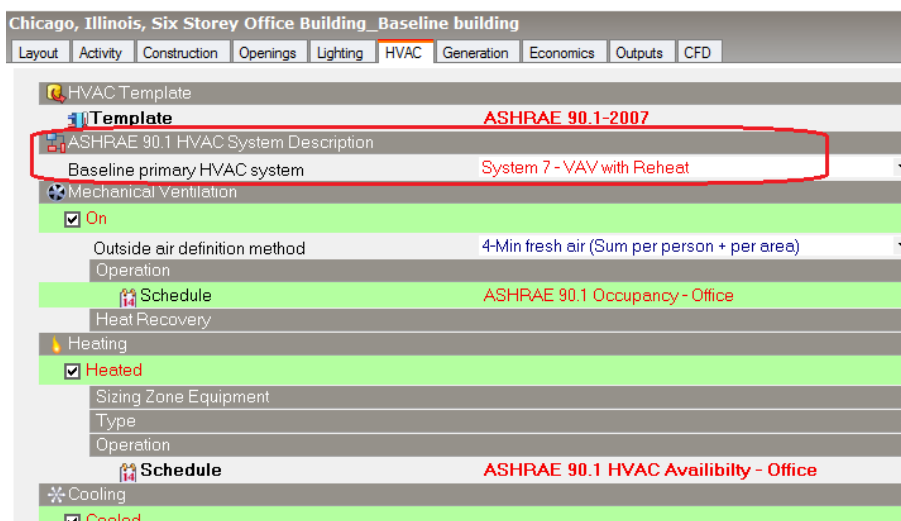


Figure 64 Building level HVAC tab stores Baseline primary HVAC system information

Once the baseline HVAC system is selected, you must assign zones to be served by the HVAC system and click the Finish button to complete the wizard (Figure 65). The selected zones will be grouped and assigned to an HVAC zone group or to multiple zone groups, depending on which HVAC system is finally chosen.

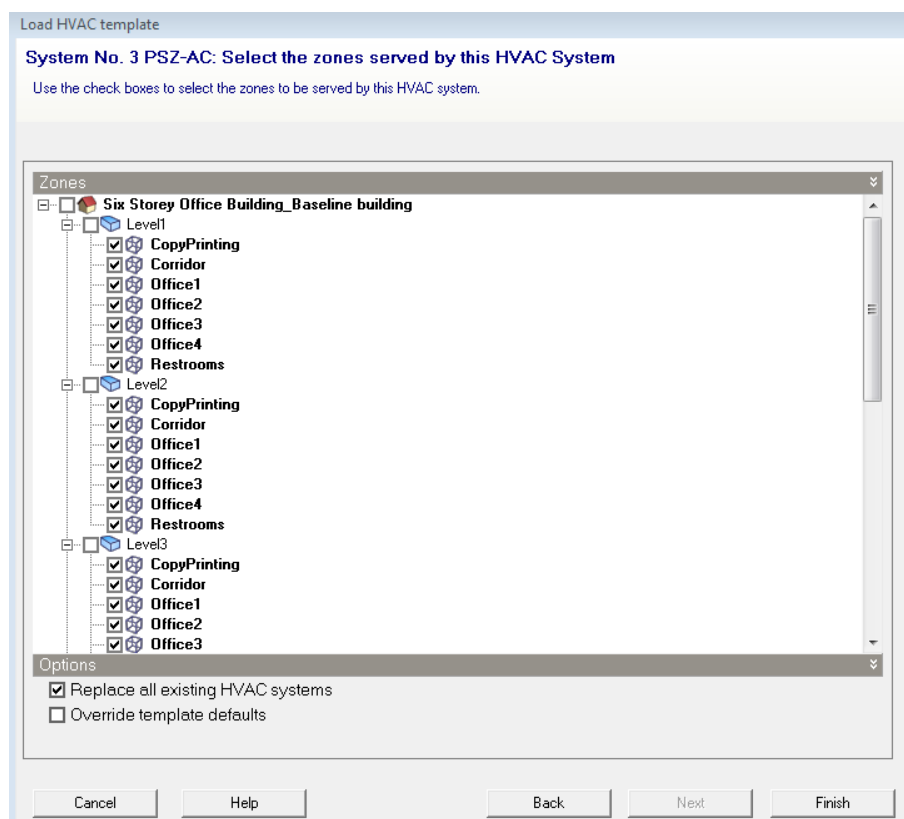


Figure 65 Zones selected for HVAC zone groups

Click the Finish button to close the wizard and load the HVAC system to the layout screen. The behavior of the “Load HVAC Template” wizard depends on the baseline HVAC system selected, as described below.

6.2.1.2 Baseline HVAC system selection

Prior to ASHRAE 90.1 2013, the primary baseline HVAC system is decided by the building type and its application together with the fuel type used in the project, i.e. either ‘Fossil fuel, Fossil/Electric Hybrid, and Purchased Heat’ or ‘Electric and Other’ (Figure 66).

TABLE G3.1.1A Baseline HVAC System Types

Building Type	Fossil Fuel, Fossil/Electric Hybrid, and Purchased Heat	Electric and Other
Residential	System 1—PTAC	System 2—PTHP
Nonresidential and 3 Floors or Less and <25,000 ft ²	System 3—PSZ-AC	System 4—PSZ-HP
Nonresidential and 4 or 5 Floors and <25,000 ft ² or 5 Floors or Less and 25,000 ft ² to 150,000 ft ²	System 5—Packaged VAV with Reheat	System 6—Packaged VAV with PFP Boxes
Nonresidential and More than 5 Floors or >150,000 ft ²	System 7—VAV with Reheat	System 8—VAV with PFP Boxes
Heated Only Storage	System 9—Heating and Ventilation	System 10—Heating and Ventilation

Figure 66 ASHRAE 90.1 2010 baseline HVAC system types are decided by building type and fuel type

From ASHRAE 90.1 2013, the primary baseline HVAC system is decided by the building type and its application together with the climate zone where the project is located. The details are shown in Figure 67 below (ASHRAE

90.1 2016 as an example, where climate zone 0 is included). Note that there were some mistakes in Table G3.1.1.-3, “Other residential” should be “Other non-residential”.

Table G3.1.1-3 Baseline HVAC System Types

<i>Building Type, Number of Floors, and Gross Conditioned Floor Area</i>	<i>Climate Zones 3B, 3C, and 4 to 8</i>	<i>Climate Zones 0 to 3A</i>
<i>Residential</i>	<i>System 1—PTAC</i>	<i>System 2—PTHP</i>
Public assembly <120,000 ft ²	System 3—PSZ-AC	System 4—PSZ-HP
Public assembly ≥120,000 ft ²	System 12—SZ-CV-HW	System 13—SZ-CV-ER
Heated-only storage	System 9—Heating and ventilation	System 10—Heating and ventilation
Retail and 2 floors or fewer	System 3—PSZ-AC	System 4—PSZ-HP
Other residential and 3 floors or fewer and <25,000 ft ²	System 3—PSZ-AC	System 4—PSZ-HP
Other residential and 4 or 5 floors and <25,000 ft ² or 5 floors or fewer and 25,000 ft ² to 150,000 ft ²	System 5—Packaged VAV with reheat	System 6—Packaged VAV with PFP boxes
Other residential and more than 5 floors or >150,000 ft ²	System 7—VAV with reheat	System 8—VAV with PFP boxes

Figure 67 ASHRAE 90.1 2016 baseline HVAC system types are decided by building type and climate zone

6.2.1.3 Systems #3 and #4 - single zone systems

The Baseline HVAC Wizard applies a special process when systems #3 or #4 are selected as they are single-zone systems, i.e., each HVAC zone is assigned the same independent HVAC system. The Baseline HVAC Wizard automatically sets this arrangement up as shown below.

When system #3 has been selected as the baseline HVAC system, the example screenshot below shows four zones selected to be served by this system on the zones page (Figure 68).

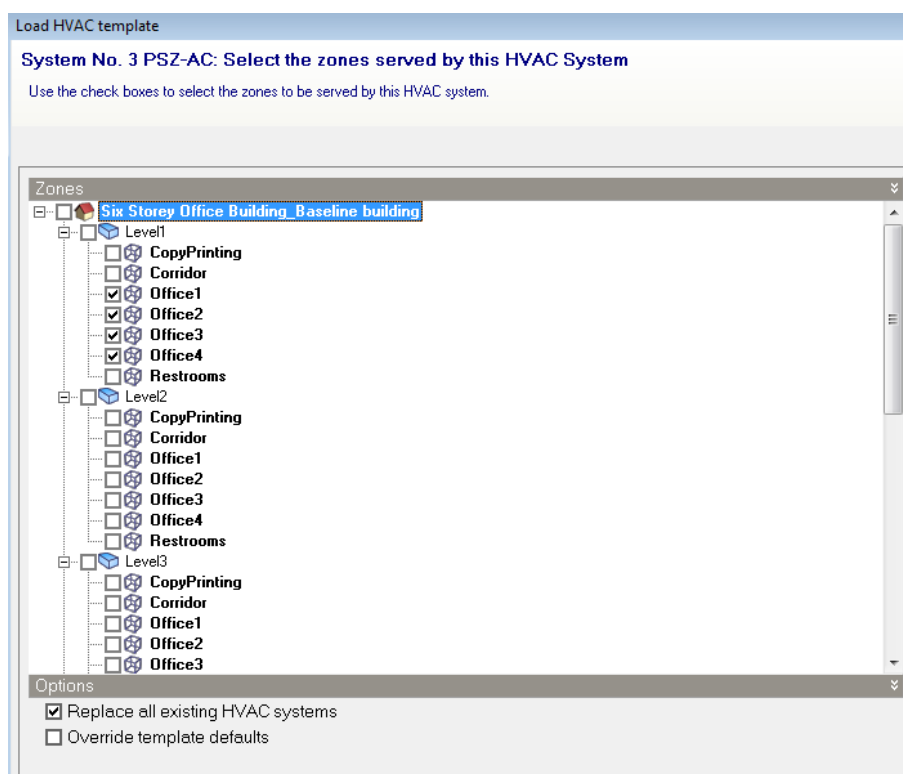


Figure 68 Four zones served by single zone system #3

After running the wizard, the layout window shows four separate HVAC system for 4 zone groups with each containing a single zone (Figure 69).

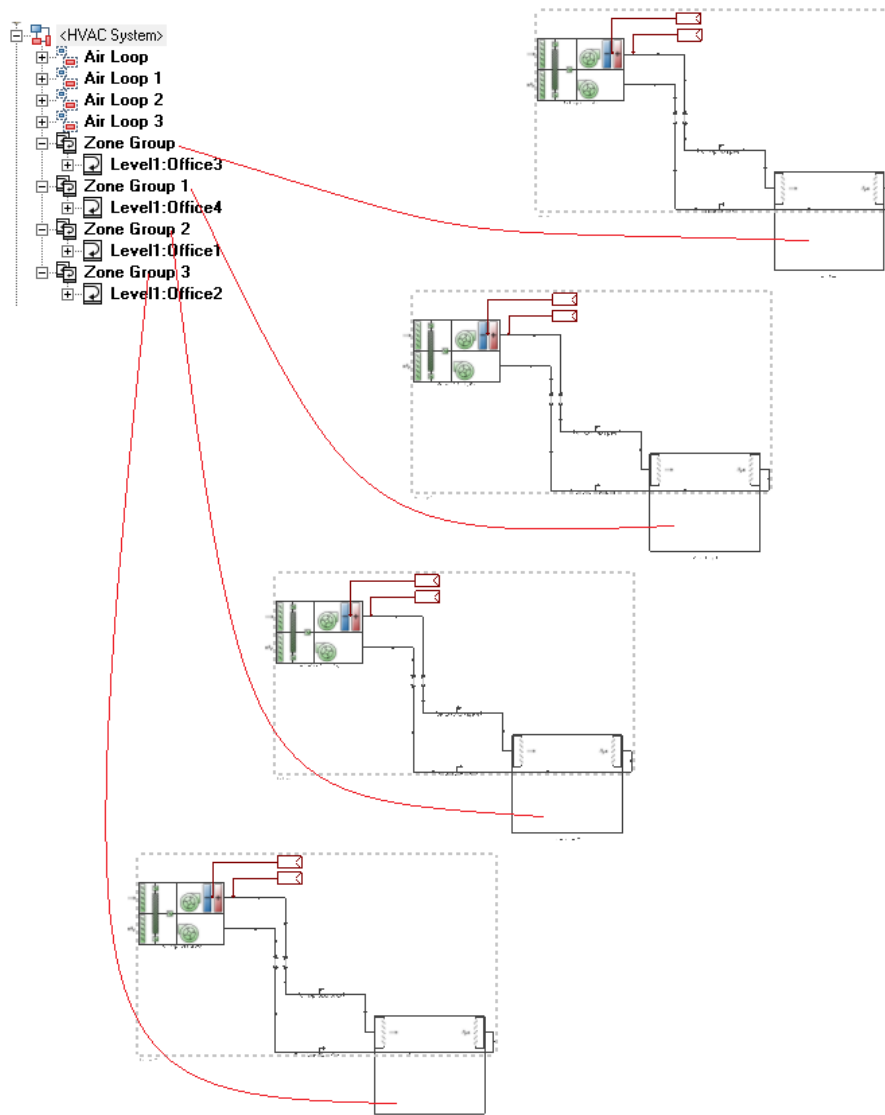


Figure 69 Layout of a single zone HVAC system

6.2.1.4 Systems #5 – #8 – each floor to have a separate HVAC system

If one of the systems #5 to #8 is selected, there is an additional option to select how floors are to be defined. This instructs the wizard to generate zone groups from selected zones based on the option selected (Figure 70).

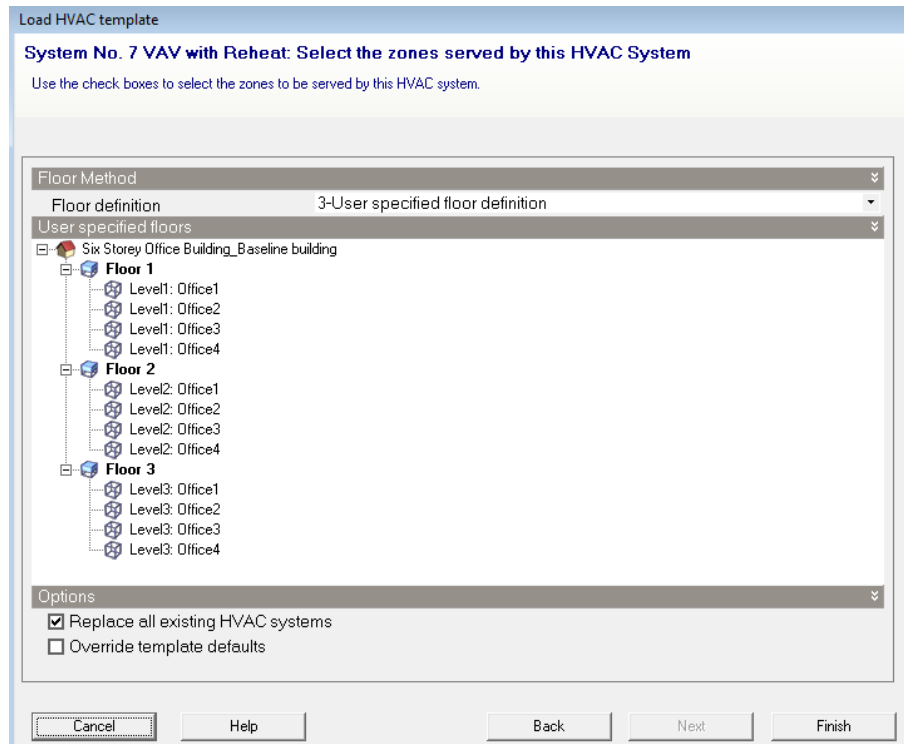


Figure 70 Zones list based on user specified floor definition

For option “3-User specified floor definition”, please refer to section 4.3.2.4 ASHRAE 90.1 floor definition for how user-specified floors are defined.

Using the example shown in Figure 70, the HVAC system will be generated on the layout screen with three HVAC zone groups, each containing four zones under each floor definition. The number of chillers and boilers will be correctly set (Figure 71) based on ASHRAE 90.1 App G Sections G3.1.3.2 and G3.1.3.7. The template is currently configured with a maximum of three chillers. If more than three chillers are required for large buildings, the extra chiller(s) can be added manually by navigating to the chilled water loop supply side.

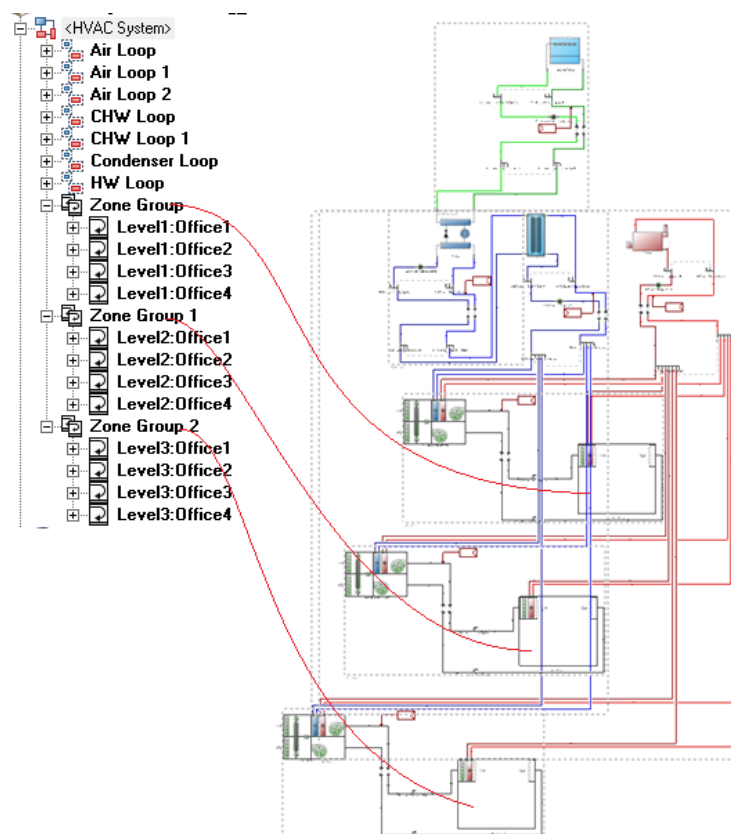


Figure 71 System #7 applies to three different floors

Note for Systems #9 and #10: For ASHRAE 90.1 2010, systems #9 and #10 should be applied to single zones, while in ASHRAE 90.1 2013 and 2016, these two systems should apply to each floor. The Baseline HVAC wizard implements this change so the systems can be loaded into an appropriate arrangement based on the version of the ASHRAE 90.1 energy code selected.

It is worth noting that the HVAC wizard can be run multiple times to override the existing system or to add additional HVAC systems, such as non-predominant HVAC systems, service hot water (SHW) a.k.a. domestic hot water (DHW) systems etc.

Note: Normally, you need to enable the “Override template defaults” option, which is shown as the second checkbox in Figure 65 and Figure 70 above, and then set the relevant parameter(s) in the wizard pages that follow. This will be discussed in detail in the following section.

6.2.1.5 Configuration of multiple chillers for systems #7, #8, #11, #12 and #13

ASHRAE 90.1 App G PRM Heat Rejection section states: “Each chiller shall be modeled with separate condenser water and chilled-water pumps interlocked to operate with the associated chiller”. The correct interpretation of this section is to model one cooling tower (one cell per tower) for each baseline building chiller. Each baseline building chiller has its own condenser water pump that operates with the chiller.

Figure 72 below, shows how, when two chillers are needed for a baseline HVAC system, the second condenser loop (highlighted in red) can be added manually, and each chiller is connected to a separate condenser loop.

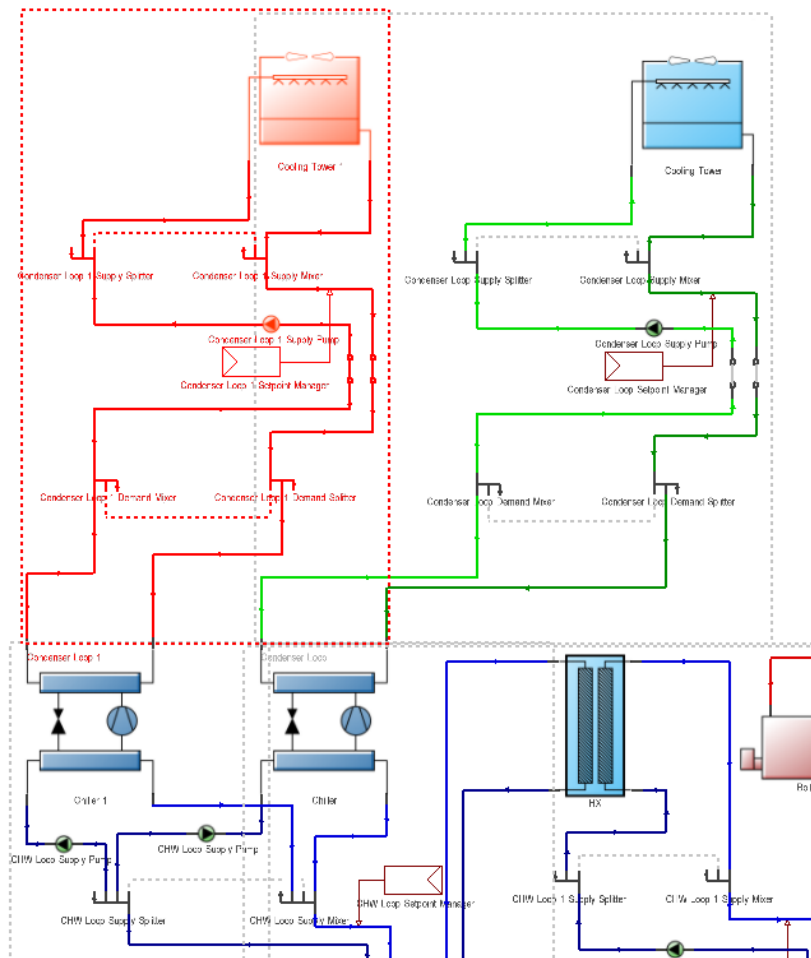


Figure 72 Manually add another condenser loop and make connections

6.2.1.6 Override template defaults

To ensure that the Baseline HVAC Wizard generates an HVAC system that complies with the ASHRAE 90.1 Standard Appendix G baseline HVAC definitions, it is important to use the “Override template defaults” option (Figure 73), which is checked by default when running the HVAC Wizard for the baseline building.

Note: Any further modifications that need to be made to the baseline HVAC system can be made manually to system components after the selected system has been loaded to the model.

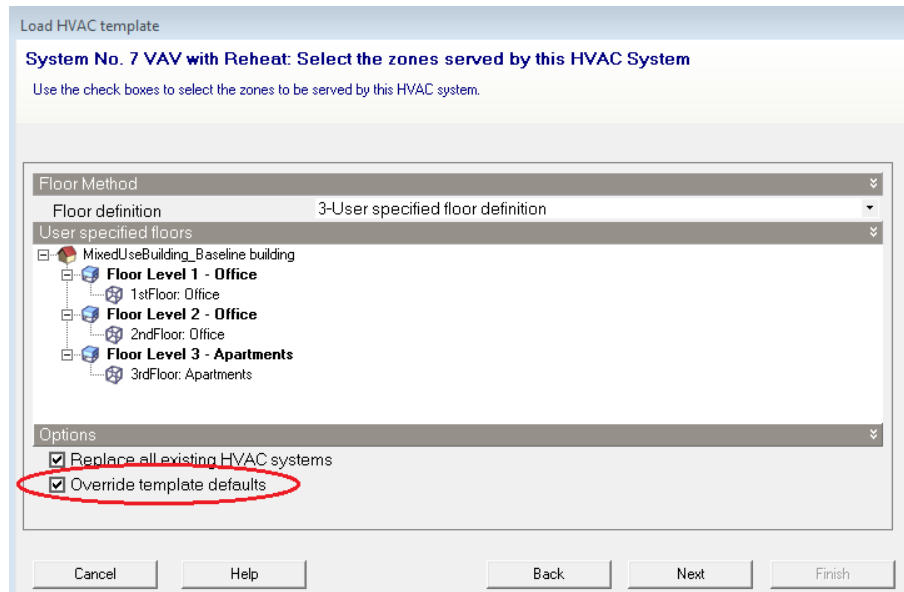


Figure 73 Enable Override template defaults option for Baseline HVAC Wizard

Figure 74 shows how the default input to the air handling unit can be changed, if required, by ASHRAE 90.1 Standard definitions.

The system fan power defined in ASHRAE 90.1 Standard Appendix G (in short App G) G3.1.2.9 together with Table G3.1.2.9 is already included in the default normalized fan pressure rise input setting in DesignBuilder. This is equivalent to the fan power to air flow rate ratio. However, if the fan pressure drop adjustments defined in ASHRAE 90.1 Standard section 6.5.3.1.1 are to be considered, then users need to calculate a revised fan pressure rise and enter it here.

For detailed baseline fan pressure rise explanation and calculation, see [Appendix B](#).

For ASHRAE 90.1 2007 and 2010, outdoor air economizers must be included in baseline HVAC Systems #3 to #8 if the climate zone meets the conditions specified in App G Table G3.1.2.6A. Baseline HVAC systems #1 or #2 do not require an outdoor air economizer. For ASHRAE 90.1 2013, similar requirements are defined in Tables G3.1.2.7 and G3.1.2.8, while in ASHRAE 90.1 2016 Tables G3.1.2.6 and G3.1.2.7 define the requirements. The requirement for the economizer and high-limit shutoff temperatures are automatically set in the software.

Users can make changes here if they don't agree with the default settings proposed by the wizard.

App G G3.1.2.10 section requires a complex check (normally based on the known design supply air capacity) to decide whether or not the exhaust air energy recovery is needed.

Note: DesignBuilder sets heat recovery to be on with an effectiveness of 0.5 by default. However a manual check of these settings is required and manual changes are often needed.

Load HVAC template

System No. 7 VAV with Reheat: Air Handling Unit

Enter details on the Air System

AHU Fans	
Supply Fan	
Pressure rise (Pa)	1439.298
Fan total efficiency	0.60
☒ Part-load performance	Fan Part-Load Power, ASHRAE 90.1-2007 Appendix G
Extract Fan	
☐ Include extract fan	
Recirculation	
☒ On	
Economiser (Free Cooling)	
Economiser control type	2-Fixed dry bulb
High-limit shutoff DB (°C)	21.11
Heat Recovery	
☒ On	
Sensible effectiveness	0.50
Latent effectiveness	0.000

Cancel Help Back Next Finish

Figure 74 Override air handling unit default settings

The hot water system default settings are shown in Figure 75 below.

Hot water pump power for baseline HVAC systems #1, #5 and #7 (other systems do not have hot water loops), is defined in App G G3.1.3.5, which requires baseline building design hot-water pump power to be 19 W/gpm. This figure is included into DesignBuilder pump head input which represents the pump power to water flow rate ratio.

Load HVAC template

System No. 7 VAV with Reheat: Hot Water System

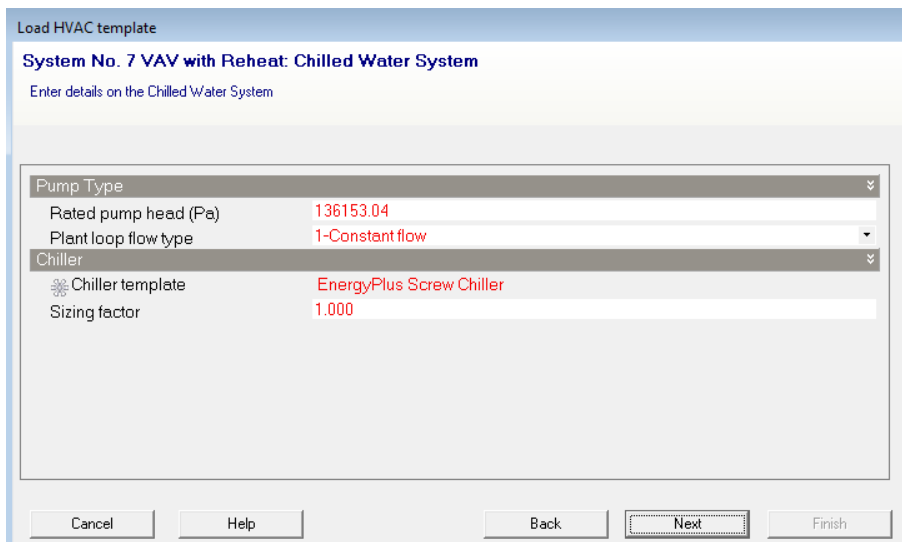
Enter details on the Hot Water System

Pump Type	
Rated pump head (Pa)	235241.37
Plant loop flow type	2-Variable flow
☒ Performance curve template	Pump Part-Load Power, Default Variable Speed
Boiler	
 Boiler template	ASHRAE 90.1 Appendix G baseline boiler.
Design capacity (W)	Autosize

Cancel Help Back Next Finish

Figure 75 Override hot water system default settings

Similar to hot water systems, the chilled water system pump head includes consideration of the 22W/gpm for baseline building design pump power required by App G G3.1.3.10 (Figure 76).



Load HVAC template

System No. 7 VAV with Reheat: Chilled Water System

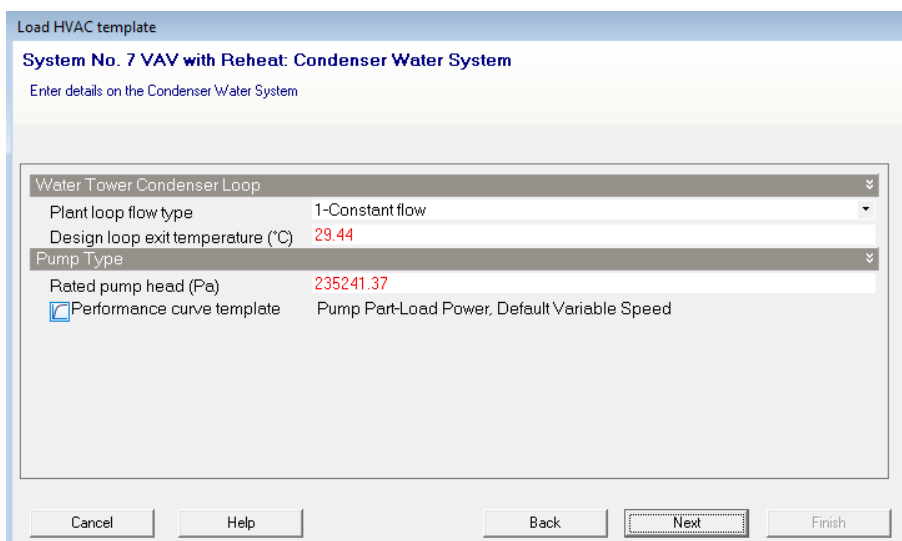
Enter details on the Chilled Water System

Pump Type	
Rated pump head (Pa)	136153.04
Plant loop flow type	1-Constant flow
Chiller	
Chiller template	EnergyPlus Screw Chiller
Sizing factor	1.000

Cancel Help Back Next Finish

Figure 76 Override chilled water system default settings

Likewise, the condenser pump head includes consideration of the 19W/gpm for baseline building design condenser-water pump power defined in App G G3.1.3.11 (Figure 77).



Load HVAC template

System No. 7 VAV with Reheat: Condenser Water System

Enter details on the Condenser Water System

Water Tower Condenser Loop	
Plant loop flow type	1-Constant flow
Design loop exit temperature (°C)	29.44
Pump Type	
Rated pump head (Pa)	235241.37
☒ Performance curve template	Pump Part-Load Power, Default Variable Speed

Cancel Help Back Next Finish

Figure 77 Override condenser water system default settings

The final page of the wizard allows a simple HVAC template to be set (Figure 78). This updates the data on the HVAC tab at zone level for consistency with the Detailed HVAC system most recently loaded for that zone. This is especially important for running cooling or heating design calculations.

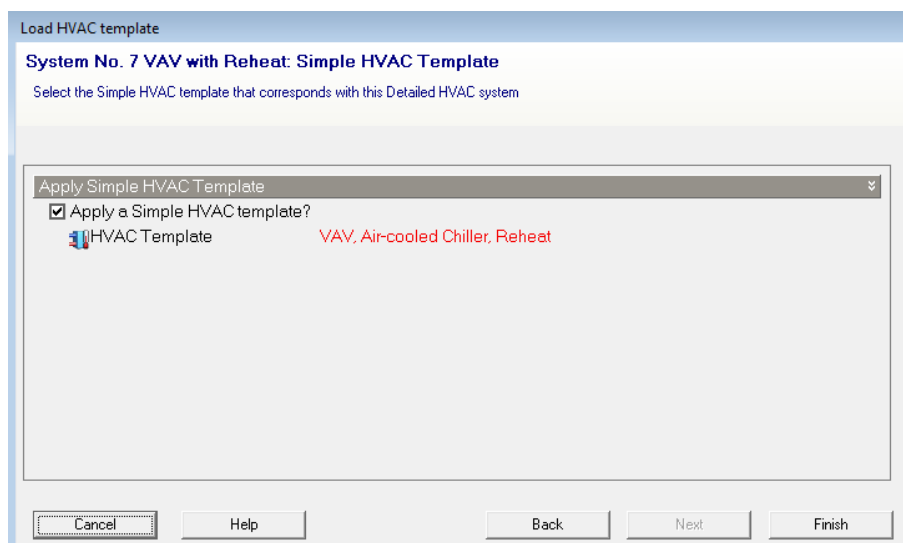


Figure 78 Simple HVAC template page

Note: After the HVAC system has been loaded for the baseline building, further changes can be made by manually editing data on HVAC loops and components.

6.2.2 Fine tuning (manual adjustment)

The DesignBuilder guided HVAC selection described above, allows you to quickly and easily select and load the correct system as a starting point. However, once this has been loaded, the system should be manually checked to ensure full compliance with ASHRAE 90.1 Appendix G rules. For example, you may need to run cooling and heating design calculations in order to obtain zone sizing data; or you may need to run a test simulation to generate plant and equipment sizing data from EnergyPlus outputs (typically via the “Summary” simulation results tab or by reading the E+ output eio file for example).

Here is a list of key items to check:

- You should check that the prescriptive requirements have been met in the ASHRAE 90.1 proposed model, such as checking the equipment minimum efficiencies required by Appendix G clause G3.1.2.1, together with section 6.4 of ASHRAE 90.1 Standard, which references Tables 6.8.1A through 6.8.1K that define the minimum equipment efficiency requirements. For DX coil efficiency input, see [Appendix A](#).
- Check whether preheat coils are required in the baseline HVAC system based on Clause G3.1.2.3.
- Check whether the baseline HVAC system needs to enable exhaust air energy recovery following the definitions of G3.1.2.10. Then make appropriate settings on the air handling unit (AHU) dialog “Outdoor Air System” tab.
- Set the baseline HVAC hot water pump type to either variable speed or constant speed per Appendix G section G3.1.3.5. Likewise, set the chilled water pump type to either variable or constant speed per section G3.1.3.10.
- If the baseline HVAC system is either #6 or #8, size the fans in parallel VAV fan-powered boxes properly as per section G3.1.3.14 (see Appendix C for more details).
- If applicable, set the baseline chiller condenser heat recovery per section 6.5.6.2.1.

While we consider these to be the main manual interventions that are likely to be required, you should check the whole HVAC system to ensure it fully meets ASHRAE 90.1 requirements.

7. Simulations

The proposed and baseline building simulations are run individually as they are separate buildings. DesignBuilder strongly advises that you undertake appropriate quality control checks prior to running the final proposed and baseline building simulations for ASHRAE 90.1 purposes.

7.1 ASHRAE 90.1 simulations

ASHRAE 90.1 simulations are run from the “ASHRAE 90.1” tab on the “Simulation” screen (Figure 79). The simulation options for ASHRAE 90.1 purposes are restricted to ensure that the correct comparison between the proposed and baseline buildings can be made in accordance with ASHRAE 90.1 requirements.

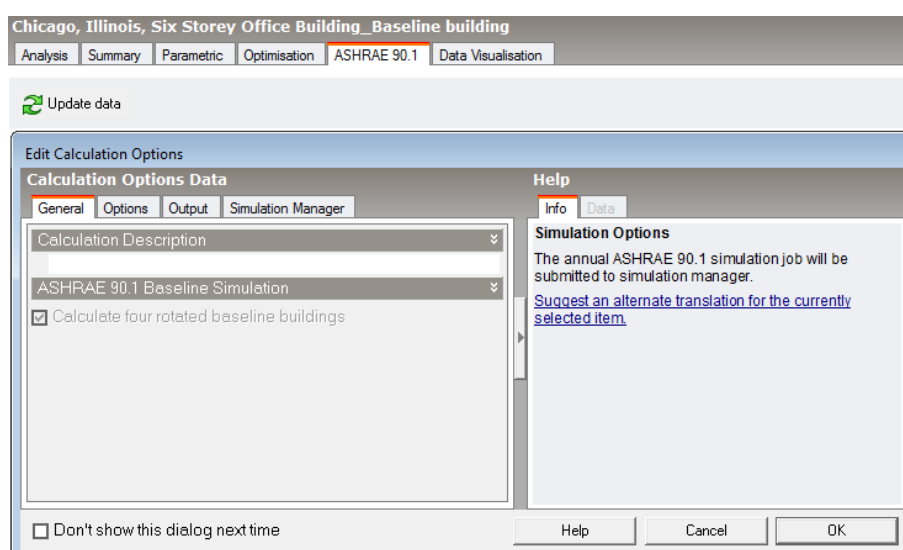


Figure 79 Calculation Options for ASHRAE 90.1 simulations

DesignBuilder advises running the first simulation for the Proposed building level to generate those results, then selecting the Baseline building model to run the 4 automated baseline building simulations, or a single simulation if the baseline model meets the criteria of the exception (see the note below).

Note: For ASHRAE 90.1 2010 and later, there is an exemption that allows the baseline simulations to be run without rotation if certain criteria for window-to-wall ratios are met. This exemption is handled automatically by DesignBuilder (see Figure 80).

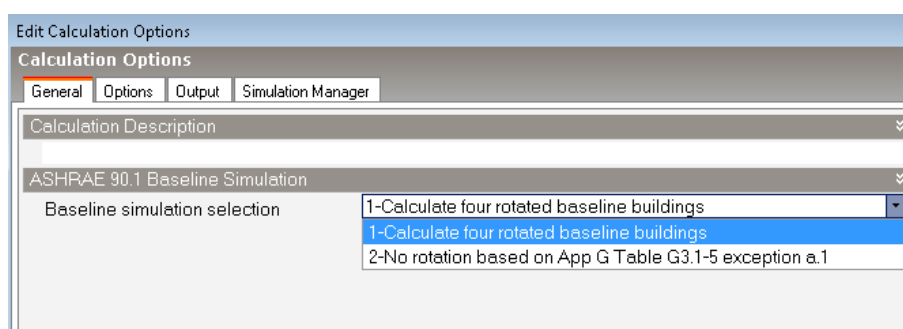


Figure 80 Calculation options for baseline building simulation

7.2 Using the Simulation Manager

The ASHRAE 90.1 simulations are always run using the Simulation Manager. The “Simulation Manager” tab on the Calculation options dialog (screenshot in Figure 81 below) provides options for either a local or a remote job server.

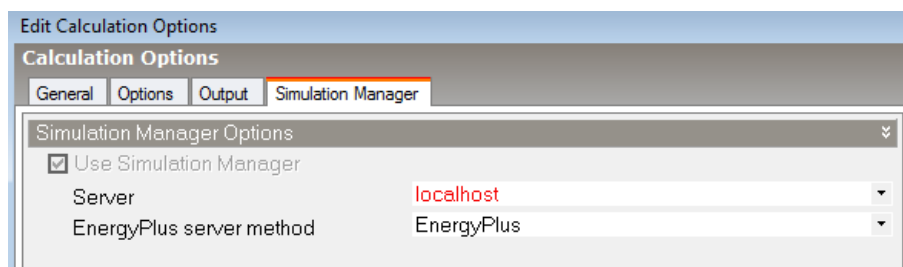


Figure 81 Simulation manager used for ASHRAE 90.1 simulations

The Simulation Manager allows the four rotated baseline buildings (if they are needed) to be run simultaneously in parallel and fully automates that process.

7.3 Simulation options

For the baseline building, the solar distribution is automatically set to “1-Minimal shadowing” (Figure 82), in line with ASHRAE 90.1 Table G3.1-5 (Baseline section) “The baseline building shall be modeled so that it does not shade itself”.

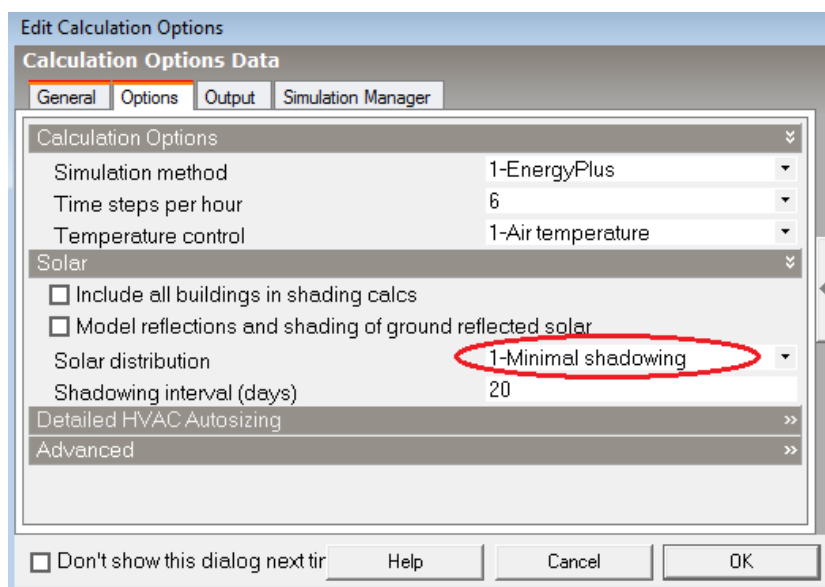


Figure 82 Calculation Options

7.4 Simulation output options

To ensure there is sufficient output data for data reporting and to avoid generating unnecessary data that would otherwise slow the process down, DesignBuilder checks and greys out (so they cannot be unchecked) the following “Summary Annual Report” checkboxes before running ASHRAE 90.1 simulations (Figure 83).

- LEED Summary
- Annual Building Utility Performance Summary (ABUPS)

- Demand End Use Components Summary
- Input Verification and Results Summary
- Equipment Summary
- Envelope Summary
- System Summary
- Component Sizing Summary

The other non-essential output options can be checked if required when additional data is required, however you should leave these unchecked if you do not require this data:

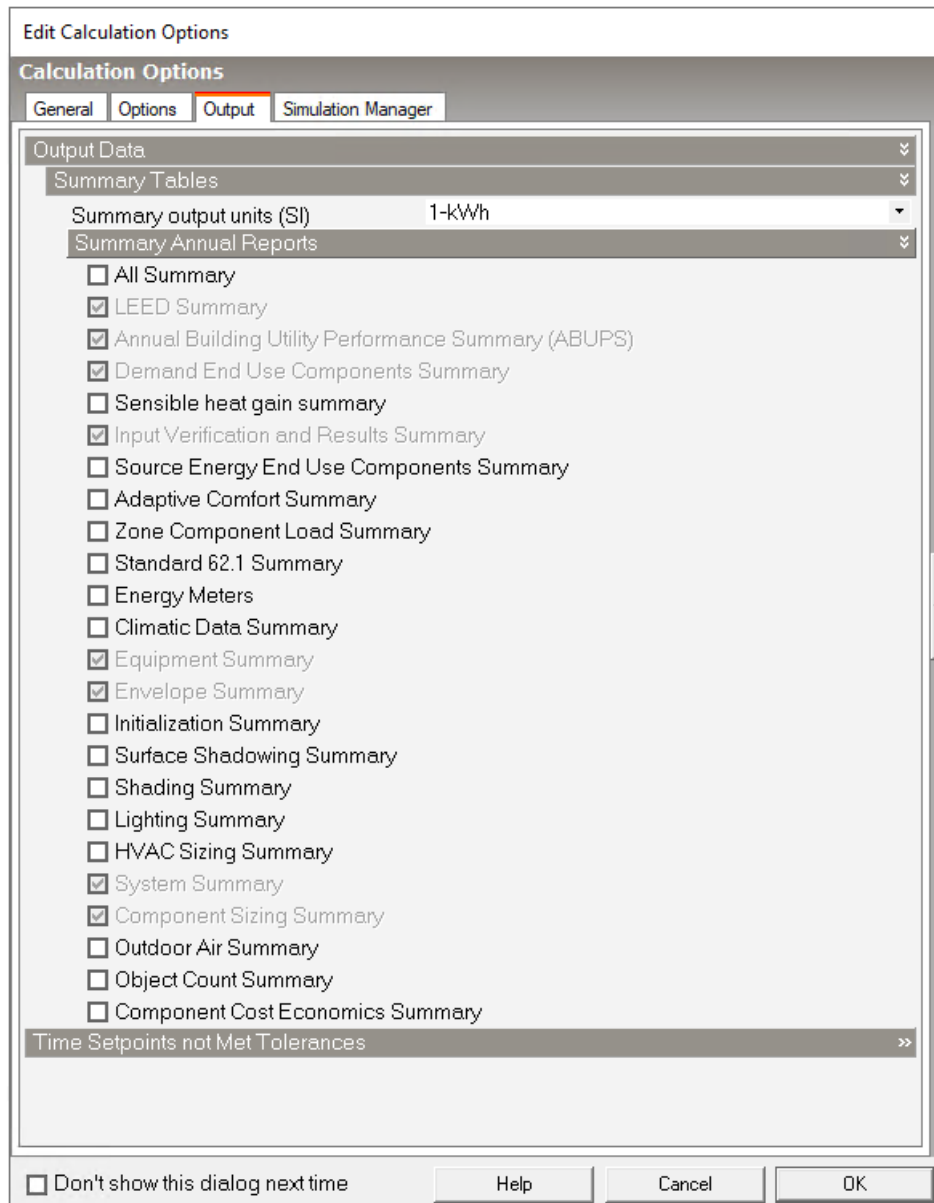


Figure 83 Important Summary Annual Reports Setting

7.5 Simulated data

After the ASHRAE 90.1 simulations have been run, the simulated results data is transferred and stored in a folder on the local drive:

C:\Users\(\username)\AppData\Local\DesignBuilder\EnergyPlus\ASHRAE901

Four different rotated baseline buildings have a suffix related to each of their output results, i.e. _B000, _B090, _B180 and _B270 that indicate the baseline building has been rotated for 0°, 90°, 180° and 270° respectively (Figure 84), while proposed building results are differentiated with a suffix of _p000.

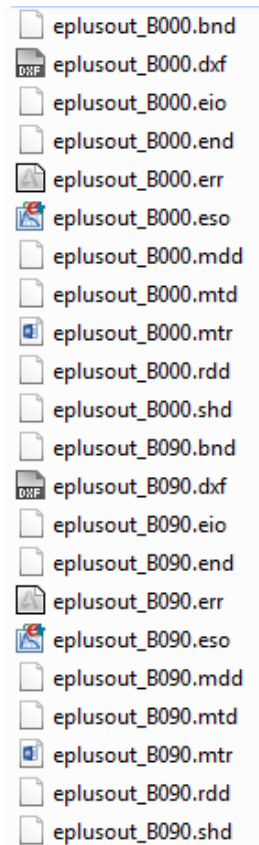


Figure 84 Simulated data stored on the local drive

8. Outputs and Post Processing

DesignBuilder recommends that you run “standard” simulations on the “Analysis” tab before running ASHRAE 90.1 simulations to address any issues that either stop simulations from running or cause unrealistic outputs.

You must also undertake appropriate quality control checks prior to running the final proposed and baseline building simulations for ASHRAE 90.1 purposes. As a minimum, we advise that you check all model data inputs then run shorter test simulations to check key sub-hourly results. For example, run summer and winter design week simulations to check cooling and heating plant operation, and swing season weeks to check whether controls that should prevent inappropriate simultaneous heating and cooling are operating correctly. The DesignBuilder Results Viewer tool can help you to visualize correct operation down to the HVAC system node level. Then finally run an annual simulation to view annual and monthly results to “sanity-check” key energy consumption values and unmet load hours against appropriate metrics.

The LEED-specific summary report outputs described above should be reviewed. Examples of these are shown in Tables 1, 2 and 3 below. DesignBuilder results can also be displayed in “Grid” form and exported to a spreadsheet in .csv format for further analysis if required.

EAp2-4/5. Performance Rating Method Compliance

	Electric Energy Use [kWh]	Electric Demand [W]	Natural Gas Energy Use [therm]	Natural Gas Demand [Btu/h]	Additional Energy Use [kBtu]	Additional Demand [Btu/h]
Interior Lighting	34413.18	7290.92	0.00	0.00	0.00	0.00
Exterior Lighting	0.00	0.00	0.00	0.00	0.00	0.00
Space Heating	0.00	0.00	3010.54	428082.85	0.00	0.00
Space Cooling	3462.43	4395.25	0.00	0.00	0.00	0.00
Pumps	4908.23	1802.36	0.00	0.00	0.00	0.00
Heat Rejection	211.43	853.99	0.00	0.00	0.00	0.00
Fans-Interior	10290.68	1155.93	0.00	0.00	0.00	0.00
Fans-Parking Garage	0.00	0.00	0.00	0.00	0.00	0.00
Service Water Heating	0.00	0.00	0.00	0.00	0.00	0.00
Receptacle Equipment	11873.28	4328.98	0.00	0.00	0.00	0.00
Interior Lighting (process)	0.00	0.00	0.00	0.00	0.00	0.00
Refrigeration Equipment	0.00	0.00	0.00	0.00	0.00	0.00
Cooking	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Process	0.00	0.00	0.00	0.00	0.00	0.00
Elevators and Escalators	0.00	0.00	0.00	0.00	0.00	0.00
Total Line	65159.22		3010.54		0.00	

Table 1 LEED EAp2-4/5 PRM Compliance
EAp2-6. Energy Use Summary

	Process Subtotal [GJ]	Total Energy Use [GJ]
Electricity	2202.59	5482.13
Natural Gas	0.00	233.54
Total	2202.59	5715.67
Additional	0.00	0.00

Table 2 LEED Energy Use Summary
EAp2-7. Energy Cost Summary

	Process Subtotal [\$]	Total Energy Cost [\$]
Electricity	30606.07	76176.92
Natural Gas	0.00	2291.71
Other		0.00
Total	30606.07	78468.63
Additional	0.00	

Process energy cost based on ratio of process to total energy.

Table 3 LEED Energy Cost Summary

LEED EAp2-4/5 (Table 1), EAp2-6 (Table 2) and EAp2-7 (Table 3) are examples (from a proposed building simulation) of how EnergyPlus output summaries fit the LEED EA Prerequisite 2: Minimum Energy Performance document.

8.1 Unmet load hours

To verify that the baseline building and the proposed building have reasonable equipment sizes and are controlled correctly, you must check unmet load hours, i.e. hours during the simulation period when loads are not met and temperature setpoints are not met. High unmet load hours indicate that the equipment is undersized and/or incorrectly controlled.

8.1.1 Unmet hours for LEED

LEED summary table EAp2-2 Advisory Messages summarizes the unmet hours (Figure 85).

EAp2-2. Advisory Messages

	Data
Number of hours heating loads not met	0.00
Number of hours cooling loads not met	0.00
Number of hours not met	0.00

Figure 85 LEED summary table EAp2-2 shows unmet hours

The “Unmet hours” of a building are the summation of the number of hours when the heating or the cooling set point temperature of a zone is not met either by the HVAC system or by the plant.

8.1.2 Manipulate model to address unmet load hours

Maintaining unmet load hours below the criteria set in ASHRAE 90.1 is mandatory unless it can be proven that exceeding the limit does not unduly impact on building performance.

8.1.2.1 Unmet hours criteria from ASHRAE 90.1 Standard

In order for equipment to be acceptably sized under the rules of the building performance rating method, two conditions must be met:

- The unmet load hours for both the proposed design and the baseline building design shall not exceed 300 hours per year (of the 8760 hours simulated).
- The unmet load hours for the proposed design shall not exceed the number of unmet load hours for the baseline building design by more than 50.

8.1.2.2 Dealing with unmet hours that exceed the limits

If unmet load hours in the proposed building exceed the unmet load hours in the baseline building by more than 50, then the size of equipment in the baseline building shall be reduced incrementally, until the condition is satisfied.

If unmet load hours for either the proposed design or baseline building design exceed 300, then the simulated capacities shall be increased incrementally, and the building with unmet loads shall be re-simulated until the unmet load hours are reduced to 300 or less. For the proposed building, this means that the construction drawings may need to be modified and larger equipment specified.

Alternatively in some cases, unmet load hours exceeding these limits may be accepted at the discretion of the rating authority, provided that sufficient justification is given indicating that the accuracy of the simulation is not significantly compromised by these unmet loads.

However, in all cases it is important that the unmet load hours of the proposed design do not exceed that of the baseline design by more than the stated 50 hours. This is to ensure that energy savings are not claimed in the proposed design by providing a lower level of performance than in the baseline building.

8.2 Annual energy consumption

After both the proposed and baseline building simulations have been run, the comparison between baseline and proposed building results for annual energy end uses is shown on the “ASHRAE 90.1” tab. The data is broken down by end use categories, such as heating, cooling, interior lighting, exterior lighting and interior equipment and so on (Figure 86).

The comparison based on energy costs can also be viewed (Figure 87) by selecting “2-Costs” for the “Show” setting in the Display Options panel which is located at the left bottom corner of DesignBuilder screen (Figure 88). To allow the cost comparisons to be made, the tariff (utility rate) definitions on the Economics tab at building level must be enabled and configured prior to simulations.

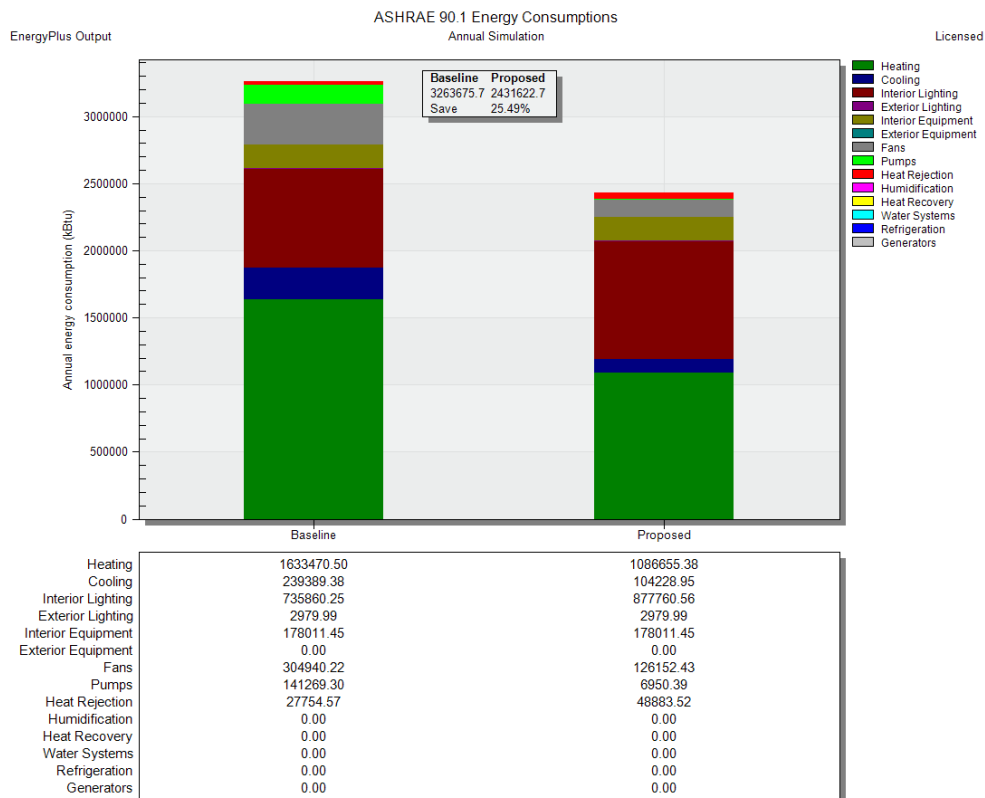


Figure 86 Output results in terms of annual energy end uses

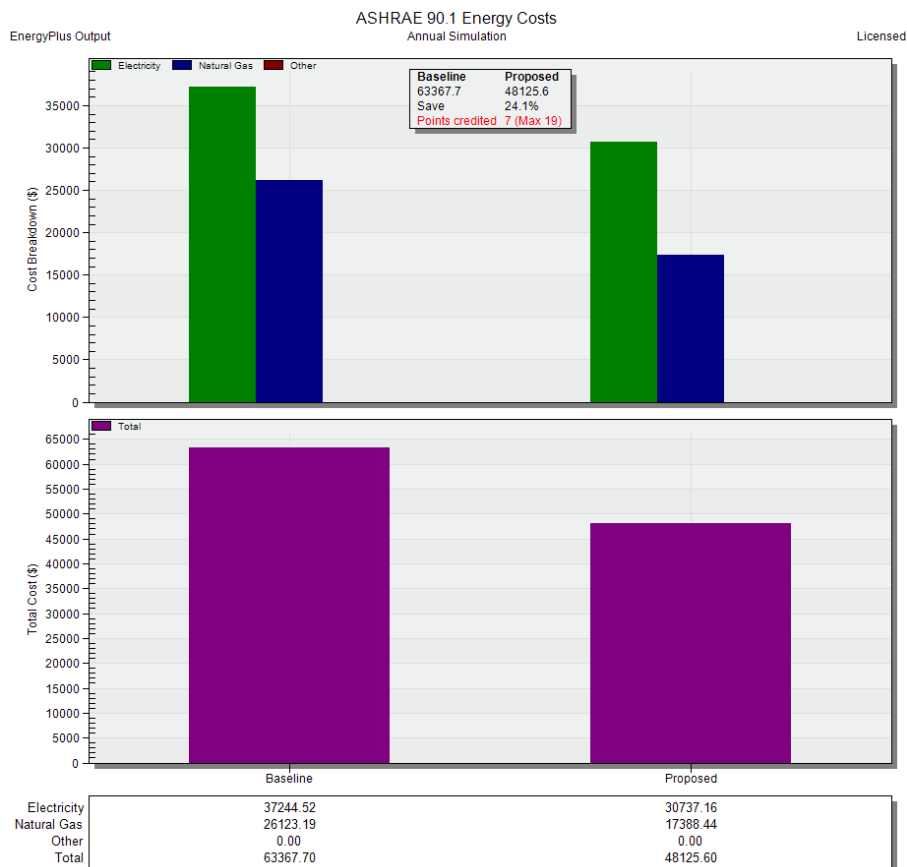


Figure 87 Output results in terms of annual energy costs

Display Options

General

Detailed



Data			
Show	2-Costs		
LEED Options			
LEED 2009	1-New construction		
Sub category	1-New building		

Figure 88 Display options that allow show energy costs comparison

On the energy costs comparison graph, points credited are displayed based on the energy costs saving percentage shown on the same graph, as well as LEED options selected from Display Options (Figure 88).

8.3 Data reporting tool

DesignBuilder includes a tool for automatically populating the LEED version 4.0 or 4.1 Minimum Energy Performance Calculator report with inputs and simulated data.

Please refer to the separate modelling guide for more details:

LEED v4 and v4.1 Minimum Energy Performance Calculator Reporting - User Guide.

Appendix A: Baseline Cooling and Heating Coil Efficiency Input

From the ASHRAE 90.1 2016 Standard, all HVAC equipment in the baseline building design shall be modeled at the minimum efficiency levels, both part load and full load, in accordance with Tables G3.5.1 through G3.5.6. The efficiency rating that includes the supply fan energy shall be adjusted to remove the supply fan energy so that supply fan energy can be modeled separately.

For Baseline HVAC Systems #1 through #6, calculate the minimum $COP_{nfcooling}$ and $COP_{nfheating}$ using the equation for the applicable performance rating as indicated in Tables 6.8.1-1 through 6.8.1-4. Where a full- and part-load efficiency rating is provided in Tables 6.8.1-1 through 6.8.1-4.

The full-load equations below shall be used:

$$COP_{nfcooling} = 7.84E-8 \times EER \times Q + 0.338 \times EER$$

$$COP_{nfcooling} = -0.0076 \times SEER^2 + 0.3796 \times SEER$$

$$COP_{nfheating} = 1.48E-7 \times COP_{47} \times Q + 1.062 \times COP_{47}$$

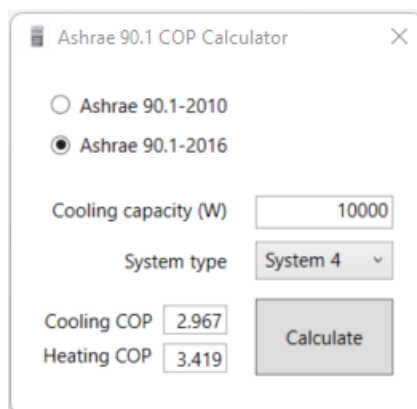
(Applies to heat pump heating efficiency only.)

$$COP_{nfheating} = -0.0296 \times HSPF^2 + 0.7134 \times HSPF$$

Where, $COP_{nfcooling}$ and $COP_{nfheating}$ are the packaged HVAC equipment cooling and heating energy efficiency, respectively, to be used in the baseline building design, which excludes supply fan power, and Q is the AHRI-rated cooling capacity in Btu/h. EER, SEER, COP, and HSPF shall be at AHRI test conditions.

The above calculation requires a sizing run to the model as the cooling capacity is an input.

A standalone utility is available to help calculate this performance efficiency (COP) input. It includes the calculations for both cooling and heating coils for baseline systems #1 through #6. The utility can be downloaded [here](#).



Appendix B: Fan Pressure Rise Input for a Given Fan Power

B1. Fan pressure rise calculation

The fan pressure rise is commonly calculated as:

$$\Delta H[in. w. c.] = \frac{P}{Q} \left[\frac{horsepower}{CFM} \right] \times \eta \times 6356$$

Where, P is fan power (horsepower), Q is fan volumetric flow rate (CFM), ΔH is fan pressure rise (in.w.c. that stands for inch water column) and η is fan total efficiency (-).

If [W/CFM] is used instead of [horsepower/CFM],

$$\Delta H[in. w. c.] = \frac{P/Q [W/CFM] \times \eta \times 6356}{745.699872}$$

B2. Fan pressure rise input for Baseline HVAC systems defined in ASHRAE 90.1 App G

ASHRAE 90.1-2007 states in clause G3.1.2.9 System Fan Power:

For Systems 1 and 2,

$$P_{fan} = CFM_S \cdot 0.3 .$$

For systems 3 through 8,

$$P_{fan} = bhp \times 746 / \text{Fan Motor Efficiency} .$$

As a value for fan efficiency of 0.6 (60%) being used, the fan pressure rise for each baseline HVAC system can be calculated in the table below.

Systems	G3.1.2.9, G3.1.3.14 (PFP)	Formula	IP[in.w.c.]	SI[Pa]
#1 and #2	$P_{fan}[W] = CFM_s \times 0.3$	$\Delta H[in. w. c.] = 0.3 \times \eta \times \frac{6356}{745.699872}$	1.5463	384.786
#3 and #4 *	$P[horsepower] = CFM_s \times 0.00094$	$\Delta H[in. w. c.] = 0.00094 \times \eta \times 6356$	3.5848	892.052
#5 - #8 *	$P[horsepower] = CFM_s \times 0.0013$	$\Delta H[in. w. c.] = 0.0013 \times \eta \times 6356$	4.9577	1233.689
PFP fans	$W/CFM = 0.35$	$\Delta H[in. w. c.] = 0.35 \times \eta \times \frac{6356}{745.699872}$	1.7899	445.404

* These calculations do not take into account the fan pressure drop adjustment which has been defined in Table 6.5.3.1.1A and Table 6.5.3.1.1B that are listed in the appendix.

** PFP fans and motors typically do not have the same efficiency as larger fans and motors, so efficiency value of 60% may not be very realistic.

Appendix C: Size PIU Fans for Systems #6 and #8

The size of the VAV fan-powered boxes is defined in the ASHRAE 90.1 Standard Appendix G G3.1.1.14 (Figure 89).

G3.1.3.14 Fan Power and Control (Systems 6 and 8)

Fans in parallel *VAV* fan-powered boxes shall run as the first stage of heating before the *reheat* coil is energized. Fans in parallel *VAV* fan-powered boxes shall be sized for 50% of the peak design primary air (from the *VAV* air-handling unit) flow rate and shall be modeled with 0.35 W/cfm fan power. Minimum volume *set points* for fan-powered boxes shall be equal to 30% of peak design primary airflow rate or the rate required to meet the minimum *outdoor air ventilation* requirement, whichever is larger. The supply air temperature *set point* shall be constant at the *design condition*.

Figure 89 ASHRAE 90.1 2016 App G G3.1.3.14 Clause

This configuration requires a sizing run to the model. To do that, perform a short period (e.g., on typical summer week) simulation with default Autosize settings for Parallel PIU objects (Figure 90).

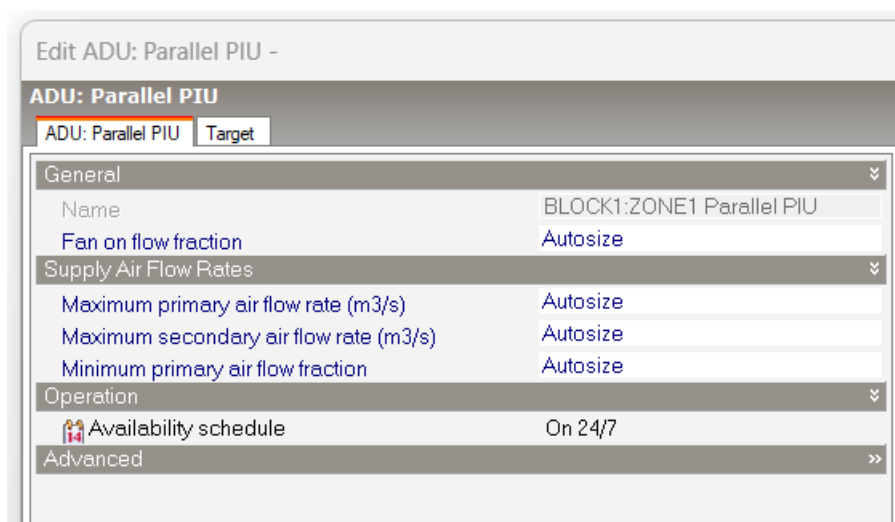


Figure 90 ADU: Parallel PIU with default Autosize input

After the simulation, go to Summary tab, then navigate to AirTerminal:SingleDuct:ParallelPIU:Reheat under Report: Component Sizing Summary (Figure 91).

Report: Component Sizing Summary

[Table of Contents](#)

For: Entire Facility

Timestamp: 2023-08-15 15:04:11

AirTerminal:SingleDuct:ParallelPIU:Reheat

	Design Size Maximum Primary Air Flow Rate [m3/s]	Design Size Maximum Secondary Air Flow Rate [m3/s]	Design Size Minimum Primary Air Flow Fraction	Design Size Fan On Flow Fraction
BLOCK1:ZONE1 PARALLEL PIU	1.01	1.01	0.055615	0.055615

User-Specified values were used. Design Size values were used if no User-Specified values were provided.

Fan:ConstantVolume

	Design Size Maximum Flow Rate [m3/s]
BLOCK1:ZONE1 PARALLEL PIU SUPPLY FAN	1.01

User-Specified values were used. Design Size values were used if no User-Specified values were provided.

Figure 91 EnergyPlus Summar AirTerminal:SingleDuct:ParallelPIU:Reheat Report

Following the definition in G3.1.3.14, obtain the minimum primary air flow fraction, which in this case is 0.3, determined by the maximum of 0.3 and 0.055615, where 0.055615 is the Design Size Minimum Primary Air Flow Fraction read from the table in Figure 91 above.

Calculate the maximum secondary air flow rate, in this case, $1.01 \times 0.5 = 0.505 \text{ m}^3/\text{s}$.

Edit to ADU: Parallel PIU dialog gain, input 0.505 for maximum secondary air flow rate, 0.3 for minimum primary air flow fraction. Input 0.3 for fan on flow fraction as well (Figure 92).

Edit ADU: Parallel PIU -

ADU: Parallel PIU

ADU: Parallel PIU Target

General

Name BLOCK1:ZONE1 Parallel PIU

Fan on flow fraction 0.30

Supply Air Flow Rates

Maximum primary air flow rate (m3/s) Autosize

Maximum secondary air flow rate (m3/s) 0.50500

Minimum primary air flow fraction 0.30

Operation

Availability schedule On 24/7

Advanced >>

Figure 92 Input back data from the calculations above

Also, check that the associated fan dialog (Figure 93), has the maximum flow rate of 0.505m3/s.

Edit Fan -

Fan

Fan Target

General

Name BLOCK1:ZONE1 Parallel PIU Supply Fan

Type 1-Constant volume

Fan total efficiency 0.60000

Pressure rise (Pa) 445.4

End-use subcategory General

Flow Rates

Maximum flow rate (m3/s) 0.505000

Motor

Motor efficiency 0.90000

Motor in airstream fraction 1.000

Operation

Availability schedule On 24/7

Figure 93 Associated Fan Settings

Appendix D - QA Checklist for LEED EA Modelling Credits:

1. Prepare for LEED modelling with DesignBuilder.
 - a. You have experience in BPM, DesignBuilder Simulation and Detailed HVAC.
 - b. You have reviewed DesignBuilder's training material and LEED modelling guides.
 - c. You have access to the necessary resources (see [Appendix E](#)).
2. Compliance requirements:
 - a. Update your checklist of all LEED and ASHRAE compliance requirements for your project.
3. Official project documentation:
 - a. Review your collected official project documentation supporting your modelling inputs.
4. Proposed building model:
 - a. Orientation, Overshadowing, Climate Data, and Design Day data is correctly applied.
 - b. Building, Block, and Zone areas align with the architectural drawings and area schedule.
 - c. Model constructions, form, and shading were checked and reviewed in Visualisation.
 - d. Model settings (loads, occupancy, schedules, etc.) were checked and reviewed in MDGV.
 - e. Everything aligns with 2 and 3.
5. Proposed HVAC model:
 - a. HVAC components, efficiency, sizing, control, and zoning were checked.
 - b. Everything aligns with 2 and 3.
6. Test Simulations:
 - a. Review short test simulations in Summer, Winter and Fall and sanity-check the results.
 - b. Run an annual simulation and review the results and LEED summary report.
7. Baseline building model:
 - a. Baseline building tool was used, and the input parameters were carefully checked.
 - b. Model was reviewed, and corrections were made if necessary.
 - c. If the proposed model contained mistakes, delete the baseline building and return to 4.
 - d. Everything aligns with 2.
8. Baseline model HVAC:
 - a. The correct ASHRAE 90.1 system type and control settings is modelled.
 - b. HVAC components, efficiency, sizing, control, and zoning were checked. Use MDGV.
 - c. Everything aligns with 2.
9. Test Simulations:
 - a. Review short test simulations in Summer, Winter and Fall and sanity-check the results.
 - b. Run an annual simulation and review the results and LEED summary report.
10. Run ASHRAE 90.1 simulations for both buildings.
 - a. Review the MEPC report to address the flagged possible errors.
 - b. If necessary, some inputs in the MEPC report should be adjusted manually.
11. Report writing:
 - a. Write a LEED modelling report in line with 2.
 - b. Neatly package all supporting documentation
 - c. Peer-review your report in line with your company policy before submitting the project.

Appendix E - Modelling Resources for LEED EA Credits

1. Building performance modelling:
 - a. ASHRAE Fundamentals
 - b. ASHRAE 209 Standard
 - c. ASHRAE 90.1 Standard
2. DesignBuilder Experience and Training:
 - a. Modules: Simulation, Detailed HVAC, Visualisation, Results Viewer.
 - b. Tutorials.
 - c. On-Demand Training.
 - d. LEED Webinar.
3. DesignBuilder LEED modelling guides.
 - a. ASHRAE 90.1 App G PRM User Guide
 - b. LEED v4 Minimum Energy Performance Calculator User Guide
4. EA credits that DesignBuilder can calculate (LEED v4 and 4.1):
 - a. Optimise Energy Performance
 - b. Minimum Energy Performance
 - c. On-site Renewable Energy
 - d. Green Power and Carbon Offset details

[More information](#)
5. LEED resources:
 - a. LEED manual
 - b. Link to [all the LEED credits](#)
 - c. Minimum Energy Performance Calculator (MEPC) Tool
 - d. LEED user forum (with a database of frequently asked questions)
6. ASHRAE Standards
 - a. ASHRAE 90.1 Standard (make sure of the version)
 - b. ASHRAE 90.1 Standard User Manual.
 - c. ASHRAE 62.1 Standard
 - d. ASHRAE 55 Standard