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Aggregate Building Simulator (ABS) Methodology Development, Application, and User Manual

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WJ Gorrissen

November 2011

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Pacific Northwest National Laboratory
Richland, Washington 99352

Summary

Building energy simulation, through computer modeling, is of growing importance in myriad uses from the design of individual building to the design of national policy. The Building Technologies Program (BTP) has supported the development of EnergyPlus and has made it a requirement that where possible, this tool be used for program planning and analysis. As such, PNNL has adopted EnergyPlus as a tool for examining the medium and long-term impacts of BTP program activities.

As the relationship between the national building stock and various global energy issues becomes a greater concern, it has been deemed necessary to develop a system of predicting the energy consumption of large groups of buildings. Ideally this system is to take advantage of the most advanced energy simulation software available, be able to execute runs quickly, and provide concise and useful results at a level of detail that meets the users' needs without inundating them with data. For program planning and evaluation purposes it is desirable for this system to be able to model the consumption of the following groups of buildings:

- The stock of buildings as they currently exist
- The current stock of buildings assuming one or more changes (e.g., replace all windows with high performance windows) to all or a portion of the stock
- New buildings built to a common level of performance (e.g., the current energy code)
- New buildings built with a higher level of performance (e.g., 30% or 50% above code)

While EnergyPlus is detailed, accurate, and the premier building energy simulation tool, it is difficult to use it to rapidly simulate large numbers of buildings. The tool outlined in this report was developed in an effort to overcome the challenges hindering the use of EnergyPlus in large-scale, multi-building simulations. To develop this modeling system three tools were used, the output of each becoming the input for the next, these tools were:

- GParm, a mail merge utility
- National Renewable Energy Laboratory Preprocessor, an application programming interface for EnergyPlus
- Energy Plus, a whole building energy simulation program

The interaction between these tools and the organization of the resulting outputs is controlled through the use of various utilities in a Linux environment. This modeling system is known as the Aggregate Building Simulator (ABS).

The resulting methodology that was developed allows the user to quickly develop and execute energy simulations of many buildings simultaneously, taking advantage of parallel processing to greatly reduce total simulation times. The result of these simulations can then be rapidly condensed and presented in a useful and intuitive manner.

To test this methodology and demonstrate its effectiveness, a simulation making use of all available functionality was performed. This test consisted of a large group of buildings with diverse

characteristics, required a custom report variable set, and the building characteristics that were simulated that were beyond the current functionality of the preprocessor.

The building characteristic that was selected for consideration was window type, specifically, comparing a set of buildings having energy star windows (with properties varying to meet the requirements for their climate) with four other sets of buildings, all with high performance electrochromic (EC) windows. EC windows were selected for use in the test simulation because of their complexity, the preprocessor's inability to handle the required control types, and to demonstrate the text substitution capability.

This report, and the operation of ABS, assumes that the reader is already conversant with:

- EnergyPlus modeling and the requirements for executing that model and interpreting the results. (For more information on the use of EnergyPlus see the link to the User's Manual listed in the references.)
- Linux syntax and basic commands.

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1.0 Introduction

EnergyPlus is a powerful tool developed to meet the needs of a diverse group of end users. It is widely considered to be the premier tool for building energy simulation. An EnergyPlus input file can represent an almost infinite number of combinations of building characteristics. The depth and breadth of the inputs give EnergyPlus the flexibility to be usefully applied to a wide range of detailed projects, it also makes the software difficult to use without an in-depth knowledge of the program and the building that the user wishes to represent. In addition, with input files easily reaching thousands of lines in length, the process of putting together a simulation for even a single building is time consuming and has a high potential for error.

The complexity and detail of the EnergyPlus algorithms also contribute to long simulation times and vast quantities of output information. A typical building will generally take about 5 minutes to simulate and will produce many thousands of lines of output text spread across multiple files.

All of the aforementioned issues do not present much of a problem when only a small number of simulations are being performed. If, on the other hand, one wishes to run a large scale parametric building simulation, things quickly become unwieldy. When doing an analysis requiring the simulation of many different types, sizes, and vintages of buildings in a variety of different climate zones the process can become cumbersome with total simulation times start to run into the days. Additionally, even the most powerful desktop computers and business productivity software quickly grind to a halt when dealing with thousands of output files that are produced from which the data needs to be aggregated.

As part of the impacts analysis project, the Building Technologies Program needed an approach to regional and national analysis using EnergyPlus. As such, ABS was developed to overcome the three linked issues that arise from multiple building EnergyPlus simulations (input complexity, long simulation times and post processing massive amounts of data), while taking advantage of a number of separate tools and techniques (**Figure 1**). This methodology reduces the required inputs to a single file containing multiple series' of variable values, each representing a single building. This single input then drives a multi threaded simulation in a Linux environment, drastically reducing the total time required. The methodology further capitalizes on the powerful command line tools available in the Linux environment to quickly aggregate the multiple simulation outputs into a single file allowing for useful comparison of outputs across individual buildings.

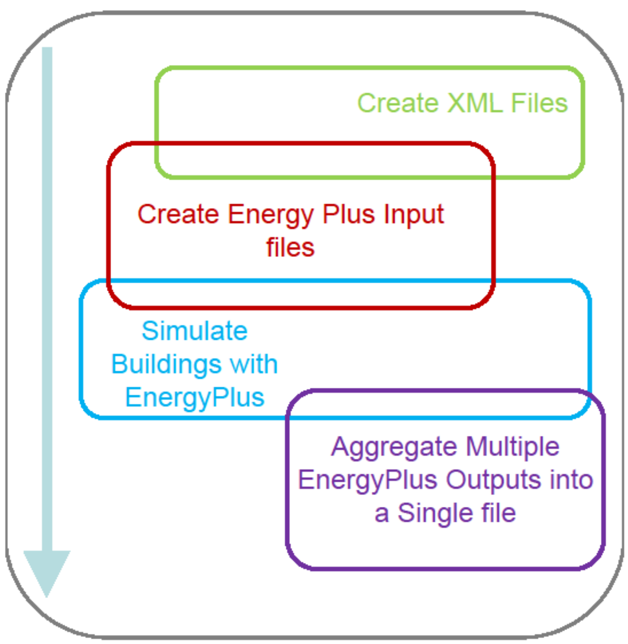

Figure 1: Overall process flow chart

To test this methodology and demonstrate its effectiveness, a simulation making use of all available functionality was performed. This test consisted of a large group of buildings with diverse characteristics, required a custom report variable set, and the building characteristics that were simulated that were beyond the current functionality of the preprocessor.

Chapter 2 describes the five categories of inputs to ABS: simulation parameters, building attributes, constructions, loads, and systems. Chapter 3 explains the ABS process from input file setup to output generation while model execution and use is laid out in Chapter 4. Chapter 5 then describes a test of the methodology consisting of a large group of buildings with diverse characteristics that required a custom report variable set and employed some building characteristics that were beyond the current functionality of the XML preprocessor. Lastly, Chapter 6 provides some conclusions from the development and use of ABS. While not essential, a working knowledge of EnergyPlus and Linux are valuable in understanding this report and the operation the Aggregate Building Simulator (ABS).

2.0 Inputs

All the simulated buildings are represented in a single, comma separated, text (CSV) file. Each line in the input file represents a single building and creates a single EnergyPlus input file. As currently configured, there are up to 709 variable values that the user can easily define for each building. Other than the requirement that each building have the same number of variables defined, there is no lower limit with respect to how many values are used to describe a building. If a variable is not defined, it is set to a reasonable value, inferred based on the other user inputs for that specific building, using the Aggregate Building Simulator (ABS) Input Generator (see Appendix A). The input file contains, in general, variables related to five different aspects of the simulation (see Appendix B for a complete listing of all inputs):

- Simulation parameters
  - Define how the simulation is carried out, including: simulation timestep, simulation run period, convergence tolerances, and others.
- Building attributes
  - Control shape and size of the building and include: floor area, number of stories, footprint shape, rotation, location, and others.
- Constructions
  - Define the fabric of the building, either layer by layer or using single layer theoretical materials. All energy related properties can be defined for windows, walls, roofs, and floors.
- Loads
  - Internal loads (people, lighting, and miscellaneous) can be defined for each building. The loads are considered to be located uniformly throughout each building. Power density, sensible ratio, heat to space and fuel type (electric or gas) can be defined for two types of miscellaneous load.
- Systems
  - The system variables control the attributes of the heating, ventilation, and air conditioning (HVAC) and domestic hot water (DHW) systems. The DHW system is defined in terms of fuel, rated capacity, storage volume, and efficiency. For HVAC systems, all sizing is handled by EnergyPlus, but the user can define system type, fuel type and the efficiency of the various components.

In addition to the CSV input file that defines the building characteristics, a GPARM/XML[1] template file is also needed to create the individual EnergyPlus input files. This template file contains all of the default variable values and serves to relate the variable to specific objects in the EnergyPlus input

[1] Extensible markup language (XML) is simply a standardized way of conveying information and is useful when one wishes to pass information between two pieces of software that use different types of inputs.

files. There is typically no need for a user to modify the template file. However, if a particular functionality is required and is not handled within the current capabilities of the methodology, the template file can be modified to expand these capabilities.

2.1 Outputs

The final product of the methodology outlined here is a single file containing an aggregation of all the individual meter.csv files[2] that are produced by EnergyPlus. The resultant file has the timesteps along the vertical axis and the output variables, grouped by building, along the horizontal axis. The file contains a mixture of units and values collected over varying periods, so care needs to be taken when interpreting the results. See Section 3.5 Output Generation for a more complete description of the output.

[2] One of the outputs available within EnergyPlus is meters. A meter is energy consumption associated with a piece of equipment, end-use, or building and can be output at the time step, hourly, monthly, or annually.

3.0 Process

The steps to producing the required outputs from the CSV and template files are outlined below in Figure 2. Each of the main steps is shown with the external inputs and outputs shown in green, internal inputs and outputs in blue, and internal processes in yellow. The heavy colored lines show the high level process stages and the colored text, their associated commands. Each step will be examined below in detail.

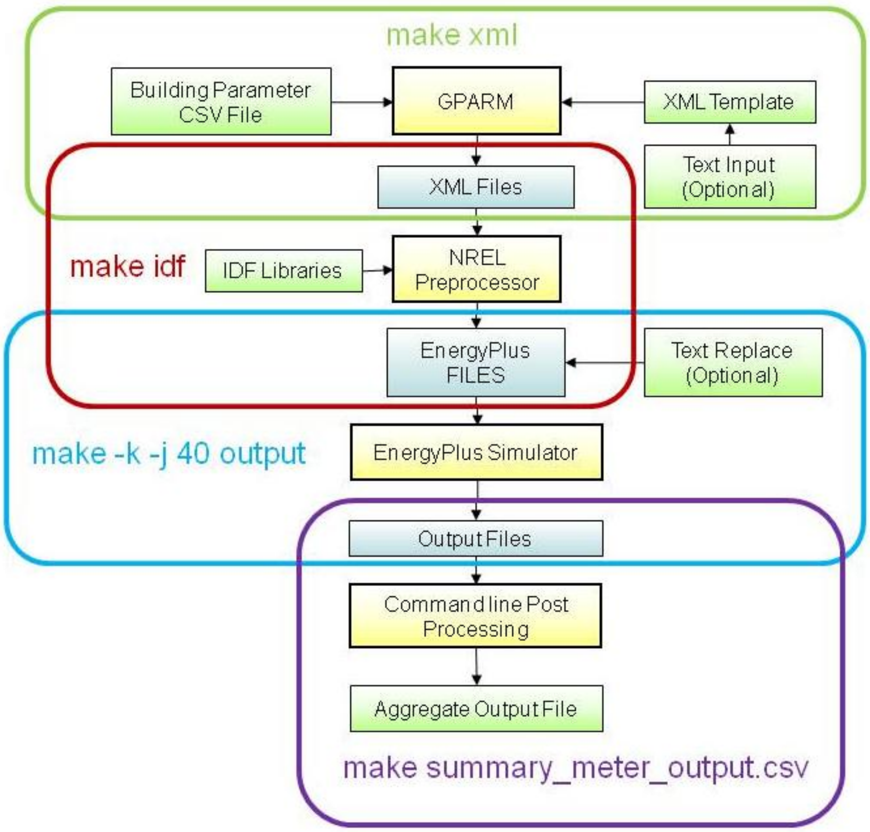

Figure 2: Detailed process flow chart

3.1 Input file Setup

The initial step of the process is to set up the parameter and template files. The parameter file should be filled in with all the variables that the user wishes to parameterize and also with those variables for which default values are not appropriate. This latter category includes any variable that has absolute units such as floor area and number of floors, versus variables that are scaled, such as lighting power density, where using the default values produces more realistic results. To see a description of each variable and its default value see Appendix B.

3.1.1 Predefined output variable sets

In order to define which output variables are produced during the simulations, one of the following output variable set names can be entered as the value for the input variable *ReportVarSetKey*:

- BasicReportsAndABUPS
- BasicReportsAndABUPS_CSV
- ReportVarforDX
- ReportVarforIECstudy
- ReportVarforVAVChillerBoiler
- ReportTestForReader
- BasicReportsAndAPUBS_BEOpt
- ReportsForCBECSAnalyses
- BasicReportsAndABUPS_Benchmark
- ReportsForSmallCBECSmicroCogenAnalyses
- HourlyEnergyOnly

3.1.2 Defining custom variable output set

It is possible to create a custom variable set. To create a one-time report variable set, the desired output objects (written in standard EnergyPlus Input Data Format IDF) are placed in the template file between the *<subtext>* and *</subtext>* tags. (Any text entered between these tags is passed directly into each IDF file and hence, needs to be entered in proper EnergyPlus syntax.) If new variables have been entered in this manner and the user does not wish to return any other results, the value of *ReportVarSetKey* should be set equal to *Null_Set*.

3.1.3 Reusing custom variable output set

If the user wishes to create a variable output set that can be reused for other projects, it is possible to create a new output package that can then be called using *ReportVarSetKey.* To accomplish this, the user needs to point to the Macro Control path[3] and open the HPBReportVariableSets.imf file. The new output variable set should be appended to the existing content of the file in the flowing format:

##def Name_of_variable_set[]

Desired outputs, in proper EnergyPlus Syntax

##enddef

The user can now call the above output variable set by assigning its name (the text between *##def* and *[]*) to the *ReportVarSetKey* variable.

3.2 XML File Creation (Make XML)

With the CSV and template files defined, the user can now create a set of XML files that are used to build the required EnergyPlus input files. This is accomplished by using a mail merge utility called GParm to combine the CSV file with the template file, creating one XML file for each row of the CSV file as shown in Figure 3. Each XML file contains the desired characteristics of a single building. The XML files can now be submitted to the NREL preprocessor.

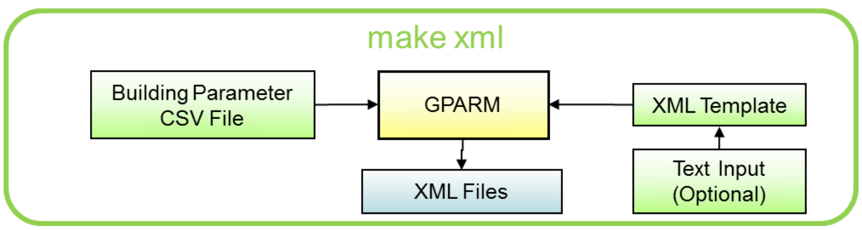

Figure 3: XML File Creation

3.3 IDF File Creation (Make IDF)

Developed by NREL as a tool to simplify the process of interfacing with the EnergyPlus simulation engine, the preprocessor is described in the documentation as:

> *…a computer program that reads an abstract description of a building and writes a complete, fully-functional EnergyPlus input file. The building XML model is the text input file to the preprocessor, contains a minimal set of high-level parameters to describe the building type, geometry, loads, and systems. The preprocessor constructs the resulting EnergyPlus building*

[3] The macro control path points to the directory in which key files used over the course of the methodology are stored. Typically these files are located wherever the NREL (National Renewable Energy Laboratory) preprocessor (a key element of the methodology) is saved, under /bin/include/.

model by automatically generating and connecting all of the required EnergyPlus objects based on a set of built-in modeling assumptions. (NREL 2008)

The preprocessor essentially allows the user to define only those attributes that are related to a building's energy performance, automatically generating the IDF language required by EnergyPlus. By driving the preprocessor inputs using a CSV file and an XML template, the Aggregate Building Simulation (ABS) tool further reduces the required expertise of the user and makes it possible to easily generate the multiple building input files required for large-scale parametric runs as shown in Figure 4. To further facilitate the production of building attribute input files, a CSV input generator was developed using PNNL internal funding. A short description of the input file generator is available in Appendix A.

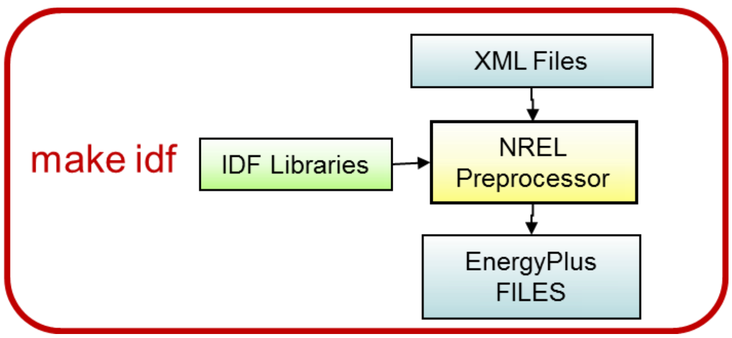

Figure 4: IDF File Creation

3.4 Energy Simulation

All of the actual energy modeling is performed using EnergyPlus. According to the documentation:

EnergyPlus is an energy analysis and thermal load simulation program. Based on a user's description of a building from the perspective of the building's physical make-up, associated mechanical systems, etc., EnergyPlus will calculate the heating and cooling loads necessary to maintain thermal control setpoints, conditions throughout an [sic] secondary HVAC system and coil loads, and the energy consumption of primary plant equipment as well as many other simulation details that are necessary to verify that the simulation is performing as the actual building would. (EnergyPlus 2010)

The complexity of the EnergyPlus inputs and the need to perform many simultaneous simulations was a key driver behind the development of ABS. With the ABS modeling system, the user does not directly interact with EnergyPlus in any way other than setting the simulation parameters in the CSV input file. The methodology also does not require any previous knowledge of EnergyPlus although it is extremely useful when modeling something outside the capability of the preprocessor.

3.5 Output Generation

Following the EnergyPlus simulations all outputs are aggregated into a single output CSV file. Each row in all the output files (representing the results for a particular timestep) is combined together, and the results are then collected into a single file, as shown in Figure 5 and Figure 6.

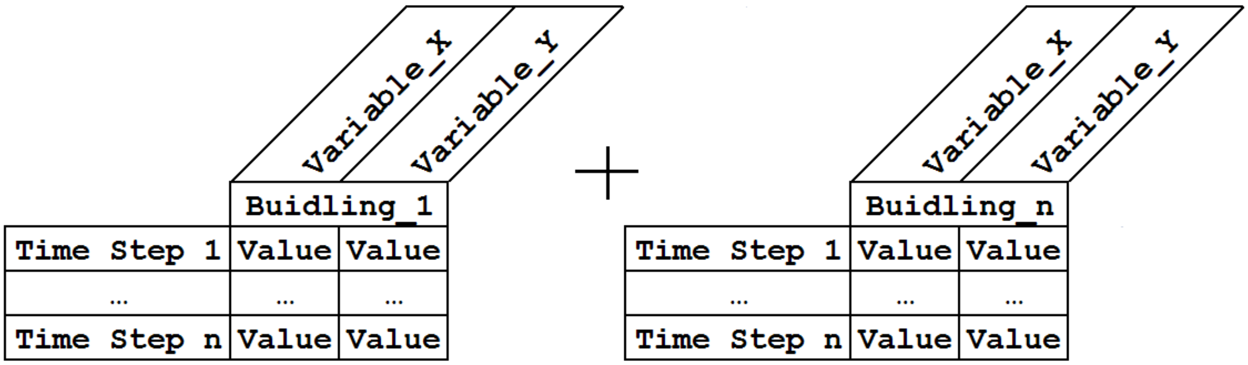

Figure 5: Sample of typical energy plus meter output files

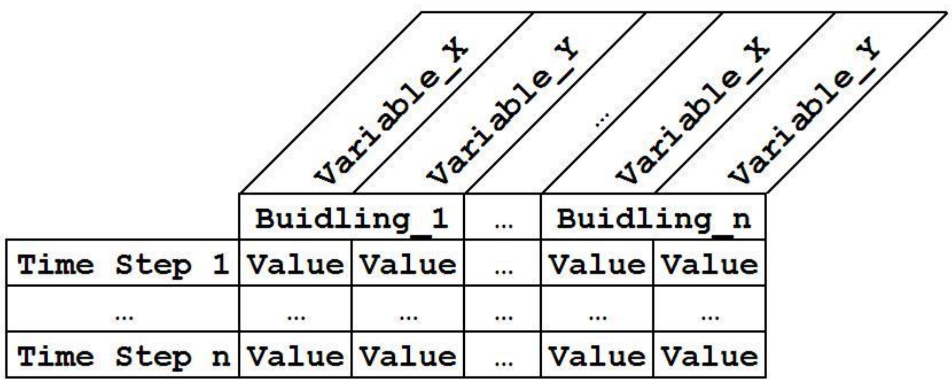

Figure 6: Sample of typical ABS summary output

4.0 Execution

With each of the required inputs developed, the user can now follow the detailed execution steps laid out below. The process execution can be restarted from the beginning of any of the main steps.

4.1 Make File Setup

To control the execution of each of the processes outlined in Section 3 and to ensure the methodology is flexible and simple to execute, *Make* (a software development utility) is used to control execution order and file dependencies. *Make* was originally developed to compile executable files from chains of interdependent source files. For the purpose of executing the methodology outlined here, the *Make* utility is used in a similar fashion to control the dependencies between the various input and output files as well as to control the required Linux commands. *Make* file dependencies work based on the file timestamps. If a file is changed, any files that depend on that changed file are, in turn, remade. This ensures that only files that have been changed are re-run, either through the preprocessor or EnergyPlus. Because all XML files are dependent on a single CSV file, this system breaks down if the XML files are remade; every XML file will have a new timestamp and so the entire process will be re-run. Care should be taken to not unnecessarily rebuild the XML files because this could lead to many hours of unnecessary simulation of unchanged files[4].

[4] If changes need to be made to only a small number of the XML files, the best approach is to delete from the CSV file all but the rows corresponding to those XML files (leaving the row ID numbers unchanged). Rerunning the entire methodology with the reduced CSV will only simulate the buildings of interest.

To ensure flexibility, the first portion of the *Make* file defines a number of variables, as shown in Table 1. Any changes that a user needs to make to set up a new run will occur in these variables.

Table 1. Make file variables

Variable		Function
EXCELXML_DIR	=	Project Directory
GPARM	=	Path to GParm Script
RUNEPLUS	=	Path to Energy Plus
PPROC	=	Path to preprocessor
XMLFILE_DIR	=	XMLFile Directory
INPUT_DIR	=	IDF File Directory
OUTPUT_DIR	=	EnergyPlus Output Directory
TEMPLATE_FILE	=	Name of template file
PARM_FILE	=	Name of parameter file

4.2 Make File Commands

Once the variables have been defined and the *Make* file saved to the project directory (under the name "makefile", with no extension or quotes) it is executed with the following steps:

1. Create XML files (Figure 7). This is executed as a separate step because all of the XML files created depend on a single input file, therefore if the XML files are remade, all the timestamps will be updated and all simulations will be rerun. The command *make XML* executes the following:

$(GPARM) -p $(PARM_FILE) -t $(TEMPLATE_FILE) -d $(XMLFILE_DIR) -f 'Building_{}.XML' -n 8

- All variables areas defined as above
- **-p**, **-t**, and **-d** indicate the parameter file, the template file, and the destination directory, respectively.
- **-f 'Building_{}.XML'** controls the naming of the output files, in this case the braces, {}, are replaced by the ID number (value in first column) of the corresponding row in the CSV file, creating Building_1.XML to Building_n.XML.
- **-n 8** causes the process to run on eight cores on a single node; it is typically not useful to run GParm on more than one node because the data transfer times become longer than the processing times.

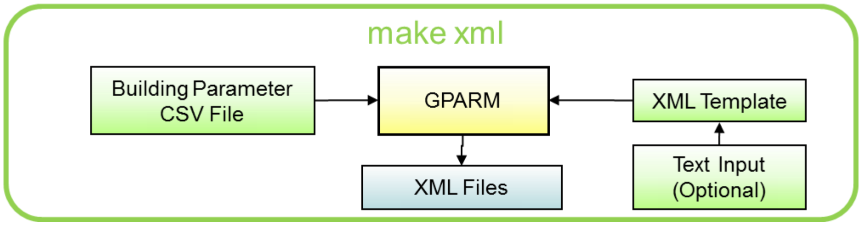

Figure 7: XML File Creation

2. Execute all remaining commands. The command *make all* runs the preprocessor, executes the EnergyPlus runs, and aggregates the results by running the following lines of code:

make idf (Figure 8)
./input/%.idf: ./XMLFiles/%.XML
$(PPROC) $< $@

- These lines check if any file within the dependency has been modified and runs the preprocessor if any changes are detected.

- The first line is the *make* command that is called to execute this step; the user could enter this rather than *make all* if he or she wished to execute one step at a time.

- The second line defines the file dependencies, using the **%** as a wild card to represent all files that have the appropriate extension. In this case, the IDF files from the **input** directory depend on the XML files from the **XMLFiles** directory.

- The third line is the command that is executed for each input (XML) file. **PPROC** is the variable representing the directory where the preprocessor is located and the command to run it. The '**<** 'symbol is used to represent the input file, the XML file in this case, and the '**@**' represents the target file, the IDF file in this case. In a *Make* file the '**$**' symbol is used before calling variables.

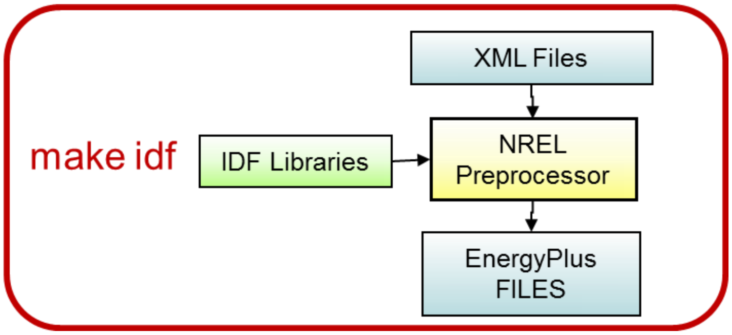

Figure 8: IDF File Creation

make -k -j 40 output (Figure 9)
$(OUTPUT_DIR)/%.meter.CSV: $(INPUT_DIR)/%.idf
@/tools/bin/qwait $(RUNEPLUS) -o $ -i $(INPUT_DIR) -p $(OUTPUT_DIR) `basename $<`*

- These lines check if any file within the dependency has been modified and runs EnergyPlus if any changes are detected.

- This first line is the *make* command associated with this step. The **-j** indicates that the number following controls how many processers should be made available to run separate instances of EnergyPlus. This number is limited by the properties of the cluster being used. The **-k** ensures that the whole process will continue even if errors occur.

- The second line defines the file dependencies; in this case the output '.meter.CSV' files depend on the IDF files.

- The third line is the command that executes EnergyPlus as needed. **@/tools/bin/qwait** runs the command through the clusters queuing system, as dictated by the value following **-j** in the *make* command. **-o $*** controls the output file name, in this case taking the same name as the input file. **-i** and **-p** control the input and output file paths, respectively. **`basename $<`** removes the path from the input (IDF) file leaving only the file name to be passed to runeplus[5] as the input file.

[5] Runeplus is a script developed to facilitate running EnergyPlus in the Linux environment.

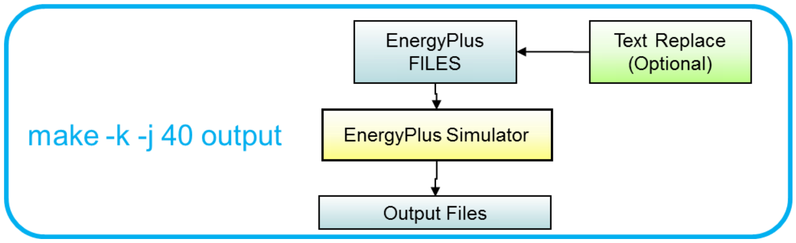

Figure 9: Make –k –j Output

make summary_meter_output.CSV (Figure 10)
cd ./output
find Building_?.meter.CSV | sort -t_ -k 2,2 -n | xargs paste -d , > ../summary_meter_output_1.CSV
find Building_??.meter.CSV | sort -t_ -k 2,2 -n | xargs paste -d , > ../summary_meter_output_2.CSV
find Building_???.meter.CSV | sort -t_ -k 2,2 -n | xargs paste -d , > ../summary_meter_output_3.CSV
find Building_1???.meter.CSV | sort -t_ -k 2,2 -n | xargs paste -d , > ../summary_meter_output_4.CSV
find Building_2???.meter.CSV | sort -t_ -k 2,2 -n | xargs paste -d , > ../summary_meter_output_5.CSV
find Building_3???.meter.CSV | sort -t_ -k 2,2 -n | xargs paste -d , > ../summary_meter_output_6.CSV
find Building_4???.meter.CSV | sort -t_ -k 2,2 -n | xargs paste -d , > ../summary_meter_output_7.CSV
find Building_5???.meter.CSV | sort -t_ -k 2,2 -n | xargs paste -d , > ../summary_meter_output_8.CSV
find Building_6???.meter.CSV | sort -t_ -k 2,2 -n | xargs paste -d , > ../summary_meter_output_9.CSV
find summary_meter_output_?.CSV | sort -t_ -k 4,4 -n | xargs paste -d , > ./summary_meter_output.CSV
sed -i 's/,Date\/Time,/,/g' summary_meter_output.CSV
sed -i 's/, ..\/.. ..:..:..,/,/g' summary_meter_output.CSV

- These lines aggregate all of the individual outputs into a single file containing all of the simulation results.

- The first line is the *make* command that initiates this portion of the *Make* file

- The second line (**cd ./output**) changes the current directory to the output directory.

- Lines 3 through 11 combine the output files by combining each of the rows. **find Building_?.meter.CSV** produces a list of the output files where the name matches the pattern **Building_?.meter.CSV**. The list is then passed as an argument to **sort -t_ -k 2,2 –n,** which puts the files in numerical order and passes them to **xargs paste -d ,** which does the final concatenation into the intermediate summary file **summary_meter_output_n.CSV**.

- Line 12 concatenates together the results on lines 3 through 11 to produce a final summary file containing the data for every output file. This is accomplished in the same manner as above using **find**, **sort**, and **paste**.

- The last two lines remove the timestamp from all but the first column by using **sed** to find and delete the desired entries.

- This method is currently limited to simulations of less than 7000 buildings; to increase this capability, simply copy the 11th line (***find Building_6???***) and paste it directly underneath itself. Add 1 to the building designation number (*Building_6???* Becomes *Building_7???*) and the intermediate summary file number (*summary_meter_output_9.CSV becomes summary_meter_output_10.CSV).*

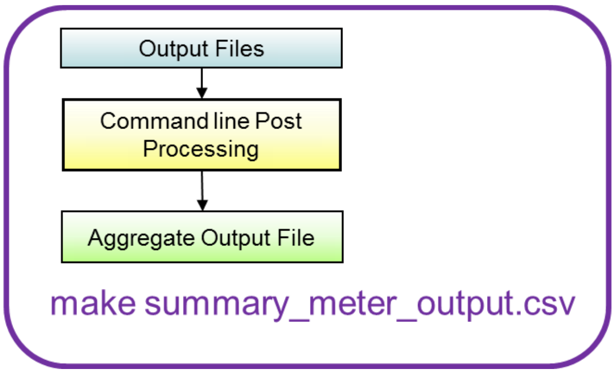

Figure 10: Make –k –j Output

4.3 Advanced use

As was mentioned above, it is possible to directly pass pieces of IDF building description from the template file through to each IDF file. This is used to simulate building systems that fall outside the capabilities of the preprocessor. This is an advanced capability that requires the user to be proficient in the use of EnergyPlus and to have a basic understanding of regular expressions[6], the Linux command line interface, and the *sed* (Linux stream editor) utility.

Generally there are two parts to increasing the simulation capabilities in this way. First, the user must create the required EnergyPlus objects in the proper IDF format and place the objects between the *<subtext>* and *</subtext>* tags in the template file. The objects are included in addition to any output variable objects that the user has placed between the tags; the order of the objects has no impact on the final results.

The next step occurs after the preprocessor is run, creating the IDF files, but before the actual EnergyPlus simulation. To access the files before EnergyPlus runs, it will be necessary to enter the

[6] Regular expressions provide a means to search not only based on the content of text, but also based on the location and arraignment of text. As well one can also use regular expressions to match types or ranges of charters.

individual *make* commands (*make idf*, *make -k -j 40 output*, and *make summary_meter_output.CSV*) rather than *make all*. After the IDF files have been made using *make idf,* the user must modify the files to make use of the objects passed through from the template file. This usually involves assigning the new objects to some element of the IDF that are created by the preprocessor, typically by using the *sed* command to search for a particular string or regular expression and replace it with another. The *sed* command generally takes the following format:

sed -i ‘s/string to find/string to replace/g’

The user must take care to choose a search string that will not capture more than intended, as well the user must understand that the search string is actually a regular expression and any metacharacters must be proceeded by a back slash (\). In certain instances, the user may wish to replace one entire, preprocessor created object with a user created one; in this case, *sed* is used as well by leaving the “*string to replace*” portion of the command blank and placing the entire block of text that needs to be deleted in the “*string to find*” portion. After applying any user created object(s) as needed, the simulation is continued with the *make -k -j 40 output* command; care should be taken not to use the *make all* command because all XML files will be remade and changes will be lost.

5.0 Testing

To test the methodology outlined above, a simulation making use of all available functionality was required. This test needed to consist of a large group of buildings with diverse characteristics, require a custom report variable set, and some building characteristics would need to be simulated that were beyond the current functionality of the XML preprocessor.

5.1 Input Setup

To execute this test, a set of 3,360 buildings was selected for simulation. The CSV file was populated with building input parameters selected to approximate buildings with the following characteristics:

- Age: 7 vintages: from pre-1946 to present
- Size: 6 floor areas:
    - Commercial: less than 5,000 ft^2 to greater than 100,000 ft^2
    - Residential[7]: generally less than 1000 ft^2 to greater than 4000 ft^2
- Use type: 16 building types, 11 commercial and 5 residential
- Climate: the five climates zones representing 79% of recent building construction (Belzer 2010).

To capture building heating and cooling loads irrespective of the technology used, and facilitate comparison between buildings, the HVAC system selected for all buildings uses district heating and district chiller water distributed throughout the building via air handling units.

5.2 Report Variable Set Creation

Because none of the existing output variable sets reported only district heating, district chiller water, and electricity use, a custom report set was created in the *HPBReportVariableSets.imf* file, as shown in Figure 11. The *ReportVarSetKey* variable was then set equal to the name given to this variable set, *HourlyEnergyAndPurchWaterOnly*.

[7] Residential size categories are different for each type of dwelling; the numbers listed here are approximate

```
##def HourlyEnergyAndPurchWaterOnly[]

  Output:Meter,
    Electricity:Building,                  !- Name
    Hourly;                                !- Reporting Frequency

  Output:Meter,
    InteriorLights:Electricity,            !- Name
    Hourly;                                !- Reporting Frequency

  Output:Meter,
    DistrictCooling:Facility,              !- Name
    Hourly;                                !- Reporting Frequency

  Output:Meter,
    DistrictHeating:Facility,              !- Name
    Hourly;                                !- Reporting Frequency

##enddef
```

Figure 11: Custom report output variable set

The building characteristic that was selected for variation between simulations was window type, specifically, comparing a set of buildings having energy star windows (with properties varying to meet the requirements for their climate) with four other sets of buildings, all with high performance electrochromic (EC) windows. The four building sets with electrochromic super windows all have windows that meet the EERE 2020 Window Technical Targets in terms of U-value and light/dark VT and SHGC shown in Table 2.

Table 2: EERE 2020 Electrochromic Window Technical Targets

	Light State	**Dark State**
U-Value (Btu/h·ft^2·^{o}F)	0.56	0.56
SHGC	0.53	0.09
VT	65%	2%

Each building set with EC windows was modeled with different control strategies:

1. EC always in clear state
2. EC window switch to dark state in response to excessive (>20) discomfort glare index in zone
3. EC windows modulate to dark state when daylighting set point has been reached
4. EC windows switch to dark state either because of excessive (>20) discomfort glare index or modulate until daylighting set point is met.

5.3 Text Substitution

EC windows were selected for use in the test simulation because of their complexity, the preprocessor's inability to handle the required control types, and to demonstrate the text substitution capability. The glass properties for the light state EC windows were passed through the preprocessor by first being defined in the CSV input file as a single sheet of theoretical glass. The glass properties were determined using the EnergyPlus object WindowMaterial:SimpleGlazingSystem. This object was new in EnergyPlus 4.0 and allows the user to define a glazing material using only u-value, solar heat gain coefficient (SHGC), and visible transmittance (VT). By simulating a dummy building that had simple glazing systems representing both the EC light and dark states, the detailed properties of an equivalent sheet of glass were determined. Table 3 shows these properties.

Table 3: Electrochromic window properties for light and dark state

	Light State	Dark State
Thickness	0.05469	0.05469
Solar Transmittance	0.45003	0.03694
Solar Reflectance Front	0.38255	0.8517
Solar Reflectance Back	0.38255	0.8517
Visible Transmittance	0.65	0.02
Visible Reflectance Front	0.13254	0.23173
Visible Reflectance Back	0.15003	0.43056
IR Transmittance	0	0
Emissivity Front	0.84	0.84
Emissivity Back	0.84	0.84
Conductivity	0.03411	0.03411

The light state windows properties (Table 4) are entered in the CSV because they are considered to be typical window case (and so are applied to the building as any normal window would be). The dark state is considered the altered case so its properties (Figure 12) must be entered separately in the text substitution portion of the XML template between the subtext tags in the XML template file. This is because EnergyPlus models any sort of changeable window, including EC windows, to include two descriptions of the window, one in the "open" state, and one in the "closed" state. The open case is assigned to a surface, while the closed case is assigned to a shading control object. The shading control object is assigned to the same surface as the open state window and modulates between the two states based on different inputs. The shading control objects were included in the template file and passed through to each IDF file, as shown in Figure 13.

Table 4: Electrochromic window light state properties

Variable Name	Variable Value
SWinGlass1Name	THEORETICAL GLASS [LIGHT]
SWinGlass1Thickness	0.05469
SWinGlass1SolarTrans	0.45003
SWinGlass1SolarReflectFront	0.38255
SWinGlass1SolarReflectBack	0.38255
SWinGlass1VisibleTrans	0.65
SWinGlass1VisibleReflectFront	0.13254
SWinGlass1VisibleReflectBack	0.15003
SWinGlass1IRTrans	0
SWinGlass1IREmmFront	0.84
SWinGlass1IREmmBack	0.84
SWinGlass1Conductivity	0.03411

```
<SubText>

!*****************************************
! Electrochromic Glass Objects
!*****************************************


WindowMaterial:Glazing,
    THEORETICAL GLASS [DARK],   !- Name
    SpectralAverage,            !- Optical Data Type
    ,                           !- Window Glass Spectral Data Set Name
    0.05469,                    !- Thickness {m}
    0.03694,                    !- Solar Transmittance at Normal Incidence
    0.85170,                    !- Front Side Solar Reflectance at Normal Incidence
    0.85170,                    !- Back Side Solar Reflectance at Normal Incidence
    0.02000,                    !- Visible Transmittance at Normal Incidence
    0.23173,                    !- Front Side Visible Reflectance at Normal Incidence
    0.43056,                    !- Back Side Visible Reflectance at Normal Incidence
    0.00000,                    !- Infrared Transmittance at Normal Incidence
    0.84000,                    !- Front Side Infrared Hemispherical Emissivity
    0.84000,                    !- Back Side Infrared Hemispherical Emissivity
    0.03411,                    !- Conductivity {W/m-K}


Construction,
    Dark State EC Window,       !- Name
    THEORETICAL GLASS [DARK];   !- Layer 1

...

...
</Subtext>
```

Figure 12: Electrochromic window dark state properties

```
<SubText>
...

...
!*****************************************
! Shading Control Objects
!*****************************************

WINDOWproperty:SHADINGCONTROL,
    EC_Always_Off,              !- User Supplied Shading Control Name
    SwitchableGlazing,          !- Shading Type
    Dark State EC Window,       !- Name of construction with shading
    OnIfHighGlare,              !- Shading Control Type
    ,                           !- Schedule Name
    2000,                       !- SetPoint [W/m2, W or deg C]
    NO,                         !- Shading Control Is Scheduled
    NO,                         !- Glare Control Is Active
    ,                           !- Material Name of Shading Device
    FixedSlatAngle,             !- Type of Slat Angle Control for Blinds
    ;                           !- Slat Angle Schedule Name

WINDOWproperty:SHADINGCONTROL,
    EC_On_For_Glare,            !- User Supplied Shading Control Name
    SwitchableGlazing,          !- Shading Type
    Dark State EC Window,       !- Name of construction with shading
    OnIfHighGlare,              !- Shading Control Type
    ,                           !- Schedule Name
    100,                        !- SetPoint [W/m2, W or deg C]
    NO,                         !- Shading Control Is Scheduled
    YES,                        !- Glare Control Is Active
    ,                           !- Material Name of Shading Device
    FixedSlatAngle,             !- Type of Slat Angle Control for Blinds
    ;                           !- Slat Angle Schedule Name

WINDOWproperty:SHADINGCONTROL,
    EC_Meets_Daylight,                  !- User Supplied Shading Control Name
    SwitchableGlazing,          !- Shading Type
    Dark State EC Window,               !- Name of construction with shading
    MeetDaylightIlluminanceSetpoint,            !- Shading Control Type
    ,                           !- Schedule Name
    20.0,                       !- SetPoint [W/m2, W or deg C]
    NO,                         !- Shading Control Is Scheduled
    NO,                         !- Glare Control Is Active
    ,                           !- Material Name of Shading Device
    FixedSlatAngle,             !- Type of Slat Angle Control for Blinds
    ;                           !- Slat Angle Schedule Name

WINDOWproperty:SHADINGCONTROL,
    EC_Meets_Daylight_On_For_Glare,             !- User Supplied Shading Control Name
    SwitchableGlazing,          !- Shading Type
    Dark State EC Window,               !- Name of construction with shading
    MeetDaylightIlluminanceSetpoint,            !- Shading Control Type
    ,                           !- Schedule Name
    20.0,                       !- SetPoint [W/m2, W or deg C]
    NO,                         !- Shading Control Is Scheduled
    YES,                        !- Glare Control Is Active
    ,                           !- Material Name of Shading Device
    FixedSlatAngle,             !- Type of Slat Angle Control for Blinds
    ;                           !- Slat Angle Schedule Name


</Subtext>
```

Figure 13: Shading control objects used to model electrochromic windows

5.4 Text Search and Replace

With the CSV and template file prepared, it was then possible to create the XML file with the command *make XML* and then to create the IDF files with the command *make idf*. This process was repeated once for each control strategy, ending with four different project directories, each containing a set of 3,360 IDF files. *Sed* was then used to assign control strategies to the window objects in each IDF; for example, to assign the control strategy of turning the EC window on when high glare is present uses:

*sed –i 's/ , !- Shading Control Name/EC_On_For_Glare, !- Shading Control Name/g' *.idf*

to go from the shading control strategy shown in Figure 14 to the strategy shown in Figure 15.

```
FenestrationSurface:Detailed,
    ZN_1_FLR_1_SEC_1_Wall_1_window_1,    !- Name
    Window,                              !- Surface Type
    Theoretical_EC_Light,                !- Construction Name
    ZN_1_FLR_1_SEC_1_Wall_1,             !- Building Surface Name
    ,                                    !- Outside Boundary Condition Object
    AutoCalculate,                       !- View Factor to Ground
    ,                                    !- Shading Control Name
    ,                                    !- Frame and Divider Name
    1.0000,                              !- Multiplier
    4,                                   !- Number of Vertices
    0.0500,  0.0000,  1.5504,            !- X1, Y1, Z1
    0.0500,  0.0000,  1.1000,            !- X2, Y2, Z2
    15.5664,  0.0000,  1.1000,           !- X3, Y3, Z3
    15.5664,  0.0000,  1.5504;           !- X4, Y4, Z4
```

Figure 14: Shading control strategy for Energy Star windows

```
FenestrationSurface:Detailed,
    ZN_1_FLR_1_SEC_1_Wall_1_window_1,    !- Name
    Window,                              !- Surface Type
    Theoretical_EC_Light,                !- Construction Name
    ZN_1_FLR_1_SEC_1_Wall_1,             !- Building Surface Name
    ,                                    !- Outside Boundary Condition Object
    AutoCalculate,                       !- View Factor to Ground
    EC_On_For_Glare,                     !- Shading Control Name
    ,                                    !- Frame and Divider Name
    1.0000,                              !- Multiplier
    4,                                   !- Number of Vertices
    0.0500,  0.0000,  1.5504,            !- X1, Y1, Z1
    0.0500,  0.0000,  1.1000,            !- X2, Y2, Z2
    15.5664,  0.0000,  1.1000,           !- X3, Y3, Z3
    15.5664,  0.0000,  1.5504;           !- X4, Y4, Z4
```

Figure 15: Shading control strategy for electrochromic windows

5.5 Baseline Development

This was repeated for the other two EC control strategies, where it was necessary (no changes were required for the *EC always off* strategy) to complete the four different sets of IDF files with EC windows. A further set of IDF files was created by assuming that all windows were uncontrolled and met the current Energy Star window requirements for their climate, as shown in Table 5:

Table 5: Energy Star window requirements

Climate	U-Value	SHGC	VT
Northern	1.70	0.45	0.63
North Central	1.82	0.4	0.56
South Central	1.99	0.3	0.42
Southern	3.41	0.27	0.378

5.6 Simulation and Output Aggregation

The five sets (one Energy Star baseline set plus four different EC control strategy sets) of IDF files were then run through EnergyPlus (using the *make -k -j 40 output* command) to produce the required outputs for each building.

The outputs were aggregated into a single output summary file using the command *make summary_meter_output.CSV*. This groups the output files into intermediate summary files of 100 files or less and then combines those intermediate files into one large output file. The intermediate files are necessary to both make the data reasonably easy to work with and to facilitate final output aggregation. For the demonstration run of 3,360 buildings, where each produced four hourly output variables, the resultant summary file contained nearly 1.4 GB of data. Annual energy use intensity (EUI) results are shown below in Tables 6 through 9.

Table 6: Total electricity consumption

Results Aggregated By:	Total Electricity (kBtu/yr/ft^2)					
	Baseline	Baseline with daylighting	EC Always Off	EC On For Glare	EC On For Daylighting	EC On For Glare And Daylighting
Assembly	18	16	15	16	15	16
Education	26	23	23	24	23	23
Food Sales	108	104	103	105	103	105
Food Service	88	81	80	83	80	82
Health Care	50	46	46	47	46	46
Lodging	28	26	26	26	25	25
Mercantile and Service	26	22	21	23	21	23
Office	27	24	24	25	24	24
Public Order/Safety	18	15	15	16	15	15
Warehouse and Storage	13	12	12	13	12	13
Other	15	13	12	14	12	13
Single Family Detached	24	22	22	22	22	22
Single Family Attached	120	114	113	116	113	115
2 to 4 Unit Buildings	23	22	22	22	21	21
5 or More Unit Buildings	20	18	18	18	17	18
Mobile Homes	46	43	43	44	43	43
1945	39	36	36	37	35	36
1955	39	36	35	36	35	36
1965	41	38	37	38	37	38
1976	41	38	38	39	38	38
1984	41	38	38	39	38	38
1990	44	41	41	42	41	41
2000	39	36	36	37	36	37
USA_GA_ATLANTA	38	35	34	36	34	35
USA_IL_CHICAGO-OHARE	39	36	36	37	36	36
USA_MD_BALTIMORE	44	41	41	42	40	41
USA_CA_LOS_ANGELES	38	35	34	35	34	35
USA_TX_HOUSTON	44	41	41	42	41	41

Table 7: Interior lighting consumption

Results Aggregated By:	Interior Lights Electricity (kBtu/yr/ft2)					
	Baseline	Baseline with daylighting	EC Always Off	EC On For Glare	EC On For Daylighting	EC On For Glare And Daylighting
Assembly	9	7	6	7	6	6
Education	10	8	7	8	7	8
Food Sales	14	11	10	11	10	11
Food Service	24	18	17	19	17	18
Health Care	11	7	7	8	7	7
Lodging	11	9	9	9	9	9
Mercantile and Service	18	14	13	15	13	15
Office	10	7	7	7	7	7
Public Order/Safety	10	7	7	8	7	7
Warehouse and Storage	8	7	6	7	6	7
Other	11	8	7	9	7	9
Single Family Detached	11	10	9	10	9	10
Single Family Attached	55	49	47	50	47	50
2 to 4 Unit Buildings	11	9	9	10	9	9
5 or More Unit Buildings	11	9	9	9	9	9
Mobile Homes	11	9	8	9	8	9
1945	15	11	11	12	11	12
1955	15	12	11	12	11	12
1965	15	12	11	12	11	12
1976	15	12	11	12	11	12
1984	15	12	11	12	11	12
1990	15	12	11	12	11	12
2000	15	12	11	12	11	12
USA_GA_ATLANTA	15	12	11	12	11	12
USA_IL_CHICAGO-OHARE	15	11	11	12	11	12
USA_MD_BALTIMORE	15	11	11	12	11	12
USA_CA_LOS_ANGELES	15	12	11	12	11	12
USA_TX_HOUSTON	15	12	11	12	11	12

Table 8: Cooling load

Results Aggregated By:	Cooling Load (kBtu/yr/ft2)					
	Baseline	Baseline with daylighting	EC Always Off	EC On For Glare	EC On For Daylighting	EC On For Glare And Daylighting
Assembly	31	29	32	30	29	28
Education	33	32	34	33	30	30
Food Sales	68	66	68	67	68	67
Food Service	66	62	64	62	63	62
Health Care	83	82	86	84	79	79
Lodging	42	39	45	42	34	34
Mercantile and Service	29	28	28	28	28	28
Office	29	27	32	28	24	24
Public Order/Safety	26	25	26	25	24	24
Warehouse and Storage	52	52	53	52	52	52
Other	33	32	32	32	32	32
Single Family Detached	25	24	26	24	26	25
Single Family Attached	109	105	114	105	113	106
2 to 4 Unit Buildings	29	28	35	30	24	24
5 or More Unit Buildings	24	23	28	25	19	19
Mobile Homes	36	35	39	34	34	34
1945	58	57	60	58	56	55
1955	55	54	57	55	53	52
1965	51	49	53	50	48	48
1976	41	40	43	40	39	39
1984	37	35	38	36	35	34
1990	35	33	36	34	32	32
2000	36	34	37	35	33	33
USA_GA_ATLANTA	46	45	49	46	45	44
USA_IL_CHICAGO-OHARE	35	34	34	33	31	31
USA_MD_BALTIMORE	42	41	43	40	39	38
USA_CA_LOS_ANGELES	31	29	34	31	30	29
USA_TX_HOUSTON	70	68	72	70	67	67

Table 9: Heating load

Results Aggregated By:	Heating Load (kBtu/yr/ft2)					
	Baseline	Baseline with daylighting	EC Always Off	EC On For Glare	EC On For Daylighting	EC On For Glare And Daylighting
Assembly	15	15	14	14	14	14
Education	15	15	13	14	14	14
Food Sales	14	14	13	14	13	14
Food Service	24	24	22	23	23	23
Health Care	63	63	59	62	59	59
Lodging	27	26	23	25	21	21
Mercantile and Service	20	21	20	20	20	20
Office	10	10	7	9	8	8
Public Order/Safety	16	17	15	16	15	15
Warehouse and Storage	86	86	85	86	85	86
Other	45	45	44	44	44	44
Single Family Detached	10	10	8	8	8	8
Single Family Attached	36	36	27	32	27	31
2 to 4 Unit Buildings	12	12	9	10	8	9
5 or More Unit Buildings	11	11	7	9	9	9
Mobile Homes	28	29	24	26	25	26
1945	40	40	37	39	37	38
1955	37	37	34	35	34	34
1965	32	32	29	30	29	30
1976	23	23	21	22	21	21
1984	20	20	17	19	18	18
1990	18	19	16	17	16	17
2000	19	19	16	18	17	17
USA_GA_ATLANTA	24	24	21	22	21	22
USA_IL_CHICAGO-OHARE	49	49	45	47	45	46
USA_MD_BALTIMORE	38	38	35	37	35	35
USA_CA_LOS_ANGELES	9	9	8	9	8	8
USA_TX_HOUSTON	15	15	13	14	13	13

6.0 Conclusions

The tool outlined in this report was developed in an effort to overcome the challenges hindering the use of EnergyPlus in large-scale, multi-building simulations. These challenges include the requirement for highly complex and detailed inputs, excessive simulation time, and massive quantities of output data. By reducing required inputs to a list of easily understandable variables, allowing the user to capitalize on the benefits of parallel computing, and automatically collecting the pertinent output data into a single file, the ABS methodology greatly broadens the usefulness of the EnergyPlus software.

The ABS has the potential to be put to a wide variety of uses, including simulating the overall impact of mandated changes to the built environment, parametric simulations to compare the impact of adjusting a single building attribute, as well as developing local or regional building energy consumption profiles. In general, the ABS vastly expands the control volume within which EnergyPlus can provide useful information, moving from the limitations of a single building or facility to where the scope is limited only by access to computing power and knowledge of the building stock one intends to simulate.

7.0 References

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EnergyPlus Example File Generator. 2011. http://apps1.eere.energy.gov/buildings/energyplus/cfm/inputs/index.cfm#building_geometry/. Last accessed October 27, 2011.

APPENDIX A

Aggregate Building Simulator Input Generator

Appendix A: Aggregate Building Simulator Input Generator

The Aggregate Building Simulator Input Generator (ABSIG) is a tool developed through internal funding to facilitate the production of the required comma separated value (CSV) inputs for the Aggregate Building Simulator (ABS). The design intention is to allow for the production of an entire input file with a minimal knowledge of the buildings to be simulated. The users can easily specify as much detail as they wish, but as a minimum they must provide:

- Use
- Location
- Floor area
- Vintage.

From these four inputs, all of the required ABS input variables can be inferred. The inferences are derived from a number of sources, including:

- Commercial Building Energy Consumption Survey (CBECS)
- Residential Energy Consumption Survey (RECS)
- End-Use Load and Consumer Assessment Program (ELCAP)
- American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) standard design and construction practices.

Inferences from these sources are arrived at in two main ways. From the survey data (CEBECS, RECS, and ELCAP), ordinary least squares dummy variable regression is used to develop the probabilities that certain building attributes exist; while the way codes and standards change over time and across locations is used to predict when the implementation of certain technologies likely occurred.

When a user enters the minimum set of information required, all of the variables required by the ABS are inferred within the excel spread sheet through a series of look up tables that populate the second sheet of the workbook. To use this auto generated input, the user must first copy the entire input sheet and paste its values alone to a new work book. The new work book can then be saved in the ABS project directory in the comma separated value format. For a detailed list of the available variables and brief descriptions of each, please see Appendix B.

APPENDIX B

Aggregate Building Simulator Input Variables, Description, Default Values

Appendix B: Aggregate Building Simulator Input Variables, Description, Default Values

Variable	Description	Default	Units
TimeStepInHour	Time steps per hour used by EnergyPlus	4	per hour
RunStartMonth	Begin Month For energy Plus Simulation	1	Month
RunStartDay	Begin day For energy Plus Simulation	1	Day
RunStopMonth	End Month For energy Plus Simulation	12	Month
RunStopDay	End day For energy Plus Simulation	31	Day
MaxNumberOfWarmupDays	Maximum days before simulation that energy plus has to achieve convergence	25	Day
LoadConvergeTolerance	maximum level of divergence allowed in load calculations	0.04	
TemperatureConvergeTolerance	maximum level of divergence allowed in temperature calculations	0.2	C
UpdateShadowInterval	how often (in days) to update shadows	30	Day
MaxHVACIterations	maximum number of interrelations HVAC simulation has to achieve convergence	25	integer
MinSystemTimeStep	minimum timestep allowed for system simulation	5	per hour
EnergyPlusVersion	version of energy plus to use	3.1	N/A
PrimarySpaceType	Primary function of building to be modeled	Office	N/A
Location	Location of Building	USA_WA_SEATTLE	N/A
ConstructsLibrary	Library to use for default constructions	HPBStandardConstructions.imf	N/A
SWinName	Name of South Window	EC_Window_Light	N/A
SWinNumberPanes	Number of Panes for south windows	1	integer
SWinGlass1Name	South window pane 1 attributes	THEORETICAL GLASS [LIGHT]	N/A
SWinGlass1Thickness	South window pane 1 attributes	0.05469	Meter
SWinGlass1SolarTrans	South window pane 1 attributes	0.45003	%
SWinGlass1SolarReflectFront	South window pane 1 attributes	0.38255	%
SWinGlass1SolarReflectBack	South window pane 1 attributes	0.38255	%
SWinGlass1VisibleTrans	South window pane 1 attributes	0.65	%
SWinGlass1VisibleReflectFront	South window pane 1 attributes	0.13254	%
SWinGlass1VisibleReflectBack	South window pane 1 attributes	0.15003	%
SWinGlass1IRTrans	South window pane 1 attributes	0	%
SWinGlass1IREmmFront	South window pane 1 attributes	0.84	%

Variable	Description	Default	Units
SWinGlass1IREmmBack	South window pane 1 attributes	0.84	%
SWinGlass1Conductivity	South window pane 1 attributes	0.03411	W/m-K
SWinGasName	South window gas attributes	'AIR 6MM'	N/A
SWinGasType	South window gas attributes	Air	N/A
SWinGasThickness	South window gas attributes	0.0063	Meter
SWinGlass2Name	South window pane 2 attributes	Theoretical Glass [117]	N/A
SWinGlass2Thickness	South window pane 2 attributes	0.003	Meter
SWinGlass2SolarTrans	South window pane 2 attributes	0.39333	%
SWinGlass2SolarReflectFront	South window pane 2 attributes	0.55667	%
SWinGlass2SolarReflectBack	South window pane 2 attributes	0.55667	%
SWinGlass2VisibleTrans	South window pane 2 attributes	0.507883	%
SWinGlass2VisibleReflectFront	South window pane 2 attributes	0.442117	%
SWinGlass2VisibleReflectBack	South window pane 2 attributes	0.442117	%
SWinGlass2IRTrans	South window pane 2 attributes	0	%
SWinGlass2IREmmFront	South window pane 2 attributes	0.84	%
SWinGlass2IREmmBack	South window pane 2 attributes	0.84	%
SWinGlass2Conductivity	South window pane 2 attributes	0.9	W/m-K
SWinGlass3Name	South window pane 3 attributes	Theoretical Glass [117]	N/A
SWinGlass3Thickness	South window pane 3 attributes	0.003	Meter
SWinGlass3SolarTrans	South window pane 3 attributes	0.39333	%
SWinGlass3SolarReflectFront	South window pane 3 attributes	0.55667	%
SWinGlass3SolarReflectBack	South window pane 3 attributes	0.55667	%
SWinGlass3VisibleTrans	South window pane 3 attributes	0.507883	%
SWinGlass3VisibleReflectFront	South window pane 3 attributes	0.442117	%
SWinGlass3VisibleReflectBack	South window pane 3 attributes	0.442117	%
SWinGlass3IRTrans	South window pane 3 attributes	0	%
SWinGlass3IREmmFront	South window pane 3 attributes	0.84	%
SWinGlass3IREmmBack	South window pane 3 attributes	0.84	%
SWinGlass3Conductivity	South window pane 3 attributes	0.9	W/m-K
SWinGlass4Name	South window pane 4 attributes	Theoretical Glass [117]	N/A
SWinGlass4Thickness	South window pane 4 attributes	0.003	Meter
SWinGlass4SolarTrans	South window pane 4 attributes	0.39333	%
SWinGlass4SolarReflectFront	South window pane 4 attributes	0.55667	%
SWinGlass4SolarReflectBack	South window pane 4 attributes	0.55667	%
SWinGlass4VisibleTrans	South window pane 4 attributes	0.507883	%
SWinGlass4VisibleReflectFront	South window pane 4 attributes	0.442117	%
SWinGlass4VisibleReflectBack	South window pane 4 attributes	0.442117	%
SWinGlass4IRTrans	South window pane 4 attributes	0	%
SWinGlass4IREmmFront	South window pane 4 attributes	0.84	%

Variable	Description	Default	Units
SWinGlass4IREmmBack	South window pane 4 attributes	0.84	%
SWinGlass4Conductivity	South window pane 4 attributes	0.9	W/m-K
EWinName	Name of East Window	EC_Window_Light	N/A
EWinNumberPanes	Number of Panes for East windows	1	integer
EWinGlass1Name	East window pane 1 attributes	THEORETICAL GLASS [LIGHT]	N/A
EWinGlass1Thickness	East window pane 1 attributes	0.05469	Meter
EWinGlass1SolarTrans	East window pane 1 attributes	0.45003	%
EWinGlass1SolarReflectFront	East window pane 1 attributes	0.38255	%
EWinGlass1SolarReflectBack	East window pane 1 attributes	0.38255	%
EWinGlass1VisibleTrans	East window pane 1 attributes	0.65	%
EWinGlass1VisibleReflectFront	East window pane 1 attributes	0.13254	%
EWinGlass1VisibleReflectBack	East window pane 1 attributes	0.15003	%
EWinGlass1IRTrans	East window pane 1 attributes	0	%
EWinGlass1IREmmFront	East window pane 1 attributes	0.84	%
EWinGlass1IREmmBack	East window pane 1 attributes	0.84	%
EWinGlass1Conductivity	East window pane 1 attributes	0.03411	W/m-K
EWinGasName	East window gas attributes	'AIR 6MM'	N/A
EWinGasType	East window gas attributes	Air	N/A
EWinGasThickness	East window gas attributes	0.0063	Meter
EWinGlass2Name	East window pane 2 attributes	Theoretical Glass [117]	N/A
EWinGlass2Thickness	East window pane 2 attributes	0.003	Meter
EWinGlass2SolarTrans	East window pane 2 attributes	0.39333	%
EWinGlass2SolarReflectFront	East window pane 2 attributes	0.55667	%
EWinGlass2SolarReflectBack	East window pane 2 attributes	0.55667	%
EWinGlass2VisibleTrans	East window pane 2 attributes	0.507883	%
EWinGlass2VisibleReflectFront	East window pane 2 attributes	0.442117	%
EWinGlass2VisibleReflectBack	East window pane 2 attributes	0.442117	%
EWinGlass2IRTrans	East window pane 2 attributes	0	%
EWinGlass2IREmmFront	East window pane 2 attributes	0.84	%
EWinGlass2IREmmBack	East window pane 2 attributes	0.84	%
EWinGlass2Conductivity	East window pane 2 attributes	0.9	W/m-K
EWinGlass3Name	East window pane 3 attributes	Theoretical Glass [117]	N/A
EWinGlass3Thickness	East window pane 3 attributes	0.003	Meter
EWinGlass3SolarTrans	East window pane 3 attributes	0.39333	%
EWinGlass3SolarReflectFront	East window pane 3 attributes	0.55667	%
EWinGlass3SolarReflectBack	East window pane 3 attributes	0.55667	%
EWinGlass3VisibleTrans	East window pane 3 attributes	0.507883	%
EWinGlass3VisibleReflectFront	East window pane 3 attributes	0.442117	%
EWinGlass3VisibleReflectBack	East window pane 3 attributes	0.442117	%

Variable	Description	Default	Units
EWinGlass3IRTrans	East window pane 3 attributes	0	%
EWinGlass3IREmmFront	East window pane 3 attributes	0.84	%
EWinGlass3IREmmBack	East window pane 3 attributes	0.84	%
EWinGlass3Conductivity	East window pane 3 attributes	0.9	W/m-K
EWinGlass4Name	East window pane 4 attributes	Theoretical Glass [117]	N/A
EWinGlass4Thickness	East window pane 4 attributes	0.003	Meter
EWinGlass4SolarTrans	East window pane 4 attributes	0.39333	%
EWinGlass4SolarReflectFront	East window pane 4 attributes	0.55667	%
EWinGlass4SolarReflectBack	East window pane 4 attributes	0.55667	%
EWinGlass4VisibleTrans	East window pane 4 attributes	0.507883	%
EWinGlass4VisibleReflectFront	East window pane 4 attributes	0.442117	%
EWinGlass4VisibleReflectBack	East window pane 4 attributes	0.442117	%
EWinGlass4IRTrans	East window pane 4 attributes	0	%
EWinGlass4IREmmFront	East window pane 4 attributes	0.84	%
EWinGlass4IREmmBack	East window pane 4 attributes	0.84	%
EWinGlass4Conductivity	East window pane 4 attributes	0.9	W/m-K
NWinName	Name of North Window	EC_Window_Light	N/A
NWinNumberPanes	Number of Panes for North windows	1	integer
NWinGlass1Name	North window pane 1 attributes	THEORETICAL GLASS [LIGHT]	N/A
NWinGlass1Thickness	North window pane 1 attributes	0.05469	Meter
NWinGlass1SolarTrans	North window pane 1 attributes	0.45003	%
NWinGlass1SolarReflectFront	North window pane 1 attributes	0.38255	%
NWinGlass1SolarReflectBack	North window pane 1 attributes	0.38255	%
NWinGlass1VisibleTrans	North window pane 1 attributes	0.65	%
NWinGlass1VisibleReflectFront	North window pane 1 attributes	0.13254	%
NWinGlass1VisibleReflectBack	North window pane 1 attributes	0.15003	%
NWinGlass1IRTrans	North window pane 1 attributes	0	%
NWinGlass1IREmmFront	North window pane 1 attributes	0.84	%
NWinGlass1IREmmBack	North window pane 1 attributes	0.84	%
NWinGlass1Conductivity	North window pane 1 attributes	0.03411	W/m-K
NWinGasName	North window gas attributes	'AIR 6MM'	N/A
NWinGasType	North window gas attributes	Air	N/A
NWinGasThickness	North window gas attributes	0.0063	Meter
NWinGlass2Name	North window pane 2 attributes	Theoretical Glass [117]	N/A
NWinGlass2Thickness	North window pane 2 attributes	0.003	Meter
NWinGlass2SolarTrans	North window pane 2 attributes	0.39333	%
NWinGlass2SolarReflectFront	North window pane 2 attributes	0.55667	%
NWinGlass2SolarReflectBack	North window pane 2 attributes	0.55667	%
NWinGlass2VisibleTrans	North window pane 2 attributes	0.507883	%

Variable	Description	Default	Units
NWinGlass2VisibleReflectFront	North window pane 2 attributes	0.442117	%
NWinGlass2VisibleReflectBack	North window pane 2 attributes	0.442117	%
NWinGlass2IRTrans	North window pane 2 attributes	0	%
NWinGlass2IREmmFront	North window pane 2 attributes	0.84	%
NWinGlass2IREmmBack	North window pane 2 attributes	0.84	%
NWinGlass2Conductivity	North window pane 2 attributes	0.9	W/m-K
NWinGlass3Name	North window pane 3 attributes	Theoretical Glass [117]	N/A
NWinGlass3Thickness	North window pane 3 attributes	0.003	Meter
NWinGlass3SolarTrans	North window pane 3 attributes	0.39333	%
NWinGlass3SolarReflectFront	North window pane 3 attributes	0.55667	%
NWinGlass3SolarReflectBack	North window pane 3 attributes	0.55667	%
NWinGlass3VisibleTrans	North window pane 3 attributes	0.507883	%
NWinGlass3VisibleReflectFront	North window pane 3 attributes	0.442117	%
NWinGlass3VisibleReflectBack	North window pane 3 attributes	0.442117	%
NWinGlass3IRTrans	North window pane 3 attributes	0	%
NWinGlass3IREmmFront	North window pane 3 attributes	0.84	%
NWinGlass3IREmmBack	North window pane 3 attributes	0.84	%
NWinGlass3Conductivity	North window pane 3 attributes	0.9	W/m-K
NWinGlass4Name	North window pane 4 attributes	Theoretical Glass [117]	N/A
NWinGlass4Thickness	North window pane 4 attributes	0.003	Meter
NWinGlass4SolarTrans	North window pane 4 attributes	0.39333	%
NWinGlass4SolarReflectFront	North window pane 4 attributes	0.55667	%
NWinGlass4SolarReflectBack	North window pane 4 attributes	0.55667	%
NWinGlass4VisibleTrans	North window pane 4 attributes	0.507883	%
NWinGlass4VisibleReflectFront	North window pane 4 attributes	0.442117	%
NWinGlass4VisibleReflectBack	North window pane 4 attributes	0.442117	%
NWinGlass4IRTrans	North window pane 4 attributes	0	%
NWinGlass4IREmmFront	North window pane 4 attributes	0.84	%
NWinGlass4IREmmBack	North window pane 4 attributes	0.84	%
NWinGlass4Conductivity	North window pane 4 attributes	0.9	W/m-K
WWinName	Name of West Window	EC_Window_Light	N/A
WWinNumberPanes	Number of Panes for West windows	1	integer
WWinGlass1Name	West window pane 1 attributes	THEORETICAL GLASS [LIGHT]	N/A
WWinGlass1Thickness	West window pane 1 attributes	0.05469	Meter
WWinGlass1SolarTrans	West window pane 1 attributes	0.45003	%
WWinGlass1SolarReflectFront	West window pane 1 attributes	0.38255	%
WWinGlass1SolarReflectBack	West window pane 1 attributes	0.38255	%
WWinGlass1VisibleTrans	West window pane 1 attributes	0.65	%
WWinGlass1VisibleReflectFront	West window pane 1 attributes	0.13254	%

Variable	Description	Default	Units
WWinGlass1VisibleReflectBack	West window pane 1 attributes	0.15003	%
WWinGlass1IRTrans	West window pane 1 attributes	0	%
WWinGlass1IREmmFront	West window pane 1 attributes	0.84	%
WWinGlass1IREmmBack	West window pane 1 attributes	0.84	%
WWinGlass1Conductivity	West window pane 1 attributes	0.03411	W/m-K
WWinGasName	West window gas attributes	'AIR 6MM'	N/A
WWinGasType	West window gas attributes	Air	N/A
WWinGasThickness	West window gas attributes	0.0063	Meter
WWinGlass2Name	West window pane 2 attributes	Theoretical Glass [117]	N/A
WWinGlass2Thickness	West window pane 2 attributes	0.003	Meter
WWinGlass2SolarTrans	West window pane 2 attributes	0.39333	%
WWinGlass2SolarReflectFront	West window pane 2 attributes	0.55667	%
WWinGlass2SolarReflectBack	West window pane 2 attributes	0.55667	%
WWinGlass2VisibleTrans	West window pane 2 attributes	0.507883	%
WWinGlass2VisibleReflectFront	West window pane 2 attributes	0.442117	%
WWinGlass2VisibleReflectBack	West window pane 2 attributes	0.442117	%
WWinGlass2IRTrans	West window pane 2 attributes	0	%
WWinGlass2IREmmFront	West window pane 2 attributes	0.84	%
WWinGlass2IREmmBack	West window pane 2 attributes	0.84	%
WWinGlass2Conductivity	West window pane 2 attributes	0.9	W/m-K
WWinGlass3Name	West window pane 3 attributes	Theoretical Glass [117]	N/A
WWinGlass3Thickness	West window pane 3 attributes	0.003	Meter
WWinGlass3SolarTrans	West window pane 3 attributes	0.39333	%
WWinGlass3SolarReflectFront	West window pane 3 attributes	0.55667	%
WWinGlass3SolarReflectBack	West window pane 3 attributes	0.55667	%
WWinGlass3VisibleTrans	West window pane 3 attributes	0.507883	%
WWinGlass3VisibleReflectFront	West window pane 3 attributes	0.442117	%
WWinGlass3VisibleReflectBack	West window pane 3 attributes	0.442117	%
WWinGlass3IRTrans	West window pane 3 attributes	0	%
WWinGlass3IREmmFront	West window pane 3 attributes	0.84	%
WWinGlass3IREmmBack	West window pane 3 attributes	0.84	%
WWinGlass3Conductivity	West window pane 3 attributes	0.9	W/m-K
WWinGlass4Name	West window pane 4 attributes	Theoretical Glass [117]	N/A
WWinGlass4Thickness	West window pane 4 attributes	0.003	Meter
WWinGlass4SolarTrans	West window pane 4 attributes	0.39333	%
WWinGlass4SolarReflectFront	West window pane 4 attributes	0.55667	%
WWinGlass4SolarReflectBack	West window pane 4 attributes	0.55667	%
WWinGlass4VisibleTrans	West window pane 4 attributes	0.507883	%
WWinGlass4VisibleReflectFront	West window pane 4 attributes	0.442117	%

Variable	Description	Default	Units
WWinGlass4VisibleReflectBack	West window pane 4 attributes	0.442117	%
WWinGlass4IRTrans	West window pane 4 attributes	0	%
WWinGlass4IREmmFront	West window pane 4 attributes	0.84	%
WWinGlass4IREmmBack	West window pane 4 attributes	0.84	%
WWinGlass4Conductivity	West window pane 4 attributes	0.9	W/m-K
SkyLiName	Name of Sky Light	Dbl LoE (e2=.2) Clr 6mm/6mm Air	N/A
SkyLiNumberPanes	Number of Panes for Sky Light	2	integer
SkyLiType	Describes Installation Type	'All Skylights without Curb'	N/A
SkyLiInstallConfig	Describes distribution of skylights	'All Top Zones'	N/A
SkyLiAreaFrac	Roof Area percentage covered by skylights	0	%
SkyLiGlass1Name	Sky Light pane 1 attributes	'PYR B CLEAR 6MM'	N/A
SkyLiGlass1Thickness	Sky Light pane 1 attributes	0.006	Meter
SkyLiGlass1SolarTrans	Sky Light pane 1 attributes	0.68	%
SkyLiGlass1SolarReflectFront	Sky Light pane 1 attributes	0.09	%
SkyLiGlass1SolarReflectBack	Sky Light pane 1 attributes	0.1	%
SkyLiGlass1VisibleTrans	Sky Light pane 1 attributes	0.81	%
SkyLiGlass1VisibleReflectFront	Sky Light pane 1 attributes	0.11	%
SkyLiGlass1VisibleReflectBack	Sky Light pane 1 attributes	0.12	%
SkyLiGlass1IRTrans	Sky Light pane 1 attributes	0	%
SkyLiGlass1IREmmFront	Sky Light pane 1 attributes	0.84	%
SkyLiGlass1IREmmBack	Sky Light pane 1 attributes	0.2	%
SkyLiGlass1Conductivity	Sky Light pane 1 attributes	0.9	W/m-K
SkyLiGasName	Sky Light gas attributes	'AIR 6MM'	N/A
SkyLiGasType	Sky Light gas attributes	'Air'	N/A
SkyLiGasThickness	Sky Light gas attributes	0.0063	Meter
SkyLiGlass2Name	Sky Light pane 2 attributes	'CLEAR 6MM'	N/A
SkyLiGlass2Thickness	Sky Light pane 2 attributes	0.006	Meter
SkyLiGlass2SolarTrans	Sky Light pane 2 attributes	0.775	%
SkyLiGlass2SolarReflectFront	Sky Light pane 2 attributes	0.071	%
SkyLiGlass2SolarReflectBack	Sky Light pane 2 attributes	0.071	%
SkyLiGlass2VisibleTrans	Sky Light pane 2 attributes	0.881	%
SkyLiGlass2VisibleReflectFront	Sky Light pane 2 attributes	0.08	%
SkyLiGlass2VisibleReflectBack	Sky Light pane 2 attributes	0.08	%
SkyLiGlass2IRTrans	Sky Light pane 2 attributes	0	%
SkyLiGlass2IREmmFront	Sky Light pane 2 attributes	0.84	%
SkyLiGlass2IREmmBack	Sky Light pane 2 attributes	0.84	%
SkyLiGlass2Conductivity	Sky Light pane 2 attributes	0.9	W/m-K
RoofNumLayers	Number of layers in roof construction	3	integer

Variable	Description	Default	Units
RoofDesc	Description of roof construction	IEAD_R-20 ci_Roof	N/A
RoofType	Type of Roof	Insulation Entirely Above Deck	N/A
RoofLayer1Name	Roof Layer 1 attributes	Roof Membrane	N/A
RoofLayer1Roughness	Roof Layer 1 attributes	VeryRough	N/A
RoofLayer1Thickness	Roof Layer 1 attributes	0.0095	Meter
RoofLayer1Conductivity	Roof Layer 1 attributes	0.16	W/m-K
RoofLayer1Density	Roof Layer 1 attributes	1121.29	kg/m3
RoofLayer1SpecificHeat	Roof Layer 1 attributes	1460	J(kg-K)
RoofLayer1AbsorThermal	Roof Layer 1 attributes	0.9	%
RoofLayer1AbsorSolar	Roof Layer 1 attributes	0.7	%
RoofLayer1AbsorVis	Roof Layer 1 attributes	0.7	%
RoofLayer2Name	Roof Layer 2 attributes	Roof Insulation [13]	N/A
RoofLayer2Roughness	Roof Layer 2 attributes	MediumRough	N/A
RoofLayer2Thickness	Roof Layer 2 attributes	0.167335	Meter
RoofLayer2Conductivity	Roof Layer 2 attributes	0.049	W/m-K
RoofLayer2Density	Roof Layer 2 attributes	265	kg/m3
RoofLayer2SpecificHeat	Roof Layer 2 attributes	836.8	J(kg-K)
RoofLayer2AbsorThermal	Roof Layer 2 attributes	0.9	%
RoofLayer2AbsorSolar	Roof Layer 2 attributes	0.7	%
RoofLayer2AbsorVis	Roof Layer 2 attributes	0.7	%
RoofLayer3Name	Roof Layer 3 attributes	Metal Decking	N/A
RoofLayer3Roughness	Roof Layer 3 attributes	MediumSmooth	N/A
RoofLayer3Thickness	Roof Layer 3 attributes	0.001524	Meter
RoofLayer3Conductivity	Roof Layer 3 attributes	45.006	W/m-K
RoofLayer3Density	Roof Layer 3 attributes	7680	kg/m3
RoofLayer3SpecificHeat	Roof Layer 3 attributes	418.4	J(kg-K)
RoofLayer3AbsorThermal	Roof Layer 3 attributes	0.9	%
RoofLayer3AbsorSolar	Roof Layer 3 attributes	0.7	%
RoofLayer3AbsorVis	Roof Layer 3 attributes	0.3	%
IntWallDesc	Interior Wall Description	Standard_Int-Wall	N/A
IntWallType	Interior Wall Type	Standard	N/A
IntWallLayer1Name	Interior Wall Layer 1 Attributes	GP01 1/2 GYPSUM	N/A
IntWallLayer1Roughness	Interior Wall Layer 1 Attributes	Smooth	N/A
IntWallLayer1Thickness	Interior Wall Layer 1 Attributes	0.01271	Meter
IntWallLayer1Conductivity	Interior Wall Layer 1 Attributes	0.16	W/m-K
IntWallLayer1Density	Interior Wall Layer 1 Attributes	800	kg/m3
IntWallLayer1SpecificHeat	Interior Wall Layer 1 Attributes	1090	J(kg-K)
IntWallLayer1AbsorThermal	Interior Wall Layer 1 Attributes	0.9	%
IntWallLayer1AbsorSolar	Interior Wall Layer 1 Attributes	0.7	%

Variable	Description	Default	Units
IntWallLayer1AbsorVis	Interior Wall Layer 1 Attributes	0.5	%
IntWallLayer2Name	Interior Wall Layer 2 Attributes	GP01 1/2 GYPSUM	N/A
IntWallLayer2Roughness	Interior Wall Layer 2 Attributes	Smooth	N/A
IntWallLayer2Thickness	Interior Wall Layer 2 Attributes	0.01271	Meter
IntWallLayer2Conductivity	Interior Wall Layer 2 Attributes	0.16	W/m-K
IntWallLayer2Density	Interior Wall Layer 2 Attributes	800	kg/m3
IntWallLayer2SpecificHeat	Interior Wall Layer 2 Attributes	1090	J(kg-K)
IntWallLayer2AbsorThermal	Interior Wall Layer 2 Attributes	0.9	%
IntWallLayer2AbsorSolar	Interior Wall Layer 2 Attributes	0.7	%
IntWallLayer2AbsorVis	Interior Wall Layer 2 Attributes	0.5	%
ExtWallNumLayers	Exterior Walls Number of Layers	3	
ExtWallDesc	Exterior Walls Description	Steel-Framed_R-13 + R-7.5 ci_Ext-wall	N/A
ExtWallType	Exterior Walls Type	Steel-Framed	N/A
ExtWallLayer1Name	Exterior Wall Layer 1 Attributes	Composite 2x4 Steel Stud R11 #3	N/A
ExtWallLayer1Roughness	Exterior Wall Layer 1 Attributes	Smooth	N/A
ExtWallLayer1Thickness	Exterior Wall Layer 1 Attributes	0.025	Meter
ExtWallLayer1Conductivity	Exterior Wall Layer 1 Attributes	0.452	W/m-K
ExtWallLayer1Density	Exterior Wall Layer 1 Attributes	413.782	kg/m3
ExtWallLayer1SpecificHeat	Exterior Wall Layer 1 Attributes	1048	J(kg-K)
ExtWallLayer1AbsorThermal	Exterior Wall Layer 1 Attributes	0.9	%
ExtWallLayer1AbsorSolar	Exterior Wall Layer 1 Attributes	0.7	%
ExtWallLayer1AbsorVis	Exterior Wall Layer 1 Attributes	0.7	%
ExtWallLayer2Name	Exterior Wall Layer 2 Attributes	Composite 2x4 Steel Stud R11 #2	N/A
ExtWallLayer2Roughness	Exterior Wall Layer 2 Attributes	Smooth	N/A
ExtWallLayer2Thickness	Exterior Wall Layer 2 Attributes	0.089	Meter
ExtWallLayer2Conductivity	Exterior Wall Layer 2 Attributes	0.06	W/m-K
ExtWallLayer2Density	Exterior Wall Layer 2 Attributes	118.223	kg/m3
ExtWallLayer2SpecificHeat	Exterior Wall Layer 2 Attributes	1048	J(kg-K)
ExtWallLayer2AbsorThermal	Exterior Wall Layer 2 Attributes	0.9	%
ExtWallLayer2AbsorSolar	Exterior Wall Layer 2 Attributes	0.7	%
ExtWallLayer2AbsorVis	Exterior Wall Layer 2 Attributes	0.7	%
ExtWallLayer3Name	Exterior Wall Layer 3 Attributes	Composite 2x4 Steel Stud R11 #1	N/A
ExtWallLayer3Roughness	Exterior Wall Layer 3 Attributes	Smooth	N/A
ExtWallLayer3Thickness	Exterior Wall Layer 3 Attributes	0.013	Meter
ExtWallLayer3Conductivity	Exterior Wall Layer 3 Attributes	0.72	W/m-K
ExtWallLayer3Density	Exterior Wall Layer 3 Attributes	640	kg/m3
ExtWallLayer3SpecificHeat	Exterior Wall Layer 3 Attributes	1048	J(kg-K)

Variable	Description	Default	Units
ExtWallLayer3AbsorThermal	Exterior Wall Layer 3 Attributes	0.9	%
ExtWallLayer3AbsorSolar	Exterior Wall Layer 3 Attributes	0.7	%
ExtWallLayer3AbsorVis	Exterior Wall Layer 3 Attributes	0.7	%
ExtSlabNumLayers	Exterior Slab Number of Layers	2	integer
ExtSlabConstDesc	Exterior Slab Description	Unheated - 8in Slab with Carpet_Ext-slab	N/A
ExtSlabConstrutionType	Exterior Slab Type	Unheated - 8in Slab with Carpet	N/A
ExtSlabLayer1Name	Exterior Slab Layer 1 Attributes	MAT-CC05 8 HW CONCRETE	N/A
ExtSlabLayer1Roughness	Exterior Slab Layer 1 Attributes	Rough	N/A
ExtSlabLayer1Thickness	Exterior Slab Layer 1 Attributes	0.20321	Meter
ExtSlabLayer1Conductivity	Exterior Slab Layer 1 Attributes	1.311	W/m-K
ExtSlabLayer1Density	Exterior Slab Layer 1 Attributes	2240	kg/m3
ExtSlabLayer1SpecificHeat	Exterior Slab Layer 1 Attributes	836.8	J(kg-K)
ExtSlabLayer1AbsorThermal	Exterior Slab Layer 1 Attributes	0.9	%
ExtSlabLayer1AbsorSolar	Exterior Slab Layer 1 Attributes	0.7	%
ExtSlabLayer1AbsorVis	Exterior Slab Layer 1 Attributes	0.7	%
ExtSlabLayer2Name	Exterior Slab Layer 2 Attributes	CP02 CARPET PAD	N/A
ExtSlabLayer2Roughness	Exterior Slab Layer 2 Attributes	VeryRough	N/A
ExtSlabLayer2ThermalRes	Exterior Slab Layer 2 Attributes	0.21648	(m2-K)/W
ExtSlabLayer2AbsorThermal	Exterior Slab Layer 2 Attributes	0.9	%
ExtSlabLayer2AbsorSolar	Exterior Slab Layer 2 Attributes	0.7	%
ExtSlabLayer2AbsorVis	Exterior Slab Layer 2 Attributes	0.8	%
FloorNumLayers	Floor Number of Layers	3	integer
FloorConstDesc	Floor Description	Mass_R-10.4 ci_osedFloor	N/A
FloorConstrutionType	Floor Type	Mass	N/A
FloorLayer1Name	Floor Layer 1 Attributes	Floor Insulation [4]	N/A
FloorLayer1Roughness	Floor Layer 1 Attributes	MediumRough	N/A
FloorLayer1Thickness	Floor Layer 1 Attributes	0.0795397	Meter
FloorLayer1Conductivity	Floor Layer 1 Attributes	0.045	W/m-K
FloorLayer1Density	Floor Layer 1 Attributes	265	kg/m3
FloorLayer1SpecificHeat	Floor Layer 1 Attributes	836.8	J(kg-K)
FloorLayer1AbsorThermal	Floor Layer 1 Attributes	0.9	%
FloorLayer1AbsorSolar	Floor Layer 1 Attributes	0.7	%
FloorLayer1AbsorVis	Floor Layer 1 Attributes	0.7	%
FloorLayer2Name	Floor Layer 2 Attributes	MAT-CC05 8 HW CONCRETE	N/A
FloorLayer2Roughness	Floor Layer 2 Attributes	Rough	N/A
FloorLayer2Thickness	Floor Layer 2 Attributes	0.20321	Meter
FloorLayer2Conductivity	Floor Layer 2 Attributes	1.311	W/m-K
FloorLayer2Density	Floor Layer 2 Attributes	2240	kg/m3

Variable	Description	Default	Units
FloorLayer2SpecificHeat	Floor Layer 2 Attributes	836.8	J(kg-K)
FloorLayer2AbsorThermal	Floor Layer 2 Attributes	0.9	%
FloorLayer2AbsorSolar	Floor Layer 2 Attributes	0.7	%
FloorLayer2AbsorVis	Floor Layer 2 Attributes	0.7	%
FloorLayer3Name	Floor Layer 3 Attributes	CP02 CARPET PAD	N/A
FloorLayer3Roughness	Floor Layer 3 Attributes	VeryRough	N/A
FloorLayer3ThermalRes	Floor Layer 3 Attributes	0.21648	(m2-K)/W
FloorLayer3AbsorThermal	Floor Layer 3 Attributes	0.9	%
FloorLayer3AbsorSolar	Floor Layer 3 Attributes	0.7	%
FloorLayer3AbsorVis	Floor Layer 3 Attributes	0.8	%
DoorDesc	Swinging Door Description	Swinging_door	N/A
DoorType	Swinging Door Type	Swinging	N/A
DoorLayer1Name	Swinging Door Layer 1 attributes	METAL Door Medium 18Ga_1	N/A
DoorLayer1Roughness	Swinging Door Layer 1 attributes	Smooth	N/A
DoorLayer1Thickness	Swinging Door Layer 1 attributes	0.0013106	Meter
DoorLayer1Conductivity	Swinging Door Layer 1 attributes	45.3149	W/m-K
DoorLayer1Density	Swinging Door Layer 1 attributes	7833.03	kg/m3
DoorLayer1SpecificHeat	Swinging Door Layer 1 attributes	502.08	J(kg-K)
DoorLayer1AbsorThermal	Swinging Door Layer 1 attributes	0.8	%
DoorLayer1AbsorSolar	Swinging Door Layer 1 attributes	0.5	%
DoorLayer1AbsorVis	Swinging Door Layer 1 attributes	0.5	%
DoorLayer2Name	Swinging Door Layer 2 attributes	AIR	N/A
DoorLayer2Roughness	Swinging Door Layer 2 attributes	Smooth	N/A
DoorLayer2ThermalResistance	Swinging Door Layer 2 attributes	0.251489	(m2-K)/W
DoorLayer2AbsorThermal	Swinging Door Layer 2 attributes	0.8	%
DoorLayer2AbsorSolar	Swinging Door Layer 2 attributes	0.5	%
DoorLayer2AbsorVis	Swinging Door Layer 2 attributes	0.5	%
DoorLayer3Name	Swinging Door Layer 3 attributes	METAL Door Medium 18Ga_2	N/A
DoorLayer3Roughness	Swinging Door Layer 3 attributes	Smooth	N/A
DoorLayer3Thickness	Swinging Door Layer 3 attributes	0.0013106	Meter
DoorLayer3Conductivity	Swinging Door Layer 3 attributes	45.3149	W/m-K
DoorLayer3Density	Swinging Door Layer 3 attributes	7833.03	kg/m3
DoorLayer3SpecificHeat	Swinging Door Layer 3 attributes	502.08	J(kg-K)
DoorLayer3AbsorThermal	Swinging Door Layer 3 attributes	0.8	%
DoorLayer3AbsorSolar	Swinging Door Layer 3 attributes	0.5	%
DoorLayer3AbsorVis	Swinging Door Layer 3 attributes	0.5	%
NSDoorDesc	Non-Swinging Door Description	Non-Swinging_NR_door	N/A
NSDoorType	Non-Swinging Door Type	Non-Swinging	N/A
NSDoorLayer1Name	Non-Swinging Door Layer 1 attributes	METAL Door Medium 18Ga	N/A

Variable	Description	Default	Units
NSDoorLayer1Roughness	Non-Swinging Door Layer 1 attributes	Smooth	N/A
NSDoorLayer1Thickness	Non-Swinging Door Layer 1 attributes	0.0013106	Meter
NSDoorLayer1Conductivity	Non-Swinging Door Layer 1 attributes	45.3149	W/m-K
NSDoorLayer1Density	Non-Swinging Door Layer 1 attributes	7833.03	kg/m3
NSDoorLayer1SpecificHeat	Non-Swinging Door Layer 1 attributes	502.08	J(kg-K)
NSDoorLayer1AbsorThermal	Non-Swinging Door Layer 1 attributes	0.8	%
NSDoorLayer1AbsorSolar	Non-Swinging Door Layer 1 attributes	0.5	%
NSDoorLayer1AbsorVis	Non-Swinging Door Layer 1 attributes	0.5	%
NSDoorLayer2Name	Non-Swinging Door Layer 2 attributes	AIR [2]	N/A
NSDoorLayer2Roughness	Non-Swinging Door Layer 2 attributes	Smooth	N/A
NSDoorLayer2ThermalResistance	Non-Swinging Door Layer 2 attributes	0.352085	(m2-K)/W
NSDoorLayer2AbsorThermal	Non-Swinging Door Layer 2 attributes	0.8	%
NSDoorLayer2AbsorSolar	Non-Swinging Door Layer 2 attributes	0.5	%
NSDoorLayer2AbsorVis	Non-Swinging Door Layer 2 attributes	0.5	%
NSDoorLayer3Name	Non-Swinging Door Layer 3 attributes	METAL Door Medium 18Ga_2	N/A
NSDoorLayer3Roughness	Non-Swinging Door Layer 3 attributes	Smooth	N/A
NSDoorLayer3Thickness	Non-Swinging Door Layer 3 attributes	0.0013106	Meter
NSDoorLayer3Conductivity	Non-Swinging Door Layer 3 attributes	45.3149	W/m-K
NSDoorLayer3Density	Non-Swinging Door Layer 3 attributes	7833.03	kg/m3
NSDoorLayer3SpecificHeat	Non-Swinging Door Layer 3 attributes	502.08	J(kg-K)
NSDoorLayer3AbsorThermal	Non-Swinging Door Layer 3 attributes	0.8	%
NSDoorLayer3AbsorSolar	Non-Swinging Door Layer 3 attributes	0.5	%
NSDoorLayer3AbsorVis	Non-Swinging Door Layer 3 attributes	0.5	%
NumFloors	Number of stories in building	1	integer
PerimDepth	depth of the perimeter zone	4.57	Meter
FloortoFloorHeight	total height of each story (including slab thickness)	3.8	Meter
PlenumHeight	height form floor level to drop ceiling	3	Meter
Rotation	rotation of building in degrees	0	degrees

Variable	Description	Default	Units
UseVirtualPlenum	set to true if building has drop ceiling	'true'	N/A
FootprintType	description of the shape of the building foot print, see Appendix C	Rectangle	N/A
AspectRatio	aspect ration of building, only applies to foot print shape of rectangle	2	Ratio
ZoneLayout	zone configuration, either perimeter and core or minimum zones	Perimeter and Core	N/A
Length1	Key foot print dimension, see Appendix C	40	Meter
Width1	Key foot print dimension, see Appendix C	20	Meter
Length2	Key foot print dimension, see Appendix C	15	Meter
Width2	Key foot print dimension, see Appendix C	5	Meter
End1	Key foot print dimension, see Appendix C	20	Meter
End2	Key foot print dimension, see Appendix C	20	Meter
Offset1	Key foot print dimension, see Appendix C	15	Meter
Offset2	Key foot print dimension, see Appendix C	15	Meter
Offset3	Key foot print dimension, see Appendix C	0	Meter
HasDayLi	Defines if a building has daylighting	No	N/A
DayLiContType	defines the control type for daylighting	Stepped	N/A
DayLiContSetPt	daylighting setpoint	398	lux
DayLiNumSteps	Number of steps in daylighting control	3	integer
DayLiNumSensors	Number of daylighting sensors	1	integer
DayLiMinInputFr	minimum daylighting fixture input power fraction	0.3	%
DayLiMinOutputFr	minimum daylighting fixture output fraction	0.2	%
SWinWallAreaFraction	South window wall area fraction	0.4	%
SWinSillHeight	south window sill height	1.1	Meter
SWinEdgeOffSet	distance of south window form edge of building	0.05	Meter
SWinType	South window geometry style	Banded	N/A
SOHOffset	South over hang offset	0	Meter
SOHDepth	South over hang depth	0	Meter
SFinOffset	South fin offset	0	Meter
SFinDepth	South fin depth	0	Meter
EWinWallAreaFraction	South window wall area fraction	0.4	%

Variable	Description	Default	Units
EWinSillHeight	south window sill height	1.1	Meter
EWinEdgeOffSet	distance of south window form edge of building	0.05	Meter
EWinType	South window geometry style	Banded	N/A
EOHOffset	South over hang offset	0	Meter
EOHDepth	South over hang depth	0	Meter
EFinOffset	South fin offset	0	Meter
EFinDepth	South fin depth	0	Meter
NWinWallAreaFraction	South window wall area fraction	0.4	%
NWinSillHeight	south window sill height	1.1	Meter
NWinEdgeOffSet	distance of south window form edge of building	0.05	Meter
NWinType	South window geometry style	Banded	N/A
NOHOffset	South over hang offset	0	Meter
NOHDepth	South over hang depth	0	Meter
NFinOffset	South fin offset	0	Meter
NFinDepth	South fin depth	0	Meter
WWinWallAreaFraction	South window wall area fraction	0.4	%
WWinSillHeight	south window sill height	1.1	Meter
WWinEdgeOffSet	distance of south window form edge of building	0.05	Meter
WWinType	South window geometry style	Banded	N/A
WOHOffset	South over hang offset	0	Meter
WOHDepth	South over hang depth	0	Meter
WFinOffset	South fin offset	0	Meter
WFinDepth	South fin depth	0	Meter
PeopleDensity	Density of occupants	3.91	Person/100m2
LiPowerDensity	lighting power density	10.76	W/m2
LiFractionRadiant	fraction of light energy that is radiant	0.7	%
LiFractionReturn	fraction of light energy that is added to return air flow	0	%
Equip1EquipmentName	Name of miscellaneous equipment 1	PlugMisc1	N/A
Equip1EquipmentType	Fuel of miscellaneous equipment 1	Electric	N/A
Equip1PowerDensity	Power density of miscellaneous equipment 1	8.07	W/m2
Equip1RadiantFraction	Fuel of miscellaneous equipment 1	0.5	%
Equip1LatentFraction	radiant fraction of energy for miscellaneous equipment 1	0	%
Equip1LostFraction	fraction of energy not going to space for miscellaneous equipment 1	0	%

Variable	Description	Default	Units
Equip2EquipmentName	Name of miscellaneous equipment 1	PlugMisc2	N/A
Equip2EquipmentType	Fuel of miscellaneous equipment 1	gas	N/A
Equip2PowerDensity	Power density of miscellaneous equipment 1	0	W/m2
Equip2RadiantFraction	Fuel of miscellaneous equipment 1	0	%
Equip2LatentFraction	radiant fraction of energy for miscellaneous equipment 1	0	%
Equip2LostFraction	fraction of energy not going to space for miscellaneous equipment 1	0.7	%
InfiltrationRate	rate that outdoor air enters building in an uncontrolled manner	0.3	ACH
TypicalHoursPerDay	number of hours that the buildings is typically occupied	8	hours
OAPerArea	Volume outdoor air brought in by HVAC system per m2	0	(m3/s) per m2
OAPerPerson	Volume outdoor air brought in by HVAC system per person	0	(m3/s) per person
HVACSystemType	Type of HVAC system to model	PSZ-AC	N/A
ZoneDistType	zone HVAC distribution mechanism	AHU	N/A
ReheatCoilType	fuel for reheat coil	HOT WATER	N/A
ReheatCoilEfficiency	efficiency of reheat coil	0	%
MinFlowFraction	minimum flow of supply air for VAV systems	0.3	%
UseNightCycle	0	TRUE	Boolean
SATManagerType	Supply air temperature reset type	OutsideAir	N/A
UseEconomizer	Determines if economizer is used or not	FALSE	Boolean
MotorizedDamper		FALSE	Boolean
UseControllerMechVent		FALSE	Boolean
CoolingCoilFuel	Fuel for cooling coil	Water	N/A
HeatingCoilFuel	Fuel for heating coil	Water	N/A
SysFanType	defines system fan type	Variable	N/A
SysFanEfficiency	defines system fan efficiency	0.6	%
SysFanPressureDrop	defines system fan pressure drop	500	pa
HeatingPumpType	defines type of circulation pump for heating system	Variable	N/A
HeatingPumpEfficiency	defines efficiency of heating system pump	0.9	%
HeatingPumpHead	defines head of heating system pump	15000	pa
BoilerEfficiency	Defines boiler efficiency	0.8	%
BiolerFuel	Defines boiler fuel	NaturalGas	N/A

Variable	Description	Default	Units
CoolingPumpType	defines type of circulation pump for cooling system	Variable	N/A
CoolingPumpEfficiency	defines efficiency of cooling system pump	0.9	%
CoolingPumpHead	defines head of cooling system pump	15000	pa
ChillerType	Type of chiller to be used	Electrically Operated Rotary Screw and Scroll	N/A
ChillerCondenserType	chiller condenser cooling mechanism	Water Cooled	N/A
CoolingCOP	Coefficient of performance for the cooling system	3	Factor
ChillerModelType	defining how chiller is simulated in EnergyPlus	ELECTRIC DOE2	N/A
HeatRejectionType	if condenser is water cooled defines type of cooling	WaterCooledSingleSpeedTower	N/A
ZoneCoolFanEfficiency	efficiency of fan used in zone for cooling system	0.6	%
ZoneCoolFanPressureDrop	pressure drop of fan used in zone for cooling system	500	pa
PTACOperMode	operation mode of packaged terminal air conditioner	CyclingFanAndCompressor	N/A
ZoneFanEfficiency	efficiency of fan used in zone for heating system	0.6	%
ZoneFanPressureDrop	pressure drop of fan used in zone for heating system	300	pa
HeatCoilEfficiency	efficiency of heating coil	0.8	%
HeatingCOP	coefficient of performance for heat pump	3	Factor
HPOperMode	operation mode of heat pump	CyclingFanAndCompressor	N/A
HeatCoilType	Type of heating coil	Water	N/A
PTHPOperMode	operation mode of packaged terminal heat pump	CyclingFanAndCompressor	N/A
FanCoilType	function of fan coil	HeatCool	N/A
DHWUseRateType	defines units for domestic hot water use rate	PersonPerHour	N/A
DHWUseRate	domestic hot water use volume	0.001	m3
DHWSupplyTemp	domestic hot water delivery temperature	40	C
DHWSetPoint	domestic hot water storage temperature	60	C
DHWPumpType	domestic hot water system pump type	Variable	N/A
DHWPumpEfficiency	domestic hot water system pump efficiency	1	%
DHWPumpHead	domestic hot water system pump	179352	pa

Variable	Description	Default	Units
	head		
DHWHeaterType	domestic hot water heater type	Storage Tank	N/A
DHWHeaterFuelType	domestic hot water fuel type	Electric	N/A
DHWHeaterEfficiency	domestic hot water heater efficiency	1	%
DHWHeaterVolume	domestic hot water heater volume	0.25	m3
DHWHeaterCapacity	domestic hot water heater capacity	4500	W/m2
DHWHeaterUValue	domestic hot water heater U value	0	W/(m2-K)
DHWHeaterAspectRatio	domestic hot water heater aspect ratio	2	Ratio
DHWHeaterNumberNodes	domestic hot water heater number of nodes for simulation	1	integer

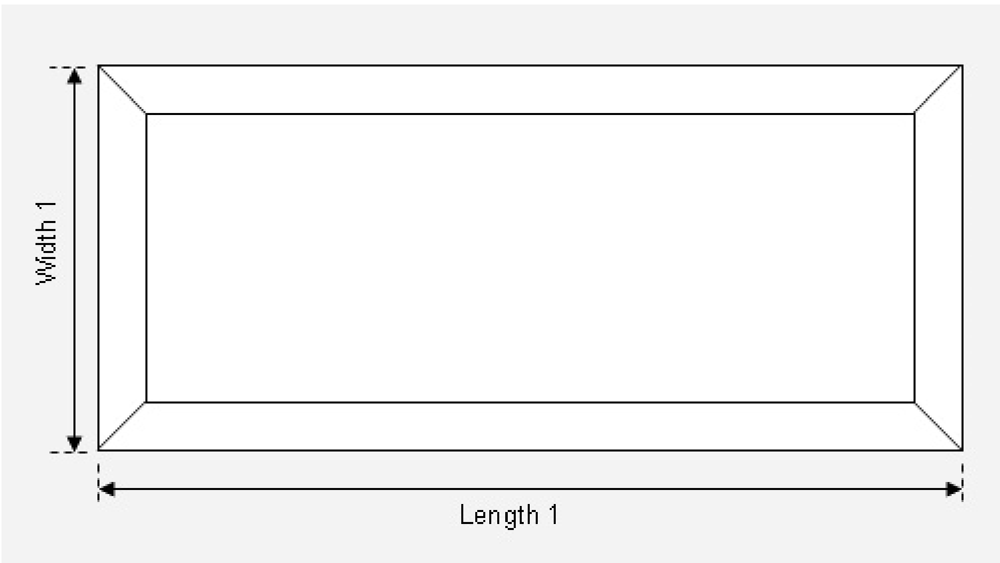
APPENDIX C

Aggregate Building Simulator Allowable Footprint Shapes

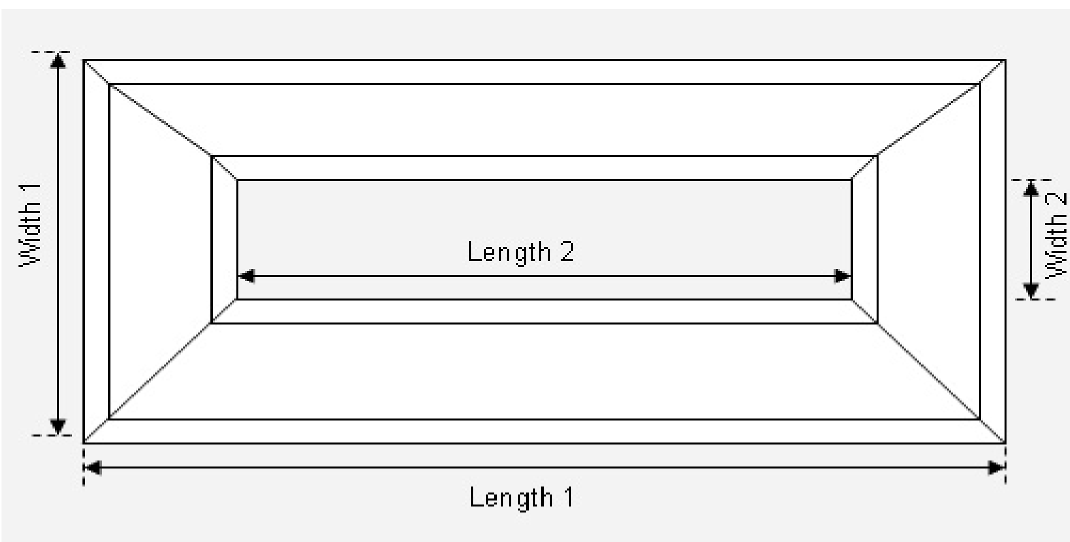
Appendix C: Aggregate Building Simulator Allowable Footprint Shapes

The ABS can handle six different footprints that cover most building configurations; these are shown below (EnergyPlus Example File Generator, 2010).

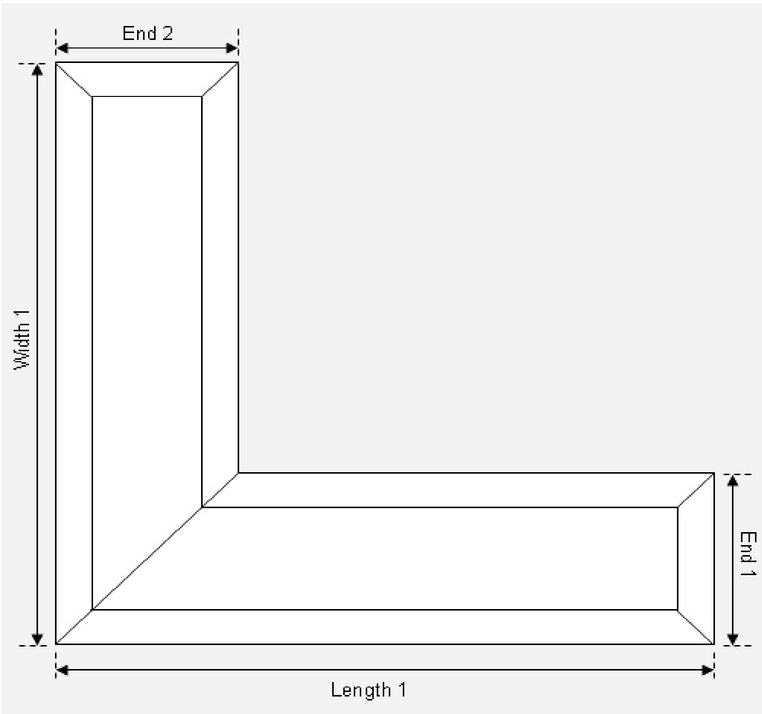
Rectangle



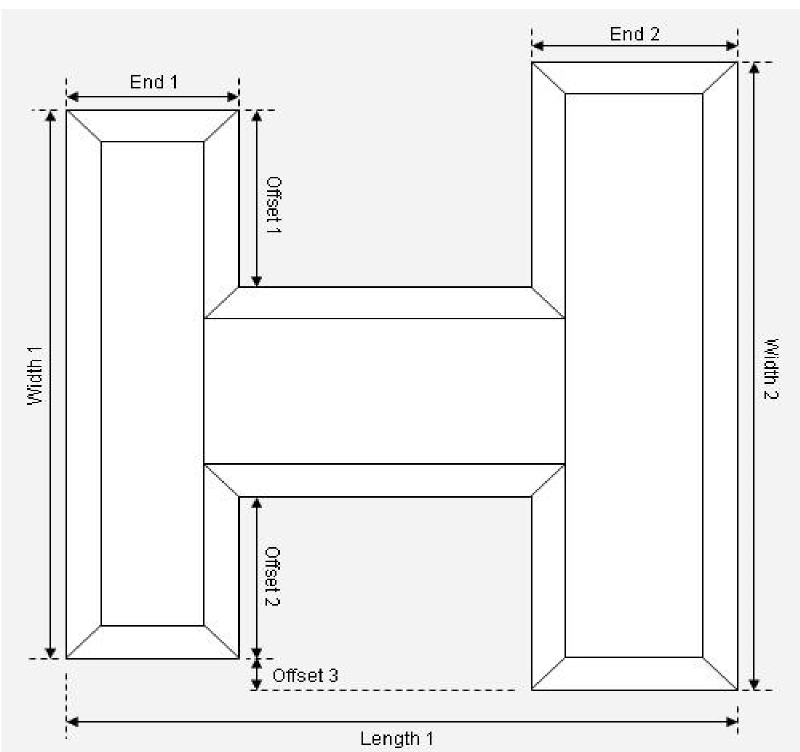
Court Yard



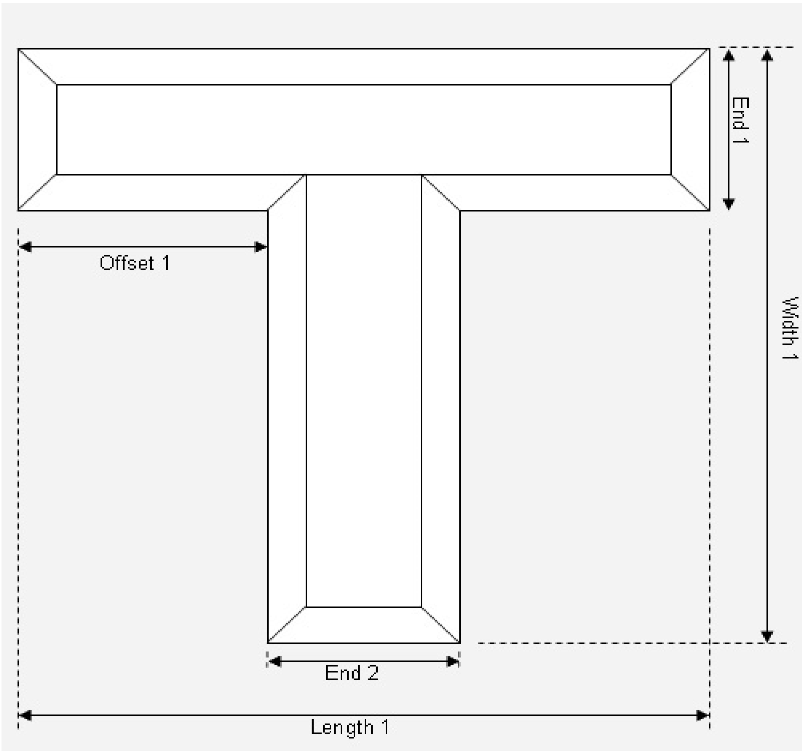
L-Shape



H-Shape



T-shape



U-Shape