Title
High-Fidelity Building Emulator for Integrated Comfort and Energy Analysis using EnergyPlus and Radiance

Journal
Building Simulation Conference Proceedings, 19

ISSN
2522-2708

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Publication Date
2025-08-24

DOI
10.26868/25222708.2025.1653

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Abstract

The growing need for smart, energy-efficient, and occupant-centric buildings has created a demand for advanced control systems that can optimize building operations to balance energy savings, demand flexibility, and comfort. However, current building energy simulation tools, such as EnergyPlus, have limitations that hinder the development and evaluation of these complex control systems. To address this challenge, we introduce a high-fidelity building emulator that dynamically couples EnergyPlus with Radiance for enhanced daylight modeling. The introduced workflow allows researchers and practitioners to rapidly develop and evaluate innovative control solutions. An example study looking at a south-facing office zone revealed up to 67% deviation in predicted light levels, which can significantly impact building assessment.

Key Innovations

- Introduction of a high-fidelity building emulator with dynamic coupling between the EnergyPlus building energy modeling tool and the Radiance daylight and visual comfort tool allowing integrated analysis of interdependent comfort and energy aspects in buildings.
- Streamlined integration of EnergyPlus, Radiance, and external controls through the open-source *frads* Python package enabling system interaction at simulation runtime and automatic model translation.

Practical implications

This paper introduces a workflow to couple EnergyPlus and Radiance during simulation runtime for real-time data exchange to emulate realistic energy and daylighting performance of buildings. This workflow is abstracted and simplified through the introduction of the *frads* Python package. This easy-to-use and open-source software tool allows developers, practitioners, and other stakeholders to rapidly and interactively evaluate occupant comfort and its implication on overall building energy consumption.

Introduction

The increasing demand for smart, energy-efficient, and occupant-centric building design has highlighted the need for advanced building control systems. Buildings equipped with such control systems can adaptively optimize building system operation to balance energy savings, demand flexibility, comfort, and health.

The suite of available smart building control concepts and devices is vast, ranging from simple rule-based controls (Park et al. 2019) for single devices, over smart devices and appliances, to cutting-edge predictive control systems (Drgoňa et al. 2020). However, orchestrating the interdependent relationships between building loads and electricity generation is nontrivial. For example, one approach to predictive control is model predictive control (MPC), which uses mathematical models to represent a building's thermal and electrical behaviors, occupancy patterns, Heating, Ventilation, and Air conditioning (HVAC) systems, and other components. By incorporating typical 24-hour weather forecasts, MPC predicts electricity demand and employs numerical solvers to balance objectives like energy efficiency, cost reduction, and resiliency. (Gehbauer, Lee, and Wang 2023).

Dynamic fenestration systems are an enabling tehcnology for smart bulding controls. They refer to window systems that can change their performance properties, including solar heat gain coefficient and visible transmittance, in response to environmental conditions to optimize energy efficiency, occupant's comfort, daylighting, and/or view quality. Examples of dynamic fenestration systems are electrochromic glass, thermochromic glass, and motorized blinds or shades.

The development and evaluation of advanced control systems is complex. Buildings are complex systems where daylight and thermal dynamics are deeply intertwined, with sunlight admitted through windows influencing cooling and heating loads, occupant comfort, and lighting energy usage. Since evaluating new control approaches using real buildings is often impractical due to lengthy evaluation period, diverse architecture and HVAC systems, and high cost of construction and operation, digital simulation has become a widely adopted tool in the building design process. While existing tools support many use cases, emerging advanced control systems typically integrate multiple building subsystems and therefore require a new generation of high-fidelity simulators. Such building simulators provide a realistic building response from a digitally emulated building, which is often referred to as a digital twin. This evaluation in software allows the exploration of many environmental, occupational, extreme, and control scenarios to thoughtlessly assess the performance of buildings - or in case of this paper, the performance of advanced control systems.

The EnergyPlus[1] (Crawley et al. 2001) is a widely used whole-building energy analysis and thermal load simulation tool. It uses physics-based heat balance calculations to compute heating and cooling loads based on user-defined building geometry, envelope materials, system structures, and operation schedules. While EnergyPlus provides high-fidelity building and HVAC modeling capability, it utilizes an oversimplified daylighting model. To predict daylight availability and visual discomfort, EnergyPlus uses the split-flux (Hopkinson, Longmore, and Petherbridge 1954) and radiosity daylight calculation methods (Winkelmann and Selkowitz 1985). Further, EnergyPlus uses the Discomfort Glare Index (DGI) metric for visual discomfort evaluation, which only accounts for contrast glare that occurs when there is an overly bright light source in a dim environment. Neglecting saturation glare from an overly-lit environment, DGI shows less accuracy in bright environments where illuminance is over 3,000 lux (Quek et al. 2021). In contrast, the Daylight Glare Probability (DGP) metric is a more robust glare evaluation method that accounts for both contrast and saturation glare effects (Quek et al. 2021). Illuminance sufficiency and glare-risk calculation are highly sensitive to deviations due to the nature of their underlying mechanisms. For instance, if the daylight level falls below the work plane illuminance (WPI) setpoint, artificial lighting activates, significantly impacting electricity use and energy balances. Differences in how accurately daylight is modeled can result in substantial differences in energy performance.

The Radiance[2] (Larson and Shakespeare 1998) tool is a high-fidelity daylighting and lighting simulation tool. It uses state-of-the-art ray-tracing and matrix-based methods to simulate daylighting/lighting conditions under various sky conditions, fenestration systems, and building geometry and materials. While Radiance provides greater accuracy in predicting daylight, glare, and other visual comfort metrics, Radiance does not provide energy or heat balance calculations. The Framework for Lighting and Energy Simulation[3] (*frads*) provides a streamlined workflow for annual daylighting and dynamic facade simulations using Radiance matrix-based methods (Wang, Ward, and S. Lee 2021). By abstracting Radiance commands into higher-level Python functions, it reduces the complexity of setting up matrix-based simulations. The automated process minimizes user interventions and the potential for errors, simplifying the analysis of complex, time-varying daylight calculations efficiently.

We therefore propose the coupling of both, EnergyPlus and Radiance tools, to assemble a high-fidelity ”gold-standard” emulation model based on their complementary functionalities to realistically compute both energy and comfort. This is particularly relevant when evaluating integrated control systems that coordinate multiple building subsystems, such as lighting and HVAC, or advanced controls designed to reduce energy, cost, or emissions. Currently available methods for coupling EnergyPlus and Radiance include (a) EnergyPlus’ Energy Management System (EMS), (b) Functional Mock-up Interface (FMI) (Nouidui, Wetter, and Zuo 2014), (c) Building Control Virtual Test Bed (BCVTB) (Wetter 2011), and (d) OpenStudio. The coupling through EMS and OpenStudio requires pre-computation of the external tool, e.g., Radiance, and results are provided as static inputs for EnergyPlus. This static coupling is insufficient for modeling advanced control systems that make real-time operational decisions based on current system states, and dynamically send those control signals to the fenestration, lighting, and/or HVAC systems. The co-simulation of EnergyPlus with external tools, such as FMI and BCVTB, is complex and requires an additional master engine that calls each tool separately, compiles the external tools in synchronization with the EnergyPlus model, and orchestrates data-exchange between them.

This paper presents a workflow that dynamically couples

[1]EnergyPlus: https://energyplus.net/

[2]Radiance: https://www.radiance-online.org/

[3]Framework for lighting and energy simulation: https://github.com/LBNL-ETA/frads

EnergyPlus and Radiance with real-time data exchange at simulation runtime. It expands the *frads* Python package to provide a high-level abstraction of the complex co-simulation interactions, allowing developers, practitioners, and other stakeholders to rapidly and interactively evaluate occupant comfort and its implication on overall building energy consumption. The framework automatically translates the EnergyPlus model into Radiance, avoiding user errors when synchronizing energy and daylight models and overall eliminating a complex and time-consuming step for tool coupling.

The dynamic coupling of simulation tools is discussed and examples of increased fidelity and its effect on energy consumption are provided.

Methodology

The virtual evaluation of advanced building control systems involves two components: an emulator and a controller. The emulator predicts the building systems' behaviors in response to the system operations, while the controller processes data from the emulator, implements control algorithms, and makes optimized decisions. EnergyPlus is used for the thermal framework, while Radiance enhances the daylighting calculation of the emulator. The following subsections describe the co-simulation workflow to couple EnergyPlus with Radiance.

Daylight Model

The ray-tracing method traces the paths of light rays as they interact with building interior surfaces and objects to calculate the distribution and intensity of daylight. While ray-tracing is highly accurate, it is computationally intensive which makes it unfit for illuminance and glare computation in adaptive control modeling. As a result, the workflow utilizes a matrix-based simulation which has greater computational efficiency than ray-tracing yet with comparable accuracy. In particular, the workflow utilizes the three-phase matrix-based simulation method which handles dynamic glazing and shading systems more efficiently in comparison to the two-phase method, and provides sufficient accuracy with less computational complexity in comparison to the five-phase method (McNeil and Lee 2013), (Wang, Ward, and Lee 2018). The three-phase method splits the flux into three phases with each phase represented in matrix format: sky to the exterior of the fenestration (sky), exterior to the interior of the fenestration (window), and interior of the fenestration to the simulated space (view) (Subramaniam 2017). The sky matrix is generated from direct normal irradiance (DNI) and diffuse horizontal irradiance (DHI) data. The window matrices are bi-directional scattering distribution work planes (BSDFs) built from EnergyPlus' *Construction:ComplexFenestrationState* object. The view matrices are built from the EnergyPlus model's geometry with default material definitions. The matrix-based method shortens the computation time for dynamic sky and fenestration shading configuration as each phase is self-contained and can be updated without re-running the entire simulation. DGP can be calculated using the Radiance internal methods, where the computation time heavily depends on the parameters of the rendering, ranging from minutes to hours. The enhanced simplified Daylight Glare Probability (eDGPs) was built upon the original DGP metric improving computational efficiency while maintaining accuracy (Wienold 2009). The calculation of eDGPs involves the three-phase method to determine vertical illuminance for saturation glare and an 800 by 800 pixels zero ambient bounce rendering to assess contrast glare.

Through this work, the *frads* package was expanded to seamlessly integrate with the EnergyPlus. It automatically translates geometries, material properties, and dynamic facade definitions from EnergyPlus to Radiance, and computes dynamic facade energy and non-energy performance metrics at each timestep.

Instantiation

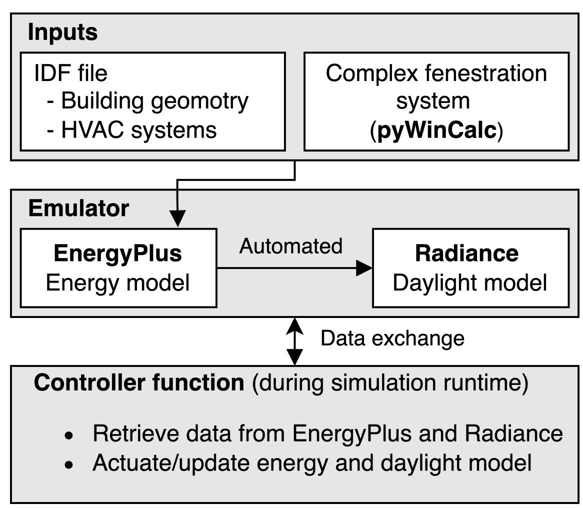

Figure 1: Automated Workflow for Emulator Coupling.

The automated workflow instantiates both the EnergyPlus and Radiance models and is illustrated in Figure 1. The first step to set up the emulator is the preparation of inputs, shown in the top gray box. The inputs in the simulation consist of two types: static parameters, such as construction details, and time-varying inputs, including weather, occupancy; and dynamic facade states.

The EnergyPlus simulation is initialized with an Input Data File (IDF), which contains user description of the building and associated systems' geometry, materials, structure, and schedules. Users can also provide an EnergyPlus Weather (EPW) file that contains weather information to simulate various weather or location-based conditions. In EnergyPlus, each operable fenestration state is represented as a *Construction:ComplexFenestrationState* object, which stores state-specific properties—including solar/visible transmittance and absorptance—in a matrix format. In comparison to the other window material modeling methods in EnergyPlus (i.e. *WindowMaterial:SimpleGlazingSystem*), *Construction:ComplexFenestrationState* provides a higher accuracy in modeling complex fenestration systems that have advanced glazing materials, adaptive shading devices, and dynamic thermal/optical properties. The Lawrence Berkeley National Laboratory's (LBNL) WINDOW tool can calculate solar and optical properties of most market-available glazing units and create associated *Construction:ComplexFenestrationState* objects for EnergyPlus. The introduced automated workflow uses pyWinCalc[4], a Python-based derivative of WINDOW, to automatically calculate the solar and optical properties of the complex fenestration systems without user interaction.

To ensure synchronized model setups across the simulation engines, frads provides a functionality to automatically translate the EnergyPlus into a Radiance model. It also adds additional dimensionality to the two-dimensional EnergyPlus model, which is important for walls with external windows to account for shadow and reflectional effects. The emulator consisting of the energy model from EnergyPlus and daylight model from Radiance exchanges data with the controller during simulation runtime through the EnergyPlus API as described in the section below.

Co-Simulation

The coupling of the thermal and daylight models is implemented using the EnergyPlus Python API[5], introduced in version 9.3 and built on EnergyPlus' EMS. While the EMS control algorithms are written in EnergyPlus Runtime Language (ERL) with limitations in linking to external tools, the EnergyPlus Python API expands the tool's capabilities by allowing users to load and utilize external Python modeling and simulation tools during runtime.

Inheriting the EMS structure, the EnergyPlus Python API allows the interaction with sensors, actuators, and calling points within the EnergyPlus model. Sensors are used to get information from the EnergyPlus model, e.g., outdoor air temperature, incident solar radiation, time of the day, occupancy count, etc., and can be used as control input. Actuators are used to actuate or change components within the EnergyPlus model, e.g., set point temperature of the zone thermostat, lighting power level of the zone lighting system, and window fenestration shading state, etc. Calling points refer to computational steps during the EnergyPlus execution, and when the EnergyPlus simulation pauses to execute control algorithms and/or run external control programs. A Python function that defines model interactions through various sensors and actuators calls is registered to a calling point. This workflow re-purposes this interface to couple the Radiance daylight and lighting controls. The co-simulation workflow is illustrated in Figure 2.

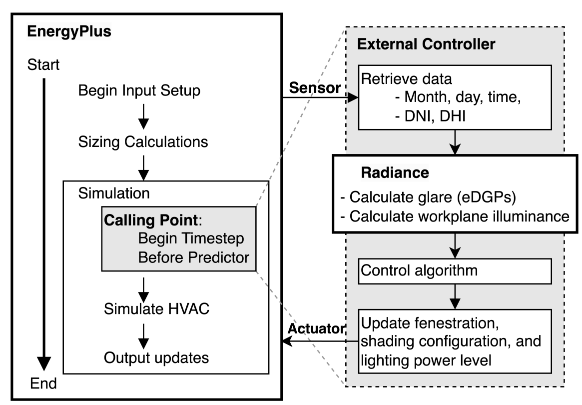

Figure 2: Co-Simulation of EnergyPlus and Radiance.

The EnergyPlus simulation consists of several distinct calculation and modeling phases. When EnergyPlus starts a simulation, it first conducts various sizing calculations and determines initial values to start the simulation. Next, it sets up the simulation environment for the design days and/or simulation of the user-defined run periods. EnergyPlus loops through all timesteps within the simulation run periods; while at each timestep, it calculates the zone thermal and electrical loads, models

[4]Python wrapper for WINDOW: https://github.com/LBNL-ETA/pyWinCalc

[5]Python bindings for the EnergyPlus API: https://energyplus.readthedocs.io/en/latest/api.html

the HVAC system's response, and computes the resulting zone conditions. The beginning and end of each calculation and modeling phase correspond to calling points, at which users can read, assign, or override EnergyPlus simulation runtime data.

For instance, users can use the "begin timestep before predictor" calling point to pause the simulation before calculating zone loads at the start of each simulation timestep. Inside the user-defined Python function, DNI, DHI, and date/time are retrieved from EnergyPlus and passed to Radiance to compute WPI, eDGPs, vertical illuminance, and required lighting power from artificial lighting. If available, external controllers like MPC can access outputs from EnergyPlus and Radiance to inform operational decisions. Fenestration/shading states, HVAC temperature setpoints, and lighting power setpoints are then overridden within the EnergyPlus model. Since EnergyPlus can only reference one window/construction material at a time, dynamic façade behavior requires runtime updates to these materials. Upon completion of actions defined in the Python function, the EnergyPlus simulation is resumed and proceeds to heat balance calculation with the updated states and setpoints. The bi-directional feedback loop between EnergyPlus and Radiance repeats for the next timestep when reaching the calling point.

Application

An example application is introduced to compare EnergyPlus's native split-flux method with the newly implemented three-phase matrix method in predicting WPI and glare risk. The metrics are evaluated against Radiance's ground truth state-of-the-art ray-tracing method and the full DGP metric analysis.

The example model is based on the U.S. Department of Energy's prototypical medium office[6]. A single south-facing perimeter trapezoid zone of approximately 4.5 m x 49.9 m is selected with a 1.3 m x 49.9 m window, and 1 m window sill height. The window features an electrochromic glazing system with four tinting states: 60% visible-transmittance (Tvis) for the clear state, 18% Tvis, 6% Tvis, and 1% Tvis representing the fully tinted state. The electrochromic system is tinted based on a time logic to simulate a dynamic fenestration system and to compare the performance of the daylight calculation models for evaluating fenestration systems with various optical properties. The building is located in San Francisco, California, and spans seven sunny days in September.

[6]Department of Energy's Prototypical Buildings: https://www.energycodes.gov/prototype-building-models

At every 10 minute timestep, WPI is computed with the ray-tracing, three-phase, and EnergyPlus's built-in split-flux methods. Additionally, glare risk is assessed using DGP as ground truth, eDGPs provided by Radiance as operational metric, and DGI natively provided by EnergyPlus as baseline. WPI is computed using Radiance's ray-tracing program (*rtrace*) with five ambient bounces. The full DGP assessment requires the compilation of a high dynamic range (HDR) image which is rendered at an 800 x 800 pixel resolution with five ambient bounces. To compute the glare metrics, a virtual view sensor is located at the center of the room looking at the window. The sun is not in the field of view of the view sensor during the simulation period. The electrochromic system is modeled as *brtdfunc* material type in Radiance for the ray-tracing method, as BSDF Klems matrix for the three-phase method, and as *WindowMaterial:SimpleGlazingSystem* object in EnergyPlus for the split-flux method.

The electric lighting system for the 207 m^2 perimeter zone is defined by the prototypical model's 1 W/ft^2 lighting power density which results in a maximal lighting electricity consumption of 2.2 kW. A linear dimming profile is implemented to dim lights based on available daylight from the window to meet the WPI threshold of 500 lux. The zone includes a total of 525 virtual WPI sensors which are equally spaced out in a 2 x 2 ft (0.6 m) grid at 2 ft (0.76 m) height. Each sensor controls the corresponding fraction of the total electric lighting power.

Results

The simulation was carried out for seven sunny days in September, which results in a total of 515 timesteps during daytime hours for each WPI and glare-risk dataset, and 1,007 data points for lighting energy consumption during both daytime and nighttime. Results for a single day, September 8, are highlighted.

At each day, the electrochromic tint is changed based on a fixed schedule. It starts fully clear at 60% Tvis at nighttime before 9 am, transitions to 18% Tvis from 9 am to 11 am, reduces to the darkest 1% Tvis from 11 am to 1 pm, increases to 6% Tvis from 1 pm to 3 pm, and lastly returns to the clear 60% Tvis after 3 pm.

The Figure 3 illustrates the variances between the different calculation methods for WPI. The average WPI calculated by the three-phase method, in orange, closely aligns with the state-of-art ray-tracing method, in green, with a Mean Absolute Error (MAE) of 160 lux (10.63%), Root Mean Square Error (RMSE) of 251 lux (16.72%), and Mean Bias Error (MBE) of -120 lux (-8.01%). In

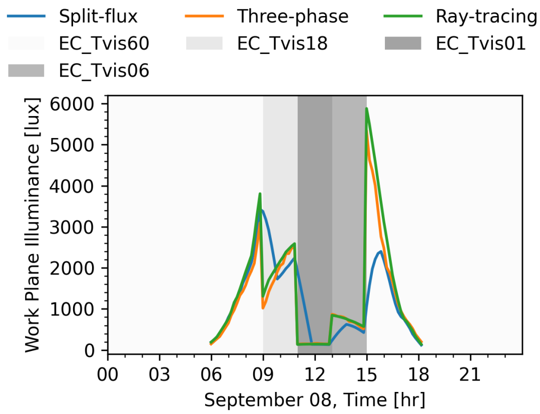

Figure 3: Comparison of work plane illuminance using different computational methods for a sunny day in September.

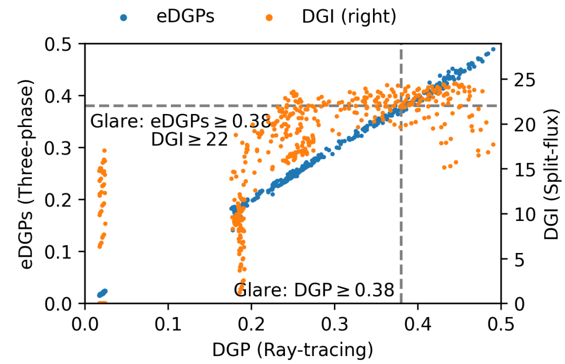

Figure 4: Evaluation of eDGPs and DGI versus the ground-truth DPG method for the daylight-hours of the seven day simulation period in September.

contrast, the split-flux method, in blue, calculates average WPI with a high deviation from the ray-tracing, resulting in an MAE of 538 lux (35.80%), RMSE of 1,006 lux (66.95%), and MBE of -216 lux (-14.41%). In the morning before 9 am, at the fully clear electrochromic state, both split-flux and three-phase methods are closely aligned to the ray-tracing results, with a MAE of 190 lux (10.89%) and 273 lux (15.66 %), respectively. However, as the window tint reduces to 18% and later to 1% Tvis the split-flux overestimates WPI (MAE: 53.75% and MBE: 37.00%). While ray-tracing and the three-phase methods show sharp decrease in WPI when the electrochromic window transitions to darker tint states, the split flux calculation shows a more gradual drop over an hour in response to the changes in glazing's optical properties. During the same period, three-phase results remain closely aligned to ray-tracing's WPI with a MAE of 77 lux (7.17%) and a slight underestimation from 9 am to 11 am. After 1 pm and until the sunset, while the tint increases to 6% and later to 60% Tvis, split-flux method underestimates the WPI with a MBE of -228 lux (-32.11%) and -999 lux (-43.60%) during the two tinting phases, respectively. In contrast to the three-phase method, split-flux is not able to capture the peaking of WPI at 3 pm when the electrochromic window becomes fully clear.

The Figure 4 illustrates the effect of dynamic tinting on the glare probability as a scatter plot relative to the DGP ground truth model. The eDGPs, in blue, is calculated with the three-phase method and shows a higher accuracy in predicting glare risk than DGI, in orange, computed by EnergyPlus's built-in split-flux model. When compared to DGP, DGI has an accuracy of 82.33% and eDGPs has an accuracy of 98.83% in predicting a binary classification of glare (i.e., DGP $\geq$ 0.38, eDGPs $\geq$ 0.38, and DGI $\geq$ 22) indicated by the dashed lines. The rates for true-positive and true-negative are 0.69 and 0.85 for DGI, and 0.95 and 0.99 for eDGPs, respectively. The three methods capture glare from 8 am to 9 am when the glazing is fully clear and no glare from 9:15 to 3 pm when the glazing tints dark. DGI continues to predict glare shortly after 9 am (i.e., when window transitions from 60% to 18% Tvis) and 5 pm (i.e., an hour after adjusting to 60% Tvis) when the other two glare metrics indicate no glare. Reversely, while both DGP and eDGPs predict glare when the electrochromic is fully clear from 8 am to 9 am and from 3 pm to 4 pm, DGI suggests no glare.

The Figure 5 shows the resulting lighting power demand from daylight-responsive dimming given the different methods of calculating daylight-induced WPI. During the simulated seven-day period, the average daily electric lighting consumption for the split-flux method is 32.66 kWh and 32.80 kWh for the three-phase method, showing a difference of less than 1%. On September 8, the lighting energy consumption based on the two daylight modeling methods has the best agreement when the electrochromic system is fully clear in the morning and evening hours. The lighting consumption rates diverge when the window system tints to darker states. As a result of split-flux's WPI overestimation in the morning and underestimation in the afternoon, see Figure 3, the split-flux-based control algorithm results in 1 kWh (55%) lower lighting consumption from 9 am to noon

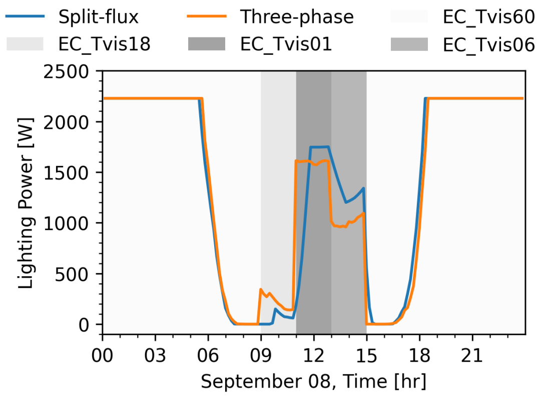

Figure 5: Electric lighting power consumption for daylight dimming based on different computational methods of a sunny day in September.

and 1 kWh (25%) higher consumption from noon to 3 pm compared to the three-phase controller.

Discussion

Next generation building control systems operate at a high level of performance and control accuracy, beyond those of traditional control systems. Given this high performance and related sensitivity to deviations from projected/expected building system response, it is necessary to provide highly realistic building system responses when developing and testing such control systems. This study has shown that the daylight-related methods within EnergyPlus may be sufficient to evaluate current building control systems, but show great deviations during certain operational periods, which can distort evaluations of next generation control systems.

The native EnergyPlus' split-flux model overestimated WPI particularly in the morning hours (MBE: 398 lux, 37.00 %). This overestimation may lead a building control system to increase window shading, e.g., by darkening tint states or lowering shades, which reduces the transmitted solar irradiation, obstructs view for the occupant, and artificially lowers glare probability. All of these impact how the building would perform in the real world, skewing the energy and non-energy benefits. Reversely, the split-flux model underestimates WPI in the afternoon (MBE: -706 lux, 43.59%), which potentially leads to higher electric lighting consumption due to daylight-dimming control and artificial reduction in cooling loads due to decreased transmitted solar irradiation. Split-flux's inability to capture the afternoon peak in WPI suggests the likelihood of underestimating visual discomfort. In contrast, the three-phase model shows a better agreement with state-of-the-art ray-tracing in WPI computation, with a slight underestimation through the day and a reduced MBE of -120 lux (-8.01%).

Another effect observed with the native EnergyPlus computation is a limitation in capturing the dynamic change of facade shading states due to a buggy implementation of changes in the EnergyPlus window properties. In EnergyPlus, the daylight coefficient calculation for the split-flux method is programmed to reset at the next full simulated hour, regardless of updated fenestration properties[7]. Consequently, changing the window construction state during runtime can delay WPI result calculations by up to an hour, as shown in Figure 5. This delay contributes greatly to the morning WPI overestimation and the afternoon WPI underestimation. It hinders the modeling of instantaneous adaptive shading systems and realistic facade operation.

However, the discrepancies in WPI between the split-flux and three-phase methods do not result in a significant difference in the lighting electricity consumption for the simulated week in September. This effect can be attributed to the canceling out of positive and negative deviations over time, resulting in little energy difference. However, when taking into account time-dependent metrics such as time-of-use tariffs, tariffs with monthly peak pricing, integration with time-varying generation from distributed energy resources (DER), or building demand response, then the time of when and how much electricity is consumed becomes critical and effects of deviating daylight models can be more significant.

Prior studies suggest that DGI is more reliable in predicting visual discomfort in darker environments with illuminance levels below 3,000 lux (Quek et al. 2021). This study used electrochromic tinting to ensure appropriate light levels and mostly remained below the 3,000 lux limit. Nevertheless, eDGPs showed superior ability in predicting binary classification of glare or no glare and provides a scale to evaluate glare levels.

The Radiance's ray-tracing methodology is the ground-truth, state-of-the-art daylight model available. However, the computation of illuminance and DGP for 515 timesteps took 11 hours and 10 CPU processors to execute. On the other hand, EnergyPlus' split-flux daylight model computes orders of magnitudes faster, with a total simulation time of about one minute with a single CPU processor. The three-phase method offers a middle

[7] https://github.com/NREL/EnergyPlus/issues/4266

ground, balancing high accuracy with a reasonable simulation time of five minutes for the seven-day simulation. This co-simulation workflow of EnergyPlus and Radiance can be used to benchmark the performance of energy, daylight, and comfort related building system control algorithms. Taking advantage of the large existing Python modeling, simulation, and data-handling tools, this workflow can easily be extended and coupled to other external simulation tools (e.g., Spawn-of-EnergyPlus) and/or control developments (e.g., MPC, machine learning, etc.) to more realistically emulate building performance and benefits.

Conclusion

A high-fidelity building emulator which couples the popular EnergyPlus and Radiance tools in a user-friendly way was introduced. This dynamic coupling allows enhanced daylight and glare modeling beyond EnergyPlus' native performance. The results indicate the native EnergyPlus' split-flux daylight model has a RMSE of 1,006 lux (66.95%) in predicting work plane illuminance while Radiance's three-phase matrix method has a significantly lower RMSE of 251 lux (16.72%). This improvement in realisticity allows adequate evaluation of advanced building control systems to optimize building energy consumption and occupants' well-being.

Acknowledgment

This work was supported by the Assistant Secretary for Energy Efficiency and Renewable Energy of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

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