Functional Requirements for ACM Standards Compliance Engine Software

Version 0.6

December, 2011

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NOTICE

<notes pertaining to status and/or distribution of this document>

Perhaps include notes describing sections requiring attention…

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# Introduction

## Purpose

This document is intended to provide a clear and complete description of the functional requirements for the ACM standards compliance engine software to be developed for the California Energy Commission. The intended audience for this document includes the current and future CEC building energy science technical support teams (a subset of which is the software development team), the Program Advisory Committee (PAC) of the upcoming technical support contractor, the CEC contract manager and other staff, and others serving in a review capacity for the project.

## Scope

The official name of this software product is *ACM Standards Compliance Engine Software*, though it will be frequently referred to simply as "the Software" throughout this document.

The Software will serve primarily as a performance-based method for testing compliance with residential and non-residential California energy codes and will be placed into open source with a licensing scheme designed to encourage its inclusion in open source, freeware and commercial products. The exact license and terms will be determined during the upcoming CEC 2013 building energy science technical support projects.

While focusing primarily on capabilities to test compliance of building designs to performance-based California energy codes, the Software will be designed to facilitate a variety of additional building energy model (BEM) analysis, such as testing compliance to other energy codes, analyzing building designs for green/sustainable rating systems and perhaps utilizing features of the Software to perform parametric runs on building energy models.

The Software is comprised of four principal components: a rules processing and analysis engine (referred to as the “Rules Engine”), an EnergyPlus interface (“E+ Interface”), a simplified user interface (“UI Tool”) and a compliance report generator (referred to as the “Reporting Module”). The requirements for each of these four components are fairly unique, but all will be addressed in this document.

The Rules Engine is not designed to be used as a stand-alone tool, but is rather a software component encapsulating a number of BEM analysis capabilities that can be easily integrated into a variety of other tools and interfaces. The Rules Engine is designed to facilitate the use of multiple building energy simulation engines, but the first round of development will –only connect to DOE’s EnergyPlus simulation engine via the E+ Interface.

The E+ Interface serves several roles that are critical to the accurate simulation of building models produced by the Rules Engine. Those fundamental roles include: (a) translation of building descriptions from their native SDD (Standards Data Dictionary) data model to EnergyPlus IDF files, (b) management of EnergyPlus simulations of IDF building descriptions, and (c) retrieval of EnergyPlus simulation results and their transmission to the Rules Engine. NREL’s OpenStudio software is to be enhanced in order to supply the functionality needed for the E+ Interface.

The UI Tool is intended to serve a few fundamental uses, but will lack a variety of usability and graphical features so as to minimize its potential for competing directly with commercial compliance analysis products. The principal function of the UI Tool will be to enable users to create and edit proposed building designs (based on the SDD data model) and to perform automated Title-24 compliance analysis on those models. There are not likely to be features that would help users to easily create complex building models starting with prototype or high-level building descriptors, but the user will have the ability to construct building models on a component-by-component basis. Users will be able to read/open SDD XML building models written from other BIM and simulation/analysis tools which are enhanced to provide a SDD XML export feature, which should help to minimize scenarios where a user must construct entire building models from scratch within the UI Tool.

The Reporting Module will be used to produce all standards compliance analysis forms based on a proposed model description and analysis results passed to it by the Rules Engine. The format of the output report will most likely be PDF or combination of XML/XSD/XSL files.

The functionality of the Software will target two primary use cases: (1) BEM (compliance) analysis performed via tools that incorporate the Software (tool users), and (2) the development, testing and debugging of rulesets that include the logic and operations that define how a BEM is manipulated and simulated to test its compliance to an energy code (ruleset authors).

## Definitions, Acronyms, and Abbreviations

### Definitions

***ACM Manual*** - A manual published by the CEC that documents the requirements for approval of Alternative Calculation Methods (also referred to as compliance software programs) used to demonstrate compliance with the California Energy Efficiency Standards.

***Application Programming Interface*** (API) - A mechanism that serves as an interface between different software programs in a manner that facilitates their interaction, similar to the way a software tool’s user interface facilitates interaction between the (human) user and the software running on the user’s computer.

***Building Component Library*** (BCL) *–* online data repository of building energy modeling information. The E+ interface will make use of BCL components in the SDD to OSM/IDF translation process.

***Building Transformation***- describes a building model either specified by the user or generated during the course of testing the models compliance to the Energy Code. A typical Title-24 compliance analysis run includes 5 individual building transformations, (1) the beginning user-defined building model, (2) and proposed HVAC sizing model, (3) and final/annual proposed building model, (4) the baseline HVAC sizing model and (5) and final/annual baseline building model.

***Compliance rules*** - procedures that restrict or modify attributes in the computer description of the budget building design and/or proposed design. Compliance rules restrict or overwrite building description information input by the user and are used in the process of generating the energy cost budget and design energy cost.

***Data model*** -defines the structure and organization of data associated with a specific tool or purpose. In the case of this requirements document, the term data model refers to the structure and organization of data used to describe building designs that the software analyzes and manipulates in order to determine whether the building complies with a specific energy code.

***Data-model approach ruleset*** - refers to a compliance ruleset whose rules are defined and organized based on the list of component types and attributes defined in the building data model (SDD for this project). The order in which rules are evaluated in a data-model approach ruleset is defined by the Rules Engine, as opposed to procedural approach rulesets where the rules are evaluated in the same order in which they are defined/listed in the ruleset source.

***Energy Code*** - refers to the 2013 Title-24 non-residential energy code.

***Extensible Markup Language*** (XML) - A set of rules for encoding documents in machine-readable form emphasizing simplicity, generality, and usability over the Internet.

***Input Data Format (IDF)*** – Input file format for the building energy simulation program, EnergyPlus.

***OpenStudio*** – open source, cross-platform middleware software development kit (SDK) to make it easier to use EnergyPlus, and to provide higher-level functionalities related to software interoperability, multi-domain simulation workflows (EnergyPlus + Radiance), standards, and analysis.

***OpenStudio Model –*** OpenStudio’s building energy model functional block and corresponding API.

***OpenStudio Model file format (OSM)*** – serialized file format of a single building model instance. At this time OSM is very similar to IDF.

***Portable Document Format (PDF)*** – an open standard for document exchange, first created by Adobe Systems in 1993, used for representing documents in a manner independent of application software, hardware, and operating systems. Each PDF file encapsulates a complete description of a fixed-layout flat document, including the text, fonts, graphics, and other information needed to display it.

***Procedural approach ruleset*** - refers to a compliance ruleset whose rules are defined in a series of lists (rulelists). The rules in each rulelist are evaluated on building models in the order in which they are defined within the rulelist. This is in contrast to data-model approach rulesets where rule evaluation order is determined by the Rules Engine based on each rule’s dependencies.

***Program Advisory Committee*** (PAC) - A committee to be formed and managed by the CEC’s 2013 building energy science technical support contractor to provide guidance, input, review and comment on deliverables pertaining to that contract.

***Rule Circularity*** - refers to a condition where rules that describe two or more building attributes depend on one another such that there is no specific evaluation order that ensures each attribute be set to its final value prior to being referenced by a rule setting another attribute. Rule circularities are acceptable for procedural approach rulesets, where the rule author specifies the order in which each rule is evaluated. Rule circularities are however not allowed in data-model approach rulesets where the Rule Engine is responsible for determining the order in which each rule is to be evaluated.

***Simulation engine*** - a building energy simulation computer program, such as EnergyPlus.

***the Software*** - the ACM Standards Compliance Engine Software developed in conformance with this functional requirements document.

***Software Development Kit*** (SDK) - Software that facilitates the implementation of tools that take advantage of capabilities of a particular system or are designed to operate on a particular type of hardware.

***Software Functional Requirement*** (SFR) - this document.

***Standards Data Dictionary*** (SDD) - the collection of building components and descriptors that are manipulated by the compliance rules during the process of testing a building model for compliance to an energy code.

### Acronyms, and Abbreviations

***ACM*** - Alternative Calculation Method

***AEC*** - Architectural Energy Corporation

***ASCII*** - American Standard Code for Information Interchange

***ASHRAE*** - American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

***API***– application programming interface

***BCL*** – Building Component Library

***BEM***– building energy model

***CEC*** - California Energy Commission

***CEM***- compliance energy model

***CCM*** -California Energy Commission Contract Manager

***COMNET*** - The Commercial Energy Services Network

***DOE*** - United States Department of Energy

***DLL***- dynamic link library

***IDF*** – input data format

***NREL*** - National Renewable Energy Laboratory

***OSC*** – OpenStudio Component

***OSM*** – OpenStudio Model

***PAC*** - Program Advisory Committee

***PDF*** - Portable Document Format

***SDD*** - standards data dictionary

***SDK*** - software development kit

***SFR*** - software functional requirements

***XML*** - extensible markup language

## References

California Energy Commission. 2008. *Nonresidential Alternative Calculation Method (ACM) Approval Manual for the 2008 Building Energy Efficiency Standards*. Dec-2008. CEC-400-2008-003-CMF

CEC & AEC. 2010. *Nonresidential Alternative Calculation Method (ACM) based on COMNET*. Draft - Oct-2010.

Regional Economic Research, Inc.*COMcheck-Plus Compliance Ruleset Documentation*.Dec-2003.

## Overview of This Document

There are three major sections, including this introduction, plus two appendices in this functional requirements document, as described below:

***Section 1, Introduction*** - This introduction to the functional requirements for the ACM Standards Compliance Engine Software.

***Section 2, System Description*** - A description of the ACM Standards Compliance Engine Software and how it interfaces with other software modules and data sources.

***Section 3, Requirements*** - Descriptions of the capabilities and requirements for the Software (focusing on what the software will do and not on how the software will do it).

***Section 4, Appendix - Rule Syntax and Functionality Reference -***  Documentation covering rule syntax and functionality, including a listing of all preliminary functions/routines that rules can reference to query, manipulate and analyze a building energy model.

***Section 5, Appendix - Optional Capabilities -*** Capabilities that may be included in the Software to enhance its usefulness but that are not required.

# System Description

This section describes the overall system in which the ACM Standards Compliance Engine Software will operate and to make the requirements contained in Section 3, *Requirements,* easier to understand by providing needed context.

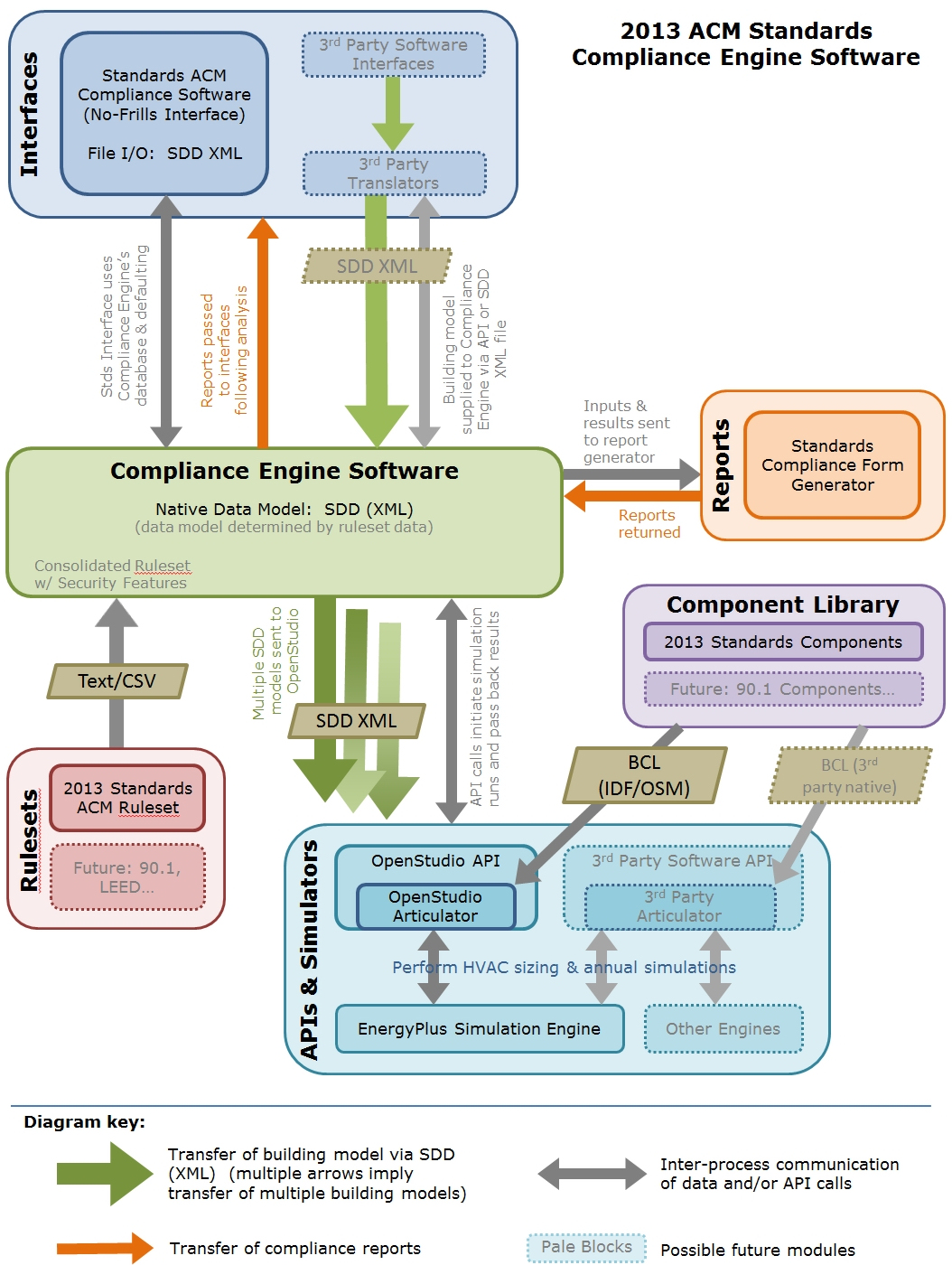
The diagram on the following page illustrates the overall vision of the Software and how it communicates and interfaces with other software modules.

The ACM Standards Compliance Engine Software (pale green in center of diagram) represents the Rules Engine software that this functional requirements document pertains to. It will be capable of receiving a proposed building energy model XML file from end-user ACM compliance tools (pale blue in top left), performing compliance analysis on the model (via a ruleset – pale red in bottom left), launching simulations in a specified simulation engine (cyan blocks at the bottom), and generating compliance reports/forms (pale orange on right). Output data and compliance forms are then be passed back to the user interface application(s).

The E+ Interface is represented by the cyan blocks immediately below the Rules Engine block. The OpenStudio API and EnergyPlus simulation engine are currently available to serve the role of the E+ Interface, though OpenStudio modules will require modification to facilitate the simulation of building models passed to it in SDD building model format. This lower right portion of the diagram is where building descriptions produced by the Rule Engine are translated into EnergyPlus IDF files and simulated, then the results are reported back to the Rules Engine.

The UI Tool is represented in this diagram as the pale blue box in the top left labeled “Standards ACM Compliance Software”. Other proposed third party products that serve the same purpose, that is, to assemble building descriptions from users and connect to the Rules Engine to perform compliance analysis on those building designs, are represented by the pale blue boxes to the right of the one representing the UI Tool. The UI Tool will store and retrieve compliance energy model projects using the SDD XML file format.

The schema/contents of the SDD XML files used to communicate building description both between various interfaces and Rules Engine and from the Rules Engine to the E+ Interface are based on the Title 24 Standards Data Dictionary (SDD) which is in the process of being finalized.



## Software Function Overview

The Software manipulates and analyzes a building energy model via logic and data contained in a ruleset and makes a compliance/noncompliance determination. Various codes use different terminology for the energy budgets (often computed using a baseline or budget model) and performance estimates (computed using a modified version of the originally submitted model) that are then compared as part of the compliance/noncompliance determination step. This document adopts the terminology used in California Title 24 and COMNET by means of the definitions in Section 1.3.1.

To accomplish its intended function, the Rules Engine Software must:

1. apply rules to a user defined building model to transform it into proposed and budget models consistent with Energy Code documentation,
2. initiate and oversee EnergyPlus energy simulations of multiple versions (HVAC sizing and final/annual) of the proposed and budget building models using capabilities provided by the OpenStudio SDK,
3. through the simulation of proposed and budget HVAC sizing simulations, and manipulation of building models based on results of those simulations, ensure that HVAC system capacities and flows for each model are adequate and consistent with requirements specified in the Energy Code,
4. retrieve energy simulation results from the final/annual proposed and budget building models and use that data in conjunction with the compliance rules to determine a pass/fail compliance result,
5. pass data to, and communicate with, the compliance reporting module to facilitate the generation of Energy Code compliance reports documenting the results of the proposed building model analysis,
6. enable calling applications to monitor compliance analysis progress, and
7. provide a mechanism which enables warning and error messages encountered during rule evaluation and energy simulation to be presented to the user either directly from the rules engine or via the interface between the rule engine and a calling (third party) application.

To accomplish its intended function, the E+ Interface must:

1. translate a SDD model to IDF/OSM using smart defaults and/or Building Component Library (BCL) components.
2. manage EnergyPlus simulations, and keep the Rules Engine apprised of progress and completion.
3. report warnings and errors related to translation and simulation back to the Rules Engine
4. communicate simulation results back to the Rules Engine, perhaps by augmenting the original SDD model

To accomplish its intended function, the E+ Interface should:

1. provide a “work while offline” mode using local copies of the relevant BCL components.

To accomplish its intended function, the User Interface (UI) Tool Software must:

1. provide one or more views of the proposed building model that communicate the hierarchical relationship of building components (building, zones, walls, windows, HVAC systems, etc.) contained in the proposed building model,
2. provide a set of user interface screens that allows the user to create, view and edit information about the proposed design,
3. interface with the Rules Engine to determine what options are available to users for certain building model inputs and what defaults are available from the compliance ruleset,
4. enable the user to initiate proposed model compliance analysis (via the Rules Engine), and
5. report analysis progress during execution of the analysis and upon completion, provide the user with access to warning and error messages and/or final compliance reports resulting from the analysis.

To accomplish its intended function, the Reporting Module Software must:

1. Accept proposed model description and analysis results from the Rules Engine and use that data to populate any/all compliance forms necessary for submission to the CEC.
2. Write output reports to one or more common formats (such as PDF) which are then made available to calling applications for display to software tool end users.

# Requirements

Many of the specific requirements for the Software in this section relate to the compliance rules, which are detailed in Section 5 (Appendix – Rule Syntax and Functionality).

## Software Functional Requirements

This section addresses the functional requirements common to all software modules: Rules Engine, E+ Interface and UI Tool.

### End User Software Configuration

The Software is intended for single, standalone users, but operating system and platform dependencies of each software module will be minimized to ensure that adapting the software for use on web or network servers will require minimal (or ideally no) source code modifications. The software is not required to perform compliance analysis in a multi-threaded fashion (to minimize analysis duration), but future implementation of such a feature should be taken into account when selecting third party class libraries integrated into the software. A multi-threaded analysis processing feature will be pursued if time/budget permits prior to delivery.

## Rules Engine Functional Requirements

This section addresses the basic processes that must be performed by the ACM Standards Compliance Engine Software; i.e., how the Software will process user defined proposed building models and determine whether they comply to the Energy Code. The functional requirements for software to implement this process have been organized into four major sections:

3.2.1 Producing Compliance Ruleset for Distribution to End Users,

3.2.2 Utilizing Ruleset Data to Perform Compliance Analysis,

3.2.3 Managing the Simulation of Compliance Energy Models (CEMs), and

3.2.4 Reporting Compliance Calculation Messages and Results.

### Producing Compliance Ruleset for Distribution to End Users

Compliance rules will use the SDD terms and logical operators to define input restrictions on proposed building model data, apply sizing algorithms and adjustment factors to the model, and perform table lookups and other manipulations of the building model in accordance with the Title 24 ACM. The rules will be developed in a series of text and/or CSV files but need to be translated into a format more suitable for distribution to end users of compliance software tools. Objectives of this translation include:

* Consolidation – ruleset source consists of a potentially large number of individual, uncompressed files which, if installed in source form on each user machine, would result in an unnecessarily large number of files written to each installed computer and accessed during each execution of the compliance software.
* Security – a digital signature or similar security mechanism is needed to ensure the integrity of the Title-24 compliance rules and securing a single, consolidated ruleset file as opposed to a large number of individual ruleset source files is more efficient.
* Runtime Performance – during the process of translating information contained in the rule targets and rule expressions, the rules can be pre-processed to minimize the time and computer resources needed to load and evaluate the ruleset during end user compliance analysis sessions.

The specific requirements of this section are that the final, end user distribution version of the compliance ruleset consist of a single file and that there be no limit on the number of individual text, CSV and/or other files that can be referenced in generating the distribution ruleset.

#### Compliance Ruleset Security

Ruleset security is particularly challenging due to the fact that both the ruleset source and the source code used to parse and apply the rules to a proposed building model will all be available to the public as open source data. The Rules Engine must be capable of verifying the authenticity of the compliance ruleset used to analyze a proposed building design. This capability is likely to be achieved through a scheme whereby digital signatures of rulesets used in analysis are compared to those computed on the original Title-24 ruleset. The scheme for achieving ruleset security, including a means by which the verification of the ruleset used in each building analyzed can be documented using the compliance reporting mechanism being implemented as part of the CEC compliance software effort. The security scheme designed to meet this requirement must be approved by the PAC prior to implementation.

#### Detecting and Reporting Compliance Rule Circularities

In the event that a ruleset is defined using the data-model approach, rule circularities cannot be present in the set of rules that describe a given building transformation. Rule circularities are a condition where rules that describe two or more building attributes depend on one another such that there is no specific rule evaluation order that ensures each attribute be set to its final value prior to being referenced by a rule setting another attribute.

The Rules Engine must be capable of detecting and reporting to the ruleset author any rule circularities that exist in a data-model approach ruleset during the course of producing a single distribution ruleset file.

### Utilizing Ruleset Data to Perform Compliance Analysis

The compliance ruleset source is comprised of a large number of individual expressions and formulas that are designed to transform various attributes of a proposed building model in a wide variety of ways to determine whether or not the building complies with the Energy Code. The Rules Engine must be capable of parsing the ruleset source and applying the building model changes identified in the rule expressions to a building description.

#### SDD Model File Format and File Input/Output

The Rules Engine must support a native SDD model file format that is human-readable and can be easily edited outside of the UI Tool or any specific, proprietary interface. Suggested formats include XML or another logically organized/structured ASCII text format. The Rules Engine must be capable of both reading SDD model data from files conforming to its native format and writing SDD model data to files of its native format.

The SDD is meant to be a high level model description, only containing the information required by the Energy Code plus a minimal amount of extra information required to fully articulate compliance energy models. The SDD may call out BCL component identifiers to facilitate translation of SDD CEMs to detailed simulation inputs. If the software must be able to work offline and BCL components are required to perform the translation of SDD CEMs to EnergyPlus IDF inputs, then either the rules engine or OpenStudio must cache a local component library, provide an API, and provide an updating mechanism to capture BCL updates when connectivity is reestablished. Some of this functionality is available from the OpenStudio ProjectDatabase, but the remainder of the task is still significant.

#### Application Programming Interface (API) to SDD Model Data

In order to help facilitate the development and integration of tools that interface with the Rules Engine (such as the UI Tool), the Rules Engine must include an API that enables tools to retrieve and set SDD model data. The Rules Engine API should also facilitate the retrieval of data residing in the ruleset that describes each building component and attribute of the SDD data model, such as valid numeric ranges, descriptions and units.

#### Confirming Proposed Building Model Validity

The Rules Engine must be capable of determining whether or not a proposed building model conforms to input value and component presence and relationship restrictions identified in the ruleset source prior to performing manipulations of the building model used to test the model’s compliance to the Energy Code. If errors are identified by checks residing in the ruleset source, then those errors must be reported back to the end user and/or calling application and further compliance analysis on that proposed building model is aborted. The following are some examples of errors detected by the ruleset that should cause further analysis of a proposed building model to be aborted. This list is only a sample and does not include each and every type of restriction that a ruleset can check for when reporting proposed building model errors:

* A numeric value or list selection (such as negative value specified for the U-factor of a wall assembly) does not fall within an excepted range defined by the ruleset.
* Certain building components identified as required by the ruleset are not present in the proposed building model (i.e. each building model must contain at least one Zone).
* Certain required building component relationships are not defined, such as walls not being associated with a parent space or conditioned thermal zones not assigned to any HVAC system.

#### Compliance Rule Evaluation Order

In the event that the compliance ruleset is defined using the data-model approach, the Rules Engine must determine the order in which all rules defined for a given building transformation are to be evaluated on the building model. The rule evaluation order is to be determined based on the dependencies that each rule might have on other attributes of the building model, such that each attribute is set to its final value prior to being referenced to determine the value of any other building attribute (for a given building transformation).

#### Compliance Analysis Processing

The Rules Engine must be capable of adapting the overall compliance analysis procedure based on the contents of the compliance ruleset. For data-model approach rulesets, this means that the collection of building transformations defined within the ruleset determines what building models are to be generated during the course of testing a proposed building design for compliance to the Energy Code. For any ruleset, the ruleset itself should determine what type of simulation is to be performed on a given building transformation and whether that simulation (for instance an HVAC sizing run) is to be performed only once or multiple times until a specific condition (defined in the rules) is met.

#### Management of Multiple Building Models

During the course of testing a proposed building model for compliance to the Energy Code, a series of unique building transformations will be defined. The Rules Engine needs to retain the SDD representation of each of these transformations during the course of the entire compliance analysis processing. In most cases, building model inputs for one transformation are based on the contents of previous transformations and in all cases, the final compliance result is determined through the comparison of certain attributes (such as TDV energy use) of particular transformations generated during the analysis.

### Managing the Simulation of Compliance Energy Models (CEMs)

The Rules Engine must be capable of initiating building energy simulations using the E+ Interface. These simulations typically fall into two individual categories, (a) simulations performed to determine whether or not HVAC equipment sizes and flows are sufficient to adequately condition the building, and (b) final/annual simulations, the results of which are compared to determine compliance of the proposed building model to the Energy Code. The Rules Engine need not keep track of whether a given simulation is of one type or another (sizing vs. annual), as it is the ruleset’s responsibility to setup the SDD building transformation with all data needed to perform a specific type of simulation.

### Reporting Compliance Calculation Messages and Results

There are three primary sources of errors, warnings or other messages that need to be communicated to the user or calling application, as well as a compliance log file. Those sources include:

* The compliance ruleset, which contains building attribute range limits as well as the ability for rules to initiate messages of various severity,
* The E+ Interface, which can report issues related to the data stored in the SDD building model passed to it for simulation or messages returned by the EnergyPlus simulation engine, and
* The Rules Engine itself, if certain aspects of the rule processing or SDD building model is somehow compromised in a manner that disrupts the analysis.

#### Compliance Analysis Log Files

Any and all messages, regardless of the severity, should be output to a compliance analysis log file which records details of each compliance analysis run. The log files should be written in ASCII text format, or another format acceptable to the PAC.

There shall also be a VerboseLog option available in the compliance analysis processing, most likely via an attribute of the SDD building model or perhaps via the function that initiates the analysis. When toggled ‘on’, messages are written to the compliance log file corresponding to each and every rule evaluation (identifying the component and attribute being set and the value or selection that attribute is being set to) and building energy simulation performed during the course of the analysis. This option should default to ‘off’ so that excessively long log files are not generated each time an analysis is run.

#### Propagation of Messages Throughout the Analysis

The Rules Engine must propagate messages of all severities and from all sources pertaining to the compliance analysis to both the compliance log file and calling application.

#### Generation of Compliance Analysis Reports

The Rules Engine will communicate directly with the Reporting Module that will handle the generation of compliance reports and forms based on building model inputs and analysis results provided to it by the Rules Engine. The environment and/or programming language(s) in which the Reporting Module will be developed is unknown at this time and therefore the method by which these two modules will be linked and pass data back and forth is difficult to anticipate, but must nevertheless be achieved in order for the overall compliance analysis system to function effectively.

#### Reporting Compliance Analysis Progress

The Rules Engine must have the ability to track and report progress of each compliance analysis run back to the calling application. The resolution of the progress indication needn’t be highly accurate, as the quantity and complexity of rules processed and the duration of individual simulation runs is difficult to anticipate.

The precise method of progress reporting shall be determined based on discussions with pilot user interface tool vendors and must be approved by the PAC. At a minimum, the interface should provide information on whether it is processing rules or running simulations, and if the latter, how many simulations of what type.

## E+ Interface Functional Requirements

This section addresses the basic processes that must be performed by the E+ Interface. The functional requirements for software serving as the E+ Interface has been organized into three major sections:

3.3.1 Generation of EnergyPlus Input (IDF) Files

3.3.2 Simulation Workflow Management

3.3.3 Retrieval of Simulation Results

### Generation of EnergyPlus Input (IDF) Files

The E+ Interface must be capable of translating any valid SDD building model into an EnergyPlus IDF file.

* The preferred translation method is to use the SDD API and the OpenStudio API to create a valid OpenStudio building model from a valid SDD model (similar to the structure of the energyplus and gbxml sub-projects in OpenStudio). Once that is accomplished, the EnergyPlus IDF file can be created in the process of executing a simulation workflow on the OpenStudio model, and retrieved later using the OpenStudio run manager functionality. Since the SDD is a high-level building model format, a number of details will need to be smart defaulted, either directly in the translator, or through the use of Building Component Library (BCL) components. In addition, initial versions of the SDD are likely to be incomplete from a building energy modeling (BEM) perspective, so the plan for design and implementation of the translator will include one or more iterative steps for adding data to the to the SDD model.

#### SDD Model Additions

To enable the creation of an OSM/IDF model from an SDD model, the SDD must be expanded into a model that contains detailed information about building geometry (vertex by vertex), internal loads (including schedules and details like radiant, latent, and return air fractions), constructions and materials, and HVAC systems (topology of equipment and zones, equipment efficiencies, performance curves, schedules and controls). As required or desired information is determined to be missing, that will have to be pushed into the SDD, into BCL components referenced by the SDD, or into lookup tables owned by the translator itself.

#### BCL Components

To reduce the amount of data that must be in the SDD, detailed model data will be added to the BCL as IDF and OSC snippets decorated with the required meta-data (attributes, provenance, etc.). At a minimum, this will consist of schedules, constructions, materials, and baseline HVAC systems. More components will likely be needed to enable the SDD to OSM translation step for proposed models.

#### SDD to OSM Translator

### The translator must accept an SDD model, either in memory or as a file, and return an OpenStudio model, which will be available in memory or as a file. For any valid SDD model, the returned OSM should also be valid and simulatable. The degree to which this goal is achieved will improve over time. The project should first aim to be able to translate one particular SDD model. Once that milestone is achieved, translator gaps should be identified and prioritized by the team. OpenStudio will have the ability to model geometry, constructions, schedules, internal loads, and the five HVAC system types called out in Title 24 2008 by the December 2011, OpenStudio 0.6.0 release.Simulation and Workflow Management

The E+ Interface must be capable of initiating and managing the simulation of each IDF file translated from SDD.

The preferred method is to use the OpenStudio RunManager, which allows for customized simulation workflows; can run multiple workflows/simulations in parallel; is accessible through C++, Ruby, C#; includes Qt widgets and emits Qt signals for monitoring progress; and provides for easy retrieval of the resulting output files.

#### Monitoring Simulation Status

OpenStudio has several places where it provides waitForFinished methods or Qt signals for monitoring workflow progress. The rules engine software can use either of those mechanisms directly, or can monitor the file system itself to keep track of progress and gain access to results and messages in a timely manner.

#### Propagation of Simulation Messages

Simulation error and warning messages must be communicated back to the Rules Engine. The compliance engine and OpenStudio teams will work together to make sure that needed information is programmatically communicated in an efficient and useful manner. The OpenStudio RunManager captures errors and warnings from EnergyPlus and other processes, making those available through an API as well as storing them on disk as text files. In general, OpenStudio has integrated logging functionality that can be filtered by channel and log level, and accessed directly or output to file.

### Retrieval of EnergyPlus Simulation Results

The E+ Interface must be capable of retrieving results of each EnergyPlus simulation and making those results available to the Rules Engine.

The OpenStudio Standards Interface provides access to input and output attributes (the latter being populated by simulation results) by component type using SDD terms. This is therefore the preferred method of results retrieval. As needed, the results can be written to an agreed upon CSV or XML format. OpenStudio has an output report XML format that may be useful for this project, and also has time dependent valuation (TDV) support.

## User Interface Tool Functional Requirements

The principal function of the UI Tool is to enable users to create and edit proposed building designs (based on the SDD data model) and to initiate (through access to the Rules Engine) automated Title-24 compliance analysis on those models. The UI Tool should provide clean, clear and efficient access to the entire SDD data model, but will not include wizards, mouse-driven geometry construction or highly graphical building or HVAC system diagrams, so as to minimize the potential for this tool to compete with other commercial energy code compliance user interfaces.

The functional requirements for software to implement this process have been organized into five major sections:

3.4.1 User Interface Framework and Internet Connectivity

3.4.2 Managing Building Energy Model Data

3.4.3 Keeping User Apprised of Compliance Analysis Progress

3.4.4 Displaying Compliance Analysis Messages and Reports

3.4.5 Program Help Documentation

### User Interface Framework and Internet Connectivity

The target platform for the UI Tool is the Windowstm operating system, and as such, the user interface must be designed and implemented to run efficiently on a Windows PC. The underlying framework of the user interface can be that of a standard Windows desktop/client program, or another framework that meets the following requirements:

1. The framework must be common to a variety of software applications that run on the Windows operating system,
2. Installation files providing support for the application framework cannot exceed 20MB (when zipped into an installer), and
3. Internet connectivity must not be required in order to install or use the application (though certain optional user interface features can be made available only when the user has an internet connection).

### Managing SDD Model Data

The user interface tool must conform to the following requirements pertaining to the management of SDD model data.

#### Native File Format

The user interface tool must support a native file format that is human-readable and can be easily edited outside of the user interface, such as XML or other logically organized/structured ASCII text. It is recommended that the user interface adopt the native file format of the Rules Engine in order to maximize compatibility with that module and minimize UI Tool-specific source code, but this is not a strict requirement. Any file format other than the native format of Rules Engine SDD models must be approved by the PAC.

##### File Reading and Writing

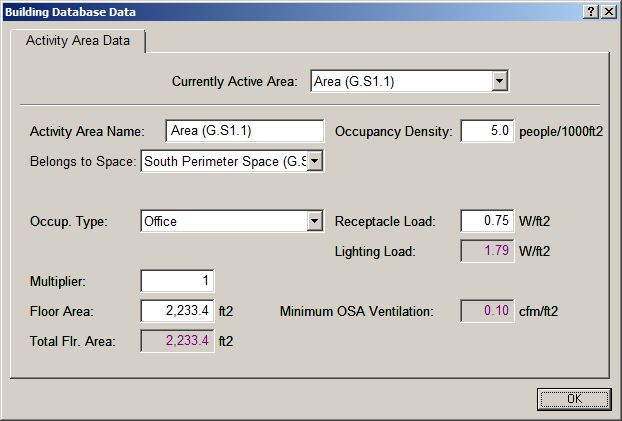
The user interface must be capable of reading/importing and writing SDD model data stored in its native file format. It is recommended that the UI Tool utilize the Rules Engine API to support SDD model file reading and writing, but this is not a strict requirement.

#### SDD Model Navigation

The user interface must be capable of displaying components of the active/loaded SDD model in a hierarchical manner that shows the parent/child relationships of components in the model as shown in the sample to the right.(Note that the user interface samples provided here do not reflect current or expected final SDD model data)

In addition to displaying component relationships, the user interface must be capable of editing those relationships, creating new components and deleting existing components.

#### Display and Edit of SDD Model Data

In addition to displaying components of the SDD model and their inter-relationships, the user interface must be capable of displaying and editing all SDD model data that describes each component.

Access to screens enabling the display and edit of component data should be provided via common user interface techniques, such as “Properties…” options from right mouse menus or double-clicking components within the hierarchical tree display.

The SDD input screens will consist primarily of non-graphical data entry fields such as edit, combobox, listbox, checkbox and button controls. The organization and contents of the dialog boxes will be designed to provide an intuitive and easy-to-use user interface. The organization of controls will be consistent with other Windows applications by starting with the most generic and descriptive inputs at the top left, geographically grouping controls that apply to similar building elements.

Standard Windows keystrokes such as <TAB> and <SHIFT>-<TAB> will enable the user to move from field to field within each menu and dialog box. The <ALT> key will provide the user with keyboard access to the top menu bar which will provide all the standard Windows application functions such as file saving and retrieval, principal program functions such as initiating the compliance analysis and application exit.

##### Display of SDD Model Defaults

The compliance ruleset facilitates the definition of proposed SDD model default values and the Rules Engine API is capable of providing access to those default values at runtime during model creation. It is recommended (though not required) that the user interface utilize the Rules Engine API to manage the user’s building model and to take advantage of that API to display building attribute default values and other pertinent SDD information.

### Keeping User Apprised of Compliance Analysis Progress

During the course of performing compliance analysis, the user interface must keep the user apprised of the analysis progress and provide the user with a button to abort the analysis. Progress should be presented to the user in at least two ways – via a progress bar that indicates percent completion through the gradual discoloration of a bar and also through a message indicating the approximate time remaining before analysis and report generation completion. Analysis completion time estimates should initially be based on model complexity and should be re-evaluated and calculated following each major stage of the analysis (in particular after each simulation).

### Displaying Compliance Analysis Messages and Reports

The user interface must be capable of displaying compliance analysis messages output from the compliance engine during the course of processing. The user interface must also enable the user to view compliance analysis reports created by the compliance report generator module.

### Program Help Documentation

The user interface must include documentation that describes general program use and features. The documentation must also include access to information about the SDD model components and attributes, such as that residing in the compliance ruleset and available to the user interface via the Rules Engine API.

## Reporting Module Functional Requirements

The principal function of the Reporting Module is to generate compliance reports documenting the pass/fail result and all required project, building model and analysis results contained in the pre-defined compliance reporting forms for the Energy Code.

The functional requirements of the Reporting Module software have been organized into four major sections:

3.5.1 Output Report Format and Contents

3.5.2 Reporting Module Language and Configuration

3.5.3 Ease of Report Additions/Changes

3.5.4 Compliance Report Security

### Output Report Format and Contents

<most likely PDF?>

<all forms fully defined or some to contain “input” fields allowing user customization (?)>

<list all forms and provide images of some/all inside this document>

### Reporting Module Language and Configuration

<C++ class library using only open source dependencies, consistent with Rules Engine (?)>

### Ease of Report Additions/Changes

<underlying source of the report definitions, contents and formats should (ideally) be customizable outside of compiled source code, as is the case w/ compliance rulesets (?)>

### Compliance Report Security

<security linked w/ that residing in the Rules Engine to document that the analysis was the result of a specific version of compliance ruleset and Rules Engine source code (?)>

## Software Performance Requirements

There are a number of things that will significantly impact the performance of the compliance analysis system that are either out of the control of the development team. Some of those aspects include:

* The time required to simulate building model performance using the EnergyPlus simulation engine is likely to represent over 90% of the time required to perform the entire compliance analysis.
* The time required to generate a compliance report is entirely unknown at this time, as that report generation system and its interface has not been well defined.
* The size and complexity of the SDD data model and compliance ruleset will affect the time required to manage the building models and evaluate the rules during the analysis, and the size and complexity here cannot be constrained without affecting the accuracy of the analysis.

Given these unknowns, it is unreasonable to place specific performance or processing time limits on the analysis as a whole. There will however be two specific performance requirements placed on the system:

1. Rules Processing – Not all rules can be evaluated in the same amount of time. Rules involving setting a SDD building attribute to a static value or value from a small look-up table will execute much more quickly than a rule that involves complex logic, more detailed table look-ups (potentially through thousands of records) and/or the calling of Rules Engine functions that are capable of performing significant building model manipulations (via rule functions implemented in source code).  
   There will however be a general performance target for rule evaluation of 10,000 rule evaluations per second (based on a 64-bit Windows 7 Professional system w/ Core i7, 1.73 GHz processor and 4GB RAM).
2. E+ Interface –The translation of SDD building models to EnergyPlus IDF files, simulation of those models and retrieval of simulation results are expected to vary with the complexity of the proposed and baseline building models. EnergyPlus simulation performance is not something that is under the control of the development team, but the translation of building models and results retrieval is. The performance target for these is as follows.  
   The translation of a building model from the SDD to EnergyPlus IDF and retrieval of EnergyPlus simulation results for that model should take no more that 20% of the time required to perform an annual EnergyPlus simulation on that model.

## Design Constraints

### Hardware Platform

The CEC Rules Engine, E+ Interface and UI Tool software can be operated on any system running Windows XP, Vista or 7.

### Development Environment

The preferred CEC Rules Engine, E+ Interface and UI Tool software development environment is Microsoft’s Visual Studio 2008, due to its wide use and to maximize consistency with NREL’s OpenStudio which targets this same environment.

#### Programming Language

The preferred CEC Rules Engine, E+ Interface and UI Tool software programming language is C++, due to its long term popularity, wide use and to maximize consistency with NREL’s OpenStudio which uses this same language.

### Operating System

The CEC Rules Engine, E+ Interface and UI Tool software will be compatible with Windows XP, Vista or 7.

#### Portability to Other Operating Systems

The CEC Rules Engine will be developed using open source, cross-platform libraries that maximize the potential and ease of porting that module to other operating systems, such as Linux and MAC. The E+ Interface must have similar dependencies, which are consistent with NREL’s OpenStudio, should that serve as the basis of the E+ Interface.

It would be desirable for the UI Tool to also be implemented with cross-platform libraries and interface framework, but due to budget and timeline limits this is not a requirement.

# Appendix -CEM and Ruleset SourceReference

Files that describe the compliance energy model (CEM) and ruleset are defined outside of source code compiled into executable (.exe or .dll) files. These software tools are designed to provide flexible frameworks and evaluation engines for models and rules that can be defined and used without having to recompile any exe or dll files associated with the tool. This design allows for the easy interchange and update of rulesets without requiring re-distribution of compiled software and also helps to ensure that non-software developers have the power to modify building models and rules without possessing the tools, knowledge or experience that goes into creating modern software tools and graphical interfaces.

This appendix describes some fundamental attributes of the building energy model that is acted upon by a ruleset as well as the individual source files that make up the CEM and rulesets.

## CEM Data Model Component Relationships

Compliance energy models are made up of a fairly broad and complex range of information, including architectural, thermodynamic, energy loads/gains and HVAC equipment performance and controls. Inputs covering these various areas are divided into separate components by topic or use that enable the consolidation of energy simulation input data so that the model needn’t include an excessive amount of duplicate data. In order to facilitate this data consolidation while also allowing for a great amount of flexibility and specificity in the building models, the underlying data storage mechanism must be capable of managing component relationships that fall into a couple of different categories that we refer to as (a) parent/child and (b) object assignment.

### Component Parent/Child Relationships

Compliance energy models are comprised primarily of hierarchical components. An example of topmost components in a CEM might be those that describe aspects of the site and overall facility. The next level of components describe individual buildings and floors within each building, then spaces/zones followed by walls and finally windows and doors. The relationship between these components is referred to as parent/child. A space within a building belongs to one and only one parent floor, making the space a child of the floor. A wall is a child of a space, that space being the parent of the wall, etc.

### Component Assignment

Many components of the building model are designed to consolidate data that describes the performance characteristics of another component or other energy simulation data that might otherwise be repeated many times throughout a building model. Examples of components of this nature include wall construction, window performance, internal gains hourly profiles, and a variety of other data. A single component describing these data in a CEM can typically be assigned to many other components, sometimes of varying type themselves. For instance, window performance data can be stored in a Glass Type component that can be referenced through many individual windows and/or skylights throughout a building model.

## CEM Data Model Source Files

There are two separate files that define the CEM data model. The first and primary file lists and provides information pertaining to each component of the data model and all attributes/properties that can be used to describe each component. The secondary CEM data model source file defines the character strings and associated numeric values for each CEM model attribute that can be specified by the user as a selection from a pre-defined list of options (referred to as enumerations).

### CEM Base.txt

The CEM Base text file lists the individual component types and attributes that describe each type of CEM component. The principal data that describes each component type includes:

* Short and long names used to identify the component type (SName & LName),
* An integer value specifying the maximum number of components of that type that can be present in a single building model (MD),
* Up to 5 individual parent component type names (short names of up to five other component types that can serve as a parent to this component type) (P1-P5), and
* Topic ID to facilitate help documentation linkages (HI).

Each individual CEM component can be described by many individual attributes. The principal data that describes each component attribute or property includes:

* Short and long names used to identify the attribute (SName & LName),
* The type of data that describes the attribute, such as float, integer, character string, symbol or object assignment (VType),
* The number of values that define this attribute (1 for a single value vs. > 1 for arrays of values) (NV),
* A character string to label the units that describe the attribute (UL),
* The name of the component type that can be assigned to this attribute (if the attribute is an object assignment) (OC), and
* Item ID to facilitate help documentation linkages (HI).

### CEMEnumerations.txt

The CEMEnumerations file is where the lists of options are defined for each CEM component attribute that is defined as type Symbol, meaning that it is specified by the user as a selection from a list of pre-defined options. Each symbol (single option within a list) is identified by a unique numeric value and the lists of options available to the user can depend on properties of the local component or any global components of the building model.

## Compliance Ruleset Source Files

The compliance rules input files are ASCII text files that include all the data and logic necessary to test compliance of a building model to the Energy Code. The formats of these files are designed to make creation and maintenance of compliance rulesets as simple as possible for rule authority organizations.

The source files describing a compliance ruleset can be defined in a couple of different ways. Past rulesets of this nature have been organized to include a series of procedural-oriented lists of rules accompanied by a series of supporting files that provide additional data referenced by the rules or used during rule evaluation. Each list of rules is designed to manipulate a building model in a certain way, and these lists may be evaluated multiple times or perhaps not at all during the course of a single compliance analysis based on the individual building model being analyzed by the ruleset. Source files consistent with this organization can be found in the Procedural Compliance Ruleset Source Files section below.

A newer organization of ruleset source files is referred to as the data model approach. This approach consolidates data and rules related to each individual building model component attribute into a single block of text (as opposed to the procedural rulesets where this data might be spread across several individual files). Source files consistent with this organization can be found in the Data Model Approach Ruleset Source Files section below.

### Procedural Compliance Ruleset Source Files

Procedurally organized rulesets are made up of a variety of individual text/CSV files that contain tables of information or rules. Each of the unique types of file that can be included in a procedurally organized ruleset is described in the following sections. As is the case throughout the text source files, file headers should be referenced for the latest information describing the format and contents of each file.

#### Primary Compliance Ruleset Text File

The primary ruleset text file contains a series of identifiers and references to other files that are to be compiled into the ruleset. These identifiers and subordinate file references include:

* Ruleset structure version – a numeric version ID denoting the version of ruleset structure or organization that the ruleset is compatible with to facilitate ruleset source backward compatibility.
* Ruleset ID & version – identifiers available at runtime to identify the ruleset and its version.
* Table list – a list of references to text/CSV look-up tables containing data that can be referenced by rules throughout the ruleset.
* Data types – a separate text file containing ruleset-specific data pertaining to each individual building model component attribute.
* Range – a separate text file containing range limits (message, warnings and errors) for a variety of building model component attributes.
* Enumerations – a file similar to the CEMEnumerations text file that enable ruleset-specific option lists that override those contained in the CEMEnumerations file.
* Resets – a file used to identify a series of component attribute relationships that cause certain attributes to be re-defaulted (user input removed) in the event that other attributes are modified by the user or compliance ruleset.
* Component Libraries – one or more files that include individual component definitions that can be imported into building models and referenced in building models generated by the ruleset.
* Rulelist Files – individual files that contain lists of rules designed to manipulate a building model.

#### Rulelist Text File

A text file that contains one or more rulelists (individual lists of rules). There are a series of pre-defined (reserved) rulelist names that are applied to a building model during certain phases of the compliance analysis and rule authors can create any number of additional rulelists that can be reference by rules contained in either the pre-defined or other supplemental rulelists.

Refer to the Rule Syntax and Functionality Reference section of this document for more information on the format of rules and rulelists.

#### Look-up Table Text/CSV File

Each compliance ruleset can reference one or more tables of data. The use of tables is often the most convenient way to integrate conditional data. These files can contain any number of both independent and dependent data arranged in columns. This format is consistent with tables of building description inputs provided in many compliance rule documents.

Each look-up table reference includes three pieces of data:

* a table name which can be referenced throughout the compliance rule expressions as if it were a predefined ruleset function,
* the number of table independents (the number of values passed into a look-up table in order to return a specific dependent value), and
* the number of dependents defined in the table.

Throughout the compliance rule expressions, data contained in the look-up tables can be referenced by indicating the table name followed by parenthesis’ containing look-up values for each independent variable in the table and a 1-based integer index identifying the dependent variable to return.

#### Data Types Text File

The data types file includes a series of values that are used by the compliance ruleset and user interfaces alike. These data are specified for each individual component attribute defined in the building data model and include:

* Attribute classification – one of several options such as Compulsory, Required, Prescribed, Default Optional and NotInput, used primarily by user interfaces in determining how to handle the interface to the attribute.
* An integer flag value (0/1) indicating whether or not it is a “primary” attribute (an independent variable upon which other attributes describing the same building component depend). Attributes with this flag value set should be collected immediately after a component of the type that this attribute describes is created in a user interface.
* An integer flag value (0/1) indicating whether or not the attribute can be edited by the user from within a user interface. This flag should be set to TRUE for all attributes which must be input by the user and should be set to FALSE for all attributes whose values are prescribed by the compliance rules.
* Additional flag values that can be referenced by user interfaces (refer to a DataTypes.txt file header for more details).

#### Range Limits Text File

In order to help guide the user and prevent the input of errant data, the compliance ruleset can define a series of range checks to be performed on any data input or modified by the user. The data describing each individual range check include:

* The name of the attribute for which the range check is defined.
* A flag indicating whether the range check value represents a minimum or a maximum value.
* The floating point range check value.
* A logical condition (such as “Building:Area> 0”)which must evaluate to TRUE in order for the range check to be enforced (or “none” if it is to be enforced at all times).
* A range check classification, including Message, Warning and Error.
* A message that provides an explanation of the range check violation.

#### Enumerations Text File

A text file whose contents and format is identical to that described above in the section entitled CEMEnumerations.txt.

#### Attribute Reset Definitions Text File

This file contains a series of building component attribute groups. Each group is led by one or more records beginning with a value of 0 followed by a component attribute and each group is concluded by one or more records beginning with a value of 1 (followed by a component attribute). Whenever the user modifies a building attribute that is referenced in a ‘0’ (leading) reset data record, then all attributes that are referenced in subsequent ‘1’ (trailing) records will be re-defaulted, meaning that any user-specified data is removed and the attribute is then re-defaulted.

#### Component Library Text File

Each compliance ruleset can reference one or more libraries, each of which contains any number of building components which may be referenced by the compliance rule expressions. This file is formatted very much like the ASCII files which store the user input for building description data. The main difference is that the library is made up of a collection of building components which do not describe a single building or project, but instead describe a wide variety of schedules, equipment performance curves, and any other components which are specifically defined by the compliance ruleset.

### Data Model Approach Ruleset Source Files

The syntax for the data model ruleset approach is significantly different than the procedural compliance ruleset syntax and is described in the following sections. Conceptually, the data model ruleset approach is based on a few simple concepts that together provide an expanded method of expressing the rules for a performance based building energy standard such as the Non-residential Alternative Calculation Method (NACM) of California’s Building Energy Efficiency Standards (Title 24).

At a high level, there are three main components of the Compliance Engine to understand:

* The hierarchical building data representation (the SDD XML)
* The ruleset that transforms the hierarchical building data representation provided by the user into similar hierarchical building data representations for the proposed and baseline building.
* Each hierarchical building data representation gets translated into input suitable for a building energy simulation program and then simulated. The simulation results for the baseline and proposed would be compared and if the proposed energy costs (based on time-dependant valuation for Title 24) are less than the baseline the building would pass.

This chapter focuses on the second part, the ruleset, but it is important to understand how the ruleset is connected to the hierarchical data representation and the simulation program. The following paragraphs provide a conceptual overview and the sections that follow dive deeper into the details.

* The user’s building description is expressed in a XML document based on a XML Schema file. This XML document would typically be generated by a software program used during the building design process. Such a program would usually have a graphical user interface that allows users to edit the geometric, envelope, lighting, and HVAC attributes for a building. The XML document is an interchange format that directly corresponds to the user’s hierarchical building data representation.
* The software would take the XML document that corresponds to the user’s hierarchical building data representation and the rules expressed in a specific syntax and create one or more hierarchical building data representations. Imagine if the standard consisted of only two rules that required a minimum amount of insulation and a maximum amount of lighting power. The resulting baseline hierarchical building data representation would look almost identical to the user’s hierarchical building data representations except the data items related to insulation and lighting power would likely be altered.
* The ruleset is expressed in a group of text files in the same directory which operate on the user’s hierarchical building data representation (as provided in the XML document) and create a series of similar but modified hierarchical building data representations for the proposed model and the baseline model. The files contain blocks of text for describing the ruleset including: RULE, TABLE, REPLACE, and TRANSFORMATIONS which will be described further below. All files in the ruleset would have file extensions of TXT or CSV.
* Each RULE in the group of text files is based on a specific data element from hierarchical building data representation and uses spreadsheet-like expressions to show how that data element should be modified for the proposed version and the baseline version (and any other version) of each created hierarchical building data representation. The ordering of the RULEs is not important since the rule processor program determines how each is dependent on one another and computes the values in the proper order. See the section titled RULE and RULE NEW Blocks below for more details.
* For expressing complex rules, intermediate values are computed using RULE NEW blocks which have the same syntax as the RULE block. New temporary data elements are created in each hierarchical building data representation that can be used for other computations. See the section titled RULE and RULE NEW Blocks below for more details.
* RULEs can reference TABLEs of data that are either present in the same text file or in other text files. Each TABLE effectively creates a new function that can be used within a specific expression in a RULE with independent and dependent variables. The each TABLE would be complete with every possible combination of independent variables. Each TABLE consists of one or more columns of independent values and one or more columns of dependant values. The RULEs reference a specific TABLE and provide values that are looked up to find a result. Much of the standard is represented as tables so this feature is used to represent those tables. See the section titled TABLE Block below for more details.
* When portions of one or more of the hierarchical building data representations need to be removed and replaced, the text files of the rules contain a REPLACE block which describes which portions of the hierarchical data building representation are removed and how they are replaced. This is usually limited to only certain hierarchical building data representations (baseline or proposed, etc.). The rules related to the inserted data elements would contain the details on how to set their values in this case. See the section titled REPLACE Block below for more details.
* One at a time, the hierarchical building data representations created by the rules for the proposed and baseline (and perhaps others) would be translated into a building energy simulation input file such as an IDF file for EnergyPlus or an INP file for DOE-2. Each would be simulated and the summary results from the simulation would be added back into the data model. Having the results available for other rules is especially important for sizing of HVAC equipment.
* The number of different hierarchical building data models transformed by the software can itself be defined using the TRANSFORMATIONS block. The TRANSFORMATIONS block describes each transformed hierarchical building data model based on the original user provided hierarchical building data model. Commonly, the TRANSFORMATIONS include a proposed model used for HVAC component sizing, a proposed model, a baseline model used for HVAC component sizing, and a baseline model.

The ruleset is completely described using text files. The files should be organized by topic but this is for the convenience of the rule developers, since ultimately the contents of all files are compiled together. No file is the “main” file. Dependencies of the rules in the files are determined on an expression-by-expression basis so no ordering of the files is required. Circular referencing would be flagged by the compiler and identified so the rule author can correct. Most files will contain both RULE blocks and TABLE blocks and one file would contain a single TRANSFORMATIONS block. All files in a directory with TXT or CSV file extensions would be part of the ruleset.

The following sections provide additional details on each block that can appear in the group of text files that express the rules.

#### RULE and RULE NEW Blocks

Most files will contain RULE blocks which begin with a line labeled RULE and end with a line ENDRULE as shown below:

RULE<data model element>

<content of a rule>

ENDRULE

Each RULE block operates on a single specific data element from the data model. It would contain everything related to that data element including defaults, maximum, minimum, transformations for the proposed and baseline building, references, error messages, help messages, units, etc. The RULE block would be divided into areas for defaulting, proposed, and baseline as well as general restrictions. The rules for each transformation are the last parts of the RULE block using the names from the TRANSFORMATIONS block. The RULE blocks do not need to be shown in the order of execution and instead are evaluated in order of dependency, like cells in a spreadsheet. Strict dependency checking is expected that is not tied to any conditional expressions. Dynamic dependency checking that does rely on how conditional expressions are evaluated does not need to be supported.

The <data model element> is a reference to the data element that the results of the rule expressions get assigned. For example, building.envelope.window.fenestrationConstruction.solarHeatGainCoefficient would reference the Solar Heat Gain Coefficient for all windows in the building. The portions of the RULE block that sets the values would be evaluated and the result set to the value of that data element. The RULE is executed for each specific instance of the data element in the hierarchical building data representation. If the rule pertains to windows, it would be executed for each window in the data model. However, since expressions can contain logical conditions, the values can be changed or not changed depending on the specific logic.

Each RULE block starts with the RULE line and ends with the ENDRULE line and can contain the sections shown below:

RULE <data model element>

DESCRIPTION

HELP

REFERENCE

MINIMUM

COMMONMINIMUM

COMMONMAXIMUM

MAXIMUM

UNITS

OPTION

DEFAULT

PROPOSEDSIZING

PROPOSED

BASELINESIZING

BASELINE

ENDRULE

After each section, an expression, a list of options, values, or text may appear.

A fictitious example of a complete rule is shown below:

RULE building.construction.rValue

DESCRIPTION

"Insulation R Value”

HELP

"Multiple lines of help about the rules pertaining to this particular

rule. The start and end double quotes can be on different lines"

REFERENCE

NonResACM2.1

Section6.3Table23

MINIMUM

0.001

COMMONMINIMUM

8

COMMONMAXIMUM

38

MAXIMUM

100.00

UNITS

h-ft2-F/Btu

DEFAULT

11

PROPOSEDSIZING

u.building.construction.rValue

PROPOSED

u.building.construction.rValue

BASELINESIZING

IF building.climateZone > 3 THEN

12

ELSE

14

ENDIF

BASELINE

bz.building.construction.rValue

ENDRULE building.construction.rValue

The DESCRIPTION, HELP and REFERENCE sections provide information about the rule. The primary purpose of these sections is to provide rule reviewers with additional context on the purpose of the rule. When an error occurs this information would be provided to the user so they know where to start looking to find a reason for the error.

The sections called MINIMUM, COMMONMINIMUM, COMMONMAXIMUM, and MAXIMUM show the allowed and preferred range of values for the data model element. If the value is below the MINIMUM or above the MAXIMUM values, a run time error is produced and building model would be deemed non-compliant. The COMMONMIMIMUM and COMMONMAXIMUM are values which will prompt the user to provide additional supporting documentation if values are outside that range. The values, such as the 38 in the COMMMONMAXIMUM example above, are usually just numeric however, they could also be computed values represented by a expression including functions. While the MINIMUM, COMMONMINIMUM, COMMONMAXIMUM, and MAXIMUM sections are primarily needed to filter invalid values from the USER data model, their use with the transformed data models provide an additional check on computed values. It is expected that they would be evaluated at the end of the process for error reporting only.

The UNITS block shows the specific units that apply to the numeric values shown in other parts of the rule. The UNITS shown should be consistent with the units used in the data model XML schema. If the values in the UNITS block are not consistent an error would be generated.

The DEFAULT block shows the value used if not provided by the user data model.

The remaining sections each correspond to a specific transformation defined in the TRANSFORMATION block described below. For the NACM ruleset development effort, it is anticipated that four transformations will be used titled PROPOSEDSIZING, PROPOSED, BASELINESIZLING, BASELINE but theoretically fewer or more transformations could be defined within each RULE block. For each transformation, the value shown or computed from the expression is put into the data model for the data model element referenced at the top of the RULE. These sections are the foundation of the use of rules to modify data elements in a data model. They define the value of data model elements for each TRANSFORMATION, and therefore, are the actionable statements evaluated in each case. The expressions can be as simple as a numeric value or as complicated as nested IF statements.

The previous example did not include the OPTION section. The OPTION section is only for data model elements that are not numeric, and instead can be one of a specific group of identifiers. This is often called an enumerated list. The list shown in the OPTION block will also be represented in the XML Schema file. The two sources of OPTION values should be checked for consistency. All values shown in OPTION blocks are available, none are available conditionly.

The RULE NEW block is very similar to the normal RULE block but instead targeting an existing data element in the data model, the rule defines a new temporary data element of the data model. The syntax is:

RULE NEW <new data model element>

<content of a rule>

ENDRULE

In every other respect the functionality is the same as RULE. The new data element that is created by RULE NEW in the data model exists only during the evaluation of each transformation in the ruleset and does not exist after the transformed data models are finished being created. One way to think of RULE NEW is as an intermediate variable or calculation. When a single RULE becomes too complex, it might make sense to try to break it down to a RULE and one or more RULE NEW blocks each which has simpler logic and together compute complex values. When defining a data model element with a single RULE that is exceedingly complex, it can beneficial to both the rule author and review to break down rule expressions into separate, intermediate RULE NEW blocks, each with simpler logical steps.

Another common scenario where RULE NEW is appropriate is when the result of a single operation or function is required in several rules, such as the window/wall ratio for each wall. Instead of each RULE of the wall including the logic required to calculate this value for each rule, defining that logic once via a RULE NEW and then referencing the new data element in each RULE that relies on that data greatly reduces duplication of (potentially) complex expressions.

The following table shows when each section of the RULE and RULE NEW is required, optional, or not applicable.

Table X. RULE and RULE NEW Sections

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **RULE** | | | **RULE NEW** | |
| **Section** | *Numeric* | *List* | *Numeric* | | *List* |
| **DESCRIPTION** | Required | Required | Required | | Required |
| **HELP** | Required | Required | Optional | | Optional |
| **REFERENCE** | Optional | Optional | Optional | | Optional |
| **MINIMUM** | Optional | Not Applicable | Optional | | Not Applicable |
| **COMMONMINIMUM** | Optional | Not Applicable | Optional | | Not Applicable |
| **COMMONMAXIMUM** | Optional | Not Applicable | Optional | | Not Applicable |
| **MAXIMUM** | Optional | Not Applicable | Optional | | Not Applicable |
| **UNITS** | Required | Not Applicable | Required | | Not Applicable |
| **OPTION** | Not Applicable | Required | Not Applicable | | Required |
| **DEFAULT** | Optional | Optional | Optional | | Optional |

Note: Each transformation is required.

It is expected to be common practice to provide a block of comments for each rule including the approach, name of rule author, revisions, and dates of revisions.

#### TABLE Block

Tables are very commonly used in setting requirements for building energy standards so it is not surprising that they are used extensively when implementing a ruleset on the same topic. The syntax for using the TABLE block is shown below:

TABLE <table-name>

<col-1><col-2><col-3>…

<ind/dep-1><ind/dep-2><ind/dep-3>

<val-1-1><val-1-2><val-1-3>

<val-2-1><val-2-2><val-2-3>

<val-3-1><val-3-2><val-3-3>

ENDTABLE

Each TABLE can be in the same file as the RULE expression that references it or it can be located in a separate file. When located in the same file as the RULE, the columns are fixed width and are usually used for smaller tables. If it is located in a separate file, it can be a CSV file with the columns separated by commas instead of spaces. Use of a separate CSV file is common for larger tables. When the TABLE is located in a CSV file, the file must be located in the same directory as the files that contain the RULE blocks. The syntax for the TABLE when located in the CSV is the same as when it is located in the file with the RULEs except commas are used to separate the columns.

The first row contains the names of each column. The second row is a designation if the column is INDEPENDENT or DEPENDENT. Columns that are independent are used to lookup values and are provided as arguments for the expression. Columns that are dependent are the resulting values and are returned as the value when used in an expression. The remaining rows are the values for the columns. The following provides a more specific example, although it is fictional.

TABLE RValueTable

ClimateZone Building RValue

INDEPENDENT INDEPENDENT DEPENDENT

1 Residential 5

1 NonResidential 7

2 Residential 6

2 NonResidential 7

3 Residential 9

3 NonResidential 9

4 Residential 3

4 NonResidential 4

ENDTABLE RValueTable

Each table must be complete with every combination of independent values as are shown. An asterisk can be used in any independent column of the table to indicate that any value for that independent value can be used. It is a shortcut that is equivalent to that row being repeated with every possible value for that column. The following table is equivalent to the one shown above since the RValue for ClimateZone 3 is the same for both Residential and NonResidential.

TABLE RValueTable

ClimateZone Building RValue

INDEPENDENT INDEPENDENT DEPENDENT

1 Residential 5

1 NonResidential 7

2 Residential 6

2 NonResidential 7

3 \* 9

4 Residential 3

4 NonResidential 4

ENDTABLE RValueTable

Expressions will be described more in a following section but it is important to understand the syntax of how TABLEs are referenced. The following shows how a table would be referenced within a RULE expression:

RvalueTable.RValue(ClimateZone=u.location, Building=u.classification)

The syntax is similar to how functions are called. The name of the table is followed by a period followed by the dependent variable represent the “function” being called. For tables with multiple dependent variables the function syntax would be different for each dependent variable. The arguments ClimateZone and Building are explicitly assigned to within the parenthesis and can appear in any order. In this example the value of data element u.location is assigned to ClimateZone. All arguments must be assigned or an error condition occurs. If the values passed as arguments do not correspond with items shown in the table, a run time error occurs.

Each TABLE shall be checked by the software during rule compilation to be consistent with each possible set of INDEPENDENT values shown. The checking would be limited to looking at each column of INDEPENDENT values and finding unique values and ensuring that every combination of these unique values exists in the table. No checking outside the individual table would be needed.

#### TRANSFORMATIONS Block

A typical TRANSFORMATIONS block is shown below:

TRANSFORMATIONS

USER,u

PROPOSEDSIZING,pz

PROPOSED,p

BASELINESIZING,bz

BASELINE,b

ENDTRANSFORMATIONS

This block only needs to occur in a single file and provides identifiers for sections in the RULE and RULE NEW blocks as well as abbreviations used in expressions in RULE and RULE NEW blocks. Each row shows the name of a transformation and abbreviation of a transformation separated by a comma. There should be no limit on the number of transformations possible but for the T24 NACM ruleset, the five transformations shown are expected. At minimum two rows should appear. The first row should always indicate the USER transformation and its abbreviation. The USER transformation is the data model coming into the software from the user. Given the use of the transformation names and abbreviations in RULES, it is likely that the software parsing the ruleset files should first locate the TRANSFORMATION block so that the RULE section names that are transformations can be validated.

#### REPLACE Block

<waiting finalization of syntax>

#### Expressions

Expressions are used in RULE, RULE NEW, and REPLACE blocks. In RULE and RULE NEW they are used for each transformation as well as MINIMUM, COMMONMINIMUM, COMMONMAXIMUM, MAXIMUM, and DEFAULT sections. They consist of a notation similar to how expressions are used in spreadsheets. The simplest expression would be a simple number such as:

2

But more common expressions usually involve mathematical functions such as the following:

8 + 7

3 \* 24

(2 + 3) \* 4

Expressions can be more than just numbers and can reference other parts of the hierarchical building data representation and that is where they become most useful:

u.building.envelope.window.height \* bz.building.envelope.Multiplier

Unlike a spreadsheet, no equals sign is needed prior to the expression. Expressions can also reference functions such as:

SQRT(bz.building.envelope.wallArea)

More on details on functions appear in the Section X.X Functions.

Expressions can include more complicated logical statements such as:

IF <conditional-expression> THEN

<true-expression>

ELSE

<false-expression>

ENDIF

Both the true-expression and false-expression must be present since each expression needs to return a value. Similarly, an expression can also include a SWITCH statement with similar syntax and functionality as found in other programming languages.

SWITCH <choice-expression>

CASE <choice1>

<expression-value1>

CASE <choice2>

<expression-value2>

CASE <choice3,choice4>

<expression-value3and4>

DEFAULT

<expression-default>

ENDSWITCH

Please note that SWITCH and IF statements can be nested. Also it may be worth considering to replace SWITCH statements with the use of TABLES, since they are often more readable.

String constants can appear over multiple lines with a double quote indicating the beginning of the string on one line and the double quote indicating the end of a string on another line. This is to encourage long and meaningful explanations of data elements in the ruleset. The line breaks are removed when using the string.

#### Referencing Data Model Elements

Expressions will frequently reference data elements from the data model. The method of referencing those data elements is to provide a full path to the data element as shown in previous examples. Each level starting with the root to the leaf element are shown delimited by periods. No relative referencing is available using the Data Model Rule Syntax so that readers will always understand how a reference fits within the entire data model.

u.building.envelope.window.height

Abbreviations of the reference may also be used, if the abbreviations are used throughout the entire reference except for the leaf element. Using abbreviations the previous reference could also be expressed as:

u.bldg.env.win.height

This syntax allows expressions to be shorter.

#### Functions

A number of functions are available for use within expressions. The most common mathematical functions are supported, such as shown in section 5.2.4.2. Not many <maybe none?> of the Building Database Functions shown in Section 5.2.6 apply to the Data Model Rule Syntax since they take a different approach to organizing the values in the data model.

Some related functions are shown below.

sumacross(u.wall, u.wall.area)

sumacrossif(u.wall, u.wall.area, u.wall.area > 1000)

minacross(u.wall, u.wall.area)

minacrossif(u.wall, u.wall.area, u.wall.area > 1000)

maxacross(u.wall, u.wall.area)

maxacrossif(u.wall, u.wall.area, u.wall.area > 1000)

#### RepeatIf

<waiting finalization of syntax>

#### Capitalization

The Data Model Rule Syntax is case insensitive so whether something is indicated in capital letters or lowercase, they have the same meaning.

#### Comments

Comments can be indicated as any text following a double slash “//” symbol.

#### Reference

<Will include BNF description of syntax>

# Appendix - Rule Syntax and Functionality Reference

Each compliance rule is made up of a title and an expression. Each rule expression identifies a building component type and one or more attribute names, followed by the equality operator and a statement which evaluates to the value to be posted to the attribute identified prior to (to the left of) the equality operator. The following provides an example of the most basic compliance rule expression.

Proj:RunYear = { 1991 }

This expression sets the project’s RunYear attribute to the value ‘1991’. Note that the start and end of each rule expression is denoted by opening and closing curly brackets.

Each compliance rule is evaluated in the order defined for each list of rules (rulelist) contained in the ruleset. When each rule is evaluated, it is evaluated for each and every component contained in the building database of the type identified by the first part of the attribute name portion of the rule expression. Therefore, the above rule expression would be evaluated for every component defined in the database of type ‘Proj’.

The following sections will describe each component of a rule expression, starting with the attribute name and continuing on to cover the entire set of function calls and statements compatible with the compliance rules processor engine.

Rule examples throughout the following sections are nicely formatted with indented rows aligning executable statements to best illustrate the use of these rule features. However, there are no requirements with regard to lining up portions of each expression in particular columns, so alignment of this nature has no effect on the evaluation of the rule.

## Identifying the Rule Target

The sample rule expression provided above starts with the character string ‘Proj:RunYear’. This character string is referred to as an attribute name and includes two or more parts, separated by a colon. The first part of every attribute name identifies a building component type, in this case ‘Proj’ which is an abbreviation for the Project building component type. The second part of every attribute name identifies an attribute which describes the type of building component identified in the first part (‘RunYear’).

Most compliance rule expressions begin with two-part attribute names as described above, however attribute names can contain additional parts which reference other building components. For example, the following compliance rule sets the ‘Absorp’ attribute of each wall construction component assigned to each exterior wall (‘ExtWall’) via the ‘Construction’ attribute.

ExtWall:Construction:Absorp = { 0.7 }

When evaluating this expression the rule processor loops over each exterior wall (‘ExtWall’) defined in the building database. If the exterior wall’s ‘Construction’ attribute is defined and references a valid construction component, then that construction component’s ‘Absorp’ attribute is set to the value 0.7. This example extends the normal two-part attribute name into a three-part attribute name. The rule processor supports as many attribute name parts as can be referenced based on the definition of the compliance software’s building data model.

There is one other characteristic which is sometimes included in attribute name definitions, and that is an array index. In the event an attribute is defined by a collection of values (as opposed to just a single value), each attribute name which references that attribute should define which array value the attribute name is actually referencing. The following rule expression provides an example of such a case which sets an occupancy density value (units are in people per 1,000 square feet).

Space:OccDensity[1] = { 20 }

The space attribute ‘OccDensity’ is defined as an array of 4 values. Each of these 4 values can be specifically referenced by including an array index (1-4) within square brackets immediately following the attribute name. You can include array indices on the end of any (not just the last) attribute defined as an array of values, but not following a component type string (the first part of each attribute name).

## Compliance Rule Expression Statements

Everything contained within the starting and ending curly brackets following the equality operator of each rule expression is referred to as the compliance rule expression statement. These statements can contain a wide variety of parts, including constant numeric values or character strings, references to other database attributes, function calls and if..then and/or case/switch statements. The preceding examples all contain statements which are in the form of constant numeric values. The following example includes a statement consisting of a constant character string.

ExtWall:ConstructionType = { "WoodFramingAndOtherWall" }

When using constant character string statements to set database attributes of type string, the only thing you need to remember is to include the entire string on a single line. The expression syntax does not support character strings entry which spans multiple lines in the rules text file

You can also use constant character string statements to set database attributes of type symbol, which is the case with the example above. In addition to the rule about including the entire string on a single line of the ruleset file, you must also remember to define the string to be the exact contents (case sensitive) of one of the enumerations defined in the building database to describe that attribute. In the above example, we could have set ‘ExtWall:ConstructionType’ to one of the strings “MassHeavyWall”, “MassLightWall”, “MassMediumWall”, “MetalBuildingWall”, “MetalFramingWall”, or “WoodFramingAndOtherWall”. Setting ‘ExtWall:ConstructionType’ to any other character string would result in a rule evaluation error.

### Referencing Other Database Attributes

Compliance rule statements can reference attributes which describe the same component which is identified by the first portion of the attribute name portion of the rule expression (to the left of the equality operator). These types of references are called local. Rule statements can also reference a variety of other component’s attributes which are somehow related to the component identified by the first portion of the attribute name. Any rule statement may also reference attributes which define components which are classified as “Global”.

The first and most important thing to understand when referencing other component’s attributes is what component is the local component. For an expression which starts with the attribute name ‘Proj:RunYear’, the local component is the project. The local component is always identified as the leftmost (first) portion of the attribute name. For an expression which starts with the attribute name ‘ExtWall:Construction:Absorp’, the local component is the exterior wall and NOT the construction which is assigned to the exterior wall.

Rule statements reference component attributes via a set of functions. Which function you use to reference a component’s attribute depends on the relationship between the local component and the component whose attribute you are referencing. The following bullets describe each type of component attribute referencing available in the compliance rules processor.

#### Global References

An expression may reference attributes which describe any building component which is classified as global. Global component types include Project, Site and Building. The user is only able to define one of each of the global building components for each compliance project. Referencing global component attributes is performed via the Global() function. The Global() function requires one argument, a two-part attribute name (Component:Attribute). The Global() attribute name argument must include both and only these two parts, with no subordinate component references. The following example rule sets each window’s height to the product of its current height and the building’s ‘WinAreaMult’ attribute:

Window:Height = { Local( Height ) \* Global( Bldg:WinAreaMult )

#### References To All Components of a Specified Type

An expression may generically reference the sum or maximum value of a particular attribute for all components of a specified type currently defined in the building database. This is performed via the SumAll() and MaxAll() functions, each of which require a single two-part attribute name argument. The first part of the attribute name argument identifies the type of building component to sum across, and the second part identifies the attribute to sum. The following example sets the building’s ‘WallArea’ attribute to the sum of all ‘TotExtWallArea’ attributes for every space defined in the building.

Bldg:WallArea = { SumAll( Space:TotExtWallArea ) }

#### Local References

An expression may reference attributes which describe the same component as the one being described by the expression. Referencing local component attributes is performed via the Local() function. The Local() function requires one argument, a one-part attribute name (Attribute only). The Local() attribute name argument need not (and must not) include a component type in the attribute name, since this is defined by the component type provided in the attribute name preceding the equality operator in the rule expression. For example, an expression defining each window’s area can reference that window’s Height and Width attributes as shown in the following sample expression:

Window:Area = { Local( Height ) \* Local( Width ) }

#### Assigned Component References

An expression may reference attributes which describe a component that is assigned to the local component. For example, if a Construction (Cons) component can be attached to an Exterior Wall (ExtWall) component via the exterior wall’s Construction attribute, then expressions which describe an ExtWall can reference attributes which describe the Cons which is assigned to that ExtWall. However, the reverse condition does not apply (i.e. expressions which describe a Cons can not reference attributes which describe an ExtWall which may have that Cons assigned to it). This local referencing functionality is provided via the LocalRef() function, which accepts a single attribute name argument. The LocalRef() function argument must contain multiple parts, but each part must be an attribute name, starting with an attribute of the local component, followed by attribute names of each referenced component. An example of a local reference is an exterior wall’s U-value being set to the U-value of the construction which is assigned to the exterior wall, as shown here:

ExtWall:UValue = { LocalRef( Construction:UValue ) }

#### Parent References

An expression may reference attributes which describe the component which serves as the parent of the local component which is being described by the expression. For example, since every Exterior Wall has a parent Space, then expressions which define attributes for an Exterior Wall may reference attributes which describe that Exterior Wall’s parent Space. Such references are performed via the Parent() function which requires a single attribute name argument. Like the Local() function, the Parent() function’s attribute name argument must only contain a single (attribute name) part, since the component type is already known to be the component type of the currently assigned parent component. Additional functions are available for referencing attributes which describe a component’s grandparent (Parent2()) and great-grandparent (Parent3()). For example, an exterior wall’s height can be set to the height of its parent space by the rule:

ExtWall:Height = { Parent( Height ) }

#### Parental Assigned Component References

An expression may reference attributes which describe a component that is assigned to the parent component of the component being described by the expression. This is performed via the ParentRef() function, whose single argument has the same restrictions as defined for the LocalRef() function. Additional functions are available for referencing attributes which describe a component assigned to the grandparent (Parent2Ref()) and great-grandparent (Parent3Ref()) of a component. In the following example, each thermal zone’s ‘PeakAirFlow’ attribute is set equal to the product of its current ‘PeakAirFlow’ and the ‘FanFactor’ attribute associated with the HVAC sizing rules component which is assigned to that zone’s parent HVAC system (via the ‘DesignRules’ attribute):

Zone:PeakAirFlow = { Local( PeakAirFlow ) \*  
 ParentRef( DesignRules:FanFactor ) }

#### Child Component References

An expression may reference attributes of a single attached child component. This is performed via the ChildRef() function, which requires two arguments. The first argument is an attribute name containing two or more parts, specifying both the child component type and attribute. The second argument is a one-based integer index into the local component’s list of children for the specified component type. For example, a Thermal Zone’s ScheduleType attribute can be set to the same value as it’s first child Space’s ScheduleType using this expression:

Zone:ScheduleType = { ChildRef( Space:ScheduleType, 1 ) }

#### Child Component Attribute Sums & Maximums

An expression may reference the sum or maximum value of a particular attribute for all components which serve as children of the local component. This is performed via the SumChildren() and MaxChild() functions, each of which require a single attribute name argument. The attribute name argument must be two-part, starting with the component type of the children whose attributes are to be referenced, followed by the name of the attribute to be summed/peaked for all children of the type specified by the first part. For example, since every exterior wall can have one or more child windows. The following example uses SumChildren() to set each exterior wall’s ‘TotWinArea’ attribute to the sum of all attached window components’ ‘TotArea’ attributes:

ExtWall:TotWinArea = { SumChildren( Win:TotArea ) }

#### Referencing the Number of Attached Child Components

An expression may reference the number of components (of a particular type) which are attached as children to the local component. This is performed via the ChildCount() function which requires a single component type argument. This argument is equivalent to the first part of most attribute names and identifies the type of child component which will be counted. There are no occurrences of this function in existing compliance rulesets, so the following example was created for your reference. In this example, we set the ‘AvgWinArea’ attribute for each exterior wall to zero if no child windows exist, or to the sum of the wall’s child window areas divided by the number of child windows attached to the wall. Note that the attribute being set in this example ‘AvgWinArea’ is provided for the sole purpose of creating this example and in fact does not exist in the current building database.

ExtWall:AvgWinArea = { if (ChildCount( Win ) > 0) then  
 SumChildren( Win:TotArea ) /  
 ChildCount( Win )  
else 0 endif }

#### Reverse Reference Attribute Sums & Maximums

An expression may reference the sum or maximum value of a particular attribute for all components which reference or assign the local component. This is performed via the SumRevRef() and MaxRevRef() functions, each of which require two attribute name arguments. The first attribute name argument must be two-part, starting with the component type of the component which references or assigns the local component and ending with the attribute used to reference/assign the local component. The second attribute name argument must also be a two-part “component:attribute” name which identifies the attribute of the referencing component to sum or find the peak value of. For example, the SumRevRef() function is required in order to determine the total square footage which each HVAC system serves. In this case, the local component is the HVAC system and the components which we will sum across are all the spaces which are served by the HVAC system. The first SumRevRef() function argument identifies the component:attribute pair which reference the local component (HVAC system), in this case it is Space:HVACSystem. The second SumRevRef() function argument identifies the Space attribute which we will sum, in this case Space:TotArea. Here is how such a rule would be written:

HVACSys:FloorArea = { SumRevRef( Space:HVACSystem, Space:TotArea ) }

#### Assigning Compliance Library Components

An expression may be used to assign a building component defined in the compliance ruleset’s building component library to a database attribute of type object. This is performed via the RuleLibrary() function, which requires two arguments. The first argument identifies the type of component to retrieve from the ruleset’s library. The second argument contains a double-quoted character string consisting of the name of the library component to be retrieved. For example, a heat pump’s ‘CoolEIRCurve’ attribute can be assigned to the performance curve stored in the ruleset’s library by the name “Pckgd Cool EIR” with the expression:

HtPump:CoolEIRCurve = {RuleLibrary( Curve, "Pckgd Cool EIR" )}

### Referencing Table Look-Up Values

All look-up tables which are defined in the TABLELIST section of the rules file can be referenced by compliance rule statements as if they were pre-defined rule processor functions (similar to those defined in the previous subsection). In order to retrieve a value from a look-up table, the user must provide the look-up table name followed (in parentheses) by values for each independent attribute and a one-based index into the dependent attributes identifying which to return. In the following example, the table OccupAssumpTable was defined as containing one independent attribute and 12 dependent attributes. Therefore, references to this table look-up must contain two arguments, the first defining the independent value to be looked up and the second providing an index (1-12) to identify which dependent table value to return. This example sets the ‘ScheduleType’ attribute for each space to the 1st dependent value contained in the OccupAssumpTable based on the space’s ‘OccType’ attribute.

Space:ScheduleType = { OccupAssumpTable( Local( OccType ), 1 ) }

For another example, lets look at a table look-up designed to set each HVAC system’s ‘’ attribute. The table SystemTypeTable is defined to contain 5 independent attributes and 1 dependent attribute. Therefore, all table look-ups for the SystemTypeTable will contain six arguments, the first five passing in the values for the five independent attributes and the last one to define which dependent attribute to return (in this case, the last argument must be 1). It just so happens that the five independent attributes designed for this table are (1) schedule type (Nonres, Hotel, or Res), (2) a low-rise flag (0 => high rise, 1 => low rise), (3) zone type, (4) heating source and (5) cooling source.

HVACSys:Type = { SystemTypeTable( Local( ScheduleType ),  
 Global( Bldg:LowRise ),  
 Local( ZoneType ),   
 Local( HeatSource ),  
 Local( CoolSource ), 1 ) }

### Executable Expression Statements

The compliance rules processor is compatible with two types of executable expression statements, including if...then...else and case (switch) statements. These statements are used to reference other database values in order to create multiple branches for a single expression. The exact syntax for using these statements must be followed in order to ensure accurate evaluation.

#### if...then...else Statement

The syntax associated with the if...then...else statement is quite simple. Each ‘if’ is directly followed by an expression (which evaluates to TRUE or FALSE) which is in turn followed by a ‘then’ and a statement which is evaluated only if the expression following the ‘if’ evaluates to TRUE. If the user wishes, they may follow this statement by an ‘else’ and another statement which is evaluates only if the expression following the ‘if’ evaluates to FALSE. Finally, each ‘if’ statement must be concluded with an ‘endif’. A simple example of an if...then...else statement is the following rule which sets each window’s ‘SkyArea’ to the product of the window’s ‘Height’ and ‘Width’ attributes if the ‘Tilt’ of it’s parent wall is <= 45.

Win:SkyArea = { if (Parent( Tilt ) <= 45) then   
 Local( Height ) \* Local( Width )  
 else  
 0  
 endif }

The expression following the ‘if’ can result in ANDing and/or ORing multiple expressions together using standard syntax for either FORTRAN or C programming languages (i.e. Use ‘.AND.’ or ‘&&’ to denote AND, and use ‘.OR.’ or ‘||’ to denote OR). The following example sets the ‘SlabPerimArea’ attribute of all underground walls to the parent space’s ‘ExtPerim’ attribute, but only if the underground wall’s ‘Type’ attribute is equal to either 1 or 2.

UndWall:SlabPerimArea = { if ( Local( Type ) == 1 .OR.  
Local( Type ) == 2 ) then  
 Parent( ExtPerim )  
 else  
 0.0  
 endif }

If more than two branches are required, you can nest multiple if...then...else statements as illustrated in the following example.

Furnace:HIR = { if (Local( Configuration ) == 0) then  
 1/(0.005163 \* Local( AFUE ) + 0.4033)  
 else  
 if (Local( AFUE ) <= 83.5) then  
 1/(0.002907 \* Local( AFUE ) + 0.5787)  
 else  
 1/(0.011116 \* Local( AFUE ) - 0.098185)  
 endif  
 endif }

#### case (switch) Statement

The case statement is very useful when you wish to create an expression with several branches based on a single attribute being equal to several individual values. Each case statement begins with the word ‘switch’ followed by an expression which is typically a reference to another building database variable. Following this expression is one or more case statements, each having the form ‘case’ followed by a constant value, followed by a colon, followed by a statement which is evaluated in the event the original expression is equal to the constant value of this case. The last case of the group is the default case and for this case the ‘case’ and following constant value is replaced by a single ‘default’. At the end of the case statement is a ‘endswitch’. Like if...then...else statements, case statements can be nested within each other. A simple example of a case statement is the following rule which sets each space’s ‘MassWeight’ to a specified value (either 30 or 80) based on the value of the space’s ‘Conditioning’ attribute.

Space:MassWeight = { switch ( Local( Conditioning ) )  
 case 0 : 80  
 case 1 : 80  
 case 2 : 80  
 case 3 : 30  
 case 4 : 30  
 default : 80  
 endswitch }

#### Nestingif…then…else and case Statements

Both if...then...else and case statements can be nested together into a single rule expression. This example sets an HVAC system’s ‘FanPowerIdx’ based on its ‘Type’ and ‘FanPowerIdx’ attributes:

HVACSys:FanPowerIdx = {   
 switch Local( Type )  
 case 1: if ( Local( FanPowerIdx ) <= 0.40 ) then  
 0.40  
 else if ( Local( FanPowerIdx ) <= 0.80 ) then  
 Local( FanPowerIdx )  
 else  
 0.80  
 endif endif  
 case 2: if ( Local( FanPowerIdx ) <= 0.40 ) then  
 0.40  
 else if ( Local( FanPowerIdx ) <= 0.80 ) then  
 Local( FanPowerIdx )  
 else  
 0.80  
 endif endif  
 default: 1.25  
 endswitch }

### Expression Syntax and Functionality Tables

The following tables provide a summary of the expression syntax and functionality defined in the preceding sections.

#### Arithmetic and Logical Expression Operators

***Arithmetic:*** \* Multiplication

/ Division

+ Addition

- Subtraction (or Unary Minus)

% Remainder (mod)

\*\* Exponential

***Logical:*** || or .OR. Or

&& or .AND. And

! or .NOT. Not

== or .EQ. Equal

!= or .NE. Not equal

>or .GT. Greater than

<or .LT. Less than

>= or .GE. Greater than or equal to

<= or .LE. Less than or equal to

#### Standard Expression Functions

abs( x ) Absolute value

max( x1, x2 ) Maximum

min( x1, x2 ) Minimum

int( x ) Rounds x to nearest integer

ftoa( x ) Converts a floating point number to a character string

strlen( x ) Number of characters contained in string x

strlower( x ) Returns an all lower case version of string x

strupper( x ) Returns an all upper case version of string x

log( x ) Natural logarithm

log10( x ) Base-10 logarithm

exp( x ) Exponential (e raised to the power x)

pow( x1, x2 ) Power (x1 raised to the power x2)

mod( x1, x2 ) Modulus (remainder) of x1 / x2

sqrt( x ) Square root

sin( x ) Sine (angle expressed in radians)

asin( x ) Arcsine (result in radians)

cos( x ) Cosine (angle expressed in radians)

acos( x ) Arccosine (result in radians)

tan( x ) Tangent (angle expressed in radians)

atan( x ) Arctangent (result in radians)

*Note:* All function names are case insensitive.

#### Expression Comment Syntax

**//** Single line comment, ignores all characters until the end of line encountered

**/\*** Single or multiline comment, ending with the end comment symbol **\*/**

; Single line comment, ignores all characters until the end of line encountered

#### Executable Expression Statements

**if** (*expression*) **then**

*statement*

**else if** (*expression*) **then**

*statement*

**else**

*statement*

**endif**

**endif**

*Note:* Each if statement must contain an else.

**switch** (*expression*)

**case** (*const*) : *statement*

**case** (*const*) : *statement*

**default** : *statement*

**endswitch**

*Note:* Each switch statement must contain a default.

*Note:* The individual case values listed as *const* must be either numeric constants or   
 enumerations which can be directly translated into numeric constants at parse-time  
 in order to prevent excessive evaluation-time error checking and minimize the  
 complexity of the statement.

*Notes*: All reserved words in bold (if, else, endif, ...) are case insensitive.

If and Switch statements can be nested as long as the expression evaluates to a single return value.

### Format Specifications

Several of the expression functions allow for the formatting of character string and numeric data into messages and strings output to files or database properties. These functions include Format(), PostError() and PostWarning().

Format specifications always begin with a percent sign (%). When the string/message argument of the above listed functions includes a single format specification, it converts the value of the first argument following the string/message and outputs it accordingly. A second format specification causes the second argument to be converted and output, and so on. A maximum of 7 format specifications and subsequent arguments can be included in a single function call and if there are more arguments than there are format specifications, the extra arguments are ignored.

Format specifications are written as “%[flags][width][.precision]type”, where the portions enclosed in square brackets are optional. The following table describes supported options for each component of the format specification fields.

#### Format Specification Fields

***flags:*** Optional character(s) that control justification of output and printing of signs, blanks and decimal points. More than one flag can appear in a single format specification.

- Left align the result within the given field width (default is right aligned).

+ Prefix the output value with a sign (+ or –) (default is only show sign if value is negative).

0 If width is prefixed with 0, zeros are added until the minimum width is reached. If 0 and – appear,  
 the 0 is ignored.

‘ ’ (blank space) Prefix the output value with a blank if the output value is positive; the blank is ignored  
 if both the ‘ ’ and + flags appear

***width:*** Optional number that specifies the minimum number of characters output. This value can only serve to increase the width of an output string and will not truncate the value.

***precision:*** Optional number that specifies the maximum number of characters printed for all or part of the output field.

for type = e, E or f Specifies the number of digits after the decimal point.

for type = g or G Specifies the maximum number of significant digits to output.

for type = s or S Specifies the maximum number of characters to be output.

***type:*** Required character that determines whether the associated argument is interpreted as a string or a number.

e Signed value having the form [ – ]d.dddd e [sign]ddd where d is a single digit, dddd is one or  
 more digits, ddd is exactly three digits, and sign is + or –.

E Identical to the e format (above) except that E (as opposed to e) precedes the exponent.

f Signed value having the form [ – ]dddd.dddd, where dddd is one or more digits. The number of  
 digits before the decimal point depends on the magnitude of the number, and the number of  
 digits after the decimal point depends on the requested precision.

g Signed value printed in f or e format, whichever is more compact for the given value and  
 precision. The e format is used only when the exponent of the value is less than –4 or greater  
 than or equal to the precision argument. Trailing zeros are truncated, and the decimal point  
 appears only if one or more digits follow it.

G Identical to the g format (above) except that E (as opposed to e) precedes the exponent (when  
 appropriate).

s Character string of length not to exceed precision.

### Building Database Functions

**Global( comp:attrbt*[i]* )** or **#G( comp:attrbt*[i]* )**Returns the *i*th value of the attribute (attrbt) describing global component (comp)

For example, in order to scale up and/or down the overall window area of a building, a building-wide window area multiplier is calculated (Bldg:WinAreaMult) and then applied to each window in the building via the rule:

Window:Height = { Local( Height ) \* Global( Bldg:WinAreaMult ) }

**GlobalStatus( comp:attrbt*[i]* )** or **#GST( comp:attrbt*[i]* )**Returns the status of the property corresponding to the function argument (comp:attrbt*[i]*), as described in the Global() function description above.  
The following are valid return values for this (and all other) property status retrieval functions:  
 0 Undefined  
 1 Program Default (defaulted within program source code)  
 2 Ruleset Default (defaulted via symbol definitions within the ruleset)  
 3 Ruleset Library (value was included in ruleset library component definition)  
 4 Ruleset Defined (defaulted via rules in the ruleset)  
 5 User Default (defaulted based on data in user-defined default file)  
 6 User Library (value was included in user library component definition)  
 7 User Defined (value was specified by the user)  
 8 Simulation Result (value imported from the most recent simulation output)

**GlobalSymbolString( comp:attrbt*[i]* )** or **#GSS( comp:attrbt*[i]* )**Returns the symbolic string corresponding to the global component property identified by the function argument (comp:attrbt*[i]*), as described in the Global() function description above. Each symbolic property within the database has associated with it a list of symbols. Each item in a symbol list includes a character string (typically selected within a drop-down list control, or combobox) and a numeric value. When retrieving data for symbolic properties, the Global() function returns only the numeric value associated with the currently selected symbol. The GlobalSymbolString() function was therefore implemented in order to provide access to the character string associated with the currently selected symbol.

**Local(attrbt*[i]* )** or **#L( attrbt*[i]* )**Returns the *i*th value of the local attribute (attrbt)

For example, this rule which calculates the area of each exterior wall does so by multiplying the each wall’s width and height, like so:

ExtWall:Area = { Local( Height ) \* Local( Width ) }

**LocalSymbolString( attrbt*[i]* )** or **#LSS( attrbt*[i]* )**Returns the symbolic string corresponding to the local attribute identified by the function argument (attrbt*[i]*), as described in the Local() function description above. Each symbolic property within the database has associated with it a list of symbols. Each item in a symbol list includes a character string (typically selected within a drop-down list control, or combobox) and a numeric value. When retrieving data for symbolic properties, the Local() function returns only the numeric value associated with the currently selected symbol. The LocalSymbolString() function was therefore implemented in order to provide access to the character string associated with the currently selected symbol.

**LocalStatus( attrbt*[i]* )** or **#LST( attrbt*[i]* )**Returns the status of the property corresponding to the local attribute identified by the function argument (attrbt*[i]*), as described in the Local() function description above.  
Refer to the description of the GlobalStatus() function (above) for a listing of valid return values for this function.

Building Database Functions (continued)

**LocalCompAssigned(attrbt*[i]* )** or **#LCA( attrbt*[i]* )**Returns the value 1 if the *i*th value of the local attribute (attrbt) has a component assigned to it. Otherwise, this function returns the value 0.

For example, this rule calculates the BrakeHP of a HVAC system’s return fan after first confirming that a return fan is assigned to the system:

HVACSys:ReturnFan:BrakeHP = { if (LocalCompAssigned( ReturnFan ) == 1) then  
 LocalRef( ReturnFan:AirFlow ) \*  
 LocalRef( ReturnFan:FanKW ) \*  
 LocalRef( ReturnFan:MotorEff ) / 0.746  
 else 0.0 endif }

**LocalIsDefault(attrbt*[i]* )** or **#LID( attrbt*[i]* )**Returns the value 1 if the *i*th value of the local attribute (attrbt) has been set to the reserved keyword “DEFAULT”. Otherwise, this function returns the value 0.

For example, this rule calculates the EERb of each heat pump if and only if the heat pump’s CAPa is not set to “DEFAULT”:

HtPump:EERb = { if (LocalIsDefault( CAPa )) then  
 DEFAULT  
 else Local( SEER ) / (1 - 0.5 \* Local( Cd ))  
 endif }

**LocalRef(attrbt1*[i]*:attrbt2*[i]:attrbt3[i]...* )** or **#LR( attrbt1*[i]*:attrbt2*[i]:attrbt3[i]...* )**Returns the *i*th value of the attribute (attrbt*N*) for the component referenced by the last attrbt argument listed. Each attribute listed must be a component assignment except the last one. Each subsequent attribute is an element describing the component assigned by the previously encountered attribute. There will always be at least two attributes listed, and more may be included to indicate additional levels of component referencing.

For example, the following rule calculates the total wattage across all fixtures assigned to each lighting system:

LtSys:TotalWatts = { ( LocalRef( Fixture[1]:TotalWatts ) \*  
 Local( NumFixtures[1] ) ) +  
 ( LocalRef( Fixture[2]:TotalWatts ) \*  
 Local( NumFixtures[2] ) ) +  
 ( LocalRef( Fixture[3]:TotalWatts ) \*  
 Local( NumFixtures[3] ) ) +  
 ( LocalRef( Fixture[4]:TotalWatts ) \*  
 Local( NumFixtures[4] ) ) }

**Parent(attrbt*[i]* )** or **#P( attrbt*[i]* )**Returns the *i*th value of the parent’s attribute (attrbt)

For example, this rule which calculates the fixture density for a lighting system by dividing the area of its parent Space by the number of fixtures, like so:

LtSys:SqFtPerFixture = { Parent( Area ) / Local( NumFixtures ) }

**Parent2(attrbt*[i]* )** or **#P2( attrbt*[i]* )**Returns the *i*th value of the grandparent’s attribute (attrbt)

This function acts just like the Parent() function above, except that it references attributes which describe the grandparent, rather than parent, of the local component.

Building Database Functions (continued)

**Parent3(attrbt*[i]* )** or **#P3( attrbt*[i]* )**Returns the *i*th value of the great-grandparent’s attribute (attrbt)

This function acts just like the Parent() function above, except that it references attributes which describe the great-grandparent, rather than parent, of the local component.

**ParentCompAssigned(attrbt*[i]* )** or **#PCA( attrbt*[i]* )**Returns the value 1 if the *i*th value of the parent’s attribute (attrbt) has a component assigned to it. Otherwise, this function returns the value 0.

**ParentStatus( attrbt*[i]* )** or **#PST( attrbt*[i]* )**Returns the status of the property corresponding to the parent component’s attribute identified by the function argument (attrbt*[i]*), as described in the Parent() function above.  
Refer to the description of the GlobalStatus() function (above) for a listing of valid return values for this function.

**ParentIsDefault(attrbt*[i]* )** or **#PID( attrbt*[i]* )**Returns the value 1 if the *i*th value of the parent’s attribute (attrbt) has been set to the reserved keyword “DEFAULT”. Otherwise, this function returns the value 0.

**ParentRef(attrbt1*[i]*:attrbt2*[i]:attrbt3[i]...* )** or **#PR( attrbt1*[i]*:attrbt2*[i]:attrbt3[i]...* )**Exactly the same as LocalRef() described above with the exception that attrbt1 is a attribute which describes the current component’s parent component.

**Parent2Ref(attrbt1*[i]*:attrbt2*[i]:attrbt3[i]...* )** or **#PR2( attrbt1*[i]*:attrbt2*[i]:attrbt3[i]...* )**Exactly the same as ParentRef() described above with the exception that attrbt1 is a attribute which describes the current component’s grandparent component.

**Parent3Ref(attrbt1*[i]*:attrbt2*[i]:attrbt3[i]...* )** or **#PR3( attrbt1*[i]*:attrbt2*[i]:attrbt3[i]...* )**Exactly the same as ParentRef() described above with the exception that attrbt1 is a attribute which describes the current component’s great-grandparent component.

**ChildRef( comp:attrbt1*[i]*:attrbt2*[i]:attrbt3[i]...*, n )** or **#CR( comp:attrbt1*[i]*:attrbt2*[i]:attrbt3[i]...*, n )**Exactly the same as LocalRef() described above with the exception that attrbt1 is a attribute which describes the (n)th child component of type (comp).

**SumChildren( comp:attrbt*[i]* )** or **#SC( comp:attrbt*[i]* )**Returns the sum across all children of type (comp) of the *i*th value of the child’s attribute (attrbt). All children, and children of those children are searched for all components of type “comp”.

For example, the following rule sums the areas of all child windows for each exterior wall:

ExtWall:TotWinArea = { SumChildren( Win:TotArea ) }

**SumAll( comp:attrbt*[i]* )** or **#SA( comp:attrbt*[i]* )**Returns the sum across all building components of type (comp) of the *i*th value of the component’s attribute (attrbt) regardless of any parent/child or reference attachments.

For example, the following rule creates a building-wide sum of all exterior wall area by summing the TotExtWallArea attribute of each Space in the project:

Bldg:ExtWallArea = { SumAll( Space:TotExtWallArea ) }

Building Database Functions (continued)

**SumRevRef( comp:attrbt1*[i]*, comp:attrbt2*[i]* )** or  
**#SR( comp:attrbt1*[i]*, comp:attrbt2*[i]* )**Returns the sum of attrbt2[i] values for all components which reference the local component via the comp:attrbt1[i] attribute. This function was defined primarily to allow HVAC systems to reference attributes that describe the Spaces which assign each system, since no parent/child relationship exists between the HVAC systems and the Spaces they serve.

For example, the following rule calculates the total floor area that each HVAC system serves by summing the area of all Spaces which reference each system:

HVACSys:FloorArea = { SumRevRef( Space:HVACSystem, Space:TotArea ) }

**MaxChild( comp:attrbt*[i]* )** or **#MC( comp:attrbt*[i]* )**

**MinChild( comp:attrbt*[i]* ) or #MIC( comp:attrbt*[i]* )**Returns the maximum or minimum value across all children of type (comp) of the *i*th value of the child’s attribute (attrbt). All children, and children of those children are searched for all components of type “comp”.

For example, the following rule calculates the largest schedule type ID across all child Activity Areas for each Space:

Space:SchedTypeNum = { MaxChild( ActArea:SchedTypeNum ) }

**MaxAll( comp:attrbt*[i]* )** or **#MA( comp:attrbt*[i]* )**

**MinAll( comp:attrbt*[i]* )** or **#MIA( comp:attrbt*[i]* )**Returns the maximum or minimum value across all building components of type (comp) of the *i*th value of the component’s attribute (attrbt) regardless of any parent/child or reference attachments.

**MaxRevRef( comp:attrbt1*[i]*, comp:attrbt2*[i]* )** or  
**#MR( comp:attrbt1*[i]*, comp:attrbt2*[i]* )**

**MinRevRef( comp:attrbt1*[i]*, comp:attrbt2*[i]* )** or  
**#MIR( comp:attrbt1*[i]*, comp:attrbt2*[i]* )**Returns the maximum or minimum value of attrbt2[i] values for all components which reference the local component via the comp:attrbt1[i] attribute.

For example, the following rule calculates the largest schedule type ID across all Spaces which assign each HVAC system:

HVACSys:SchedTypeNum = { MaxRevRef( Space:HVACSystem, Space:SchedTypeNum ) }

*Note:* Each of the above listed functions will automatically return a value of the same type as the final attribute which it references. In the event that the expression is to evaluate to a symbol, the return value shall be an integer value.

*Note:* For all functions mentioned above, the argument *i* is a one-based index and must be included when calling these functions only when the number of values which describe the attribute (attrbt) is greater than 1 (i.e. an array or list of data).

*Note:* All *i* arguments must be in the form of a numeric constant (not an expression).

Building Database Functions (continued)

**SumRevRef( comp:attrbt1*[i]*, comp:attrbt2*[i]* )** or  
**#SR( comp:attrbt1*[i]*, comp:attrbt2*[i]* )**Returns the sum of attrbt2[i] values for all components which reference the local component via the comp:attrbt1[i] attribute. This function was defined primarily to allow HVAC systems to reference attributes that describe the Spaces which assign each system, since no parent/child relationship exists between the HVAC systems and the Spaces they serve.

For example, the following rule calculates the total floor area that each HVAC system serves by summing the area of all Spaces which reference each system:

HVACSys:FloorArea = { SumRevRef( Space:HVACSystem, Space:TotArea ) }

**MaxChild( comp:attrbt*[i]* )** or **#MC( comp:attrbt*[i]* )**

**MinChild( comp:attrbt*[i]* ) or #MIC( comp:attrbt*[i]* )**Returns the maximum or minimum value across all children of type (comp) of the *i*th value of the child’s attribute (attrbt). All children, and children of those children are searched for all components of type “comp”.

For example, the following rule calculates the largest schedule type ID across all child Activity Areas for each Space:

Space:SchedTypeNum = { MaxChild( ActArea:SchedTypeNum ) }

**MaxAll( comp:attrbt*[i]* )** or **#MA( comp:attrbt*[i]* )**

**MinAll( comp:attrbt*[i]* )** or **#MIA( comp:attrbt*[i]* )**Returns the maximum or minimum value across all building components of type (comp) of the *i*th value of the component’s attribute (attrbt) regardless of any parent/child or reference attachments.

**MaxRevRef( comp:attrbt1*[i]*, comp:attrbt2*[i]* )** or  
**#MR( comp:attrbt1*[i]*, comp:attrbt2*[i]* )**

**MinRevRef( comp:attrbt1*[i]*, comp:attrbt2*[i]* )** or  
**#MIR( comp:attrbt1*[i]*, comp:attrbt2*[i]* )**Returns the maximum or minimum value of attrbt2[i] values for all components which reference the local component via the comp:attrbt1[i] attribute.

For example, the following rule calculates the largest schedule type ID across all Spaces which assign each HVAC system:

HVACSys:SchedTypeNum = { MaxRevRef( Space:HVACSystem, Space:SchedTypeNum ) }

*Note:* Each of the above listed functions will automatically return a value of the same type as the final attribute which it references. In the event that the expression is to evaluate to a symbol, the return value shall be an integer value.

*Note:* For all functions mentioned above, the argument *i* is a one-based index and must be included when calling these functions only when the number of values which describe the attribute (attrbt) is greater than 1 (i.e. an array or list of data).

*Note:* All *i* arguments must be in the form of a numeric constant (not an expression).

Building Database Functions (continued)

**MaxAllComp( comp:attrbt*[i]* )** or **#MAC( comp:attrbt*[i]* )**This function is identical to the MaxAll() function described above, with the exception that the value (actually a character string) returned consists of the name of the component for which the maximum comp:attrbt*[i]* value was found.

**MaxRevRefComp( comp:attrbt1*[i]*, comp:attrbt2*[i]* )** or **#MRC( comp:attrbt1*[i]*, comp:attrbt2*[i]* )**This function is identical to the MaxRevRef() function described above, with the exception that the value (actually a character string) returned consists of the name of the component for which the maximum value was found.

**CountRefs( comp:attrbt1*[i]*, *comp:attrbt2[i]* )** or **#CRS( comp:attrbt1*[i]*, *comp:attrbt2[i]* )**Returns the sum of the comp:attrbt2[i] values (or 1 if comp:attrbt2[i] is not specified) for all components which reference the local component via the comp:attrbt1[i] attribute.  
If comp:attrbt1 is defined as an array of component assignments and the array index for this argument is either not specified or [1], then each individual assignment across the entire array will be counted as a unique assignment for which the value 1 (or comp:attrbt2[i] if specified) is summed to calculate the return value.

**CountNoRefs( comp:attrbt1*[i]*, *comp:attrbt2[i]*, *comp:attrbt3[i]* )** or **#CNRS( comp:attrbt1*[i]*, *comp:attrbt2[i]*, *comp:attrbt3[i]* )**Very similar to the CountRefs() function above, although the primary function here is to count the lack of references to any component. The first (comp:attrbt1[i]) argument is interpreted and used exactly as with CountRefs() function, in that it describes the property which we will scan for component assignments. If comp:attrbt2[i] is specified, then it represents the largest argument 1 array index to scan for missing assignments.  
The return value from this function is 0 if all component assignments (based on arguments 1 & 2) exist and are valid. If one or more missing or invalid assignments are found, then the return value will be the value associated with comp:attrbt3[i] (if specified), or 1 (if comp:attrbt3[i] is not specified).

**CountUniqueParentRefs( comp:attrbt1*[i]*, *comp:attrbt2[i]* )** or **#CUPRS( comp:attrbt1*[i]*, *comp:attrbt2[i]* )**The meaning and usage of arguments in this function are identical to that of the CountRef() function above, with one important difference. For this function, not all component references are counted, but rather only those that have a unique parent component.

**ChildCount( comp )** or **#CC( comp )**Returns the number of children of type (comp) attached to the building component.

**ChildIndex(*bOnlyComponentsOfSameType* )** or **#CHI( *bOnlyComponentsOfSameType* )**Returns the index (1-N) associated with the object on which the rule is evaluated in relation to all other child components of its parent component. If specified, the boolean (0/1, 0 being the default) *bOnlyComponentsOfSameType* argument determines whether or not the index returned will be in relation to only those children of the component type for which the rule is being evaluated (value of 1) versus all child components of the parent (value of 0).

Building Database Functions (continued)

**CreateChildren( comp, num children, “Name Prefix”*, “Rulelist Name”, EvalOption* )**or **#CCH( comp, num children, “Name Prefix”*, “Rulelist Name”, EvalOption* )**Causes the creation of one or more (num children) components of the type “comp” where each new component’s parent is the primary component for which the rule is being evaluated (the leftmost component in the left side of the rule expression). The “Name Prefix” argument forms the beginning of each new child component’s name, followed by an index which ensures that the component’s name is unique. The optional “Rulelist Name” argument names a rulelist that can be evaluated immediately following the successful creation of the child component(s). The final (and also optional) argument, EvalOption, is a numeric value of either 0 or 1. An EvalOption value of 1 is the default and causes the rulelist to be evaluated only on the newly created child components. Alternatively, an EvalOption value of 0 causes the rulelist to be evaluated for all components in the building description.

For example, the following rule causes a single child window to be created for each exterior wall that is a child of a conditioned or indirectly conditioned space:

ExtWall:Action = { if (Parent( Conditioning ) < 4) then  
 CreateChildren( Win, 1, "BudgetWin" )  
 else 0 Endif }

**DeleteChildren( comp, *“Rulelist Name”, EvalOption* )**or **#DCH( comp, *“Rulelist Name”, EvalOption* )**Causes the deletion of all child components of type “comp” for each primary (parent) component for which the rule is being evaluated (the leftmost component in the left side of the rule expression). The optional “Rulelist Name” argument names a rulelist that can be evaluated immediately following the successful deletion of the child component(s). The final (and also optional) argument, EvalOption, is a numeric value of either 0 or 1. An EvalOption value of 1 is the default and causes the rulelist to be evaluated only on the parent component. Alternatively, an EvalOption value of 0 causes the rulelist to be evaluated for all components in the building description.

For example, the following rule causes all child windows to be deleted for each exterior wall that is a child of a conditioned or indirectly conditioned space:

ExtWall:Action = { if (Parent( Conditioning ) < 4) then  
 DeleteChildren( Win )  
 else 0 Endif }

**CreateComp( comp, “Name Prefix”*, “Rulelist Name”, EvalOption* )**or **#CCO( comp, “Name Prefix”*, “Rulelist Name”, EvalOption* )**Causes the creation of a building component of the type “comp” and the return value is a reference to the new component which can be used to assign that component to an existing building component. The “Name Prefix” argument forms the beginning of the new component’s name, followed by an index that ensures the new component name’s uniqueness. The optional “Rulelist Name” argument names a rulelist that can be evaluated immediately following the successful creation of the new component. The final (and also optional) argument, EvalOption, is a numeric value of either 0 or 1. An EvalOption value of 1 is the default and causes the rulelist to be evaluated only on the newly created component. Alternatively, an EvalOption value of 0 causes the rulelist to be evaluated for all components in the building description.

Building Database Functions (continued)

**CompExists( comp, “Comp Name” )** or **#CE( comp, “Comp Name” )**This function checks for the existence of a building component of the type “comp” and name “CompName”. This function returns 1 if the component exists, otherwise 0.

**CompName( comp, iCompIndex )** or **#CN( comp, iCompIndex )**Returns the name of the (iCompIndex)th building component of the type “comp”. The iCompIndex argument must be an integer value greater than 0.

**ComponentIndex()** or **#COI()**Returns the index (1-N) of the building component for which the rule is being evaluated in relation to all other building components of the same type.

**ComponentCount( comp )** or **#CMPC( comp )**Returns the total number of building components of the type “comp” currently defined in the database.

**UniqueComponentName( “Name Prefix” )** or **#UCN( “Name Prefix” )**This function is used to find a unique component name within the database. If no component in the database exists by the name “Name Prefix”, then this same argument character string is returned by the function. If there is a building component by this name already defined, then a trailing “-#” is appended to the name prefix and returned, where # is the lowest integer value greater than 0 for which no building component of that name exists.

**DeleteComp(*“Rulelist Name”, EvalOption* )**or **#DCO( *“Rulelist Name”, EvalOption* )**Causes the deletion of a component currently assigned to the property identified by the left side of the rule expression. The optional “Rulelist Name” argument names a rulelist that can be evaluated immediately following the successful deletion of the assigned component. The second (and also optional) argument, EvalOption, is a numeric value of either 0 or 1. An EvalOption value of 1 is the default and causes the rulelist to be evaluated only on the primary component for which the rule is being evaluated (the leftmost component in the left side of the rule expression). Alternatively, an EvalOption value of 0 causes the rulelist to be evaluated for all components in the building description.

For example, the following rule causes any air economizer of type “None” (0) assigned to an HVAC system to be deleted:

HVACSys:AirEcon = { if (LocalRef( AirEcon:Type ) == 0) then  
 DeleteComp()  
 else Local( AirEcon )  
 Endif }

**DeleteAllComps( comp, *“Rulelist Name”, EvalOption* )**or **#DAC( comp, *“Rulelist Name”, EvalOption* )**Causes the deletion of all components of type “comp” that currently exist in the building description. The optional “Rulelist Name” argument names a rulelist that can be evaluated immediately following the successful deletion of the components. The second (and also optional) argument, EvalOption, is a numeric value of either 0 or 1. An EvalOption value of 0 is the default and causes the rulelist to be evaluated for all components in the building description. Alternatively, an EvalOption value of 1 causes the rulelist to be evaluated only on the primary component for which the rule is being evaluated (the leftmost component in the left side of the rule expression).

Building Database Functions (continued)

**EnsureSymbolExists()** or **#ESE()**Returns the numeric value corresponding to the current symbol selection if that selection is valid, otherwise it returns the default symbol value. This function helps to ensure that certain symbolic attributes are always assigned to valid symbols.

**RuleLibrary( comp, “Comp Name” )** or **#RL( comp, “Comp Name” )**Returns a reference to the component of type (comp) which is named “Comp Name”.

For example, the following rule defaults each window’s glass type to the minimally-compliant glass type contained in the ruleset library:

Win:GlassType = { RuleLibrary( Glass, “Minimally-Compliant Window Glass” ) }

**EvalRulelist( “Rulelist Name”, *EvalOption* )** or **#ER(“Rulelist Name”, *EvalOption* )**Causes the compliance rulelist by the name “Rulelist Name” to be evaluated. The second EvalOption argument is optional. An EvalOption value of 0 (the default) causes the rulelist to be evaluated for all components in the building description. An EvalOption value of 1 causes the rulelist to be evaluated only on the primary component for which the rule is being evaluated.

For example, the following rule causes the rulelist named “EnvelopeConstruction” to be evaluated:

Proj:Action = { EvalRulelist( "EnvelopeConstruction" ) }

In the following example, the rulelist named “” is evaluated only in the event an economizer is already assigned to the HVAC system. By specifying an EvalOption argument of 1, only rules where the left side begins “HVACSys:…” will be evaluated, and only for the HVACSys component from which the rulelist was being called:

HVACSys:AirEcon = {  
 if (LocalCompAssigned( AirEcon ) == 0) then  
 CreateComp( Econ, "BudgetAirEcon", "BudgetEconRules" )  
 else EvalRuleList( "BudgetEconRules", 1 )  
 endif }

**WizardZoning( iZoningType, bForceZoning )** or **#WZ( iZoningType, bForceZoning )**This function causes building footprint and thermal zone defaulting source code in the BDBase32.dll library to be executed and returns the value 1 if the code evaluated successfully, or 0 if errors occurred (in which case error messages are written to the ruleset evaluation log file). The second, bForceZoning, boolean (0/1) argument indicates whether or not all footprint and zoning is to be re-evaluated (if this argument is a non-zero value) versus only performing zoning associated w/ newly modified data (if bForceZoning equals 0).  
Values associated with the first (iZoningType) argument are as follows:  
 1 Refresh footprint and thermal zoning based on data stored in database  
 2 Position skylights based on data stored in database  
 3 Calculate daylighting fractions and position daylighting controls  
 4 Calculate the most general set of 3-5 primary facing building orientations  
 5 Refresh building footprint properties only

**CurrentTime()** or **#CT()**Returns an integer value corresponding to the time when the rule is evaluated, according to the computer’s system clock. The actual value represents the number of seconds that has elapsed since midnight, January 1, 1970.

For example, the following rule, when placed in the budget conversion rulelist, sets the exact time in which the proposed building description is being converted into the budget building:

Proj:BudgConvTime = { CurrentTime() }

Building Database Functions (continued)

**CurrentYear()** or **#CY()**Returns an integer value corresponding to the year when the rule is evaluated, according to the computer’s system clock.

**Date( year, month, day )** or **#D( year, month, day )**Returns a integer value corresponding to the number of seconds that has elapsed between midnight, January 1, 1970 and midnight the day identified by the function arguments. The year argument is a four-digit year (i.e. 1999), the month argument is an integer value between 1 and 31 and the day argument is an integer value between 1 and the number of days in the month identified by the month argument.

For example, the following rule sets a schedule’s start date to January 1 of the analysis year:

Sched:StartDate = { Date( Global( Proj:AnalysisYear ), 1, 1 ) }

**NumDaysInMoDaRange( iStartMonthDay, iEndMonthDay )** or **#MDND( iStartMonthDay, iEndMonthDay )**Returns the number of days spanned by the two month/day arguments, each of which are equivalent to ((Month Index (1-12) \* 100) + Day Index (1-31)). The start and end month/day arguments must be in the range 101 thru 1231, for example 101 represents January 1st, 306 represents March 6th and 1130 represents November 30th.  
The end month/day argument can be a value less than the start month/day argument, in which case the number of days spanning the two is assumed to cross a year boundary.  
February is modeled as having 28 days, regardless of whether or not the simulation year is a leap year (due to limitations of the DOE-2.1E simulation engine).

**MonthDayShift( iStartMonthDay, iNumDaysToShift, iYear )** or **#MDS( iStartMonthDay, iNumDaysToShift, iYear )**Returns the month/day value associated with the first (iStartMonthDay) argument shifted by value of the second (iNumDaysToShift) number of days argument for the year specified as the third and final argument. Both the first argument (iStartMonthDay) and return value (only if iYear is equal to 0) are numbers that describe a date equivalent to ((Month Index (1-12) \* 100) + Day Index (1-31)). All month/day values must be in the range 101 thru 1231, for example 101 represents January 1st, 306 represents March 6th and 1130 represents November 30th.  
The second argument value, iNumDaysToShift, can be either positive or negative, but cannot cause the return value to wrap from the selected year into the subsequent or previous years.  
If the third argument (iYear) is equal to 0, then the return value will be a month/day value (as described above). If the iYear argument is greater than 0, then it is assumed to be a four-digit year in which case the return value corresponds to the number of seconds that has elapsed between midnight, January 1, 1970 and midnight on the day resulting from the start month/day shifted by iNumDaysToShift.

Building Database Functions (continued)

**Format( “string w/ format specs”*, var1, var2, … varN* )** or **#FMT( “string w/ format specs”*, var1, var2, … varN* )**Returns a character string based on the specified function arguments. The “string w/ format specs” function argument consists of the character string to be returned, including format specification fields that enable the reporting of string or numeric data referenced by optional arguments var1-N. Refer to the preceding [Table 3-5](#_Format_Specifications) describing compatible format specification fields for more information.

**FltToStr( Value, DecimalPrecision, InclCommas, ZeroFillLeftToLength )** or **#F2S( Value, DecimalPrecision, InclCommas, ZeroFillLeftToLength )**This function provides customized formatting of floating point values, including commas (based on location settings stored in the Windows operating system) and a specified decimal precision. The return value is a character string containing the formatted number.  
The Value argument consists of the number to be represented in the returned character string. The DecimalPrecision argument is an integer value specifying the decimal precision for the formatted number. The InclCommas argument is a boolean (0/1) value indicating whether or not to include commas (or other digit grouping symbol specified in the Windows operating system’s regional/language settings) in the resulting character string. The ZeroFillToLength argument is an integer value that defines a minimum length for the resulting character string, causing leading zeroes to be added to the string until the minimum length is achieved.

**EnsureStringUniqueness( comp:attrbt*[i], MaxStringLength* )** or  
**#ESU( comp:attrbt*[i], MaxStringLength* )**The purpose of this function is to scan through all occurrences of building components of type “comp”, to ensure that the character strings stored in each attrbt*[i]* property are unique. If/when non-unique strings are encountered, they are trimmed in length (as required based on the optional second MaxStringLength argument) and then appended w/ numeric values beginning w/ “ 2” until a unique string is found.  
The return value is the number of comp:attrbt*[i]* character strings that were modified to ensure uniqueness.

**StoreBEMBase( “File Ext”, InputOnlyOption )** or **#SB( “File Ext”, InputOnlyOption )**This function is provided to assist in ruleset debugging efforts and causes the building database to be written to a file. The first argument consists of the file extension you would like the output database file to use. The file directory and name will be consistent with the currently active project file. The second option is a numeric flag value 0 or 1, where 1 indicates you would like only user inputs to be written to the database file and 0 causes all values to be written.  
For example, lets say you have a rule that you suspect is not modifying the database as you designed it to. Simply include two separate calls to this function. One immediately prior to and one following the rule in question, making sure to provide different “File Ext” arguments for each. By comparing the two output database files you can determine exactly how the rule in question is modifying the database. Here is an example of such a scenario:

Proj:Action = { StoreBDBase( "DBG1", 0 ) }  
 < -- rule in question goes here -- >  
 Proj:Action = { StoreBDBase( "DBG2", 0 ) }

Building Database Functions (continued)

**PostError( “string w/ format specs”*, var1, var2, … varN* )** or **#PE( “string w/ format specs”*, var1, var2, … varN* )**This function is identical to the Format() function described above in terms of both argument descriptions and return value (character string). The only difference lies in the fact that the character string returned by this function is also posted to the log file as an error message.

**PostWarning( “string w/ format specs”*, var1, var2, … varN* )** or **#PW( “string w/ format specs”*, var1, var2, … varN* )**This function is identical to the Format() function described above in terms of both argument descriptions and return value (character string). The only difference lies in the fact that the character string returned by this function is also posted to the log file as a warning message.

**FirstBitwiseMatchComp( )** or **#FBMC( )**<description to follow>.

**BitwiseMatchCount( )** or **#BMC( )**<description to follow>.

**UniqueComponentName( )** or **#UCN( )**<description to follow>.

**EnsureStringUniqueness( )** or **#ESU( )**<description to follow>.

**FileExists( )** or **#FE( )**<description to follow>.

**ImportComponentFromFile( )** or **#ICFF( )**<description to follow>.

**EnsureChildAssigned( )** or **#ECA( )**<description to follow>.

**SplitPath( )** or **#SP( )**<description to follow>.

**MaxRevRefArray( )** or **#MRA( )**<description to follow>.

**CountOccurrences( )** or **#CO( )**<description to follow>.

**SumIntoArrayElement( )** or **#SIA( )**<description to follow>.

**SumRevRefEx( )** or **#SRE( )**<description to follow>.

**LocalSymbolInvalid( )** or **#LSI( )**<description to follow>.

**MessageBox( )** or **#MBX( )**<description to follow>.

**GlobalRef( )** or **#GR( )**<description to follow>.

**BEMProcDBID( )** or **#DBID( )**<description to follow>.

**PostMessageToLog( )** or **#PM2L( )**<description to follow>.

**FindInString( )** or **#FIS( )**<description to follow>.

**ReplaceInString( )** or **#RIS( )**<description to follow>.

**LocalMaxStringLength( )** or **#LMSL( )**<description to follow>.

**ParentStringArrayElement( )** or **#PSAE( )**<description to follow>.

**ParentComponentType( )** or **#PCT( )**<description to follow>.

**LocalArrayIndex( )** or **#LAI( )**<description to follow>.

**ComponentArray( )** or **#CA( )**<description to follow>.

**GlobalCompAssigned( )** or **#GCA( )**<description to follow>.

**HourlyResultSum( )** or **#HRS( )**<description to follow>.

**ApplyHourlyResultMultipliers( )** or **#HRM( )**<description to follow>.

**ComponentType( )** or **#CTP( )**<description to follow>.

**SumAcrossIf( )** or **#SAI( )**<description to follow>.

**SumChildrenIf( )** or **#SCI( )**<description to follow>.

**WriteToFile( )** or **#W2F( )**<description to follow>.

**LogDuration( )** or **#LD( )**<description to follow>.

**GlobalValid( )** or **#GV( )**<description to follow>.

**LocalValid( )** or **#LV( )**<description to follow>.

**ParentValid( )** or **#PV( )**<description to follow>.

**Parent2Valid( )** or **#PV2( )**<description to follow>.

**Parent3Valid( )** or **#PV3( )**<description to follow>.

**IfValidAnd( )** or **#IVA( )**<description to follow>.

**( )** or **#( )**<description to follow>.

**( )** or **#( )**<description to follow>.

**( )** or **#( )**<description to follow>.

**( )** or **#( )**<description to follow>.

**PolyLoopArea( )** or **#PLA( )**<description to follow>.

**ScalePolyLoop( )** or **#SPL( )**<description to follow>.

**ConsAssmUFactor( )** or **#CAUF( )**<description to follow>.

**DaylightableArea( )** or **#DA( )**<description to follow>.

**InitializePolyLoop( )** or **#IPL( )**<description to follow>.

**CreatePolyLoopChild( )** or **#CPL( )**<description to follow>.

**( )** or **#( )**<description to follow>.

**( )** or **#( )**<description to follow>.

**ConsUFactorRes( )** or **#CUFR( )**<description to follow>.

**( )** or **#( )**<description to follow>.

*Note:* All function names are case insensitive.

# Appendix - Optional Capabilities

Capabilities in this section may be incorporated or excluded from the Software as time and budget allow and based on priorities set forth by the development team, CCM and PAC. If not addressed during the initial phase of development, these capabilities are likely candidates for inclusion in future versions of the Software.

## Optional Capability #1

The Software may contain …

## Optional Capability #2

The Software may contain …