FLORIDA SOLAR ENERGY CENTER®

Creating Energy Independence

Advancement of DOE's EnergyPlus Building Energy Simulation Program

FSEC-CR-1899-11

Final Technical Report for
DOE Project # DE-FC26-04NT42768
UCF/FSEC 20126036
Reporting Period: April 2006 - September 2011

September 30, 2011

Submitted to:

Paul Giles
National Energy Technology Laboratory
626 Cochran's Mill Road, P. O. Box 10940
Pittsburgh, PA 15236-0940

Submitted by

Lixing Gu
Don Shirey
Richard Raustad
Bereket Nigussie
Chandan Sharma
Florida Solar Energy Ctr

Linda Lawrie
DHL Consulting
Rick Strand
University of Illinois
Curt Pedersen
COPA

Dan Fisher
Edwin Lee
Oklahoma State U
Mike Witte
Jason Glazer
GARD Analytics
Chip Barnaby
Wrightsoft

1679 Clearlake Road
Cocoa, Florida 32922, USA
(321) 638-1000

www.floridaenergycenter.org

A Research Institute of the University of Central Florida

Disclaimer

This report was prepared with the support of the U.S. Department of Energy (DOE), under Award No. DE-FC26-04NT42768. However, any opinions, findings, conclusions, or recommendations expressed herein are those of the author and do not necessarily reflect the views of the DOE.

The Florida Solar Energy Center/University of Central Florida nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the Florida Solar Energy Center/University of Central Florida or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the Florida Solar Energy Center/University of Central Florida or any agency thereof.

ACKNOWLEDGEMENTS

The authors thank the National Energy Technology Laboratory and the project managers, Paul Giles and Jeffrey Kooser, for funding this work. Sincere appreciation is expressed to Amir Roth, the acting program manager for building performance simulation tools at DOE's Building Technologies Program for providing valuable guidance to the project development. Authors also express sincere thanks to Drury Crawley, the Building Performance Products Director at Bentley Systems, Inc. and the former program manager for building performance simulation tools at DOE's Building Technologies Program for providing extensive guidance we need to perform the work successfully.

EXECUTIVE SUMMARY

EnergyPlus™ is a new generation computer software analysis tool that has been developed, tested, and commercialized to support DOE's Building Technologies (BT) Program in terms of whole-building, component, and systems R&D (<http://www.energyplus.gov>). It is also being used to support evaluation and decision making of zero energy building (ZEB) energy efficiency and supply technologies during new building design and existing building retrofits.

The 5-year project was managed by the National Energy Technology Laboratory and was divided into 5 budget period between 2006 and 2011. During the project period, 11 versions of EnergyPlus were released. This report summarizes work performed by an EnergyPlus development team led by the University of Central Florida's Florida Solar Energy Center (UCF/FSEC). The team members consist of DHL Consulting, C. O. Pedersen Associates, University of Illinois at Urbana-Champaign, Oklahoma State University, GARD Analytics, Inc., and WrightSoft Corporation.

The project tasks involved new feature development, testing and validation, user support and training, and general EnergyPlus support. The team developed 146 new features during the 5-year period to advance the EnergyPlus capabilities. Annual contributions of new features are 7 in budget period 1, 19 in period 2, 36 in period 3, 41 in period 4, and 43 in period 5, respectively. Table 1 lists new feature titles divided arranged by category. The testing and validation task focused on running test suite and publishing report, developing new IEA test suite cases, testing and validating new source code, addressing change requests, and creating and testing installation package. The user support and training task provided support for users and interface developers, and organized and taught workshops. The general support task involved upgrading StarTeam (team sharing) software and updating existing utility software.

The project met the DOE objectives and completed all tasks successfully. Although the EnergyPlus software was enhanced significantly under this project, more enhancements are needed for further improvement to ensure that EnergyPlus is able to simulate the latest technologies and perform desired HVAC system operations for the development of next generation HVAC systems. Additional development will be performed under a new 5-year project managed by the National Renewable Energy Laboratory.

Table 01 A summary of new features developed in the project

Category	New features
General	Review of Entire EnergyPlus Code Review of EnergyPlus Source Code and Utility Programs Reduce computational time Implement Double-Precision Real Variables Throughout Code Enhance Weather Processor Enhance Existing Design Day Object Reduce Computational Time Enhance the Weather Processing Program Warm-up Convergence Improvements Document Developer Test Suite Run Requirements and Details Perform Simulations in Parallel Update ASHRAE Weather Data Procedures Integration of AutoDesk code donation
Datasets	Develop Equipment Performance Data Sets for Certain Equipment Types

Input	Develop New Input Verification and Result Summary Reports Flexible Corner Starting Positions Add Input Flexibility for Internal Gains and Ventilation/Infiltration Objects Compact HVAC Extensions Revise Object & Input Field Naming Conventions Global People, Lights, Thermostats for Building Eliminate Redundant Input in Selected Compound Objects Deprecate Supply Air Fraction Field From Unitary System Objects HVACTemplate Extensions Tabular Performance Inputs
Windows and Daylighting	Rework of Shadowing Algorithms for More Complex Geometries Integrate ASHWAT Shaded Fenestration Model Into EnergyPlus
Zone and Surface Models	Investigate Algorithms for Modeling Airflow Through Large Horizontal Openings Enhance VENTILATION, MIXING and CROSS MIXING Objects Add Model for Thermal Chimneys Enhance the Ventilated Slab Model Add Source/Sink Capability in Conduction Finite Difference Model Complete Interzone IR Radiation Exchange Model Allow Alternate Method for Inputting Rectangular Surfaces Add Capability for Checking Solution Algorithms Based on the ASHRAE RP1052 Workbook Expanded Variable Thermal Conductivity Option Stand-Alone Room Air Dehumidifier Model Research Zone Heat Balance Solution Techniques to Reduce Time Step Dependence Add Model for Zone Makeup Air Units Construction Specific Solution Algorithms Extend CondFD Solution Algorithm to Transparent Insulation Verify Zone Multipliers/ Groups CTF Improvements Integration of ASHRAE RP-1383 Models Complete Extension of CondFD Solution Algorithm to Transparent Insulation Improve Solar Shading and Interior Solar Distribution Calculations Refactor Triangulation Routine for >4 sided Surfaces Add Analytical Solution to Zone Air Heat Balance Model CO ₂ Concentration and Controls
Natural and Mechanical Ventilation	Model for Hybrid (Mixed-Mode) Ventilation Systems Additional Hybrid (Mixed-mode) Ventilation Controls Resolve Conflicts Between Multiple System Modify AirflowNetwork Height-Dependent Wind Speed Model Implement Airflow Model for Large Horizontal Openings Simplified Natural Ventilation Model Based on Physical Correlation and Opening Size Simplified Model of Interaction between Mechanical Ventilation, Infiltration and Duct Leakage
HVAC	Additional Air-Side Economizer Controls Enhance Air Distribution System Model to Include More Coil Types Enhance Existing DXSystem:AirLoop Object Allow Absorption Chiller Connection to a Steam Loop Enhance Existing Boiler Model for Condensing Boilers Improve Control for Unitary/Furnace Systems under Low-load Conditions Enhance Unitary System Model for 2-Speed Systems Reorganize Condenser Loop Simulation Add Model for Piping Pressure Drop Add Models for Dry and Evaporative Fluid Coolers Enhancements to Plant Flow Resolver Add Model for CoolTowers Enhanced Feature for Furnace/Unitary Systems to Allow High Humidity Control with Cycling Supply Air Fan Removal of Dual Control Layers for Radiant Systems Radiant System Condensation Handling Improvements Add Piping Pressure Drop Model and Improved Pump Model Plant Demand Side Equipment Simulation Enhancement Enhance Air Distribution System Model to Include More Component Types Enhance On/Off Fan Energy Calculations Improved Bypass Control for Air-to-Air Flat Plate Heat Exchangers Add Basin Heater to Remaining Cooling Towers and Evaporative Condensers Unify Coil Arrangement for Unitary Systems Complete Deprecation of Fan Operating Mode from DX Coil Objects Add Water-to-Air Heat Pump Option for Zone Equipment Control of Minimum Air Flow Fraction for VAV Terminals

	<p>Enhance System Availability Managers to Control Zone Equipment Operation</p> <p>Improve Convergence Tolerance for Unitary Systems</p> <p>Primary-Secondary Variable Flow Cooling/Heating Plant Systems</p> <p>Upgrade Existing Furnace Model</p> <p>Upgrade Energy Recovery Ventilator Controls and Autosizing</p> <p>Improved Hydronic Loop Capacitance Model</p> <p>Enhanced Unit Ventilator Model</p> <p>Integrated Radiator/ Baseboard Heater Model</p> <p>Integrated and Non-Integrated Waterside Economizer</p> <p>Packaged Terminal Air Conditioner Model</p> <p>Enhanced Supply Air Fan Controls for Unitary Air Conditioners and Heat Pumps</p> <p>Model for Heat Losses and Gains to Water Distribution</p> <p>Convective/Radiant Electric Baseboard Model</p> <p>Convective-Only Baseboard Input/Output Improvements</p> <p>Supply/Return Loop Heat Transfer to Support CHP & District Heating</p> <p>Enhance Pipe Heat Transfer Solver</p> <p>Improved Pump Controls</p> <p>Variable Refrigerant Flow Heat Pump Model</p> <p>Add All-Off Equipment Operation Scheme Option for Plant and Condenser Loops</p> <p>Enhance Plant and Condenser Loop Component Models to Use Fluid Property Routines</p> <p>Upgrade/Enhance ZoneHVAC:IdealLoadsAirSystem Object</p> <p>New Setpoint Manager Accounting for Multiple Zone Impacts</p> <p>Add Overcool Option for High Humidity Control to Furnace/Unitary System</p> <p>Calculate Standard Ratings for Primary HVAC Components</p>
Output	<p>Enhance EnergyPlus Reporting</p> <p>Revise Report Variable and Meter Naming Conventions</p> <p>Add EnergyPlus Output Compatible with Radiance</p> <p>MathDiff for Table Reports</p> <p>Create Thermal Component Loads Report</p> <p>IP Units Option for Table Reports</p> <p>Refactor Output Variable Reporting</p> <p>TDD Pipe Illuminance Reporting</p> <p>Improve Tabular Output Reports</p>
Electrical Systems	<p>Add Wind Turbine Model</p> <p>Improve Electric Load Center Dispatch</p>
Economics	<p>Economic Enhancements</p> <p>Dual-Setpoint Humidistat with Deadband</p> <p>Phase II EMS-Style Controls at the Cooling/Heating Plant Component and “Loop” Levels</p>
Controls and User Functions	<p>Energy Management System Controls</p> <p>Availability Managers and Multiple Set Point Managers</p> <p>Complete Phase 2 EMS-Style Controls at Cooling/Heating Plant Component and “Loop” Levels</p>
Utilities	<p>Add Objects for Code Compliance</p> <p>Equipment Performance Curve Fit Tool</p> <p>EP-Launch – Integrate Basement and Slab with EnergyPlus</p> <p>Auto-Rotate Building and Average Simulation Results Simulation</p> <p>Develop Utility to Compare Results from Multiple Simulations</p> <p>Develop Utility to Simplify Parameter Substitution Across Multiple Simulations</p> <p>Upgrade VB 6.0 Utilities to New Programming Language/ Environment for Windows, Linux and Macintosh</p> <p>EP-Launch – Run Multiple Simulations Simultaneously on Multi-Core Processors</p> <p>EP-Launch – Improve Output File Management</p> <p>IDF Editor – Enhanced Cross Referencing of Objects</p> <p>IDF Editor – Improve Node Entry and Management</p>

TABLE OF CONTENTS

Introduction	1
Summary of new feature development	3
New features in Budget Period 1 (2006-2007)	3
New features in Budget Period 2 (2007-2008)	4
New features in Budget Period 3 (2008-2009)	7
New features in Budget Period 4 (2009-2010)	12
New features in Budget Period 5 (2010-2011)	18
Summary of testing and validation	25
Testing and validation tasks in Budget Period 1 (2006-2007)	25
Testing and validation tasks in Budget Period 2 (2007-2008)	26
Testing and validation tasks in Budget Period 3 (2008-2009)	27
Testing and validation tasks in Budget Period 4 (2009-2010)	27
Testing and validation tasks in Budget Period 5 (2010-2011)	28
Summary of user support and training	30
User support and training tasks in Budget Period 1 (2006-2007)	30
User support and training tasks in Budget Period 2 (2007-2008)	30
User support and training tasks in Budget Period 3 (2008-2009)	31
User support and training tasks in Budget Period 4 (2009-2010)	31
User support and training tasks in Budget Period 5 (2010-2011)	32
Summary of general EnergyPlus support	33
General EnergyPlus support tasks in Budget Period 1 (2006-2007)	33
General EnergyPlus support tasks in Budget Period 2 (2007-2008)	34
General EnergyPlus support tasks in Budget Period 3 (2008-2009)	34
General EnergyPlus support tasks in Budget Period 4 (2009-2010)	34
General EnergyPlus support tasks in Budget Period 5 (2010-2011)	35
Conclusions	37

Appendix A New Features.....	39
New Features in Version 6.0.0	39
General	39
Datasets	39
Input	39
Windows and Daylighting	39
Zone and Surface Models.....	39
Natural and Mechanical Ventilation	39
HVAC	40
Refrigeration.....	40
Electrical Systems	40
Controls and User Functions	40
Economics.....	40
Output	40
Utilities.....	41
Platforms	41
New Features in Version 5.0.0	41
Datasets	41
Input	41
Geometry/Window/Wall/Shading	41
Daylighting	41
Zone Model	41
Natural and Mechanical Ventilation	41
HVAC and Refrigeration	42
Electrical Systems	42
Controls and User Functions	42
On-Site Energy Supply	42
Output	42

Utilities.....	42
Documentation and Guides	42
Validation and Testing	43
Platforms	43
New Features in Version 4.0.0	43
Datasets	43
Design Day.....	43
Input	43
Geometry/Window/Wall/Shading	43
Natural and Mechanical Ventilation	43
HVAC	43
Controls and User Functions	44
Environmental Impacts	44
Output	44
Utilities.....	44
Documentation and Guides	44
Validation and Testing	44
Platforms	45
New Features in Version 3.1.0	45
Input	45
Daylighting	45
Zone Model	45
Natural and Mechanical Ventilation	45
HVAC	45
Output	46
Utilities.....	46
Documentation and Guides	46
New Features in Version 3.0.0	46

Data Sets	46
Input	46
Zone Model	47
Natural and Mechanical Ventilation	47
HVAC	47
On-Site Energy Supply	48
Economics.....	48
Output	48
Utilities.....	48
Documentation and Guides	48
New Features in Version 2.2.0	48
Data Sets	48
Daylighting	48
Design Day.....	49
Input	49
Zone Model	49
Natural and Mechanical Ventilation	49
HVAC	49
On-Site Energy Supply	49
Environmental Impacts	50
Output	50
Utilities.....	50
Documentation and Guides	50
New Features in Version 2.1.0	50
Data Sets	50
Input	50
Geometry/Window/Wall/Shading	50
Zone Model	50

Natural and Mechanical Ventilation	50
HVAC	50
Output	51
Utilities.....	51
Documentation and Guides	51
New Features in Version 2.0.0	51
Data Sets	51
Input	52
Geometry/Window/Walls/Shading	52
Zone Model	52
Natural and Mechanical Ventilation	52
HVAC	52
Water Manager.....	53
On-Site Energy Supply	53
Output	53
Utilities.....	53
Documentation and Guides	53
Appendix B Milestones	54
Appendix C Concise list of deliverables	56
Appendix D A List of Supporting Documentations.....	70
Appendix E Publications	72
Papers.....	72
Testing Reports.....	72

Introduction

EnergyPlus is a building energy simulation program that focuses on improving the energy efficiency and long term economic feasibility of buildings. EnergyPlus has been recognized worldwide for its excellence in technical ability to accurately model buildings.

EnergyPlus was initially released in April 2001, with 9 additional releases before this project started in 2006. However, the simulation program was still lacking sufficient capabilities to meet the DOE Building Technology (BT) multi-year plan objective as the primary calculation engine for evaluating the design and operating energy performance of integrated low- and zero-energy building including control sensors, strategies, and systems. The specific objectives required by DOE BT for this project during its five year period are given below:

- Continue the development of EnergyPlus by adding features that will make the program better to model a variety of buildings including those that incorporate existing and advanced technologies, keeping the program at the cutting edge of simulation technology.
- Provide help for those actually using the program in the design process and also aid others who are also attempting to expand the capabilities of the program for research purposes.
- Promote and expand the use of the EnergyPlus program among the general public.
- Support DOE's goals for improving the energy efficiency of the national building stock on the way to its target of 'zero energy buildings' (ZEB).

The project was performed by an EnergyPlus development team led by the University of Central Florida's Florida Solar Energy Center (UCF/FSEC). The team members consist of DHL Consulting, C. O. Pedersen Associates, University of Illinois at Urbana-Champaign, Oklahoma State University, GARD Analytics, Inc. and WrightSoft. WrightSoft joined the team in 2009 and performed two subtasks.

This project addresses the BT specific objectives by four main tasks: new feature development, testing and validation, user support and training, and general EnergyPlus support. Since this report will include efforts during a five year period, it is necessary to provide only a summary of work to make the report relatively concise. The detailed work was documented in all EnergyPlus manuals, references and publications (Appendixes D and E).

Section "Summary of new feature development" provides a summary of new features developed during the project period. Five main sub-sections present new features based on yearly budget period. Each new feature contains task title, developer institution name, and a scope and completion date. Section "Summary of testing and validation" presents a summary of performed tasks to ensure that simulation results maintain a high level of accuracy. Testing reports were published for each EnergyPlus version release. Section "Summary of user support and training" shows a summary of the team efforts to support requests, hold training courses, present current research to professional groups, improve program documentation, notify other model and interface developers of on-going work and upcoming changes to the program, and correct problems found in the program. Section "Summary of general EnergyPlus support" provides a summary of team efforts to upgrade and maintain StarTeam software and update exiting utility software.

The report has five appendixes. Appendix A provides a list of new features of each release from Version 2.0 to Version 6.0. In addition to the formal releases, an interim version 6.0.0.037 was released in May, 2011. Appendix B shows milestones during the project period. Appendix C presents a concise list of deliverables. Appendix D shows a list of documentations to help users understand the program. Appendix E provides a list of publications supported by the project.

Summary of new feature development

The new feature development includes review of existing technology, development of simulation models for new program capabilities, and coding of improvement to the simulation environment to enhance usability, run times, and expandability.

The 5-year project was divided into five budget periods. All new features were defined in each budget period in the project. The report provides a list of new feature summaries based on budget periods. Each period-based summary includes a list of tasks in the corresponding budget period. Each task consists of task title, institution name that implemented this task, a brief statement of work, and completed date.

New features in Budget Period 1 (2006-2007)

There are seven new features in the budget period 1.

TASK 1: EnergyPlus Development (Budget Period 1)

Subtask 1.1: Primary-Secondary Variable Flow Cooling/Heating Plant Systems (OSU, UIUC)

Scope: The Recipient shall implement the ability to model both constant primary-variable secondary, and variable primary-constant secondary plant loop systems. These models will be implemented in the enhanced plant loop managers that were previously developed. Constant primary-variable secondary systems will be ported from the old loop managers, and variable primary-constant secondary systems will be developed in an analogous manner. The models will be developed to facilitate extension to other more complex loop topologies (primary-secondary-tertiary).

Accomplishments: Completed 3/07

Subtask 1.2: Energy Management System Controls (OSU)

Scope: The Recipient shall work closely with the National Renewable Energy Laboratory (NREL) to add energy management system (EMS) modeling capabilities to EnergyPlus. NREL, through other DOE funding, will be the overall task leader and be responsible for developing EMS "monitoring" capabilities (e.g., weather, zone conditions, and equipment operation), design of the user-modifiable parameters, and the generalized framework for alternate controls and demand limiting. The Recipient shall provide critical support by developing the basic schema for supervisory control of plant equipment, and developing plant manager/EMS communication protocols and data structures.

Accomplishments: Completed 7/07.

Subtask 1.3: Upgrade Existing Furnace Model (UCF/FSEC)

Scope: The Recipient shall implement the following specific upgrades to the existing EnergyPlus furnace/unitary system model: 1) allow control of the furnace/unitary system air reheat coil based on the zone heating set point instead of the cooling set point, 2) upgrade the solution algorithm to increase its robustness in the heat-only furnace and water-to-air heat pump unitary system models, and 3) perform general code reorganization to ease future development and maintenance.

Accomplishments: Completed 8/07

Subtask 1.4: Upgrade Energy Recovery Ventilator Controls and Autosizing (UCF/FSEC)

Scope: The Recipient shall implement a new control strategy for the existing ERV model in EnergyPlus. The new ERV control strategy will boost ventilation air flow rates through ERV systems in response to elevated indoor humidity levels. In collaboration with and assistance from Lawrence Berkeley National Laboratory (LBNL), the Recipient shall

also add the capability to autosize ERV equipment based on the occupancy and/or floor area for the zone being served by this equipment.

Accomplishments: Completed 11/07

Subtask 1.5: Envelope Finite Difference Module (COPA)

Scope: The Recipient shall add the capability to model nonlinear surface material properties, including both temperature dependence and phase change behavior. This new finite difference module will serve as an alternate calculation method to the existing conduction transfer function method.

Accomplishments: Completed 07/07.

Subtask 1.6: Develop New Input Verification and Result Summary Reports (GARD)

Scope: The Recipient shall create input verification and result summary reports for EnergyPlus that may be used to document energy code compliance and beyond-code performance. The format of the reports would be aimed at businesses seeking the energy efficient commercial building tax deduction that appears in the Energy Policy Act of 2005 as well as other beyond-code programs such as U.S. Green Building Council's Leadership in Energy and Environmental Design (USGBC LEED) and American Society of Heating Refrigerating and Air-Conditioning Engineers' (A.S.H.R.A.E.) Advanced Energy Design Guide.

Accomplishments: Completed 9/06

Subtask 1.7: Improved Hydronic Loop Capacitance Model (OSU)

Scope: The Recipient shall improve the existing hydronic loop capacitance model in EnergyPlus. The existing model will be evaluated and compared with more detailed models, and the existing model will be improved as necessary to achieve better accuracy, especially for large hydronic systems (e.g., hydronic systems for large commercial buildings and district cooling/heating systems).

Accomplishments: Completed 9/07).

New features in Budget Period 2 (2007-2008)

TASK 5: EnergyPlus Development (Budget Period 2)

Subtask 5.1: Ventilated Slab Model (UIUC)

Scope: The Recipient shall implement a ventilated slab model based on the existing low temperature radiant system model. The model will include simple controls such as nighttime ventilation.

Accomplishments: Completed 12/07.

Subtask 5.2: Enhanced Unit Ventilator Model (UIUC)

Scope: The Recipient shall implement enhancements to the existing unit ventilator model as requested by numerous EnergyPlus users. These will include specification of a unit ventilator with no coil to model unconditioned ventilation air and the addition of fixed outside air controls.

Accomplishments: Completed 03/07.

Subtask 5.3: Integrated Radiator/Baseboard Heater Model (UIUC)

Scope: The Recipient shall implement a model allowing a baseboard or radiator to interact with the building surfaces through a radiant heat transfer component. The new temperature-controlled baseboard/radiator model will affect surface heat balances and thus play a role in thermal comfort predictions within the space.

Accomplishments: Completed 12/07.

Subtask 5.4: Rework of Shadowing Algorithms for More Complex Geometries (DHL)

Scope: The Recipient shall perform verification studies of the EnergyPlus shadowing algorithms for polygonal exterior shading surfaces (>4 sides) and add more reporting (e.g., shadowing profile). The shadowing algorithms will be modified as necessary.

Accomplishments: Completed 10/07

Subtask 5.5: Integrated and Non-Integrated Waterside Economizer (OSU)

Scope: The Recipient shall implement some new supervisory controls and enhance existing controls to properly sequence existing component models (plate heat exchanger and cooling tower) and coordinate their operation with the existing water chiller models.

Accomplishments: Completed 12/07.

Subtask 5.6: Packaged Terminal Air Conditioner Model (UCF/FSEC)

Scope: The Recipient shall implement a model for packaged terminal air conditioners which use a direct-expansion (DX) cooling coil and electric, gas, or hydronic heating.

Accomplishments: Completed 08/07.

Subtask 5.7: Enhanced Supply Air Fan Controls for Unitary Air Conditioners and Heat Pumps (UCF/FSEC)

Scope: The Recipient shall implement a new method for controlling the supply air fan operating mode (continuous operation versus cycling) based on a time-of-day schedule. This enhancement will be applied to the existing models for window air conditioners, packaged terminal heat pumps, furnaces and unitary systems, and the new packaged terminal air conditioner model (Subtask 5.6 above).

Accomplishments: Completed 11/07.

Subtask 5.8: Enhance the Gas Engine Heat Pump Model (UCF/FSEC)

Scope: The Recipient shall upgrade the gas engine heat pump model being developed under another DOE/NETL award to provide additional model flexibility and to support product development work at Oak Ridge National Laboratory (ORNL).

Accomplishments: Completed 01/08.

Subtask 5.9: Dual-Setpoint Humidistat with Deadband (UCF/FSEC)

Scope: The Recipient shall add the capability to specify a zone air controller with dual humidity setpoints and a deadband in between.

Accomplishments: Completed 12/07.

Subtask 5.10: Model for Hybrid (Mixed-Mode) Ventilation Systems (UCF/FSEC)

Scope: In collaboration with Lawrence Berkeley National Laboratory (LBNL), the Recipient shall add the capability to model hybrid (mixed-mode) ventilation systems which use natural ventilation to reduce mechanical ventilation and cooling/heating requirements.

Accomplishments: Completed 08/07.

Subtask 5.11: Model for Heat Losses and Gains to Water Distribution Systems (OSU, UCF/FSEC)

Scope: The Recipient shall add the capability to model heat losses and gains to water distribution systems. This will include a steady-state conduction model for heat loss/gain to air, and a first-order model for heat loss to the ground (buried pipes). OSU will lead this task, with collaborative assistance from UCF/FSEC.

Accomplishments: Completed 9/07.

Subtask 5.12: Phase II EMS-Style Controls at the Cooling/Heating Plant Component and “Loop” Levels (OSU)

Scope: The Recipient shall implement energy management system (EMS) controls at the cooling/heating plant component level (e.g., chillers, boilers, pumps, water-to-water heat pumps) and the “loop” level (e.g., turn off an entire water loop, including all associated chillers, pumps, etc. on that loop). This is the second phase of work started in FY06 (Subtask 1.2) and will include collaboration with both the National Renewable Energy Laboratory (NREL) and Lawrence Berkeley National Laboratory (LBNL).

Accomplishments: Completed 03/08.

Subtask 5.13: Model for Interzone IR Radiation Exchange (COPA)

Scope: The Recipient shall implement a model for interzone infrared (IR) radiation exchange. This will likely involve introducing special IR transparent (IRT) surfaces to link adjacent zones.

Accomplishments: Completed 12/07.

Subtask 5.14: Compact HVAC Extensions (GARD)

Scope: The Recipient shall expand the number of air distributions systems, plant arrangements, and equipment components supported by Compact HVAC. “Compact HVAC” objects allow standard HVAC configurations to be expanded into full EnergyPlus HVAC inputs with minimal user entries. The focus will be on ASHRAE Std. 90.1 Appendix G baseline systems such as PAVS, PTAC and PTHP plus plant configurations, including primary-secondary loops, domestic hot water, thermal storage, branch pumps, headered pumps, etc. The specific systems, equipment arrangements, and components to be added will be selected in close consultation with DOE.

Accomplishments: Completed 9/07.

Subtask 5.15: Enhance Airflow Network Model to Include Dedicated Zone Exhaust Air (UCF/FSEC)

Scope: The Recipient shall enhance the existing airflow network model to include dedicated zone exhaust air fans (e.g., bathroom and kitchen exhaust fans).

Accomplishments: Completed 3/07.

Subtask 5.16: Enhance Existing Air Distribution System Model: Add More Coil, Fan and Terminal Unit Choices (UCF/FSEC)

Scope: The Recipient shall enhance the existing air distribution system modeling capabilities by adding more cooling coil, heating coil, fan, and terminal unit selections. The specific new component choices to be added will be determined in close consultation with DOE.

Accomplishments: Completed 3/07).

Subtask 5.17: Verification and Summary Report Extensions (GARD)

Scope: The Recipient shall extend the verification and summary reports developed under Subtask 1.6. The specific reporting features to be added will be selected in close collaboration with DOE.

Accomplishments: Completed 8/07.

Subtask 5.18: Review of Entire EnergyPlus Code (UCF/FSEC, UIUC, OSU, DHL, GARD, COPA)

Scope: The Recipient shall undertake a thorough review of the entire EnergyPlus code to evaluate which simulation modules should be updated or replaced beginning in FY2008. LBNL and NREL will also participate in this activity. A report summarizing the results will be submitted by February 2007.

Accomplishments: Completed 4/07.

Subtask 5.19: Reduce Computational Time (DHL)

Scope: The Recipient shall work closely with LBNL to increase the computational speed of EnergyPlus. The Recipient will profile example executions to identify the most time-consuming modules/routines, develop appropriate changes without compromising code readability, then implement and test the changes.

Accomplishments: Completed 12/07.

New features in Budget Period 3 (2008-2009)

TASK 9: EnergyPlus Development (Budget Period 3)

Subtask 9.1.1: Additional Air-Side Economizer Controls (UCF/FSEC)

Scope: The Recipient shall add additional air-side economizer controls to allow a high dewpoint temperature and electronic enthalpy limit for economizer operation. These specific economizer controls support ASHRAE Standard 90.1 and California Title 24.

Accomplishments: Completed 1/08.

Subtask 9.1.2: Enhance Existing Air Distribution System Model to Include More Coil Types (UCF/FSEC)

Scope: The Recipient shall enhance the existing air distribution system modeling capabilities by adding more coil selections. The specific coil types to be added will be determined in close consultation with DOE.

Accomplishments: Completed 2/08.

Subtask 9.1.3: Investigate Algorithms for Modeling Airflow through Large Horizontal Openings (UCF/FSEC)

Scope: The Recipient shall investigate algorithms for modeling air flow through large horizontal openings. The outcome will be a new feature proposal that describes options for implementation.

Accomplishments: Completed 10/08

Subtask 9.1.4: Enhance Existing DXSystem:AirLoop Object (UCF/FSEC)

Scope: The Recipient shall enhance the existing DXSystem:AirLoop object to allow high humidity control (overcool/reheat) for additional cooling coil types. Specifically the Recipient shall allow the cool-reheat dehumidification control when a Coil:DX:CoolingBypassFactorEmpirical or Coil:DX:CoolingHXAssisted object is used.

Accomplishments: Completed 1/08.

Subtask 9.1.5: Additional Hybrid (Mixed-mode) Ventilation Controls (UCF/FSEC)

Scope: The Recipient shall enhance the capabilities of the existing hybrid (mixed-mode) ventilation model. Enhancements may include coordination of HVAC system operation with the simple Ventilation object, provide global control of window and door openings, additional control combinations (temperature and enthalpy), and new findings from the Center for the Built Environment (actual control strategies being used in building applications). The specific enhancements to be implemented will be determined in close consultation with DOE.

Accomplishments: Completed 9/08.

Subtask 9.1.6: Allow Absorption Chiller Connection to a Steam Loop (UCF/FSEC)

Scope: The Recipient shall enhance the absorption chiller model to allow a steam loop to be used as the heat source.

Accomplishments: Completed 6/08.

Subtask 9.1.7: Enhance Existing Boiler Model for Condensing Boilers (UCF/FSEC)

Scope: The Recipient shall enhance the existing boiler model to more accurately simulate the performance of a condensing boiler.

Accomplishments: Completed 7/08.

Subtask 9.1.8: Resolve Conflicts Between Multiple System Availability Managers and Multiple Set Point Managers (UCF/FSEC)

Scope: The Recipient shall implement a method for dealing with conflicting System Availability Manager and Set Point Manager objects. The program currently has no method to resolve conflicts – the last manager executed establishes the system availability or set point.

Accomplishments: Completed 8/08

Subtask 9.1.9: Improve Control for Unitary/Furnace Systems under Low-load Conditions (UCF/FSEC)

Scope: The Recipient shall revise the current control methodology for meeting the predicted zone load to include the impact of ventilation air when the supply air fan operates continuously.

Accomplishments: Completed 12/08.

Subtask 9.1.10: Enhance VENTILATION, MIXING and CROSS MIXING Objects (UCF/FSEC)

Scope: The Recipient shall add the capability to specify multiple Ventilation and Infiltration objects for a zone. In addition, the controls for the Mixing and CrossMixing objects will be enhanced (e.g., add temperature limits that control when Mixing or CrossMixing is modeled).

Accomplishments: Completed 7/08.

Subtask 9.1.11: Enhance Unitary System Model for 2-Speed Systems (UCF/FSEC)

Scope: The Recipient shall enhance the existing unitary system model to account for air distribution system leakage for two-speed constant air volume systems.

Accomplishments: Completed 9/08.

Subtask 9.1.12: Reorganize Condenser Loop Simulation (OSU, UCF/FSEC)

Scope: The Recipient shall propagate the structures and algorithms recently implemented in the EnergyPlus 'plant' loop simulation to the 'condenser' loop simulation. These upgrades will include: headered pumps, loop and branch pumps, common pipes, enhanced flow resolution, enhanced setpoint managers, and enhanced loop load calculation algorithm.

Accomplishments: Completed 07/09..

Subtask 9.1.13: Add Model for Piping Pressure Drop (OSU)

Scope: The Recipient shall add a model for piping system pressure drop and an improved calculation for pump energy consumption.

Accomplishments: Completed 09/08.

Subtask 9.1.14: Add Models for Dry and Evaporative Fluid Coolers (OSU)

Scope: The Recipient shall implement new models for dry fluid coolers and evaporative fluid coolers. Both new models will be based on the existing cooling tower models and will utilize cooling tower features and source code where possible.

Accomplishments: Completed 08/08.

Subtask 9.1.15: Enhancements to Plant Flow Resolver (OSU)

Scope: The Recipient shall modify the plant loop flow resolver to make it completely independent of any particular loop manager. 'Flow Lock' logic will be packaged as an external function or subroutine that can be called by any new plant loop module. Existing plant loop modules will also be revised to call this new function/subroutine.

Accomplishments: Completed 12/08

Subtask 9.1.16: Implement Double-Precision Real Variables Throughout Code (DHL)

Scope: The Recipient shall implement double-precision real variables throughout the EnergyPlus source code. This will help avoid problems with outside developers compiling with single precision by mistake. Module developer documentation will be modified to define the proper syntax that should be used for future development.

Accomplishments: Completed 04/08.

Subtask 9.1.17: Enhance Weather Processor (DHL)

Scope: The Recipient shall enhance the EnergyPlus weather processor by adding a solar radiation model (e.g., calculate direct normal and diffuse solar radiation from cloud cover and other available data based on published algorithms) and extend the weather file format to include rainfall.

Accomplishments: Completed 06/09.

Subtask 9.1.18: Add Input Flexibility for Internal Gains and Ventilation/Infiltration/Mixing/CrossMixing Objects (DHL)

Scope: The Recipient shall add flexibility to EnergyPlus by allowing internal gains and ventilation/infiltration/mixing/crossmixing objects to be input on a per-unit-area or per-person basis as appropriate.

Accomplishments: Completed 04/08.

Subtask 9.1.19: Enhance Existing Design Day Object (DHL)

Scope: The Recipient shall add the capability for users to specify beam and diffuse solar profiles for design days. In addition, the capability to use one or more days from a weather file as a design day or design period will be added.

Accomplishments: Completed 04/08.

Subtask 9.1.20: Reduce Computational Time (DHL)

Scope: The Recipient shall work to increase the computational speed of EnergyPlus. The Recipient will profile example executions to identify the most time-consuming modules/routines, develop appropriate changes without compromising code readability, then implement and test the changes.

Accomplishments: Completed 11/08

Subtask 9.1.21: Add Model for CoolTowers (UIUC)

Scope: The Recipient shall add a model for a cooltower. A cooltower is a passive cooling system that brings dry, hot air into the top of a chimney-like structure, passes it through a wetted pad where it gains humidity but drops in temperature, and then allows the air (which is now dense due to the humidification) to naturally drop through the chimney and into the space. This natural cooling strategy provides cooling without the use of a fan. The only power consumed by the system is the power required to pump water up to the top of the tower to the wetted pad. The model will track cooling provided to individual spaces, water and power consumption, and other appropriate system variables. The new model will be linked into the air heat balance in a fashion similar to the current infiltration and simple ventilation models but will not be linked to an HVAC air loop as cooltowers are typically standalone systems.

Accomplishments: Completed 08/08.

Subtask 9.1.22: Add Model for Thermal Chimneys (UIUC)

Scope: The Recipient shall add a model for a thermal chimney. A thermal chimney is a device that uses stack driven air movement to ventilate spaces within a building. The air within a thermal chimney is heated naturally using solar energy. The air increases in temperature which causes its density to drop. This drop in density results in a natural vertical movement of air and a local drop in pressure. The drop in pressure is relieved by drawing air from the building interior, and the heat gained within the thermal chimney does not enter the occupied portion of the building. These

systems are often used in support of natural ventilation systems. The EnergyPlus model will seek to model the air heat balance effects of the thermal chimney, balance air movements caused by the thermal chimney, and report other appropriate system variables. The new model will be linked into the air heat balance in a fashion similar to the current infiltration and simple ventilation models but will not be linked to an HVAC air loop. A simple fan may be added to this model to reflect the need to potentially guarantee a particular air flow rate to various spaces. However, other sophisticated ventilation strategies can be handled by other existing EnergyPlus components.

Accomplishments: Completed 07/08.

Subtask 9.1.23: Enhance the Ventilated Slab Model (UIUC)

Scope: The Recipient shall complete the second phase of the ventilated slab model. This work includes the addition of several other control parameters [MRT (Mean Radiant Temperature), OPT (Operative Temperature), OWB (Outdoor Wet-Bulb Temperature), SUR (Surface Temperature), and DPTZ (Dew Point Temperature of Zone mean air temperature)] and the addition of two new system configurations (multiple slabs in series being served by the same air stream and having air from the system being routed through a zone after it goes through the ventilated slab).

Accomplishments: Completed 02/09

Subtask 9.1.24: Add Source/Sink Capability in Conduction Finite Difference Model(COPA)

Scope: The Recipient shall add the capability to model heat sources and heat sinks within a surface construction using the conduction finite difference model. This is primarily for floor and ceiling applications, and particularly for conditions where short time step control action is required.

Accomplishments: Completed 07/09.

Subtask 9.1.25: Complete Interzone IR Radiation Exchange Model (COPA)

Scope: The Recipient shall complete the interzone infrared (IR) radiation exchange model initiated during Budget Period 2. The IR radiation exchange will be accomplished by introducing special IR Transparent (IRT) surfaces to link adjacent zones. These surfaces will transmit the IR radiation incident on them to the surfaces in adjacent zones. The special surfaces will have no thermal resistance, and they will also have zero convective heat transfer coefficients on both sides.

Accomplishments: Completed 07/08.

Subtask 9.1.26: Compact HVAC Extensions (GARD)

Scope: The Recipient shall expand the number of air distribution systems, plant arrangements, and equipment components supported by Compact HVAC. "Compact HVAC" objects allow standard HVAC configurations to be expanded into full EnergyPlus HVAC inputs with minimal user entries. Potential system types include PVAVS, PSZ-HP, constant volume chilled water/hot water system, and dedicated outdoor air systems (DOAS), plus plant configurations, including domestic hot water, thermal storage, branch pumps, headered pumps, etc. The specific systems, equipment arrangements, and components to be added will be selected in close consultation with NETL/DOE.

Accomplishments: Completed 03/10

Subtask 9.1.27: Economic Enhancements (GARD)

Scope: The Recipient shall add the following enhancements to the economics capabilities of EnergyPlus: the capability to use and report sell-to-utility and net-metering utility tariffs; monthly reporting of energy or demand associated with each charge component; computation of real-time pricing rates on an hourly basis; and user-defined monetary unit.

Accomplishments: Completed 09/08.

Subtask 9.1.28: Enhance EnergyPlus Reporting (GARD)

Scope: The Recipient shall review and comment on the beta specification for the LEED-NC Credit 1 XML schema to ensure it has data fields that are compatible with EnergyPlus and will create a new XML file output in EnergyPlus that is compatible with the final LEED-NC Credit 1 XML schema. The Recipient shall also add timebin reports of common variables and selected monthly reports from the StandardReports.idf file to the list of predefined reports. Additional

reporting enhancements will be implemented with the goal of further supporting LEED and other beyond code programs. The specific reporting enhancements will be selected in close consultation with NETL/DOE.

Accomplishments: Completed 05/11

Subtask 9.1.29: Revise Object & Input Field Naming Conventions (UCF/FSEC, DHL, GARD)

Scope: Existing naming conventions are inconsistent and confusing. Improvements will be implemented to increase program usability. Strong feedback on this issue from workshop attendees (workshops held under Subtask 11.2).

Accomplishments: Completed 11/08.

Subtask 9.2: Allow Alternate Method for Inputting Rectangular Surfaces (DHL)

Scope: The Recipient shall add an alternate method of describing rectangular surfaces and subsurfaces using origin, tilt and azimuth, similar to the way surfaces were described in BLAST and DOE-2.1E.

Accomplishments: Completed 01/09.

Subtask 9.3: Add Capability for Checking Solution Algorithms Based on the ASHRAE RP1052 Workbook (COPA)

Scope: The Recipient shall develop a direct steady periodic boundary condition implementation within EnergyPlus. The advantage of using this capability is that it acts directly on the surface, and does not depend on other parts of the program. This capability will help users resolve differences in results obtained when using the conventional CTF solution algorithm and the CondFD solution algorithm.

Accomplishments: Completed 12/08.

Subtask 9.4: Expanded Variable Thermal Conductivity Option (COPA)

Scope: The Recipient shall expand the current temperature-dependent thermal conductivity model (within the existing Conduction Finite Difference Model) to incorporate piecewise linear functional behavior enabling changes in conductivity over small temperature differences. This enhancement will allow for improved modeling of a different thermal conductivity for the two phases of some phase change materials.

Accomplishments: Completed 07/09.

Subtask 9.5: Stand-Alone Room Air Dehumidifier Model (UCF/FSEC)

Scope: The Recipient shall add the capability for EnergyPlus to model stand-alone room air dehumidifiers.

Accomplishments: Completed 08/09.

Subtask 9.6: Enhanced Feature for Furnace/Unitary Systems to Allow High Humidity Control with Cycling Supply Air Fan (UCF/FSEC)

Scope: The Recipient shall expand the existing Furnace/Unitary System models to allow control of high indoor air humidity levels (based on a humidistat set point) when the system's supply air fan is allowed to cycle on and off during a simulation time step.

Accomplishments: Completed 12/08.

Subtask 9.7: Research Zone Heat Balance Solution Techniques to Reduce Time Step Dependence (UCF/FSEC)

Scope: The Recipient shall research the existing EnergyPlus Zone Heat Balance Model formulation and propose new methods of solving or reformulating model equations to remove the dependence of results on length of the zone time step. If time and budget permit, implement the new method or reformulated model equations based on option selected by EnergyPlus development team.

Accomplishments: Completed 03/09.

New features in Budget Period 4 (2009-2010)

TASK 13: EnergyPlus Development (Budget Period 4)

All but the following eight subtasks were previously completed. See previous progress reports for details.

Subtask 13.1.1: Revise Report Variable and Meter Naming Conventions (GARD, UCF/FSEC, DHL)

Scope: One of the major changes in version 3.0 of EnergyPlus (released in November 2008) was a wholesale revamping of the IDD/IDF naming structure. Many object names, field names, and choice field key values were revised to provide a more intuitive and consistent naming scheme. This subtask is a similar effort to revise the names used for output report variables and meters. NREL will assist with completing this subtask.

Accomplishments: Completed 07/11

Subtask 13.1.2: Review of EnergyPlus Source Code and Utility Programs (GARD, UIUC, COPA, DHL, OSU, UCF/FSEC)

Scope: The Recipient shall review the EnergyPlus source code and utility programs with the goal of identifying modules that should be updated or replace beginning in FY2010. LBNL, ORNL and NREL will also participate in this activity.

Accomplishments: Completed 05/09.

Subtask 13.1.3: Add Model for Zone Makeup Air Units (UIUC)

Scope: The Recipient shall evaluate the requirements for a "Zone Makeup Air Unit" and add modeling capabilities to EnergyPlus that allow the simulation of such devices. The new model should interact with the Zone Exhaust Fan (constant or variable speed) and allow multiple make up air units in a zone that can be tied to unique exhaust fans. In addition, the model should autosize for delivering neutral temperature air to the zone and should be general enough to model a zone-level dedicated outside air component (DOAS).

Accomplishments: Completed 03/10.

Subtask 13.1.4: Improved Controls for Combination Radiant/Convective Cooling Systems (UIUC)

Scope: In conjunction with Subtask 13.1.3, the Recipient shall implement controls into the new model for zone makeup units that allow improved simulation of combined conventional/radiant systems in EnergyPlus. The new zone air makeup unit needs to be configured to handle a sensible load, a purely latent load, the total load (sensible plus latent), or the maximum of the sensible and latent loads. The latent load only mode is necessary to work in conjunction with a radiant cooling system that handles the sensible space load. The other configurations will allow increased flexibility for makeup air system operation.

Accomplishments: Completed 03/10.

Subtask 13.1.5: Add Wind Turbine Model (UIUC)

Scope: The Recipient shall add a model to EnergyPlus that allows the simulation of wind turbine systems (both horizontal and vertical axis). The model should allow user input to modify the wind speed for surroundings and/or height or internal calculations to take these factors into account. UIUC will contact the National Renewable Energy Laboratory (NREL) to see if an appropriate existing model is available and coordinate efforts with NREL as necessary.

Accomplishments: Completed 01/10.

Subtask 13.1.6: Removal of Dual Control Layers for Radiant Systems (UIUC)

Scope: Currently in EnergyPlus, the radiant systems have two independent layers of controls. This is at times confusing for users. Therefore, the Recipient shall remove one layer of controls from the radiant systems so that they

only control on their own control logic rather than on the conventional forced-air thermostat logic. The radiant systems included in this subtask include the high temperature radiant heater, the low temperature hydronic radiant systems (constant and variable flow), and the low temperature electric radiant system.

Accomplishments: Completed 11/09.

Subtask 13.1.7: Radiant System Condensation Handling Improvements (UIUC)

Scope: The Recipient shall implement user controls over system shut-down due to moisture condensation. In addition, an optional input will be added to specify the tolerance between the actual dewpoint and lowest surface temperature allowed. The method for dealing with moisture condensation will also be improved in both the fixed and variable flow systems. Currently, both system types simply turn the system off when condensation is anticipated. This algorithm will be changed so that the systems attempt to keep running at a lower capacity. In the fixed flow system, the temperature sent to the system will be varied by recirculating more local flow. In the variable flow system, the flow to the radiant system will be reduced in an attempt to keep running but without resulting in condensation.

Accomplishments: Completed 08/11.

Subtask 13.1.8: Improvements to Existing Baseboard Radiator Model (UIUC)

Scope: The current output variables for hydronic baseboard/radiators include only energy related quantities. Under this subtask, additional output reporting variables will be added for fluid side temperatures (inlet, outlet) and flow rates. In addition, a steam-based baseboard/radiator model will be developed based on the recently-added radiant/convective hot water baseboard radiator model. This will be implemented in a similar fashion to the recently-added model with a heat exchanger formulation that includes a fluid at constant temperature and also the heat of vaporization of water. This steam baseboard unit will interact with the steam loop modeling capabilities in EnergyPlus.

Accomplishments: Completed 11/09

Subtask 13.1.9: Construction Specific Solution Algorithms (COPA)

Scope: EnergyPlus presently has two major solution algorithms to simulate the basic wall conduction heat transfer process: Conduction Transfer Functions (CTF) and Finite Difference Conduction (CondFD). Currently, the solution algorithm is selected on an "all surfaces" basis, and it is not possible to select the appropriate algorithm to match the requirements of the surface construction. Under this subtask, the Recipient shall provide a construction specific algorithm selection capability to EnergyPlus. In this way, the surfaces having simpler constructions and no advanced characteristics can continue to be simulated using CTF, while the surfaces having complex requirements can be simulated using the CondFD algorithm. The subtask will also include investigating the possibility of using simpler construction models to enable employing the CondFD for all surfaces without a significant computation time penalty.

Accomplishments: Completed 03/10.

Subtask 13.1.10: Extend CondFD Solution Algorithm to Transparent Insulation (COPA)

Scope: Currently in EnergyPlus, modeling transparent insulation is linked solely with the CTF wall conduction heat transfer solution algorithm. Under this subtask, the Recipient shall extend EnergyPlus' CondFD wall conduction heat transfer solution algorithm to include the ability to model transparent insulation. The result will allow modeling of transparent insulation material (TIM) layers in conjunction with phase change material (PCM) layers.

Accomplishments: Completed 03/10.

Subtask 13.1.11: Add Objects for Code Compliance (DHL)

Scope: Code compliance calculations require some high level inputs not normally used directly by simulation engines but are necessary information for compliance reporting. One possible approach to providing this data is to include additional "compliance tag" data in the Input Data Dictionary / Input Data File that would not be directly used by the EnergyPlus simulation engine itself but maybe by other utility programs or user interfaces for reporting. Under this subtask, the Recipient will investigate various approaches and implement the approved method. The decision regarding the approved method will be made with the assistance of DOE and the EnergyPlus development team.

Accomplishments: Completed 11/09.

Subtask 13.1.12: Error Message Documentation (DHL)

Scope (revised via Mod No. 13, Nov. 30, 2010): The Recipient shall begin the process of documenting EnergyPlus error messages, as well as possible causes and solutions, in a central location. In coordination with other development team members, the Recipient shall establish the location for this information and define the structure/guidelines that will be used for documenting the error messages/causes/solutions. The Recipient shall create a minimum of 15 examples using the established structure.

Accomplishments: Complete 05/11.

Subtask 13.1.13: Verify Zone Multipliers/Groups (DHL)

Scope: The Recipient shall review the EnergyPlus source code and make sure zone multipliers are used consistently. In addition, the documentation will be reviewed and modifications made as necessary to provide consistent documentation for both program users and developers.

Accomplishments: Completed 05/10

Subtask 13.1.14: Enhance the Weather Processing Program (DHL)

Scope: The Recipient shall revise the custom format feature in the Weather processing program to give better feedback to users creating definition files (DEF). The current source code uses "namelist" input and the error detection/correction of Fortran is not robust enough for most users. In addition, the Recipient will investigate adding a feature to the Weather processing program to assist users in creating definition files (for custom formats).

Accomplishments: Completed 11/09.

Subtask 13.1.15: Reduce Simulation Execution Time (DHL)

Scope: The Recipient shall work to increase the computational speed of EnergyPlus. The Recipient will investigate the use of hash or other speedy functions to traverse name (usually user supplied) keys for reporting. DHL will also address concerns from Enhancement list item Envelope_2007_11.

Accomplishments: Completed 09/09.

Subtask 13.1.16: Complete Phase 2 EMS-Style Controls at Cooling/Heating Plant Component and "Loop" Levels (OSU)

Scope: The Recipient shall complete the Phase 2 effort begun under Subtask 5.12 in Budget Period 2. Energy management system (EMS) controls will be implemented at the cooling/heating plant component level (e.g., chillers, boilers, pumps, water-to-water heat pumps) and the "loop" level (e.g., turn off an entire water loop, including all associated chillers, pumps, etc. on that loop). This subtask will include collaboration with National Renewable Energy Laboratory (NREL). This subtask will include the development of EMS plant control input files required to verify the implementation and provide some basic examples to facilitate use of the plant EMS by EnergyPlus users.

Accomplishments: Completed 03/10.

Subtask 13.1.17: Add Piping Pressure Drop Model and Improved Pump Model (OSU, UCF/FSEC)

Scope: The Recipient shall add a model to EnergyPlus for estimating pressure drop by a fluid flowing through a piping system (fluid loop). In addition, a new pump model will be added (or existing model improved) which will take into account pressure drop variations. This effort will be coordinated with other similar development efforts related to modeling pressure drop in air loops (e.g., LBNL fan/duct model for commercial buildings, NREL Fan Pressure Rise Adjustments for Bypass, etc.).

Accomplishments: Completed 08/09

Subtask 13.1.18: Plant Demand Side Equipment Simulation Enhancement (OSU)

Scope: The Recipient shall upgrade the plant loop demand side solver to include a 'sequential' simulation of the demand side equipment, similar to what is already done on the supply side.

Accomplishments: Completed 09/08

Subtask 13.1.19: Modify AirflowNetwork Height-Dependent Wind Speed Model (UCF/FSEC)

Scope: There are two existing methods available in EnergyPlus to calculate local wind speed. One is a global function WindSpeedAt and the other is used only in the AirflowNetwork model. The Recipient shall modify the AirflowNetwork model to utilize the global function for wind speed. In addition, provisions will be made to allow users to specify if the local wind speed is calculated at the exterior air node height or the height of the centroid of exterior building surfaces.

Accomplishments: Completed 02/09.

Subtask 13.1.20: Enhance Air Distribution System Model to Include More Component Types (UCF/FSEC)

Scope: The Recipient shall enhance the existing air distribution system modeling capabilities by adding more component selections. The specific components to be added will be determined in consultation with DOE and the EnergyPlus development team.

Accomplishments: Completed 02/09.

Subtask 13.1.21: Enhance On/Off Fan Energy Calculations (UCF/FSEC)

Scope: The Recipient shall enhance the on/off fan model to better account for energy consumption variations at different air flow rates. Other EnergyPlus models that coordinate with this fan model (e.g., unitary systems and PTHP) will be modified as necessary based on the revisions to the fan model.

Accomplishments: Completed 02/09.

Subtask 13.1.22: Improved Bypass Control for Air-to-Air Flat Plate Heat Exchangers (UCF/FSEC)

Scope: The Recipient shall revise the air-bypass control method in the flat plate air-to-air heat exchanger model to be consistent with the air-bypass method used in the sensible/latent air-to-air heat exchanger model. Heat exchanger air-bypass can be invoked when the air-side economizer of an air-conditioning system is active.

Accomplishments: Completed 02/09.

Subtask 13.1.23: Add Basin Heater to Remaining Cooling Towers and Evaporative Condensers (UCF/FSEC)

Scope: Several existing models for outdoor heat rejection equipment include basin heaters. Under this subtask, the Recipient shall add a basin heater to the remaining cooling tower and evaporative-condenser models for consistency.

Accomplishments: Completed 05/10

Subtask 13.1.24: Unify Coil Arrangement for Unitary Systems (UCF/FSEC)

Scope: The Recipient shall modify the cooling and heating coil placement requirements in unitary systems so that they are consistent when modeling high humidity control or temperature control. The current model requires different coil arrangements depending on which control method is used (temperature or humidity), which is an unnecessary burden on users.

Accomplishments: Completed 09/09.

Subtask 13.1.25: Complete Deprecation of Fan Operating Mode from DX Coil Objects (UCF/FSEC)

Scope: The Recipient shall complete the process of deprecating and/or removing the fan operating mode input field for the direct expansion coils objects. The fan operating mode is now established by the parent object (e.g., unitary system).

Accomplishments: Completed 04/09.

Subtask 13.1.26: Add Water-To-Air Heat Pump Option for Zone Equipment (UCF/FSEC)

Scope: The Recipient shall add the ability to model water-to-air heat pumps as zone equipment. This might be added as an option to the existing packaged terminal heat pump (PTHP) object, or create a new object based substantially on the existing PTHP object but with the specialized input requirements for the water-to-air option (to avoid confusion regarding the existing PTHP object and its inputs).

Accomplishments: Completed 07/09.

Subtask 13.1.27: Equipment Performance Curve Fit Tool (UCF/FSEC)

Scope: The Recipient shall develop a tool to assist users in developing the necessary performance curve fits for EnergyPlus related to chillers, DX cooling coils, heat pumps, etc. This may be a spreadsheet tool or a utility program with a graphical user interface. This effort will be coordinated with other similar development efforts (e.g., water-to-air heat pump tool being developed by OSU).

Accomplishments: Completed 08/11

Subtask 13.1.28: Control of Minimum Air Flow Fraction for VAV Terminals (UCF/FSEC)

Scope: The Recipient shall implement at least one method for controlling/modifying the minimum air flow fraction of VAV terminals. This effort will be coordinated with similar work being performed at NREL (scheduled minimum flow fraction). Examples of control signals might include occupancy or zone exhaust air flow rate.

Accomplishments: Completed 03/10

Subtask 13.1.29: Enhance System Availability Managers to Control Zone Equipment Operation (UCF/FSEC)

Scope (revised via Mod No. 13, Nov. 30, 2010): EnergyPlus system availability managers currently force certain zone equipment to have the same availability status as the central air distribution system (air loop) that serves that zone. Other zone equipment is not impacted at all by the availability status of the air loop that serves that zone. The Recipient shall add flexibility for the user to specify when zone equipment availability is dependent or independent of (central air) system availability. This flexibility will be limited to certain zone equipment due to current limitations in zone air flow calculations. However, the structure of the enhanced flexibility will be established so that its application to additional zone equipment will be easily expanded in the future (e.g., when limitations in zone air flow calculations are addressed).

Accomplishments: Completed 04/11.

Subtask 13.1.30: MathDiff for Table Reports (GARD)

Scope: Regression testing is crucial for quality control for EnergyPlus. During the beta testing for the first version of EnergyPlus, GARD developed a program called MathDiff used to compare hourly and timestep based output files and report their differences. MathDiff continues to be heavily used for each release of EnergyPlus. The EnergyPlus development team currently has no tool to compare output from monthly and predefined table reports for regression testing. Under this subtask, the Recipient shall develop a new comparison tool similar to MathDiff, but for table reports. This new tool will be written in a language like FORTRAN or Basic so that it will run as a standalone exe or in Python as a script and be available on multiple popular operating systems. The programming language selection will be based on development team discussions including DOE.

Accomplishments: Completed 12/09, minor bug fixes in 01/10).

Subtask 13.1.31: EP-Launch – Integrate Basement and Slab with EnergyPlus Simulation (GARD)

Scope: The Recipient shall integrate input and output of the Basement and Slab programs into the normal stream of data into and out of EnergyPlus. The results from the Basement and Slab program will be automatically included in the input data file (IDF) as an input to EnergyPlus. The documentation for Basement and Slab will be revised to reflect that they can be used directly in an IDF file. The ability to separately run Basement and Slab, such as via EP-Launch, will not be removed during this subtask. The decision of how to approach this will be made with the assistance of DOE and the EnergyPlus development team.

Accomplishments: Completed 02/10.

Subtask 13.1.32: Support NREL Baseline Building Project (GARD)

Scope: The National Renewable Energy Laboratory (NREL) is developing tools to help users create ASHRAE Std. 90.1 Appendix G and Title 24 building simulation models. The Recipient shall participate in this effort by providing peer review and offering guidance related to the software and data dictionary development effort. This will extend the NREL example file generator effort to custom buildings created in tools such as the EnergyPlus OpenStudio plug-in for Google SketchUp.

Accomplishments: Completed 11/09.

Subtask 13.2: Create Thermal Component Loads Report (GARD)

Scope: EnergyPlus currently reports the overall heat loads and heat gains for a space but does not report the individual contributions of the heat loads and heat gains from walls, roofs, floors, windows, interior walls, infiltration, occupancy, lighting, and internal equipment. The Recipient shall add new report variables that approximate the contribution to the total timestep loads and gains for a space of each of these components. In addition, new predefined and monthly reports that use the new report variables will be added.

Accomplishments: Completed 09/11

Subtask 13.3: Auto-Rotate Building and Average Simulation Results (GARD)

Scope: One portion of ASHRAE Standard 90.1 Appendix G that frustrates designers is the requirement to rotate the baseline building model as stated in Table G3.1 section 5 "the baseline building performance shall be generated by simulating the building with its actual orientation and again after rotating the entire building 90, 180, and 270 degrees then averaging the results." The Recipient shall create a new utility that takes an EnergyPlus input data (IDF) file, rotates the building in each cardinal direction and averages the results for the four simulations. This utility will be created to work on Windows XP, Windows Vista, Macintosh OSX, and Linux operating systems. It will also be able to be used in conjunction with the EnergyPlus OpenStudio plug-in for Google SketchUp.

Accomplishments: Completed 06/09.

Subtask 13.4: Develop Utility to Compare Results from Multiple Simulations (GARD)

Scope: The Recipient shall create a software utility that allows EnergyPlus users to compare ABUPS reports (at least the energy-use portion) and other summary tabular reports. With this utility, users will be able to select multiple existing HTML outputs and have the comparisons shown side by side. The comparisons will include tables, stacked bars and other graphs. Two possible approaches exist for the utility, either a stand alone program or one that will run within a web browser. The approach used will be determined based on the capabilities needed by the software and in cooperation with the EnergyPlus development team including DOE. The type of graphics will be controllable including colors, shapes, etc. In addition, the utility will be able to graph schedules or other inputs that lend themselves to graphic displays.

Accomplishments: Completed 03/10.

Subtask 13.5: Develop Utility to Simplify Parameter Substitution Across Multiple Simulations (GARD)

Scope: The Recipient shall develop a utility program that will allow for easy parameter substitution across multiple simulations. This approach will be made as easy as possible so that users familiar with EnergyPlus who are not programmers could use the method. The parametric substitution utility will be part of the batch file that runs EnergyPlus. EP-Launch will be modified to utilize this new form of controlling runs and IDF Editor will be modified to recognize parameter names.

Accomplishments: Completed 09/09.

Subtask 13.6: IP Units Option for Table Reports (GARD)

Scope: The Recipient shall add the option to use Inch-Pound (IP) units in monthly and annual predefined table reports. The unit conversions will be centralized in EnergyPlus in a single Data Module to ensure that future unit conversion enhancements will be consistent. The unit conversions will be based on those used within IDF Editor and the convertESOMTR utility.

Accomplishments: Completed 02/09.

Subtask 13.7: IDF Editor – Add IP Units Support for Remaining Objects (GARD)

Scope: The Recipient shall enhance the IDF Editor to support Inch-Pound (IP) units on an object-by-object basis for schedule objects, fluid property objects, and objects where the fields can have multiple possible units. These enhancements will complete the IP unit support in IDF Editor. The decision on how to approach this enhancement will be made in consultation with DOE and the EnergyPlus development team.

Accomplishments: Completed 12/09.

Subtask 13.8: Implement Airflow Model for Large Horizontal Openings (UCF/FSEC)

Scope: Under Subtask 9.1 in Budget Period 3, the Recipient investigated algorithms for modeling air flow through large horizontal openings and a new feature proposal was developed to describe options for implementation. Under Subtask 13.8, the Recipient shall implement the air flow model as outlined in the feature proposal. In addition, the Recipient shall assist the National Renewable Energy Laboratory (NREL) in integrating this new model with EnergyPlus' RoomAir models.

Accomplishments: Completed 08/11.

Subtask 13.9: Improve Convergence Tolerance for Unitary Systems (UCF/FSEC)

Scope: The Recipient shall implement changes to EnergyPlus' Unitary HVAC System models to more precisely account for air distribution heat gains/losses and other equipment located in the air distribution ductwork downstream of the unitary system.

Accomplishments: Completed 06/09.

Subtask 13.10: Improve Electric Load Center Dispatch (UCF/FSEC)

Scope: The Recipient shall improve the model for dispatching load to various electricity generators, based on each generator's actual maximum power output for each simulation time step rather than their rated electrical power output.

Accomplishments: Completed 03/10.

New features in Budget Period 5 (2010-2011)

TASK 17: EnergyPlus Development (Budget Period 5)

Subtask 17.1.1: Warm-up Convergence Improvements (UIUC, GARD)

Scope: Every EnergyPlus simulation must have an initial condition and then a subsequent period of "warmup" to eliminate the initial condition guess so as to not allow this initial condition guess to influence the energy predictions of the program. The Recipient shall study the current warm-up convergence method, identify specific and actual cases where the current method fails, and implement and document a new or enhanced method that provides much better certainty that convergence has been achieved.

Accomplishments: Completed 06/11.

Subtask 17.1.2: CTF Improvements (UIUC)

Scope: The Recipient shall identify cases where convergence in the conduction transfer function (CTF) calculations is still a problem, determine limits, and implement a new procedure and/or identify non-convergence situations during simulation. The Engineering Reference shall be modified to include the findings and changes to procedures or detection that is performed. In addition, the Recipient shall replace the minimum 6 nodes with a single purely-resistive node or perhaps merge the R-value layer with neighboring material layers, depending on the findings of an initial review and assessment of the solution possibilities.

Accomplishments: Completed 08/11

Subtask 17.1.3: Convective/Radiant Electric Baseboard Model (UIUC)

Scope: The existing electric baseboard model is a convective-only model and does not include radiative effects as the new hot water and steam baseboard models that are being added to EnergyPlus have. Thus, to give electric baseboard users the same functionality as the other baseboard models, the Recipient shall add a new electric baseboard model to EnergyPlus that models both the radiative and convective effects so that the electric baseboard model has similar capabilities to the hot water and steam baseboard models.

Accomplishments: Completed 02/10.

Subtask 17.1.4: Convective-Only Baseboard Input/Output Improvements (UIUC)

Scope: The existing convective-only water baseboard requires the user to enter a UA value, a parameter that is difficult to estimate and is not reported by manufacturers. The new radiant-convective water baseboard model asks the user to provide commonly available rating data from which EnergyPlus calculates an approximate UA value. The Recipient shall modify the convective-only baseboard model to accept the same rating data rather than a UA value. In addition, several useful output variables will be added to the convective-only baseboard unit.

Accomplishments: Completed 12/10.

Subtask 17.1.5: Supply/Return Loop Heat Transfer to Support CHP & District Heating (OSU)

Scope: The Recipient shall extend the existing single buried pipe heat transfer model to include side-by-side and stacked dual pipes. A model will be developed to account for the thermal interactions between the pipes. The simplicity of the input data developed for the single pipe model will be maintained for the dual pipe models in order to allow users to seamlessly select the piping options.

Accomplishments: Completed 08/11

Subtask 17.1.6: Enhance Pipe Heat Transfer Solver (OSU)

Scope: The Recipient shall work to minimize the effect of the system timestep and grid spacing on the pipe heat transfer calculations. A new grid generation algorithm and a fixed timestep that is independent of the system timestep will be developed and implemented in the existing pipe heat transfer solver.

Accomplishments: Completed 09/11

Subtask 17.1.7: Improved Pump Controls (OSU)

Scope: The Recipient shall develop a pressure-based control algorithm for a variable speed pump. Unlike constant speed pumps which respond to the overall loop pressure drop according to a pre-determined pump curve, variable speed pumps modulate the pump speed in an effort to maintain the loop pressure at a specified setpoint. This subtask includes both the implementation of the pressure setpoint concept and the implementation of the pressure-based pump control algorithm.

Accomplishments: Completed 08/11

Subtask 17.1.8: Integration of ASHRAE RP-1383 Models (COPA)

Scope: ASHRAE Research Project 1383, "Develop a Radiant System Module for the Simulation and Analysis of Spaces and Systems", will extend the tool set available to designers to evaluate comfort conditions and thermal performance of rooms heated and cooled via radiant, convective, and hybrid radiant-convective systems. Its goal is to provide facilities to conveniently evaluate the comfort and performance implications of advanced heating and cooling delivery systems. EnergyPlus currently has significant capabilities that perform some of the goals outlined in the project. However, there will be several developments in the project that need to be integrated into EnergyPlus to keep it abreast of the state of the art, and also to provide general availability of the additions in a program that has annual energy analysis capability. The Recipient shall collaborate with the RP1383 prime contractor to develop the low temperature radiant models in as general a form as possible, integrate the radiant system model into EnergyPlus including control developments from RP1383 that are more robust and more advanced than those currently in EnergyPlus, and include obstructions/partitions/complex room shapes in the determination of radiant view factors (e.g., using NIST View3D program). In addition, the comfort display capabilities of RP 1383 for design day simulations will be incorporated into EnergyPlus.

Accomplishments: Completed 07/11.

Subtask 17.1.9: Complete the Extension of CondFD Solution Algorithm to Transparent Insulation (COPA)

Scope: Currently in EnergyPlus, modeling transparent insulation is linked solely with the Conduction Transfer Function (CTF) wall conduction heat transfer solution algorithm. Under this subtask, the Recipient shall extend EnergyPlus' Conduction Finite Difference (CondFD) wall conduction heat transfer solution algorithm to include the ability to model transparent insulation. The result will allow modeling of transparent insulation material (TIM) layers in conjunction with phase change material (PCM) layers. The subtask will complete the work started in Subtask 13.1.10.

Accomplishments: Completed 05/10.

Subtask 17.1.10: Improve Solar Shading & Interior Solar Distribution Calculations (DHL)

Scope: The Recipient shall perform a scoping study to a) look at other shading calculations – requested in the Envelope_2007_14 enhancement list item, and b) look at the internal solar distribution calculations from daylighting – in the Zone_2007_04 enhancement list item. Results from this investigation will possibly make enhancements to the calculations but more definitively create a more complete enhancement list item for future work (Enhancement List items Envelope_2007_14 and Zone_2007_04).

Accomplishments: Completed 05/11.

Subtask 17.1.11: Flexible Corner Starting Positions (DHL)

Scope: The Recipient shall attempt to solve (or detect) starting positions/vertex entry requirements from the GlobalGeometryRules object (Enhancement List Item Geometry_2008_01).

Accomplishments: Completed 02/11.

Subtask 17.1.12: Document Developer Test Suite Run Requirements and Details (DHL)

Scope: Several developers have different methods of running the test suite during development. The Recipient shall document those as well as make scripts and other information available to both internal and external developers (Enhancement List Item Documentation_2007_01).

Accomplishments: Completed 11/10.

Subtask 17.1.13: Refactor Output Variable Reporting (DHL)

Scope: The Recipient shall carefully review and restructure the existing output variable reporting with the goals of improving efficiency of memory use and decreasing program execution time. Allowing for different levels of reporting (e.g., limited surface reporting) will also be explored.

Accomplishments: Completed 08/10.

Subtask 17.1.14: Global People, Lights, Thermostats for Building (DHL)

Scope: The Recipient shall create a "global" setting for Internal Gains items such as People, Lights, Thermostats and other similar items. Implementation of this subtask could range from a simple approach to a more complex approach (plus add more complex items such as global infiltration or other items that don't "fit" a specific mold for implementation).

Accomplishments: Completed 07/10.

Subtask 17.1.15: TDD Pipe Illuminance Reporting (DHL)

Scope: The Recipient shall correct the deficiency noted in Enhancement List item Daylighting_2007_01 regarding tubular daylighting device illuminance reporting.

Accomplishments: Completed 03/11.

Subtask 17.1.16: Refactor Triangulation Routines for >4 sided surfaces (DHL)

Scope: The current triangulation routine fails with certain surfaces. The Recipient shall investigate if there is another algorithm that will work for more cases. Even with a new approach, the triangulation routines still may not be able to always triangulate a surface (ref: the VRML commercial routines cannot triangulate).

Accomplishments: Completed 05/10.

Subtask 17.1.17: Add Analytical Solution to Zone Air Heat Balance (UCF/FSEC)

Scope: The Recipient shall implement the analytical and Euler solution methods for solving the zone air heat balance equations, in addition to the existing 3rd order approximation method.

Accomplishments: Completed 03/10.

Subtask 17.1.18: Variable Refrigerant Flow Heat Pump Model (UCF/FSEC)

Scope: The Recipient shall add the ability to model variable refrigerant flow (VRF) heat pumps in EnergyPlus. This model will allow cooling-only or heating-only operation at this time. The model will not account for simultaneous heating and cooling operation (a.k.a. heat recovery mode) since sufficient performance data does not exist for proper model implementation.

Accomplishments: Completed 02/11.

Subtask 17.1.19: Eliminate Redundant Input in Selected Compound Objects (UCF/FSEC)

Scope: The Recipient shall eliminate redundant input fields in selected compound objects. One example is duplicate node name inputs in the compound object that are already defined in the child components (e.g., coils and fans).

Accomplishments: Completed 05/11.

Subtask 17.1.20: Deprecate Supply Air Fraction Field from Unitary System Objects (UCF/FSEC)

Scope: The Recipient shall deprecate the input field "Fraction of Supply Air Flow That Goes Through the Controlling Zone" from the AirLoopHVAC:UnitarySystem/Furnace objects. The required information will instead be gathered from other required input objects (e.g., terminal units located on the same air loop).

Accomplishments: Completed 07/10.

Subtask 17.1.21: Add All-Off Equipment Operation Scheme Option for Plant and Condenser Loops (UCF/FSEC)

Scope: The Recipient shall allow specification of an all-off condition within any of the plant or condenser operation scheme types. Alternatives include a special plant equipment object list or a special keyword in place of the plant equipment list.

Accomplishments: Completed 08/10.

Subtask 17.1.22: Develop Equipment Performance Data Sets for Certain Equipment Types (UCF/FSEC)

Scope: The Recipient shall develop input data sets for certain equipment types. Data sources will include manufacturer's published performance information and possibly detailed performance data collected in controlled laboratory or field experiments, if available. The initial focus will be on developing input data sets for rooftop packaged equipment.

Accomplishments: Completed 05/11.

Subtask 17.1.23: Enhance Plant and Condenser Loop Component Models to Use Fluid Property Routines (UCF/FSEC)

Scope: The Recipient shall implement user-defined fluid properties in plant and condenser loops and associated equipment. This will be a joint effort between UCF/FSEC and the National Renewable Energy Lab (NREL).

Accomplishments: Completed 08/11

Subtask 17.1.24: Upgrade VB 6.0 Utilities to New Programming Language/Environment for Windows, Linux and Macintosh (GARD)

Scope: Recipient shall begin converting the utility programs written in Visual Basic 6.0 to REALbasic or another cross-platform programming language which supports Windows, Linux & Macintosh. Utility programs to be converted include EP-Launch, IDF Editor, CSVproc, convertESOMTR, WinEPDraw (front end), and Weather (front end).

Accomplishments: Completed 07/11.

Subtask 17.2: HVACTemplate Extensions (GARD)

Scope: HVACTemplate objects in EnergyPlus provide users with a simplified HVAC system input option. The Recipient shall expand the number of air distribution systems, plant arrangements, and equipment components supported by HVACTemplate. In addition, enhancements to existing HVACTemplate objects will be implemented (e.g., improved error checking and improved support of autosizing). The specific systems, equipment components and arrangements, and enhancements to be implemented will be selected in consultation with DOE and NETL.

Accomplishments: Completed 05/11.

Subtask 17.3: Upgrade/Enhance ZoneHVAC:IdealLoadsAirSystem Object (GARD)

Scope: The existing ZoneHVAC:IdealLoadsAirSystem object is a simplified HVAC system model intended to provide the basis for calculating zone heating and cooling loads without modeling a complete HVAC system. Under this subtask, the Recipient shall enhance this object's modeling capabilities as requested by EnergyPlus users (e.g., economizer controls and ability to combine this system with other HVAC system types). The specific enhancements to be implemented will be selected in consultation with DOE and NETL.

Accomplishments: Completed 09/11

Subtask 17.4: Improve Tabular Output Reports (GARD)

Scope: Tabular output reporting is a feature that many users rely on to understand the results of their simulations. As EnergyPlus continues to evolve and add new features, outputs related to those new features need to be added as new reports or included in existing reports. Therefore, the Recipient shall review outstanding issues related to tabular output reports as identified by other developers, as well as review new output variables created by new modeling features. As appropriate, new outputs will be incorporated into either existing tabular reports or new tabular output reports will be created.

Accomplishments: Completed 03/11.

Subtask 17.5: Perform Simulations in Parallel (GARD)

Scope: Currently, multiple EnergyPlus simulations are performed sequentially with each being started after the previous one is completed. To take advantage of computers which now commonly contain multiple processors or multiple processing cores, the Recipient shall modify the existing RunEplus.bat batch file so that separate environments (working directories) are created for each simulation so that they do not interfere with one another. In addition, a batch file that starts a number of simulations using the multiprocessing feature will be created for testing and as an example to users.

Accomplishments: Completed 04/10.

Subtask 17.6: EP-Launch -- Run Multiple Simulations Simultaneously on Multi-Core Processors (GARD)

Scope: The Recipient shall enhance the existing EP-Launch utility program to enable additional simulations to be launched while a simulation is in progress. Users will be able to launch the additional simulations from both the single simulation and group simulation tabs within the utility program.

Accomplishments: Completed 09/10.

Subtask 17.7: EP-Launch -- Improved Output File Management (GARD)

Scope: The number of output files has grown considerably since EP-Launch was created. The Recipient shall revise the EP-Launch utility to make the management and viewing of output files easier and more flexible for the user.

Accomplishments: Completed 06/10.

Subtask 17.8: IDF Editor -- Enhanced Cross Referencing of Objects (GARD)

Scope: The Recipient shall enhance the cross-referencing capabilities of the IDF Editor utility to provide logical options in all pull down lists that reference other objects and object names.

Accomplishments: Complete 03/11.

Subtask 17.9: IDF Editor -- Improve Node Entry and Management (GARD)

Scope: Currently, entering node names in the IDF Editor utility is complicated since the node names need to be repeated in multiple places. Therefore, the Recipient shall create an easy way to specify and link nodes or equipment together in IDF Editor. At a minimum, this subtask will include creating and displaying lists of inlet or outlet nodes so that inlets and outlets are matched together. In addition, a list will be provided of the most recently used nodes to make them easier to select.

Accomplishments: Completed 03/11.

Subtask 17.10: New Setpoint Manager Accounting for Multiple Zone Impacts (UCF/FSEC)

Scope: The Recipient shall add a new set point manager to EnergyPlus that includes the impact of multiple zones when calculating the set point for controlling heating, ventilating and air-conditioning equipment.

Accomplishments: Completed 08/10.

Subtask 17.11: Tabular Performance Inputs (UCF/FSEC)

Scope: In EnergyPlus, equipment performance is most often specified using rated values along with curve fits to designate performance at off-rated conditions. Available input curve objects are generally applicable to most equipment performance. However some equipment performance does not match available curve types, and developing the required curve fits for input to EnergyPlus has proven to be confusing to some users. Therefore, the Recipient shall add the capability for users to directly enter equipment performance data in tabular format. The new input format will also allow the user to specify how EnergyPlus will determine performance between existing entered values (e.g., linear interpolation, quadratic, etc.).

Accomplishments: Completed 08/10.

Subtask 17.12: Model CO₂ Concentration and Controls (UCF/FSEC)

Scope: The Recipient shall enhance EnergyPlus to model the concentration of carbon dioxide (CO₂) in zone air. The internal data structures will be flexible to support future modeling of indoor contaminant levels. A new object will be added to specify a set point for zone air CO₂ concentration that can vary over time. A list of existing component models will be developed as candidates for controlling to the set point value (e.g., bring in more outdoor air to dilute indoor concentration levels to the set point or below). A subset of these candidate component models will be modified based on prioritization established in consultation with DOE and NETL.

Accomplishments: Completed 08/10.

Subtask 17.13: Simplified Natural Ventilation Model Based On Physical Correlation and Opening Size (UCF/FSEC)

Scope: The Recipient shall add a simplified natural ventilation model to EnergyPlus based on various physical driving forces (wind speed and temperature difference) and size of the window or door opening. The simplified model is documented in the ASHRAE Handbook of Fundamentals (2009 version, pg 16.13).

Accomplishments: Completed 03/10.

Subtask 17.14: Simplified Model of Interaction between Mechanical Ventilation, Infiltration and Duct Leakage (UCF/FSEC)

Scope: The Recipient shall implement a simplified model to account for interactions between mechanical ventilation, infiltration and duct leakage as an alternative to the more detailed AirflowNetwork model. The ASHRAE Handbook of Fundamentals defines a simplified method for determining the overall net air flow into the zone. The new EnergyPlus

model will be restricted to a limited number of zones, with the existing AirflowNetwork model being available for handling other cases.

Accomplishments: Completed 07/10.

Subtask 17.15: Add Overcool Option for High Humidity Control to Furnace/Unitary System (UCF/FSEC)

Scope: The Recipient shall add the capability for zone air overcooling as an option for limiting high humidity levels with the existing air loop furnace/unitary system models. The ability to extend this control logic to other system types will also be investigated. Users will be able to specify the maximum amount of zone air overcooling.

Accomplishments: Completed 12/10.

Subtask 17.16: Calculate Standard Ratings for Primary HVAC Components (UCF/FSEC)

Scope: The Recipient shall produce data on standard ratings for primary HVAC components and report to the EnergyPlus eio output file. Highest priority will be Seasonal Energy Efficiency Ratio (SEER) associated with small direct expansion cooling equipment. If time and funding permit, the output for other standard ratings (e.g., HSPF and IPLV) will be investigated and implemented to the extent possible.

Accomplishments: Completed 06/10.

Subtask 17.17: Integrate ASHWAT Shaded Fenestration Model into EnergyPlus (Wrightsoft)

Scope: The Recipient shall submit a new feature proposal how to implement the ASHWAT model for multi-layer fenestration systems in EnergyPlus. Produced as part of the recently-completed ASHRAE project 1311-RP, the feature proposal shall specify algorithms to model fenestration systems that include shading layers such as roller blinds, pleated drapes, venetian blinds, and insect screens.

Accomplishments: Completed 03/11.

Subtask 17.18: Update ASHRAE Weather Data Procedures (Wrightsoft)

Scope: Revised design weather data procedures are specified in the 2009 ASHRAE Handbook of Fundamentals. The daily temperature profile has been modified and the clear-day solar model is new. The Recipient shall implement these revised procedures in EnergyPlus.

Accomplishments: Completed 03/2011

Subtask 17.19: Integration of AutoDesk code donation (DHL and GARD)

Scope: AutoDesk is donating code modifications that they have internally made to EnergyPlus v4. These modifications yield speed improvements of up to 50% on large models. The Recipients shall integrate the code, assess performance, perform execution time analysis, and document changes. After code integration and performance assessment, the recipients shall perform minimal comparison of ASHRAE/IEA test suites for Version 4 and full comparison to the same suites for Version 7.

Accomplishments: Completed 08/11

Summary of testing and validation

This task consists of five subtasks:

- Run test suite and publish results
- Develop new IEA test suite cases
- Test and validate new source code
- Address change requests
- Create and test installation package

All subtasks in the testing and validation task were defined in each budget period in the project. Although the subtasks in different budget periods may have the same titles, the content may vary in different budget periods. The report provides a list of summaries based on budget periods. Each period-based summary includes a list of subtasks in the corresponding budget period. Each subtask consists of task title, institution name that implemented this task, a brief statement of work, and completed date.

Testing and validation tasks in Budget Period 1 (2006-2007)

TASK 2: EnergyPlus Testing and Validation (Budget Period 1)

Subtask 2.1: Run Test Suite/Publish Reports (GARD)

Scope: The Recipient shall perform testing and validation of EnergyPlus using a series of building energy software test suites with reference results (Envelope BESTEST [ASHRAE Standard 140], Heating Ventilating Air Conditioning (HVAC) BESTEST E100/200/300, ASHRAE 1052, HVAC Furnace BESTEST). Testing and validation is a continuous requirement during software development to evaluate the impact of enhancements and to ensure that new bugs are not introduced.

Accomplishments: Completed 10/06.

Subtask 2.2: Develop New Test Suite Cases (GARD)

Scope: The Recipient shall implement new test suite cases being developed through the International Energy Agency (IEA), ASHRAE Standard 140, other available test suites, new test suites being developed by the EnergyPlus development team, or ASHRAE Research Projects (e.g., ASHRAE RP-865). The selection of the specific test suite cases to be implemented will be determined in close consultation with DOE. This effort will include development of the specific EnergyPlus input data files, tabular organization of simulation results, and a written modelers report for the new test suite cases.

Accomplishments: Completed 12/06.

Subtask 2.3: Test/Validate New Source Code (DHL, GARD)

Scope: The Recipient shall test and validate new source code as it is submitted. Each submission will be checked for adherence to source code and documentation requirements defined in the Guide for EnergyPlus Module Developers. In addition to verifying that the checklist requirements have been met, the new source code will be reviewed for its fitness for integration with the rest of the existing EnergyPlus structure. The Recipient will make minor code changes when necessary and perform further testing and evaluation. The Recipient will also modify existing guidance documents and/or create new guidelines as necessary to help streamline the submission procedure.

Accomplishments: Completed 10/06.

Subtask 2.4: Address Change Requests (UCF/FSEC, DHL, GARD, OSU, COPA)

Scope: The Recipient shall address change requests (CRs) that arise both as a result of user support questions and bugs found when running the test suites. This involves modifying source code and/or the software documentation as required. Testing will be performed to verify that the issue has been resolved and that the changes don't cause unexpected differences in results.

Accomplishments: Completed 3/07.

Subtask 2.5: Create and Test Installation Package (DHL, GARD)

Scope: The Recipient shall create the installation package and test the entire EnergyPlus program and utilities (on both Wintel and Linux platforms) for version 1.4 which will be released to the public in early October 2006.

Accomplishments: Completed 10/06.

Testing and validation tasks in Budget Period 2 (2007-2008)

TASK 6: EnergyPlus Testing and Validation (Budget Period 2)

Subtask 6.1: Run Existing Test Suites, Publish Reports, Develop New Test Cases (GARD)

Scope: The Recipient shall perform testing and validation of EnergyPlus using a series of building energy software test suites with reference results (Envelope BESTEST [ASHRAE Standard 140], Heating Ventilating Air Conditioning (HVAC) BESTEST E100/200/300, ASHRAE 1052, HVAC Furnace BESTEST, BESTEST Ground Coupling GC100-GC190, HVAC Component Test Suite, Global Energy Balance Test Suite, and the new test suite cases developed under Subtask 2.2). Testing and validation is a continuous requirement during software development to evaluate the impact of enhancements and to ensure that new bugs are not introduced. The Recipient shall also implement new test suite cases, picking up where Subtask 2.2 left off. The selection of the new specific test suite cases to be implemented will be determined in close consultation with DOE. This effort will include development of the specific EnergyPlus input data files, tabular organization of simulation results, and a written modelers report for the new test suite cases.

Accomplishments: Completed 12/07.

Subtask 6.2: Test/Validate New Source Code (DHL, GARD)

Scope: The Recipient shall test and validate new source code as it is submitted. Each submission will be checked for adherence to source code and documentation requirements defined in the Guide for EnergyPlus Module Developers. In addition to verifying that the checklist requirements have been met, the new source code will be reviewed for its fitness for integration with the rest of the existing EnergyPlus structure. The Recipient will make minor code changes when necessary and perform further testing and evaluation. The Recipient will also modify existing guidance documents and/or create new guidelines as necessary to help streamline the submission procedure.

Accomplishments: Completed 12/07.

Subtask 6.3: Address Change Requests (UCF/FSEC, DHL, GARD, OSU, COPA, UIUC)

Scope: The Recipient shall address change requests (CRs) that arise both as a result of user support questions and bugs found when running the test suites. This involves modifying source code and/or the software documentation as required. Testing will be performed to verify that the issue has been resolved and that the changes don't cause unexpected differences in results.

Accomplishments: completed 03/08

Subtask 6.4: Create and Test Installation Package (DHL, GARD)

Scope: The Recipient shall create the installation package and test the entire EnergyPlus program and utilities (on both Wintel and Linux platforms) for new versions which will be released to the public in April 2007 and early-October 2007.

Accomplishments: Completed 11/07.

Subtask 6.5: HERS BESTEST Addition to ASHRAE Standard 140 (UCF/FSEC)

Scope: The Recipient shall provide the processing and ASHRAE SSPC 140 follow-through necessary to modify the HERS BESTEST procedures, as published by NREL in 1995, and put them in a form suitable for an addendum to

ASHRAE Standard 140. This will include all modifications necessitated by the ASHRAE public review process that are approved by the SSPC 140 Committee and all reporting forms necessary for submission of the addended Standard 140 software results to DOE.

Accomplishments: Complete 12/09

Testing and validation tasks in Budget Period 3 (2008-2009)

TASK 10: EnergyPlus Testing and Validation (Budget Period 3)

Subtask 10.1: Run Existing Test Suites, Publish Reports, Develop New Test Cases (GARD)

Scope: The Recipient shall Perform testing and validation of EnergyPlus using a series of building energy software test suites, some of which have reference results available (Envelope BESTEST [ASHRAE Standard 140], Heating Ventilating Air Conditioning (HVAC) BESTEST E100/200/300, ASHRAE 1052-RP, HVAC Furnace BESTEST, BESTEST Ground Coupling GC100-GC190, HVAC Component Test Suite, and Global Energy Balance Test Suite). This will also include new test suite cases implemented during Budget Period 2, as appropriate. Also during Budget Period 3 and in consultation with DOE, implement or revise IEA test suite cases in EnergyPlus as they become finalized, support ASHRAE Standard 140 development with new and edited test suites, and work further to resolve discrepancies with CEN 13791 test suite cases.

Accomplishments: Completed 04/09.

Subtask 10.2: Test/Validate New Source Code (DHL, GARD)

Scope: The Recipient shall test and validate new source code as it is submitted. Each submission will be checked for adherence to source code and documentation requirements defined in the Guide for EnergyPlus Module Developers. In addition to verifying that the checklist requirements have been met, the new source code will be reviewed for its fitness for integration with the rest of the existing EnergyPlus structure. The Recipient will make minor code changes when necessary and perform further testing and evaluation. The Recipient will also modify existing guidance documents and/or create new guidelines as necessary to help streamline the submission procedure.

Accomplishments: Completed 11/08.

Subtask 10.3: Address Change Requests (UCF/FSEC, DHL, GARD, OSU, COPA, UIUC)

Scope: The Recipient shall address change requests (CRs) that arise both as a result of user support questions and bugs found when running the test suites. This involves modifying source code and/or the software documentation as required. Testing will be performed to verify that the issue has been resolved and that the changes don't cause unexpected differences in results.

Accomplishments: Completed 01/09.

Subtask 10.4: Create and Test Installation Package (DHL, GARD)

Scope: The Recipient shall create the installation package and test the entire EnergyPlus program and utilities (on both Wintel and Linux platforms) for new versions which will be released to the public in April 2008 and early-October 2008.

Accomplishments: Completed 11/08.

Testing and validation tasks in Budget Period 4 (2009-2010)

TASK 14: EnergyPlus Testing and Validation (Budget Period 4)

All subtasks were completed by February 2010. See previous progress reports for details.

Subtask 14.1: Run Test Suites/Publish Reports (GARD)

Scope: The Recipient shall perform testing and validation of EnergyPlus using a series of building energy software test suites with reference results (Envelope BESTEST [ASHRAE Standard 140], HVAC BESTEST [ASHRAE Std. 140, CE100-545], ASHRAE 1052-RP, HVAC Furnace BESTEST [ASHRAE Std. 140, HE100-HE230]). This will also include new test suite cases implemented during the current Budget Period or previous Budget Periods, as appropriate. Testing and validation is a continuous requirement during software development to evaluate the impact of enhancements and to ensure that new bugs are not introduced. The published test reports for the test suites will be updated and posted on the EnergyPlus web site within one month following each version release of the program. In consultation with DOE, the Recipient shall revise existing test suite cases in EnergyPlus as they are updated and/or expanded, and if possible develop new test suite cases. In addition, the Recipient shall support ASHRAE Standard 140 development, which may include preparing results spreadsheet templates, editing existing test suite specifications to be submitted as addenda to Standard 140, and developing new test suite specifications.

Accomplishments: Completed 02/10

Subtask 14.2: Test/Validate New Source Code (GARD, DHL)

Scope: The Recipient shall review and comment on submitted new feature proposals. The Recipient shall also test and validate new source code as it is submitted. Each submission will be checked for adherence to source code and documentation requirements defined in the Guide for EnergyPlus Module Developers. In addition to verifying that the checklist requirements have been met, the new source code will be reviewed for its fitness for integration with the rest of the existing EnergyPlus structure. The Recipient shall make minor code changes if required and perform further testing and evaluation. The Recipient shall also modify existing guidance documents and/or create new guidelines as necessary to help streamline the submission procedure.

Accomplishments: Completed 02/10

Subtask 14.3: Address Change Requests (UCF/FSEC, OSU, UIUC, GARD, DHL, COPA)

Scope: The Recipient shall address change requests (CRs) that arise both as a result of user support questions and bugs found when running the test suites. This involves modifying source code and/or the software documentation as required. Testing will be performed to verify that the issue has been resolved and that the changes don't cause unexpected differences in results.

Accomplishments: Completed 02/10

Subtask 14.4: Create and Test Installation Package (DHL, GARD)

Scope: The Recipient shall create the installation package and test the entire EnergyPlus program and utilities (on both Wintel and Linux platforms) for new versions which will be released to the public in April 2009 and early-October 2009.

Accomplishments: Completed 11/09.

Testing and validation tasks in Budget Period 5 (2010-2011)

TASK 18: EnergyPlus Testing and Validation (Budget Period 5)

Subtask 18.1: Run Test Suites/Publish Reports (GARD)

Scope: The Recipient shall perform testing and validation of EnergyPlus using a series of building energy software test suites with reference results (Envelope BESTEST [ASHRAE Standard 140], HVAC BESTEST [ASHRAE Std. 140, CE100-545], ASHRAE 1052-RP, HVAC Furnace BESTEST [ASHRAE Std. 140, HE100-HE230]). This will also include new test suite cases implemented during the current Budget Period or previous Budget Periods, as appropriate. Testing and validation is a continuous requirement during software development to evaluate the impact of enhancements and to ensure that new bugs are not introduced. The published test reports for the test suites will be updated and posted on the EnergyPlus web site within one month following each version release of the program. In consultation with DOE and NETL, the Recipient shall revise existing test suite cases in EnergyPlus as they are updated and/or expanded, and if possible develop new test suite cases. In addition, the Recipient shall support ASHRAE Standard 140 development, which may include preparing results spreadsheet templates, editing existing test suite specifications to be submitted as addenda to Standard 140, and developing new test suite specifications.

Accomplishments: Completed 04/11.

Subtask 18.2: Test/Validate New Source Code (GARD, DHL)

Scope: The Recipient shall review and comment on submitted new feature proposals. The Recipient shall also test and validate new source code as it is submitted. Each submission will be checked for adherence to source code and documentation requirements defined in the Guide for EnergyPlus Module Developers. In addition to verifying that the checklist requirements have been met, the new source code will be reviewed for its fitness for integration with the rest of the existing EnergyPlus structure. The Recipient shall make minor code changes if required and perform further testing and evaluation. The Recipient shall also modify existing guidance documents and/or create new guidelines as necessary to help streamline the submission procedure.

Accomplishments: Completed 03/11.

Subtask 18.3: Address Change Requests (UCF/FSEC, OSU, UIUC, GARD, DHL, COPA)

Scope: The Recipient shall address change requests (CRs) that arise both as a result of user support questions and bugs found when running the test suites. This involves modifying source code and/or the software documentation as required. Testing will be performed to verify that the issue has been resolved and that the changes don't cause unexpected differences in results.

Accomplishments: Completed 08/11

Subtask 18.4: Create and Test Installation Package (DHL, GARD)

Scope: The Recipient shall create the installation package and test the entire EnergyPlus program and utilities (on Windows XP and Vista operating systems) for new versions which will be released to the public in April 2010 and early-October 2010.

Accomplishments: Completed 10/10.

Summary of user support and training

This task consists of four subtasks:

- Support Users and Interface Developers
- Upgrade Weather Converter Program
- Organize and Teach at Least One Workshop
- Update Training Materials

All subtasks in the user support and training task were defined in each budget period in the project. Different budget periods may have different subtasks. The report provides a list of summaries based on budget periods. Each period-based summary includes a list of subtasks in the corresponding budget period. Each subtask consists of task title, institution name that implemented this task, a brief statement of work, and completed date.

User support and training tasks in Budget Period 1 (2006-2007)

TASK 3: EnergyPlus User Support and Training (Budget Period 1)

Subtask 3.1: Support Users and Interface Developers (UCF/FSEC, DHL, GARD, OSU, COPA)

Scope: The Recipient shall provide support for users and interface developers through email correspondence. Addressing questions about EnergyPlus functionality, and specific questions on implementation and use of existing EnergyPlus models, is a collaborative effort among the Recipient, LBNL and NREL.

Accomplishments: Completed 3/07.

Subtask 3.2: Upgrade Weather Converter Program (DHL)

Scope: The Recipient shall upgrade the existing EnergyPlus weather converter utility program and support documents. Specifically, changes will be made to the weather converter program to support the translation of additional weather formats into the format required by EnergyPlus, and additional weather statistics and reporting features will also be added. Furthermore, this weather utility program will be refined to allow additional user control of "missing" data (particularly missing solar data).

Accomplishments: Completed 9/06.

Subtask 3.3: Organize and Teach at Least One Workshop (GARD)

Scope: The Recipient shall organize and teach at least one workshop, with student fees covering nearly all workshop labor and other expenses. Leading-edge design firms will be invited to attend each workshop. The workshops will supplement other training material updates and workshops that will be completed in FY06 through other DOE funding.

Accomplishments: Completed 3/07.

User support and training tasks in Budget Period 2 (2007-2008)

TASK 7: EnergyPlus User Support and Training (Budget Period 2)

Subtask 7.1: Support Users and Interface Developers (UCF/FSEC, DHL, GARD, OSU)

Scope: The Recipient shall provide support for users and interface developers through email correspondence. Addressing questions about EnergyPlus functionality, and specific questions on implementation and use of existing EnergyPlus models, is a collaborative effort among the Recipient, LBNL and NREL. This subtask will also include the development of an EnergyPlus Basics Manual by DHL and GARD. An accounting of the number of e-mails, and of the categories of questions asked, will be included in the annual report to NETL and DOE. Furthermore, this task may include assisting other DOE BT subprograms transition their simulation program needs to EnergyPlus, including attending planning meetings and assisting/mentoring other developers as they add new features/enhancements to EnergyPlus as required by their subprogram area.

Accomplishments: Completed 04/07.

Subtask 7.2: Update Training Materials (GARD)

Scope: The Recipient shall update the existing training materials (presentation slides and hands-on exercises) for the course "Introduction to EnergyPlus" to reflect changes and additions to EnergyPlus (two revision cycles). Improvements will be made to improve their effectiveness in teaching the material based on feedback from previous training sessions.

Accomplishments: Completed 04/07

Subtask 7.3: Organize and Teach Workshops (GARD)

Scope: The Recipient shall organize and teach at least two workshops, with student fees covering a significant portion of workshop labor and other expenses. Leading-edge design firms will be invited to attend each workshop.

Accomplishments: Completed 03/07.

User support and training tasks in Budget Period 3 (2008-2009)

TASK 11: EnergyPlus User Support and Training (Budget Period 3)

Subtask 11.1: Support Users and Interface Developers (UCF/FSEC, DHL, GARD, OSU)

Scope: The Recipient shall provide support for users and interface developers through email correspondence. Addressing questions about EnergyPlus functionality, and specific questions on implementation and use of existing EnergyPlus models, is a collaborative effort among the Recipient, LBNL and NREL. An accounting of the number of e-mails, and of the categories of questions asked, will be included in the annual report to NETL and DOE. This subtask will also include enhancements to the EnergyPlus Basics Manual developed in FY07 based on feedback from users and training classes.

Accomplishments: Completed 11/08.

Subtask 11.2: Organize and Teach Workshops (GARD)

Scope: The Recipient shall organize and teach two face-to-face workshops, with student fees covering a significant portion of workshop labor and other expenses. Leading-edge design firms will be invited to attend each workshop. In addition, assist with planning, coordinating, and presenting four web-based seminars (webinars).

Accomplishments: Completed 11/08.

User support and training tasks in Budget Period 4 (2009-2010)

TASK 15: EnergyPlus User Support and Training (Budget Period 4)

Subtask 15.1: Support Users and Interface Developers (UCF/FSEC, DHL, GARD, OSU)

Scope: The Recipient shall provide support for users and interface developers through email correspondence. Addressing questions about EnergyPlus functionality, and specific questions on implementation and use of existing EnergyPlus models, is a collaborative effort among the Recipient, LBNL, NREL and ORNL. An accounting of the number of e-mails, and of the categories of questions asked, will be included in the annual report to NETL and DOE.

Accomplishments: Completed 02/10.

Subtask 15.2: Update Training Materials (GARD)

Scope: The Recipient shall update the various EnergyPlus training materials to reflect the latest program updates. Improvements will be made to improve their effectiveness in teaching the material based on feedback from previous training sessions.

Accomplishments: Completed 10/09.

Subtask 15.3: Organize and Teach at Least One Workshop (GARD)

Scope: The Recipient will organize and teach at least two training workshops, with student fees covering nearly all workshop labor and other expenses. Leading-edge design firms will be invited to attend each workshop. In addition, four web-based seminars will be planned, coordinated and presented.

Accomplishments: Completed 03/11.

User support and training tasks in Budget Period 5 (2010-2011)

TASK 19: EnergyPlus User Support and Training (Budget Period 5)**Subtask 19.1: Support Users and Interface Developers (UCF/FSEC, DHL, GARD, OSU)**

Scope: The Recipient shall provide support for users and interface developers through email correspondence. Addressing questions about EnergyPlus functionality, and specific questions on implementation and use of existing EnergyPlus models, is a collaborative effort among the Recipient, LBNL, NREL and ORNL. An accounting of the number of e-mails, and of the categories of questions asked, will be included in the annual report to NETL and DOE.

Accomplishments: Completed 03/11.

Subtask 19.2: Update Training Materials (GARD)

Scope: The Recipient shall update the various EnergyPlus training materials to reflect the latest program updates. Improvements will be made to improve their effectiveness in teaching the material based on feedback from previous training sessions.

Accomplishments: Completed 04/11.

Subtask 19.3: Organize and Teach at Least One Workshop (GARD)

Scope: The Recipient will organize and teach at least two training workshops, with student fees covering nearly all workshop labor and other expenses. Leading-edge design firms will be invited to attend each workshop. In addition, four web-based seminars will be planned, coordinated and presented.

Accomplishments: Completed 8/10.

Summary of general EnergyPlus support

This task consists of five subtasks:

- Upgrade and maintain StarTeam software
- Update existing utility software
- Reduced computational speed
- Display building geometry in an alternative format

All subtasks in the user support and training task were defined in each budget period in the project. Different budget periods may have different subtasks. The report provides a list of summaries based on budget periods. Each period-based summary includes a list of subtasks in the corresponding budget period. Each subtask consists of task title, institution name that implemented this task, a brief statement of work, and completed date.

General EnergyPlus support tasks in Budget Period 1 (2006-2007)

Subtask 4.1: Upgrade and Maintain StarTeam Software (UCF/FSEC)

Scope: The Recipient shall maintain Borland's StarTeam software configuration management system as the central electronic repository and archive for all source code, documentation, training materials, and any other information related to EnergyPlus. Nightly backups of the StarTeam database and information vault will be performed by the Recipient to limit the amount of data loss in the event of server hardware or software failure. Critical operating system patches will be installed on the StarTeam servers as necessary, primarily to decrease vulnerability to computer viruses and other "electronic" attacks. Furthermore, the version of the StarTeam software running on the servers and client software will be updated to take advantage of new features.

Accomplishments: Completed 10/06.

Subtask 4.2: Update Existing Utility Software (GARD)

Scope: The Recipient shall update the existing EnergyPlus utility programs that help users achieve better usage of the software. This will be completed in advance of the release of version 1.4 in early October 2006.

Accomplishments: Completed 9/06.

Subtask 4.3: Reduce Computational Time (DHL)

Scope: The Recipient shall work closely with LBNL to increase the computational speed of EnergyPlus. The Recipient will profile example executions to identify the most time-consuming modules/routines, develop appropriate changes without compromising code readability, then implement and test the changes.

Accomplishments: Completed 11/06.

Subtask 4.4: Display Building Geometry in an Alternate Format (DHL)

Scope: The Recipient shall add further building geometry display capabilities to EnergyPlus. A literature search will be performed prior to implementation to determine the best new output format capability that should be added. Recipient will advise DOE of the literature search results before proceeding with implementation.

Accomplishments: Completed 9/06.

General EnergyPlus support tasks in Budget Period 2 (2007-2008)

TASK 8: General EnergyPlus Support (Budget Period 2)

Subtask 8.1: Maintain StarTeam Software (UCF/FSEC)

Scope: The Recipient shall maintain Borland's StarTeam software configuration management system as the central electronic repository and archive for all source code, documentation, training materials, and any other information related to EnergyPlus. Nightly backups of the StarTeam database and information vault will be performed by the Recipient to limit the amount of data loss in the event of server hardware or software failure. Critical operating system patches will be installed on the StarTeam servers as necessary, primarily to decrease vulnerability to computer viruses and other "electronic" attacks. StarTeam software licenses will be renewed.

Accomplishments: Completed 12/07.

Subtask 8.2: Update Existing Utility Software (GARD, DHL)

Scope: The Recipient will update existing EnergyPlus utility programs that help users achieve better usage of the software. This will be completed in advance of the release of new versions of EnergyPlus in April 2007 and early-October 2007. In addition several utility programs will be enhanced with new capabilities, including EP-Launch, IDF Editor and Weather Converter. Selection of specific enhancements and improvements will be determined in close consultation with DOE.

Accomplishments: Completed 09/07.

General EnergyPlus support tasks in Budget Period 3 (2008-2009)

TASK 12: General EnergyPlus Support (Budget Period 3)

All subtasks were completed by December 2008. See previous progress reports for details.

Subtask 12.1: Maintain StarTeam Software (UCF/FSEC)

Scope: The Recipient shall maintain Borland's StarTeam software configuration management system as the central electronic repository and archive for all source code, documentation, training materials, and any other information related to EnergyPlus. Nightly backups of the StarTeam database and information vault will be performed by the Recipient to limit the amount of data loss in the event of server hardware or software failure. Critical operating system patches will be installed on the StarTeam servers as necessary, primarily to decrease vulnerability to computer viruses and other "electronic" attacks. StarTeam software licenses will be renewed. Furthermore, the version of the StarTeam software running on the servers (and associated hardware as required) and client software will be updated to take advantage of new features.

Accomplishments: Completed 12/08.

Subtask 12.2: Update Existing Utility Software (GARD, DHL)

Scope: The Recipient will update existing EnergyPlus utility programs that help users achieve better usage of the software. This will be completed in advance of the release of new versions of EnergyPlus in April 2008 and early-October 2008. In addition several utility programs will be enhanced with new capabilities, including EP-Launch, IDF Editor and Weather Converter. Selection of specific enhancements and improvements will be determined in close consultation with DOE.

Accomplishments: Completed 12/08.

General EnergyPlus support tasks in Budget Period 4 (2009-2010)

TASK 16: General EnergyPlus Support (Budget Period 4)

All subtasks were completed by February 2010. See previous progress reports for details.

Subtask 16.1: Upgrade and Maintain StarTeam Software Configuration Management System (UCF/FSEC)

Scope: The Recipient shall maintain Borland's StarTeam software configuration management system as the central electronic repository and archive for all source code, documentation, training materials, and any other information related to EnergyPlus. Nightly backups of the StarTeam database and information vault will be performed by the Recipient to limit the amount of data loss in the event of server hardware or software failure. Critical operating system patches will be installed on the StarTeam servers as necessary, primarily to decrease vulnerability to computer viruses and other "electronic" attacks. StarTeam software licenses will be renewed. Furthermore, the version of the StarTeam software running on the servers and client software will be updated to take advantage of new features.

Accomplishments: Completed 02/10

Subtask 16.2: Update Existing Utility Software (GARD, DHL)

Scope: The Recipient shall update, as necessary, the existing EnergyPlus utility programs that help users achieve better usage of the software (e.g., EP-Launch, IDF Editor, HVAC Diagram, Expand Objects, CSVProc, ConvertESOMTR, WeatherConverter, WinEPDraw). This will be completed in advance of the release of new versions of EnergyPlus in April 2009 and in early-October 2009.

Accomplishments: Completed 10/09.

General EnergyPlus support tasks in Budget Period 5 (2010-2011)

Subtask 20.1: Maintain StarTeam Software Configuration Management System (UCF/FSEC)

Scope: The Recipient shall maintain Borland's StarTeam software configuration management system as the central electronic repository and archive for all source code, documentation, training materials, and any other information related to EnergyPlus. Nightly backups of the StarTeam database and information vault will be performed by the Recipient to limit the amount of data loss in the event of server hardware or software failure. Critical operating system patches will be installed on the StarTeam servers as necessary, primarily to decrease vulnerability to computer viruses and other "electronic" attacks. StarTeam software licenses will be renewed.

Accomplishments: Completed 08/11

Subtask 20.2: Update Existing Utility Software (GARD, DHL)

Scope: The Recipient shall update, as necessary, the existing EnergyPlus utility programs that help users achieve better usage of the software (e.g., EP-Launch, IDF Editor, HVAC Diagram, Expand Objects, CSVProc, ConvertESOMTR, WeatherConverter, WinEPDraw). This will be completed in advance of the release of new versions of EnergyPlus in April 2010 and in early-October 2010.

Accomplishments: Completed 10/10.

Subtask 20.3: Plant Demand Side Equipment Simulation Enhancement (OSU)

Scope: The Recipients will specifically check for simulation scenarios that result in excessive iterations and the 'Max iterations exceeded' error message, in order to ensure the robustness of the code developed under this task. Additional diagnostic and error checking code is required. The code will then take appropriate action to ensure rapid convergence of the simulation.

Accomplishments: Complete 09/11

Conclusions

The project met the specific objectives required by DOE BT to continue development of EnergyPlus by adding new features, provide help for users in design process, promote and expand the use among generic public and support DOE's goals for improving building energy efficiency. There were 11 releases during the five year project period. The following table lists version numbers and corresponding release dates.

Table 1. Release versions and dates

Number	Version	Release Date
1	1.3	Apr. 2006
2	1.4	Oct. 2006
3	2.0	Apr. 2007
4	2.1	Oct. 2007
5	2.2	Apr. 2008
6	3.0	Nov. 2008
7	3.1	Apr. 2009
8	4.0	Oct. 2009
9	5.0	Apr. 2010
10	6.0	Oct. 2010
11	6.0.0.037	May 2011

The team delivered 146 new features to significantly enhance the EnergyPlus capabilities, so that the simulation tool can be used to support evaluation and decision making of zero energy building (ZEB) energy efficiency and supply technologies during new building design and existing building retrofits. In order to ensure high quality, the team performed testing and validation. The testing reports were published for every release. During the project period, the team provided technical support and training classes for users and interface developers. The majority of user support was accomplished through <http://energyplus.helpserve.com>. At the same time, the team also provided general support to upgrade and maintain StarTeam software and update existing utility software to help users generate inputs effectively. The excellent maintenance of software's electronic depository is a foundation for the team to track software revisions and evaluate necessary improvements. The main accomplishments are highlighted below:

- authored nearly half of the more than 2500 subroutines and functions that compose the EnergyPlus source code
- authored virtually all of the utility programs that are distributed with EnergyPlus
- addressed 82% of identified change requests (e.g., minor enhancements or bug fixes)
- led efforts to rigorously test and validate EnergyPlus using a variety of methods, including internationally recognized building energy software test methods and reference result

- based on recent emphasis from DOE to reduce increase execution speed, implemented various modifications from March 2010 through October 2010 which reduced the time required to simulate a suite of approximately 400 test files by more than 22%
- Developed 300 enhancement items as 66% of total items.

All tasks in the project were completed successfully. Although the EnergyPlus software was enhanced significantly under this project, more enhancements are needed for further improvement to ensure that EnergyPlus is able to simulate the cutting edge technologies and perform desired HAVC system operations for the development of next generation HVAC systems. The team will continue to develop EnergyPlus under a new 5-year project managed by the National Renewable Energy Laboratory.

Appendix A New Features

This appendix contains a list of new features from Version 2.0 to Version 6.0 in reverse chronological order. In addition, we also released an interim version 6.0.0.037. No highlights are provided. The new features are extracted from www.energyplus.gov. The contributions are not only from the team members listed in the report, but also from other developers, such as national lab teams and others. The detailed developer list may be available from the EnergyPlus documentation Acknowledgments.pdf.

New Features in Version 6.0.0

General

- Significant speed increases, up to 25-40% execution time reduction in most simulations, depending on specific features used.
- Revised reference building example files (formerly benchmark buildings).
- New detailed 130-zone hospital baseline and low energy example files.

Datasets

- New dataset for life cycle costing with regional U.S. fuel escalation factors.
- Doubled the number of refrigerated cases in the refrigerated case dataset.

Input

- Zone lists supported in most internal gains, infiltration, ventilation, thermostat, and demand manager zone name fields to apply a single input object to multiple zones.
- New lookup table object allows alternate performance input format to eliminate the need for regression analysis, can be used in place of existing curve objects, and can create curve objects.

Windows and Daylighting

- New reporting of pre-calculated hourly daylight factors.
- Allow glazing defined with spectral data to be used with between-glass shades and blinds.
- Window 6.3 (fenestration modeling software) will be able to export EnergyPlus IDF segments for window modeling.

Zone and Surface Models

- New surface heat transfer convection coefficient options, including adaptive model, many new correlations, and user-defined equations.
- Movable outside insulation, with transparent insulation material (TIM) capability, added to conduction finite difference model.
- Ecoroof model now has two moisture diffusion calculation methods - simple and advanced.

Natural and Mechanical Ventilation

- New comprehensive modeling of CO₂ concentrations in zone air, including internal emission sources and ventilation controls.

- New simplified model for interactions between mechanical ventilation, infiltration and duct leakage.

HVAC

- New separate sizing factors for heating and cooling.
- Enhanced Fan Coil model to allow constant water-flow capacity control with multi-speed and variable-speed fan.
- Enhanced inputs for variable volume fan minimum power rate.
- Enhanced reheat coil sizing.
- New component model for central fans with load-dependent power calculations accounting for fan pressure rise variations, duct static pressure reset, and fan, belt, motor, and VFD efficiency variations.
- Enhanced hot water coil model with variable UA resulting in significant improvement in hot water flow rate calculations.
- New basin heater model added to the single speed, two speed, multi speed and multi mode DX coil models.
- New multi-cell feature added for three types of cooling towers: single speed, two-speed, and the variable speed.
- New HVACTemplate support for heating/cooling sizing factors, VAV minimum flow rate options, VAV terminal unit controls.

Refrigeration

- Multiple refrigeration systems can now share a single condenser.
- Refrigeration condenser fan models enhanced and added input for minimum air flow rate.
- Refrigeration condenser output enhanced to identify recovered energy used internally for defrost and for other purposes.

Electrical Systems

- New transformer model for electrical power service and on-site generation.

Controls and User Functions

- New dual-max control for VAV reheat terminal units with reverse acting damper and hot-water coil.
- New maximum supply air temperature limit for VAV reheat terminal units.
- New averaged setpoint managers allow control of supply temperature and humidity ratio based on requirements of multiple zones.
- New setpoint managers that allow control of supply air humidity ratio of a central system serving multiple zones based on the critical zone humidification or dehumidification requirements.
- New “All-Off” equipment operation scheme option added for plant and condenser loops.
- Weather variables added as energy management system (EMS) actuators.

Economics

- New life cycle cost calculations.

Output

- New reporting of EER and IEER (in addition to SEER) for DX cooling coils with air cooled condensers.

- Enhanced SQLite output to include error file content.

Utilities

- New EP-Launch option to run multiple simulations simultaneously, taking advantage of multiple processors (Windows platform only).
- Enhanced output file access in EP-Launch (Windows platform only).
- IDF Converter (Transition GUI) can now save intermediate versions.

Platforms

- Windows (XP, Vista, Windows 7)
- Linux (Ubuntu 9.04 and above, Redhat 5.4 and above)
- Mac (10.5, 10.6)
- EnergyPlus V 6.0 has been tested on all of these platforms.
- ParametricPreprocessor executable added to Linux and Mac distribution.
And many other enhancements and speed improvements throughout.

New Features in Version 5.0.0

Datasets

- New refrigerated case data set

Input

- Slab and Basement preprocessors integrated to run automatically prior to EnergyPlus simulation
- New "Unit Type" field for schedules to support units conversions of schedule values
- Added ExternalInterface to connect to the Building Controls Virtual Test Bed using Ptolemy

Geometry/Window/Wall/Shading

- 2-node ConductionFiniteDifferenceSimplified model added

Daylighting

- Allow switchable windows like electrochromic windows to continuously dim, instead of only switching to fully dark state. Allows the zone to meet the maximum glare index while providing daylight for spaces

Zone Model

- Analytical and Euler solution options for zone air heat balance added

Natural and Mechanical Ventilation

- Added minimum outdoor air flow rate operation controls to single and dual duct VAV air terminals
- Added maximum supply air flow rate during reheat to single duct VAV air terminal
- New object ZoneHVAC:OutdoorAir to describe outdoor air flow rate for use by other objects
- New ZoneVentilation:WindandStackOpenArea object calculates ventilation rates based on winds and stack effects
- Zone HVAC outdoor air unit module for make-up air and DOAS

HVAC and Refrigeration

- Refrigeration loops can now model CO2 secondary loops
- Lighting in refrigerated cases revised to better match manufacturer's practices
- Zone-side impacts of refrigerant piping heat exchange added
- Default 'on' schedules for refrigerated cases and walk-ins added
- Dual layer controls for radiant systems removed
- Basin heater added to all chillers except absorption chillers
- Basin heater added to one and two speed cooling towers
- Pumps can ride curves based on pressure
- New steam baseboard with radiant heat
- New electric radiant/convective baseboard
- Added HVACTemplate:Zone:WaterToAirHeatPump and HVACTemplate:Plant:MixedWaterLoop
- Standard rating (net) cooling capacity and SEER value reported for single speed DX cooling coil with air-cooled condenser

Electrical Systems

- Improved methodology for electric load dispatch via the electric load center

Controls and User Functions

- Enhancements to EMS including: system timestep built-in variable, detect unbalanced parentheses in Erl, custom schedule output, and coupling with ExternalInterface
- External Interface to the Building Controls Virtual Test Bed (BCVTB) opens EnergyPlus to external programs.

On-Site Energy Supply

- Wind turbine module (horizontal and vertical axis turbines)

Output

- New predefined output table for DX cooling coils as part of EquipmentSummary report summarize the calculated capacity and SEER values
- New simulations database table and tabular reports data added to SQL database output
- Added report variables for beam and diffuse solar radiation for blinds
- Users can turn off most surface variables to a minimal critical set with single command. Allows tremendous reduction in execution time for large projects with many surfaces

Utilities

- New utility EP-Compare allows users to graphically compare results from two simulations
- IDF Editor supports IP units in schedules and other objects
- EP-Launch, IDF Editor, and WeatherConverter updates throughout

Documentation and Guides

- Two new guides: Tips and Tricks Using EnergyPlus, and External Interface Application Guide

- Input/Output Reference and Engineering Reference updated and extended for all new features and updates. Total documentation now exceeds 4,700 pages
- New translation capability added to EnergyPlus web site allows translation into 50 languages

Validation and Testing

- New testing report: EnergyPlus Testing with IEA BESTEST Mechanical Equipment & Control Strategies for a Chilled Water and a Hot Water System

Platforms

- Windows (XP, Vista, Windows 7)
- Linux (Ubuntu 9.04 and above, Redhat 5.4 and above)
- Mac (10.5, 10.6)

New Features in Version 4.0.0

Datasets

- SandiaPVdata.imf macro data set updated with latest set of input data from SNL for Sandia PV model
- Weather (EPW) and stat files now include field for rainfall

Design Day

- 2009 Design Data
- Design day definitions from 2009 HOF are created and used in several input files.

Input

- Simple definition of underground walls and floors with C and F factors for code compliance.
- Users can now define a window glazing system using U-factor, solar heat gain coefficient (SHGC), and visible transmittance (VT).
- Delimiter field added to Schedule:File object.
- Switchable windows report variables: switching factor (tint level) and visible transmittance at each time step.
- Inputs for parametric preprocessor added including values, logic, run control, and file naming.

Geometry/Window/Wall/Shading

- Source sink simulation and variable thermal conductivity property added to Conduction Finite Difference model

Natural and Mechanical Ventilation

- Large Horizontal Openings added to AirflowNetwork

HVAC

- Plant and Condenser Loops merged with significant improvements throughout.
- Walk-in Refrigeration, Refrigeration Cascade Condenser, and Refrigeration Secondary Loop

- Evaporative Fluid Cooler
- Zone water-to-air heat pump (ZoneHVAC:WaterToAirHeatPump)
- Zone air dehumidifier (ZoneHVAC:Dehumidifier:DX)
- Plant Pressure Drop can be calculated
- Improved convergence tolerance for most unitary systems
- Improved control of heat recovery in outside air systems during economizer operation

Controls and User Functions

- EnergyManagementSystem implemented, including EnergyPlus runtime language with numerous actuators

Environmental Impacts

- Schedules for fuel factors fully implemented in output reporting

Output

- Fanger PPD thermal comfort report variable added.
- Daylight metrics added: Time Exceeding Daylight Illuminance Setpoint at Ref Point 1 and 2.
- Air Node Density can be reported for air nodes.
- Infiltration, Mixing, and Ventilation air flow rates may be reported using standard density or current density.
- ReportDuringWarmup added to Output:Diagnostics object.

Utilities

- ParametricPreprocessor utility creates multiple IDF files from one and varying them parametrically.
- IDFConverter utility available -- a GUI for transitioning input files, including converting a list of files, from any older version to any newer version.
- Weather Converter can now calculate solar radiation from available data. Improved export and import of .wea (Ecotect) files.
- EP-Launch now automatically checks for updated versions of EnergyPlus, it runs the ParametricPreprocessor when necessary, and the utility tab includes IDFConverter.
- IDF Editor saves IP/SI view status with each file edited.

Documentation and Guides

- Two new application guides: Energy Management System Application Guide and Using EnergyPlus for Compliance.
- Input/Output Reference and Engineering Reference updated and extended for all new features and updates. Total documentation now exceeds 4,400 pages.

Validation and Testing

- New EnergyPlus testing reports:
 - IEA BESTEST In-Depth Ground Coupled Heat Transfer Tests Related to Slab-on-Grade Construction

- IEA BESTEST Multi-Zone Non-Airflow In-Depth Diagnostic Cases MZ320 - MZ360

Platforms

- Windows (tested for Windows 7), Linux, Mac (tested for Snow Leopard)

New Features in Version 3.1.0

Input

- Users can now define surfaces as simple rectangles (Simple Rectangular Surfaces) for walls, roofs, ceilings, floors, windows, doors, glazed doors, and shading.
- New detailed surfaces objects (Wall:Detailed, RoofCeiling:Detailed, FloorDetailed).
- InputProcessor can now output defaults, autosizing, and autocalculation statistics.
- New Constant Schedule allows simpler schedule definition.

Daylighting

- New variables for reporting visual discomfort: Time Exceeding Glare Index Setpoint at Ref Point 1 and Time Exceeding Glare Index Setpoint at Ref Point 2.

Zone Model

- Thermochromic windows can now be modeled.
- New Adiabatic Surface option for Outside Boundary Condition.
- New Sinusoidal option for Other Side Coefficient Boundary Conditions allows users to apply a sinusoidal schedule to the surface boundary conditions.
- Two new simplified infiltration models added: Sherman-Grimsrud and AIM-2.
- Ventilated slab has additional SerialSlab system configuration option, allowing multiple ventilated slabs in different zones to be connected in series.

Natural and Mechanical Ventilation

- UFAD model upgraded.
- AirflowNetwork wind speed model for height-dependency improved.
- Air Distribution System Model includes more components: heating coil and three heat exchangers.
- Demand Control Ventilation model based on ventilation rate procedure of Standard 62.1-2007.

HVAC

- New Unitary Air-to-Air Heat Pump and Packaged VAV HVAC Templates.
- Improved control of unitary equipment under low-load conditions (Furnaces, Heat Pumps, PTAC, PTHP, and Window AC).
- Furnaces/Unitary Systems now allow high humidity control with cycling supply air fan systems.
- Cool Beam model added.
- Option to size system flow rate and terminal units based on minimum ventilation requirements added; other zone equipment will be sized on zone loads
- Fan:OnOff now models multi-speed fan performance.

- Minimum stops on VAV terminals with reheat can now be scheduled.
- SensibleAndLatent and Desiccant Heat Exchangers now have economizer lockout option.
- Revised air-bypass logic for HeatExchanger:AirToAir:FlatPlace to match the logic used for HeatExchanger:AirToAir:SensibleAndLatent.
- Refrigeration racks and systems now accept either the name of a case or caselist, and compressor or compressorlist.
- Improved moisture condensation controls for Low Temperature Radiant systems.
- EvaporativeCooler:Direct:ResearchSpecial model added.
- Water consumption model for Indirect Evaporative Cooler extended. Secondary air flow rate can now be autosized.

Output

- New tabular reports to support LEED EA Credit 1 forms.
- Tabular reports now can be in Inch-Pound units.
- Improved diagnostics, warnings, and informative messages throughout.
- Output:Reports object converted to simpler Output:Surfaces:List, Output:Surfaces:Drawing objects.

Utilities

- New AppGPostProcess utility in combination with Building:Compliance object averages the results from four building rotation runs for Standard 90.1 Appendix G compliance.
- Datasets can now be directly opened from a menu in IDFEditor.
- Weather Converter updated to allow more custom date formats.
- Weather Converter now can include rainfall information (where available) in EnergyPlus weather data files.

Documentation and Guides

- Input/Output Reference and Engineering Reference updated and extended for all new features and updates. Total documentation now exceeds 4,000 pages.

New Features in Version 3.0.0

Data Sets

- Refrigerant properties for R404a, R410a, and R507a added to the refrigerant database.
- New library of compressor performance curves for refrigeration systems created.
- New performance curves for condensing and high-temperature boilers.
- California Title 24 Time Dependent Valuation (TDV) factor schedules (2008) dataset added.
- California Title 24 operating schedules dataset added.

Input

- Version 3.0 includes widespread changes to input syntax. The complete set of input objects was revised to make the EnergyPlus™ input 'language' more consistent, logical, and informative. Although the majority of words used to describe input object names, field names and key choices have changed,

the underlying meanings remain the same. (Yes, this will require substantial changes to existing input data files--aided by the Transition program which can be accessed through the EP-Launch utility.)

- New examples input files for all new features.

Zone Model

- New Ventilated Slab model includes radiant heating and cooling interactions with hollow core slabs
- Infiltration models now allow air flow rate per unit of exterior wall area as an optional input.
- Interior pipe heat transfer loads added into zone air heat balance calculations.
- New optional algorithms for fully-coupled, 1-D finite element heat and moisture transport model for simulating the movement and storage of heat & moisture in and through building surfaces.
- The algorithm for variable system timestep was revised. Changes include uniform system timestep length across zone timestep and stricter management of history terms for zone air conditions.

Natural and Mechanical Ventilation

- Additional hybrid (mixed-mode) ventilation controls added to allow global control of surface openings based on master zone, limit opening levels based on wind speed, and allow control of Mixing and Ventilation objects.
- Temperature limit controls added to Mixing and Cross-Mixing objects.
- New Thermal Chimney model added--uses solar radiation to enhance natural ventilation.
- New CoolTower model added--uses natural evaporative cooling to cool incoming air.
- Added new outside air minimum and maximum fractions to easily model 100% (or any fixed value) OA systems, leakage or stuck OA dampers.

HVAC

- Refrigeration system capabilities expanded with more detailed component models. Users can now simulate: (1) variable evaporating temperatures, (2) variable condensing temperatures, (3) mechanical subcoolers that transfer refrigeration loads from less efficient low- temperature systems to more efficient medium-temperature systems, and (4) liquid suction subcoolers.
- Improved error trapping for refrigerant and glycol properties at extreme temperatures and pressures.
- Single-speed cooling towers can now use fluid bypass as capacity control, saving water but requiring more fan energy.
- New linear curve to complement other curve objects.
- Absorption chiller now can connect to steam or hot water loop.
- Enhanced absorption chiller model added.
- Radiant-convective baseboard model added.
- Boiler model upgraded to include performance curve which accounts for load as function of operating temperatures.
- Set Point Managers now test for control node conflicts.
- New system availability managers added: Scheduled On and Scheduled Off.
- New Underground Pipe object added; upgraded Pipe Heat Transfer objects.
- New Fluid Cooler objects added--single and two-speed dry cooling towers for hydronic loops.
- Component sizing factors added for boilers, chillers, and cooling towers.
- Added chilled water thermal storage tank models for both mixed and stratified tanks.

- New Compact HVAC objects:
 - Packaged single-zone heat pump system (PSZ-HP)
 - Packaged variable volume system (PVAVS)
 - Constant volume chilled water/hot water system (single-zone and multi-zone)

On-Site Energy Supply

- PV model restructured to separately model inverters and storage systems.
- DC-to-AC inverter model added along with simple battery model.
- Simple Photovoltaic-Thermal model added for pre-heating outside air and hot water heating.

Economics

- Energy cost calculations now includes real time pricing, minimum monthly charge, and buy/sell/net metering as new inputs
- A new monetary unit object (Currency Type) added
- Additional economic reporting of energy and demand for each charge

Output

- SQLite added as another output format option, providing optional export of time-series results directly to database.
- Standard monthly reports can now be specified by name in the predefined report object without having to include a detailed monthly report object.

Utilities

- EP-Launch now handles blank weather files as if no weather file is specified in group simulations.
- IDF Editor new features include wrapping long text strings over multiple lines within cells, required fields now shown with blue field names, and added recently used file list.

Documentation and Guides

- Input/Output Reference and Engineering Reference updated and extended for all new features and updates. Total documentation now exceeds 3800 pages.

New Features in Version 2.2.0

Data Sets

- Electronic enthalpy air-side economizer curves
- Microturbine electric generators

Daylighting

- Reference point Illuminance levels calculated by DElight now included in standard output variables.
- DElight reference points now show up on DXF outputs.

Design Day

- Design days now allow scheduled input for Beam and Diffuse Solar values.
- Design days allow users to select periods from weather files to be used in design/sizing calculations.

Input

- Example input files created for all new features (More than 245 example input files now available). An additional set of realistic, benchmark files (15) have been added.

Zone Model

- Internal gains can now be entered in intensity:
 - People can be entered as number of people, people/floor area or vice versa (area/person).
 - Lighting can be entered as total Watts, Watts/floor area or Watts/person.
 - Equipment (electric, gas, other) can be entered as Watts, Watts/floor area or Watts/person.

Natural and Mechanical Ventilation

- Outside Air Controller now allows boosted air flow rates for high humidity control. A schedule may also be used to operate the outside air economizer based on a time-of-day schedule. Each of these features is also included in the controller for the stand-alone energy recovery ventilator.
- Infiltration can be entered as total volume, volume/floor area, volume/exterior surface area, or air changes per hour.
- Ventilation, mixing and cross mixing can be entered as total volume, volume/floor area, volume/person, or air changes/hour.
- Airflow network model now includes more coil types, including water cooling, water heating, detailed flat water cooling, multimode DX cooling, and multispeed cooling and heating.
- Multiple infiltration and ventilation objects now allowed in each zone, and the temperature control limits for the ventilation object can now be scheduled (instead of constant).

HVAC

- Dual-setpoint humidistat with deadband now available.
- Water heater volume and capacity can be autosized.
- New desiccant dehumidifier with additional capabilities and flexibility compared to the existing solid desiccant dehumidifier model.
- Supply air fan operating mode (continuous versus cycling) can now be scheduled based on time-of-day for window air conditioner, packaged terminal heat pump and water-to-air heat pump.
- New economizer controls added to Controller:Outside Air and Controller:Stand Alone ERV objects. New controls include Dew Point Temperature limit and Electronic (Variable) Enthalpy limit.
- DX System (DXSystem:Airloop object) now allows cool-reheat dehumidification control type.

On-Site Energy Supply

- New operating scheme for electric generators to follow thermal loads.
- New microturbine electric generator model.
- Upgraded equivalent one-diode PV model to include options for BIPV and inverter.

Environmental Impacts

- Environmental emissions can now be scheduled for all fuel types.

Output

- New detailed reports on Internal Gains (People, Lights, Equipment) as well as Simple Air Flow (Infiltration, Ventilation, Mixing, Cross Mixing) in the .EIO file.
- New report variables for summed zone load components.
- Added additional column in internal heat gains reporting that shows the sum of gains/floor area.

Utilities

- Many enhancements in the IDF Editor and HVAC Diagramming tools.

Documentation and Guides

- Input/Output Reference and Engineering Reference updated and extended for all new features and updates. Total documentation now exceeds 3700 pages.

New Features in Version 2.1.0

Data Sets

- Color schemes for DXF (original and default)

Input

- Example input files created for all new features (More than 225 example input files now available).

Geometry/Window/Wall/Shading

- Surface Surround Subsurface error detection more robust (less false errors)
- Autocalculate now allowed for shading surfaces (number of vertices)

Zone Model

- Zone sizing calculations now include heat gains from domestic/service hot water uses and water heaters.
- User now can choose between ASHRAE Clear Sky and Zhang-Huang solar radiation models for use in design day calculations.

Natural and Mechanical Ventilation

- New system availability manager allows system-level control of hybrid ventilation systems.

HVAC

- Water-cooled condenser option added to refrigeration compressor racks for useful heat recovery.
- Chilled and hot-water coils can now be used in the outside air system to preheat or precool outside air.
- New desiccant dehumidifier with additional capabilities and flexibility compared to the existing solid desiccant dehumidifier model.

- Water side economizer (including simulation of integrated and non-integrated water side economizers).
- Water heater improved for indirect heating (e.g. with remote boiler) and autosizable design flow rates for plant connections.
- Packaged terminal air conditioner (PTAC) added to model a fan, DX cooling coil, and a gas, electric, hydronic or steam heating coil serving a single zone.
- Multispeed heat pump with up to four discrete speeds for both cooling and heating.
- Heat losses (and gains) from plant piping.
- New and updated Compact HVAC objects:
 - Compact HVAC chilled water coils now use the COIL:WATER:COOLING model by default, COIL:Water:DetailedFlatCooling can be selected as an option.
 - Compact HVAC unitary system now supports the draw-thru fan placement option, and allows a schedule for the supply fan operating mode (continuous or cycling).
 - New Compact HVAC options for dehumidification and humidification controls for unitary and VAV system types.
 - New primary-secondary loop options for Compact HVAC chilled water loops.
- Compact HVAC expanded to support specification of outside air as a combination of flow/person, flow/area and flow/zone.
- Compact HVAC baseboard heat option added for unitary and VAV zones.
- New Compact HVAC objects for unitary heat pump, unitary VAV, packaged terminal air conditioner, and packaged terminal heat pump.

Output

- New tabular reports: surface shadowing, shading, lighting, HVAC sizing, system and component sizing, and outside air.
- New Report:SurfaceColorScheme allow users to select their own colors for building elements in the DXF output.

Utilities

- WeatherConverter now produces KML output (for Google Earth) of latitude, longitude, elevation, and a few climate statistics for locations in a list processing run.
- Add comma delimited form of CLM (ESP-r ASCII files) conversion to WeatherConverter.
- WinEPDraw produces in new default colors.

Documentation and Guides

- Completely rewritten Getting Started manual provides more hands-on example exercises and other information for getting up to speed on EnergyPlus.
- Input/Output Reference and Engineering Reference updated and extended for all new features and updates. Total documentation now exceeds 3500 pages.

New Features in Version 2.0.0

Data Sets

- New materials data set based on ASHRAE 2005 HOF replaces legacy DOE-2 and BLAST data.

- Updated solar collector data set from the SRCC adds 55 more collectors for a total of 173.
- Added air change rate to ventilation loads report in StandardReports data set.

Input

- Objects and name lengths can now be 100 characters. (Previous limit was 60).
- New weather data for 86 locations added: 69 in Australia, 16 in Canada, and 1 in Iran.
- Three new unit ventilator input files created: UnitVent5Zone.idf, UnitVent5ZoneAuto.idf, UnitVent5ZoneFixedOANoCoilOpt.idf.
- Three new thermal storage example input files created: IceStorage-Parallel.idf, IceStorage-Series-ChillerDownstream.idf, IceStorage-Series-ChillerUpstream.idf.
- Example input files created for all new features (More than 225 example files now available)

Geometry/Window/Walls/Shading

- Shadowing Calculations object now allows user to specify maximum figures in shadowing overlaps.
- Phase change materials (PCM) with variable thermal conductivity and a temperature-enthalpy function incorporated in conduction finite difference solution algorithm.
- Basement program now outputs EnergyPlus IDF for wall and floor surface temperatures.
- Users can now enter interzone surfaces once and EnergyPlus will automatically create the mirror interzone surface.

Zone Model

- Zone Sizing modified to allow standards-type calculation of design outside air flow rates; allows min cooling and max heating limits on design supply air flow rates.

Natural and Mechanical Ventilation

- Zone forced air units added to reporting of mechanical ventilation rate and loads
- Simple Ventilation object now reports air changes per hour
- New options in UnitVentilator include no coil option and fixed amount for outside air control strategy.
- AirflowNetwork model can now use Zone Exhaust Fan, OnOff supply fan and the DX heating coil objects.

HVAC

- Water-to-air heat pumps now use RegulaFalsi solution technique to improve robustness and to speed up simulation.
- Applicability schedule added to System Availability Manager:Low Temperature Turn Off (to support thermal storage).
- Evaporative condenser option added to existing refrigerated case compressor racks including availability schedule and basin heater with controls.
- Draw-through fan configuration added for furnaces, unitary system and air-to-air heat pumps.
- Different supply air flow rates now allowed for cooling, heating and when no cooling or heating is required in unitary, furnace and air-to-air heat pumps.
- Common Pipe for Primary-Secondary systems provides an alternative to the Connection component object to model Primary-Secondary systems

- Balanced flow desiccant heat exchanger option added for the existing heat exchanger-assisted DX cooling coil object.
- Stratified water heater model added.
- Uniform load distribution option added to plant load range based operation scheme.
- Height-dependent air temperature and wind speed now available for most HVAC systems.

Water Manager

- Green roof simulation added.

On-Site Energy Supply

- Fuel cell model updated.
- Combustion micro cogeneration model added.

Output

- Report Variables and Meter Variables (rdd and mdd) separately reported and output as IDF.
- Meters can now report cumulative value in addition to resetting at reporting time interval.

Utilities

- New EP-Launch utility tab added where users can launch Basement, CalcSoilSurfTemp, CoeffCheck, CoeffConv, Slab and Weather utilities.
- CSVproc now supported in EP-Launch.
- IDF Editor now preserves the order of user IDFs and includes a large number of other new features.

Documentation and Guides

- Input/Output Reference and Engineering Reference updated and extended for all new features and updates. Total documentation now exceeds 3300 pages.

[Contacts](#) | [Web Site Policies](#) | [U.S. Department of Energy](#) | [U](#)

Appendix B Milestones

This appendix contains milestones during project period. Each milestone lists the title, responsible institution, target date, status, actual completion date, and remarks.

Milestone	Responsibility	Due Date (MM/YY)	Status	Actual/Expected Completion Date (MM/YY)	Remarks
Budget Period 1					
Completion of new IEA test suite cases and modeler's report	GARD	10/06	Complete	12/06	
Completion of Phase I Energy Management System Implementation	NREL, OSU	9/06	Complete	7/07	
Completion of Phase II Upgrades to Plant Loop Simulations	OSU, UIUC	9/06	Complete	3/07	
Budget Period 2					
EnergyPlus version 1.4 release	UCF/FSEC, UIUC, OSU, DHL, GARD, COPA	10/06	Complete	10/06	
EnergyPlus version 2.0 release	UCF/FSEC, UIUC, OSU, DHL, GARD, COPA	4/07	Complete	4/07	
Completion of Phase II EMS-system controls	OSU	9/07	Complete	05/08	
Completion of new test suite cases and modeler's report	GARD	9/07	Complete	12/07	
Budget Period 3					
EnergyPlus version 2.1 release	UCF/FSEC, UIUC, OSU, DHL, GARD, COPA	10/07	Complete	10/07	
EnergyPlus version 2.2 release	UCF/FSEC, UIUC, OSU, DHL, GARD, COPA	04/08	Complete	04/08	
Completion of new test suite cases and modeler's report	GARD	11/08	Complete	07/09	
Budget Period 4					
EnergyPlus version 3.0 release	UCF/FSEC, UIUC, OSU, DHL, GARD,	10/08	Complete	11/08	

	COPA				
EnergyPlus version 3.1 release	UCF/FSEC, UIUC, OSU, DHL, GARD, COPA	04/09	Complete	04/09	
EnergyPlus version 4.0 release	UCF/FSEC, UIUC, OSU, DHL, GARD, COPA	10/09	Complete	10/09	
Completion of new test suite cases and modeler's report	GARD	11/09	Complete	11/09	
Budget Period 5					
EnergyPlus version 5.0 release	UCF/FSEC, UIUC, OSU, DHL, GARD, COPA	04/10	Complete	04/10	
EnergyPlus version 6.0 release	UCF/FSEC, UIUC, OSU, DHL, GARD, COPA	10/10	Complete	10/10	
Completion of new test suite cases and modeler's report	GARD	11/10	Complete	04/11	

Appendix C Concise list of deliverables

This appendix contains a concise list of deliverable items without scope. The items include all subtasks under four main tasks.

Deliverable	Responsibility	Due Date (MM/YY)	Status	Actual/Expected Completion Date (MM/YY)	Remarks
Task 1. EnergyPlus Development (Budget Period 1)					
Subtask 1.1: <i>Primary-Secondary Variable Flow Cooling/Heating Plant Systems</i>	OSU, UIUC	9/06	Complete	3/07	
Subtask 1.2: <i>Energy Management System Controls</i>	OSU	9/06	Complete	7/07	
Subtask 1.3: <i>Upgrade Existing Furnace Model</i>	UCF/FSEC	9/06	Complete	8/07	
Subtask 1.4: <i>Upgrade Energy Recovery Ventilator Controls and Autosizing</i>	UCF/FSEC	9/06	Complete	11/07	
Subtask 1.5: <i>Envelope Finite Difference Module</i>	COPA	9/06	Complete	10/06	
Subtask 1.6: <i>Develop New Input Verification and Result Summary Reports</i>	GARD	9/06	Complete	8/06	
Subtask 1.7: <i>Improved Hydronic Loop Capacitance Model</i>	OSU	9/06	Complete	9/07	
Task 2. EnergyPlus Testing and Validation (Budget Period 1)					
Subtask 2.1: <i>Run Test Suite/Publish Reports</i>	GARD	9/06	Complete	10/06	
Subtask 2.2: <i>Develop New Test Suite Cases</i>	GARD	9/06	Complete	12/06	
Subtask 2.3: <i>Test/Validate New Source Code</i>	DHL, GARD	10/06	Complete	10/06	
Subtask 2.4: <i>Address Change Requests</i>	FSEC, DHL, GARD, OSU, COPA	10/06	Complete	12/06	

Subtask 2.5: Create and Test Installation Package	DHL, GARD	10/06	Complete	10/06	
Task 3. EnergyPlus User Support and Training (Budget Period 1)					
Subtask 3.1: Support Users and Interface Developers	FSEC, DHL, GARD, OSU, COPA	10/06	Complete	11/06	
Subtask 3.2: Upgrade Weather Utility Program	DHL	9/06	Complete	9/06	
Subtask 3.3: Organize and Teach at Least One Workshop	GARD	8/06	Complete	8/06	
Task 4. General EnergyPlus Support (Budget Period 1)					
Subtask 4.1: Upgrade and Maintain StarTeam Software	UCF/FSEC	10/06	Complete	10/06	
Subtask 4.2: Update Existing Utility Software	GARD	9/06	Complete	9/06	
Subtask 4.3: Reduce Computational Speed	DHL	9/06	Complete	11/06	
Subtask 4.4: Display Building Geometry in an Alternate Format	DHL	9/06	Complete	9/06	
Task 5. EnergyPlus Development (Budget Period 2)					
Subtask 5.1: Ventilated Slab Model	UIUC	9/07	Complete	12/07	
Subtask 5.2: Enhanced Unit Ventilator Model	UIUC	9/07	Complete	1/07	
Subtask 5.3: Integrated Radiator/Baseboard Heater Model	UIUC	9/07	Complete	12/07	
Subtask 5.4: Rework of Shadowing Algorithms for More Complex Geometries	DHL	3/07	Complete	10/07	
Subtask 5.5: Integrated and Non-Integrated Waterside Economizer	OSU	3/07	Complete	12/07	

Subtask 5.6: <i>Packaged Terminal Air Conditioner Model</i>	UCF/FSEC	3/07	Complete	8/07	
Subtask 5.7: <i>Enhanced Supply Air Fan Controls for Unitary Air Conditioners and Heat Pumps</i>	UCF/FSEC	3/07	Complete	11/07	
Subtask 5.8: <i>Enhance the Gas Engine Heat Pump Model</i>	UCF/FSEC	10/07	Complete	1/08	
Subtask 5.9: <i>Dual-Setpoint Humidistat with Deadband</i>	UCF/FSEC	9/07	Complete	12/07	
Subtask 5.10: <i>Model for Hybrid (Mixed-Mode) Ventilation Systems</i>	UCF/FSEC	9/07	Complete	7/07	
Subtask 5.11: <i>Model for Heat Losses and Gains to Water Distribution Systems</i>	OSU, UCF/FSEC	9/07	Complete	9/07	
Subtask 5.12: <i>Phase II EMS-Style Controls at the Cooling/Heating Plant Component and "Loop" Levels</i>	OSU	9/07	Complete	3/08	
Subtask 5.13: <i>Model for Interzone IR Radiation Exchange</i>	COPA	9/07	Complete	12/07	
Subtask 5.14: <i>Compact HVAC Extensions</i>	GARD	9/07	Complete	9/07	
Subtask 5.15: <i>Enhance Airflow Network Model to Include Dedicated Zone Exhaust Air</i>	UCF/FSEC	9/07	Complete	3/07	
Subtask 5.16: <i>Enhance Existing Air Distribution System Model: Add More Coil, Fan and Terminal Unit Choices</i>	UCF/FSEC	3/07	Complete	3/07	
Subtask 5.17: <i>Verification and Summary Report Extensions</i>	GARD	9/07	Complete	8/07	
Subtask 5.18: <i>Review of Entire EnergyPlus Code</i>	UCF/FSEC, UIUC, OSU, DHL, GARD, COPA	2/07	Complete	4/07	
Subtask 5.19: <i>Reduce computational time</i>	DHL	3/07, 9/07	Complete	3/07, 12/07	
Task 6. EnergyPlus Testing and Validation (Budget Period 2)					

Subtask 6.1: Run Existing Test Suites, Publish Reports, Develop New Test Cases	GARD	9/07	Complete	12/07	
Subtask 6.2: Test/Validate New Source Code	DHL, GARD	9/07	Complete	12/07	
Subtask 6.3: Address Change Requests	UCF/FSEC, UIUC, OSU, DHL, GARD, COPA	9/07	Complete	03/08	
Subtask 6.4: Create and Test Installation Package	DHL, GARD	3/07, 9/07	Complete	v2.0 4/07 v2.1 11/07	
Subtask 6.5: HERS BESTEST Addition to ASHRAE Standard 140	UCF/FSEC	10/08	Complete	12/09	
Task 7. EnergyPlus User Support and Training (Budget Period 2)					
Subtask 7.1: Support Users and Interface Developers	UCF/FSEC, DHL, GARD, OSU	9/07	On-going	12/07	
Subtask 7.2: Update Training Materials	GARD	11/06, 6/07	Complete	v1.4 12/06, v2.0 4/07	
Subtask 7.3: Organize and Teach Workshops	GARD	6/07	Complete	3/07	
Task 8. General EnergyPlus Support (Budget Period 2)					
Subtask 8.1: Maintain StarTeam Software Configuration Management System	UCF/FSEC	10/07	Complete	12/07	
Subtask 8.2: Update Existing Utility Software	GARD, DHL	9/07	Complete	v2.0 4/07 v2.1 9/07	
Task 9. EnergyPlus Development (Budget Period 3)					
Subtask 9.1.1: Additional Air-Side Economizer Controls	UCF/FSEC	03/08	Complete	01/08	
Subtask 9.1.2: Enhance Air Distribution System Model to Include More Coil Types	UCF/FSEC	03/08	Complete	2/08	
Subtask 9.1.3: Investigate Algorithms for Modeling Airflow Through Large Horizontal Openings	UCF/FSEC	03/08	Complete	10/08	

Subtask 9.1.4: Enhance Existing DXSystem:AirLoop Object	UCF/FSEC	03/08	Complete	01/08	
Subtask 9.1.5: Additional Hybrid (Mixed-mode) Ventilation Controls	UCF/FSEC	09/08	Complete	09/08	
Subtask 9.1.6: Allow Absorption Chiller Connection to a Steam Loop	UCF/FSEC	09/08	Complete	06/08	
Subtask 9.1.7: Enhance Existing Boiler Model for Condensing Boilers	UCF/FSEC	09/08	Complete	07/08	
Subtask 9.1.8: Resolve Conflicts Between Multiple System Availability Managers and Multiple Set Point Managers	UCF/FSEC	09/08	Complete	08/08	
Subtask 9.1.9: Improve Control for Unitary/Furnace Systems under Low-load Conditions	UCF/FSEC	09/08	Complete	12/08	
Subtask 9.1.10: Enhance VENTILATION, MIXING and CROSS MIXING Objects	UCF/FSEC	09/08	Complete	07/08	
Subtask 9.1.11: Enhance Unitary System Model for 2-Speed Systems	UCF/FSEC	09/08	Complete	09/08	
Subtask 9.1.12: Reorganize Condenser Loop Simulation	OSU, UCF/FSEC	09/08	Complete	07/09	
Subtask 9.1.13: Add Model for Piping Pressure Drop	OSU	09/08	Complete	BP4 (subtask 13..1.17)	
Subtask 9.1.14: Add Models for Dry and Evaporative Fluid Coolers	OSU	09/08	Complete	08/08	
Subtask 9.1.15: Enhancements to Plant Flow Resolver	OSU	09/08	Complete	12/08	
Subtask 9.1.16: Implement Double-Precision Real Variables Throughout Code	DHL	03/08	Complete	04/08	
Subtask 9.1.17: Enhance Weather Processor	DHL	09/08	Complete	06/09	
Subtask 9.1.18: Add Input Flexibility for Internal Gains and Ventilation/Infiltration Objects	DHL	03/08	Complete	04/08	

Subtask 9.1.19: Enhance Existing Design Day Object	DHL	03/08	Complete	04/08	
Subtask 9.1.20: Reduce Computational Time	DHL	03/08, 09/08	Complete	03/08, 11/08	
Subtask 9.1.21: Add Model for CoolTowers	UIUC	09/08	Complete	08/08	
Subtask 9.1.22: Add Model for Thermal Chimneys	UIUC	09/08	Complete	07/08	
Subtask 9.1.23: Enhance the Ventilated Slab Model	UIUC	09/08	Complete	02/09	
Subtask 9.1.24: Add Source/Sink Capability in Conduction Finite Difference Model	COPA	09/08	COmplete	07/09	
Subtask 9.1.25: Complete Interzone IR Radiation Exchange Model	COPA	09/08	Complete	07/08	
Subtask 9.1.26: Compact HVAC Extensions	GARD	12/08	Complete	03/10	
Subtask 9.1.27: Economic Enhancements	GARD	09/08	Complete	09/08	
Subtask 9.1.28: Enhance EnergyPlus Reporting	GARD	09/08	Complete	05/11	
Subtask 9.1.29: Revise Object & Input Field Naming Conventions	UCF/FSEC, DHL, GARD	11/08	Complete	11/08	
Subtask 9.2: Allow Alternate Method for Inputting Rectangular Surfaces	DHL	10/08	Complete	01/09	
Subtask 9.3: Add Capability for Checking Solution Algorithms Based on the ASHRAE RP1052 Workbook	COPA	10/08	Complete	12/08	
Subtask 9.4: Expanded Variable Thermal Conductivity Option	COPA	11/08	Complete	07/09	
Subtask 9.5: Stand-Alone Room Air Dehumidifier Model	UCF/FSEC	12/08	Complete	08/09	

Subtask 9.6: Enhanced Feature for Furnace/Unitary Systems to Allow High Humidity Control with Cycling Supply Air Fan	UCF/FSEC	11/08	Complete	12/08	
Subtask 9.7: Research Zone Heat Balance Solution Techniques to Reduce Time Step Dependence	UCF/FSEC	12/08	Complete	03/09	
Task 10. EnergyPlus Testing and Validation (Budget Period 3)					
Subtask 10.1: Run Existing Test Suites, Publish Reports, Develop New Test Cases	GARD	12/08	Complete	04/09	
Subtask 10.2: Test/Validate New Source Code	DHL, GARD	09/08	Complete	12/08	
Subtask 10.3: Address Change Requests	UCF/FSEC, UIUC, OSU, DHL, GARD, COPA	09/08	Complete	01/09	
Subtask 10.4: Create and Test Installation Package	DHL, GARD	03/08, 09/08	Complete	03/08, 11/08	
Task 11. EnergyPlus User Support and Training (Budget Period 3)					
Subtask 11.1: Support Users and Interface Developers	UCF/FSEC, DHL, GARD, OSU	09/08	Complete	12/08	
Subtask 11.2: Organize and Teach Workshops	GARD	11/08	Complete	12/08	
Task 12. General EnergyPlus Support (Budget Period 3)					
Subtask 12.1: Maintain StarTeam Software Configuration Management System	UCF/FSEC	10/08	Complete	12/08	
Subtask 12.2: Update Existing Utility Software	GARD, DHL	09/08	Complete	12/08	
Task 13. EnergyPlus Development (Budget Period 4)					
Subtask 13.1.1: Revise Report Variable and Meter Naming Conventions	GARD, UCF/FSEC, DHL	09/09	Complete	07/11	

Subtask 13.1.2: Review of EnergyPlus Source Code and Utility Programs	GARD, UIUC, COPA, DHL, OSU, UCF/ FSEC	02/09	Complete	05/09	
Subtask 13.1.3: Add Model for Zone Makeup Air Units	UIUC	09/09	Complete	12/09	
Subtask 13.1.4: Improved Controls for Combination Radiant/Convective Cooling Systems	UIUC	09/09	Complete	12/09	
Subtask 13.1.5: Add Wind Turbine Model	UIUC	09/09	Complete	01/10	
Subtask 13.1.6: Removal of Dual Control Layers for Radiant Systems	UIUC	02/09	Complete	11/09	
Subtask 13.1.7: Radiant System Condensation Handling Improvements	UIUC	02/09, 09/09	Complete	12/11	
Subtask 13.1.8: Improvements to Existing Baseboard Radiator Model	UIUC	09/09	Complete	11/09	
Subtask 13.1.9: Construction Specific Solution Algorithms	COPA	09/09	Complete	03/10	
Subtask 13.1.10: Extend CondFD Solution Algorithm to Transparent Insulation	COPA	09/09	Complete	03/10	
Subtask 13.1.11: Add Objects for Code Compliance	DHL	03/09	Complete	11/09	
Subtask 13.1.12: Add EnergyPlus Output Compatible with Radiance	DHL	09/09	Complete	05/11	
Subtask 13.1.13: Verify Zone Multipliers/ Groups	DHL	03/09	Complete	05/10	
Subtask 13.1.14: Enhance the Weather Processing Program	DHL	09/09	Complete	11/09	
Subtask 13.1.15: Reduce Simulation Execution Time	DHL	03/09, 09/09	Complete	04/09, 09/09	
Subtask 13.1.16: Complete Phase 2 EMS-Style Controls at Cooling/Heating Plant Component and "Loop" Levels	OSU	08/09	Complete	03/10	

Subtask 13.1.17: Add Piping Pressure Drop Model and Improved Pump Model	OSU, UCF/ FSEC	08/09	Complete	08/09	
Subtask 13.1.18: Plant Demand Side Equipment Simulation Enhancement	OSU	08/09	Complete	09/11	
Subtask 13.1.19: Modify AirflowNetwork Height-Dependent Wind Speed Model	UCF/FSEC	02/09	Complete	02/09	
Subtask 13.1.20: Enhance Air Distribution System Model to Include More Component Types	UCF/FSEC	02/09	Complete	02/09	
Subtask 13.1.21: Enhance On/Off Fan Energy Calculations	UCF/FSEC	02/09	Complete	02/09	
Subtask 13.1.22: Improved Bypass Control for Air-to-Air Flat Plate Heat Exchangers	UCF/FSEC	02/09	Complete	02/09	
Subtask 13.1.23: Add Basin Heater to Remaining Cooling Towers and Evaporative Condensers	UCF/FSEC	08/09	Complete	05/10	
Subtask 13.1.24: Unify Coil Arrangement for Unitary Systems	UCF/FSEC	08/09	Complete	09/09	
Subtask 13.1.25: Complete Deprecation of Fan Operating Mode from DX Coil Objects	UCF/FSEC	08/09	Complete	04/09	
Subtask 13.1.26: Add Water-to-Air Heat Pump Option for Zone Equipment	UCF/FSEC	08/09	Complete	07/09	
Subtask 13.1.27: Equipment Performance Curve Fit Tool	UCF/FSEC	08/09	Complete	07/11	
Subtask 13.1.28: Control of Minimum Air Flow Fraction for VAV Terminals	UCF/FSEC	08/09	Complete	03/10	
Subtask 13.1.29: Enhance System Availability Managers to Control Zone Equipment Operation	UCF/FSEC	11/09	Complete	04/11	
Subtask 13.1.30: MathDiff for Table Reports	GARD	08/09	Complete	12/09	
Subtask 13.1.31: EP-Launch – Integrate Basement and Slab with EnergyPlus Simulation	GARD	08/09	Complete	02/10	

Subtask 13.1.32: Support NREL Baseline Building Project	GARD	11/09	Complete	11/09	
Subtask 13.2: Create Thermal Component Loads Report	GARD	08/09	Complete	08/11	
Subtask 13.3: Auto-Rotate Building and Average Simulation Results	GARD	03/09	Complete	06/09, 09/09	
Subtask 13.4: Develop Utility to Compare Results from Multiple Simulations	GARD	08/09	Complete	03/10	
Subtask 13.5: Develop Utility to Simplify Parameter Substitution Across Multiple Simulations	GARD	03/09	Complete	09/09	
Subtask 13.6: IP Units Option for Table Reports	GARD	03/09	Complete	02/09	
Subtask 13.7: IDF Editor – Add IP Units Support for Remaining Objects	GARD	03/09	Complete	12/09	
Subtask 13.8: Implement Airflow Model for Large Horizontal Openings	UCF/FSEC	08/09	Complete	08/11	
Subtask 13.9: Improve Convergence Tolerance for Unitary Systems	UCF/FSEC	08/09	Complete	06/09	
Subtask 13.10: Improve Electric Load Center Dispatch	UCF/FSEC	08/09	Complete	03/10	
Task 14. EnergyPlus Testing and Validation (Budget Period 4)					
Subtask 14.1: Run Test Suites/Publish Reports	GARD	11/09	Complete	02/10	
Subtask 14.2: Test/Validate New Source Code	GARD, DHL	11/09	Complete	02/10	
Subtask 14.3: Address Change Requests	UCF/FSEC, OSU, UIUC, GARD, DHL, COPA	11/09	Complete	02/10	
Subtask 14.4: Create and Test Installation Package	DHL, GARD	03/09, 09/09	Complete	04/09, 11/09, 10/09,	
Task 15. EnergyPlus User Support and Training (Budget Period 4)					

Subtask 15.1: Support Users and Interface Developers	UCF/FSEC, DHL, GARD, OSU	11/09	Complete	02/10	
Subtask 15.2: Update Training Materials	GARD	05/09, 11/09	Complete	06/09, 10/09	
Subtask 15.3: Organize and Teach Workshops	GARD	09/09	Complete	03/11	
Task 16. General EnergyPlus Support (Budget Period 4)					
Subtask 16.1: Upgrade and Maintain StarTeam Software Configuration Management System	UCF/FSEC	11/09	Complete	02/10	
Subtask 16.2: Update Existing Utility Software	GARD, DHL	03/09, 09/09	Complete	04/09, 10/09	
Task 17. EnergyPlus Development (Budget Period 5)					
Subtask 17.1.1: Warm-up Convergence Improvements	UIUC, GARD	09/10	Complete	06/11	
Subtask 17.1.2: CTF Improvements	UIUC	09/10	Complete	08/11	
Subtask 17.1.3: Convective/Radiant Electric Baseboard Model	UIUC	02/10	Complete	02/10	
Subtask 17.1.4: Convective-Only Baseboard Input/Output Improvements	UIUC	02/10	Complete	12/10	
Subtask 17.1.5: Supply/Return Loop Heat Transfer to Support CHP & District Heating	OSU	09/10	Complete	08/11	
Subtask 17.1.6: Enhance Pipe Heat Transfer Solver	OSU	05/10	Complete	09/11	
Subtask 17.1.7: Improved Pump Controls	OSU	09/10	Complete	08/11	
Subtask 17.1.8: Integration of ASHRAE RP-1383 Models	COPA	10/10	Complete	07/11	

Subtask 17.1.9: Complete Extension of CondFD Solution Algorithm to Transparent Insulation	COPA	03/10	Complete	05/10	
Subtask 17.1.10: Improve Solar Shading and Interior Solar Distribution Calculations	DHL	08/10	Complete	05/11	
Subtask 17.1.11: Flexible Corner Starting Positions	DHL	05/10	Complete	02/11	
Subtask 17.1.12: Document Developer Test Suite Run Requirements and Details	DHL	06/10	Complete	11/10	
Subtask 17.1.13: Refactor Output Variable Reporting	DHL	08/10	Complete	08/10	
Subtask 17.1.14: Global People, Lights, Thermostats for Building	DHL	08/10	Complete	07/10	
Subtask 17.1.15: TDD Pipe Illuminance Reporting	DHL	09/10	Complete	03/11	
Subtask 17.1.16: Refactor Triangulation Routine for >4 sided Surfaces	DHL	06/10	Complete	05/11	
Subtask 17.1.17: Add Analytical Solution to Zone Air Heat Balance	UCF/FSEC	03/10	Complete	03/10	
Subtask 17.1.18: Variable Refrigerant Flow Heat Pump Model	UCF/FSEC	08/10	Complete	02/11	
Subtask 17.1.19: Eliminate Redundant Input in Selected Compound Objects	UCF/FSEC	08/10	Complete	05/11	
Subtask 17.1.20: Deprecate Supply Air Fraction Field From Unitary System Objects	UCF/FSEC	08/10	Complete	07/10	
Subtask 17.1.21: Add All-Off Equipment Operation Scheme Option for Plant and Condenser Loops	UCF/FSEC	08/10	Complete	08/10	
Subtask 17.1.22: Develop Equipment Performance Data Sets for Certain Equipment Types	UCF/FSEC	09/10	Complete	05/11	
Subtask 17.1.23: Enhance Plant and Condenser Loop Component Models to Use Fluid Property Routines	UCF/FSEC	08/10	Complete	08/11	

Subtask 17.1.24: Upgrade VB 6.0 Utilities to New Programming Language/ Environment for Windows, Linux and Macintosh	GARD	08/10	Complete	07/11	
Subtask 17.2: HVACTemplate Extensions	GARD	08/10	Complete	05/11	
Subtask 17.3: Upgrade/Enhance ZoneHVAC:IdealLoadsAirSystem Object	GARD	05/10	Complete	08/11	
Subtask 17.4: Improve Tabular Output Reports	GARD	05/10	Complete	03/11	
Subtask 17.5: Perform Simulations in Parallel	GARD	05/10	Complete	04/10	
Subtask 17.6: EP-Launch – Run Multiple Simulations Simultaneously on Multi-Core Processors	GARD	05/10	Complete	09/10	
Subtask 17.7: EP-Launch – Improve Output File Management	GARD	05/10	Complete	06/10	
Subtask 17.8: IDF Editor – Enhanced Cross Referencing of Objects	GARD	08/10	Complete	03/11	
Subtask 17.9: IDF Editor – Improve Node Entry and Management	GARD	08/10	Complete	03/11	
Subtask 17.10: New Setpoint Manager Accounting for Multiple Zone Impacts	UCF/FSEC	05/10	Complete	08/10	
Subtask 17.11: Tabular Performance Inputs	UCF/FSEC	08/10	Complete	08/10	
Subtask 17.12: Model CO ₂ Concentration and Controls	UCF/FSEC	08/10	Complete	08/10	
Subtask 17.13: Simplified Natural Ventilation Model Based on Physical Correlation and Opening Size	UCF/FSEC	03/10	Complete	03/10	
Subtask 17.14: Simplified Model of Interaction between Mechanical Ventilation, Infiltration and Duct Leakage	UCF/FSEC	08/10	Complete	07/10	
Subtask 17.15: Add Overcool Option for High Humidity Control to Furnace/Unitary System	UCF/FSEC	05/10	Complete	12/10	
Subtask 17.16: Calculate Standard Ratings for Primary HVAC Components	UCF/FSEC	05/10	Complete	06/10	
Subtask 17.17: Integrate ASHWAT Shaded Fenestration Model Into EnergyPlus	Wrightsoft	08/10	Complete	03/11	
Subtask 17.18: Update ASHRAE Weather Data Procedures	Wrightsoft	08/10	Complete	03/11	

Subtask 17.19: Integration of AutoDesk code donation	GARD, DHL	08/11	Complete	08/11	
Task 18. EnergyPlus Testing and Validation (Budget Period 5)					
Subtask 18.1: Run Test Suites/Publish Reports	GARD	05/10, 11/10	Complete	06/10, 04/11	12/10,
Subtask 18.2: Test/Validate New Source Code	GARD, DHL	11/10	Complete	05/11	
Subtask 18.3: Address Change Requests	UCF/FSEC, OSU, UIUC, GARD, DHL, COPA	11/10	Complete	08/11	
Subtask 18.4: Create and Test Installation Package	DHL, GARD	04/10, 10/10	Complete	04/10, 10/10	
Task 19. EnergyPlus User Support and Training (Budget Period 5)					
Subtask 19.1: Support Users and Interface Developers	UCF/FSEC, DHL, GARD, OSU	11/10	Complete	03/11	
Subtask 19.2: Update Training Materials	GARD	05/10, 11/10	Complete	05/10, 04/11	11/10,
Subtask 19.3: Organize and Teach Workshops	GARD	09/10	Complete	08/11	
Task 20. General EnergyPlus Support (Budget Period 5)					
Subtask 20.1: Upgrade and Maintain StarTeam Software Configuration Management System	UCF/FSEC	11/10	Complete	08/11	
Subtask 20.2: Update Existing Utility Software	GARD, DHL	03/10, 09/10	Complete	04/10, 02/11	10/10,
Subtask 20.3: Plant Demand Side Equipment Simulation Enhancement	OSU	08/11	Complete	09/11	

Appendix D A List of Supporting Documentations

This appendix provide a list of supporting documents as a part of installation package to help users understand and use the program effectively. A brief description of each document is provided under document title.

Getting Started

This document presents the background Information about building energy simulations, and the evolution of EnergyPlus from BLAST, DOE-2 and other programs. Capabilities of EnergyPlus are presented as well as a structural overview. A guide to the EnergyPlus documentation library is included in tile overview portion.

Input/Output Reference

This document contains detailed information of the input objects in EnergyPlus. Links between inputs and output variables are displayed as well as details given about input and output fields. Small excerpts show the use of objects in IDF (Input Data File) format.

Output Details/Examples

This document contains more explanations on some of the reports and other outputs than is contained in the Input/Output Reference. Reading this document will provide a user with the information necessary to interpret the various output files from EnergyPlus.

Engineering Reference

This document will provide users and developers with an understanding of the algorithms and models used to construct the program source code.

Auxiliary Programs

This document contains descriptions and instructions for using some of the less complex programs that accompany the EnergyPlus system of programs and documents.

Application Guides

- EMS Application Guide

This document contains information useful to use the advanced feature of EnergyPlus: Energy Management System tweaks. The Erl language is described and examples for use are given.

- External Interfaces Application Guide

This document explains the hook to use some external programs (specifically the Building Controls Virtual Test Bed) with EnergyPlus.

- **Tips and Tricks Using EnergyPlus**
This document is a small guide with specific hints on using EnergyPlus in specific applications that might be hard to find in other documents.
- **Using EnergyPlus for Compliance**
This document contains information specific to using EnergyPlus in Compliance and Standard Rating systems.

Developer Guides

- **Interface Developer**
This document contains information useful for independent development groups that are seeking to construct user interfaces for use with EnergyPlus.
- **Module Developer**
This document contains information specific to developing new modules and routines for EnergyPlus
- **Programming Standard**
This document specifies the rules and guidelines used to create and/or re-engineer source code to form the EnergyPlus program. Useful to anyone writing or modifying EnergyPlus modules and subroutines.

Output Details and Examples

This document contains more explanations on some of the reports and other outputs than is contained in the Input/Output Reference. Reading this document will provide a user with the information necessary to interpret the various output files from EnergyPlus.

Acknowledgments

The document referenced by this selection will illustrate the breadth and depth of those contributing to EnergyPlus development and supporting efforts.

Appendix E Publications

This Appendix contains published papers and testing reports.

Papers

Gu, Lixing, "Airflow Network Modeling in EnergyPlus", 10th International Building Performance Simulation Association Conference and Exhibition on September 3-6, 2007 in Beijing, China

Pedersen, Curtis O. 2009 "A Fundamental Approach To Cooling Load Calculations For UFADS And Stratified Spaces" *Proceedings Of Building Simulation 2009, Glasgow Scotland, IBPSA*.

Pedersen, Curtis. O. 2007. "Advanced Zone Simulation in EnergyPlus: Incorporation of Variable Properties and Phase Change Material (PCM) Capability," *Proceedings of Building Simulation 2007, Beijing China, IBPSA*.

Raustad, R.A., "A Variable Refrigerant Flow Heat Pump Air Conditioner Computer Model in Energyplus," ASHRAE Winter Meeting, 2012.

Spitler, J., J. Cullin, M. Bernier, M. Kummert, P. Cui, X. Liu, E. Lee, and D. Fisher. 2009. Preliminary intermodel comparison of ground heat exchanger simulation models. *Proceedings of 11th International Conference on Thermal Energy Storage; Effstock 2009, Stockholm, Sweden, June 14-17*.

Witte, M.J., Henninger, R.H., and D.B. Crawley, "Experience Testing EnergyPlus with the IEA BESTEST E300-E545 Series and IEA HVAC BESTEST Fuel-Fired Furnace Series," *Proceedings, SimBuild 2006*, IBSPA-USA National Conference, Cambridge, MA, August 2006.

Witte, M.J., Henninger, R.H., and D.B. Crawley, "Development of New Self-Comparison Test Suites for EnergyPlus," *Proceedings SimBuild 2008*, IBSPA-USA National Conference, Berkeley, CA, July 2008.

Testing Reports

Published for EnergyPlus versions 1.3, 1.4, 2.0, 2.1, 2.2, 3.0, 3.1, 4.0, 5.0 and 6.0 *EnergyPlus Testing with Building Thermal Envelope and Fabric Load Tests from ANSI/ASHRAE Standard 140-2004*; beginning with EnergyPlus 2.2 used ANSI/ASHRAE Standard 140-2007

Published for EnergyPlus versions 1.3, 1.4, 2.0, 2.1, 2.2, 3.0, 3.1, 4.0, 5.0 and 6.0
EnergyPlus Testing with HVAC Equipment Performance Tests CE100 to CE200 from ANSI/ASHRAE Standard 140-2004; beginning with EnergyPlus 2.2 used ANSI/ASHRAE Standard 140-2007

Published for EnergyPlus versions 1.3, 1.4, 2.0, 2.1, 2.2, 3.0, 3.1, 4.0, 5.0 and 6.0
EnergyPlus Testing with ASHRAE 1052-RP Toolkit – Building Fabric Analytical Tests

Published for EnergyPlus versions 1.3, 1.4, 2.0 and, 2.1
EnergyPlus Testing with HVAC BESTEST Part 2 - Tests E300 to E545

Published for EnergyPlus versions 2.2, 3.0, 3.1, 4.0, 5.0 and 6.0
EnergyPlus Testing with HVAC Equipment Performance Tests CE300 to CE545 from ANSI/ASHRAE Standard 140-2007

Published for EnergyPlus versions 1.3, 1.4, 2.0, and 2.1
EnergyPlus Testing with Fuel-Fired Furnace HVAC BESTEST

Published for EnergyPlus versions 2.2, 3.0, 3.1, 4.0, 5.0 and 6.0
EnergyPlus Testing with Fuel-Fired Furnace Tests HE100 to HE230 from ANSI/ASHRAE Standard 140-2007

Published for EnergyPlus versions 1.4, 2.0, 2.1, 2.2, 3.0, 3.1, 4.0, 5.0 and 6.0
EnergyPlus Testing with HVAC Equipment Component Tests

Published for EnergyPlus versions 1.4, 2.0, 2.1, 2.2, 3.0, 3.1, 4.0, 5.0 and 6.0
EnergyPlus Testing with Global Energy Balance Test

Published for EnergyPlus versions 3.1, 4.0, 5.0 and 6.0
EnergyPlus Testing with IEA BESTEST In-Depth Ground Coupled Heat Transfer Tests Related to Slab-on-Grade Construction

Published for EnergyPlus versions 4.0, 5.0 and 6.0
EnergyPlus Testing with IEA Mechanical Equipment & Control Strategies for a Chilled Water and a Hot Water System

Published for EnergyPlus versions 4.0, 5.0 and 6.0
EnergyPlus Testing with IEA BESTEST Multi-Zone Non-Airflow In-Depth Diagnostic Cases MZ320 – MZ360