INFILTRATION MODULE—ENERGYPLUS EXERCISE INSTRUCTIONS

Exercise Introduction and Objectives

The exercise provides a base file for a two-story building, measuring 104′ x 48′. The building is modeled with core and perimeter zoning for each floor.

The objective of this exercise is to study the effect of infiltration on a building's energy use. EnergyPlus contains three models for basic infiltration calculations.

- The first is the Design Flow Rate model that was inherited from EnergyPlus's predecessor programs. It is based on environmental conditions modifying a design flow rate.
- The second is the Effective Leakage Area model based on Sherman and Grimsrud (1980).
- The third is the Flow Coefficient model based on Walker and Wilson (1998).

The model formulations for the Effective Leakage Area and Flow Coefficient models are taken from the ASHRAE Handbook (2001 Chapter 26; 2005 Chapter 27), where they are referred to as "Basic" and "Enhanced," respectively.

This exercise aims to compare different infiltration data and energy usage using each of above-mentioned models.

Note:
More advanced infiltration calculations are possible using the EnergyPlus Airflow Network model for natural infiltration driven by wind when the HVAC system doesn't operate and/or driven by wind and forced air for times when the HVAC system operates.

Note:
It's common to simplify energy models by combining all the windows on a wall or in a zone into one window of equivalent size. The error in estimating conductive and radiative heat transfer across the enclosure by this simplification is usually quite small. If the windows are a significant source of infiltration, however, this simplification may introduce large errors. This modification to the building design significantly reduces the linear area of window frame and crack and thus will underestimate the amount of infiltration that occurs.

Note: About IDF Editor
Users who want a simple way to create or edit EnergyPlus input data files (IDF) can use the IDF Editor. They can view and edit any EnergyPlus object using a spreadsheet-like grid. A list is provided for inputs with several options. The IDF Editor outputs an EnergyPlus input file with proper syntax and comments to help the user understand the input values. In addition, the IDF Editor converts standard inch-pound units into SI units that are compatible with EnergyPlus. The IDF Editor does not check inputs for validity, although it highlights some numeric fields that are out of range. For the purpose of this exercise, the IDF editor is a useful input interface.

Note:
These exercise instructions and associated input files have been written to conform with EnergyPlus v5.0.0 format. Use of these instructions and input files with later versions of EnergyPlus may require changes or updates to input objects and location of data sets and weather files.

Exercise Procedure

Schedules are a usage study, and the values are usually obtained from the architect's office or from previous simulations of similar buildings. For this exercise, assume that the infiltration schedule available in the base file applies to all the models.

Data for infiltration and coefficients are entered in their respective spaces, the data being pulled from the ASHRAE Handbook or from other noted sources. Simulations are run, and energy usage data obtained for analysis. This process is repeated for all the models described above.

Output Data

Before proceeding to the simulations, the idf base file should be set for the desired output data and format. This will help to make the idf file ready for output right after infiltration data, so the process does not have to be repeated for every calculation model.

The following objects allow standard reports to be defined and utilized in EnergyPlus:

- Output: Table: Time Bins
- Output: Table: Monthly
- Output: Table: Summary Reports
- Output Control: Table: Style

No Output: Meter or Output: Variable objects need to be specified to use the standard reports. The StandardReports.idf file in the DataSets directory of EnergyPlus provides a good set of sample reports.

This exercise is limited to creating basic summary reports in html format.

Instructions

1. Start IDF Editor > File > Open > 1.InfiltrationBaseFile.idf
2. Select Class List > Output Reporting > Output: Table: Summary Reports > New Object
   Enter the following data:

Report 1 Name	AnnualBuildingUtilityPerformanceSummary
Report 2 Name	EnvelopeSummary
Report 3 Name	InputVerificationandResultsSummary
Report 4 Name	ClimateDataSummary
Report 5 Name	EquipmentSummary

These basic reports allow for a quick analysis of the building's performance. More detailed reports can be selected from the pull-down menu.

3. Select > Class List > Output Reporting > Output Control: Table: Style > New Object
   Enter the following data:

Column Separator	HTML

   Other default styles include comma (which works well for importing data into spreadsheet programs such as Microsoft® Excel®), tab (for word processing programs), fixed, etc.
4. Save changes to base file.

The idf base file is now ready for infiltration data inputs.

DESIGN FLOW RATE MODEL

In this model, the user defines a design flow rate that can be modified by temperature differences and wind speed. The calculation method selected for this exercise is **Air Changes per Hour (ACH).**

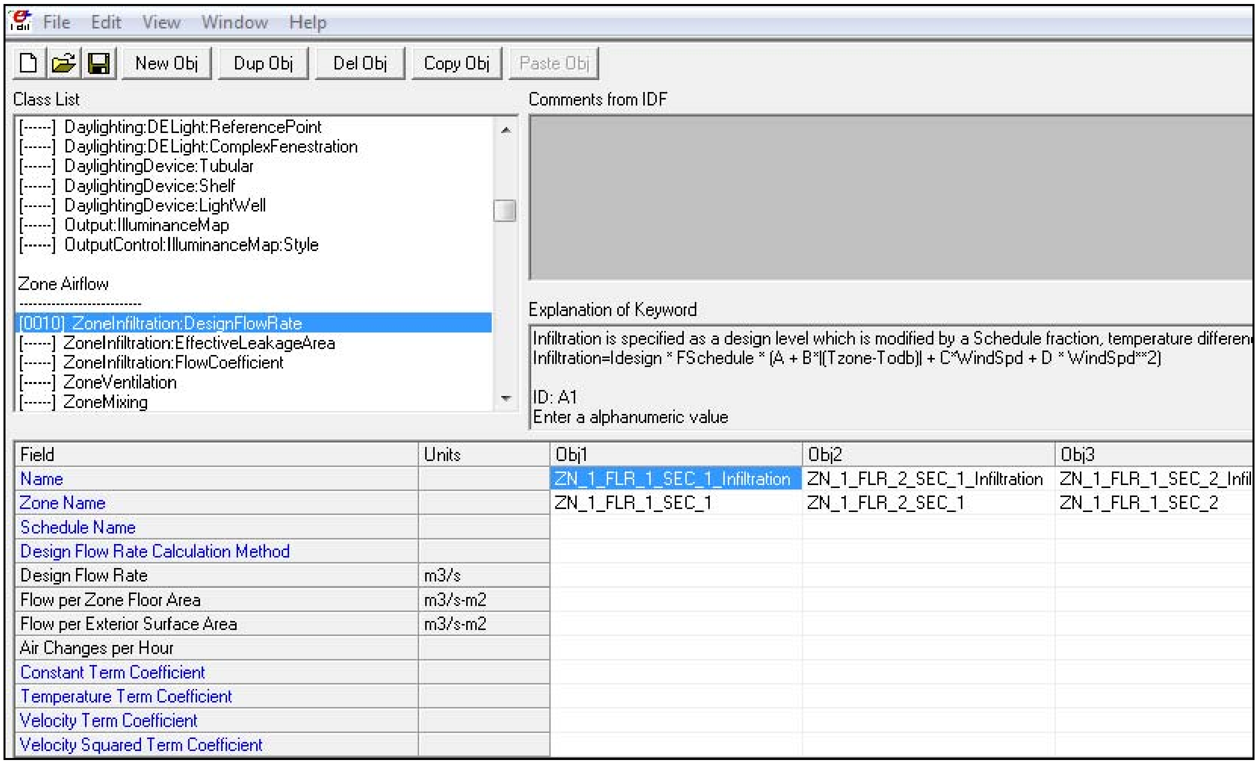
Two simulations are run to compare differences by assuming the ACH values to be **o.5ACH** and **1ACH.**

The schedule can be selected from a pull-down menu. The default values of EnergyPlus are used for the required coefficients (1, 0, 0, 0). This same data is entered for all 10 zones.

0.5ACH Model: Instructions

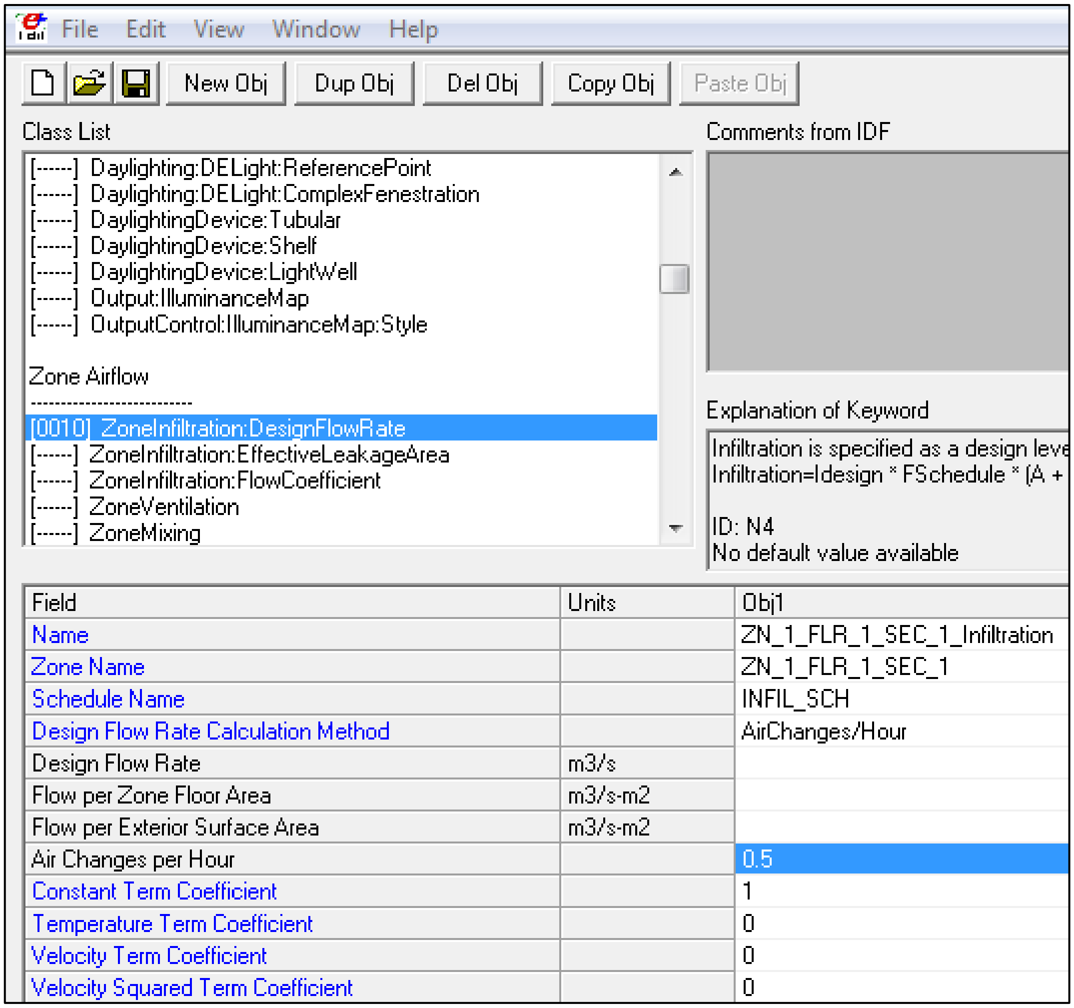
1. Start IDF Editor > File > Open > 1.InfiltrationBaseFile.idf
2. Save as 2.Infiltration_DesignFlowRate_0.5ACH.idf
3. Select Class List > Zone Airflow > Zone Infiltration: Design Flow Rate > New Object
   Create 10 new objects with the following names and zone names for each zone:

Object#	**Name**	**Zone Name**
Obj1	ZN_1_FLR_1_SEC_1_Infiltration	ZN_1_FLR_1_SEC_1
Obj2	ZN_1_FLR_2_SEC_1_Infiltration	ZN_1_FLR_2_SEC_1
Obj3	ZN_1_FLR_1_SEC_2_Infiltration	ZN_1_FLR_1_SEC_2
Obj4	ZN_1_FLR_2_SEC_2_Infiltration	ZN_1_FLR_2_SEC_2
Obj5	ZN_1_FLR_1_SEC_3_Infiltration	ZN_1_FLR_1_SEC_3
Obj6	ZN_1_FLR_2_SEC_3_Infiltration	ZN_1_FLR_2_SEC_3
Obj7	ZN_1_FLR_1_SEC_4_Infiltration	ZN_1_FLR_1_SEC_4
Obj8	ZN_1_FLR_2_SEC_4_Infiltration	ZN_1_FLR_2_SEC_4
Obj9	ZN_1_FLR_1_SEC_5_Infiltration	ZN_1_FLR_1_SEC_5
Obj10	ZN_1_FLR_2_SEC_5_Infiltration	ZN_1_FLR_2_SEC_5

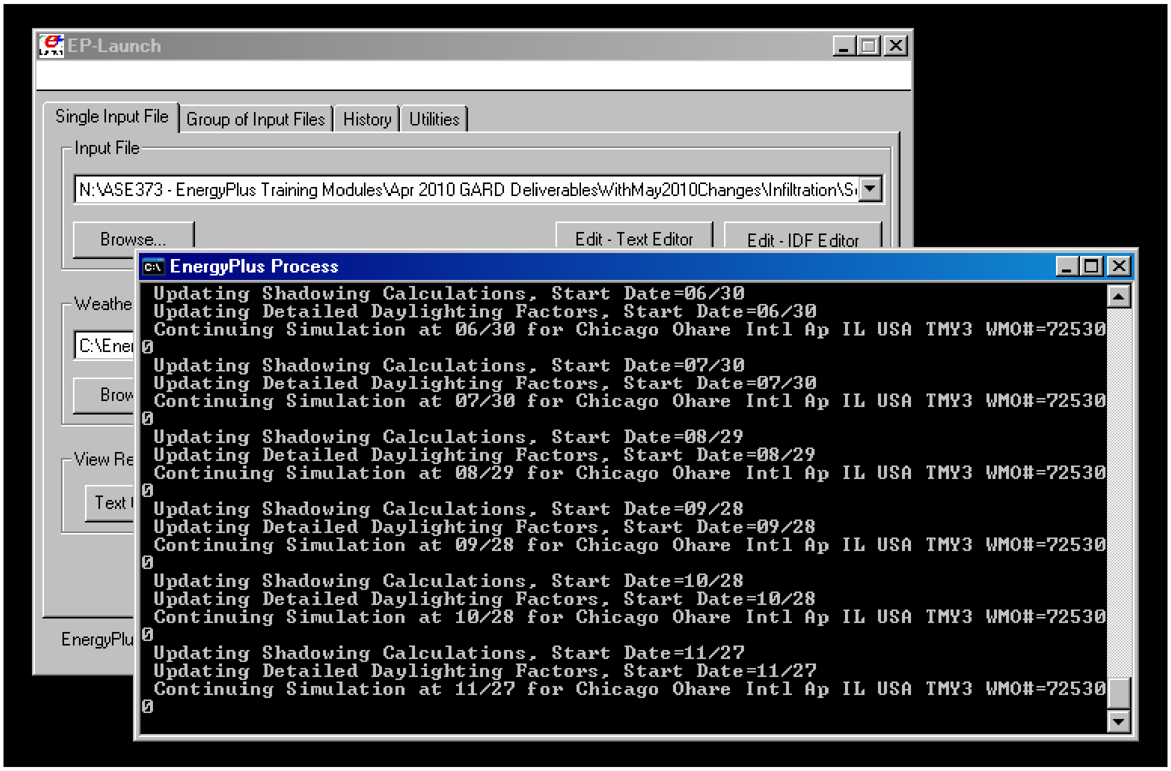


4. Enter the following data for all 10 zones:

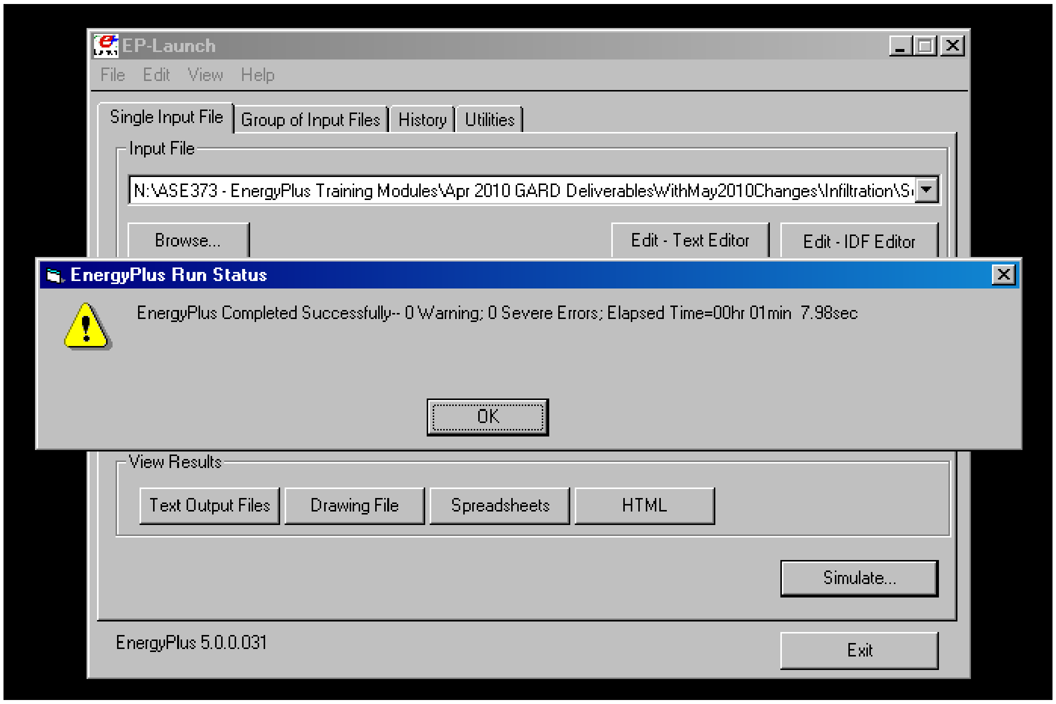
Schedule Name	INFIL_SCH
Design Flow Rate Calculation Method	Air Changes/Hour
Air Changes per Hour	0.5
Constant Term Coefficient	1
Temperature Term Coefficient	0
Velocity Term Coefficient	0
Velocity Squared Term Coefficient	0



5. Save changes. The file is now ready to simulate.
   Start > EP-Launch > Input file > Browse > Select
   2.Infiltration_DesignFlowRate_0.5ACH.idf from its destination folder.
6. Weather File > Browse > C:\EnergyPlusV5-0-0\WeatherData\USA_IL_Chicago-OHare.Intl.AP.725300_TMY3.epw
7. Simulate



Simulation in Progress



Simulation Completed

Program Version:**EnergyPlus 5.0.0.031, 5/19/2010 2:31 PM**

Tabular Output Report in Format: **HTML**

Building: **2StoryOfficeBuilding**

Environment: **Chicago Ohare Intl Ap IL USA TMY3 WMO#=725300**

Simulation Timestamp: **2010-05-19 14:31:23**

Report: **AnnualBuildingUtilityPerformanceSummary**

For: **Entire Facility**

Timestamp: **2010-05-19 14:31:23**

Values gathered over 8760.00 hours

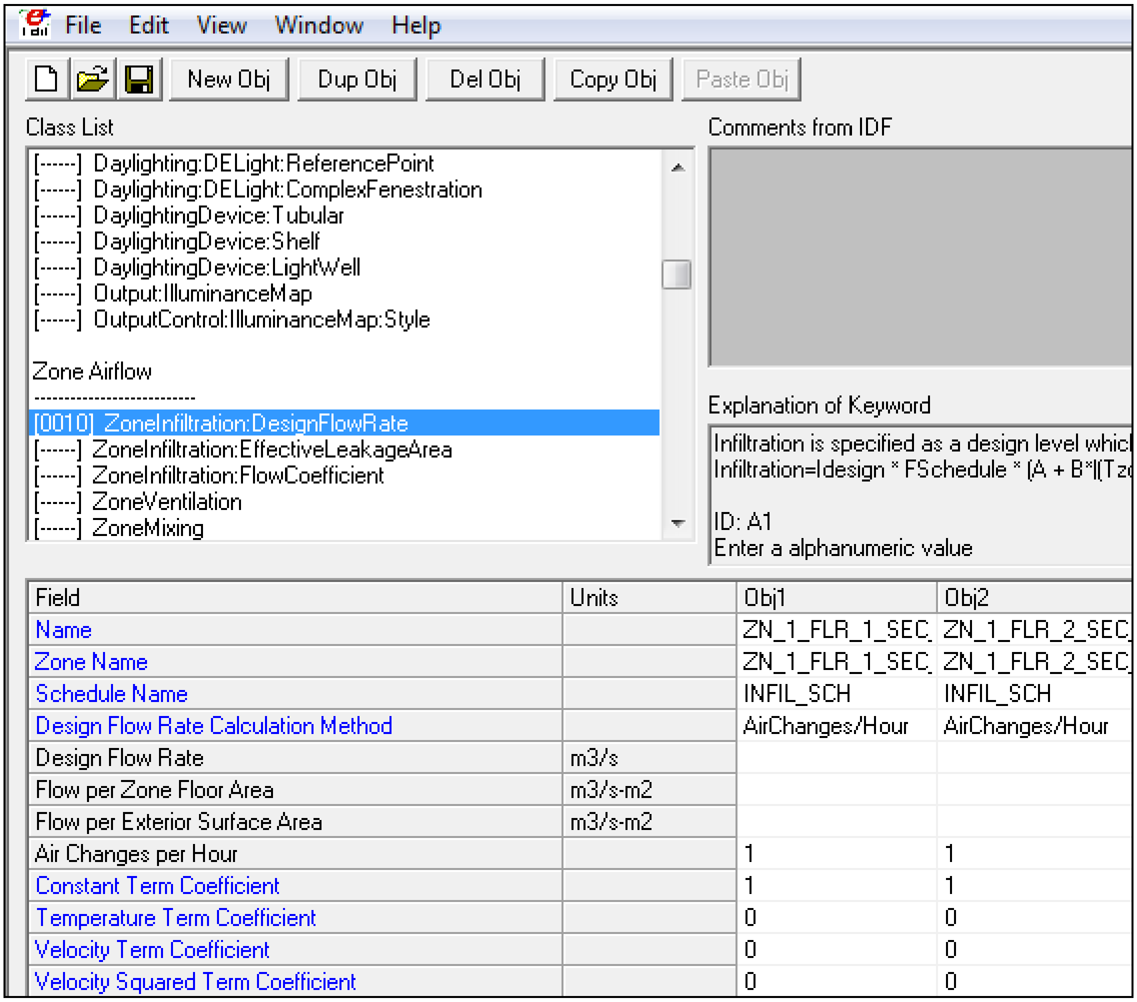
Site and Source Energy

	Total Energy [GJ]	Energy Per Total Building Area [MJ/m2]	Energy Per Conditioned Building Area [MJ/m2]
Total Site Energy	433.92	467.81	467.81
Net Site Energy	433.92	467.81	467.81
Total Source Energy	806.31	869.30	869.30
Net Source Energy	806.31	869.30	869.30

Sample Image of HTML Output

1ACH Model: Instructions

1. Start IDF Editor > File > Open > 2.Infiltration_DesignFlowRate_0.5ACH.idf
2. Save as 3.Infiltration_DesignFlowRate_1ACH.idf
3. Select Class List > Zone Airflow > Zone Infiltration: Design Flow Rate
   Change Air Changes per Hour Value for all 10 objects from **0.5** to **1**

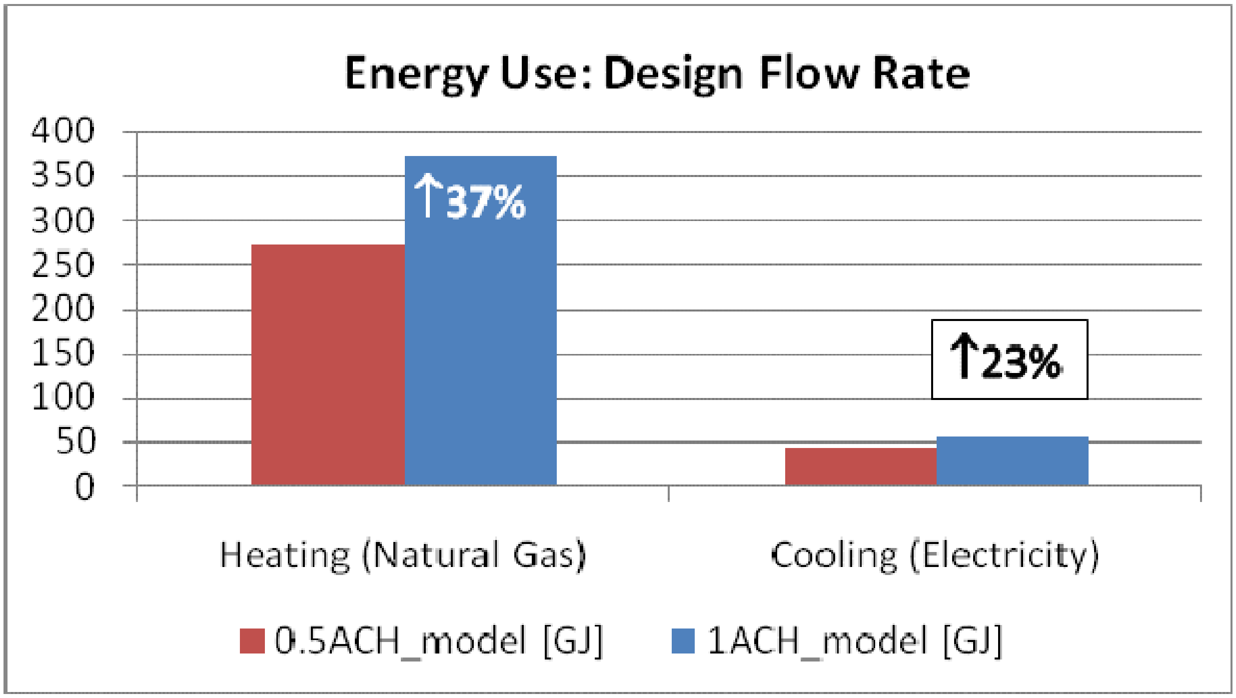


4. Save changes. The file is ready to simulate
   Start > EP-Launch > Input file > Browse > Select
   3.Infiltration_DesignFlowRate_1ACH.idf from its destination folder.
5. Weather File > Browse > C:\EnergyPlusV5-0-0\WeatherData\USA_IL_Chicago-OHare.Intl.AP.725300_TMY3.epw
6. Simulate

RESULTS

Energy End-Use Comparison

The output graphs are created from the data in the END USES Table in the Annual Building Utility Performance Summary Report.



	0.5ACH_model [GJ]	1ACH_model [GJ]
Heating (Natural Gas)	272.64	372.79
Cooling (Electricity)	44.96	55.31

EFFECTIVE LEAKAGE AREA MODEL

The Effective Leakage Area model is based on Sherman and Grimsrud (1980) and accessed using the Zone Infiltration: Effective Leakage Area input object. The model formulation used in EnergyPlus is from the ASHRAE Handbook (2001 Chapter 26; 2005 Chapter 27), where it is referred to as the “Basic” model.

We need to find Effective Leakage Area = A_L for all zones to use this method. This exercise uses the accompanying spreadsheet to calculate A_L for each zone.

The spreadsheet uses data from the 1997 ASHRAE Handbook-Fundamentals, Chapter 25, Table 3 to calculate **minimum and maximum effective leakage areas** based on user inputs of component data.

Note:
This method of finding A_L can be wildly inaccurate, so use it with caution.

Note:
ASHRAE removed the table with component values from the handbook in 2005, so look at a 2001 or earlier handbook for additional components. Check units to see if you scale entry by area of component or the component edge lengths, or if value is per component

Spreadsheet Input

The user needs to calculate the following data (in IP Units) for each zone to enter into the spreadsheet in the respective zone tables:

- Doors: number, area.
- Windows: areas, frame perimeters
- Exterior wall areas
- Joint Lengths: ceiling-floor, floor-wall

It is easier to use Google SketchUp™ to view the building zones and measure the component data to feed into the spreadsheet.

OpenStudio is a free plugin for the Google SketchUp 3D drawing program. The plugin makes it easy to view and measure the building geometry in the EnergyPlus input files.

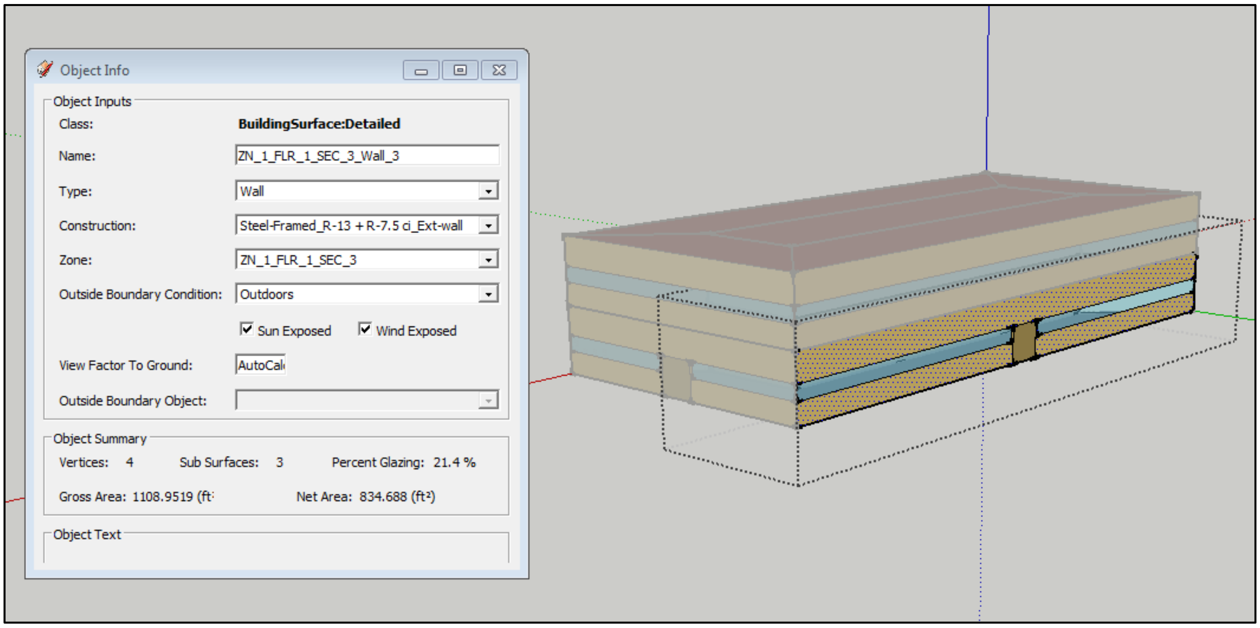


Image showing EnergyPlus object data in Google SketchUp using the OpenStudio Plugin

The following data was measured from the building to enter into the spreadsheet:

	ZN_1_FLR_1_SEC_1 ZN_1_FLR_1_SEC_3	ZN_1_FLR_1_SEC_2 ZN_1_FLR_1_SEC_4	ZN_1_FLR_2_SEC_1 ZN_1_FLR_2_SEC_3	ZN_1_FLR_2_SEC_2 ZN_1_FLR_2_SEC_4	ZN_1_FLR_1_SEC_5 ZN_1_FLR_2_SEC_5	Units
Door Frame	1	1	0	0	0	ea
Door Double	36.4154	36.4154	0	0	0	ft^2
Window Framing	237.85	100.42	255.0707	117.7064	0	ft^2
Window Double-	2498.125	91.21	217.55	105.22	0	lftc
Walls Sheathing	834.688	374.9063	853.8812	394.0907	0	ft^2
Ceiling-Wall	104.0625	48	104.0625	48	184.625	lftc
Floor-Wall Joint	104.0625	48	104.0625	48	184.625	lftc

Note:
Symmetry of the building zones on each floor allows us to use the same data for two zones.

This exercise involves simulation and comparison of energy usage based on **minimum** and **maximum** leakage areas calculated by the spreadsheet.

Stack Coefficient and Wind Coefficient values are calculated from the 2009 ASHRAE Handbook, Chapter 16, Tables 4-6, for a building height of 20 feet, Shelter Class 5.

1. Stack Coefficient = C_s = 0.0003625 $(L/s)^2/(cm^4.K)$
2. Wind Coefficient = C_w = 0.0000455 $(L/s)^2/[cm^4.(m/s)^2]$

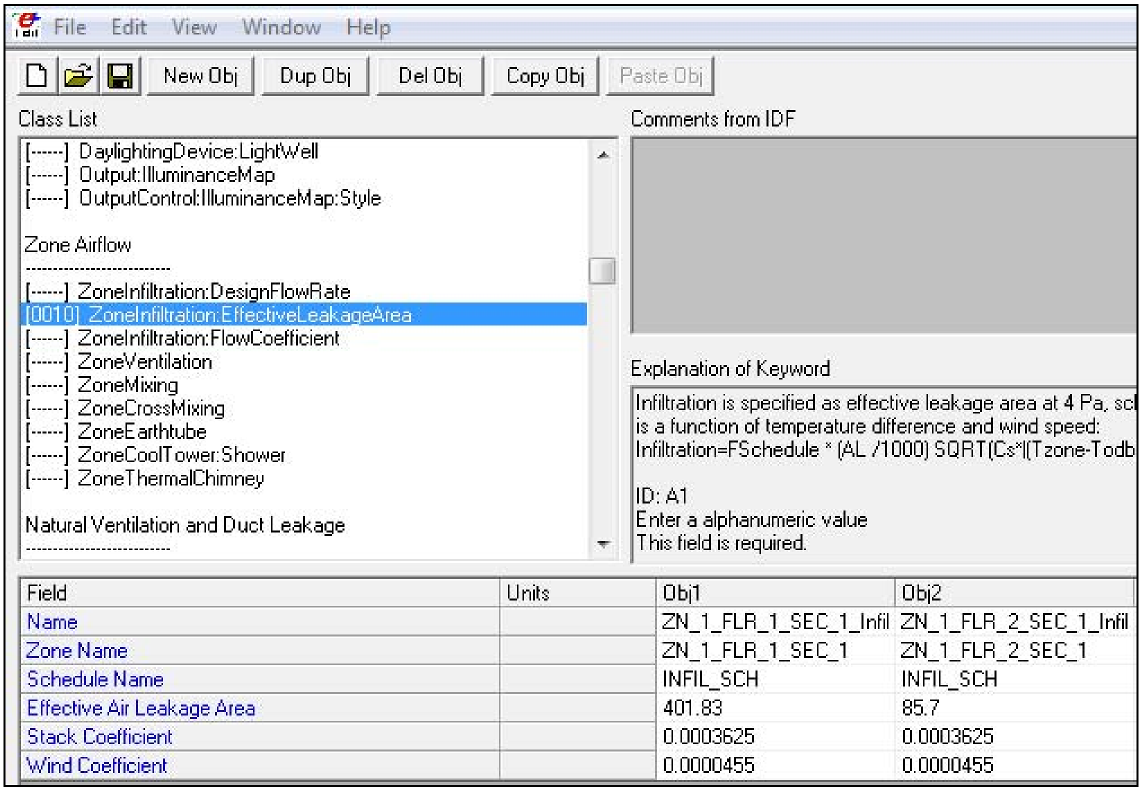
Minimum Leakage Area Model: Instructions

1. Start IDF Editor > File > Open > 1.InfiltrationBaseFile.idf
2. Save as 4.Infiltration_EffectiveLeakageArea_min.idf
3. Select Class List > Zone Airflow > Zone Infiltration: Effective Leakage Area > New Object
   Create 10 new objects with the following names and zone names for each zone:

Object#	**Name**	**Zone Name**	**Effective Air Leakage Area**
Obj1	ZN_1_FLR_1_SEC_1_Infiltration	ZN_1_FLR_1_SEC_1	401.83
Obj2	ZN_1_FLR_2_SEC_1_Infiltration	ZN_1_FLR_2_SEC_1	85.70
Obj3	ZN_1_FLR_1_SEC_2_Infiltration	ZN_1_FLR_1_SEC_2	48.58
Obj4	ZN_1_FLR_2_SEC_2_Infiltration	ZN_1_FLR_2_SEC_2	40.20
Obj5	ZN_1_FLR_1_SEC_3_Infiltration	ZN_1_FLR_1_SEC_3	401.83
Obj6	ZN_1_FLR_2_SEC_3_Infiltration	ZN_1_FLR_2_SEC_3	85.70
Obj7	ZN_1_FLR_1_SEC_4_Infiltration	ZN_1_FLR_1_SEC_4	48.58
Obj8	ZN_1_FLR_2_SEC_4_Infiltration	ZN_1_FLR_2_SEC_4	40.20
Obj9	ZN_1_FLR_1_SEC_5_Infiltration	ZN_1_FLR_1_SEC_5	13.22
Obj10	ZN_1_FLR_2_SEC_5_Infiltration	ZN_1_FLR_2_SEC_5	13.22

4. Enter the following data for all 10 zones:

Schedule Name	INFIL_SCH
Stack Coefficient	0.0003625
Wind Coefficient	0.0000455



5. Save changes. The file is now ready to simulate.
6. Start > EP-Launch > Input file > Browse > Select 4.Infiltration_EffectiveLeakageArea_min.idf from its destination folder.
7. Weather File > Browse > C:\EnergyPlusV5-0-0\WeatherData\USA_IL_Chicago-OHare.Intl.AP.725300_TMY3.epw
8. Simulate

Maximum Leakage Area Model: Instructions

1. Start IDF Editor > File > Open > 4.Infiltration_EffectiveLeakageArea_min.idf
2. Save as 5.Infiltration_EffectiveLeakageArea_max.idf
3. Select Class List > Zone Air Flow > Zone Infiltration: Effective Leakage Area
4. Enter the following Maximum Effective Leakage Area data changing the previous values:

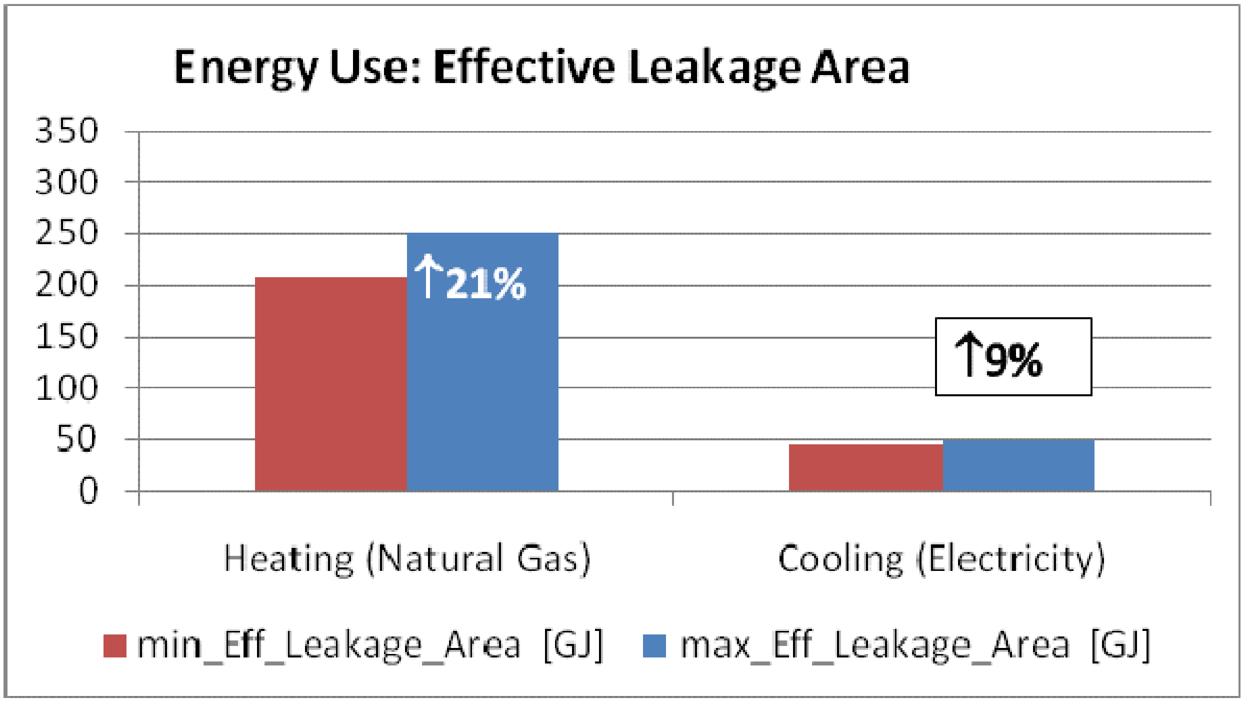
Object#	**Name**	**Zone Name**	**Effective Air Leakage Area**
Obj1	ZN_1_FLR_1_SEC_1_Infiltration	ZN_1_FLR_1_SEC_1	1059.79
Obj2	ZN_1_FLR_2_SEC_1_Infiltration	ZN_1_FLR_2_SEC_1	265.95
Obj3	ZN_1_FLR_1_SEC_2_Infiltration	ZN_1_FLR_1_SEC_2	218.62
Obj4	ZN_1_FLR_2_SEC_2_Infiltration	ZN_1_FLR_2_SEC_2	124.18
Obj5	ZN_1_FLR_1_SEC_3_Infiltration	ZN_1_FLR_1_SEC_3	1059.79
Obj6	ZN_1_FLR_2_SEC_3_Infiltration	ZN_1_FLR_2_SEC_3	265.95
Obj7	ZN_1_FLR_1_SEC_4_Infiltration	ZN_1_FLR_1_SEC_4	218.62
Obj8	ZN_1_FLR_2_SEC_4_Infiltration	ZN_1_FLR_2_SEC_4	124.18
Obj9	ZN_1_FLR_1_SEC_5_Infiltration	ZN_1_FLR_1_SEC_5	208.21
Obj10	ZN_1_FLR_2_SEC_5_Infiltration	ZN_1_FLR_2_SEC_5	208.21

5. Save changes. The file is now ready to simulate.
6. Start > EP-Launch > Input file > Browse > Select 5.Infiltration_EffectiveLeakageArea_max.idf from its destination folder.
7. Weather File > Browse > C:\EnergyPlusV5-0-0\WeatherData\USA_IL_Chicago-OHare.Intl.AP.725300_TMY3.epw
8. Simulate

RESULTS

Energy End Use Comparison

The output graphs are created from the data in the END USES Table in the Annual Building Utility Performance Summary Report.



	min_Eff_Leakage_Area [GJ]	**max_Eff_Leakage_Area [GJ]**
Heating (Natural Gas)	208.55	251.89
Cooling (Electricity)	44.28	48.40

FLOW COEFFICIENT MODEL

The Flow Coefficient model is based on Walker and Wilson (1998) and accessed using the Zone Infiltration: Flow Coefficient input object. The model formulation used in EnergyPlus is from the ASHRAE Handbook (2001 Chapter 26; 2005 Chapter 27), where it is referred to as the "Enhanced" or "AIM-2" model.

We need to calculate flow coefficients for all zones to use this method. This exercise uses the accompanying spreadsheet to calculate the flow coefficients using the minimum and maximum effective leakage areas calculated in the earlier exercise.

This exercise involves simulation and comparison of energy usage based on **minimum** and **maximum flow coefficients** calculated by the spreadsheet.

Stack coefficient, shelter factor and wind coefficient values are calculated from the 2009 ASHRAE Handbook, Chapter 16, Tables 6-9, for a building height of 20 feet, Shelter Class 5, no flue assumed.

1. Stack Coefficient = C_s = 0.088 $(Pa/K)^n$
2. Wind Coefficient = C_w = 0.17 $(Pa.s^2/m^2)^n$
3. Shelter Factor = s = 0.30
4. Pressure Exponent = 0.67 (default)

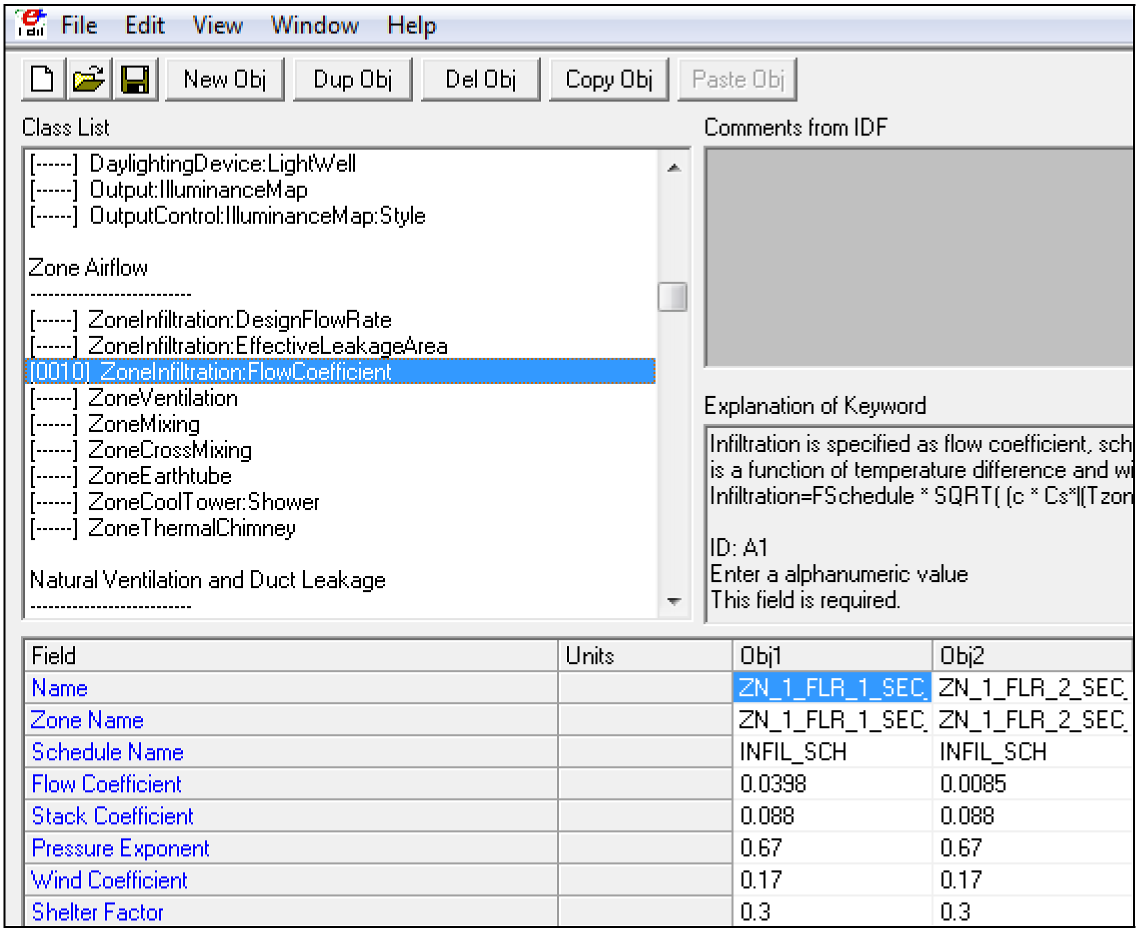
Flow Coefficient Model_Minimum: Instructions

1. Start IDF Editor > File > Open > 1.InfiltrationBaseFile.idf
2. Save as 6.Infiltration_FlowCoefficient_min.idf
3. Select Class List > Zone Airflow > Zone Infiltration: Flow Coefficient > New Object
   Create 10 new objects with the following data for each zone:

Object#	Name	Zone Name	Flow Coefficient
Obj1	ZN_1_FLR_1_SEC_1_Infiltration	ZN_1_FLR_1_SEC_1	0.0398
Obj2	ZN_1_FLR_2_SEC_1_Infiltration	ZN_1_FLR_2_SEC_1	0.0085
Obj3	ZN_1_FLR_1_SEC_2_Infiltration	ZN_1_FLR_1_SEC_2	0.0048
Obj4	ZN_1_FLR_2_SEC_2_Infiltration	ZN_1_FLR_2_SEC_2	0.0040
Obj5	ZN_1_FLR_1_SEC_3_Infiltration	ZN_1_FLR_1_SEC_3	0.0398
Obj6	ZN_1_FLR_2_SEC_3_Infiltration	ZN_1_FLR_2_SEC_3	0.0085
Obj7	ZN_1_FLR_1_SEC_4_Infiltration	ZN_1_FLR_1_SEC_4	0.0048
Obj8	ZN_1_FLR_2_SEC_4_Infiltration	ZN_1_FLR_2_SEC_4	0.0040
Obj9	ZN_1_FLR_1_SEC_5_Infiltration	ZN_1_FLR_1_SEC_5	0.0013
Obj10	ZN_1_FLR_2_SEC_5_Infiltration	ZN_1_FLR_2_SEC_5	0.0013

4. Enter the following data for all 10 zones:

Schedule Name	INFIL_SCH
Stack Coefficient	0.088
Pressure Exponent	0.67
Wind Coefficient	0.17
Shelter Factor	0.3



5. Save changes. The file is now ready to simulate.
6. Start > EP-Launch > Input file > Browse > Select 6.Infiltration_FlowCoefficient_min.idf from its destination folder.
7. Weather File > Browse > C:\EnergyPlusV5-0-0\WeatherData\USA_IL_Chicago-OHare.Intl.AP.725300_TMY3.epw
8. Simulate

Flow Coefficient Model_Maximum: Instructions

1. Start IDF Editor > File > Open > 6.Infiltration_FlowCoefficient_min.idf
2. Save as 7.Infiltration_ FlowCoefficient _max.idf
3. Select Class List > Zone Air Flow > Zone Infiltration: Flow Coefficient
4. Enter the following Flow Coefficient data changing the previous values:

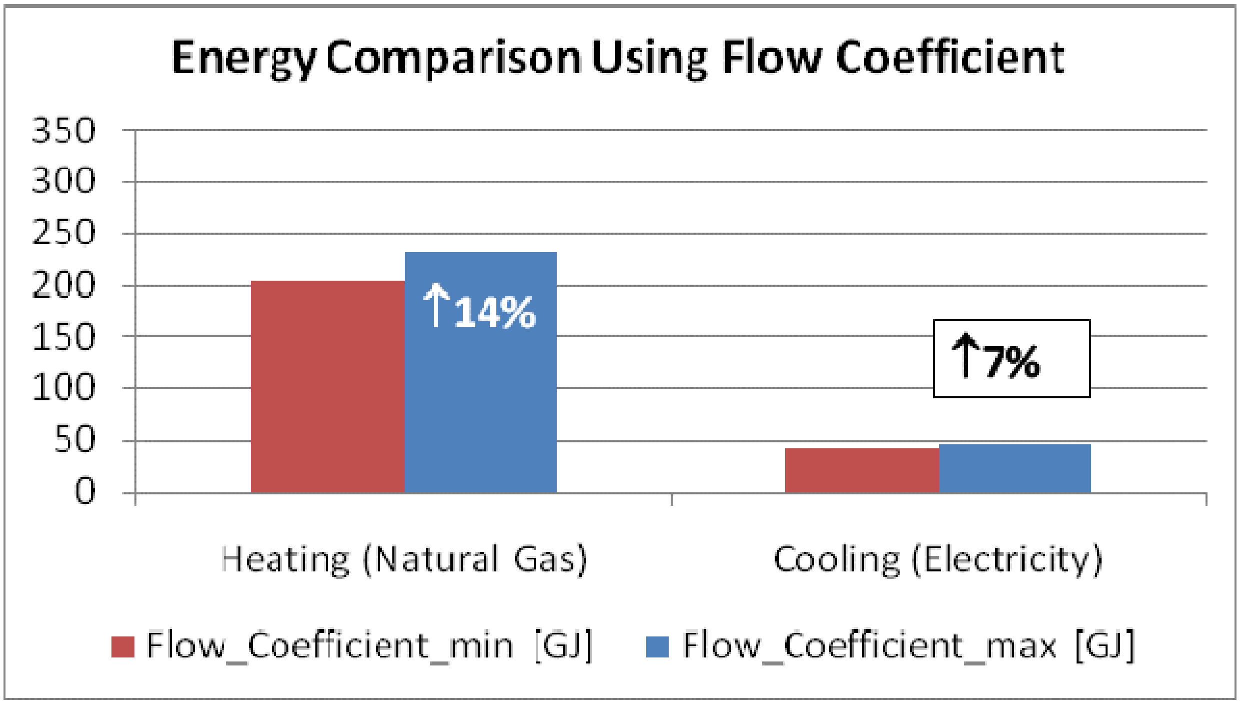
Object#	Name	Zone Name	Flow Coefficient
Obj1	ZN_1_FLR_1_SEC_1_Infiltration	ZN_1_FLR_1_SEC_1	0.1048
Obj2	ZN_1_FLR_2_SEC_1_Infiltration	ZN_1_FLR_2_SEC_1	0.0263
Obj3	ZN_1_FLR_1_SEC_2_Infiltration	ZN_1_FLR_1_SEC_2	0.0216
Obj4	ZN_1_FLR_2_SEC_2_Infiltration	ZN_1_FLR_2_SEC_2	0.0123
Obj5	ZN_1_FLR_1_SEC_3_Infiltration	ZN_1_FLR_1_SEC_3	0.1048
Obj6	ZN_1_FLR_2_SEC_3_Infiltration	ZN_1_FLR_2_SEC_3	0.0263
Obj7	ZN_1_FLR_1_SEC_4_Infiltration	ZN_1_FLR_1_SEC_4	0.0216
Obj8	ZN_1_FLR_2_SEC_4_Infiltration	ZN_1_FLR_2_SEC_4	0.0123
Obj9	ZN_1_FLR_1_SEC_5_Infiltration	ZN_1_FLR_1_SEC_5	0.0206
Obj10	ZN_1_FLR_2_SEC_5_Infiltration	ZN_1_FLR_2_SEC_5	0.0206

5. Save changes. The file is now ready to simulate.
6. Start > EP-Launch > Input file > Browse > Select 7.Infiltration_FlowCoefficient_max.idf from its destination folder.
7. Weather File > Browse > C:\EnergyPlusV5-0-0\WeatherData\USA_IL_Chicago-OHare.Intl.AP.725300_TMY3.epw
8. Simulate

RESULTS

Energy End-Use Comparison

The output graphs are created from the data in END USES Table in the Annual Building Utility Performance Summary Report.



	Flow_Coefficient_min [GJ]	Flow_Coefficient_max [GJ]
Heating (Natural Gas)	203.28	232.66
Cooling (Electricity)	44.02	47.10

This material is based upon work supported by the U.S. Department of Energy under Award Number DE-FG26-07NT43330 to the Alliance to Save Energy.