Public Interest Energy Research (PIER) Program
FINAL PROJECT REPORT

SIMERGY – A GRAPHICAL USER INTERFACE FOR ENERGYPLUS

Prepared for: California Energy Commission
Prepared by: Lawrence Berkeley National Laboratory

SEPTEMBER 2014
CEC-500-2015-007

Prepared by:

Primary Author(s):
Philip Haves,
Richard See (Digital Alchemy, Seattle, WA)
Kevin Settlemyre (Sustainable IQ, Boston, MA)

Lawrence Berkeley National Laboratory
One Cyclotron Road
Berkeley, CA 94720
510-486-6512
http://simulationresearch.lbl.gov/projects/gui

Contract Number: 500-10-052

Prepared for:

California Energy Commission

Heather Bird
Contract Manager

Virginia Lew
Office Manager
Energy Efficiency Research Office

Laurie ten Hope
Deputy Director
ENERGY RESEARCH AND DEVELOPMENT DIVISION

Robert P. Oglesby
Executive Director

DISCLAIMER

This report was prepared as the result of work sponsored by the California Energy Commission. It does not necessarily represent the views of the Energy Commission, its employees or the State of California. The Energy Commission, the State of California, its employees, contractors and subcontractors make no warranty, express or implied, and assume no legal liability for the information in this report; nor does any party represent that the uses of this information will not infringe upon privately owned rights. This report has not been approved or disapproved by the California Energy Commission nor has the California Energy Commission passed upon the accuracy or adequacy of the information in this report.

ACKNOWLEDGEMENTS

The authors wish to thank Justin Kelly (HOK Architects) and Vladimir Bazjanac and Junia Compostella di Sanguinetto (Lawrence Berkeley National Laboratory) for assistance with testing the importation of building geometry information from computer-aided design tools and Jason Kirkpatrick (Skidmore, Owens and Merrill) for advice on the modeling of heating, ventilation and air-conditioning systems in EnergyPlus. The authors wish to acknowledge the contributions of subcontractors Kolderup Consulting, Arup and the Building Performance Team to the development of heating, ventilation and air conditioning system templates.

PREFACE

The California Energy Commission Energy Research and Development Division supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The Energy Research and Development Division conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The Energy Research and Development Division strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

Energy Research and Development Division funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

Simergy – A Graphical User Interface for EnergyPlus is the final report for the Graphical User Interface for EnergyPlus project (Contract Number 500-10-052) conducted by Lawrence Berkeley National Laboratory. The information from this project contributes to Energy Research and Development Division's Buildings End-Use Energy Efficiency Program.

When the source of a table, figure or photo is not otherwise credited, it is the work of the author of the report.

For more information about the Energy Research and Development Division, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-327-1551.

ABSTRACT

A free graphical user interface – Simergy – has been developed to help practitioners use the U.S. Department of Energy's whole-building energy simulation program, EnergyPlus, which is intended for both innovative and conventional low-energy building design analysis. This project, funded by the California Energy Commission, sought to further the development of Simergy in preparation for its first public release in July 2013.

User interface requirements were defined through a series of workshops for practitioners. Simergy includes a "drag and drop" component-level schematic editor for heating, ventilation, and air-conditioning systems. Building envelope geometry can be imported from computer-aided design tools using standard industry formats or can be generated by Simergy. Development of a comprehensive set of templates and libraries is at an advanced stage, with the major building types and construction assembles essentially complete. An interactive output reporting framework has also been implemented.

This report details how Simergy could be further extended for use in the early stages of design by simplifying the user interface and making extensive use of templates for envelope characteristics, schedules and heating, ventilating and air-conditioning systems.

Simulation software is used both for evaluating new technology for inclusion in Title 24 enhancements and for demonstrating compliance with current Title 24. The California Energy Commission is significantly revising the process to demonstrate compliance with Title 24. One key component of this revision is a switch from procedures based directly on the DOE-2 simulation engine to a process in which EnergyPlus is the reference model. This report describes how Simergy could be linked to new software, developed with funding from the California Energy Commission's Standards Development Office, to support performance-based code compliance for California commercial buildings.

Keywords: EnergyPlus, graphical user interface, Simergy, building information model, energy simulation

Please use the following citation for this report:

Haves, Philip, Richard See and Kevin Settlemyre. 2014. ***Simergy – A Graphical User Interface for EnergyPlus.*** California Energy Commission. Publication Number: CEC-500-2015-007.

TABLE OF CONTENTS

Acknowledgements ..... **ii**

PREFACE ..... **iii**

ABSTRACT ..... **iv**

TABLE OF CONTENTS ..... **v**

LIST OF FIGURES ..... **vi**

LIST OF TABLES ..... **vii**

EXECUTIVE SUMMARY **1**

Introduction 1

Purpose 2

Objectives 2

Summary of Work Performed 2

Benefits to California 2

Conclusions and Recommendations 3

CHAPTER 1: Introduction **5**

1.1 Goals and Objectives 6

CHAPTER 2: Project Approach **8**

2.1 Simergy Modeling Capabilities 8

2.1.1 Building Envelope 8

2.1.2 HVAC Systems 8

2.2 Early Stage Design 9

2.3 Title 24 Compliance 10

CHAPTER 3: Project Results **12**

3.1 Simergy Modeling Capabilities 12

3.1.1 Building Envelope 12

3.2 Extension of Simergy for Early Stage Design 19

3.2.1 Climate Analysis 19

3.2.3 Preliminary Energy Analysis - Future Recommended Development 21

3.3 Extension of Simergy for Code Compliance 23
3.3.1 Future Recommended Development 24
CHAPTER 4: Project Outcomes 26
4.1 Simergy Modeling Capabilities 26
4.1.1 Building Envelope 26
4.1.2 HVAC Systems 26
4.2 Early Stage Design 26
4.3 Title 24 Compliance 27
4.4 Benefits to California 27
CHAPTER 5: Conclusions and Recommendations 29
GLOSSARY 31
REFERENCES 32

LIST OF FIGURES

Table 2.1: Categories of materials and constructions in Simergy libraries 8
Table 2.2: Categories of HVAC components in Simergy libraries 8
Figure 2.1: Shifting design effort to the early stages of design (courtesy of HOK Architects). 10
Figure 3.1: Import of building geometry using IFC 12
Figure 3.2: Import of building geometry using gbXML. 13
Figure 3.3: Import of building geometry using 2-D floor plans 14
Figure 3.4: Extrusion and stacking of standard floor plan shapes. 14
Figure 3.5: Screenshot showing building element types in the Constructions template with example libraries 16
Figure 3.6: Air, hot water, chilled water and condenser loops 17
Figure 3.7: Use of the Zone HVAC Group Template workspace to create a Zone HVAC Group with Radiant Heating and Cooling and Demand Controlled Ventilation 18
Figure 3.8: Psychrometric chart overlaid with regions of potential applicability for different strategies for heating or cooling – part of the Climate Consultant weather data visualization tool developed by the University of California Los Angeles with support from the Energy Commission (Climate Consultant, 2014). 20
Figure 3.9: Preliminary mockup of top level interface screen 21

Figure 3.10: Preliminary mockup of a results screen for whole building performance.....22

LIST OF TABLES

Table 2.1: Categories of materials and constructions in Simergy libraries 8

Table 2.2: Categories of HVAC components in Simergy libraries 8

EXECUTIVE SUMMARY

Introduction

A new generation of more powerful and effective design analysis tools is required to support an integrated design process for the zero-net-energy buildings needed to meet California's 'big bold' energy efficiency goals. EnergyPlus is widely viewed as the premier building simulation engine for low energy design; however, a major barrier to widespread EnergyPlus adoption by practitioners has been the lack of a free comprehensive graphical user interface[1] to make the program easy and efficient to use. Design practitioners, particularly those for whom energy efficiency is an important issue, are generally very enthusiastic about EnergyPlus modeling capabilities but are typically unable to use EnergyPlus because the manual data entry process is too slow and error-prone to be viable within the constraints of normal design fees. Simergy has been developed in response to these limitations, with support from the California Energy Commission, the U.S. Department of Energy, Infosys Technologies, Trane, the Northwest Energy Efficiency Alliance and Hydro-Québec.

Simulation software is used both for evaluating new technology for inclusion in California's Title 24 and for demonstrating compliance with current Title 24. The California Energy Commission is significantly revising the process to demonstrate compliance with Title 24. One key component of this revision is a switch from procedures based directly on the DOE-2 building energy simulation program to a process in which the Department of Energy's current whole building energy simulation tool EnergyPlus is the reference model. DOE-2, developed by Department of Energy in the 1970's, is a widely used and accepted freeware building energy analysis program that can predict the energy use and cost for all types of buildings. EnergyPlus is the Department of Energy's free, flagship building energy simulation tool to replace DOE-2. EnergyPlus is more accurate, involves fewer workarounds, and enables the analysis of innovative and complex mechanical system and building design energy usage. The Department of Energy continues to fund extensions to EnergyPlus to support both low energy and conventional design for new construction and existing buildings. It was these considerations that led the California Energy Commission to select EnergyPlus to play a key role in Title 24, both in the analysis for 2013 California Building Energy Efficiency Standard compliance and beyond.

This project, funded by the California Energy Commission, sought to further the development of Simergy in preparation for its first public release in July of 2013. This report details how Simergy could be further extended for use in the early stages of design. Furthermore, this report proposes linkages to new software, developed with funding from the California Energy Commission's Standards Development Office, to support performance-based code compliance for California commercial buildings.

---

[1] A graphical user interface is a human-computer interface (i.e., a way for humans to interact with computers) that uses windows, icons and menus and which can be manipulated by a mouse (and often to a limited extent by a keyboard as well).

Purpose

The purpose of the work reported here was to further the development of a free interface to enable the widespread adoption of EnergyPlus. This interface, Simergy, continues to be developed by a team led by Lawrence Berkeley National Laboratory and guided by six leading architecture and engineering firms, with programming from a team of professional software developers. The goal is to make EnergyPlus accessible to building designers and other professionals by substantially simplifying the process of assembling building models, promoting its wider adoption.

Objectives

The main objectives of the project were to:

- Extend the support for high performance envelope components and configurations in Simergy
- Extend the support for heating, ventilation and air conditioning systems in Simergy, including advanced heating systems and thermally activated cooling systems
- Support for domestic hot water systems in Simergy
- Identify how Simergy could be extended to enable EnergyPlus to be used effectively in early stage design
- Determine how the California Energy Commission-funded compliance software toolkit can be utilized in Simergy

Summary of Work Performed

The outcomes of the work include the following:

- Version 1.0 of Simergy was released at http://simergy.lbl.gov/ on 7/22/13. Roughly 4,000 copies were downloaded in the first three months. The release included:
    - A set of libraries of façade constructions and templates for façade configurations
    - A set of libraries and templates of thermally activated heating and cooling components systems.
- Ways to adapt Simergy for early stage design were identified and are documented in this report.
- Ways to link code compliance software to Simergy were identified. A method of interfacing the California Energy Commission's Software Developers Toolkit for performance-based code compliance is described in this report.

Benefits to California

Improved building energy performance, including progress towards the State's 'Big Bold' energy efficiency strategies[2], will require significant changes to current practices for both retrofit

[2] In order to guide market transformation in a number of key sectors, the California Energy Efficiency Strategic Plan embraces four specific programmatic goals, known as the "Big Bold Energy Efficiency Strategies" (BBEES), established by the CPUC in D.07-10-032 and D.07-12-051.These goals were selected

and new construction. A barrier to the increased adoption of low energy systems and high efficiency components is the risk, perceived and actual, that the resulting improvement in performance of the building may not be sufficient to justify the additional investment. This risk can be mitigated by the use of more comprehensive and accurate analysis tools, such as EnergyPlus, rather than tools based on DOE-2. (The limitations of such tools include the need for work-arounds for radiant systems and underfloor air distribution systems and do not treat natural ventilation systems that involve air flow between zones.)

The work reported here has resulted in the public release of Simergy v1.0, providing California design practitioners with a free tool that enables them to make efficient use of the low energy systems modeling capabilities of EnergyPlus. More energy-efficient building design is expected to lead to lower actual building energy consumption, which benefits California by helping to mitigate climate change, reduce air pollution and reduce utility bills. Furthermore, the release of Simergy provides California design practitioners with the means to use the design analysis engine, EnergyPlus, that is the basis for performance-based compliance with Title 24 starting in July, 2014.

Conclusions and Recommendations

A new, comprehensive graphical user interface for EnergyPlus – Simergy – has been developed and Version 1.0 has been released. The number of downloads (~1,000) in the first 48 hours indicates a strong pent-up demand for a free, practitioner-oriented interface for EnergyPlus and the ~4,000 downloads to date indicate a growing interest and opportunity to get substantial adoption of EnergyPlus through Simergy.

The authors submit that the California Energy Commission continue to support the development of Simergy, both through direct funding and by continuing to advocate for the support and adoption of Simergy, in particular by the California Public Utilities Commission and investor- and publicly owned utilities.

---

not only for their potential impact, but also for their easy comprehension and their ability to galvanize market players.

1. All new residential construction in California will be zero net energy by 2020;
2. All new commercial construction in California will be zero net energy by 2030;
3. Heating, Ventilation and Air Conditioning (HVAC) will be transformed to ensure that its energy performance is optimal for California's climate; and
4. All eligible low-income customers will be given the opportunity to participate in the low income energy efficiency program by 2020.

CHAPTER 1: Introduction

A new generation of more powerful and effective design analysis tools is required to support an integrated design process for the zero-net-energy buildings needed to meet California's 'Big Bold' energy efficiency goals. EnergyPlus (EnergyPlus, 2014) is widely viewed as the premier building simulation engine for low energy design. Despite demonstrated interest by design practitioners interested in energy efficiency, most are unable to use EnergyPlus as a stand-alone tool. EnergyPlus' manual data entry process is too slow and error-prone to be viable within the constraints of normal design fees. Furthermore, a major barrier to the widespread EnergyPlus adoption by practitioners has been the lack of a free comprehensive graphical user interface[3] to make the program easy and efficient to use. Such an interface, Simergy (See et al., 2011), has been developed with support from the California Energy Commission (Energy Commission), the United States. Department of Energy (DOE), Infosys Technologies, Trane, the Northwest Energy Efficiency Alliance and Hydro-Québec.

Energy simulation is used both for evaluating new technology for inclusion in future versions of California's Title 24 building energy code and for demonstrating compliance with current Title 24. The Energy Commission is significantly revising the process to demonstrate compliance with Title 24. One key component of this revision is a switch from procedures based directly on the DOE-2 building energy simulation program, developed by DOE in the 1970's, to a process in which DOE's current whole building energy simulation tool EnergyPlus is the reference model. EnergyPlus is DOE's free, flagship building energy simulation tool to replace DOE-2. EnergyPlus is more accurate, involves fewer workarounds, and enables the analysis of innovative and complex mechanical system and building design energy usage. Also, DOE continues to fund extensions to EnergyPlus to support both low energy and conventional design for new construction and existing buildings. It was these considerations that led the Energy Commission to select EnergyPlus to play a key role in Title 24, both in the analysis for 2013 California Building Energy Efficiency Standard compliance and beyond.

The purpose of this project was to further the development of a free interface to enable the widespread adoption of EnergyPlus. This interface, Simergy, continues to be developed by a team led by Lawrence Berkeley National Laboratory (LBNL) and guided by six leading architecture and engineering firms, with programming from a team of professional software developers, led by architecture, engineering and construction (AEC) software developers Digital Alchemy. The goal is to make EnergyPlus accessible to building designers and other professionals by substantially simplifying the process of assembling building models, promoting its wider adoption.

[3] A graphical user interface (GUI) is a human-computer interface (i.e., a way for humans to interact with computers) that uses windows, icons and menus and which can be manipulated by a mouse (and often to a limited extent by a keyboard as well).

This project, funded by the California Energy Commission, sought to further the development of Simergy in preparation for its first public release in July of 2013. Furthermore, this report details Simergy could be further extended for use in the early stages of design and how it could be linked to new software, developed with funding from the Energy Commission's Standards Development Office, to support performance-based code compliance for California commercial buildings.

1.1 Goals and Objectives

The main goal of the overall Simergy project, of which the work reported here forms a part, is to dramatically increase the use of EnergyPlus by developing a user interface that:

- Is distributed free of charge to the end user.
- Is efficient and easy to use.
- Supports import from industry design applications, such as Building Information Models (BIM) and computer-aided design (CAD).
- Supports integration of BIM model data with model data in the EnergyPlus Input Data File (IDF) format.
- Supports import of existing EnergyPlus data sets.
- Generates EnergyPlus IDF and manages running the EnergyPlus simulation engine.
- Manages and helps interpretation of simulation results for individual runs, and comparisons to baselines and design alternatives.
- Supports both inch-pound and metric units.
- In the longer term, supports workflows for existing buildings, including the use of metered data and calibration.
- In the longer term, imports manufactures' product data, for example, heating, ventilation and air conditioning (HVAC) equipment, based on ASHRAE Standard 205 *Data Exchange Protocols for Energy Simulation of HVAC&R Equipment Performance*, which is currently under development.

The objectives of the work reported here were to:

- Extend the support for high performance envelope components and configurations in Simergy
- Extend the support for HVAC systems in Simergy, including advanced heating systems and thermally activated cooling systems
- Provide support for domestic hot water (DHW) systems in Simergy
- Identify how Simergy could be extended to enable EnergyPlus to be used effectively in early stage design
- Determine how the compliance software toolkit funded by the Energy Commission can be utilized in Simergy

These objectives were substantially achieved, as described in the remainder of this report. The one exception is the support for DHW systems, which could not be implemented because the topology of fluid distribution systems is limited to closed loops in version 1.0. It is planned to implement DHW systems in version 1.2.

CHAPTER 2:
Project Approach

2.1 Simergy Modeling Capabilities

2.1.1 Building Envelope

Early in the user requirements definition phase of Simergy development, it was decided to implement two methods of generating the geometrical description of the building:

1. Importing 3-D geometry from BIM
2. Internal generation of building geometry by vertical extrusion of floor plans

In the first case, construction descriptions for walls, windows, *and etcetera* are imported from BIM along with the geometrical description. In the second case, the construction descriptions are selected from previously defined library entities, allowing a wide range of façade constructions including exterior shading and operable windows for natural ventilation. The libraries of windows reference the glazing construction and shading controls libraries and include opening information for operable windows. The library categories for materials and constructions are shown in Table 2.1.

Table 2.1: Categories of materials and constructions in Simergy libraries

Materials	Doors
Material and Glazing Layers	Windows
Material and Glazing Layer Sets	Solar Shades

The constructions templates consist of library entries for different generic type of construction element. A template consisting of a set of construction library entries can be prepared for any construction practice or energy code baseline construction set for a particular building type and climate zone.

2.1.2 HVAC Systems

There are libraries for all classes of HVAC components supported by Simergy. The categories of components are shown in Table 2.2.

Table 2.2: Categories of HVAC components in Simergy libraries

Ducts, Pipes Fittings	Coils and Heat Exchangers	Air Terminals	Site Demand
Fans and Pumps	Electrical and Miscellaneous Equipment	Service Hot Water	Site Power
Plant Equipment	Zonal and Unitary Equipment	Storage	

HVAC templates define how components are connected together to define subsystems – air loops, water loops and combinations of terminal units and other zone equipment. In Simergy, the templates define the supply side equipment and their connections, e.g. an air handling unit or boiler. The demand side is generated automatically, e.g. the chillers on the supply side of the chilled water loops form the demand side for the condenser water loops. These relationships are illustrated in graphical examples in Section 3.1.

The HVAC systems and components supported by Simergy were selected to provide the designer with a range of low energy system options that either reduce the demand of the building for natural gas or use it more efficiently than conventional systems, including:

- Radiant slab heating and cooling
- Heat pumps
- Absorption chillers

2.2 Early Stage Design

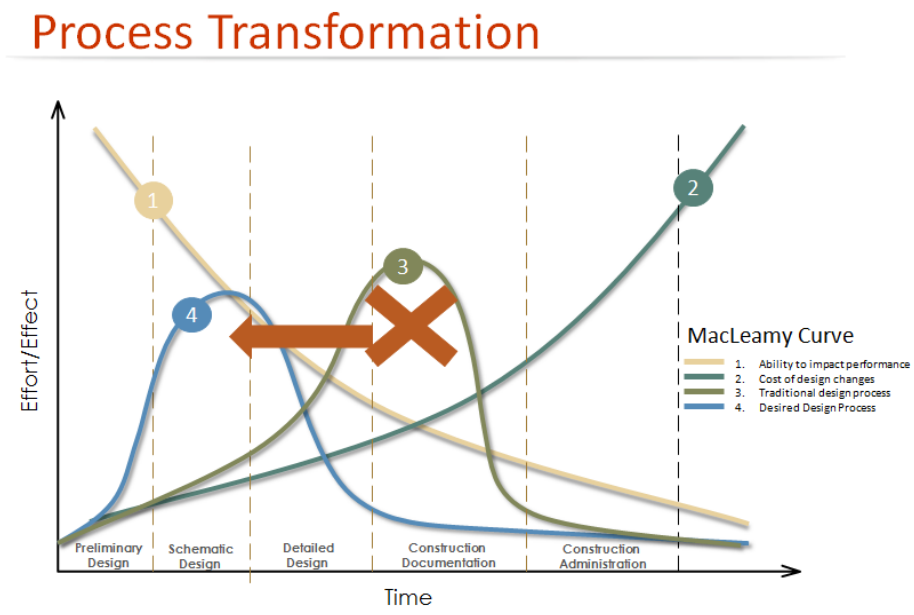
The researchers discussed the use of analysis tools in early stage design with individuals in a number of organizations including HOK Architects, Institute for Sustainable Building Performance, Sustainable-IQ and UC Berkeley Department of Architecture. The consensus was that it is desirable to use a detailed simulation tool for analysis in early design, as long as the interface is simple enough, and the simulation runs fast enough, to keep up with the rate at which ideas are generated in the early meetings, at which most of the key design decisions are made.

One reason to prefer a more detailed simulation tool is that it can treat the interactions between the different aspects of the design, which need to be addressed if the aggressive performance targets implicit in California's energy goals are to be attained. Furthermore, the model can grow incrementally without having to be re-implemented in another tool as the design progresses.

As reported by design practitioner participants in a recent workshop at Stanford University[4], there is, increasingly, a requirement for energy modeling in early stage design, particularly from more sophisticated clients. The process of shifting design effort in general, and energy analysis in particular, to the early stages of design, is illustrated in Figure 1. The figure also shows the benefits this shift can bring in terms of impact on performance and the cost of design changes.

[4] 1st Stanford workshop on Computational Methods for Sustainable Building Design September 26th-27th, 2013

Figure 2.1: Shifting design effort to the early stages of design (courtesy of HOK Architects).



The characteristics of a design analysis tool required for it to be useful in the early stages of design include:

- Ease of switching the focus of attention from one aspect to another, e.g. from massing to high level HVAC strategy to orientation, while addressing the interactions between these different aspects.
- User interface representation of each aspect of the design with a relatively small number of parameters. In some cases, these parameters represent system choices, e.g. HVAC systems, represented by pre-configured templates
- A combination of models that are as simple as possible, with partial weather years that include extreme and typical periods is required to maximize the speed of simulation and minimize the delay in providing feedback, while the design approaches that generated the simulation runs are still under active consideration
- Presentation of results that provide maximum insight to the different disciplines involved in integrated design. Different visual presentations may be needed for different disciplines, with different responsibilities

Preliminary mockups of some of the interface screens that include some of these characteristics are presented in Section 3.2. However, this is still an immature area and substantial further research is required.

2.3 Title 24 Compliance

As part of a major change to the process of demonstrating performance-based compliance with the Title-24 building energy code, the Energy Commission Standards Development Office has funded the development of the California Building Energy Code Compliance Non-Residential

(CBECC-Com) Software for building types covered by Title-24 (CBECC-Com, 2014). The key features of CBECC-Com are:

- Determination of compliance is performed using EnergyPlus, rather than tools based on DOE-2, US DOE's previous whole building energy simulation program
- The procedure for defining the baseline building (the 'Standard Design model') is represented by a set of rules, which are interpreted by a 'rules processing engine' included in CBECC-Com.
- Different versions of Title-24 and, in principle, other codes and standards, such as ASHRAE Standard 90.1 (ASHRAE, 2013), can be represented by different rule sets.
- CBECC-Com includes a simple user interface that allows the design that is to be analyzed for compliance to input using a series of interactive screens. Building geometry is defined using the OpenStudio plug-in for SketchUp developed by the National Renewable Energy Laboratory (NREL).
- A complete simulation model of the design can be input to CBECC-Com by translating it into a format defined by the Energy Commission's Standards Data Dictionary (SDD), which is the basis of one of the internal data models used in CBECC-Com. Developers of third party, e.g. commercial simulation tools, can enable their tools to be used for Title-24 compliance by adding the capability to output their design models in SDD format.
- The software architecture of CBECC-Com, and its implementation in the form of a software development kit (SDK), also allows for third party simulation tools to be used to perform the actual compliance analysis. The Energy Commission Standards Development Office has funded the development of accuracy tests to be used as part of an accreditation procedure for third party tools.

The steps required to interface Simergy to CBECC-Com are:

1. Develop a translator from the SimModel[5] data format used in Simergy to the SDD format used in CBECC-Com
2. Develop a reverse translator from SDD to SimModel. Performing the compliance analysis by running EnergyPlus from Simergy, rather than using the OpenStudio Translator module in the current version of CBECC-Com, to enable the Simergy results visualization capabilities to be used for the code compliance analysis as well as in the development of the design.
3. Integrate Simergy and CBECC-Com and develop user interface screens to support the compliance analysis process.

Further details are given in Section 3.3.

[5] SimModel is a data schema, developed for Simergy that represents those aspects of the building design that are required for energy simulation and related analyses. SimModel is primarily a union of the EnergyPlus input data schema, defined by the EnergyPlus Input Data Dictionary, and the Industry Foundation Classes (IFC) data schema developed by BuildingSMART (formerly the International Alliance for Interoperability).

CHAPTER 3: Project Results

3.1 Simergy Modeling Capabilities

3.1.1 Building Envelope

Geometry Import from Building Information Models (BIM)

Simergy is capable of importing a 3-D description of the geometry of the building fabric from an object-based CAD tool, sometimes referred to as a BIM tool. Autodesk's object-based 3-D CAD tool Revit, which currently has the largest share of the market, can export in Industry Foundation Classes (IFC) format (BuildingSMART, 2011) and in Green Building Extensible Markup Language (gbXML) format (gbXML.org, 2011), although Revit had not, at the time of writing, completed the IFC certification process. (There is, currently, no certification process for gbXML.) Simergy can import in either IFC or gbXML format; Figure 3.1 illustrates import from Graphisoft's object-based 3-D CAD tool ArchiCAD using the IFC format.

Figure 3.1: Import of building geometry using IFC

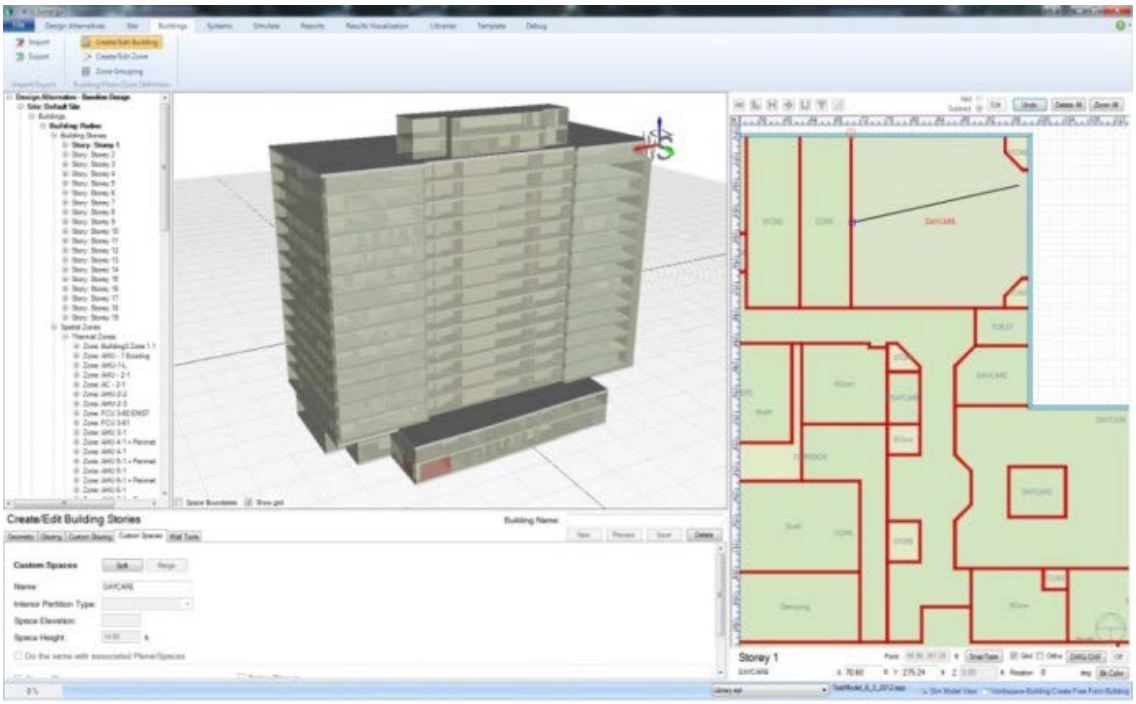
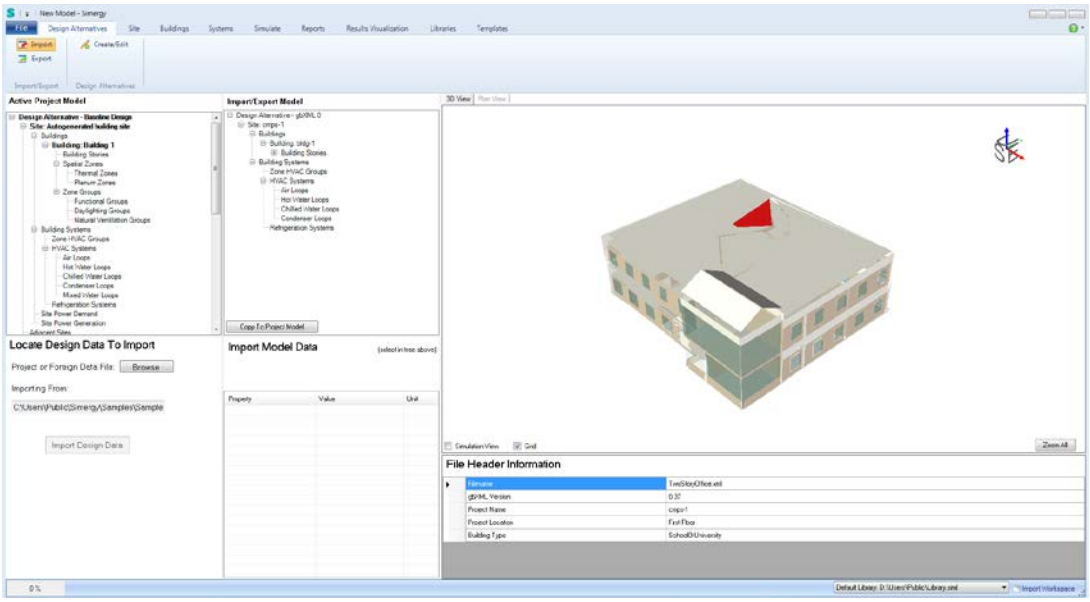


Figure 3.2 illustrates import of a file in gbXML format. The segment of the roof highlighted in red illustrates the excessive tessellation sometimes found in gbXML models.

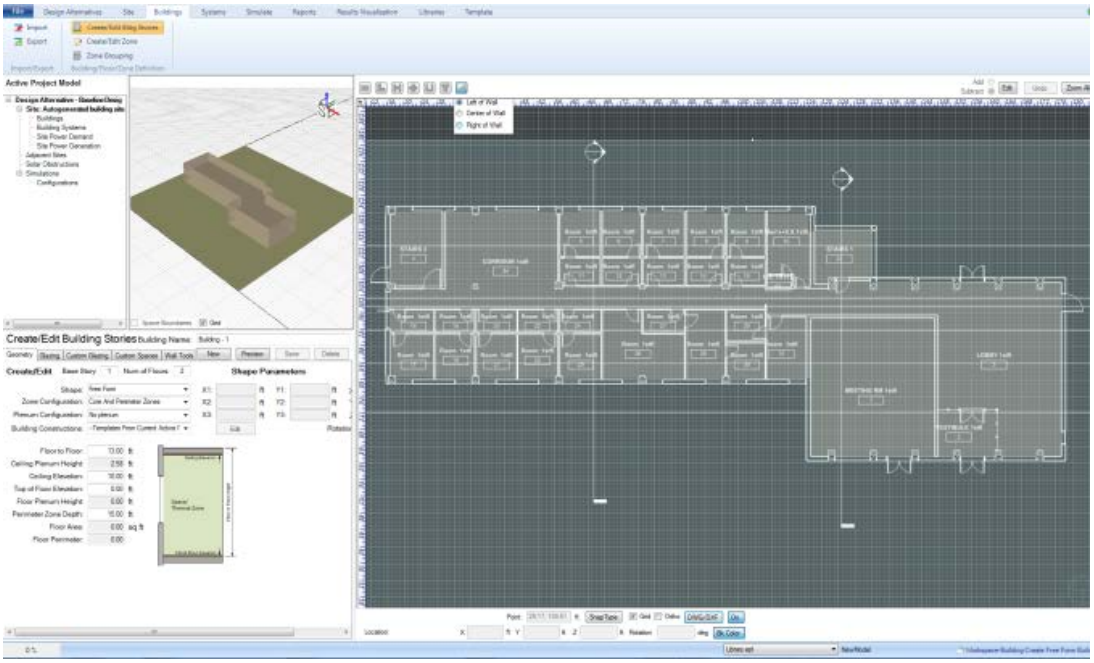
Figure 3.2: Import of building geometry using gbXML.



Generation of Building Geometry from 2-D Floor Plans

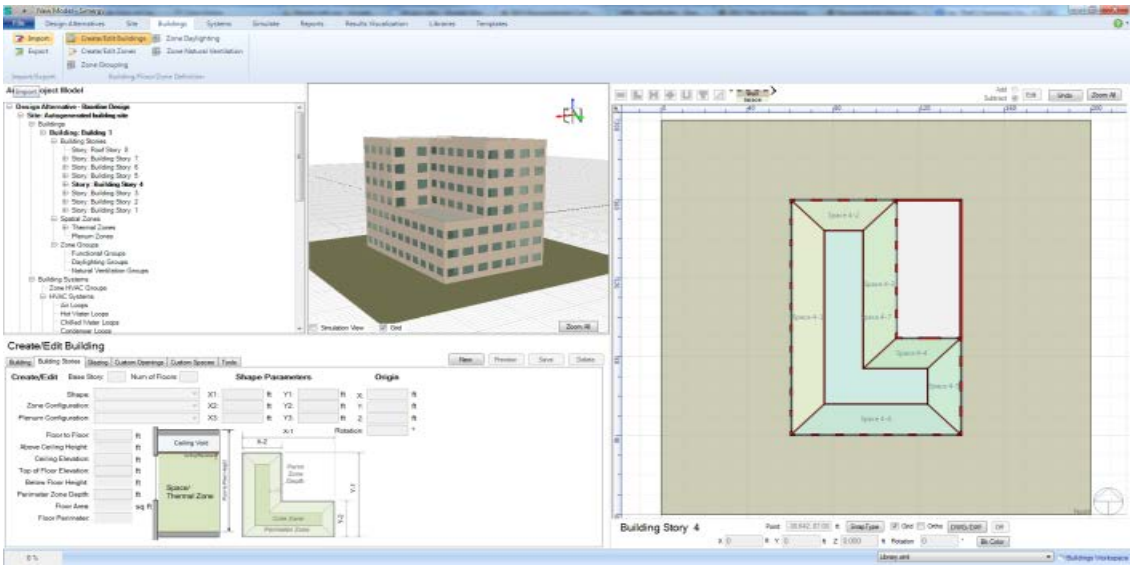
The most widely used method of importing geometrical information from CAD is to draw over 2-D floor plans, in either .dwg or .dxf format (two standard formats used by multiple CAD tool vendors), snapping to vertices and intersections in the floor plan and then extruding vertically, as shown in Figure 3.3. This process can be repeated for each floor if the floor plans are different or can be used to generate multiple stories with the same floor plan.

Figure 3.3: Import of building geometry using 2-D floor plans



The lower left hand pane in Figure 3.3 is used to define the floor to ceiling height and the presence and height of floor or ceiling voids or plena. A similar process is used when extruding standard floor plan shapes, as shown in Figure 3.4. The shapes along the top of the right hand pane indicate the available floor plan shapes, which may be stacked, as shown, after defining their dimensions using the lower left hand pane.

Figure 3.4: Extrusion and stacking of standard floor plan shapes.



Building Envelope Libraries and Templates

The libraries of constructions are implemented in a three level hierarchy:

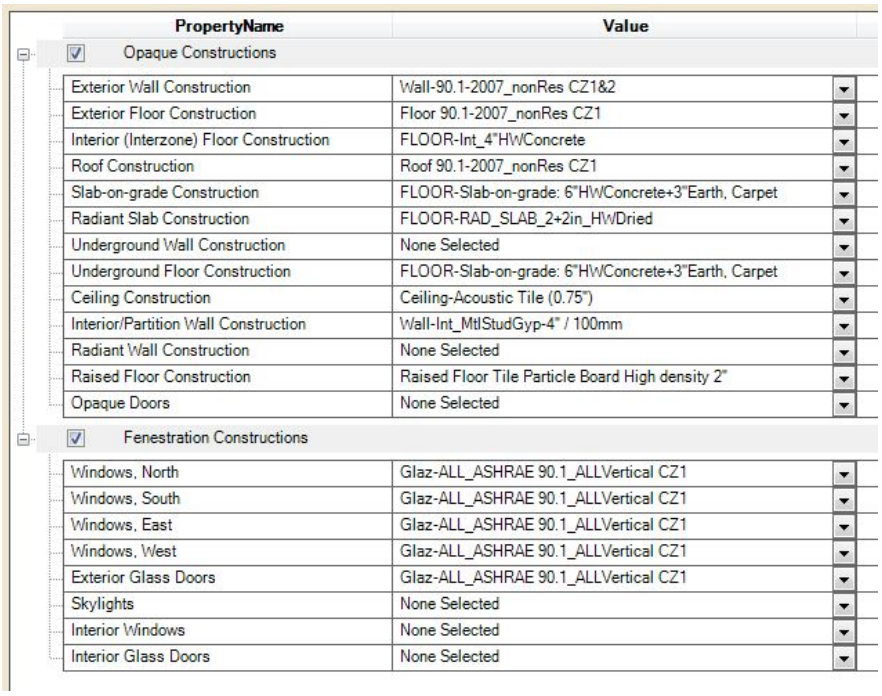
- Material Layer Sets – e.g. Concrete Floor: 6″ Medium Weight Concrete + Carpet
- Material Layers – e.g. 6″ Medium Weight Concrete
- Materials – e.g. Medium Weight Concrete

Glazings (single and multi-pane constructions) use the same three layer scheme. The libraries of windows reference the glazing construction and shading controls libraries and include opening information for operable windows.

The constructions templates consist of library entries for different generic types of construction elements, as shown in Figure 3.5.

A template consisting of a set of construction library entries can be prepared for any construction practice or energy code baseline construction set for a particular building type and climate zone.

Figure 3.5: Screenshot showing building element types in the Constructions template with example libraries



PropertyName	Value
Opaque Constructions	
Exterior Wall Construction	Wall-90.1-2007_nonRes CZ1&2
Exterior Floor Construction	Floor 90.1-2007_nonRes CZ1
Interior (Interzone) Floor Construction	FLOOR-Int_4"HWConcrete
Roof Construction	Roof 90.1-2007_nonRes CZ1
Slab-on-grade Construction	FLOOR-Slab-on-grade: 6"HWConcrete+3"Earth, Carpet
Radiant Slab Construction	FLOOR-RAD_SLAB_2+2in_HWDried
Underground Wall Construction	None Selected
Underground Floor Construction	FLOOR-Slab-on-grade: 6"HWConcrete+3"Earth, Carpet
Ceiling Construction	Ceiling-Acoustic Tile (0.75")
Interior/Partition Wall Construction	Wall-Int_MtlStudGyp-4" / 100mm
Radiant Wall Construction	None Selected
Raised Floor Construction	Raised Floor Tile Particle Board High density 2"
Opaque Doors	None Selected
Fenestration Constructions	
Windows, North	Glaz-ALL_ASHRAE 90.1_ALLVertical CZ1
Windows, South	Glaz-ALL_ASHRAE 90.1_ALLVertical CZ1
Windows, East	Glaz-ALL_ASHRAE 90.1_ALLVertical CZ1
Windows, West	Glaz-ALL_ASHRAE 90.1_ALLVertical CZ1
Exterior Glass Doors	Glaz-ALL_ASHRAE 90.1_ALLVertical CZ1
Skylights	None Selected
Interior Windows	None Selected
Interior Glass Doors	None Selected

3.1.2 HVAC Systems

HVAC systems in Simergy fall into two categories:

- Zone level unitary equipment, e.g. window air-conditioners
- Central system, typically multi-zone

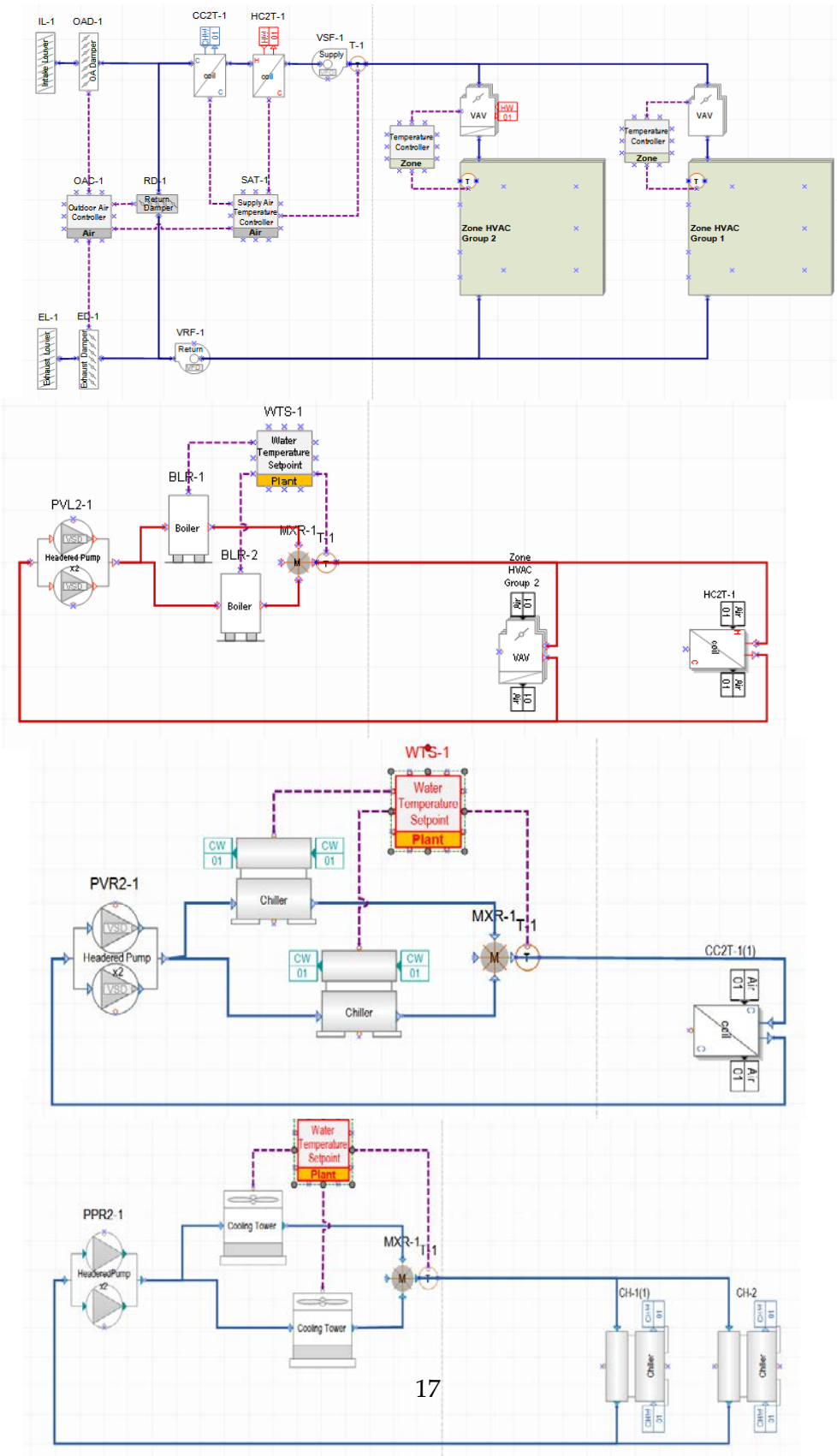
Central systems are described in terms of coupled loops:

- Air loops – air handling units with ducted distribution systems and air terminal units
- Chilled water loops – chillers with piped distribution systems and coils and/or radiant slabs or panels
- Condenser water – cooling towers with piped distribution systems and chillers and/or water-to-water heat exchangers for water-side free cooling
- Hot water – boilers, solar collectors with piped distribution systems and coils and/or radiant slabs or panels and/or absorption chillers

Domestic hot water systems are modeled in EnergyPlus using a variant of the hot water loop; because of technical difficulties, which have now been overcome, this capability is only now being implemented in Simergy. Steam systems are implemented as a special loop type in EnergyPlus – the return part of the loop consists of piping and a pump for the condensate, all of which is assumed to return to the boiler. Again, because of technical difficulties, which have now been overcome, this capability is only now being implemented in Simergy. Figure 3.6

shows the air, hot water, chilled water and condenser loops for a conventional single duct VAV system.

Figure 3.6: Air, hot water, chilled water and condenser loops

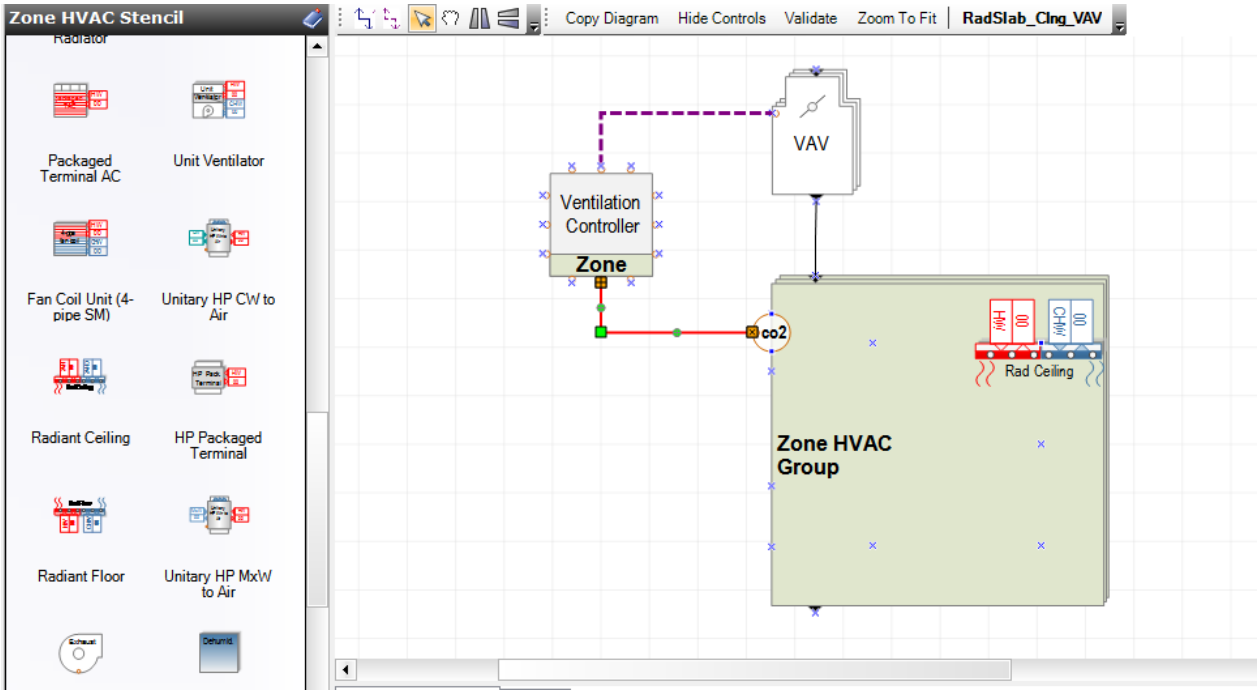


The air loop has a heating coil in the air handling unit and a reheat coil for each of the zones that comprise Zone HVAC Group 2. The "HW 01" tags on these coils indicate that they are also in Hot Water Loop #1, as shown the second loop in Figure 3.5. Similarly, the CHW 01 tag on the cooling coil indicates that the coil is also part of Chilled Water Loop #1. The CW 01 tags on the condensers of the chillers indicate that the chillers are also part of Condenser Water Loop #1.

The demand side of each loop – shown on the right hand side of the diagram of each loop – is generated automatically when the components are assigned by the user to the appropriate loop (note that there can be more than one of each type of loop). The zones in each Zone HVAC Group are assigned by selecting them from the tree in the top left side pane of the Create/Edit Zone HVAC Groups workspace. The supply side of each loop can either be created by dragging and dropping individual components in the Diagram workspace or by using, and possibly modifying, a previously defined template. Pre-defining templates is usually a more effective way to work – the configuration and connections of the template can be validated before inserting it into the loop and, once saved, it is readily available for reuse.

The Diagram Zone HVAC Groups workspace is used to generate Zone HVAC Groups with different equipment configurations. Figure 3.7 shows the generation of a Zone HVAC Group in which each zone has a radiant ceiling slab and demand controlled ventilation based on measured CO_2 concentration.

Figure 3.7: Use of the Zone HVAC Group Template workspace to create a Zone HVAC Group with Radiant Heating and Cooling and Demand Controlled Ventilation



Radiant slab heating and cooling is supported in v1.0 of Simergy. Heat pumps and absorption chillers are partially supported and it is planned to support them fully in v1.1.

3.2 Extension of Simergy for Early Stage Design

Based on the consensus, described in Section 2.2, that it is desirable to use a detailed simulation tool for analysis in early design, as long as the interface is simple enough, and the simulation runs fast enough, a preliminary design was developed. New components of this design, not currently included or under development in Simergy include:

- Climate Analysis
- Site Analysis
- Preliminary Energy Analysis

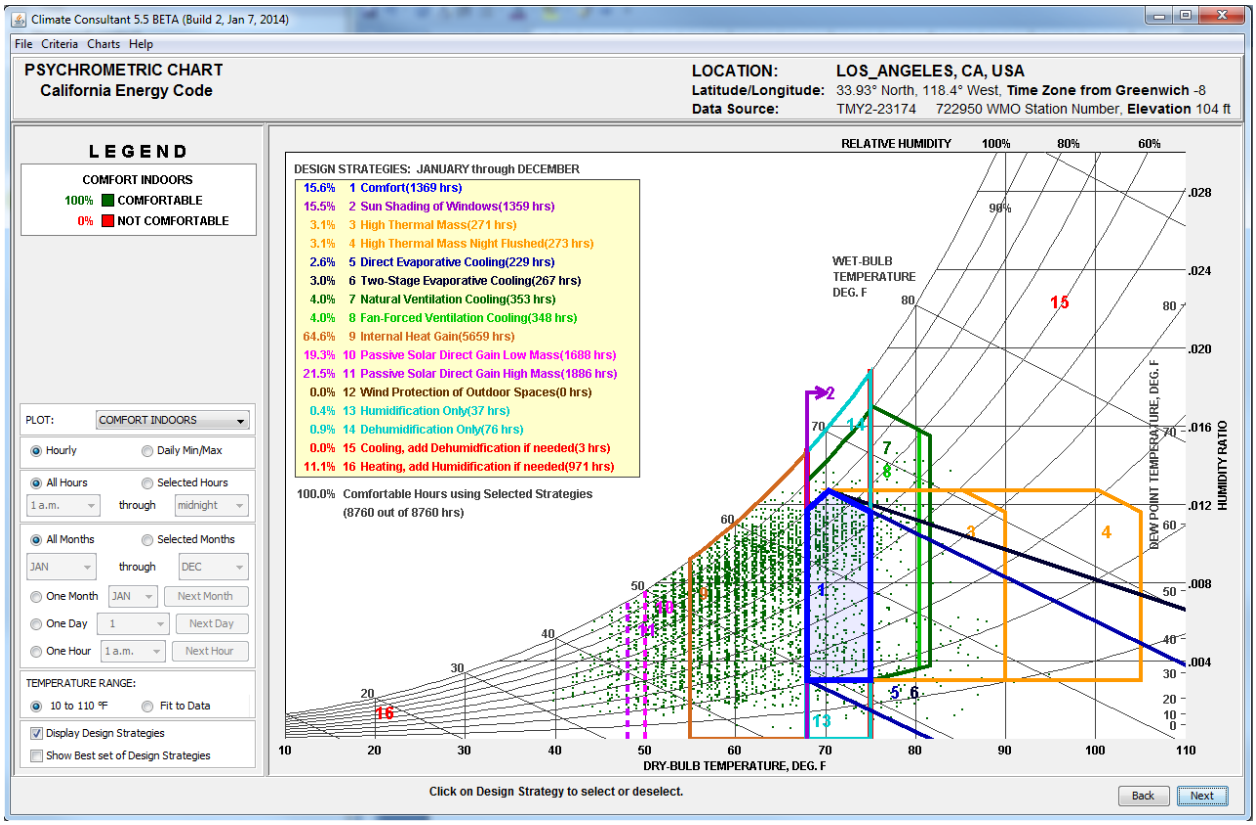
3.2.1 Climate Analysis

An understanding of the climate is an important first step in the design of low energy buildings. This understanding has two components, the range of conditions that make up the majority of the year and determine the energy performance of candidate HVAC and lighting systems, and the extreme conditions that determine whether a candidate system can maintain acceptable conditions, and what architectural measures are required to make a candidate system viable.

A number of leading firms are creating their own tools for the first stages of design to analyze climate data. Commercial tools are available; however, a number of leading firms feel these tools do not fully provide what they need in early stage design and so are creating their own. In particular, they want tools that can help tell an engaging story of the potentially relevant strategies in a way that can be communicated to the design team and, potentially, to the client.

One method of presenting temperature and humidity data that is familiar to architects is the bioclimatic chart presented by Olgay and Olgay (1963), in which ambient temperature is plotted against relative humidity. Engineers in the US use a form of the psychrometric chart in which humidity ratio is plotted against ambient temperature. In case, hourly temperature and humidity data for typical or extreme years can be plotted on the chart to visualize the distribution of these key drivers. Some forms of these charts are divided into regions in which different cooling strategies may be applicable, e.g. evaporative cooling – see Figure 3.8 for an example. However, these charts are unable to show solar radiation and wind speed, and their temporal relationships to temperature and humidity. In addition no effective methods have been developed to visualize the relationships between meteorological variables beyond plots of different pairs of variables. Further public interest research and development (R&D) is needed to meet the needs of practitioners outside the leading firms that are developing their own tools, starting with a review of the wide range of existing prototype tools, typically developed in academe. In particular, there is a need to identify or develop standard ways of presenting both climate and building performance data that will become familiar to practitioners and enable ready understanding.

Figure 3.8: Psychrometric chart overlaid with regions of potential applicability for different strategies for heating or cooling – part of the Climate Consultant weather data visualization tool developed by the University of California Los Angeles with support from the Energy Commission (Climate Consultant, 2014).



3.2.2 Site Analysis

Both shading by adjacent buildings and self-shading by designs with concave forms can have a significant effect on daylighting, and heating and cooling loads. Shading of direct beam is relatively easy to calculate and to visual using a standalone tool such as Ecotect (Ecotect, 2014) or by using EnergyPlus with a suitable user interface, which could be developed as an extension of Simergy. Shading of diffuse radiation, which is important for daylighting, can be calculated using EnergyPlus, but is rather more difficult to visualize and currently requires the use of computationally-intensive tools such as Radiance (Radiance, 2014).

Wind speeds and flow patterns around buildings affect the potential for natural ventilation. Relatively accurate prediction requires wind tunnel measurements or careful computational fluid dynamics simulations, both of which are time-consuming and expensive and hence tend to be used in the later stages of design. Very approximate estimates of the wind pressure distributions on building surfaces can be obtained by assuming a cuboidal building form in an unobstructed location and these estimates can be used to determine if further investigation, using more detailed methods, is called for – this is the approach currently used in Simergy,

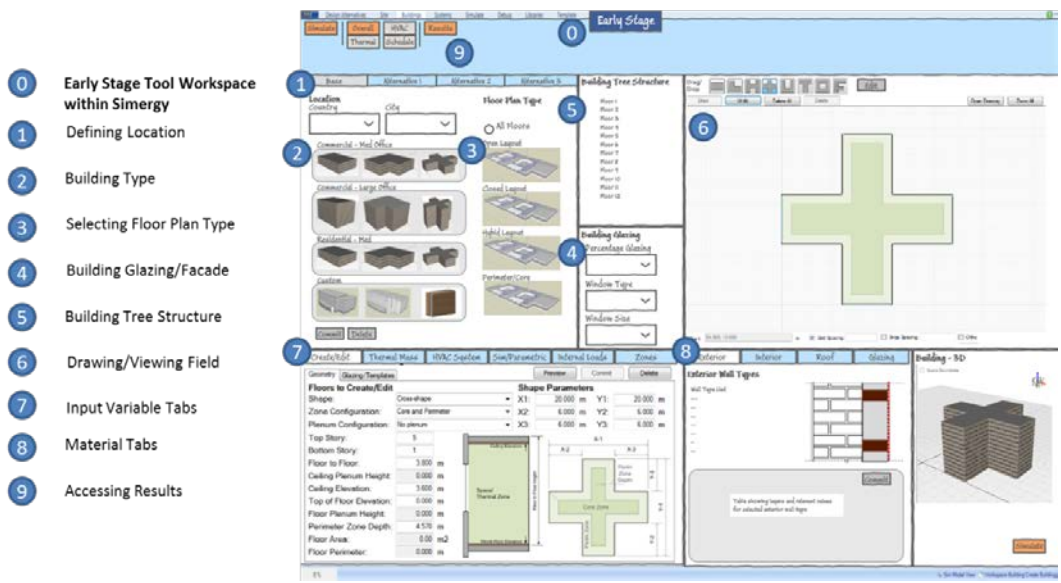
although it is planned to support the import of wind pressure coefficient data produced outside Simergy in a later version.

3.2.3 Preliminary Energy Analysis - Future Recommended Development

Input

One characteristic of early stage design is that there is a wide variety of different aspects of the design for which high level decisions are required relatively quickly. A number of these aspects have a significant effect on energy performance and interact with each other, e.g. orientation, plan depth, window-to-wall ratio, glazing properties, shading, thermal mass and high level HVAC system selection, including natural ventilation. A simple extension of Simergy for early stage design would have a top level interface that allows key parameters for each of these aspects to be set from a single screen. A preliminary mockup, which allows some of these aspects to be addressed on a single screen and others to be addressed on linked screens accessed by a single mouse click, is shown in Figure 3.9. Appropriate default occupancy and internal gain levels and schedules would be configurable using the 'libraries and templates' facility in Simergy.

Figure 3.9: Preliminary mockup of top level interface screen



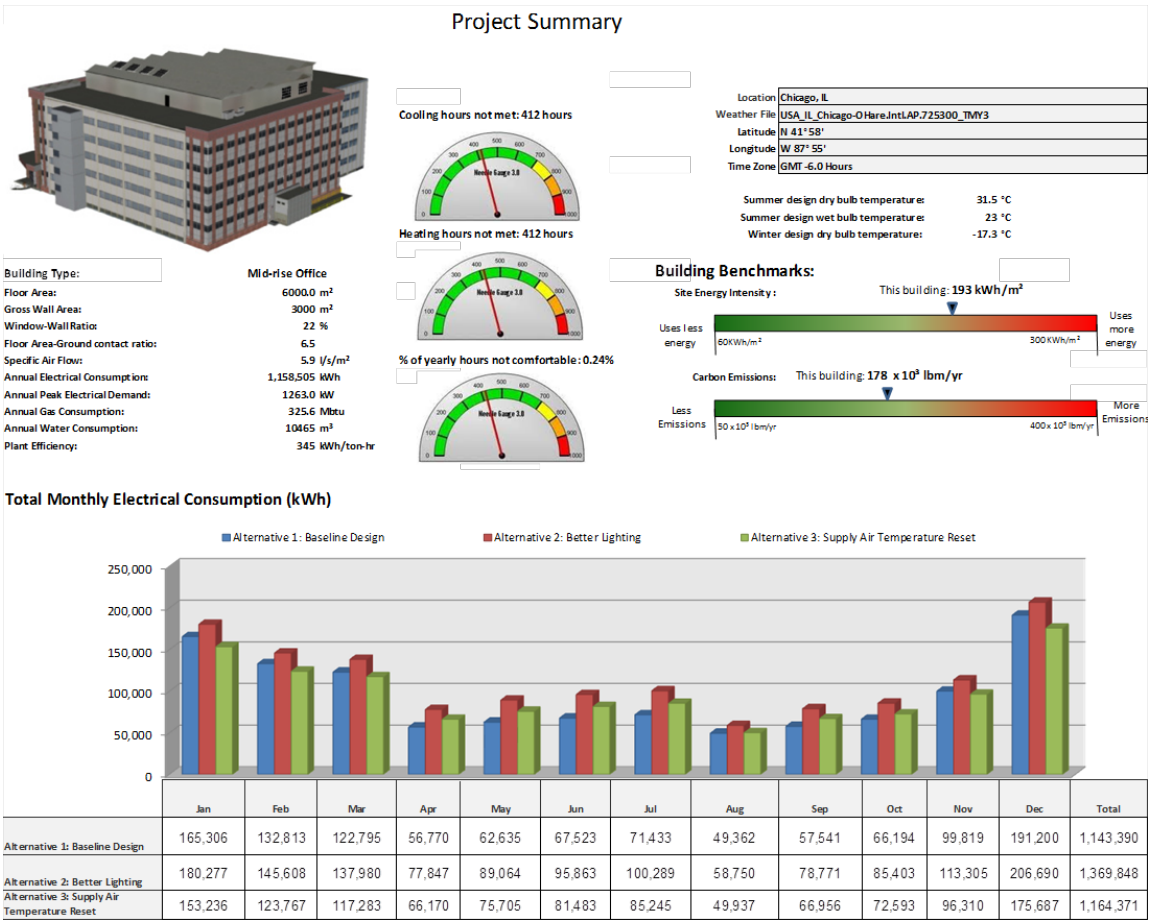
The choice of HVAC system type is often not considered in the earliest stages of design yet can have a significant effect on other design decisions. One obvious example is that natural ventilation systems impose particular requirements on building form. Another example is that mechanical systems such as displacement ventilation have limited cooling capacity on a floor area basis and so require high performance facades to limit perimeter cooling loads. Most of the mockup screen shown in Figure 3.9 is devoted to building form and constructions but HVAC system selection is accessed through a single mouse click at the top of the screen. As the design of the interface evolves, high level HVAC system selection could be included in the top level screen. The current version of Simergy provides for HVAC templates at the subsystem level –

zone equipment, air loops and the different water loops - so that multiple templates are required to specify a complete HVAC system. High level HVAC system selection could be enabled by introducing 'super-templates' that combine different subsystem templates to form a complete HVAC system.

Output

As regards simulation output, Simergy already makes extensive use of predefined reports and templates for results visualization and this approach would be further developed. Figure 3.10 shows a preliminary mockup of a results screen that summarizes whole building performance in a predominantly graphical form.

Figure 3.10: Preliminary mockup of a results screen for whole building performance



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Alternative 1: Baseline Design	165,306	132,813	122,795	56,770	62,635	67,523	71,433	49,362	57,541	66,194	99,819	191,200	1,143,390
Alternative 2: Better Lighting	180,277	145,608	137,980	77,847	89,064	95,863	100,289	58,750	78,771	85,403	113,305	206,690	1,369,848
Alternative 3: Supply Air Temperature Reset	153,236	123,767	117,283	66,170	75,705	81,483	85,245	49,937	66,956	72,593	96,310	175,687	1,164,371

New results visualization templates would be prepared to provide insight into whole building performance, both through the visualization of the interaction of the various design elements in the performance of a single design solution and through the comparison of the operation of the various elements in different design alternatives. Support for parametric run generation and analysis would also be included.

Speed

A key requirement for an early stage design tool is that it is capable of generating results quickly enough to be able to influence key design decisions. One interpretation of this requirement is that the tool should be flexible and fast enough to provide feedback on a design idea generated in an integrated design team meeting before that idea has been adopted by the team. The process of generating an evaluation of a design idea involves three steps, each of which can take a significant amount of time:

- **Input**: generating or modifying a simulation input file that represents the design idea
- **Simulation:** running the model over a range of weather and occupancy conditions
- **Output:** visualization and interpretation of the simulation results

The approach to speeding up the input has focused on simplifying the building description process by using templates to limit the level of detail required from the user. Simulation can be speeded up in several different ways:

- Increasing the execution speed of the simulation engine – there are on-going efforts by the EnergyPlus Development Team to speed up EnergyPlus by means of more efficient algorithms and by multi-threading to make use of multi-core processors in personal computers
- Reducing the number of thermal zones in the model by larger scale aggregation of spaces and in the simulation by the use of zone and floor multipliers. An alternative approach is to model only representative zones, as is done, for example, in the COMFEN design analysis tool for commercial building facades (COMFEN, 2014).
- Shortening the run period to just long enough to capture dynamic behavior, such as diurnal thermal storage, during different seasons

3.3 Extension of Simergy for Code Compliance

As discussed in Section 2.3, extension of Simergy to include code compliance capabilities for Title-24 involves the following steps:

1. Develop a translator from the SimModel data format used in Simergy to the SDD format used in the Energy Commission's CBECC-Com SDK (software development kit)
2. Develop a reverse translator from SDD to SimModel. Performing the compliance analysis by running EnergyPlus from Simergy, rather than using the OpenStudio Translator module in the current version of CBECC-Com, would enable the Simergy results visualization capabilities to be used for the code compliance analysis as well as in the development of the design.
3. Integrate Simergy and CBECC-Com and develop user interface screens to support the compliance analysis process.

Once the design model has been converted to SDD format, when it is referred to as the User Model, the CBECC-Com rules processing engine uses it to generate two models:

- The Proposed Model: the occupancy and operation schedules in the User Model are replaced with standard schedules, defined in the Title 24 Alternative Calculation Manual (ACM), and any construction U-factors or equipment efficiencies that do not meet Title 24 mandatory requirements for the climate zone and building type are replaced with the minimum code-compliant values.
- The Standard Model (sometimes referred to as the Baseline Model) is generated from the Proposed Model by substituting a standard HVAC system, based on the building type and size, and replacing any construction U-factors or equipment efficiencies that exceed Title 24 minimum requirements for the climate zone and building type with the minimum code-compliant values.

These models are then translated into EnergyPlus and simulations are run to compare their performance, based on Time Dependent Valuation (TDV) of the energy consumption. This takes into account the variation in the value of electricity by time of day, day of the week, season and climate zone, and the variation in the value of natural gas by season and climate zone.

3.3.1 Future Recommended Development

SimModel to SDD Translator

The first step in the implementation of code compliance capabilities in Simergy involves the development of a translator to convert the model developed by the designer in Simergy to the SDD format that is used as the input data format in the CBECC-Com. This task would be facilitated by the development by the CBECC-Com development team of an XML representation of the SDD data schema (SDD-XML) – this development is currently being considered by the CBECC-Com development team. Since there is an XML representation of Simergy's SimModel data schema (SimXML), the availability of SDD-XML would enable the process of developing a translator to make use of tools developed to analyze and validate XML schema. This would enable a faster, semi-automated process that would produce a more robust translator and make it easier to upgrade the translator in response to extensions to the SDD data schema.

One limitation of CBECC-Com is that it must be possible to represent all elements of the design in SDD format in order to generate the Proposed Model and the Standard Model. The current version of SDD has limited capability to represent different HVAC systems, although the Energy Commission Standards Development Office has indicated that it is planned to extend the range of HVAC components included in SDD in order to enable designs that include systems based on those components to be certified as compliant with Title 24 and eligible for Savings by Design incentive payments. Thus, the SDD data schema is expected to be updated on a regular basis and efficient methods of updating translators to and from SDD will be required to produce updated translators in a timely fashion at limited cost.

SDD to SimModel Translator

The current CBECC-Com first translates the Proposed and Standard Models from SDD format to the format used by the OpenStudio platform (OpenStudio, 2014), developed by NREL, and then exports the models from OpenStudio in the EnergyPlus Input Data Format (IDF) for

simulation. An alternative approach is to implement the translation from SDD to IDF via the Simergy SimModel format. Since models are routinely exported from Simergy to EnergyPlus by the SimModel to IDF translator in Simergy, the remaining task is to develop a translator from SDD to SimModel. This translation is the reverse of the translation to be developed for the SimModel to SDD translator described above and the development process would make use of the same SDD-XML and SimXML data schemas and XML mapping tools.

One advantage of the approach just described is that the results from the simulations will be available in the Simergy Results Visualization tab. This will enable detailed time series comparisons of the performance of the Proposed and Standard models, allowing the user to investigate the causes of the difference, or lack of difference, between the behavior of the Proposed and Standard models and hence identify possible ways of improving the design. If resources permit, a workspace that shows differences of specific parameters and schedules between the Proposed and Standard models will be included, so the user can easily visualize the differences in the model inputs and relate them to differences in performance.

Simergy — CBECC-Com Integration and User Interface

Since CBECC-Com is implemented as an SDK, it should be possible to incorporate the rules processing modules and data in Simergy without significant changes to the Simergy software architecture. User interface screens will need to be added to manage the workflow in which a design is analyzed for Title 24 compliance. The steps are:

1. Translation of the SimModel representation of the design to SDD format. Since SDD cannot currently represent all the building components and systems that can be represented in SimModel, the interface will need to report translation errors due to design elements that are not supported by SDD.
2. Generation of the Proposed and Standard Models. The interface will need to report errors detected by the rules processing routines.
3. Translation of the Proposed and Standard Models to SimModel format. The interface will need to report errors encountered in the translation process.
4. Simulation of the Proposed and Standard Models. The interface will need to report errors encountered in the translation from SimModel to IDF and EnergyPlus input and run-time errors. (This is already done in Simergy.)
5. Presentation of the results of simulating the Proposed and Standard models and the calculation of the TDV savings, positive or negative.
6. Visualization of the detailed simulation time series output, including graphical comparisons of the Proposed and Standard Model results. (This is already done in Simergy.)
7. Generation of a Title-24 compliance report.

An additional requirement is to synchronize the versions of EnergyPlus used by Simergy and CBECC-com. Simergy currently supports version 7.2 and CBECC-com uses version 8.0. The current release of EnergyPlus is version 8.1.

CHAPTER 4:
Project Outcomes

4.1 Simergy Modeling Capabilities

4.1.1 Building Envelope

Version 1 of Simergy can create building geometry using one of four different methods:

1. Internal generation of building geometry by vertical extrusion of standard floor plan shapes
2. Importing 2-D floor plans from architectural CAD tools and extruding vertically
3. Importing 3-D geometry from BIM in IFC format
4. Importing 3-D geometry from BIM in gbXML format

Method #1 is applicable in Schematic Design, before interior layouts are available from the architect. Methods #2-4 are applicable from 50percent Detailed Design and later. Method #2 is currently the most widely used import method. Import of 3-D geometry is still subject to a number of difficulties, which maybe categorized as follows:

- Imprecise drawing in the CAD tool – guidelines are needed for users
- CAD tool export problems – Autodesk's Revit is still in the process of being certified for IFC export; there is currently no testing and certification program for gbXML

When used in conjunction with the substantial number of materials and constructions in the library, these geometry creation methods provide the user with a range of options for modeling building envelopes easily and efficiently.

4.1.2 HVAC Systems

Simergy has graphical tools for creating diagrammatic representations of HVAC systems. These tools enable the user to edit predefined templates or to create new system descriptions that resemble conventional mechanical system drawings. The system configurations can be validated with Simergy, trapping a range of input errors before running EnergyPlus and having to deal with EnergyPlus error messages. Simergy ships with a number of HVAC templates that can be used to model the baseline systems required for ASHRAE Standard 90.1 Appendix G and California Title 24 analyses and includes an extensive library structure to support the efficient use of these templates. These capabilities make it considerably easier to define HVAC systems in Simergy than when using the text-based editor (IDFEditor) that ships with EnergyPlus.

4.2 Early Stage Design

An approach to making Simergy an effective tool for use in early stage design has been identified based on input from design practitioners and others. This approach is described in Section 3.2 and could form the basis of a workplan to define detailed user requirements, generate a functional specification and produce a prototype implementation. It is anticipated that several iterations of the cycle of testing, modification of user requirements and re-

implementation would be required. The active participation of practitioners of integrated design and specialists in interface design, including visualization, would be required to tackle this challenging problem.

4.3 Title 24 Compliance

A detailed review of the current state of the CBECC-Com software has been performed and is summarized in Section 3.3. The steps required to interface Simergy to CBECC-Com are:

1. Develop a translator from the SimModel data format used in Simergy to the SDD format used in CBECC-Com
2. Develop a reverse translator from SDD to SimModel. Performing the compliance analysis by running EnergyPlus from Simergy, rather than using the OpenStudio Translator module in the current version of CBECC-Com, would enable the Simergy results visualization capabilities to be used for the code compliance analysis as well as in the development of the design.
3. Integrate Simergy and CBECC-Com and develop user interface screens to support the compliance analysis process.

Linking CBECC-Com to Simergy would enable California practitioners to get immediate feedback on Title 24 compliance and exceedance for low energy building designs. Supplementing the Title 24 rule set with a closely related rule set to enable calculation of potential utility incentive payments would provide further useful feedback to the designer during the course of the design. (Current California Investor Owned Utility[6] incentive payments are based on a variant of the Title 24 compliance analysis that uses expected occupancy and operation schedules instead of the standard schedules used for Title 24 analysis.)

4.4 Benefits to California

Improved building energy performance, including progress towards the State's 'Big Bold' goals, will require significant changes to current practice for both retrofit and new construction. A barrier to the increased adoption of low energy systems and high efficiency components is the risk, perceived and actual, that the resulting improvement in the performance of the building may not be sufficient to justify the additional investment. This risk can be mitigated by the use of more comprehensive and accurate analysis tools, such as EnergyPlus, rather than tools based on DOE-2. (The limitations of such tools include the need for work-arounds for radiant systems and underfloor air distribution systems and do not treat natural ventilation systems that involve air flow between zones.)

The work reported here has resulted in the public release of Simergy v1.0, providing California design practitioners with a free tool that enables them to make efficient use of the low energy

[6] California Investor Owned Utilities include Pacific Gas & Electric, Southern California Edison, Southern California Gas, and San Diego Gas and Electric

systems modeling capabilities of EnergyPlus. More energy-efficient building design is expected to lead to lower actual building energy consumption, which benefits California by helping to mitigate climate change, reduce air pollution and reduce utility bills. A further benefit of the work reported here is that the release of Simergy provides California design practitioners with the means to use the design analysis engine, EnergyPlus, that is the basis for performance-based compliance with Title 24 starting in July, 2014.

CHAPTER 5:
Conclusions and Recommendations

A new, comprehensive graphical user interface (GUI) for EnergyPlus – Simergy – has reached an advanced stage of development. User requirements were defined through a series of workshops for practitioners. Simergy includes a 'drag and drop' component-level schematic editor for HVAC systems. Building envelope geometry can be imported from CAD / BIM tools using IFC's or gbXML or can be generated by Simergy. A rule-based data validation framework has been included to support checking of the model for compliance with the modeling rules for EnergyPlus. Development of a comprehensive set of templates and libraries is at an advanced stage, with the major building types and construction assembles essentially complete. An interactive output reporting framework has also been implemented. Version 1.0 of Simergy was released in July, 2013 and an update release is planned for early in the second quarter of 2014.

Simergy is a significant improvement on existing EnergyPlus graphical user interface tools in terms of user workflow and productivity. The strong interest in Simergy in the architecture and engineering community and the new role of EnergyPlus as the primary reference model for Title 24 indicate that Simergy can be expected to increase the use of EnergyPlus by design practitioners. Use of EnergyPlus enables the design of more efficient buildings than do simulation tools based on the DOE-2 engine because EnergyPlus supports the analysis of a wider range of low energy systems, including natural ventilation, radiant cooling and underfloor air distribution. More energy-efficient building design is expected to lead to lower actual building energy consumption, which benefits California by helping to mitigate climate change, reduce air pollution and reduce utility bills.

It is recommended that the Energy Commission continue to support the development of Simergy, both through direct funding and by continuing to advocate for the support and adoption of Simergy, in particular by the California Public Utilities Commission and investor- and publicly owned utilities. Specific areas for further development of Simergy include:

- Early stage design (as discussed in Section 3.2)
- Automated performance-based code compliance analysis (as discussed in Section 3.3)
- Application to existing buildings:
    - Model-based retro-commissioning
    - Retrofit analysis
    - Retrofit measure commissioning
    - Model-based performance monitoring and fault detection

A generic area that would benefit from further R&D is visualization of building performance, whether measured or predicted by simulation. This is particularly applicable to building operations and to early stage design, where there is also a need for effective visualization of climate data. A related area, discussed in Section 3.2, is the visualization of climate data. There is a need to identify or develop standard ways of presenting both climate and building

performance data that will become familiar to practitioners and enable ready understanding of these complex types of data.

GLOSSARY

Term	Definition
BIM	Building Information Model
CAD	Computer aided design
CBECC-Com	California Building Energy Code Compliance Non-Residential
DOE	U.S. Department of Energy
gbXML	Green building extensible mark-up language
GUI	Graphical user interface
HVAC	Heating, ventilation and air-conditioning
IDF	Input Data File (EnergyPlus)
IFC	Industry Foundation Classes
NREL	National Renewable Energy Laboratory
PIER	California Energy Commission Public Interest Energy Research Program
R&D	Research and development
RD&D	Research, development, and demonstration
SDD	Standards Data Dictionary
SDK	Software development kit

REFERENCES

ASHRAE, 2013, ANSI/ASHRAE/IES Standard 90.1-2013 -- Energy Standard for Buildings Except Low-Rise Residential Buildings, ASHRAE, Atlanta, GA.

BuildingSMART, 2011. http://buildingsmart-tech.org/

CBECC-Com, 2014 /http://bees.archenergy.com/

Climate Consultant, 2014. http://www.energy-design-tools.aud.ucla.edu/

Comfen, 2014. http://windows.lbl.gov/software/comfen/comfen.html

Ecotect, 2014. http://usa.autodesk.com/ecotect-analysis/

EnergyPlus, 2014. http://www.energyplus.gov/

gbXML.org, 2011. http://www.gbxml.org/

Olgay, V. and Olgay, A. 1963. *Design with climate: bioclimatic approach to architectural regionalism.* Princeton University Press, Princeton, NJ.

OpenStudio, 2014. http://openstudio.nrel.gov/

Radiance, 2014. http://radsite.lbl.gov/radiance/framew.html

See, R., Haves, P., Sreekanthan, P., Basarkar, M. and Settlemyre, K. "Development of a Comprehensive User Interface for the EnergyPlus Whole Building Energy Simulation Program." *Proc. Building Simulation '11*, Sydney, Australia, November 2011