EnergyPlus™ Version 9.4.0 Documentation

Acknowledgments and Copyright Notices

U.S. Department of Energy

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Build: 998c4b761e

Contents

Chapter 1

Notices and Acknowledgments

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Portions of the EnergyPlus™ software package have been developed and copyrighted by other individuals, companies and institutions. These portions have been incorporated into the EnergyPlus software package under license.

In addition to the primary authorship of the LBNL Simulation Research Group (http://simulationresearch.lbl.gov/) and the UIUC Building Systems Laboratory, the following have contributed to EnergyPlus Versions (includes all minor revisions):

Portions of the EnergyPlus weather processor were developed by US Department of Energy, Office of Building Technologies.

Portions of the input processing, output processing, weather processor, BLAST Translator were developed by US Army Corps of Engineers, Construction Engineering Research Laboratories, 2902 Newmark Drive, Champaign IL 61821. http://www.erdc.usace.army.mil/Locations/ConstructionEngineeringResearchLaboratory.aspx

Portions of this software package were developed for Ernest Orlando Lawrence Berkeley National Laboratory and Florida Solar Energy Center by Linda Lawrie of DHL Consulting.

Portions of this software package were developed for Ernest Orlando Lawrence Berkeley National Laboratory and Florida Solar Energy Center by C.O. Pedersen Associates.

Portions of the EnergyPlus utility software (EP-Launch, IDFEditor, DOE2Translator, HVAC-Diagram, ExpandObjects, CSVProc, ParametricPreprocessor, AppGPostProcess, EP-Compare, and convertESOMTR) were developed by GARD Analytics, Inc. 115 S. Wilke Road, Suite 105, Arlington Heights, IL, USA, <info@gard.com>, www.gard.com. GARD Analytics performed independent verification and validation testing of the software after developing the testing strategy and plan. GARD Analytics was also responsible for gas absorption chiller, desiccant dehumidifier, ice storage (simple), table reports, economics and life cycle costing.

Portions of flow resolver, chiller models (absorption, electric, const cop, engine-driven, gas-turbine), generator models (diesel electric, gas turbine), furnace models, heat recovery loop, plant loop, plant condenser loop, air-change dependent inside film coefficients were developed by Oklahoma State University, 110 Engineering North, Stillwater, OK 74078.

Portions of EnergyPlus related to the models for EMPD moisture calculations, DX coils, furnace/unitary systems, air-to-air heat pumps, changeover-bypass VAV systems, packaged terminal heat pumps, cooling towers, AirflowNetwork, refrigerated cases, reformulated and electric EIR chillers, desuperheater air and water heating coils, heat pump water heaters, desiccant and generic air-to-air heat exchangers, window screens, and thermal comfort controls were developed by University of Central Florida, Florida Solar Energy Center (FSEC), 1679 Clearlake Road, Cocoa, FL 32922, www.fsec.ucf.edu/.

Portions of the refrigeration model and the exhaust-fired absorption chiller model were developed by Oak Ridge National Laboratory, Bethel Valley Road, Oak Ridge, Tennessee 37831.

Portions of EnergyPlus were developed by the National Renewable Energy Laboratory (NREL), 1617 Cole Blvd, Golden, CO 80401.

Portions of EnergyPlus related to transformer losses model, autosizing calculations, life cycle costing and chemical battery storage model were developed by Pacific Northwest National Laboratory (PNNL), P.O. Box 999, Richland, WA 99352.

EnergyPlus v1.0.1, v1.0.2, v1.0.3, v1.1, v1.1.1 (Wintel platform) included a link to TRNSYS (The Transient Energy System Simulation Tool) for photovoltaic calculations developed by Thermal Energy System Specialists, 2916 Marketplace Drive, Suite 104, Madison, WI 53719; Tel: (608) 274-2577. EnergyPlus v1.2 and later includes Photovoltaic calculations implemented in EnergyPlus by Thermal Energy System Specialists. This model was originally developed by Oystein Ulleberg, Institute for Energy Technology, Norway – based on the Duffie and Beckman equivalent one-diode model.

Portions of this software package that convert certain stand-alone heat transfer models for slab-on-grade and basement foundations were developed by William Bahnfleth, Cynthia Cogil, and Edward Clements, Department of Architectural Engineering, Pennsylvania State University, 224 Engineering Unit A, University Park, Pennsylvania 16802-1416, (814) 863-2076.

The concept and initial implementation for the EnergyPlus COM/DLL version (Wintel platform) was made possible through cooperation with DesignBuilder Software, Ltd, Andy Tindale – an EnergyPlus collaborative developer.

The thickness, conductivity, density and specific heat values of the material layers for the constructions in the Composite Wall Construction reference data set have been taken from the ASHRAE report "Modeling Two- and Three-Dimensional Heat Transfer through Composite Wall and Roof Assemblies in Hourly Energy Simulation Programs (1145-TRP)," by Enermodal Engineering Limited, Oak Ridge National Laboratory, and the Polish Academy of Sciences, January 2001.

EnergyPlus v1.2 and later versions contains DELight2, a simulation engine for daylighting and electric lighting system analysis developed at Ernest Orlando Lawrence Berkeley National Laboratory.

EnergyPlus v1.2.2 through v3.1 contained links to SPARK, a simulation engine for detailed system modeling developed at Ernest Orlando Lawrence Berkeley National Laboratory in conjunction with Ayres Sowell Associates, Inc.

The airflow calculation portion of the EnergyPlus AirflowNetwork model was based on AIRNET written by George Walton of the National Institute for Standards and Technology (NIST), 100 Bureau Drive, Gaithersburg, MD 20899. The EnergyPlus AirflowNetwork model also includes portions of stack effect and detailed large opening from an early version of COMIS (Conjunction Of Multizone Infiltration Specialists) developed by a multinational, multi-institutional effort under the auspices of the International Energy Agency's Buildings and Community Systems Agreement work-

ing group focusing on multizone air flow modeling (Annex 23) and now administered by the Swiss Federal Laboratories for Materials Testing and Research (EMPA), Division 175, Uberlandstrasse 129, CH-8600 Dubendorf, Switzerland.

The EnergyPlus model for displacement ventilation and cross-ventilation (version v1.2 and later) was developed by Guilherme Carrilho da Graca (Department of Mechanical and Aerospace Engineering, University of California, San Diego and NaturalWorks) and Paul Linden (Department of Mechanical and Aerospace Engineering, University of California, San Diego).

The EnergyPlus models for UFAD served zones were developed by Anna Liu and Paul Linden at the Department of Mechanical and Aerospace Engineering, University of California, San Diego.

ASHRAE research project 1254-RP supported the development of the following features first added in EnergyPlus v1.2.2:

- DXSystem:AirLoop enhancements (valid as OA system equipment, new humidity control options)
- New set point managers: SET POINT MANAGER:SINGLE ZONE HEATING, SET POINT MANAGER:SINGLE ZONE COOLING, and SET POINT MANAGER:OUTSIDE AIR PRETREAT
- New 2-stage DX coil with enhanced dehumidification option:
  - COIL:DX:MultiMode:CoolingEmpirical
- Additional DESICCANT DEHUMIDIFIER:SOLID setpoint control option

American Society of Heating Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, N.E., Atlanta, GA 30329[1]. Work performed by GARD Analytics, Inc., 115 S. Wilke Road, Suite 105, Arlington Heights, IL, USA[2], November 2004. These items were renamed in V3.0 to:

- SetpointManager:SingleZone:Heating
- SetpointManager:SingleZone:Cooling
- SetpointManager:OutdoorAirPretreat
- Coil:Cooling:DX:TwoStageWithHumidityControlMode
- Dehumidifier:Desiccant:NoFans

The Ecoroof (Green Roof) model, first introduced in EnergyPlus v2.0, was developed at Portland State University, by David Sailor and his students. It is based on the FASST vegetation models developed by Frankenstein and Koenig for the US Army Corps of Engineers.

The HAMT (Heat And Moisture Transfer) model, first introduced in EnergyPlus v3.0.0 was developed by Phillip Biddulph, Complex Built Environment Systems, The Bartlett School of Graduate Studies, University College London, Gower Street, London WC1E 6BT, United Kingdom. http://www.cbes.ucl.ac.uk/.

[1] http://www.ashrae.org/

[2] urlinfo@gard.com; http://www.gard.com/

The SQLite output module, first introduced in EnergyPlus v3.0.0, was developed by Gregory B. Stark, P.E., Building Synergies, LLC, 1860 Washington Street, Suite 208, Denver, Colorado 80203, United States.

Refrigeration compressor performance data and refrigeration practices were provided by CDH Energy, Cazenovia, NY 12035.

The external interface was developed by Michael Wetter and Philip Haves (Lawrence Berkeley National Laboratory) and by Rui Zhang (Carnegie Mellon University). An earlier upgrade to a development version of EnergyPlus 3.0 was implemented by Charles Corbin, Anthony Florita, Gregor Henze and Peter May-Ostendorp (University of Colorado at Boulder).

Various suggestions for time reduction, improved documentation and other items have been incorporated from Autodesk, Inc., Bentley Systems, and others.

Particular recognition goes to Noel Keen (LBNL Computational Research Division) and Geof Sawaya (Oak Ridge National Laboratory fellow) who have done extensive profiling and creation of time reduction features that have gone into the code.

Second Law modified the WaterToAirHeatPump:EquationFit module to include the variable "WaterCyclingMode". This variable determines whether the heat pump water flow is constant, whether it cycles with the compressor, or whether it is constant when the heat pump is active. WaterFlowMode is set by the HVAC wrapper object; either ZoneHVAC:WaterToAirHeatPump or AirLoopHVAC:UnitaryHeatPump:WaterToAir. Second Law, Burlington, VT, Karen Walkerman.

1.2 Other Software included or referenced directly

The following notices apply to those EnergyPlus distributions which include the interface to BCVTB or Functional Mock-up Units.

1.2.1 ZLIB DATA COMPRESSION LIBRARY

zlib 1.2.5 is a general purpose data compression library. All the code is thread safe. The data format used by the zlib library is described by RFCs (Request for Comments) 1950 to 1952 in the files http://www.ietf.org/rfc/rfc1950.txt (zlib format), rfc1951.txt (deflate format) and rfc1952.txt (gzip format).

All functions of the compression library are documented in the file zlib.h (volunteer to write man pages welcome, contact zlib@gzip.org). A usage example of the library is given in the file example.c which also tests that the library is working correctly. Another example is given in the file minigzip.c. The compression library itself is composed of all source files except example.c and minigzip.c.

To compile all files and run the test program, follow the instructions given at the top of Makefile.in. In short "./configure; make test", and if that goes well, "make install" should work for most flavors of Unix. For Windows, use one of the special makefiles in win32/ or contrib/vstudio/ . For VMS, use make_vms.com. Questions about zlib should be sent to <zlib@gzip.org>, or to Gilles Vollant <info@winimage.com> for the Windows DLL version. The zlib home page is http://zlib.net/ . Before reporting a problem, please check this site to verify that you have the latest version of zlib; otherwise get the latest version and check whether the problem still exists or not.

PLEASE read the zlib FAQ http://zlib.net/zlib_faq.html before asking for help.

Mark Nelson <markn@ieee.org> wrote an article about zlib for the Jan. 1997 issue of Dr. Dobb's Journal; a copy of the article is available online[3].

The changes made in version 1.2.5 are documented in the file ChangeLog.

Unsupported third party contributions are provided in directory contrib/ .

zlib is available in Java using the java.util.zip package, documented online[4].

A Perl interface to zlib written by Paul Marquess <pmqs@cpan.org> is available at CPAN (Comprehensive Perl Archive Network) sites, including http://search.cpan.org/pmqs/IO-Compress-Zlib/.

A Python interface to zlib written by A.M. Kuchling <amk@amk.ca> is available in Python 1.5 and later versions, see http://www.python.org/doc/lib/module-zlib.html.

zlib is built into tcl: http://wiki.tcl.tk/4610 .

An experimental package to read and write files in .zip format, written on top of zlib by Gilles Vollant <info@winimage.com>, is available in the contrib/minizip directory of zlib.

Notes for some targets:

- For Windows DLL versions, please see win32/DLL_FAQ.txt
- For 64-bit Irix, deflate.c must be compiled without any optimization. With -O, one libpng test fails. The test works in 32 bit mode (with the -n32 compiler flag). The compiler bug has been reported to SGI.
- zlib doesn't work with gcc 2.6.3 on a DEC 3000/300LX under OSF/1 2.1 it works when compiled with cc.
- On Digital Unix 4.0D (formely OSF/1) on AlphaServer, the cc option -std1 is necessary to get gzprintf working correctly. This is done by configure.
- zlib doesn't work on HP-UX 9.05 with some versions of /bin/cc. It works with other compilers. Use "make test" to check your compiler.
- gzdopen is not supported on RISCOS or BEOS.
- For PalmOs, see http://palmzlib.sourceforge.net/

Acknowledgments:

[3] http://marknelson.us/1997/01/01/zlib-engine/

[4] http://java.sun.com/developer/technicalArticles/Programming/compression/

The deflate format used by zlib was defined by Phil Katz. The deflate and zlib specifications were written by L. Peter Deutsch. Thanks to all the people who reported problems and suggested various improvements in zlib; they are too numerous to cite here.

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Jean-loup Gailly Mark Adler
jloup@gzip.org madler@alumni.caltech.edu

If you use the zlib library in a product, we would appreciate *not* receiving lengthy legal documents to sign. The sources are provided for free but without warranty of any kind. The library has been entirely written by Jean-loup Gailly and Mark Adler; it does not include third-party code.

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