SHADEFEN EP_C and EP_H calculation specification

Calculation of EP_C and EP_H is based on energy simulation of a typical residential building (house) in Houston and Minneapolis climates, respectively. Energy simulation is done for three different cases:

A. Typical house with windows replaced by adiabatic surfaces (i.e., zero heat flux through window surfaces)
B. Typical house with baseline windows
S. Typical house with baseline windows and window shade/attachment over them

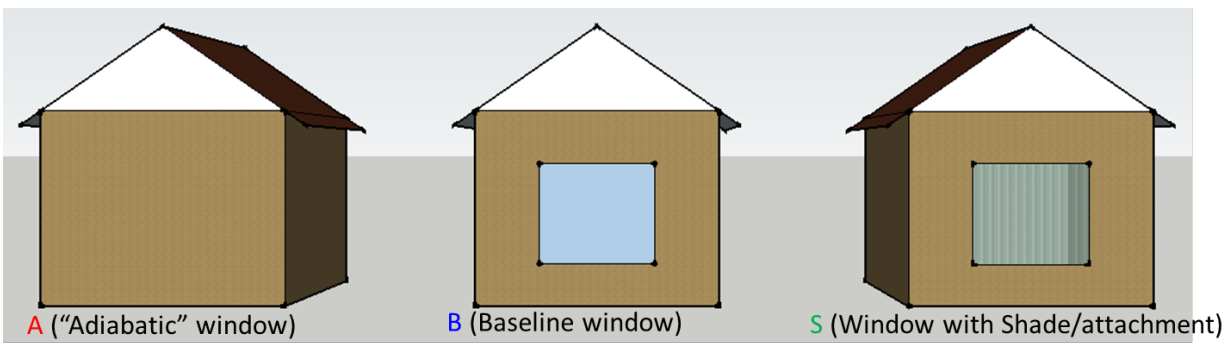


Figure 1. Schematic of three different house models

Energy simulation is done over the typical TMY3 year for each location and results of energy for each case are expressed as:

E_A: annual HVAC cooling or heating energy use of the house with "adiabatic" window
E_B: annual HVAC cooling or heating energy use of the house with baseline window only
E_S: annual HVAC cooling or heating energy use of the house with window attachment.

$E_{B-A}= E_B- E_A$, annual energy use caused by the baseline window
$E_{S-A}= E_S- E_A$, annual energy use caused by the baseline window with attachment
$E_{B-S}= E_B- E_S$, window attachment energy savings from the baseline window

Details about energy use calculation are provided in Section 2. Details of EP calculations are provided in Section 2.3

Typical house is defined from the DOE standard residential building model, combining several building vintages into a single typical house. The listing of assumptions is detailed in Appendix A.

Energy plus runs for both *Baseline* and *Adiabatic* runs are performed once for each climate, making for four sets of results (two for heating and two for cooling EP) and saved as fixed information in SHADEFEN that does not need to be rerun again.

EnergyPlus model for the house with baseline windows is run using Autosize option for HVAC. This is done once for cooling and once for heating climates. Such calculated HVAC size is then

fixed for all subsequent runs, including adiabatic and attachment cases. Baseline windows run is detailed in section 1.1.

EnergyPlus model of a house with window attachment is run at least once per product for fixed attachments (i.e., window panels, solar screens, surface-attached films), two times for 1-D operation shades (e.g., roller shades, cellular shades, pleated shades, roman shades, etc.), where one run is for shade fully closed and second run is for shade half closed (fully retracted option is identical to baseline window); and 7 runs for 2-D operation shades (venetian blinds, vertical blinds, etc.). More details are provided in section 1.3.

1. EnergyPlus Runs

Energy analysis is done using EnergyPlus simulation tool and IDF input file for EnergyPlus simulation is created from the collection of include files (*.inc). The reason for splitting IDF files in several include files is that for different runs, only individual include file would be replaced. The list of include files below are marked in green, yellow, and red, signifying common include files that are used in each of EnergyPlus runs(green), specific include files that are used in each of following cases, but are unchanged (yellow), and specific include files that are changed on the fly by SHADEFEN (red). More details about include files are provided in Appendix C.

Besides IDF files for each run, SHADEFEN also needs to provide weather data file (TMY3 file). EnergyPlus runs are done for two climate locations, Houston for Cooling and Minneapolis for Heating, so their TMY3 files need to be used for each of those runs. The weather data file names for these two climates are listed below:

- USA_TX_Houston-Bush.Intercontinental.AP.722430_TMY3.epw (for Houston)
- USA_MN_Minneapolis-St.Paul.Intl.AP.726580_TMY3.epw (for Minneapolis)

1.1 Adiabatic Windows Run

The include files needed for adiabatic windows run are listed below.

Houston:

- AERC_Base_Building_Houston.inc
- Air_infiltration_adiabatic_Houston.inc
- System_sizing_Houston.inc

Minneapolis:

- AERC_Base_Building_Minneapolis.inc
- Air_infiltration_adiabatic_Minneapolis.inc
- System_sizing_Minneapolis.inc

Both climate zones:

- Window_configuration.inc
- Window_construction_adiabatic.inc

1.2 Baseline Windows Run

For the baseline window run, the following include files are provided.

Houston:

- AERC_Base_Building_Houston.inc
- Air_infiltration_baseline_Houston.inc
- System_autosize_Houston.inc

Minneapolis:

- AERC_Base_Building_Minneapolis.inc
- Air_infiltration_baseline_Minneapolis.inc
- System_autosize_Minneapolis.inc

Both climate zones:

- Window_configuration.inc
- Window_construction_baseline.inc

1.3 Windows with Attachments

Window construction include files for windows with attachments are generated from the WINDOW files that were created for each window attachment and imported into SHADFEN. While most of window attachments have single degree of freedom in operation (retraction operation only) or 0 degree of freedom (fixed window attachments) and therefore have single construction description for its deployed position, some attachments have 2 degrees of freedom (e.g., louvered shades), resulting in 4 window construction records:

1) horizontal slats, or 0 deg
2) closed slats, or 90 deg
3) -45 deg
4) 45 deg

Depending on the degree of freedom for window attachments, different number of EnergyPlus runs will be required. Table 1 gives summary for each window attachment class/type.

Table 1. Simulation runs of different deployment situations of each shade

Shade Type	Degrees of freedom	Fully Deployed (top & bottom window w/ shade)	Half Deployed (only top window w/ shade)	Total runs
Roller shades	1	1 run	1 run	2
Cellular shades	1	1 run	1 run	2
Solar Screens	0	1 run	--	1
Applied Films	0	1 run	--	1
Venetian Blinds	2	4 runs	3 runs	7
Vertical Blinds	2	4 runs	3 runs	7
Window panels	0	1 run	--	1

Pleated Shades	1	1 run	1 run	2

1.3.1. Fully Deployed Window Attachments Runs

The include files needed for fully deployed window attachments run are listed below.

Houston:

- AERC_Base_Building_Houston.inc
- Air_infiltration_user_input_Houston.inc (see Appendix C for values)
- System_sizing_Houston.inc

Minneapolis:

- AERC_Base_Building_Minneapolis.inc
- Air_infiltration_user_input_Minneapolis.inc (see Appendix C for values)
- System_sizing_Minneapolis.inc

Both climate zones:

- Window_configuration.inc
- Window_construction_user_input.inc (except for louvered blinds)
  Louvered blinds:
  - ✓ Window_ construction_user_input0.inc
  - ✓ Window_ construction_user_input90.inc
  - ✓ Window_ construction_user_input-45.inc
  - ✓ Window_ construction_user_input+45.inc

Same configuration file is used for each window construction, substituting name of construction in each run. This can be done by parametrizing variable.

1.3.2 Half-Deployed Window Attachments Runs

The include files needed for half-deployed window attachments run are listed below.

Houston:

- AERC_Base_Building_Houston.inc
- Air_infiltration_baseline_Houston.inc
- System_sizing_Houston.inc

Minneapolis:

- AERC_Base_Building_Minneapolis.inc
- Air_infiltration_baseline_Minneapolis.inc
- System_sizing_Minneapolis.inc

Both climate zones:

- Window_configuration.inc

- Window_construction_baseline.inc
- Window_construction_user_input.inc (except for louvered blinds)
  Louvered blinds:
  - ✓ Window_ construction_user_input90.inc
  - ✓ Window_ construction_user_input-45.inc
  - ✓ Window_ construction_user_input+45.inc

Same configuration file is used for each window construction, substituting name of construction in each run. This can be done by parametrizing variable.

2. Calculation of Energy Use (ESCalc Module)

The energy use is calculated in a separate module, using the procedures detailed in this section[1]. The following energy quantities are calculated and used in the calculation of EP:

- E_A = annual HVAC cooling or heating energy use of the house with "adiabatic" window
- E_B = annual HVAC cooling or heating energy use of the house with baseline window only
- E_S = annual HVAC cooling or heating energy use of the house with window attachment.

Energy use for each case is calculated from HVAC system results of EnergyPlus simulation. Instructions for generating correct output results are provided in include file EP_Output_Fields.inc, shown in Appendix B. Results are stored in IDF_input_file_name.csv file. The following output fields are used in calculation of energy use:

Houston:

- "CENTRAL SYSTEM_UNIT1: Air System DX Cooling Coil Electric Energy [J](Hourly)"
- "CENTRAL SYSTEM_UNIT1:Air System Fan Electric Energy [J](Hourly)".

Minneapolis:

- "CENTRAL SYSTEM_UNIT1: Air System Gas Energy [J](Hourly)"
- "CENTRAL SYSTEM_UNIT1:Air System Fan Electric Energy [J](Hourly)".

For brevity and subsequent use in equations, the following nomenclature will be used:

$E_{DX\ Coil}(\tau_h)$ = CENTRAL SYSTEM_UNIT1: Air System DX Cooling Coil Electric Energy [J](Hourly)

$E_{Fan}(\tau_h)$ = CENTRAL SYSTEM_UNIT1:Air System Fan Electric Energy [J](Hourly)

$E_{Gas}(\tau_h)$ = CENTRAL SYSTEM_UNIT1: Air System Gas Energy [J](Hourly)

Total energy, required for the calculation of E_A, E_B, and E_S is calculated by summing up all hours when cooling system is on (CS=ON) in Houston and when heating system is on (HS=ON) in Minneapolis. "CS=ON" when "CENTRAL SYSTEM_UNIT1: Air System DX Cooling Coil Electric Energy [J](Hourly)", is larger than 0. Correspondingly, "HS=ON" when "CENTRAL

[1] The calculation method described here is a slight modification of the implemented procedure in ESCalc, which is described as presented here because of clarity.

SYSTEM_UNIT1: Air System Gas Energy [J](Hourly)", is larger than 0. The energy totals are also corrected to source energy using following conversion factors:

SF_E = conversion factor from electricity to source energy in GJ, $3.167 \cdot 10^{-9}$

SF_G = conversion factor from natural gas to source energy in GJ, $1.084 \cdot 10^{-9}$

2.1 Adiabatic Windows Runs

The energy use for adiabatic window runs are calculated from output of EnergyPlus simulation for adiabatic window case and normalized using source energy correction, which is applied to selected energy contributions.

Houston:

$$E_A = \left(\sum_{CS=ON} E_{DXCoil}(\tau_h)_A + \sum_{CS=ON} E_{Fan}(\tau_h)_A \right) \cdot SF_E$$

Minneapolis:

$$E_A = \left(\sum_{HS=ON} E_{Gas}(\tau_h)_A \right) \cdot SF_G + \left(\sum_{HS=ON} E_{Fan}(\tau_h)_A \right) \cdot SF_E$$

The resulting energy use E_A is expressed in GJ of source energy. E_A for both locations is calculated once and saved for the calculation of EP. The pre-calculated values for E_A are:

Houston: E_A = 58.707 GJ

Minneapolis: E_A = 90.085 GJ

2.2 Baseline Windows Runs

The energy use for baseline window runs are calculated from output of EnergyPlus simulation for baseline window case and normalized using source energy correction, which is applied to selected energy contributions.

Houston:

$$E_B = \left(\sum_{CS=ON} E_{DXCoil}(\tau_h)_B + \sum_{CS=ON} E_{Fan}(\tau_h)_B \right) \cdot SF_E$$

Minneapolis:

$$E_B = \left(\sum_{HS=ON} E_{Gas}(\tau_h)_B \right) \cdot SF_G + \left(\sum_{HS=ON} E_{Fan}(\tau_h)_B \right) \cdot SF_E$$

The resulting energy use E_B is expressed in GJ of source energy. E_B for both locations is calculated once and saved for the calculation of EP. The pre-calculated values for E_B are:

Houston: E_B = 124.417 GJ

Minneapolis: E_B = 130.355 GJ

2.2 Windows with Attachments Runs

Energy uses for windows with attachments are done on demand for each attachment for which EP is calculated. Depending on the attachment type, different level of calculation is done. Details of these calculations for different attachment types are provided below.

2.2.1 Fixed Attachments

For fixed attachments (i.e., non-operable), single and non-weighted calculation is done, similar to cases of adiabatic and baseline window energy use calculations:

Houston:

$$E_S = \left(\sum_{CS=ON} E_{DXCoil}\left(\tau_h\right)_S + \sum_{CS=ON} E_{Fan}\left(\tau_h\right)_S \right) \cdot SF_E$$

Minneapolis:

$$E_S = \left(\sum_{HS=ON} E_{Gas}\left(\tau_h\right)_S \right) \cdot SF_G + \left(\sum_{HS=ON} E_{Fan}\left(\tau_h\right)_S \right) \cdot SF_E$$

The resulting energy use E_S is expressed in GJ of source energy.

2.2.2 Operable Window Attachments with 1-D operation

For these window attachment types, the operation consists of attachment retraction to various degrees. The deployment schedule for operable window attachments, was developed from the results of a behavioral study (DRI 2013). Based on the results of the survey of 2,467 households in 12 markets, a deployment schedule was developed for 3 periods during the day, two periods during the week, and for two seasons. The behavioral study considered three different attachment deployments and identified the percentage of products that were in one of these three positions at different times of day, week and season.

The deployment positions of window attachments considered were:

1. **O:** Open (Baseline window runs)
2. **H:** Half-Open (Half-Deployed window attachment runs)
3. **C:** Closed (Fully-Deployed window attachment runs)

The periods of day considered were:

1. **M:** Morning, including work hours (6:00 a.m. to 12:00 p.m.)
2. **A:** Afternoon (12:00 p.m. to 6:00 p.m.)
3. **N:** Evening/Night (6:00 p.m. to 6.00 a.m. of next day)

The periods of week considered were:

1. **D:** Weekday
2. **E:** Weekend and holidays

Note: Each weather data file contains standard US holidays, which are assigned the weekend schedule in the EnergyPlus input.

Time-weighting of energy use is done in addition to the consideration when cooling or heating system is on, to calculate E_S. In order to describe the weighting calculation methodology, indices for hourly, daily, and weekly periods are used. Hourly energy values are labeled using τ_h. Different day in a week (i.e., weekday vs. weekends and holidays) is labeled using index τ_d, and different week in a season is labeled using index τ_w. Using this notation, the following equations are used to calculate weighted source energy use from operable window shades with 1 degree of freedom:

$$E_S = E_O + E_H + E_C \tag{1}$$

Where:

$$E_O = \sum_{\tau_w=S_1}^{S_N} \left(E_{SDO}(\tau_w) + E_{SEO}(\tau_w) \right) + \sum_{\tau_w=W_1}^{W_N} \left(E_{WDO}(\tau_w) + E_{WEO}(\tau_w) \right) \tag{2}$$

$$E_H = \sum_{\tau_w=S_1}^{S_N} \left(E_{SDH}(\tau_w) + E_{SEH}(\tau_w) \right) + \sum_{\tau_w=W_1}^{W_N} \left(E_{WDH}(\tau_w) + E_{WEH}(\tau_w) \right) \tag{3}$$

$$E_C = \sum_{\tau_w=S_1}^{S_N} \left(E_{SDC}(\tau_w) + E_{SEC}(\tau_w) \right) + \sum_{\tau_w=W_1}^{W_N} \left(E_{WDC}(\tau_w) + E_{WEC}(\tau_w) \right) \tag{4}$$

Where (Equations 5-16):

$$E_{SDO}(\tau_w) = \sum_{\tau_d=1}^{5} \left(F_{SDMO} \cdot \sum_{\tau_h=6}^{12} E_O(\tau_w,\tau_d,\tau_h) + F_{SDAO} \cdot \sum_{\tau_h=12}^{18} E_O(\tau_w,\tau_d,\tau_h) + F_{SDNO} \cdot \sum_{\tau_h=18}^{6(+1day)} E_O(\tau_w,\tau_d,\tau_h) \right)$$

$$E_{SEO}(\tau_w) = \sum_{\tau_d=6}^{7} \left(F_{SEMO} \cdot \sum_{\tau_h=6}^{12} E_O(\tau_w,\tau_d,\tau_h) + F_{SEAO} \cdot \sum_{\tau_h=12}^{18} E_O(\tau_w,\tau_d,\tau_h) + F_{SENO} \cdot \sum_{\tau_h=18}^{6(+1day)} E_O(\tau_w,\tau_d,\tau_h) \right)$$

$$E_{WDO}(\tau_w) = \sum_{\tau_d=1}^{5} \left(F_{WDMO} \cdot \sum_{\tau_h=6}^{12} E_O(\tau_w,\tau_d,\tau_h) + F_{WDAO} \cdot \sum_{\tau_h=12}^{18} E_O(\tau_w,\tau_d,\tau_h) + F_{WDNO} \cdot \sum_{\tau_h=18}^{6(+1day)} E_O(\tau_w,\tau_d,\tau_h) \right)$$

$$E_{WEO}(\tau_w) = \sum_{\tau_d=6}^{7} \left(F_{WEMO} \cdot \sum_{\tau_h=6}^{12} E_O(\tau_w,\tau_d,\tau_h) + F_{WEAO} \cdot \sum_{\tau_h=12}^{18} E_O(\tau_w,\tau_d,\tau_h) + F_{WENO} \cdot \sum_{\tau_h=18}^{6(+1day)} E_O(\tau_w,\tau_d,\tau_h) \right)$$

$$E_{SDH}(\tau_w) = \sum_{\tau_d=1}^{5} \left(F_{SDMH} \cdot \sum_{\tau_h=6}^{12} E_H(\tau_w,\tau_d,\tau_h) + F_{SDAH} \cdot \sum_{\tau_h=12}^{18} E_H(\tau_w,\tau_d,\tau_h) + F_{SDNH} \cdot \sum_{\tau_h=18}^{6(+1day)} E_H(\tau_w,\tau_d,\tau_h) \right)$$

$$E_{SEH}(\tau_w)=\sum_{\tau_d=6}^{7}\left(F_{SEMH}\cdot\sum_{\tau_h=6}^{12}E_H\left(\tau_w,\tau_d,\tau_h\right)+F_{SEAH}\cdot\sum_{\tau_h=12}^{18}E_H\left(\tau_w,\tau_d,\tau_h\right)+F_{SENH}\cdot\sum_{\tau_h=18}^{6(+1day)}E_H\left(\tau_w,\tau_d,\tau_h\right)\right)$$

$$E_{WDH}(\tau_w)=\sum_{\tau_d=1}^{5}\left(F_{WDMH}\cdot\sum_{\tau_h=6}^{12}E_H\left(\tau_w,\tau_d,\tau_h\right)+F_{WDAH}\cdot\sum_{\tau_h=12}^{18}E_H\left(\tau_w,\tau_d,\tau_h\right)+F_{WDNH}\cdot\sum_{\tau_h=18}^{6(+1day)}E_H\left(\tau_w,\tau_d,\tau_h\right)\right)$$

$$E_{WEH}(\tau_w)=\sum_{\tau_d=6}^{7}\left(F_{WEMH}\cdot\sum_{\tau_h=6}^{12}E_H\left(\tau_w,\tau_d,\tau_h\right)+F_{WEAH}\cdot\sum_{\tau_h=12}^{18}E_H\left(\tau_w,\tau_d,\tau_h\right)+F_{WENH}\cdot\sum_{\tau_h=18}^{6(+1day)}E_H\left(\tau_w,\tau_d,\tau_h\right)\right)$$

$$E_{SDC}(\tau_w)=\sum_{\tau_d=1}^{5}\left(F_{SDMC}\cdot\sum_{\tau_h=6}^{12}E_C\left(\tau_w,\tau_d,\tau_h\right)+F_{SDAC}\cdot\sum_{\tau_h=12}^{18}E_C\left(\tau_w,\tau_d,\tau_h\right)+F_{SDNC}\cdot\sum_{\tau_h=18}^{6(+1day)}E_C\left(\tau_w,\tau_d,\tau_h\right)\right)$$

$$E_{SEC}(\tau_w)=\sum_{\tau_d=6}^{7}\left(F_{SEMC}\cdot\sum_{\tau_h=6}^{12}E_C\left(\tau_w,\tau_d,\tau_h\right)+F_{SEAC}\cdot\sum_{\tau_h=12}^{18}E_C\left(\tau_w,\tau_d,\tau_h\right)+F_{SENC}\cdot\sum_{\tau_h=18}^{6(+1day)}E_C\left(\tau_w,\tau_d,\tau_h\right)\right)$$

$$E_{SWC}(\tau_w)=\sum_{\tau_d=1}^{5}\left(F_{WDMC}\cdot\sum_{\tau_h=6}^{12}E_C\left(\tau_w,\tau_d,\tau_h\right)+F_{WDAC}\cdot\sum_{\tau_h=12}^{18}E_C\left(\tau_w,\tau_d,\tau_h\right)+F_{WDNC}\cdot\sum_{\tau_h=18}^{6(+1day)}E_C\left(\tau_w,\tau_d,\tau_h\right)\right)$$

$$E_{WEC}(\tau_w)=\sum_{\tau_d=6}^{7}\left(F_{WEMC}\cdot\sum_{\tau_h=6}^{12}E_C\left(\tau_w,\tau_d,\tau_h\right)+F_{WEAC}\cdot\sum_{\tau_h=12}^{18}E_C\left(\tau_w,\tau_d,\tau_h\right)+F_{WENC}\cdot\sum_{\tau_h=18}^{6(+1day)}E_C\left(\tau_w,\tau_d,\tau_h\right)\right)$$

Where:

τ_d = days of the week, where 1=Monday, and 7=Sunday. The weekend schedule is also applicable to holidays

τ_w = weeks of the year, where S_1 = first week of the cooling season, and S_N = last week of the cooling season, W_1 = first week of the heating season, and W_N = last week of the heating season. S1, SN, W1, and WN are defined in Appendix D.

τ_h = hours in a day, where 1=1:00 a.m., 12 = 12:00 p.m., and 24 = 12:00 a.m. For the evening/night period, the summation goes from 18 (6:00 p.m.) until 24 (12 a.m.), then the hours reset to 0 and go until 6 a.m. This is indicated in the equations as (+1 day) in the upper limit of the summation sign for the evening/night period

Table 2. Energy Use Variables

	Cooling Weekday	Cooling Weekend	Heating Weekday	Heating Weekend
Open	E_{SDO}	E_{SEO}	E_{WDO}	E_{WEO}
Half-open	E_{SDH}	E_{SEH}	E_{WDH}	E_{WEH}
Closed	E_{SDC}	E_{SEC}	E_{WDC}	E_{WEC}

Table 3. Deployment Fraction Variables

	Cooling Weekday			Cooling Weekend			Heating Weekday			Heating Weekend		
Deployment	M	A	N	M	A	N	M	A	N	M	A	N
Open	F_{SDMO}	F_{SDAO}	F_{SDNO}	F_{SEMO}	F_{SEAO}	F_{SENO}	F_{WDMO}	F_{WDAO}	F_{WDNO}	F_{WEMO}	F_{WEAO}	F_{WENO}
Half-open	F_{SDMH}	F_{SDAH}	F_{SDNH}	F_{SEMH}	F_{SEAH}	F_{SENH}	F_{WDMH}	F_{WDAH}	F_{WDNH}	F_{WEMH}	F_{WEAH}	F_{WENH}
Closed	F_{SDMC}	F_{SDAC}	F_{SDNC}	F_{SEMC}	F_{SEAC}	F_{SENC}	F_{WDMC}	F_{WDAC}	F_{WDNC}	F_{WEMC}	F_{WEAC}	F_{WENC}

Deployment fraction data for North (heating) and South (cooling) climates are presented in Table 4 and Table 5.

Table 4. Deployment Schedule for North (Heating) Climate Zone

Cooling Weekday				Cooling Weekend			Heating Weekday			Heating Weekend		
Deployment	M	A	N	M	A	N	M	A	N	M	A	N
Open	0.26	0.24	0.23	0.26	0.25	0.23	0.29	0.30	0.23	0.28	0.29	0.22
Half-open	0.35	0.34	0.32	0.36	0.36	0.33	0.32	0.33	0.28	0.32	0.33	0.29
Closed	0.39	0.41	0.45	0.38	0.39	0.44	0.39	0.38	0.49	0.40	0.38	0.49

Table 5. Deployment Schedule for South (Cooling) Climate Zone

Cooling Weekday				Cooling Weekend			Heating Weekday			Heating Weekend		
Deployment	M	A	N	M	A	N	M	A	N	M	A	N
Open	0.17	0.15	0.13	0.18	0.17	0.14	0.23	0.23	0.17	0.23	0.23	0.17
Half-open	0.26	0.25	0.23	0.26	0.25	0.24	0.25	0.26	0.22	0.27	0.27	0.23
Closed	0.57	0.60	0.65	0.56	0.58	0.62	0.52	0.51	0.61	0.51	0.50	0.59

Cooling and heating periods are defined for each city in Appendix D.

$E(\tau_w, \tau_d, \tau_h)$ is calculated as follows for each city:

Houston:

$$E_O(\tau_w,\tau_d,\tau_h) = \left(E_{DXCoil}(\tau_h)_B + E_{Fan}(\tau_h)_B\right)_{CS=ON} \cdot SF_E$$

$$E_H(\tau_w,\tau_d,\tau_h) = \left(E_{DXCoil}(\tau_h)_H + E_{Fan}(\tau_h)_H\right)_{CS=ON} \cdot SF_E$$

$$E_C(\tau_w,\tau_d,\tau_h) = \left(E_{DXCoil}(\tau_h)_C + E_{Fan}(\tau_h)_C\right)_{CS=ON} \cdot SF_E$$

Minneapolis:

$$E_O(\tau_w,\tau_d,\tau_h) = \left(E_{Gas}(\tau_h)_B\right) \cdot SF_G + \left(E_{Fan}(\tau_h)_B\right)_{HS=ON} \cdot SF_E$$

$$E_H(\tau_w,\tau_d,\tau_h) = \left(E_{Gas}(\tau_h)_H\right) \cdot SF_G + \left(E_{Fan}(\tau_h)_H\right)_{HS=ON} \cdot SF_E$$

$$E_C(\tau_w,\tau_d,\tau_h) = \left(E_{Gas}(\tau_h)_C\right) \cdot SF_G + \left(E_{Fan}(\tau_h)_C\right)_{HS=ON} \cdot SF_E$$

2.2.3 Operable Window Attachments with 2-D operation

Similar to window attachments with 1 degree freedom in operation, energy use for window attachment with 2-D operation is calculated by summing-up weighting Open, Half-Open and Closed states. Because of the increased complexity of the definition of Open, and Half-Open states for attachments with 2 degrees of freedom (retraction levels and slat angle), multiple deployment states are attached to Open and Half-Open states. Currently, louvered blinds (both horizontal louvered blinds, or Venetian blinds, and vertical louvered blinds) have simulation models available for them. Assignment of different EnergyPlus runs and deployment states for louvered blinds are shown in Table .

Table 6. Deployment Information for Louvered blinds

		Run No.	Top Window	Bottom Window
Open (O)	Fully-deployed	1	0° slat angle	0° slat angle
	Fully-retracted	2	No shade	No shade
Half-Open (H)	Fully-deployed	3	45° slat angle	45° slat angle
	Fully-deployed	4	-45° slat angle	-45° slat angle
	Half-deployed	5	90° slat angle	No shade
	Half-deployed	6	45° slat angle	No shade
	Half-deployed	7	-45° slat angle	No shade
Closed (C)	Fully-deployed	8	90° slat angle	90° slat angle

The energy use for louvered blinds is the result of averaging hourly results for two open deployments, five half-open and one closed deployment schedules. Averaging procedure is detailed in Equations 17-19. Numbers in the third column in Table 6 are used in subsequent equations as an index number (1-2 for open, 3-7 for half-open, and 8 for closed).

$$E_O = \frac{\sum_{i=1}^{2}\left(\sum_{\tau_w=S_1}^{S_N}\left(E_{SDO,i}(\tau_w)+E_{SEO,i}(\tau_w)\right)+\sum_{\tau_w=W_1}^{W_N}\left(E_{WDO,i}(\tau_w)+E_{WEO,i}(\tau_w)\right)\right)}{2} \tag{17}$$

$$E_H = \frac{\sum_{i=3}^{7}\left(\sum_{\tau_w=S_1}^{S_N}\left(E_{SDH,i}(\tau_w)+E_{SEH,i}(\tau_w)\right)+\sum_{\tau_w=W_1}^{W_N}\left(E_{WDH,i}(\tau_w)+E_{WEH,i}(\tau_w)\right)\right)}{5} \tag{18}$$

$$E_C = \sum_{\tau_w=S_1}^{S_N}\left(E_{SDC,8}(\tau_w)+E_{SEC,8}(\tau_w)\right)+\sum_{\tau_w=W_1}^{W_N}\left(E_{WDC,8}(\tau_w)+E_{WEC,8}(\tau_w)\right) \tag{19}$$

An example of the application of formula to the calculation of $E_{SEO,1}$ is shown below. Other quantities are calculated in the same manner.

$$E_{SEO,1}(\tau_w) = \sum_{\tau_d=6}^{7}\left(F_{SEMO}\cdot\sum_{\tau_h=5}^{17}E_{O,1}(\tau_w,\tau_d,\tau_h)+F_{SEAO}\cdot\sum_{\tau_h=5}^{17}E_{O,1}(\tau_w,\tau_d,\tau_h)+F_{SENO}\cdot\sum_{\tau_h=5}^{17}E_{O,1}(\tau_w,\tau_d,\tau_h)\right)$$

$E(\tau_w, \tau_d, \tau_h)$ is calculated as follows for each city:

Houston:

$$E_{O,i}(\tau_w,\tau_d,\tau_h)=\left(E_{DXCoil}(\tau_h)_{O,i}+E_{Fan}(\tau_h)_{O,i}\right)_{CS=ON}\cdot SF_E \quad (i=1,2)$$

$$E_{H,i}(\tau_w,\tau_d,\tau_h)=\left(E_{DXCoil}(\tau_h)_{H,i}+E_{Fan}(\tau_h)_{H,i}\right)_{CS=ON}\cdot SF_E \quad (i=3,4,5,6,7)$$

$$E_{C,8}(\tau_w,\tau_d,\tau_h)=\left(E_{DXCoil}(\tau_h)_{C,8}+E_{Fan}(\tau_h)_{C,8}\right)_{CS=ON}\cdot SF_E$$

Minneapolis:

$$E_{O,i}(\tau_w,\tau_d,\tau_h)=\left(E_{Gas}(\tau_h)_{O,i}\right)_{HS=ON}\cdot SF_G+\left(E_{Fan}(\tau_h)_{O,i}\right)_{HS=ON}\cdot SF_E \quad (i=1,2)$$

$$E_{H,i}(\tau_w,\tau_d,\tau_h)=\left(E_{Gas}(\tau_h)_{H,i}\right)_{HS=ON}\cdot SF_G+\left(E_{Fan}(\tau_h)_{H,i}\right)_{HS=ON}\cdot SF_E \quad (i=3,4,5,6,7)$$

$$E_{C,8}(\tau_w,\tau_d,\tau_h)=\left(E_{Gas}(\tau_h)_{C,8}\right)_{HS=ON}\cdot SF_G+\left(E_{Fan}(\tau_h)_{C,8}\right)_{HS=ON}\cdot SF_E$$

2.3 Calculation of EP indices

Energy performance indices of window shade/attachment for cooling, $\mathbf{EP_C}$, or for heating, $\mathbf{EP_H}$, is defined as the ratio of annual cooling/heating energy saving resulting from the addition of window attachment ($E_{B\text{-}S}$) to the annual energy use caused by the baseline window without attachment ($E_{B\text{-}A}$)

$E_{B\text{-}A} = E_B - E_A$, annual energy use caused by the baseline window

$E_{B\text{-}S} = E_B - E_S$, window attachment energy savings from the baseline window

Therefore:

$$EP_C=\frac{E_{B-S}}{E_{B-A}} \tag{20}$$

Where E_A, E_B, ands E_S are calculated from Houston results

$$EP_H=\frac{E_{B-S}}{E_{B-A}} \tag{21}$$

Where E_A, E_B, ands E_S are calculated from Minneapolis results

3 Interface Between ESCalc and SHADEFEN

ESCalc module reads EnergyPlus output csv files, provided by SHADEFEN and returns E_S value back. E_A and E_B values can also be calculated, if requested, but are normally stored as fixed quantities in SHADEFEN.

Inputs to ESCalc:

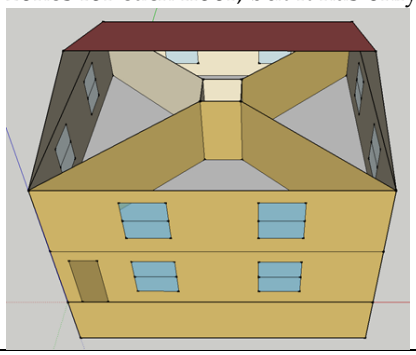
- Selection which calculation is to be performed, E_A, E_B, E_S/EP
- City; Houston or Minneapolis (alternatively could be choice between Cooling and Heating)
- Window attachment type (for E_A and E_B only, no attachment is supplied)
- Number of csv files
- Each csv file name
    - Deployment state (Open, half-open or closed)
    - Slat angle for louvered blinds

Output from ESCalc:

- E_A, E_B, and/or E_S, as requested
- EP (applicable when E_S is requested)

This interface is accomplished through XML file. XML Schema and example files are included in Appendix E

Appendix A: Assumptions for Typical US Residential Buildings Model for AERC

<table>
<tr><th>PARAMETERS</th><th>Proposed Residential Model Values</th><th>Value inputs in E+</th></tr>
<tr><td>Floor Area
(ft² & dim)</td><td>2400 ft² , 34.64ft (W) x 34.64ft (L) x8.5ft (H) x2 stories</td><td>10.55858m(X)*10.55858m(Y)*2.59m(H)*2 stories</td></tr>
<tr><td>House Type</td><td>2-story – One small core zone and four big perimeter zones for each floor, but it has only one HVAC zone.
  </td><td>Core zone Area=1.41458m*1.41458m

Refer to Residential model for AERC MEETING (0415).xlsx</td></tr>
<tr><td>Bathrooms</td><td>3</td><td></td></tr>
<tr><td>Bedrooms</td><td>3</td><td></td></tr>
<tr><td>Typical Cities</td><td>Heating: Minneapolis, MN (Climate Zone 6A)
Cooling: Houston, TX (Climate Zone 2A)</td><td>Refer to Residential model for AERC MEETING (0415).xlsx</td></tr>
<tr><td>Foundation</td><td>Unheated Basement for the north heating dominated city, viz. Minneapolis, MN;

Slab-on-grade without insulation for the south cooling dominated city, viz. Houston, TX.</td><td>Basement: 10.55858m(X)*10.55858m(Y)*(-2.13)m(H)</td></tr>
<tr><td>Insulation [a]</td><td>Envelope insulation levels vary with the locations. The following insulation requirements are referred to IECC 1998.
<table>
<tr><th>Location:</th><th>Ceiling R-value</th><th>Wall R-value</th><th>Floor R-value</th><th>Slab/Basement R-value</th></tr>
<tr><td>Houston:</td><td>R-30</td><td>R-13</td><td>R-11</td><td>Slab, R-0</td></tr>
<tr><td>Minneapolis:</td><td>R-49</td><td>R-21</td><td>R-21</td><td>Bsmt, R-11</td></tr>
</table></td><td>Minneapolis:
Exterior Floor: R21
Interior Floor: R21
Exterior Wall: R21
Ceiling: R49
Exterior Roof: R49
Basement wall: R11

Houston:
Exterior Floor: R11
Interior Floor: R11
Exterior Wall: R13
Ceiling: R30
Exterior Roof: R30

Refer to \Dropbox (BT KOHLER)\Organizations\AERC\AEP Subcommittee\ Residential model for AERC MEETING (0415)\ Model comparison</td></tr>
</table>

PARAMETERS	Proposed Residential Model Values	Value inputs in E+
Infiltration	Minneapolis: ACH50=7 Houston: ACH50=10	Minneapolis baseline window case: ELA=873; Minneapolis super insulated window case: ELA=669, air infiltration of super insulated window was 0; Houston baseline window case: ELA=1248; Houston super insulated window case: ELA=1044, air infiltration of super insulated window was 0; The converting method from ACH to ELA is described in ELACalculation.xlsx
Internal Mass Furniture (lb/ft²)	8.0 lb/ft² of floor area	
Ventilation Air Requirements	0.15 L/s per square meter of floor space	0.033456639274582m3/s =0.15*10.55858*10.55858*2
Wall framing system	Wood	
External Doors	U factor: 1.14 W/(m².k)	R=0.88
Window Area (% Floor Area)	15.1%. There are two windows (each window with dimension 2*1.4 m*0.75 m) on each orientation each floor.	2.14(w)*0.75(h)*2 Refer to Residential model for AERC MEETING (0415).xlsx
Window Type	Double clear wood frame baseline window for both climates; VT=0.639, SHGC=0.601, U=0.472 Btu/hr.ft².F, AL=2 cfm/ft² Adiabatic window: VT=0, SHGC=0, U=0, AL=0	Baseline window: double clear using CLEAR_3.DAT, wood fixed frame Adiabatic window: custom created super-insulated opaque window without frame Refer to AERC 1 Baseline window B.docx
Window Distribution	8 windows per floor, distributed evenly and centered on the external walls. Each big window was split into the upper and lower small windows.	Refer to Residential model for AERC MEETING (0415).xlsx
Heating Systems	Gas Furnace for Minneapolis, MN; Heat Pump for Houston, TX.	
Heating System Fuels	Gas for Minneapolis, MN; Electricity for Houston, TX.	
Cooling Systems	A/C for Minneapolis, MN; Heat Pump for Houston, TX.	
HVAC System Sizing	For each climate, the HVAC systems were sized based on the base window option (without window attachments).	Houston (HP): Cooling capacity: 14099.23W Heating capacity: 14099.23W Sensible heat ratio: 0.737853 Air flow rate: 0.71m3/s Minneapolis (GAC): Cooling capacity: 11657.66W Heating capacity: 17648.59W Sensible heat ratio: 0.7589 Air flow rate: 0.628m3/s Refer to Doubleclear_basement_Minneapolis, & Doubleclear_slab_Houston

PARAMETERS	Proposed Residential Model Values	Value inputs in E+
HVAC Efficiencies	Minneapolis (GAC): AFUE= 0.78 for Gas furnace heating (annual fuel utilization efficiency) Houston (HP): HSPF=6.8 for Air-cooled heat pumps heating mode (the converted COP for heating is ~1.99) Both: SEER=10.0 for Air-cooled air conditioners and heat pumps cooling mode (the converted COP for cooling is ~2.70)	(1) EER = 1.12 * SEER - 0.02 * SEER2 (2) EER = COP * 3.41 (3) Avg COP = Heat transferred / electrical energy supplied = (HSPF * 1055.056 J/BTU) / (3600 J/watt-hour) = 0.29307111 HSPF.
Thermostat Settings	Heating: 70°F, Cooling: 75°F No setback	Heating set point: 21.11 °C Cooling set point: 23.89 °C
Internal Loads	Number of People = 3 Hardwire Lights = 1.22 Watts/m² Plug-in Lights = 0.478 Watts/m² Refrigerator = 91.09 Watts – Design Level Misc. Electrical Equipment = 2.46 Watts/m² Clothes Washer = 29.6 Watts – Design Level Clothes Dryer = 222.1 Watts – Design Level Dish Washer = 68.3 Watts – Design Level Misc. Electrical Load = 182.5 Watts – Design Level Gas Cooking range =248.5 Watts – Design Level Misc. Gas Load = 0.297 Watts/m² Exterior Lights = 58 Watts – Design Level Garage Lights = 9.5 Watts – Design Level The operation schedules of the all equipment are referred to the PNNL model.	
Weather Data	USA_TX_Houston-Bush.Intercontinental.AP.722430_TMY3.epw USA_MN_Minneapolis-St.Paul.Intl.AP.726580_TMY3_2.epw	All TMY3
Number of Locations	2 typical US cities: Minneapolis, MN for heating; Houston, TX for cooling.	
Calculation Tool	EnergyPlus version 8.5 (LBN's custom version that addresses issue with TIR>0)	
Energy Code	Combination of vintages for each climate zone, but mostly like IECC 1998	
Results extracted from E+	Heating energy use, cooling energy use, fan energy use and total energy use of the house which includes the all energy uses, such as lighting.	
Attachment deployment operations	Refer to (Bickel, 2013)	
Ground temperature	For Minneapolis unheated basement with R11 insulation; For Houston, slab-on-grade with no slab insulation.	

PARAMETERS	Proposed Residential Model Values	Value inputs in E+
Super insulated window	This window can be regarded as an adiabatic surface without heat transferring.	0.003, !- Thickness {m} 0.000001, !- Solar Transmittance 0.999999, !- Front Reflectance 0.999999, !- Back Reflectance 0.000001, !- Visible Transmittance 0.999999, !- Front Visible Reflectance 0.999999, !- Back Visible Reflectance 0.000000, !- Infrared Transmittance 0.000001, !- Front Infrared Emissivity 0.000001, !- Back Infrared Emissivity 0.00000001; !- Conductivity {W/m-K}

Appendix B: Output Section in IDF File

```
!-   ===========  ALL OBJECTS IN CLASS: OUTPUT:VARIABLE ===========

  Output:Variable,*,Site Day Type Index,hourly;

  Output:Variable,*,Air System Electric Energy,hourly;

  Output:Variable,*,Air System Fan Electric Energy,hourly;

  Output:Variable,*,Air System DX Cooling Coil Electric Energy,hourly;

  Output:Variable,*,Zone Lights Electric Energy,hourly;

  Output:Variable,*,Facility Net Purchased Electric Energy,hourly;

  Output:Variable,*,Facility Total Building Electric Demand Power,hourly;

  Output:Variable,*,Facility Total HVAC Electric Demand Power,hourly;

  Output:Variable,*,Facility Total Electric Demand Power,hourly;

  Output:Variable,*,Air System Cooling Coil Total Cooling Energy,hourly;

  Output:Variable,*,Air System Heating Coil Total Heating Energy,hourly;

  Output:Variable,*,Air System Fan Air Heating Energy,hourly;

  Output:Variable,*,Air System Gas Energy,hourly;

  Output:Variable,*,Zone Gas Equipment Gas Energy,hourly;

  Output:Variable,*,Water Heater Gas Energy,hourly;
```

Appendix C: Include Files

Windows:

Same window configuration file is provided for both climate zones/cities. Also, same window configuration file is used for all windows, however with changes made for construction reference (glazing construction and frame) by SHADEFEN for different window attachment runs (e.g., For baseline window, construction reference is AERC_Doubleclear_Baseline).

Baseline Window Configuration Include File:

```
FenestrationSurface:Detailed,
  Window_ldf1_1_Bot.unit1, !- Name
  Window,                  !- Surface Type
  AERC_Doubleclear_Baseline,   !- Construction Name
  Wall_ldf1_1.unit1,       !- Building Surface Name
  ,                        !- Outside Boundary Condition Object
  ,                        !- View Factor to Ground
  ,                        !- Shading Control Name
  AERC_Wood_Frame,         !- Frame and Divider Name
  1,                       !- Multiplier
  4,                       !- Number of Vertices
  2.500000000000,0.000000000000,0.600000000000,  !- X,Y,Z ==> Vertex 1 {m}
  3.900000000000,0.000000000000,0.600000000000,  !- X,Y,Z ==> Vertex 2 {m}
  3.900000000000,0.000000000000,1.350000000000,  !- X,Y,Z ==> Vertex 3 {m}
  2.500000000000,0.000000000000,1.350000000000;  !- X,Y,Z ==> Vertex 4 {m}

FenestrationSurface:Detailed,
  Window_ldf1_1_Top.unit1, !- Name
  Window,                  !- Surface Type
  AERC_Doubleclear_Baseline,   !- Construction Name
  Wall_ldf1_1.unit1,       !- Building Surface Name
  ,                        !- Outside Boundary Condition Object
  ,                        !- View Factor to Ground
  ,                        !- Shading Control Name
  AERC_Wood_Frame,         !- Frame and Divider Name
  1,                       !- Multiplier
  4,                       !- Number of Vertices
  2.500000000000,0.000000000000,1.350000000000,  !- X,Y,Z ==> Vertex 1 {m}
  3.900000000000,0.000000000000,1.350000000000,  !- X,Y,Z ==> Vertex 2 {m}
  3.900000000000,0.000000000000,2.100000000000,  !- X,Y,Z ==> Vertex 3 {m}
  2.500000000000,0.000000000000,2.100000000000;  !- X,Y,Z ==> Vertex 4 {m}
```

B: Baseline window run: Glazing construction name is AERC_Doubleclear_Baseline. Frame construction name is AERC_Wood_Frame for both top and bottom "half" of the baseline window.

Baseline Window Construction Include File (Window_construction_baseline.inc):

```
!    Window Material/Construction file with spectral data in IDF format
Construction:ComplexFenestrationState,
AERC_Doubleclear_Baseline,                    !- name
LBNLWindow,                                   !- basis type
None,                                         !- basis symmetry type
ThermParam_Glz_10001,                         !- window thermal model
CFS_Glz_10001_Basis,                          !- basis matrix name
CFS_Glz_10001_TfSol,                          !- Tfsol
CFS_Glz_10001_RbSol,                          !- Rbsol
CFS_Glz_10001_Tfvis,                          !- Tfvis
CFS_Glz_10001_Rbvis,                          !- Rbvis
Glass_102_Layer,                              !- layer 1 name
CFS_Glz_10001_Layer_1_fAbs,                   !- fAbs
CFS_Glz_10001_Layer_1_bAbs,                   !- bAbs
Gap_1_Glz_10001_Layer_1,                      !- gap 1 name
,
Glass_102_Layer,                              !- layer 2 name
CFS_Glz_10001_Layer_2_fAbs,                   !- fAbs
CFS_Glz_10001_Layer_2_bAbs;                   !- bAbs
...
```

```
!-----------------------------------------------------
!     Window Glass Layers
!-----------------------------------------------------
WindowMaterial:Glazing,
Glass_102_Layer,                    !- Layer name : CLEAR_3.DAT
BSDF,                               !- Optical Data Type
Glass_102_Layer_SpecDat,            !- Spectral Data name
0.003048,                           !- Thickness
,                                   !- Solar Transmittance
,                                   !- Solar Front Reflectance
,                                   !- Solar Back Reflectance
,                                   !- Visible Transmittance
,                                   !- Visible Front Reflectance
,                                   !- Visible Back reflectance
0.000000,                           !- IR Transmittance
0.840000,                           !-Front Emissivity
0.840000,                           !-Back Emissivity
1.000000,                           !-Conductivity
,                                   !-Dirt Correction Factor for Sol/Vis Transmittance
,                                   !-Solar Diffusing
7.2e10,                             !-Young's modulus
0.22;                               !-Poisson's ratio

!-----------------------------------------------------------------
!      Window Gas Layers
!-----------------------------------------------------------------
WindowMaterial:Gas,
   Gap_1_W_0_0127,    !- gap name - Air
   Air,    !- type
   0.0127;    !- thickness

!-----------------------------------------------------
!     Window Frames and Dividers Data
!-----------------------------------------------------
WindowProperty:FrameAndDivider,
AERC_Wood_Frame,                    !- User Supplied Frame/Divider Name
0.076200,                           !- Frame Width {m}
,                                   !- Frame Outside Projection {m}
,                                   !- Frame Insider Projection {m}
4.018003,                           !- Frame Conductance {w/m2-K}
1.190819,                           !- Ratio of Frame-Edge Glass Conductance to Center-of-glass Co
0.300000,                           !- Frame Solar absorptance
0.300000,                           !- Frame Visible absorptance
0.9,                                !- Frame Thermal hemispherical Emissivity
...
```

Adiabatic Window Configuration Include File:

```
FenestrationSurface:Detailed,
  Window_ldf1_1_Bot.unit1, !- Name
  Window,                  !- Surface Type
  Adiabatic_Window,                !- Construction Name
  Wall_ldf1_1.unit1,       !- Building Surface Name
  ,                        !- Outside Boundary Condition Object
  ,                        !- View Factor to Ground
  ,                        !- Shading Control Name
  ,                        !- Frame and Divider Name
  1,                       !- Multiplier
  4,                       !- Number of Vertices
  2.500000000000,0.000000000000,0.600000000000,  !- X,Y,Z ==> Vertex 1 {m}
  3.900000000000,0.000000000000,0.600000000000,  !- X,Y,Z ==> Vertex 2 {m}
  3.900000000000,0.000000000000,1.350000000000,  !- X,Y,Z ==> Vertex 3 {m}
  2.500000000000,0.000000000000,1.350000000000;  !- X,Y,Z ==> Vertex 4 {m}

FenestrationSurface:Detailed,
  Window_ldf1_1_Top.unit1, !- Name
  Window,                  !- Surface Type
  Adiabatic_Window,                !- Construction Name
  Wall_ldf1_1.unit1,       !- Building Surface Name
  ,                        !- Outside Boundary Condition Object
  ,                        !- View Factor to Ground
  ,                        !- Shading Control Name
  ,                        !- Frame and Divider Name
  1,                       !- Multiplier
  4,                       !- Number of Vertices
  2.500000000000,0.000000000000,1.350000000000,  !- X,Y,Z ==> Vertex 1 {m}
  3.900000000000,0.000000000000,1.350000000000,  !- X,Y,Z ==> Vertex 2 {m}
  3.900000000000,0.000000000000,2.100000000000,  !- X,Y,Z ==> Vertex 3 {m}
  2.500000000000,0.000000000000,2.100000000000;  !- X,Y,Z ==> Vertex 4 {m}
```

A: Adiabatic window run: Glazing construction name is Adiabatic_window. Frame and divider construction name is blank (keep a comma) for both top and bottom "half" of the baseline window.

Adiabatic Window Construction Include File (Window_construction_adiabatic.inc):

```
!-----------------------------------------------------
!     Window Glass Layers
!-----------------------------------------------------

 WindowMaterial:Glazing,
  Super_Insulated_Glass,  !- Name
  SpectralAverage,        !- Optical Data Type
  ,                       !- Window Glass Spectral Data Set Name
  0.003,                  !- Thickness {m}
  0.000001,               !- Solar Transmittance at Normal Incidence
  0.999999,               !- Front Side Solar Reflectance at Normal Incidence
  0.999999,               !- Back Side Solar Reflectance at Normal Incidence
  0.000001,               !- Visible Transmittance at Normal Incidence
  0.999999,               !- Front Side Visible Reflectance at Normal Incidence
  0.999999,               !- Back Side Visible Reflectance at Normal Incidence
  0.000000,               !- Infrared Transmittance at Normal Incidence
  0.000001,               !- Front Side Infrared Hemispherical Emissivity
  0.000001,               !- Back Side Infrared Hemispherical Emissivity
  0.00000001;             !- Conductivity {W/m-K}

!-----------------------------------------------------
!     Window Construction
!-----------------------------------------------------
 Construction,
  Adiabatic_window,       !- Name
  Super_Insulated_Glass;  !- Outside Layer
```

Half-Deployed Window Configuration Include File:

```
FenestrationSurface:Detailed,
  Window_ldf1_1_Bot.unit1, !- Name
  Window,                  !- Surface Type
  AERC_Doubleclear_Baseline,   !- Construction Name
  Wall_ldf1_1.unit1,       !- Building Surface Name
  ,                        !- Outside Boundary Condition Object
  ,                        !- View Factor to Ground
  ,                        !- Shading Control Name
  AERC_Wood_Frame,         !- Frame and Divider Name
  1,                       !- Multiplier
  4,                       !- Number of Vertices
  2.500000000000,0.000000000000,0.600000000000,  !- X,Y,Z ==> Vertex 1 {m}
  3.900000000000,0.000000000000,0.600000000000,  !- X,Y,Z ==> Vertex 2 {m}
  3.900000000000,0.000000000000,1.350000000000,  !- X,Y,Z ==> Vertex 3 {m}
  2.500000000000,0.000000000000,1.350000000000;  !- X,Y,Z ==> Vertex 4 {m}

FenestrationSurface:Detailed,
  Window_ldf1_1_Top.unit1, !- Name
  Window,                  !- Surface Type
  AERC_Doubleclear_Attachment,   !- Construction Name
  Wall_ldf1_1.unit1,       !- Building Surface Name
  ,                        !- Outside Boundary Condition Object
  ,                        !- View Factor to Ground
  ,                        !- Shading Control Name
  AERC_Wood_Frame,         !- Frame and Divider Name
  1,                       !- Multiplier
  4,                       !- Number of Vertices
  2.500000000000,0.000000000000,1.350000000000,  !- X,Y,Z ==> Vertex 1 {m}
  3.900000000000,0.000000000000,1.350000000000,  !- X,Y,Z ==> Vertex 2 {m}
  3.900000000000,0.000000000000,2.100000000000,  !- X,Y,Z ==> Vertex 3 {m}
  2.500000000000,0.000000000000,2.100000000000;  !- X,Y,Z ==> Vertex 4 {m}
```

H: Attachments half deployed: Glazing Construction for "Bot" window unit AERC_Doubleclear_Baseline. Glazing Construction for "Top" window unit is AERC_Doubleclear_Attachment, which is user-specified. Frame construction name is AERC_Wood_Frame for both top and bottom "half" of the baseline window..

Fully-Deployed Window Configuration Include File :

```
FenestrationSurface:Detailed,
  Window_ldf1_1_Bot.unit1, !- Name
  Window,                  !- Surface Type
  AERC_Doubleclear_Attachment,   !- Construction Name
  Wall_ldf1_1.unit1,       !- Building Surface Name
  ,                        !- Outside Boundary Condition Object
  ,                        !- View Factor to Ground
  ,                        !- Shading Control Name
  AERC_Wood_Frame,         !- Frame and Divider Name
  1,                       !- Multiplier
  4,                       !- Number of Vertices
  2.500000000000,0.000000000000,0.600000000000,  !- X,Y,Z ==> Vertex 1 {m}
  3.900000000000,0.000000000000,0.600000000000,  !- X,Y,Z ==> Vertex 2 {m}
  3.900000000000,0.000000000000,1.350000000000,  !- X,Y,Z ==> Vertex 3 {m}
  2.500000000000,0.000000000000,1.350000000000;  !- X,Y,Z ==> Vertex 4 {m}

FenestrationSurface:Detailed,
  Window_ldf1_1_Top.unit1, !- Name
  Window,                  !- Surface Type
  AERC_Doubleclear_Attachment,   !- Construction Name
  Wall_ldf1_1.unit1,       !- Building Surface Name
  ,                        !- Outside Boundary Condition Object
  ,                        !- View Factor to Ground
  ,                        !- Shading Control Name
  AERC_Wood_Frame,         !- Frame and Divider Name
  1,                       !- Multiplier
  4,                       !- Number of Vertices
  2.500000000000,0.000000000000,1.350000000000,  !- X,Y,Z ==> Vertex 1 {m}
  3.900000000000,0.000000000000,1.350000000000,  !- X,Y,Z ==> Vertex 2 {m}
  3.900000000000,0.000000000000,2.100000000000,  !- X,Y,Z ==> Vertex 3 {m}
  2.500000000000,0.000000000000,2.100000000000;  !- X,Y,Z ==> Vertex 4 {m}
```

S: Attachments fully deployed: Glazing Construction is AERC_Doubleclear_Attachment, which is user-specified. Frame construction name is AERC_Wood_Frame for both top and bottom "half" of the baseline window.

Zone Infiltration:

Baseline window infiltration include file for Houston (Air_infiltration_baseline_Houston.inc):

```
ZoneInfiltration:EffectiveLeakageArea,
  Living_ShermanGrimsrud_unit1,  !- Name
  living_unit1,      !- Zone Name
  always_avail,      !- Schedule Name
  1248,              !- Effective Air Leakage Area {cm2}
  0.00029,           !- Stack Coefficient
  0.000231;          !- Wind Coefficient
```

B: Baseline window run: the effective air leakage area (ELA) is 1044+ELAw in Houston. ELAw is 204.

Baseline window infiltration include file for Minneapolis (Air_infiltration_baseline_Minneapolis.inc):

```
ZoneInfiltration:EffectiveLeakageArea,
  Living_ShermanGrimsrud_unit1,  !- Name
  living_unit1,      !- Zone Name
  always_avail,      !- Schedule Name
  873,               !- Effective Air Leakage Area {cm2}
  0.00029,           !- Stack Coefficient
  0.000231;          !- Wind Coefficient
```

B: Baseline window run: the effective air leakage area (ELA) is 669+ELAw in Minneapolis. ELAw is 204.

Adiabatic window infiltration include file for Houston (Air_infiltration_adiabatic_Houston.inc):

```
ZoneInfiltration:EffectiveLeakageArea,
  Living_ShermanGrimsrud_unit1,  !- Name
  living_unit1,      !- Zone Name
  always_avail,      !- Schedule Name
  1044,              !- Effective Air Leakage Area {cm2}
  0.00029,           !- Stack Coefficient
  0.000231;          !- Wind Coefficient
```

A: Adiabatic window run: the effective air leakage area (ELA) is 1044 in Houston.

Adiabatic window infiltration include file for Minneapolis (Air_infiltration_adiabatic_Minneapolis.inc):

```
ZoneInfiltration:EffectiveLeakageArea,
  Living_ShermanGrimsrud_unit1,  !- Name
  living_unit1,      !- Zone Name
  always_avail,      !- Schedule Name
  669,               !- Effective Air Leakage Area {cm2}
  0.00029,           !- Stack Coefficient
  0.000231;          !- Wind Coefficient
```

A: Adiabatic window run: the effective air leakage area (ELA) is 669 in Minneapolis.

Fully-deployed window infiltration include file for Houston (Air_infiltration_user_input_Houston.inc):

```
ZoneInfiltration:EffectiveLeakageArea,
  Living_ShermanGrimsrud_unit1,  !- Name
  living_unit1,      !- Zone Name
  always_avail,      !- Schedule Name
  1044+ELAs,         !- Effective Air Leakag
  0.00029,           !- Stack Coefficient
  0.000231;          !- Wind Coefficient
```

F: Attachments half deployed: the effective air leakage area (ELA) is $1044+ELA_S$ in Houston. ELA_S is attachment dependent and is specified as input data.

Fully-deployed window infiltration include file for Minneapolis (Air_infiltration_user_input_Minneapolis.inc):

```
ZoneInfiltration:EffectiveLeakageArea,
  Living_ShermanGrimsrud_unit1,  !- Name
  living_unit1,      !- Zone Name
  always_avail,      !- Schedule Name
  669+ELAs,          !- Effective Air Leakage
  0.00029,           !- Stack Coefficient
  0.000231;          !- Wind Coefficient
```

F: Attachments half deployed: the effective air leakage area (ELA) is $669+ELA_S$ in Houston. ELA_S is attachment dependent and is specified as input data.

HVAC:

HVAC System for Houston

- Red highlight: System_autosize_Houston.inc
- Yellow highlight: System_sizing_Houston.inc

(1)

```
Sizing:System,
  Central System_unit1,     !- AirLoop Name
  Sensible,                 !- Type of Load to Size On
  autosize,                 !- Design Outdoor Air Flow Rate {m3/s}
  0.71,                     !- Design Outdoor Air Flow Rate {m3/s}
  1,                        !- Central Heating Maximum System Air Fl
  7,                        !- Preheat Design Temperature {C}
  0.008,                    !- Preheat Design Humidity Ratio {kgWate
  11,                       !- Precool Design Temperature {C}
  0.008,                    !- Precool Design Humidity Ratio {kgWate
  12,                       !- Central Cooling Design Supply Air Tem
  50,                       !- Central Heating Design Supply Air Tem
  NonCoincident,            !- Type of Zone Sum to Use
  No,                       !- 100% Outdoor Air in Cooling
  No,                       !- 100% Outdoor Air in Heating
  0.008,                    !- Central Cooling Design Supply Air Hum
  0.008,                    !- Central Heating Design Supply Air Hum
  designday,                !- Cooling Supply Air Flow Rate Method
  ,                         !- Cooling Supply Air Flow Rate {m3/s}
  ,                         !- Cooling Supply Air Flow Rate Per Floo
  ,                         !- Cooling Fraction of Autosized Cooling
  ,                         !- Cooling Supply Air Flow Rate Per Unit
  designday,                !- Heating Supply Air Flow Rate Method
  ,                         !- Heating Supply Air Flow Rate {m3/s}
  ,                         !- Heating Supply Air Flow Rate Per Floo
  ,                         !- Heating Fraction of Autosized Heating
  ,                         !- Heating Fraction of Autosized Cooling
  ,                         !- Heating Supply Air Flow Rate Per Unit
  ZoneSum,                  !- System Outdoor Air Method
  0.5,                      !- Zone Maximum Outdoor Air Fraction {di
  CoolingDesignCapacity,    !- Cooling Design Capacity Method
  autosize,                 !- Cooling Design Capacity {W}
  10339.69,                 !- Cooling Design Capacity {W}
  ,                         !- Cooling Design Capacity Per Floor Are
  ,                         !- Fraction of Autosized Cooling Design
  HeatingDesignCapacity,    !- Heating Design Capacity Method
  autosize,                 !- Heating Design Capacity {W}
  7560.61,                  !- Heating Design Capacity {W}
  ,                         !- Heating Design Capacity Per Floor Are
  ,                         !- Fraction of Autosized Heating Design
  ;                         !- Central Cooling Capacity Control Meth
```

1, for baseline window run, this field keeps autosize, for other runs, viz. adiabatic window run, shade fully deployed run and shade half deployed run, this field replaces with 0.71

2, for baseline window run, this field keeps autosize, for other runs, this field replaces with 10339.69

3, for baseline window run, this field keeps autosize, for other runs, this field replaces with 7560.61

(2)

```
AirTerminal:SingleDuct:Uncontrolled,
  ZoneDirectAir_unit1,      !- Name
  always_avail,             !- Availability Schedule Name
  Zone Inlet Node_unit1,    !- Zone Supply Air Node Name
  autosize;                 !- Maximum Air Flow Rate {m3/s}
  0.71;                     !- Maximum Air Flow Rate {m3/s}
```

4, for baseline window run, this field keeps autosize, for other runs, this field replaces with 0.71

(3)

```
Coil:Cooling:DX:SingleSpeed,
  DX Cooling Coil_unit1,    !- Name
  always_avail,             !- Availability Schedule Name
  autosize,                 !- Gross Rated Total Cooling Capacity
  14099.66,                 !- Gross Rated Total Cooling Capacity
  autosize,                 !- Gross Rated Sensible Heat Ratio
  0.737852,                 !- Gross Rated Sensible Heat Ratio
  2.70,                     !- Gross Rated Cooling COP {W/W}
  autosize,                 !- Rated Air Flow Rate {m3/s}
  0.71,                     !- Rated Air Flow Rate {m3/s}
  ,                         !- Rated Evaporator Fan Power Per Volu
  Cooling Coil Air Inlet Node_unit1,  !- Air Inlet Node Name
  Heating Coil Air Inlet Node_unit1,  !- Air Outlet Node Name
  HPACCoolCapFT,            !- Total Cooling Capacity Function of
  HPACCoolCapFFF,           !- Total Cooling Capacity Function of
  HPACCOOLEIRFT,            !- Energy Input Ratio Function of Temp
  HPACCOOLEIRFFF,           !- Energy Input Ratio Function of Flow
  HPACCOOLPLFFPLR;          !- Part Load Fraction Correlation Curv
```

5, for baseline window run, this field keeps autosize, for other runs, this field replaces with 14099.66

6, for baseline window run, this field keeps autosize, for other runs, this field replaces with 0.737852

7, for baseline window run, this field keeps autosize, for other runs, this field replaces with 0.71

(4)

```
Fan:OnOff,
  Supply Fan_unit1,         !- Name
  always_avail,             !- Availability Schedule Name
  0.7,                      !- Fan Total Efficiency
  400,                      !- Pressure Rise {Pa}
  autosize,                 !- Maximum Flow Rate {m3/s}
  0.71,                     !- Maximum Flow Rate {m3/s}
  0.8,                      !- Motor Efficiency
  1,                        !- Motor In Airstream Fractior
  air loop inlet node_unit1,  !- Air Inlet Node Name
  cooling coil air inlet node_unit1,  !- Air Outlet Node
  ,                         !- Fan Power Ratio Function of
  ,                         !- Fan Efficiency Ratio Functi
  General;                  !- End-Use Subcategory
```

8, for baseline window run, this field keeps autosize, for other runs, this field replaces with 0.71

(5)

```
Coil:Heating:DX:SingleSpeed,
    Main DX Heating Coil_unit1,  !- Name
    always_avail,            !- Availability Schedule Name
    autosize,                !- Rated Total Heating Capacity {W}
    14099.66,                !- Rated Total Heating Capacity {W}
    1.99,                    !- Rated COP {W/W}
    autosize,                !- Rated Air Flow Rate {m3/s}
    0.71,                    !- Rated Air Flow Rate {m3/s}
    ,                        !- Rated Evaporator Fan Power Per Vo
    Heating Coil Air Inlet Node_unit1,  !- Air Inlet Node Name
    Supp Heating Coil Air Inlet Node_unit1,  !- Air Outlet Node N
    HPACHeatCapFT,           !- Total Heating Capacity Function o
    HPACHeatCapFFF,          !- Total Heating Capacity Function o
    HPACHeatEIRFT,           !- Energy Input Ratio Function of Te
    HPACHeatEIRFFF,          !- Energy Input Ratio Function of Fl
    HPACCOOLPLFFPLR,         !- Part Load Fraction Correlation Cu
    Defrost_EIR_FT,          !- Defrost Energy Input Ratio Functi
    -17.78,                  !- Minimum Outdoor Dry-Bulb Temperat
    ,                        !- Outdoor Dry-Bulb Temperature to T
    5.0,                     !- Maximum Outdoor Dry-Bulb Temperat
    200.0,                   !- Crankcase Heater Capacity {W}
    10.0,                    !- Maximum Outdoor Dry-Bulb Temperat
    ReverseCycle,            !- Defrost Strategy
    OnDemand,                !- Defrost Control
    ,                        !- Defrost Time Period Fraction
    ;                        !- Resistive Defrost Heater Capacity
```

9, for baseline window run, this field keeps autosize, for other runs, this field replaces with 14099.66

10, for baseline window run, this field keeps autosize, for other runs, this field replaces with 0.71

(6)

```
Coil:Heating:Electric,
    Supp Heating Coil_unit1, !- Name
    always_avail,            !- Availability Schedule Name
    1,                       !- Efficiency
    autosize,                !- Nominal Capacity {W}
    8337.95,                 !- Nominal Capacity {W}
    Supp Heating Coil Air Inlet Node_unit1,  !- Air Inlet No
    Air Loop Outlet Node_unit1;  !- Air Outlet Node Name

!-   ===========  ALL OBJECTS IN CLASS: AIRLOOPHVAC ========

  AirLoopHVAC,
    Central System_unit1,    !- Name
    ,                        !- Controller List Name
    availability list,       !- Availability Manager List Na
    autosize,                !- Design Supply Air Flow Rate
    0.71,                    !- Design Supply Air Flow Rate
    Air Loop Branches_unit1, !- Branch List Name
    ,                        !- Connector List Name
    Air Loop Inlet Node_unit1,  !- Supply Side Inlet Node Na
    Return Air Mixer Outlet_unit1,  !- Demand Side Outlet No
    Zone Equipment Inlet Node_unit1,  !- Demand Side Inlet N
    Air Loop Outlet Node_unit1;  !- Supply Side Outlet Node
```

11, for baseline window run, this field keeps autosize, for other runs, this field replaces with 8337.95

12, for baseline window run, this field keeps autosize, for other runs, this field replaces with 0.71

(7)

```
AirLoopHVAC:UnitaryHeatPump:AirToAir,
   Heat Pump_unit1,          !- Name
   always_avail,             !- Availability Schedule Name
   Air Loop Inlet node_unit1,  !- Air Inlet Node Name
   Air Loop Outlet Node_unit1,  !- Air Outlet Node Name
   autosize,                 !- Supply Air Flow Rate During
   0.71,                     !- Supply Air Flow Rate During Cooling
   autosize,                 !- Supply Air Flow Rate During Heating
   0.71,                     !- Supply Air Flow Rate During Heating
   0.0,                      !- Supply Air Flow Rate When No Cooling
   living_unit1,             !- Controlling Zone or Thermostat Locat
   Fan:OnOff,                !- Supply Air Fan Object Type
   Supply Fan_unit1,         !- Supply Air Fan Name
   Coil:Heating:DX:SingleSpeed,  !- Heating Coil Object Typ
   Main DX Heating Coil_unit1,  !- Heating Coil Name
   Coil:Cooling:DX:SingleSpeed,  !- Cooling Coil Object Typ
   DX Cooling Coil_unit1,    !- Cooling Coil Name
   Coil:Heating:Electric,    !- Supplemental Heating Coil Object Typ
   Supp Heating Coil_unit1,  !- Supplemental Heating Coil Name
   50,                       !- Maximum Supply Air Temperature from
   10,                       !- Maximum Outdoor Dry-Bulb Temperature
   BlowThrough,              !- Fan Placement
   fan_cycle;                !- Supply Air Fan Operating Mode Schedu
```

13, for baseline window run, this field keeps autosize, for other runs, this field replaces with 0.71

14, for baseline window run, this field keeps autosize, for other runs, this field replaces with 0.71

(8)

```
Branch,
  Air Loop Main Branch_unit1,  !- Name
  autosize,                    !- Maximum Flow Rate {m3/s}
  0.71,                        !- Maximum Flow Rate {m3/s}
  ,                            !- Pressure Drop Curve Name
  AirLoopHVAC:UnitaryHeatPump:AirtoAir,  !- Component 1
  Heat Pump_unit1,             !- Component 1 Name
  Air Loop Inlet Node_unit1,   !- Component 1 Inlet Node
  Air Loop Outlet Node_unit1,  !- Component 1 Outlet Nod
  ACTIVE;                      !- Component 1 Branch Contro
```

15, for baseline window run, this field keeps autosize, for other runs, this field replaces with 0.71

(9)

```
Pump:VariableSpeed,
  Mains Pressure_unit1,    !- Name
  Mains Inlet Node_unit1,  !- Inlet Node Name
  Mains Pressure Outlet Node_unit1,  !- Outlet Node Name
  autosize,                !- Design Maximum Flow Rate {m3/s}
  0.000009,                !- Design Maximum Flow Rate {m3/s}
  179352,                  !- Design Pump Head {Pa}
  autosize,                !- Design Power Consumption {W}
  0.9,                     !- Motor Efficiency
  0,                       !- Fraction of Motor Inefficiencies
  0,                       !- Coefficient 1 of the Part Load P
  1,                       !- Coefficient 2 of the Part Load P
  0,                       !- Coefficient 3 of the Part Load P
  0,                       !- Coefficient 4 of the Part Load P
  0,                       !- Design Minimum Flow Rate {m3/s}
  Intermittent;            !- Pump Control Type
```

16, for baseline window run, this field keeps autosize, for other runs, this field replaces with 0.000009

(10)

```
WaterHeater:Mixed,
  Water Heater_unit1,      !- Name
  0.196841372,             !- Tank Volume {m3}
  dhw_setpt,               !- Setpoint Temperature Schedule Name
  2,                       !- Deadband Temperature Difference {deltaC}
  50,                      !- Maximum Temperature Limit
  Cycle,                   !- Heater Control Type
  autosize,                !- Heater Maximum Capacity {W
  5500,                    !- Heater Maximum Capacity {W
  0,                       !- Heater Minimum Capacity {W
  0,                       !- Heater Ignition Minimum Fl
  ,                        !- Heater Ignition Delay {s}
  electricity,             !- Heater Fuel Type
  1,                       !- Heater Thermal Efficiency
  ,                        !- Part Load Factor Curve Name
  ,                        !- Off Cycle Parasitic Fuel Consumption Rate {W}
  ,                        !- Off Cycle Parasitic Fuel Type
  ,                        !- Off Cycle Parasitic Heat Fraction to Tank
  ,                        !- On Cycle Parasitic Fuel Consumption Rate {W}
  ,                        !- On Cycle Parasitic Fuel Type
  ,                        !- On Cycle Parasitic Heat Fraction to Tank
  Zone,                    !- Ambient Temperature Indicator
  ,                        !- Ambient Temperature Schedule Name
  living_unit1,            !- Ambient Temperature Zone Name
  ,                        !- Ambient Temperature Outdoor Air Node Name
  1.3306616,               !- Off Cycle Loss Coefficient to Ambient Temperature {W/K}
  1,                       !- Off Cycle Loss Fraction to Zone
  1.3306616,               !- On Cycle Loss Coefficient to Ambient Temperature {W/K}
  1,                       !- On Cycle Loss Fraction to Zone
  0,                       !- Peak Use Flow Rate {m3/s}
  ,                        !- Use Flow Rate Fraction Sch
  ,                        !- Cold Water Supply Temperat
  Water Heater use inlet node_unit1,  !- Use Side Inlet
  Water Heater use outlet node_unit1,  !- Use Side Outle
  1,                       !- Use Side Effectiveness
  ,                        !- Source Side Inlet Node Nam
  ,                        !- Source Side Outlet Node Na
  1,                       !- Source Side Effectiveness
  autosize,                !- Use Side Design Flow Rate {m3/s}
  0.000009,                !- Use Side Design Flow Rate {m3/s}
  0,                       !- Source Side Design Flow Rate {m3/s}
  1.5;                     !- Indirect Water Heating Recovery Time {hr}
```

17, for baseline window run, this field keeps autosize, for other runs, this field replaces with 5500

18, for baseline window run, this field keeps autosize, for other runs, this field replaces with 0.000009

(11)

```
PlantLoop,
  DHW Loop_unit1,            !- Name
  Water,                     !- Fluid Type
  ,                          !- User Defined Fluid Type
  DHW Loop Operation_unit1,!- Plant Equipment Operatio
  DHW Supply Outlet Node_unit1,  !- Loop Temperature S
  100,                       !- Maximum Loop Temperature
  0,                         !- Minimum Loop Temperature
  autosize,                  !- Maximum Loop Flow Rate {
  0.000009,                  !- Maximum Loop Flow Rate {
  0,                         !- Minimum Loop Flow Rate {
  autocalculate,             !- Plant Loop Volume {m3}
  0.006851,                  !- Plant Loop Volume {m3}
  Mains Inlet Node_unit1,    !- Plant Side Inlet Node Name
  DHW Supply Outlet Node_unit1,  !- Plant Side Outlet
  DHW Supply Branches_unit1,  !- Plant Side Branch Lis
  DHW Supply Connectors_unit1,  !- Plant Side Connecto
  DHW Demand Inlet Node_unit1,  !- Demand Side Inlet N
  Mains Makeup Node_unit1, !- Demand Side Outlet Node
  DHW Demand Branches_unit1,  !- Demand Side Branch Li
  DHW Demand Connectors_unit1,  !- Demand Side Connect
  Optimal;                   !- Load Distribution Scheme
```

19, for baseline window run, this field keeps autosize, for other runs, this field replaces with 0.000009

20, for baseline window run, this field keeps autocalculate, for other runs, this field replaces with 0.006851

HVAC System for Minneapolis

- Red highlight: System_autosize_Minneapolis.inc
- Yellow highlight: System_sizing_Minneapolis.inc

(1)

```
Sizing:System,
  Central System_unit1,     !- AirLoop Name
  Sensible,                 !- Type of Load to Size On
  autosize,                 !- Design Outdoor Air Flow Rate {m
  0.628,                    !- Design Outdoor Air Flow Rate {m
  1,                        !- Central Heating Maximum System
  7,                        !- Preheat Design Temperature {C}
  0.008,                    !- Preheat Design Humidity Ratio {
  11,                       !- Precool Design Temperature {C}
  0.008,                    !- Precool Design Humidity Ratio {
  12,                       !- Central Cooling Design Supply A
  50,                       !- Central Heating Design Supply Air Te
  NonCoincident,            !- Type of Zone Sum to Use
  No,                       !- 100% Outdoor Air in Cooling
  No,                       !- 100% Outdoor Air in Heating
  0.008,                    !- Central Cooling Design Supply Air Hu
  0.008,                    !- Central Heating Design Supply Air Hu
  designday,                !- Cooling Supply Air Flow Rate Me
  ,                         !- Cooling Supply Air Flow Rate {m
  ,                         !- Cooling Supply Air Flow Rate Pe
  ,                         !- Cooling Fraction of Autosized C
  ,                         !- Cooling Supply Air Flow Rate Pe
  designday,                !- Heating Supply Air Flow Rate Me
  ,                         !- Heating Supply Air Flow Rate {m
  ,                         !- Heating Supply Air Flow Rate Pe
  ,                         !- Heating Fraction of Autosized Heatin
  ,                         !- Heating Fraction of Autosized Coolin
  ,                         !- Heating Supply Air Flow Rate Per Uni
  ZoneSum,                  !- System Outdoor Air Method
  0.5,                      !- Zone Maximum Outdoor Air Fraction {d
  CoolingDesignCapacity,    !- Cooling Design Capacity Method
  autosize,                 !- Cooling Design Capacity {W}
  8895.06,                  !- Cooling Design Capacity {W}
  ,                         !- Cooling Design Capacity Per Flo
  ,                         !- Fraction of Autosized Cooling D
  HeatingDesignCapacity,    !- Heating Design Capacity Method
  autosize,                 !- Heating Design Capacity {W}
  16064.46,                 !- Heating Design Capacity {W}
  ,                         !- Heating Design Capacity Per Floor Ar
  ,                         !- Fraction of Autosized Heating Design
  ;                         !- Central Cooling Capacity Control Met
```

1, for baseline window run, this field keeps autosize, for other runs, viz. adiabatic window run, shade fully-deployed run and shade half-deployed run, this field replaces with 0.628

2, for baseline window run, this field keeps autosize, for other runs, this field replaces with 8895.06

3, for baseline window run, this field keeps autosize, for other runs, this field replaces with 16064.46

(2)

```
AirTerminal:SingleDuct:Uncontrolled,
  ZoneDirectAir_unit1,      !- Name
  always_avail,             !- Availability Schedule Name
  Zone Inlet Node_unit1,    !- Zone Supply Air Node Name
  autosize;                 !- Maximum Air Flow Rate {m3/s}
  0.628;                    !- Maximum Air Flow Rate {m3/s}
```

4, for baseline window run, this field keeps autosize, for other runs, this field replaces with 0.628

(3)

```
Coil:Cooling:DX:SingleSpeed,
  DX Cooling Coil_unit1,   !- Name
  always_avail,            !- Availability Schedule Name
  autosize,                !- Gross Rated Total Cooling Capaci
  11657.98,                !- Gross Rated Total Cooling Capacit
  autosize,                !- Gross Rated Sensible Heat Ratio
  0.758901,                !- Gross Rated Sensible Heat Ratio
  2.70,                    !- Gross Rated Cooling COP {W/W}
  autosize,                !- Rated Air Flow Rate {m3/s}
  0.628,                   !- Rated Air Flow Rate {m3/s}
  ,                        !- Rated Evaporator Fan Power Per V
  Cooling Coil Air Inlet Node_unit1,  !- Air Inlet Node Name
  Heating Coil Air Inlet Node_unit1,  !- Air Outlet Node Name
  Cool-Cap-FT,             !- Total Cooling Capacity Function
  ConstantCubic,           !- Total Cooling Capacity Function
  Cool-EIR-FT,             !- Energy Input Ratio Function of T
  ConstantCubic,           !- Energy Input Ratio Function of F
  Cool-PLF-fPLR;           !- Part Load Fraction Correlation C
```

5, for baseline window run, this field keeps autosize, for other runs, this field replaces with 11657.98

6, for baseline window run, this field keeps autosize, for other runs, this field replaces with 0.758901

7, for baseline window run, this field keeps autosize, for other runs, this field replaces with 0.628

(4)

```
Fan:OnOff,
  Supply Fan_unit1,          !- Name
  always_avail,              !- Availability Schedule Nar
  0.7,                       !- Fan Total Efficiency
  400,                       !- Pressure Rise {Pa}
  autosize,                  !- Maximum Flow Rate {m3/s}
  0.628,                     !- Maximum Flow Rate {m3/s}
  0.8,                       !- Motor Efficiency
  1,                         !- Motor In Airstream Fracti
  air loop inlet node_unit1,  !- Air Inlet Node Name
  cooling coil air inlet node_unit1,  !- Air Outlet Noc
  ,                          !- Fan Power Ratio Function
  ,                          !- Fan Efficiency Ratio Func
  General;                   !- End-Use Subcategory
```

8, for baseline window run, this field keeps autosize, for other runs, this field replaces with 0.628

(5)

```
AirLoopHVAC,
  Central System_unit1,      !- Name
  ,                          !- Controller List Name
  availability list,         !- Availability Manager List N
  autosize,                  !- Design Supply Air Flow Rate
  0.628,                     !- Design Supply Air Flow Rate {m
  Air Loop Branches_unit1,   !- Branch List Name
  ,                          !- Connector List Name
  Air Loop Inlet Node_unit1,  !- Supply Side Inlet Node Name
  Return Air Mixer Outlet_unit1,  !- Demand Side Outlet Node Nar
  Zone Equipment Inlet Node_unit1,  !- Demand Side Inlet Node Na
  Air Loop Outlet Node_unit1;  !- Supply Side Outlet Node Names

!-   ===========  ALL OBJECTS IN CLASS: AIRLOOPHVAC:UNITARYHEATCOO

AirLoopHVAC:UnitaryHeatCool,
  ACandF_unit1,              !- Name
  always_avail,              !- Availability Schedule Name
  air loop inlet node_unit1,  !- Unitary System Air Inlet
  air loop outlet node_unit1,  !- Unitary System Air Outl
  fan_cycle,                 !- Supply Air Fan Operating Mo
  80,                        !- Maximum Supply Air Temperat
  autosize,                  !- Cooling Supply Air Flow Rate {m3/s
  0.628,                     !- Cooling Supply Air Flow Rate {m3/s}
  autosize,                  !- Heating Supply Air Flow Rate {m3/s
  0.628,                     !- Heating Supply Air Flow Rate {m3/s}
  0,                         !- No Load Supply Air Flow Rate {m3/s
  living_unit1,              !- Controlling Zone or Thermostat Loc
  Fan:OnOff,                 !- Supply Fan Object Type
  Supply Fan_unit1,          !- Supply Fan Name
  BlowThrough,               !- Fan Placement
  Coil:Heating:gas,          !- Heating Coil Object Type
  Main gas Heating Coil_unit1,  !- Heating Coil Name
  Coil:Cooling:DX:SingleSpeed,  !- Cooling Coil Object Ty
  DX Cooling Coil_unit1,     !- Cooling Coil Name
  None;                      !- Dehumidification Control Ty
```

9, for baseline window run, this field keeps autosize, for other runs, this field replaces with 0.628

10, for baseline window run, this field keeps autosize, for other runs, this field replaces with 0.628

11, for baseline window run, this field keeps autosize, for other runs, this field replaces with 0.628

(6)

```
Branch,
  Air Loop Main Branch_unit1,  !- Name
  autosize,                    !- Maximum Flow Rate {m3/s}
  0.628,                       !- Maximum Flow Rate {m3/s}
  ,                            !- Pressure Drop Curve Name
  AirLoopHVAC:UnitaryHeatCool, !- Component 1 Object
  ACandF_unit1,                !- Component 1 Name
  Air Loop Inlet Node_unit1,   !- Component 1 Inlet N
  Air loop outlet node_unit1,  !- Component 1 Outlet
  ACTIVE;                      !- Component 1 Branch Con

!-   ===========  ALL OBJECTS IN CLASS: OUTDOORAIR:NOD

OutdoorAir:Node,
  outside air inlet node_unit1,  !- Name
  0.914355407629293;             !- Height Above Ground {m}

OutdoorAir:Node,
  outdoor air node_unit1,  !- Name
  1;                       !- Height Above Ground {m

!-   ===========  ALL OBJECTS IN CLASS: COIL:HEATING:G

Coil:Heating:Gas,
  Main gas heating coil_unit1,  !- Name
  always_avail,                 !- Availability Schedule
  0.78,                         !- Gas Burner Efficiency
  autosize,                     !- Nominal Capacity {W}
  17648.39,                     !- Nominal Capacity {W}
  heating coil air inlet node_unit1,  !- Air Inlet Node
  air loop outlet node_unit1;  !- Air Outlet Node Name
```

12, for baseline window run, this field keeps autosize, for other runs, this field replaces with 0.628

13, for baseline window run, this field keeps autosize, for other runs, this field replaces with 17648.39

(7)

```
Pump:VariableSpeed,
  Mains Pressure_unit1,     !- Name
  Mains Inlet Node_unit1,   !- Inlet Node Name
  Mains Pressure Outlet Node_unit1,  !- Outlet Node Name
  autosize,                 !- Design Maximum Flow Rate {m3/s}
  0.000009,                 !- Design Maximum Flow Rate {
  179352,                   !- Design Pump Head {Pa}
  autosize,                 !- Design Power Consumption {
  0.9,                      !- Motor Efficiency
  0,                        !- Fraction of Motor Ineffici
  0,                        !- Coefficient 1 of the Part
  1,                        !- Coefficient 2 of the Part
  0,                        !- Coefficient 3 of the Part
  0,                        !- Coefficient 4 of the Part Load
  0,                        !- Design Minimum Flow Rate {m3/s}
  Intermittent;             !- Pump Control Type
```

14, for baseline window run, this field keeps autosize, for other runs, this field replaces with 0.000009

(8)

```
WaterHeater:Mixed,
  Water Heater_unit1,        !- Name
  0.196841372,               !- Tank Volume {m3}
  dhw_setpt,                 !- Setpoint Temperature Schedul
  2,                         !- Deadband Temperature Differe
  50,                        !- Maximum Temperature Limit {C
  Cycle,                     !- Heater Control Type
  autosize,                  !- Heater Maximum Capacity
  11137.8,                   !- Heater Maximum Capacity
  0,                         !- Heater Minimum Capacity
  0,                         !- Heater Ignition Minimum
  ,                          !- Heater Ignition Delay {s
  naturalgas,                !- Heater Fuel Type
  0.8,                       !- Heater Thermal Efficienc
  ,                          !- Part Load Factor Curve N
  ,                          !- Off Cycle Parasitic Fuel Con
  ,                          !- Off Cycle Parasitic Fuel Typ
  ,                          !- Off Cycle Parasitic Heat Fra
  ,                          !- On Cycle Parasitic Fuel Cons
  ,                          !- On Cycle Parasitic Fuel Type
  ,                          !- On Cycle Parasitic Heat Frac
  Zone,                      !- Ambient Temperature Indicato
  ,                          !- Ambient Temperature Schedule
  living_unit1,              !- Ambient Temperature Zone Nam
  ,                          !- Ambient Temperature Outd
  1.3306616,                 !- Off Cycle Loss Coefficie
  1,                         !- Off Cycle Loss Fraction
  1.3306616,                 !- On Cycle Loss Coefficien
  1,                         !- On Cycle Loss Fraction t
  0,                         !- Peak Use Flow Rate {m3/s
  ,                          !- Use Flow Rate Fraction S
  ,                          !- Cold Water Supply Temperatur
  Water Heater use inlet node_unit1,  !- Use Side Inlet No
  Water Heater use outlet node_unit1,  !- Use Side Outlet
  1,                         !- Use Side Effectiveness
  ,                          !- Source Side Inlet Node Name
  ,                          !- Source Side Outlet Node Name
  1,                         !- Source Side Effectiveness
  autosize,                  !- Use Side Design Flow Rate {m
  0.000009,                  !- Use Side Design Flow Rate {m
  0,                         !- Source Side Design Flow Rate
  1.5;                       !- Indirect Water Heating Recov
```

15, for baseline window run, this field keeps autosize, for other runs, this field replaces with 11137.8

16, for baseline window run, this field keeps autosize, for other runs, this field replaces with 0.000009

(9)

```
PlantLoop,
  DHW Loop_unit1,            !- Name
  Water,                     !- Fluid Type
  ,                          !- User Defined Fluid Type
  DHW Loop Operation_unit1,!- Plant Equipment Operati
  DHW Supply Outlet Node_unit1,  !- Loop Temperature
  100,                       !- Maximum Loop Temperatur
  0,                         !- Minimum Loop Temperatur
  autosize,                  !- Maximum Loop Flow Rate
  0.000009,                  !- Maximum Loop Flow Rate
  0,                         !- Minimum Loop Flow Rate {m3/s}
  autocalculate,             !- Plant Loop Volume {m3}
  0.006851,                  !- Plant Loop Volume {m3}
  Mains Inlet Node_unit1,  !- Plant Side Inlet Node Name
  DHW Supply Outlet Node_unit1,  !- Plant Side Outlet
  DHW Supply Branches_unit1,  !- Plant Side Branch Li
  DHW Supply Connectors_unit1,  !- Plant Side Connect
  DHW Demand Inlet Node_unit1,  !- Demand Side Inlet
  Mains Makeup Node_unit1, !- Demand Side Outlet Node
  DHW Demand Branches_unit1,  !- Demand Side Branch L
  DHW Demand Connectors_unit1,  !- Demand Side Connec
  Optimal;                   !- Load Distribution Scheme
```

17, for baseline window run, this field keeps autosize, for other runs, this field replaces with 0.000009

18, for baseline window run, this field keeps autocalculate, for other runs, this field replaces with 0.006851

Appendix D: Cooling and Heating Season Definition

Table D1. Cooling and Heating Season Definition for Heating and Cooling EP

Minneapolis			Houston		
	Start	End		Start	End
Winter	November 1	January 31	Winter	December 1	February 28
Spring	February 1	April 30	Spring	March 1	May 31
Summer	May 1	July 31	Summer	June 1	August 31
Autumn	August 1	October 31	Autumn	September 1	November 30
Heating	September 15	March 16	Heating	October 16	April 14
Cooling	March 17	September 14	Cooling	April 15	October 15

Appendix E: ESCalc XML Schema


```xml
<?xml version="1.0" encoding="UTF-8"?>
<!-- edited with XMLSpy v2016 rel. 2 sp1 (x64) (http://www.altova.com) by D. Charlie Curcija (Lawrence Berkeley National Laboratory) -->
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema" xmlns:vc="http://www.w3.org/2007/XMLSchema-versioning" elementFormDefault="qualified" attributeFormDefault="unqualified" version="1.1" vc:minVersion="1.1">
  <xs:element name="ESCalc">
    <xs:complexType>
      <xs:sequence>
        <xs:element name="Input" minOccurs="0">
          <xs:annotation>
            <xs:documentation>ESCalc Inputs</xs:documentation>
          </xs:annotation>
          <xs:complexType>
            <xs:sequence>
              <xs:element name="Selection" maxOccurs="3">
                <xs:annotation>
                  <xs:documentation>Selection of calculation type. EA: Adiabatic Windows Run; EB: Baseline WIndows Runb; ES: Window Attachment Run</xs:documentation>
                </xs:annotation>
                <xs:simpleType>
                  <xs:restriction base="xs:string">
                    <xs:minLength value="2"/>
                    <xs:maxLength value="2"/>
                  </xs:restriction>
                </xs:simpleType>
              </xs:element>
              <xs:element name="Climate">
                <xs:annotation>
                  <xs:documentation>Selection of climate. Cooling: Houston climate data and assumptions; Heating: Minneapolis climate data and assumptions</xs:documentation>
                </xs:annotation>
                <xs:simpleType>
                  <xs:restriction base="xs:string">
                    <xs:minLength value="7"/>
                    <xs:maxLength value="7"/>
                  </xs:restriction>
                </xs:simpleType>
              </xs:element>
              <xs:element name="AttachmentType" minOccurs="0">
                <xs:annotation>
                  <xs:documentation>Selection of Attachment type. RollerShades; CellularShades; SolarScreens; AppliedFilms;  VenetianBlinds; VerticalBlinds; WindowPanels; and PleatedShades</xs:documentation>
                </xs:annotation>
                <xs:simpleType>
                  <xs:restriction base="xs:string">
                    <xs:minLength value="12"/>
                    <xs:maxLength value="14"/>
                  </xs:restriction>
                </xs:simpleType>
              </xs:element>
              <xs:element name="NoCSVFiles" type="xs:integer">
                <xs:annotation>
                  <xs:documentation>Number of supplied CSV IDF files. 1 file for EA, EB, or ES for fixed attachments; 2 files for 1D shades; and 7 files for 2D shades</xs:documentation>
                </xs:annotation>
              </xs:element>
              <xs:element name="CSVFile" maxOccurs="7">
                <xs:complexType>
                  <xs:sequence>
                    <xs:element name="CSVFileName" type="xs:string">
                      <xs:annotation>
                        <xs:documentation>Arbitrary CSV File name for each E+ run</xs:documentation>
                      </xs:annotation>
                    </xs:element>
                    <xs:element name="DeploymentState" minOccurs="0">
                      <xs:annotation>
```

```
                                <xs:documentation>Deployment State: Open (only for 1-D and 2-D shades), Half (only for 1-D and 2-
D shades), or Full (for all shades)</xs:documentation>
                              </xs:annotation>
                              <xs:simpleType>
                                <xs:restriction base="xs:string">
                                  <xs:minLength value="4"/>
                                  <xs:maxLength value="4"/>
                                </xs:restriction>
                              </xs:simpleType>
                            </xs:element>
                            <xs:element name="SlatAngle" type="xs:integer" minOccurs="0">
                              <xs:annotation>
                                <xs:documentation>Slat Angle for Louvered Blinds: 0, -45, 45, 90</xs:documentation>
                              </xs:annotation>
                            </xs:element>
                          </xs:sequence>
                        </xs:complexType>
                      </xs:element>
                    </xs:sequence>
                  </xs:complexType>
                </xs:element>
                <xs:element name="Output" minOccurs="0">
                  <xs:annotation>
                    <xs:documentation>ESCalc Outputs</xs:documentation>
                  </xs:annotation>
                  <xs:complexType>
                    <xs:sequence>
                      <xs:element name="E_HVAC" type="xs:float"/>
                      <xs:element name="EP" type="xs:float" minOccurs="0"/>
                    </xs:sequence>
                  </xs:complexType>
                </xs:element>
              </xs:sequence>
            </xs:complexType>
          </xs:element>
</xs:schema>
```


The following Figure shows schematic presentation of the Schema.

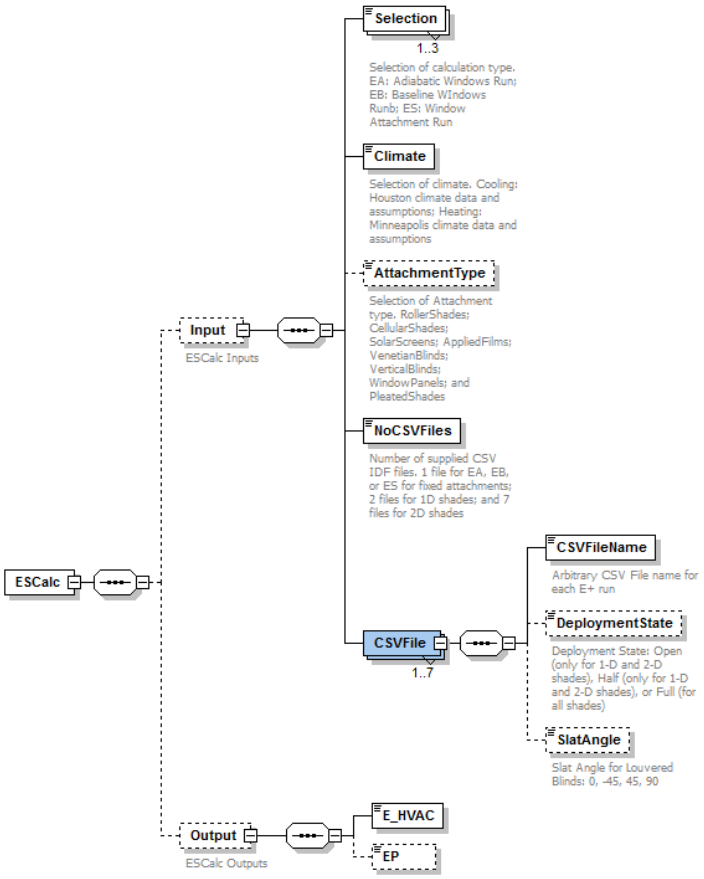


Figure E1. Schematic Presentation of the ESCalc Schema

Examples of the schema for fixed window attachment and venetian blinds products are shown next, respectively:

<u>Example of a fixed window attachment XML file:</u>

```
<?xml version="1.0" encoding="UTF-8"?>
<!-- edited with XMLSpy v2016 rel. 2 sp1 (x64) (http://www.altova.com) by D. Charlie Curcija (Lawrence Berkeley National
Laboratory) -->
<!-- Based on XML schema ESCalc.xsd.-->
<ESCalc xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:noNamespaceSchemaLocation="ESCalc_v3.xsd">
  <Input>
    <Selection>ES</Selection>
    <Climate>Houston</Climate>
    <AttachmentType>SolarScreens</AttachmentType>
    <NoCSVFiles>1</NoCSVFiles>
    <CSVFile>
      <CSVFileName>Test-File-Name-1_SS</CSVFileName>
    </CSVFile>
  </Input>
  <Output>
    <E_HVAC>115.92</E_HVAC>
    <EP>53.2</EP>
  </Output>
</ESCalc>
```

Example of venetian blind window attachment XML file:


```xml
<?xml version="1.0" encoding="UTF-8"?>
<!-- edited with XMLSpy v2016 rel. 2 sp1 (x64) (http://www.altova.com) by D. Charlie Curcija (Lawrence Berkeley National Laboratory) -->
<!-- Based on XML schema ESCalc.xsd.-->
<ESCalc xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:noNamespaceSchemaLocation="ESCalc_v3.xsd">
  <Input>
    <Selection>ES</Selection>
    <City>Minneapolis</City>
    <AttachmentType>VenetianBlinds</AttachmentType>
    <NoCSVFiles>7</NoCSVFiles>
    <CSVFile>
      <CSVFileName>Test-File-Name-2_VB_Open_0</CSVFileName>
      <DeploymentState>Full</DeploymentState>
      <SlatAngle>0</SlatAngle>
    </CSVFile>
    <CSVFile>
      <CSVFileName>Test-File-Name-2_VB_Full_-45</CSVFileName>
      <DeploymentState>Full</DeploymentState>
      <SlatAngle>-45</SlatAngle>
    </CSVFile>
    <CSVFile>
      <CSVFileName>Test-File-Name-2_VB_Full_45</CSVFileName>
      <DeploymentState>Full</DeploymentState>
      <SlatAngle>45</SlatAngle>

    </CSVFile>
    <CSVFile>
      <CSVFileName>Test-File-Name-2_VB_Full_90</CSVFileName>
      <DeploymentState>Full</DeploymentState>
      <SlatAngle>90</SlatAngle>
    </CSVFile>
    <CSVFile>
      <CSVFileName>Test-File-Name-2_VB_Half_-45</CSVFileName>
      <DeploymentState>Half</DeploymentState>
      <SlatAngle>-45</SlatAngle>
    </CSVFile>
    <CSVFile>
      <CSVFileName>Test-File-Name-2_VB_Half_45</CSVFileName>
      <DeploymentState>Half</DeploymentState>
      <SlatAngle>45</SlatAngle>
    </CSVFile>
    <CSVFile>
      <CSVFileName>Test-File-Name-2_VB_Half_90</CSVFileName>
      <DeploymentState>Half</DeploymentState>
      <SlatAngle>90</SlatAngle>
    </CSVFile>
  </Input>
  <Output>
    <E_HVAC>127.32</E_HVAC>
    <EP>34.6</EP>
  </Output>
</ESCalc>
```