



Energy, Economic and Environmental Research

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**ENERGYPLUS TRAINING MODULES
FOR BUILDING PHYSICS:
DAYLIGHTING, INFILTRATION, INSULATION,
INTERNAL GAINS, AND THERMAL MASS**

FINAL REPORT

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1 Background

EnergyPlus (www.energyplus.gov) is a whole building simulation tool which models heating, cooling, lighting, ventilating, and other energy flows as well as water in buildings. While originally based on the most popular features and capabilities of BLAST and DOE-2, EnergyPlus includes many innovative simulation capabilities such as time steps of less than an hour, modular systems and plant integrated with heat balance-based zone simulation, multizone air flow, thermal comfort, water use, natural ventilation, and photovoltaic systems. Tools like EnergyPlus are a key component in sustainable whole building design. To broaden the use of EnergyPlus, more training materials are required for use by practicing engineers and architects and by university faculty in teaching building physics and simulation.

GARD Analytics, Inc. was responsible for the overall design, review, testing, and editing of the modules. Ralph Muehleisen of the Illinois Institute of Technology was responsible for creating the modules. Akoya assisted with editing and formatting the presentations and exercise instructions.

2 Project Summary

This project focused on training modules for EnergyPlus which teach how to use EnergyPlus as well as illustrate basic concepts of building physics. The modules are designed as self-study exercises suitable for university students as well as practicing engineers and architects but also suitable for use in university lectures or professional training workshops.

Each module focuses on a particular area of building physics:

- Daylighting,
- Infiltration,
- Insulation,
- Internal Gains, and
- Thermal Mass.

These topics were selected to be useful both for practicing engineers and architects yet instructive to university students.

Each module includes presentation slides to teach the necessary concepts and one or more hands-on exercises to provide practice in using EnergyPlus. The presentation slides are suitable for use in a university course and for self-study. Each exercise starts with a baseline building provided as a starting point, and then provides instructions to create several variations by adding to or modifying features of the baseline building. The buildings are fairly simple buildings with one to five zones as appropriate for the particular objective. Results are compared across the baseline and variations with an explanation of the changes in results.

Each module contains the following components:

- Presentation slides with notes to teach the necessary EnergyPlus concepts and syntax to model a particular concept.
- Description of exercise objectives, including drawings of the building and key features to be added or modified.
- Overview of modeling approach and how EnergyPlus will be applied to the problem.
- Initial EnergyPlus input file to be used as a starting point for the exercises, or instructions to create one.
- Step-by-step instructions to accomplish the exercises in EnergyPlus.
- Completed EnergyPlus solution input files.
- Selected EnergyPlus output data illustrating the results for heating and cooling loads and overall energy and water use.
- Summary table of results showing the impact of the changes.

Each module should require approximately 2-3 hours for a novice EnergyPlus user to complete, and 1 hour for an expert EnergyPlus user.

For each module, the following deliverables have been provided:

- Powerpoint file containing presentation slides with notes
- Exercise description document(s) (including objectives, step-by-step instructions, and results summary) in Microsoft Word and pdf formats.
- Initial EnergyPlus input file(s) (if applicable)
- Complete EnergyPlus solution input files and output files.

The contents of each module are summarized in the following sections.

3 Daylighting Module

3.1 Topics Covered

- Introduction to Daylighting
- Daylighting Design Sequence with Windows
 - Feasibility Study
 - Envelope ,Window Design, and Room Depths
 - Glazing Area
 - Glazing Selection
 - Shading Strategies
 - Design of Artificial Lighting and Control System
 - Initial Cost/Benefit Analysis
- Advanced Daylighting Systems
- Daylighting Design Tools
- Example Simulations
- Softwares, References

3.2 Exercise Summary

The exercise provides a base file for a single-storied building, measuring 65ft x 15ft. The building is modeled with one zone.

The objective of this exercise is to study the effect of daylighting on a building's energy use.

This exercise aims to compare the performance and energy usage of different glazing alternatives and shading strategies. The same sets of simulations are run for Chicago, IL, and Phoenix, AZ, to study the impact of daylighting in different climates.

3.3 File List

Daylighting Exercise Instructions.doc
Daylighting Exercise Instructions.pdf
Daylighting Presentation.pptx
Daylighting_Output_Charts.xlsx
Solution Files\0.Daylighting_BaseFile.idf
Solution Files\1.Daylighting_BaseFile_Chicago.idf
Solution Files\2.Daylighting_ClearGlass_Chicago.idf
Solution Files\3.Daylighting_Blinds_Chicago.idf
Solution Files\4.Daylighting_LoEGlass_Chicago.idf
Solution Files\5.Daylighting_LightShelf_Southwall_Chicago.idf
Solution Files\6.Daylighting_LightShelf_Northwall_Chicago.idf
Solution Files\7.Daylighting_LightShelf_Eastwall_Chicago.idf
Solution Files\8.Daylighting_BaseFile_Phoenix.idf
Solution Files\9.Daylighting_ClearGlass_Phoenix.idf
Solution Files\10.Daylighting_Blinds_Phoenix.idf
Solution Files\11.Daylighting_LoEGlass_Phoenix.idf
Solution Files\12.Daylighting_LightShelf_Southwall_Phoenix.idf
Solution Files\13.Daylighting_LightShelf_Northwall_Phoenix.idf
Solution Files\14.Daylighting_LightShelf_Eastwall_Phoenix.idf
Solution Files\15.Daylighting_LoEGlass_Chicago_Illuminance Map.idf

4 Infiltration Module

4.1 Topics Covered

- Introduction
- Airtightness of commercial and institutional buildings
- Quantifying air infiltration rate
 - Actual measurement
 - Assumption: Design flow rate (ACH)
 - Single zone estimation (effective leakage area)
 - Sherman-Grimsrud Model
 - Walker-Wilson Model
 - Estimation using detailed crack method
- EnergyPlus simulations
- Stack effect
- Example simulations
 - Design flow rate model
 - Effective leakage area model
 - Flow coefficient model
- Summary

4.2 Exercise Summary

The exercise provides a base file for a two-story building, measuring 104ft x 48ft. The building is modeled with core and perimeter zoning for each floor.

The objective of this exercise is to study the effect of infiltration on a building's energy use. EnergyPlus contains three models for basic infiltration calculations.

- The first is the Design Flow Rate model that was inherited from EnergyPlus's predecessor programs. It is based on environmental conditions modifying a design flow rate.
- The second is the Effective Leakage Area model based on Sherman and Grimsrud.
- The third is the Flow Coefficient model based on Walker and Wilson.

The model formulations for the Effective Leakage Area and Flow Coefficient models are taken from the ASHRAE Handbook (2001 Chapter 26; 2005 Chapter 27), where they are referred to as "Basic" and "Enhanced," respectively. This exercise aims to compare different infiltration data and energy usage using each of above-mentioned models.

4.3 File List

Infiltration Exercise Instructions.doc
Infiltration Exercise Instructions.pdf
Infiltration Presentation.pptx
Infiltration_Output_Charts.xlsx
Solution Files\1.InfiltrationBaseFile.idf
Solution Files\2.Infiltration_DesignFlowRate_0.5ACH.idf
Solution Files\3.Infiltration_DesignFlowRate_1ACH.idf
Solution Files\4.Infiltration_EffectiveLeakageArea_min.idf
Solution Files\5.Infiltration_EffectiveLeakageArea_max.idf
Solution Files\6.Infiltration_FlowCoefficient_min.idf
Solution Files\7.Infiltration_FlowCoefficient_max.idf

5 Insulation Module

5.1 Topics Covered

- Introduction to Building Insulation
- Heat Transfer Processes
 - Conduction
 - Convection
 - Radiation
- Thermal Properties of Buildings
- Using Insulation to Reduce Heat Transfer
- Types of Insulation
- Example Simulations

5.2 Exercise Summary

This exercise provides a base file for a two-story building, measuring 104ft x 48ft. The building is modeled with core and perimeter zoning for each floor.

The objective of this exercise is to study the effect of insulation on a building's energy use. The same structure is modeled with standard steel stud wall or wood stud wall constructions and different insulation thicknesses to study the difference in energy consumption.

Another simulation is run to study the effect of different types of insulation on the roof.

5.3 File List

Insulation Exercise Instructions.doc
Insulation Exercise Instructions.pdf
Insulation Presentation.pptx
Insulation_Output_Charts.xlsx
Solution Files\1.Insulation_BaseFile.idf
Solution Files\2.Insulation_WoodStud_0.5in.idf
Solution Files\3.Insulation_WoodStud_1in.idf
Solution Files\4.Insulation_WoodStud_2in.idf
Solution Files\5.Insulation_SteelStud_0.5in.idf
Solution Files\6.Insulation_SteelStud_1in.idf
Solution Files\7.Insulation_SteelStud_2in.idf
Solution Files\8.Insulation_Roof_R40.idf

6 Internal Gains Module

6.1 Topics Covered

- Internal heat gains from
 - People
 - Lighting
 - Electric motors
 - Appliances and equipment
 - Residential spaces
- Thermal comfort
 - ASHRAE 55-2004
 - Conditions and variables for thermal comfort
 - Computation methods
 - PMV & PPD
- Control of internal gains
- Example simulations
 - EnergyPlus Input Data: Introduction
 - EnergyPlus Input Data: Schedules
 - EnergyPlus Input Data: People
 - EnergyPlus Input Data: Lights
 - EnergyPlus Input Data: Electric equipment
 - EnergyPlus Output
- Summary

6.2 Exercise Summary

The exercise provides a base file for a two-story building, measuring 104ft x 48ft. The building is modeled with core and perimeter zoning for each floor.

The objective of this exercise is to study the effect of internal gains from people, lighting and equipment on a building's energy use. The same structure is modeled as a hotel, an office and a retail building with different space-use characteristics, lighting plans and equipment data to study the difference in energy consumption.

6.3 File List

Internal Gains Exercise Instructions.doc
Internal Gains Exercise Instructions.pdf
Internal Gains Presentation.pptx
Internal_Gains_Output_Charts.xlsx
Solution Files\1.Base File.idf
Solution Files\2.HotelBldg.idf
Solution Files\3.OfficeBldg.idf
Solution Files\4.RetailBldg.idf

7 Thermal Mass Module

7.1 Topics Covered

- Introduction to Thermal Mass
- Physics of Thermal Mass
- Examples of Thermal Mass
- EnergyPlus Simulations

7.2 Exercise Summary

The exercise provides a base file for a single-story building, measuring 65ft x 15ft, typical of a small office in a strip mall. The building is modeled with one zone.

The objective of this exercise is to study the effect of thermal mass on a building's operative temperature and its energy use. The exercise will modify a base file and create three buildings with nearly identical U-values for walls and roof but with three different thermal masses. The low thermal mass building has EIFS–steel stud walls with $U=0.255$ and a roof consisting of insulation directly over a metal deck with $U = 0.235$. The medium thermal mass wall has EIFS–8-inch concrete block walls with $U = 0.286$ and a 4-inch thick concrete roof slab between the metal deck and the insulation with $U = 0.253$. The metal deck is directly exposed to the room. The high thermal mass wall is a brick cavity wall with 4-inch brick–8-inch CMU block construction with $U = 0.280$ and an 8-inch concrete roof slab with $U=0.241$ and the metal deck directly exposed to the room.

7.3 File List

Thermal Mass Exercise Instructions.doc
Thermal Mass Exercise Instructions.pdf
Thermal Mass Presentation.pptx
Thermal_Mass_Output_Charts.xlsx
Solution Files\ThermalMass_base.idf
Solution Files\ThermalMass_high.idf
Solution Files\ThermalMass_low.idf
Solution Files\ThermalMass_med.idf