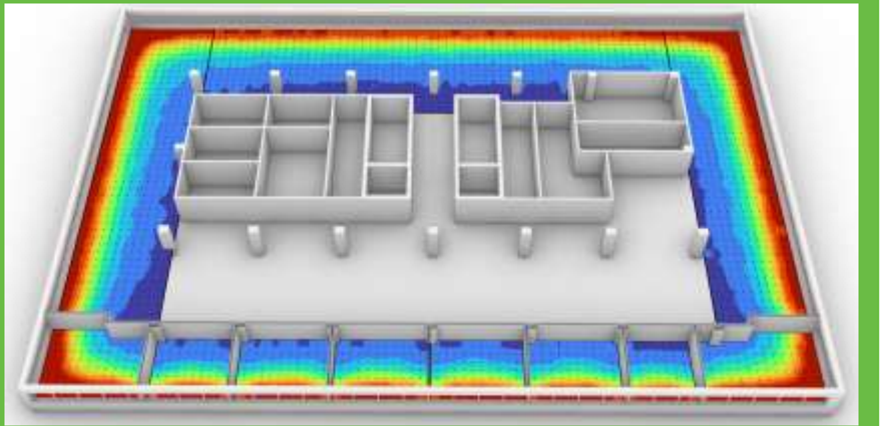
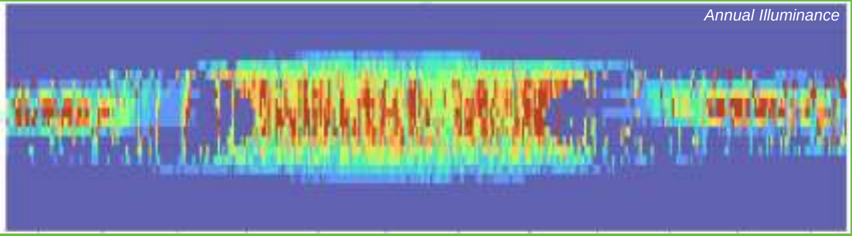
2021 BENEFIT FOA:

Commercialization of Design Tools for Predicting Occupant and Energy Impacts of Building Lighting Systems





Pacific Northwest National Laboratory | Solemma LLC
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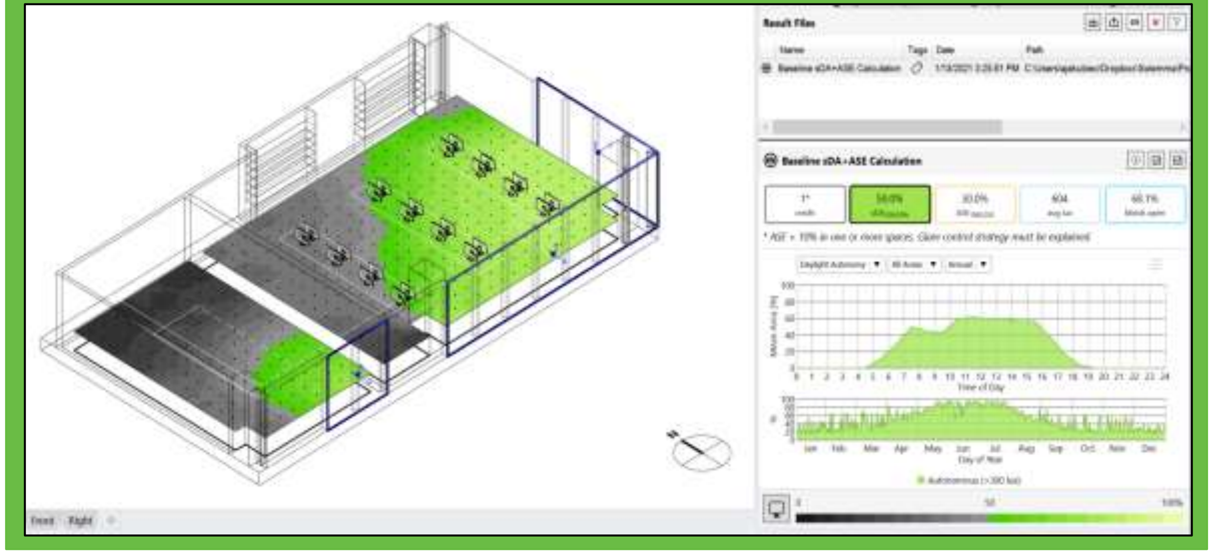
WBS#: 2196-1742, FOA Project #: DE-FOA-0002196

Project Summary

Objective and outcome

- Improve lighting software tool, ALFA, to enable more dynamic simulations of electric lighting for understanding how changes in optical distribution efficiency and spectral power distribution of light sources affect the delivered light level and color qualities at a specified target area.
- Validate ALFA for use in advanced lighting and space design through laboratory and field evaluations.



Team and Partners:

- Pacific Northwest National Laboratory
- Solemma LLC.

This project partners a leading team of lighting research engineers with a leading provider of commercial software for buildings to develop and validate new software tools that enable detailed evaluations of daylighting and electric lighting systems in buildings.

Stats

Performance Period: Jan 2022 – Dec 2024

DOE budget: $1,200k, Cost Share: $300k

Milestone 1: Create visual programming scripts

Milestone 2: Faster whole-building simulations

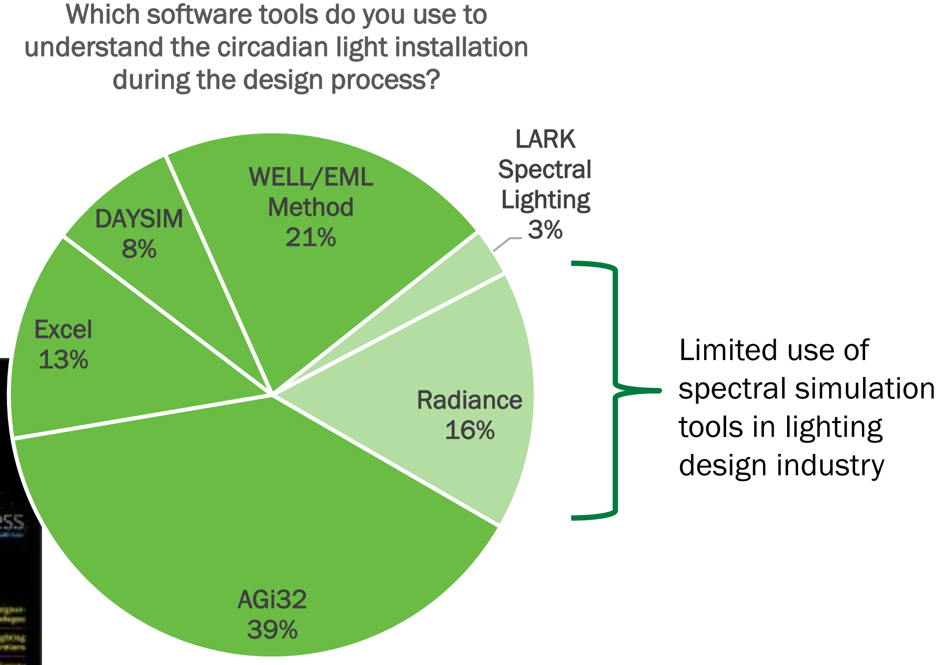
Milestone 3: SPD database for electric lighting

Problem

Traditional lighting software tools have not kept pace with advancements in lighting systems and computational capabilities. Existing tools **do not**:

- Capture the dynamism of solid-state lighting technology (luminous intensity, spectrum, distribution),
- Calculate lighting metrics beyond those established for task performance,
- Easily account for and compare the increasing number of design parameters,
- Allow for simulations of daylight, electric light, and energy, and develop quality renderings within a single tool.

(2018)



Lack of dynamic and high-resolution spectral software tools results in over-designing, the inability to realize the full potential of solid-state lighting, and loss in energy savings.

Alignment and Impact

Solid-State Lighting R&D Opportunities (2019); Lighting Application Efficiency topic:

- Priority: "Develop a general framework, mathematical model, and computer simulation approach to characterize lighting application efficiency for any lighting application."
- "Modeling software could be used and modified to understand how changes in the optical distribution efficiency and SPD of a light source in a space affect the delivered light level and color qualities at a specific target area."
- "The framework and model would need to be validated in lighting mock-ups that measure the light in an area of a space and compare it against the modeled results, which could result in improvements to the model. Once the model is validated, it could be used for advanced lighting and space design."
- Continued advancements and adoption of LED lighting has the potential to save 500 TWh per year by 2035 compared to conventional lighting technologies. Lighting Application Efficiency (LAE) research, including tools and outcomes from this project, will help to realize these savings.

Metrics	2019 Status	Interim 2025 Targets	2035 Targets
Lighting Application Efficiency framework and model	No comprehensive framework or model	Application agnostic model that can be used to optimize total *Lighting Application Efficiency*	Ubiquitous use of *Lighting Application Efficiency* modeling for building, room, lighting layout, and product design

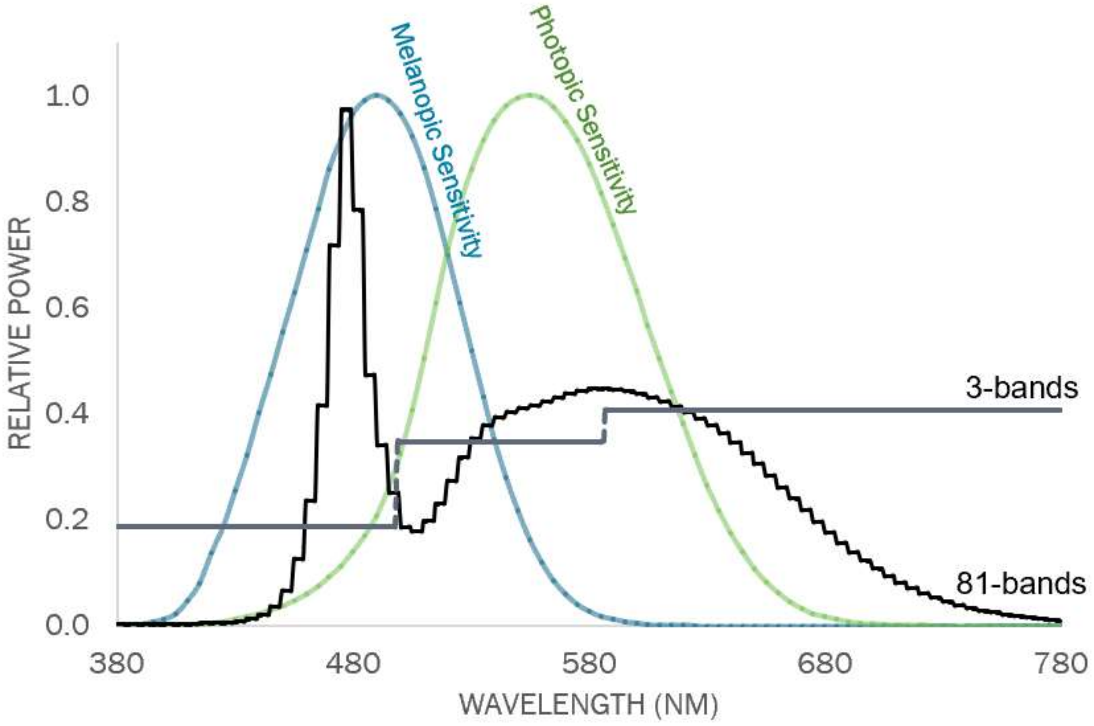
Approach

The goal of this project is to improve LAE through the advancement of software used by designers, manufacturers, and researchers for simulation of dynamic architectural lighting systems, resulting in energy-efficient lighting solutions that are optimized for occupant visual needs, health, and wellness. To accomplish this goal, the following project objectives have been established:

Objective 1: Software Development	*Objective 2: Software Evaluations*	*Objective 3: Software Commercialization*	*Objective 4: Market Education*
Complete a series of improvements to an existing software tool, Adaptive Lighting for Alertness (ALFA), informed by ongoing research, focusing on the workflow, inputs, and outputs of spectral simulations for visual and non-visual lighting design tasks.	Complete iterative laboratory and field validation studies of the software as it is revised through a direct feedback loop between PNNL and Solemma. A steering committee of design professionals as well as beta testers will help evaluate and inform software developments.	Complete steps necessary to assure software is commercially available and supported within the user community.	Accelerate the desired impacts on building energy and occupant wellness by supporting the uptake of software through tutorials, demonstrations, and conference presentations directed at the lighting and architectural communities.

Approach | Software Development

- Traditional software reduces the spectral characteristics of light sources and room surfaces to 3 or fewer spectral bands.
- Previous research by PNNL has shown that using less than 9 bands introduces notable error in simulations of LED light sources, particularly for estimating metrics with different spectral sensitivity than that used for human vision. *See "The effect of spectral resolution of light sources on photopic and α-opic quantities" by Abboushi and others (2021).*
- New software, ALFA, was designed to increase the number of spectral channels for light sources and room surfaces to 81 spectral bands.



→ **Current project aims to increase functionality of ALFA in order to integrate high-resolution spectral simulations of electric lighting into a popular whole-building simulation software tool (ClimateStudio) for architectural, daylighting, and thermal analyses. This will allow for more accurate representation of SSL technology, keeping electric lighting a prominent design consideration in broader architectural analyses.**

Approach | Software Development

Beyond integrating ALFA into whole-building design tool, ClimateStudio, software developments will include:

- Moving from simulations of a single point-in-time to annual spectral simulation of daylight and electric light
- Accounting for dynamic luminaires (intensity, distribution, spectrum), lighting controls, and shading systems via parametric modeling techniques
- Allowing users to incorporate detailed operational energy metrics and statistics, color rendering measures, and latest measures of light's impact on health and wellbeing
- Enabling comparison of multiple simulation results via scenario manager and export options

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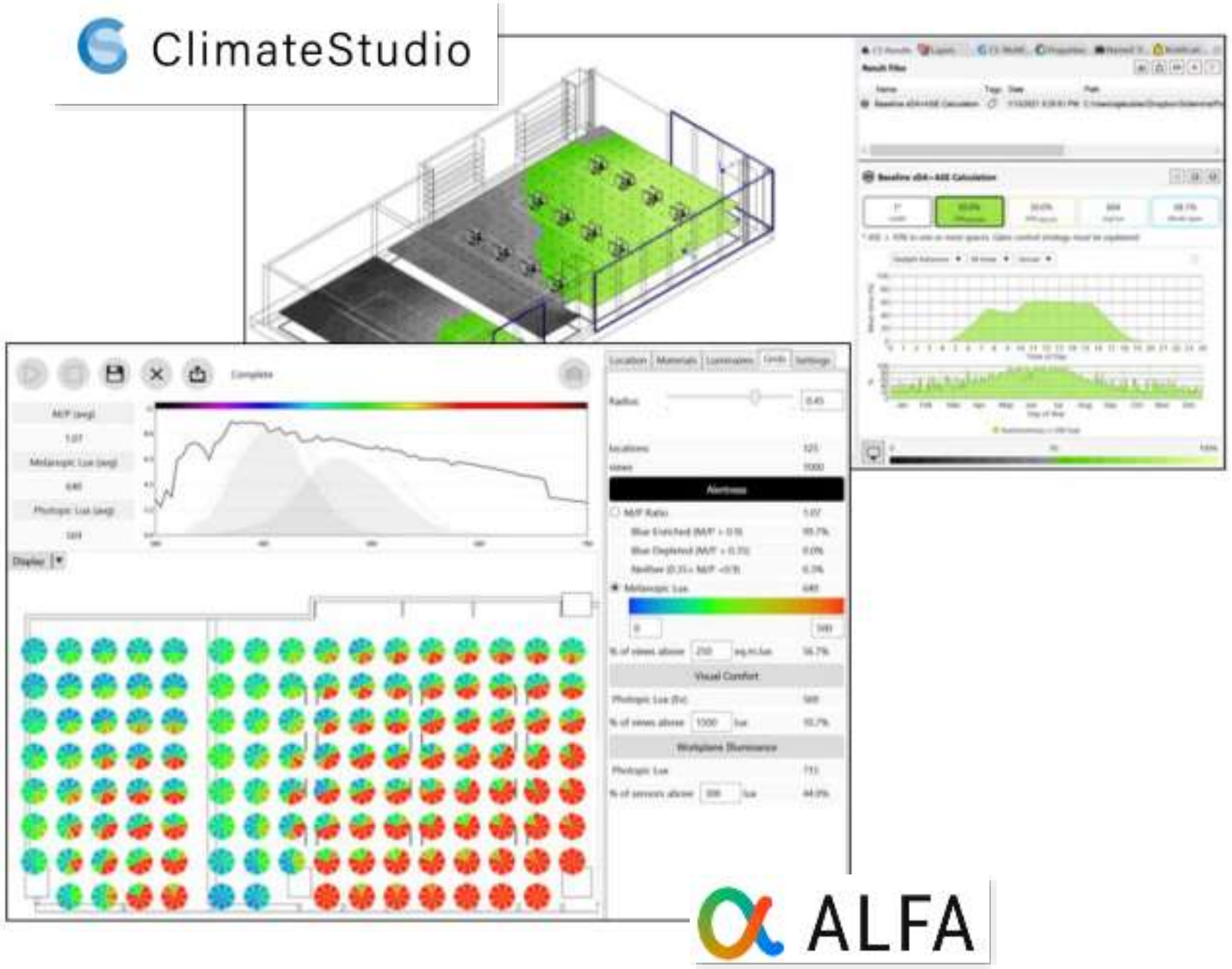
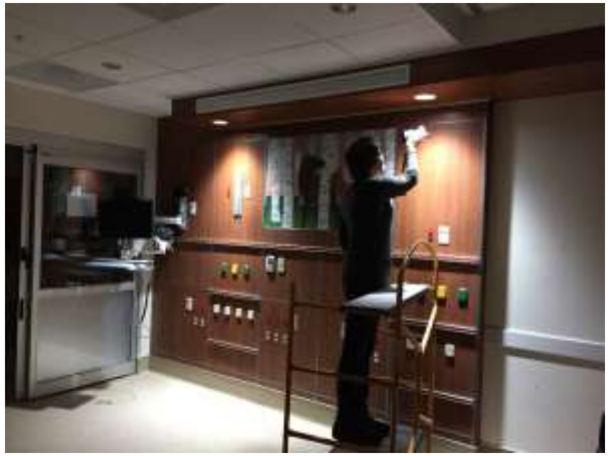


Approach | Software Evaluations

PNNL and Solemma maintain a direct feedback loop to continuously evaluate improvements to ALFA as they are implemented. These evaluations are useful for confirming the accuracy of the software as it develops and developing measurement and simulation protocols for future users.

Laboratory Studies

These studies compare ALFA-predicted values to corresponding measurements captured in PNNL's Lighting Science and Technology Laboratory (LSTL) under different electric lighting conditions.



Field Studies

PNNL's portfolio of projects across a range of applications (office, healthcare, education) lends itself to more detailed evaluations of ALFA-predicted values. These evaluations include daylight and electric lighting.

Approach | Software Evaluations

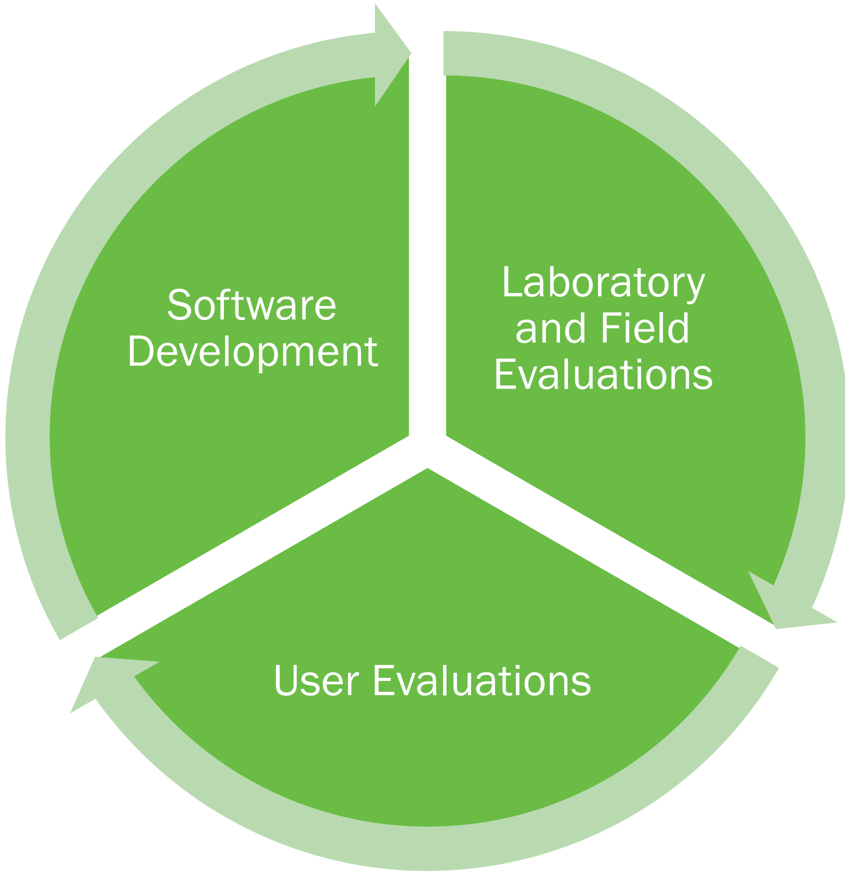
Project Steering Committee

A group of design professionals from 20 firms and companies meets twice per year to discuss developments to ClimateStudio and ALFA. The committee informs the lighting design and simulation processes and identifies areas for improvements.

Beta Testers

All users have the option to participate as release candidates, which allows for early access to the latest version of ClimateStudio and ALFA. These users can demo new functions and features, providing feedback to the project team and assuring quality is maintained as improvements are introduced to the software.

Project Feedback Loop



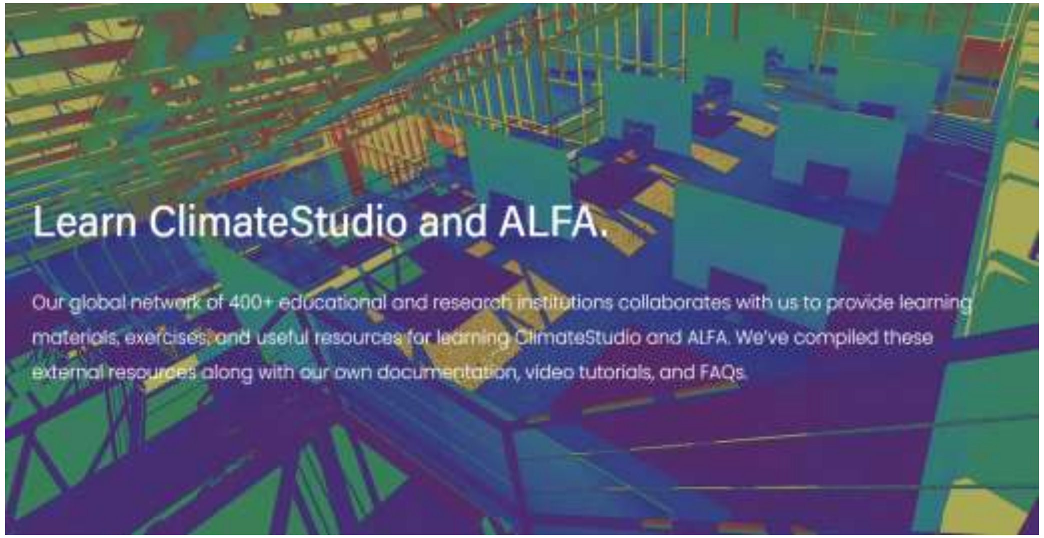
Approach | Commercialization & Market Education

The goal of this objective is to lower the technical barrier and provide support to new and current users of spectral simulation tools. This will encourage adoption and increase confidence in simulation results.

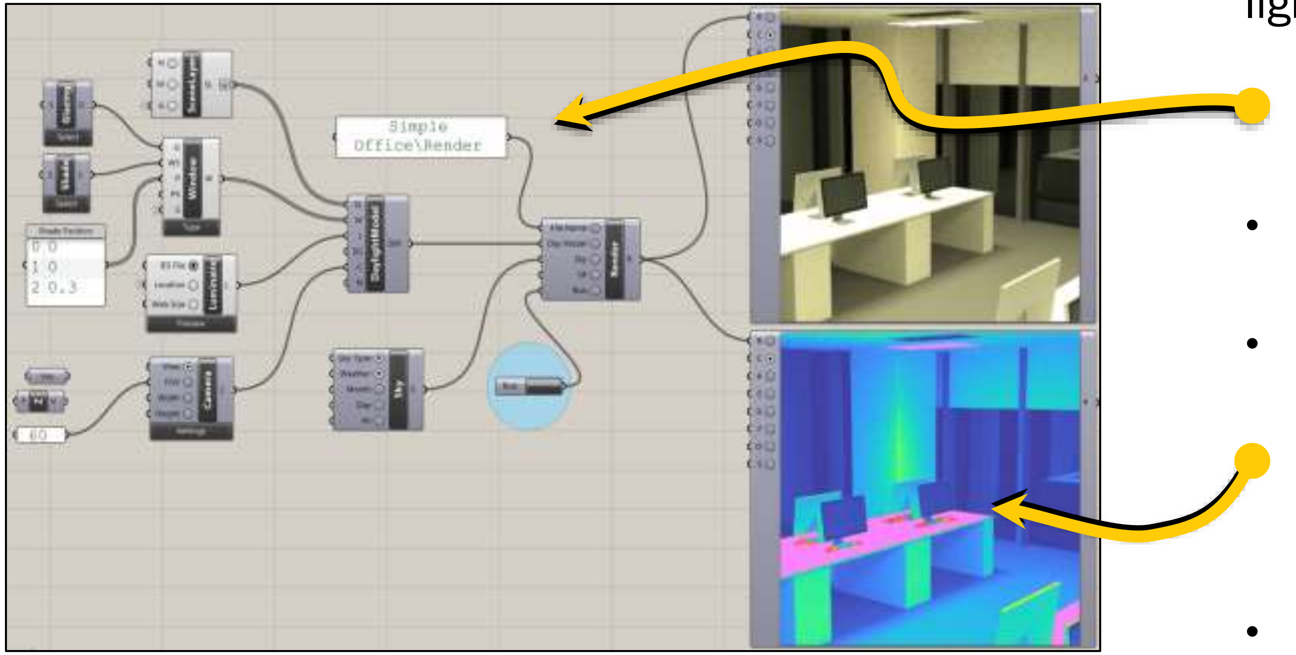
Solemma will ensure that software improvements are ready for commercialization by the end of the project timeline. This involves establishing methods for acquisition of software licenses and methods for user support.

Throughout the project, educational material will be developed for relevant stakeholder groups, assuring the value of spectral simulation software is realized. Educational material includes:

- Webinars
- Tutorials
- Demonstrations
- Conference presentations
- Journal articles



Progress | Software Development

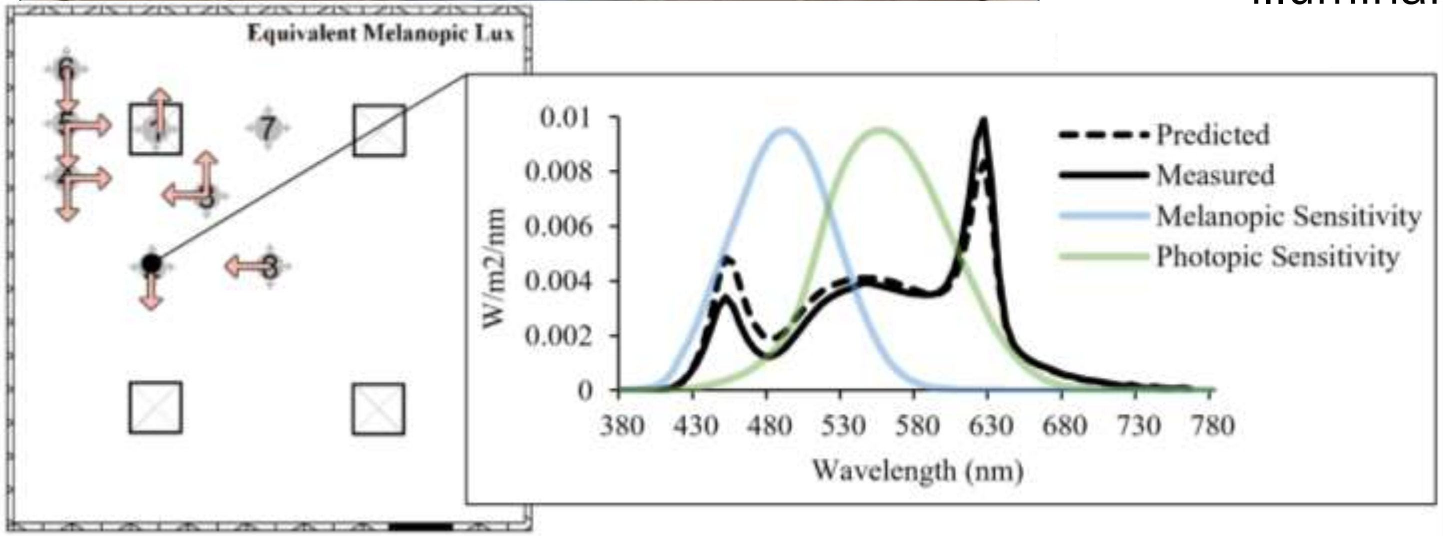


During the first year of this project, software developments have focused on **simulation workflow** to improve the underlying calculation engine for daylight and electric lighting simulations. Developments include:

- Visual programming scripts for parametric/dynamic modeling of electric light sources
- Luminaire grouping functions with post-process dimming and color adjustments
- Dynamic shading algorithms and improved glare calculations for simulations of daylight
- Improved rendering functions, allowing for more visually accurate representations of materials and light source color in architectural environments
- ClimateStudio v2.0 with significantly faster whole-building lighting simulation engine

After a successful prerelease to steering committee members, ClimateStudio v2.0 is now available for all users.

Progress | Software Evaluations



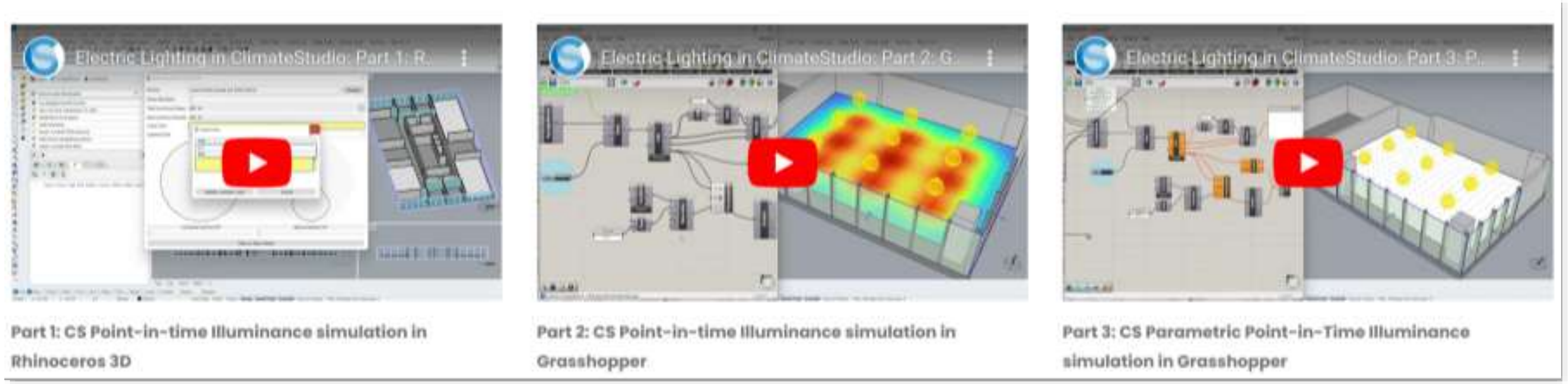
Laboratory evaluations aim to compare ALFA-predicted spectral irradiance and calculations of illuminance and circadian lighting metrics to corresponding measurements captured in a laboratory environment with LED luminaires.

- Difference in spectral irradiance within 10% for bands between 400 nm to 700 nm
- For full dataset, mean absolute percent error for illuminance and EML is 5% or less

→ Forthcoming journal article identifies potential sources of error within the simulation and measurement processes and discusses how users can minimize this error.

Progress | Commercialization and Market Education

- Published video tutorial series demonstrating newly developed functionalities



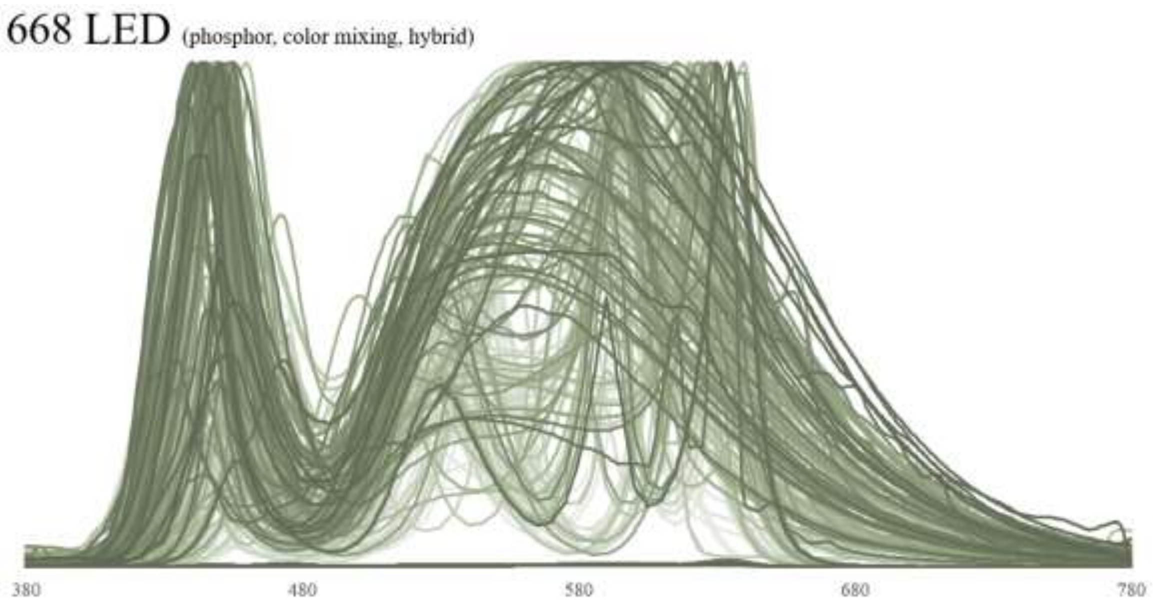
- Hosted workshops and presentations demonstrating ClimateStudio/ALFA capabilities and workflows to key stakeholders

IES Illuminating ENGINEERING SOCIETY lightfair LEDucation

- Implemented ticketing system to allow for timely technical support for ALFA

Future Work | Software Development

Sample SPDs available in TM-30 database to be included in ALFA Library



During the second half of the project, software development will focus on improvements to simulation workflow, inputs, and outputs. This will include:

- Supplementing the SPD library with a larger variety of phosphor converted and color-mixed LED spectra,
- Integrating ALFA as a plug-in for ClimateStudio,
- Calculating a greater number of occupant-based and energy metrics and allowing expert users the flexibility of defining new spectrally-dependent metrics,
- Creating a scenario manager for more comprehensive analysis of calculated metrics and design scenarios.

Future Work | Software Evaluation

Field Evaluation

Comparison of ALFA-predicted vs. measured values for spectral irradiance, illuminance, and circadian lighting metrics. Modeled spaces will be calibrated with measured values for material surfaces and spectral power distributions for electric lighting. Analysis will be used to identify errors that may result as part of the lighting design process.

Software Comparison

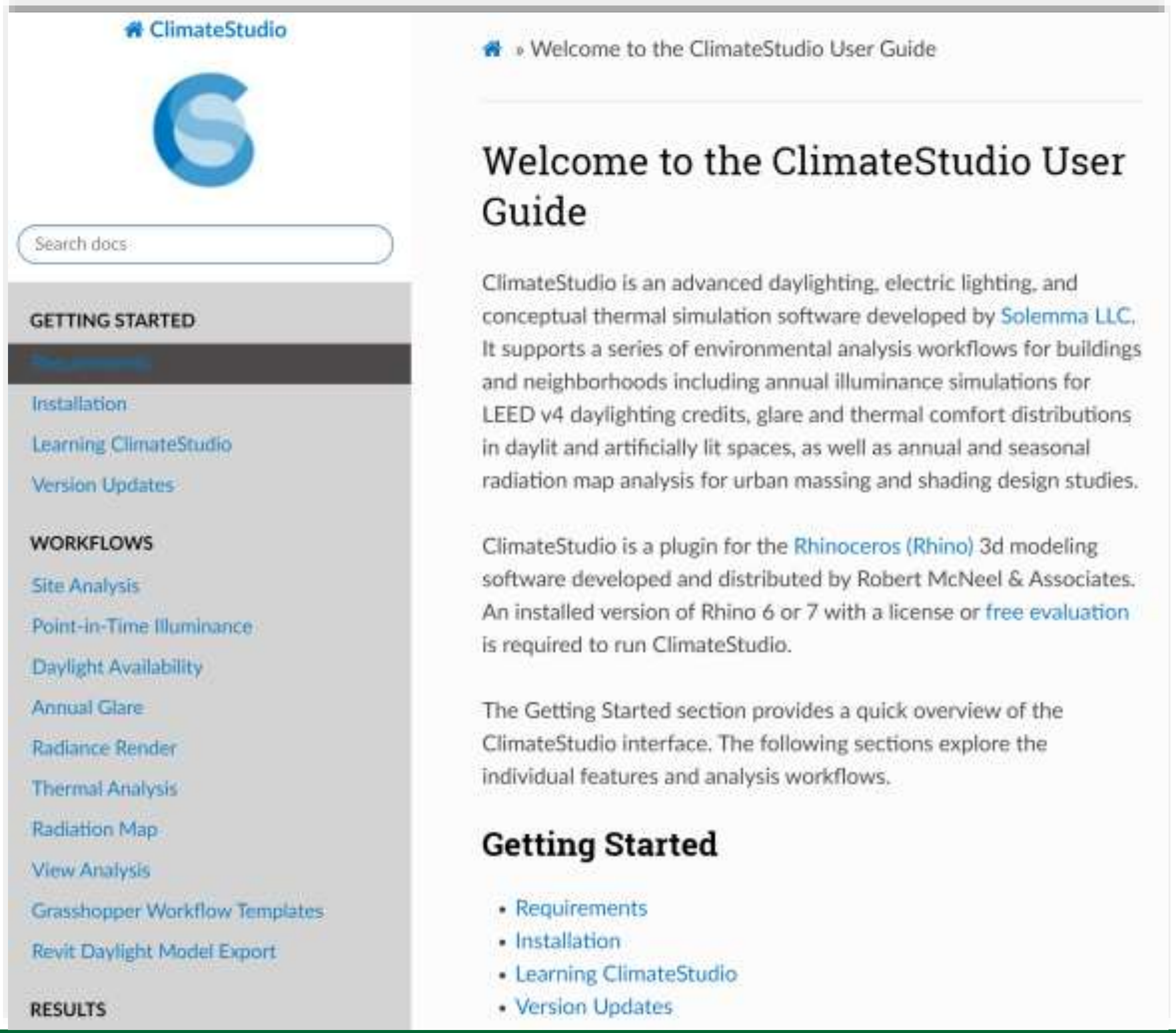
Comparison of ALFA to 9-band spectral software tool, Lark, in simulations of daylight, electric lighting, and electrochromic glazing. Simulation results will compare predicted vs. measured values for spectral irradiance, illuminance, and circadian lighting metrics and discuss the differences between available simulation methods.

Photo: https://www.forestry.oregonstate.edu/ofsc/homepage

Future Work | Market Education

In addition to publishing video tutorials and presenting to target stakeholders, a detailed user guide will be developed during Year 3. This user guide will be targeted at new users and include detailed descriptions of ALFA, spectral simulation workflows for daylight and electric light, and relevant information for calculating metrics related to human health and wellbeing.

Example of Online User Guide Currently Available for ClimateStudio:



Thank You

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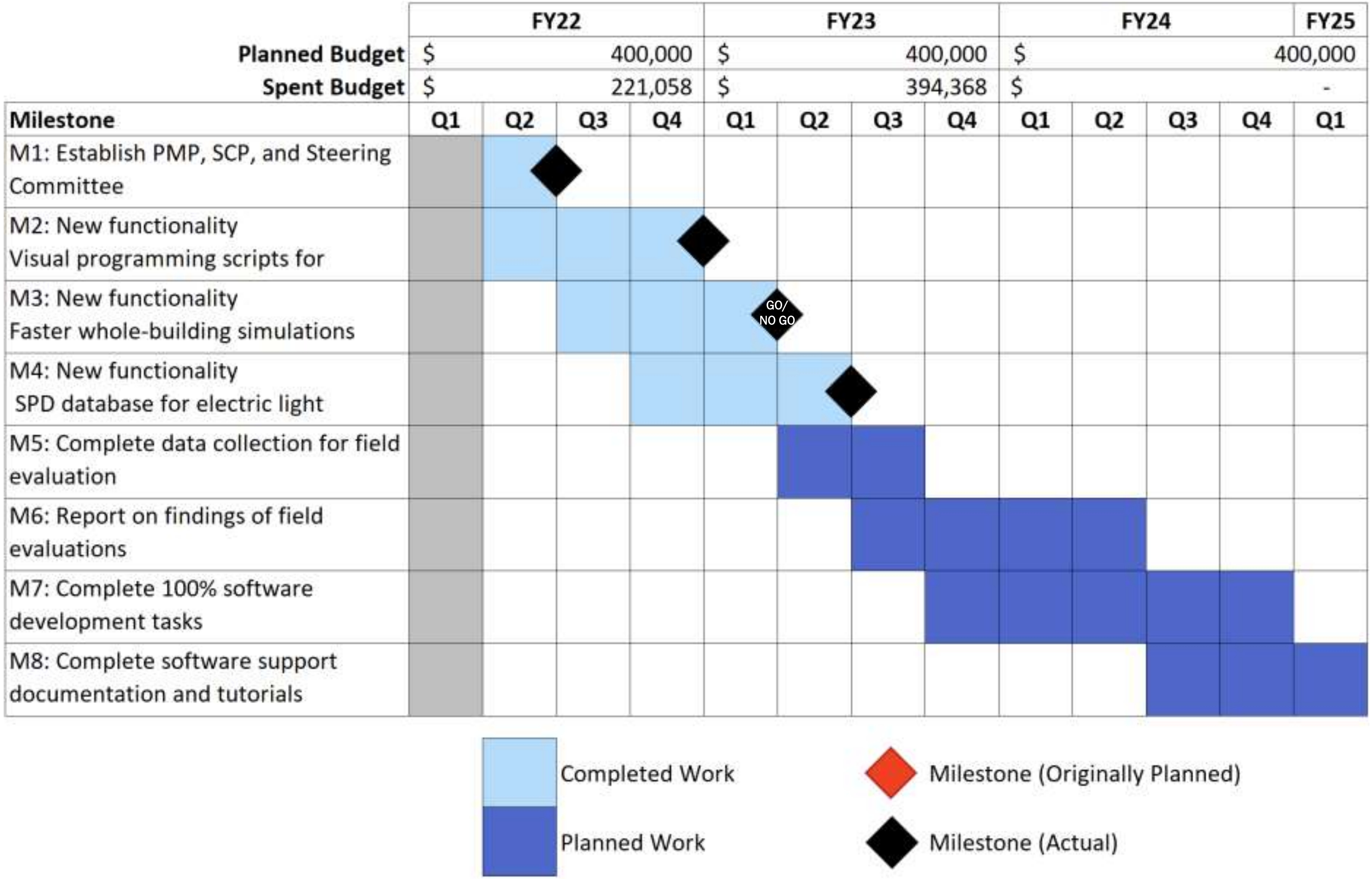
REFERENCE SLIDES

Project Execution



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