

# State of Daylighting in California

2019 Daylighting Symposium

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**Why**

Why should we care about daylighting?

## Three Questions We Want to Address

1. Does daylighting “make sense” in a world where LEDs have high efficacy and low costs?
2. Haven’t energy codes already addressed daylighting sufficiently?
3. Would adding daylighting to a compliance software tool add to much complexity?

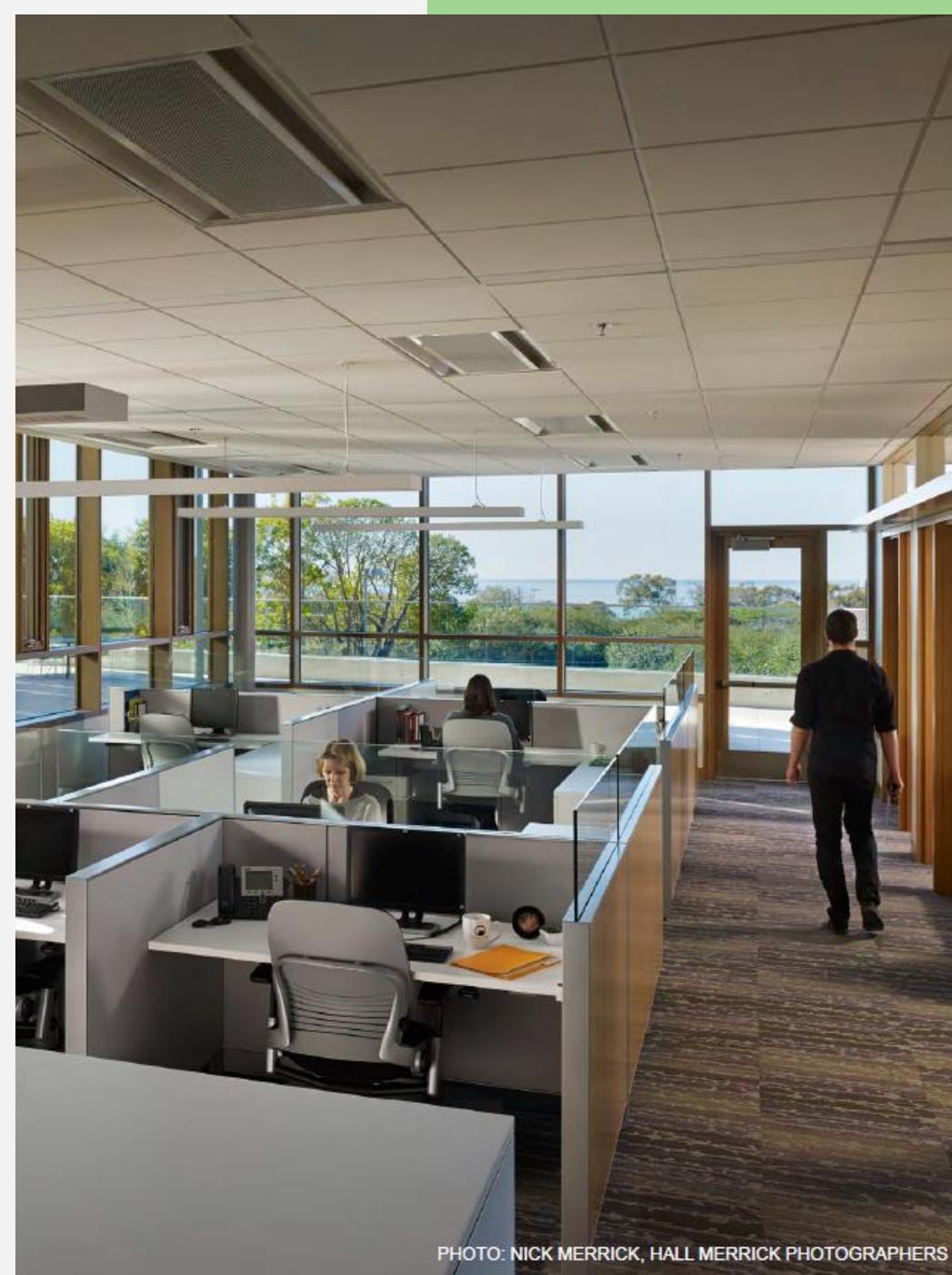
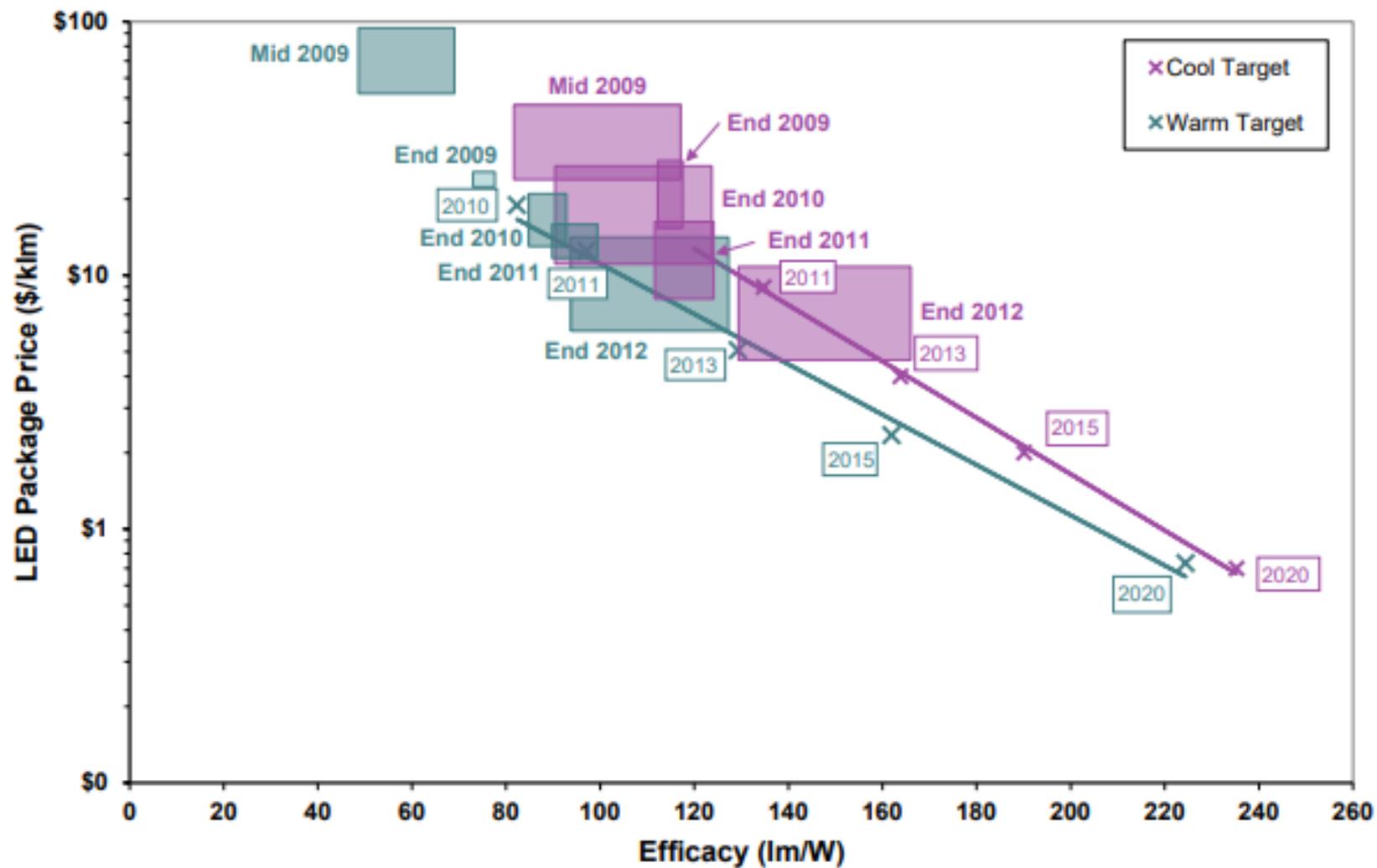
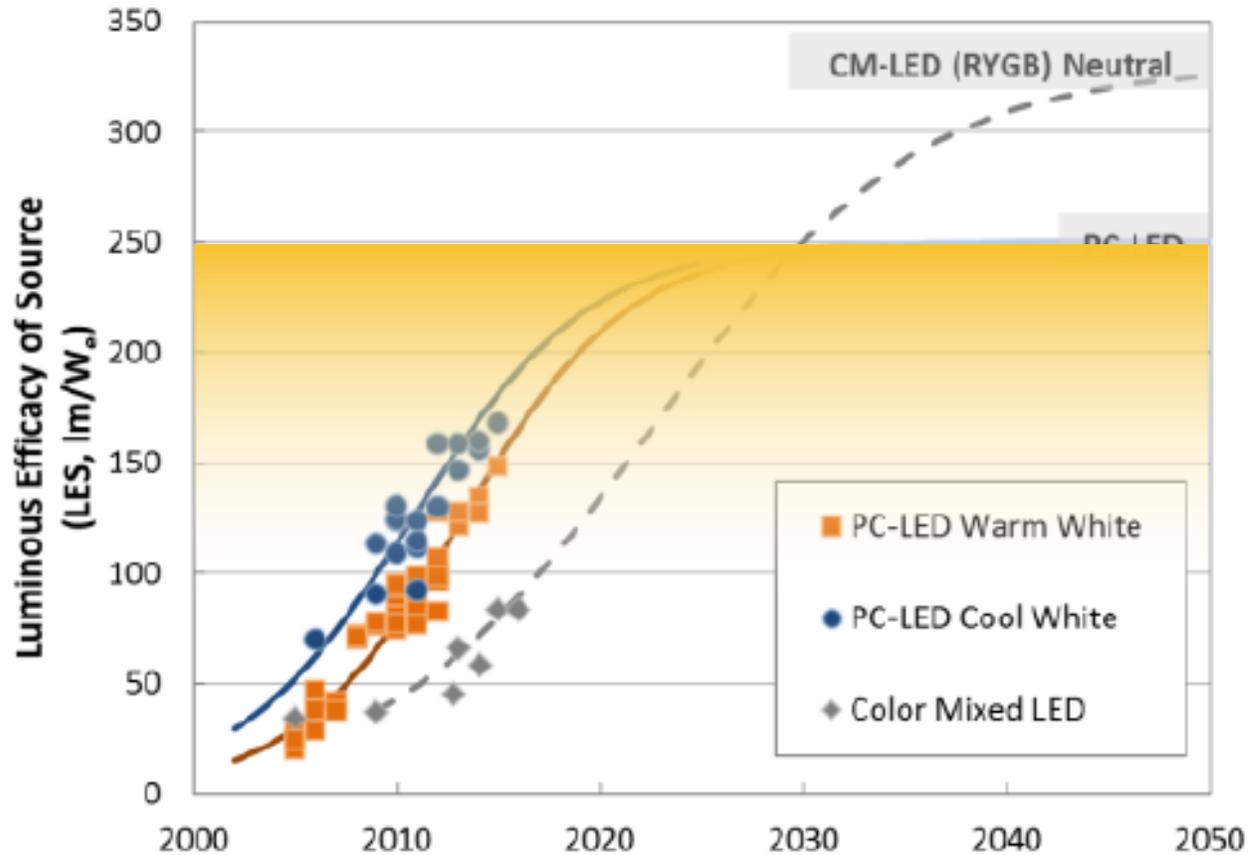


PHOTO: NICK MERRICK, HALL MERRICK PHOTOGRAPHERS

# LEDs Have Accomplished an AMAZING Feat!



# LED Efficacy Over Time



<< Daylight (250 – 150 lm/W)

Daylight through spectrally selective glazing (when done right!) ...

is still the most efficient way to light a space

# An LED Light That is ON is Still Using Energy ... Adding Carbon to the Atmosphere

There is no better efficiency  
than OFF!

Automatic controls are still cost  
effective ... even with LEDs

- At 120 Watts controlled per  
sensor



# But There is a Bigger Point ...

Buildings are not mere boxes! ...

... That we heat, cool, and light efficiently



Photo: SRG Partnership  
Portland Community College SE Campus

... They need to be comfortable ...

... conform to the function they  
were built for ...



Photo: Lincoln Barbour  
Thurston Elementary School in Springfield

... and most important,

protect our health and well-being  
while we occupy them.



PHOTO: NICK MERRICK, HALL MERRICK PHOTOGRAPHERS

# An Equation Solved for Lowest Energy Without Considering Occupants ...

$$0 \text{ kWh}_{\text{Annual Energy Use}} = a (\text{Insulation}) + b (\text{HVAC}) + c (\text{WWR}) + d (\text{Lighting})$$



# ZNE Buildings

The ones we want to build and celebrate have something in common...

They have been designed with occupants at the center!

Which inevitably leads to daylit buildings



Photo Credit: Jeremy Bittermann and David Livingston  
Packard Foundation, Palo Alto, CA

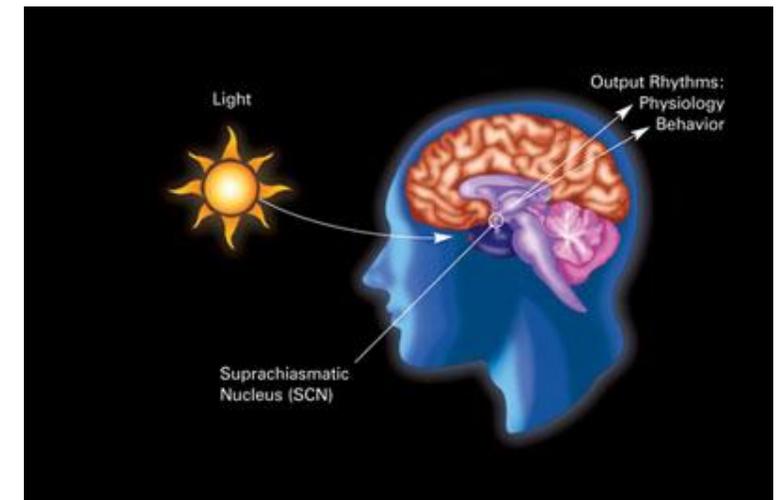
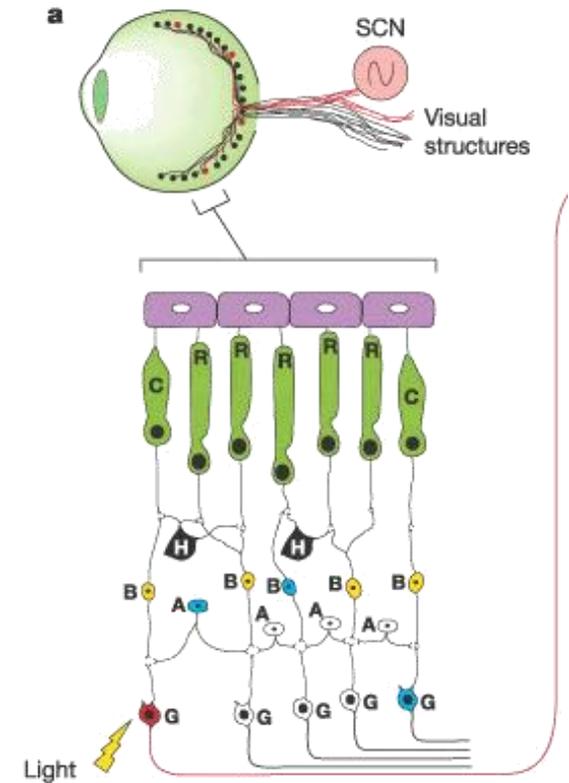
# ... Because Daylighting in Buildings

## Provides full spectrum light

- Linked to kick starting circadian cycle
- Ensures occupant health, alertness, less mental fatigue

## Provide a connection to outside

- Linked to higher productivity
- Better student performance
- Higher sales



# So What Tools Do We Have to Get There?

## Technology

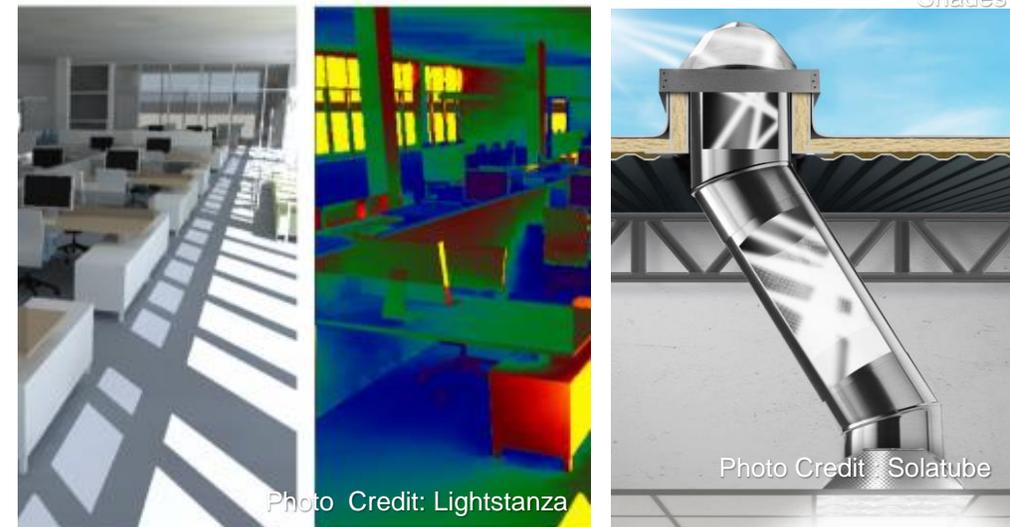
- Advances in windows let more light - less heat in
- Automated shades/blinds / Electrochromic windows
- Daylight redirecting devices

## Simulation Software

- BSDF – allows modeling of complex fenestration
- Radiance 3/5 Ph. Method – parametric analysis.
- New cloud-based, easy to use software

## Codes

- Need to set the right goals
- Encourage and reward the right type of designs!



# Daylighting in Codes Have Come a Long Way

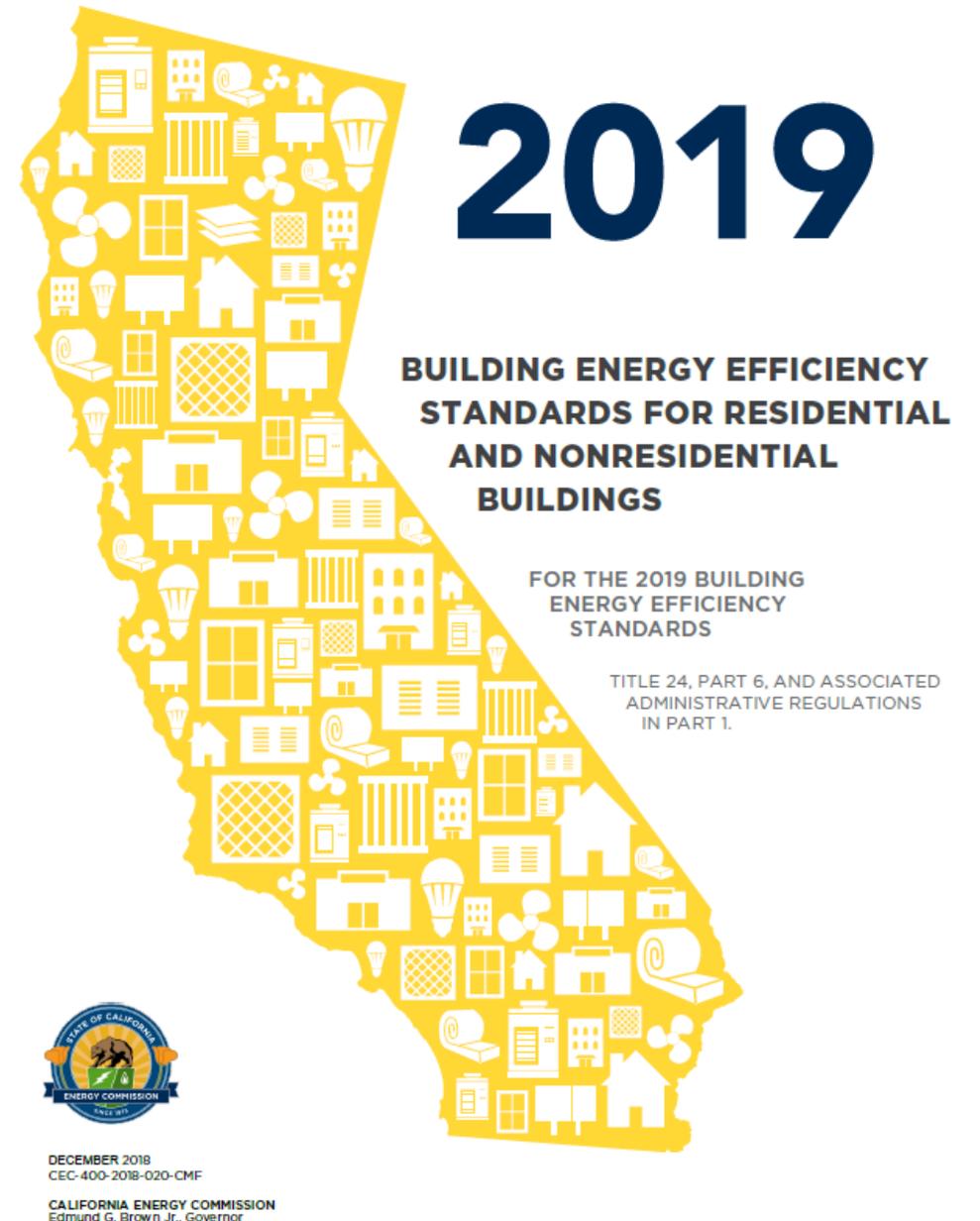
Current California Title 24 Codes Require

## Mandatory

- All Primary daylit zones controlled separately
- Minimum multi-level lighting controls
- Automatic controls in primary & skylit daylit zones

## Prescriptive

- Automatic controls in secondary daylit zones
- Minimum visible transmittance requirement
- New PAFs encourage innovative daylit designs



# But to Get to ZNE Buildings We will Need

## Performance Approach

- A way to model a building with all its daylighting features
- Go beyond prescriptive code
- Give credit to those designs

Current limitations in compliance software (CBECC-Com) does not yet allow this



# This May Not Be Simple ... But It's Doable.

## Prescriptive Code

- Continue to allow more innovative daylighting solutions to comply prescriptively

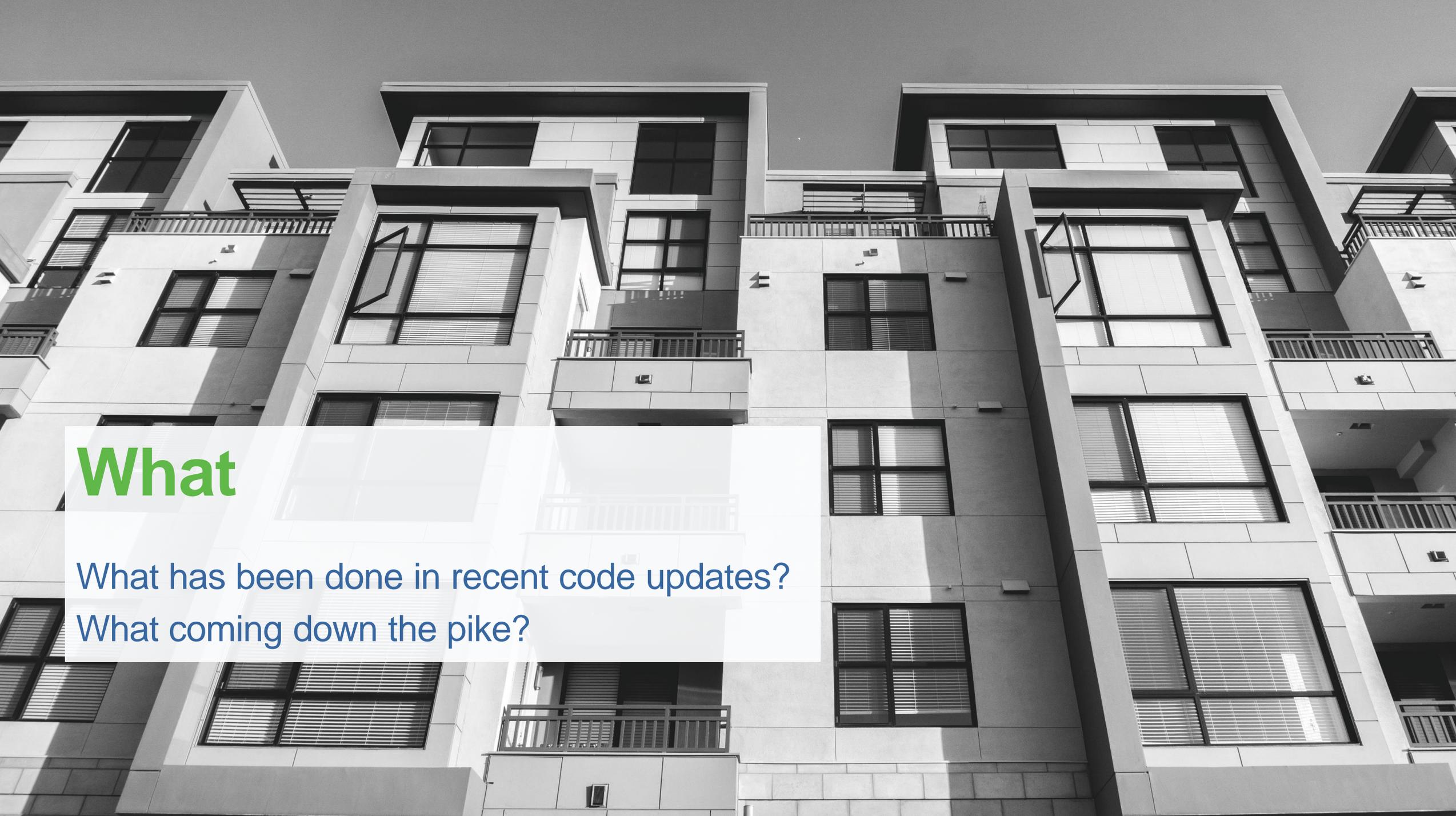
## Performance Code

- Bring Radiance to CBECC-Com
  - Enable full featured daylighting simulation
  - To give credit to daylighting designs that exceed code
  - To encourage and promote the type of ZNE buildings that we want to see!
- Address key issues:
  - Burden to the user / energy simulation
  - Burden of additional field verifications
  - Limit the number of inputs in Radiance that can be hard to verify

# This May Not Be Simple ... But It's Doable.



Let's begin the dialogue!



# What

What has been done in recent code updates?

What coming down the pike?

# 2019 California Energy Code Requirements

## Prescriptive

Do things that have been shown to be cost effective in pre-calculated analyses

## Power Adjustment Factors

in higher power lights than prescriptive if you do something that saves lighting energy

## Performance

- Use a simulation tool that uses physics equations on the whole building to calculate the energy use of the lighting system
- Compare your building to a the Standard Design building

# California 2019 Title 24 Update

- Where did we move the code forward in 2019?
- PAFs push designers to think about creative daylighting solutions
- Glare mitigation to ensure daylighting control savings
- Clerestories to make larger daylit zones



Exterior Aluminum Louvers Modern House Design  
Sun Shade Aluminium Hvac Architectural.  
04/25/2019. <http://www.excusivefloraldesigns.com/>



Intermediate Light Shelves. 04/25/2019.  
<http://2030palette.org/intermediate-light-shelves/>



Designboom. 04/25/2019.  
<https://static.designboom.com/>

# California 2019 Title 24 Update

- Update to the prescriptive requirements for Tubular Daylighting Devices
- Other cleanups: Overhang Exception, Skylit zone



Solatube SolaMaster Series. 04/25/2019.  
<https://www.solatube.com/commercial/solamaster>



SLFT LightFlex Tubular Daylighting System. 04/25/2019.  
<https://sunoptics.acuitybrands.com/products/detail/348066/sunoptics/slft/lightflex-tubular-daylighting-system>

# Power Adjustment Factors Were the Big Update for California Energy Code!

- Daylighting controls
  - Lowering of electric lights

- Amount of daylight
  - Visible transmittance
  - Window area (balance Solar Heat Gain Coefficient)

## **Distribution of daylight**

- Diffuse skylights
- Windows

# Interior or Exterior Louvers

## Distribution of daylight

Amount of daylight



Decoist. 04/25/2019. <https://www.decoist.com/2014-05-23/house-transformation-contemporary-design-singapore/>



Exterior Aluminum Louvers Modern House Design Sun Shade Aluminium Hvac Architectural. 04/25/2019. <http://www.exclusivefloraldesigns.com/>

# Interior + Exterior Light Shelf

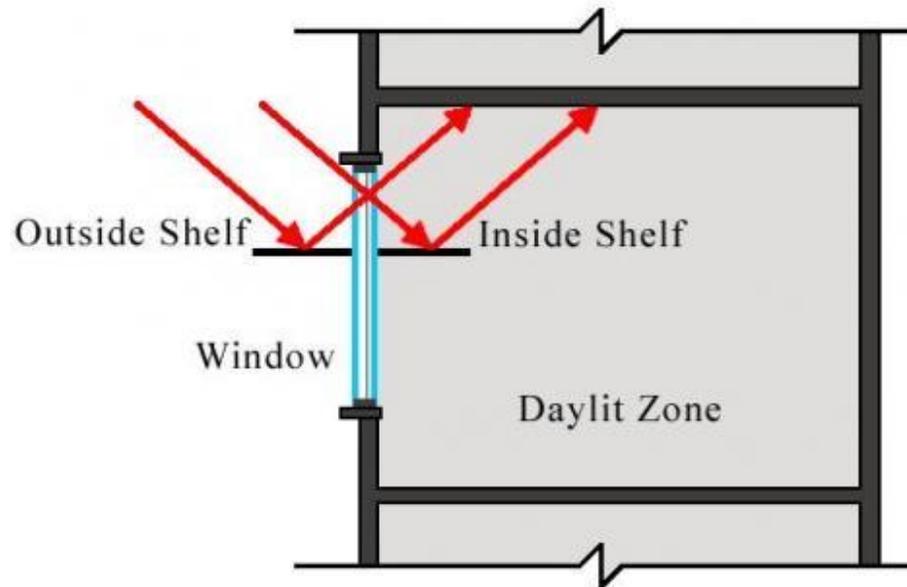
Both together

**Distribution of daylight**

Amount of daylight



Intermediate Light Shelves. 04/25/2019.  
<http://2030palette.org/intermediate-light-shelves/>



# Clerestory Windows

## Distribution of daylight

Amount of daylight



SageGlass. 04/25/2019. <https://www.sageglass.com/en/files/71abovesplitjpg>

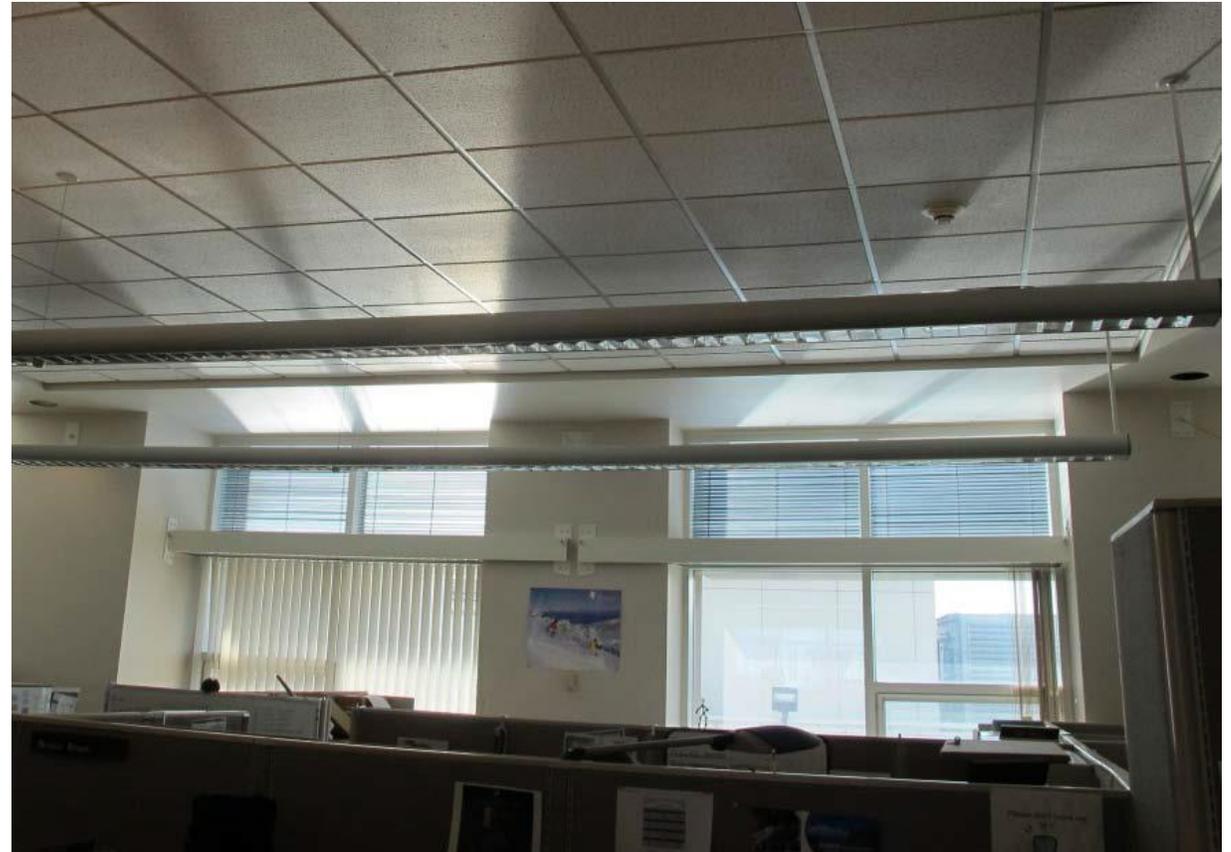
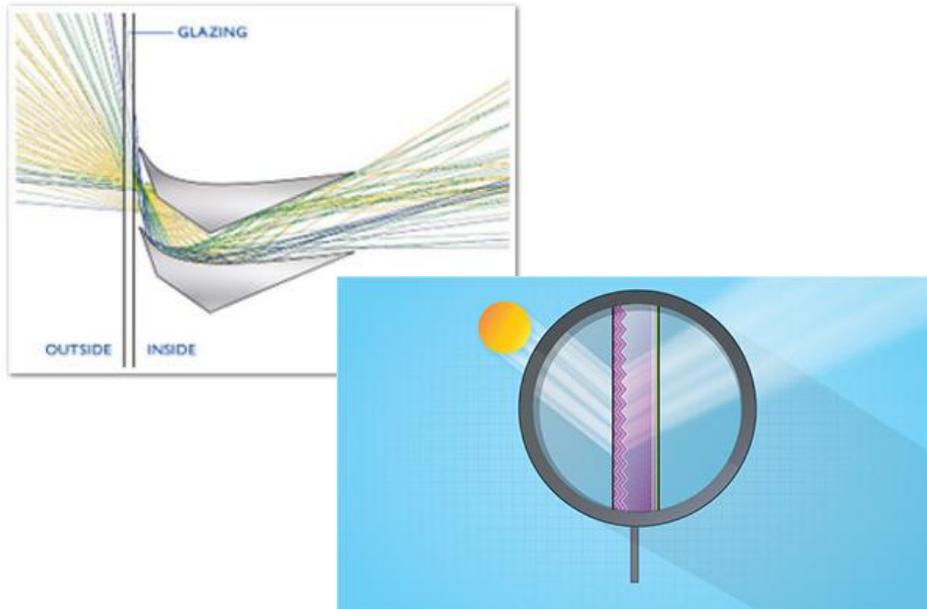


Designboom. 04/25/2019. <https://static.designboom.com/>

# Daylight Redirecting Devices (DRDs)

## Distribution of daylight

Redirects even deeper



LightLouver Description. 04/19/2019.

<http://lightlouver.com/lightlouver-description/>

How daylight redirecting film works. 04/19/2019.

[https://www.3m.com/3M/en\\_US/building-window-solutions-us/solutions/daylighting/](https://www.3m.com/3M/en_US/building-window-solutions-us/solutions/daylighting/)

T Perry, L Heschong, B Baccei . Energy Research & Development

Sacramento Municipal Utility District Report #: ET12SMUD1022. December 14, 2012

# Power Adjustment Factor Pros and Cons

(+)

## Pros

- Gradual prescriptive integration so that by 2030 does not shock industry
- Can monitor/react industry response
- Introduces to industry direction we are headed. An ad to encourage use.

(-)

## Cons

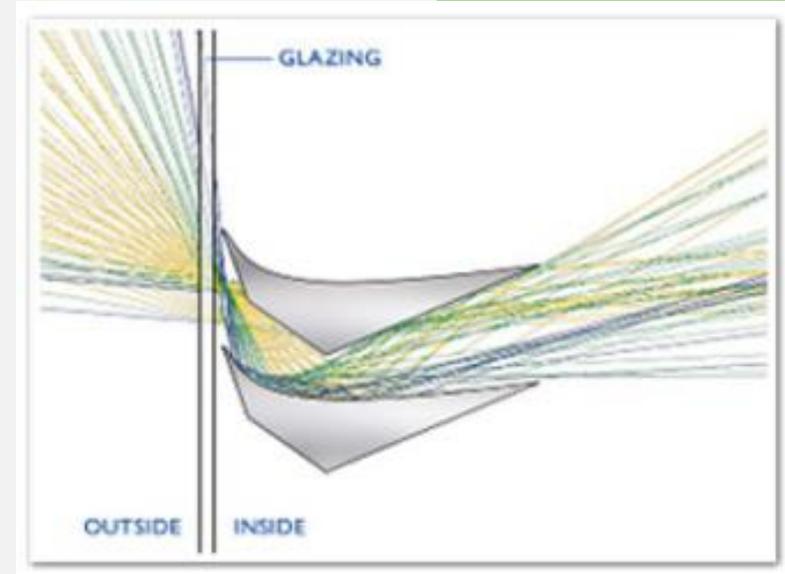
- Break even so no savings
- Designers think conservative PAF value is how much these technologies actually save
- Need to follow up (2030 only three code cycles away, historically not plenty of time)

# Daylight Redirecting Device Rating

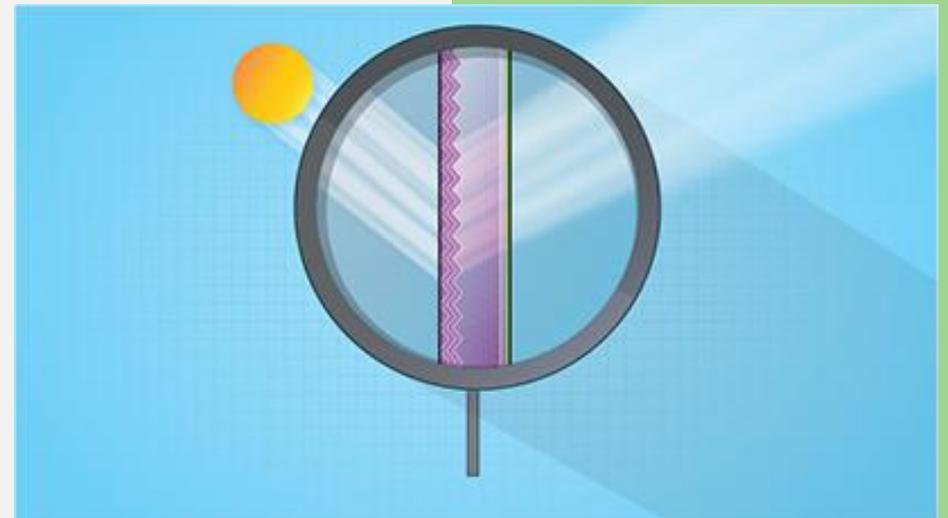
## Rating development

- BSDF testing per ASTM
- Total Transmittance and Transmittance Ratio (up/down)

Not ready for code. Need rating body.



LightLouver Description. 04/19/2019.  
<http://lightlouver.com/lightlouver-description/>



[https://www.3m.com/3M/en\\_US/building-window-solutions-us/solutions/daylighting/](https://www.3m.com/3M/en_US/building-window-solutions-us/solutions/daylighting/)

# What's next? ... Prescriptive

Single prescriptive requirement for compliance with alternatives?

- Mix of technologies from original plan and stakeholder feedback
- For now, only for selected space types

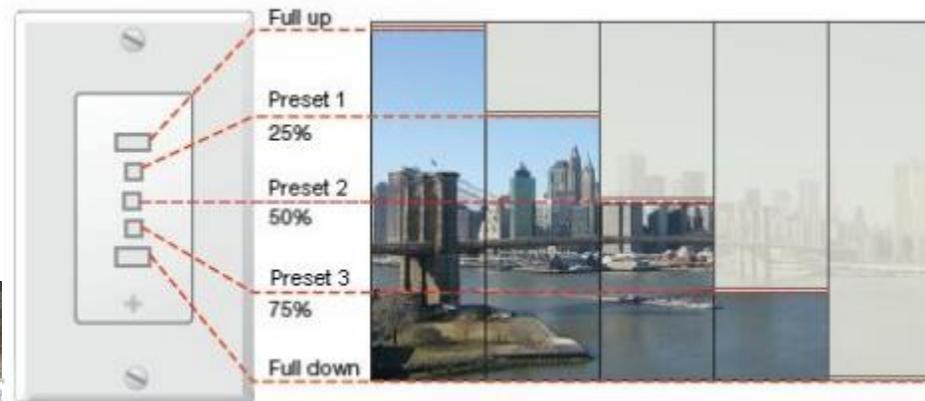


Exterior Aluminum Louvers Modern House Design Sun Shade Aluminium Hvac Architectural. 04/25/2019.

<http://www.exclusivefloraldesigns.com/>

Intermediate Light Shelves. 04/25/2019. <http://2030palette.org/intermediate-light-shelves/>

Designboom. 04/25/2019. <https://static.designboom.com/>



Product Spotlight MechoNet. 04/25/2019.

<http://gallunsnow.com/product-spotlight-mechonet/>

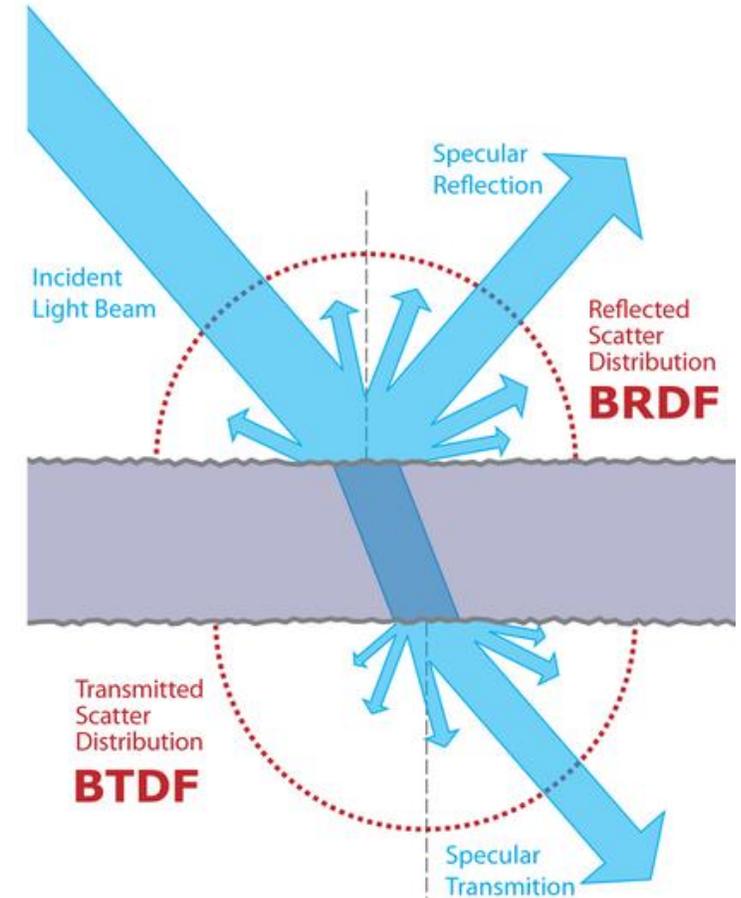


Windows for High-Performance Commercial Buildings. 04/25/2019.

<https://www.commercialwindows.org/electrochromic.php>

# What's next? ... Performance Method

- Complex Fenestration in CBECC-Com
- Bidirectional Scattering Distribution Function (BSDF)
- Math function that determines probability of light rays
- being scattered and reflected
- Combination of 2 components:
  - BRDF (reflectance)
  - BTDF (transmittance)



Wikipedia [Creative Commons Attribution-ShareAlike 3.0](#)



# Who

Who are the key stakeholders?



## California Energy Commission

- Establish scope of code cycle
- Administer public rulemaking process
- Consider (and approve) code change proposals
- Develop code change proposals
- Maintain compliance software



## Stakeholders

Participate in Energy Commission's rulemaking process:

- Develop code change proposals
- Support Energy Commission throughout rulemaking
- Provide data
- Offer feedback and suggest revisions

# Statewide Utility Codes and Standards Team

Actively supports the California Energy Commission in developing proposed changes to the California Energy Code (Title 24, Part 6)

Intent is to achieve significant energy savings through the development of code change proposals for the 2022 code update, and beyond



# Requirements for a Successful Code Change Proposal

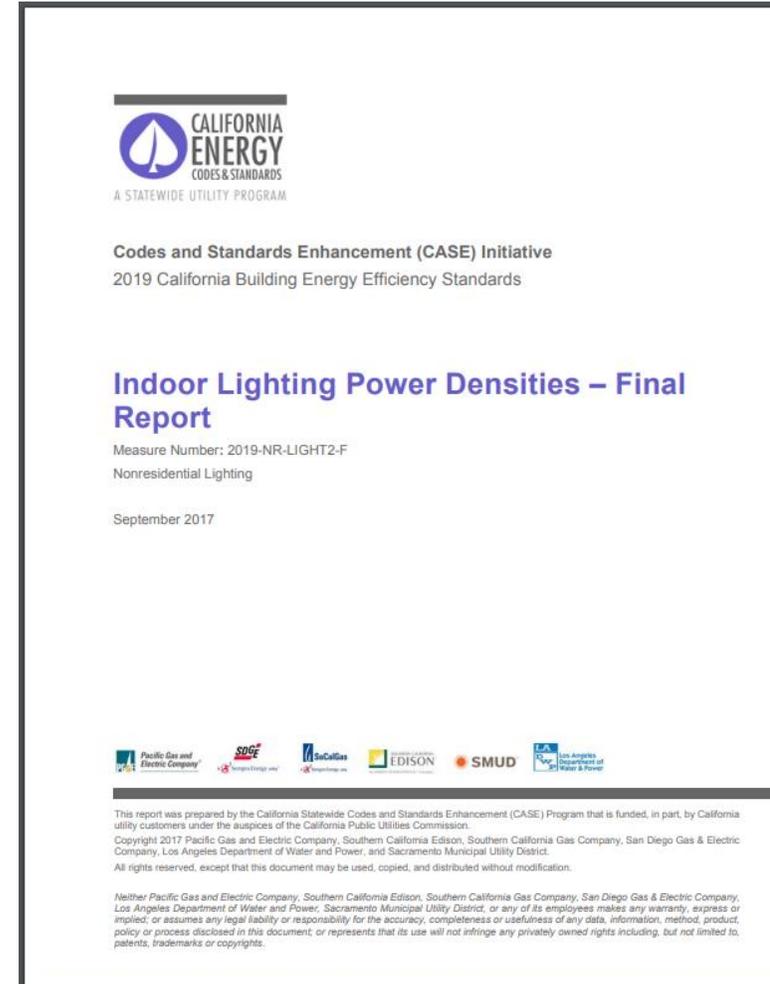
The utilities support the California Energy Commission by proposing changes to the Energy Code that are:

**Feasible** | **Cost effective** | **Enforceable** | **Non-proprietary**

# Codes and Standards Enhancement (CASE) Initiative

Provide Energy Commission information needed to adopt a change

- Energy and demand impacts
- Cost effectiveness
- Technical feasibility
- Market impacts
- Suggested code language
- Compliance and enforcement
- Compliance software recommendations
- Revisions to Compliance Manuals



# CASE Team Will Collaborate with Stakeholders Throughout Code Cycle

## Data Collection

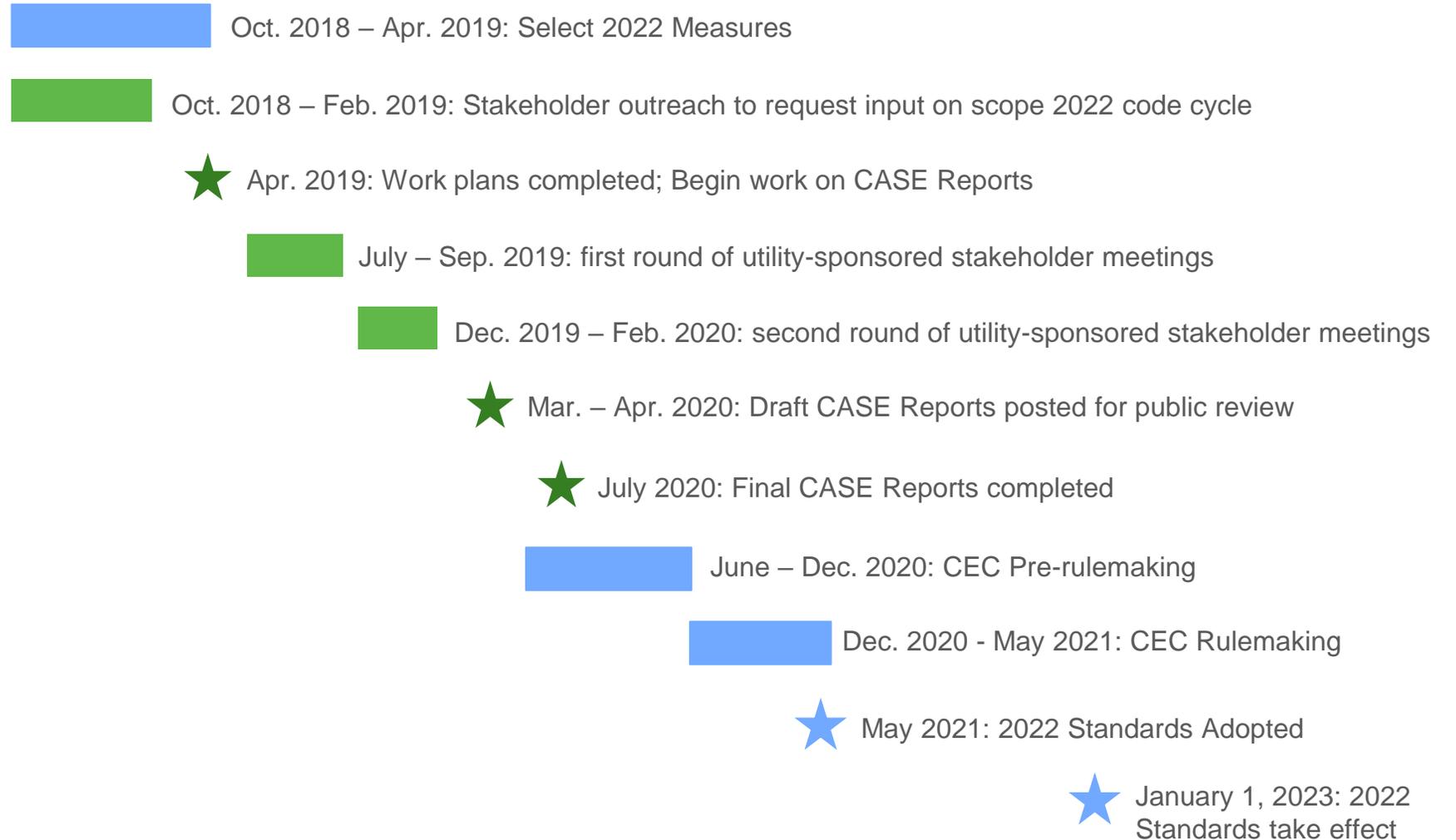
- Energy impacts
- Costs and cost savings
- Technical analysis
- Material impacts
- Market analysis

## Stakeholder Engagement

- Encourage participation in the code development process
- Provide data and information that leads to well-supported proposals



# 2022 Code Cycle Milestones



■ Utility Team Milestone  
■ CEC Milestone

# Energy Commission's Rulemaking Process:

California Energy Commission: [energy.ca.gov/title24/](https://energy.ca.gov/title24/)

Statewide Utility Codes and Standards Team: [Title24Stakeholders.com](https://Title24Stakeholders.com)



# 2022 Process is already underway ...

What's happening? When to give us your input?

Check [www.Title24Stakeholders.com](http://www.Title24Stakeholders.com) to submit measure ideas, feedback, and sign up to receive notifications on meetings and topic updates.



# ASHRAE 90.1, IECC, and Title 24

- State's building codes must result in energy performance that is equal to or better than
  - ASHRAE 90.1 (nonresidential)
  - IECC (residential)
- State's building codes are compared against the national model codes as a whole, not measure by measure
- Some ASHRAE 90.1 and IECC standards are well-suited for California

# How

How can we make it happen?



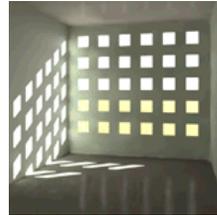
# We Are Here to Talk About That!

## Daylight is a complex topic

- **Knowledge = Research & Consensus on**
  - Daylight Glare & Glare Metrics (IES DMC – work in progress!)
  - Daylight Metrics (IES-LM-83 – future research & improvements),
  - Better understanding of Human Centric Design (Vertical Illuminance, Standards for EML)
  - Stochastic models to better predict and model human behavior
- **Expertise**
  - Training installers, commissioning agents, designers and compliance simulators to use new technologies, tools
- **Tools**
  - That can handle and manage the daylighting simulation workflow
  - Many promising improvements in simulation tools on the horizon

# Promising Tool Improvements ... Stuff on the Horizon

## Simulation Tools



*Radiance*



*OpenStudio*



*EnergyPlus*

## Plug-ins scripts and APIs

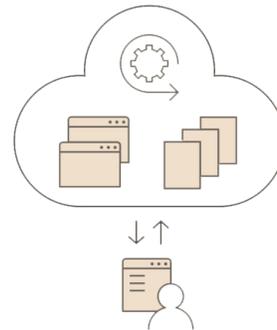


*Ruby*

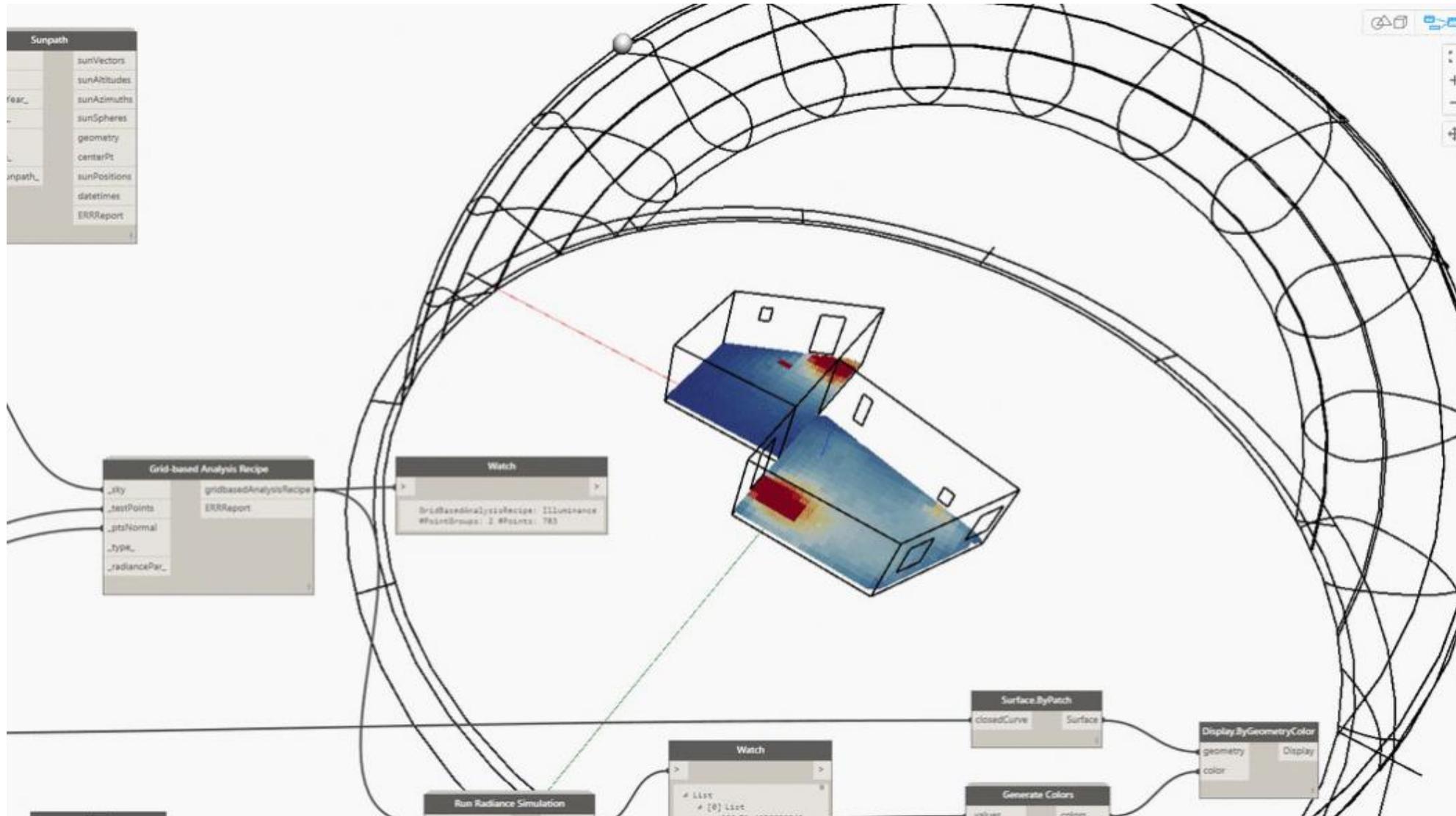


*Python*

## Cloud Platforms



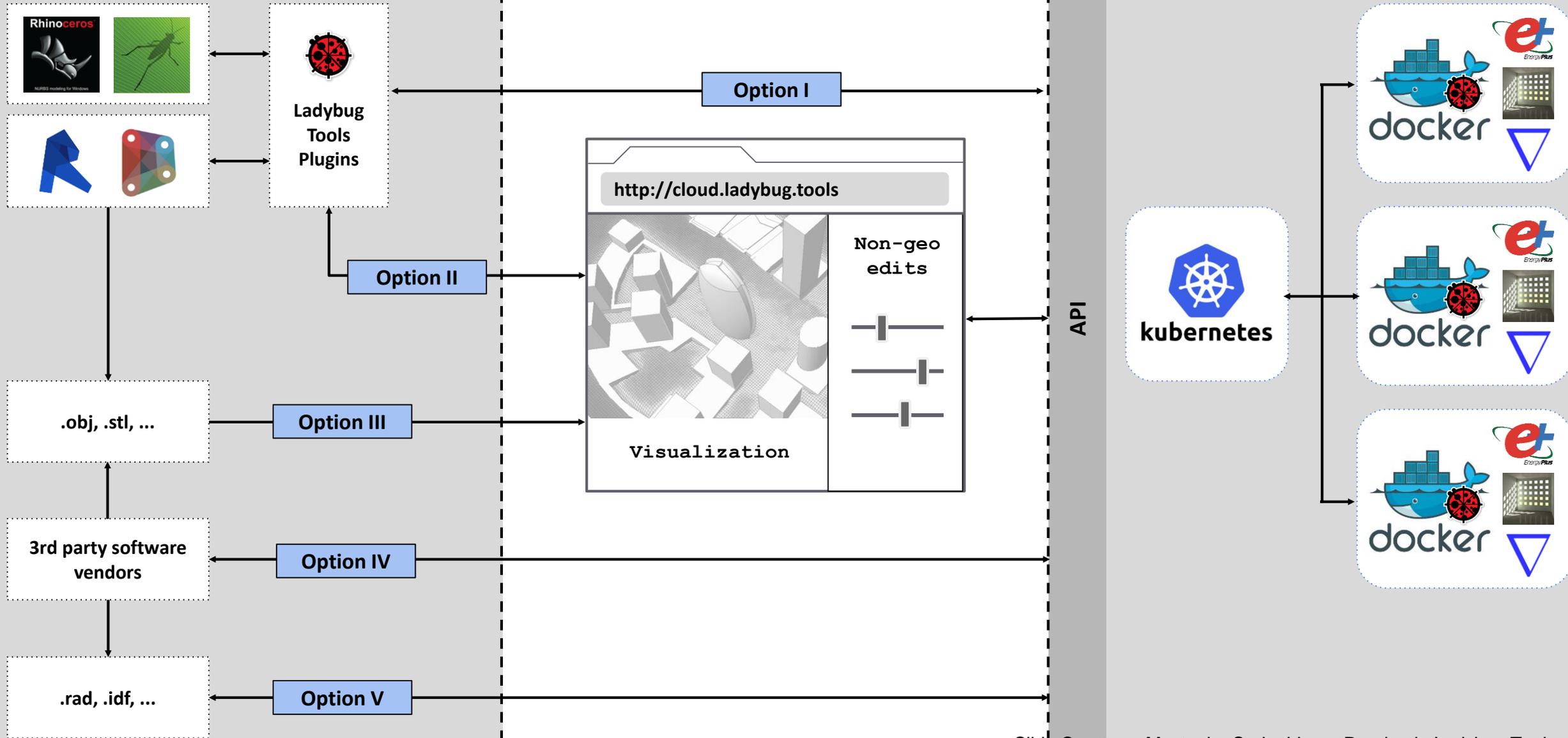
# Parametric Analysis with Daylighting Simulation



# Desktop

# Web Interface

# Server



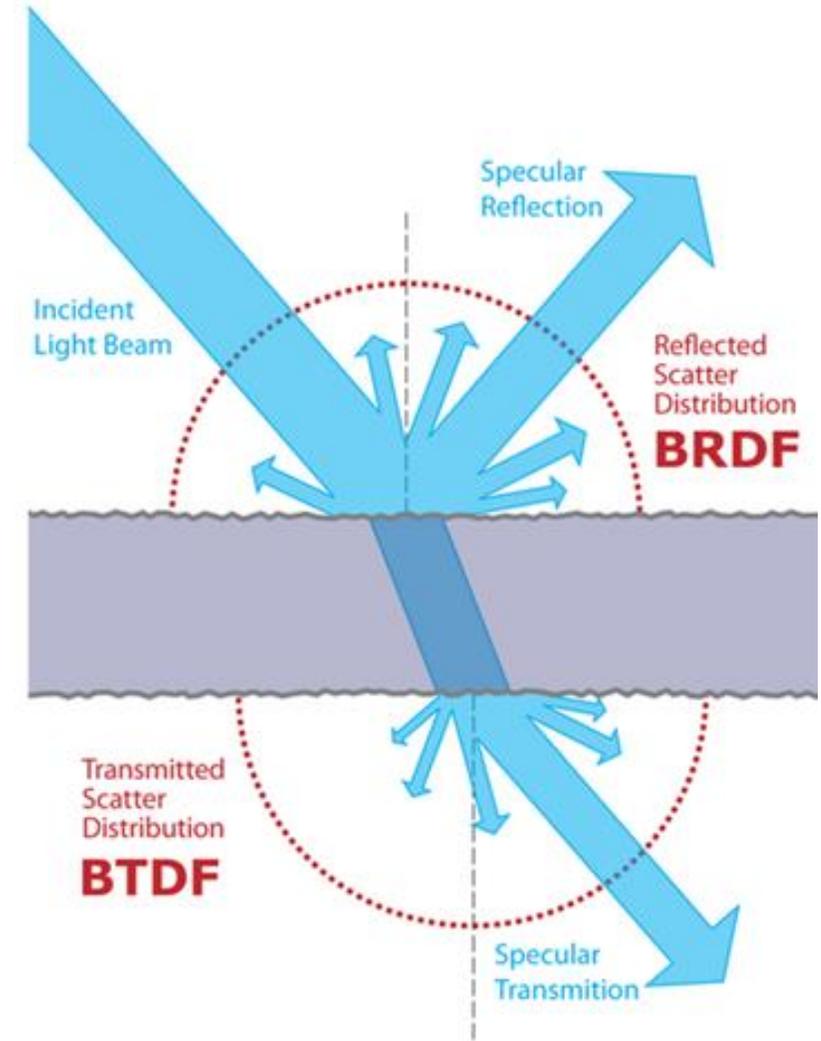
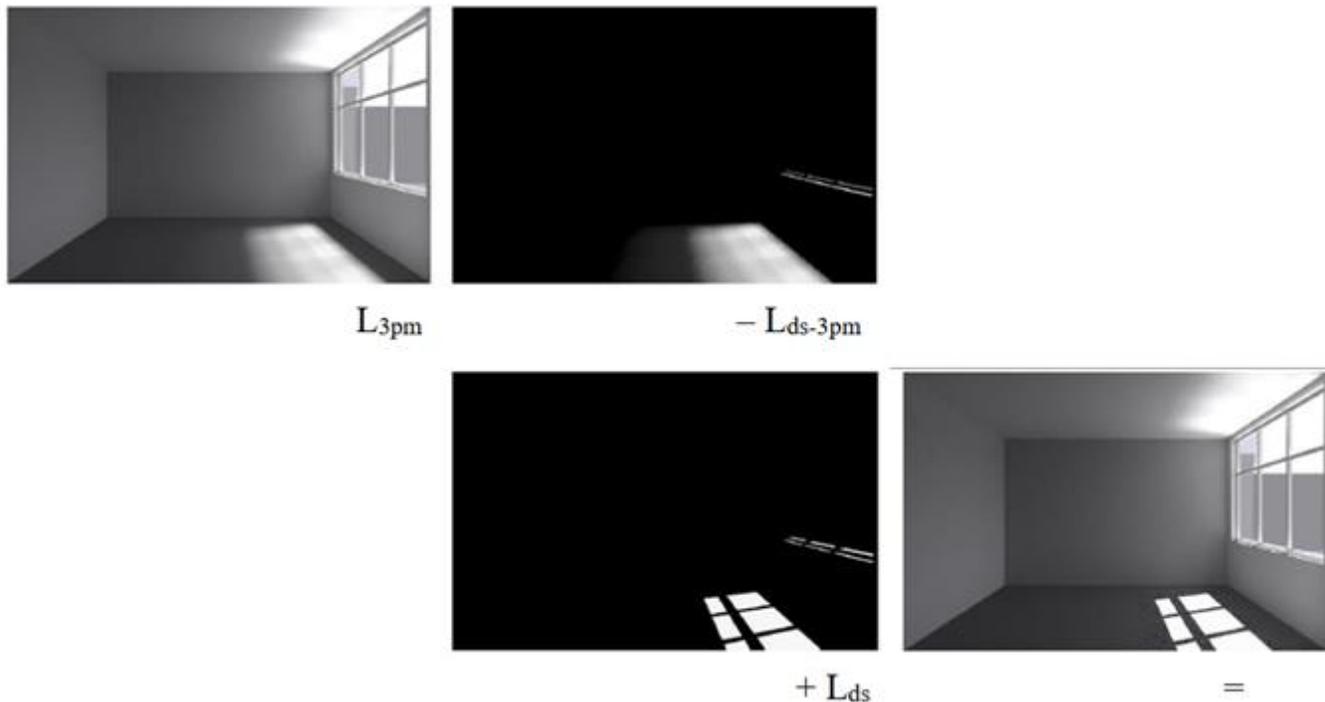
# OpenStudio Radiance Measure

- EnergyPlus** 
- Fenestration: Split-flux method
    - Daylight goes up or down only
    - Theoretical accuracy
  - BSDF: Radiosity
    - No blinds control
    - No glare metrics:
    - Algorithms “under development”
  - Open source: C++

- OpenStudio Radiance Measure** 
- Fenestration: Radiance method
    - Traces light rays from “eye” to source
    - Real-world verified
  - BSDF: Radiance method
    - Shade control
    - Glare metrics
    - Real-world verified
  - Open source: Ruby

# OpenStudio Radiance Measure Modifications

- Expand BSDF library
- Improve metrics and accuracy

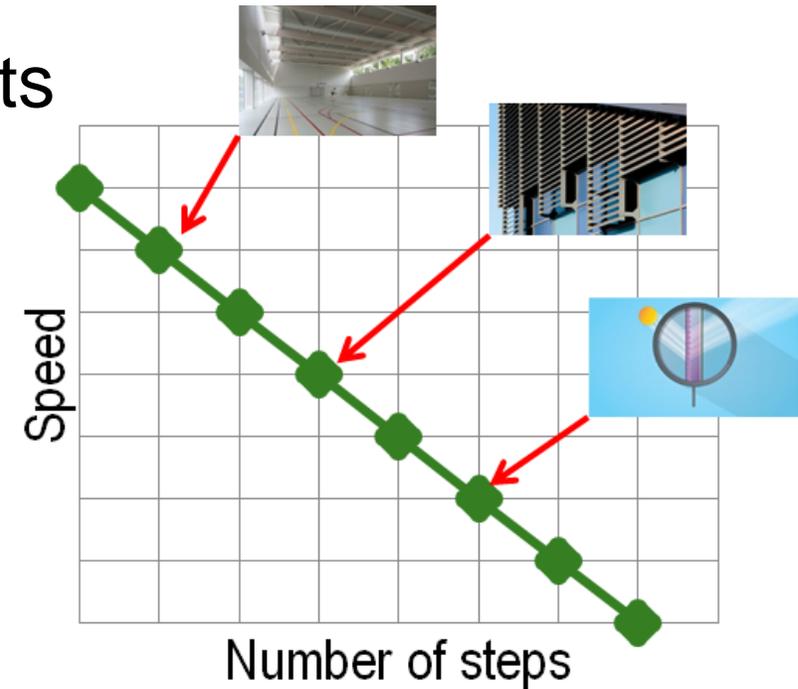


E. Lee, D. Geisler-Moroderb, G. Ward. Modeling the direct sun component in buildings using matrix algebraic approaches: Methods and validation

Wikipedia [Creative Commons Attribution-ShareAlike 3.0](https://creativecommons.org/licenses/by-sa/3.0/)

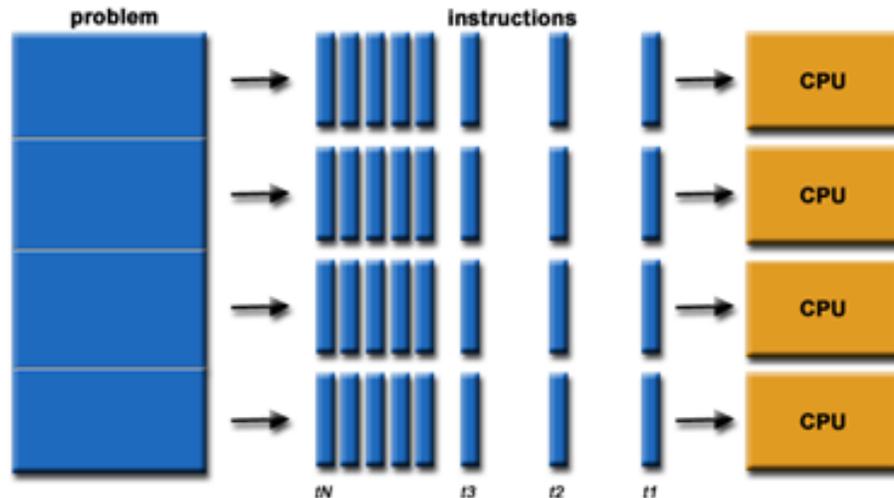
# OpenStudio Radiance Measure Speed

- CASE study runs: 3 minutes/space
- Elevate number of steps vs. speed based on technology
- Reduce to essential processes/outputs
- Maintain Results Database



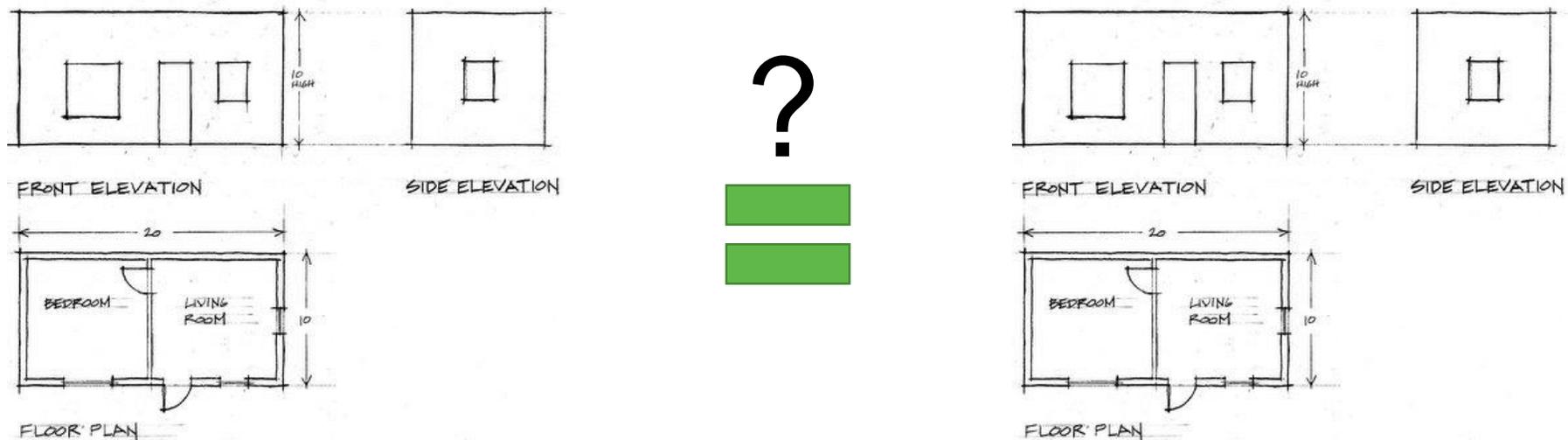
# OpenStudio Radiance Measure Speed

- **Put OpenStudio Radiance on server:**
  - Runs in background, Parallel process, Run-length encoding
  - OpenStudio already has cloud computing capability built-in
  - Other benefit: protects source code (Ruby)



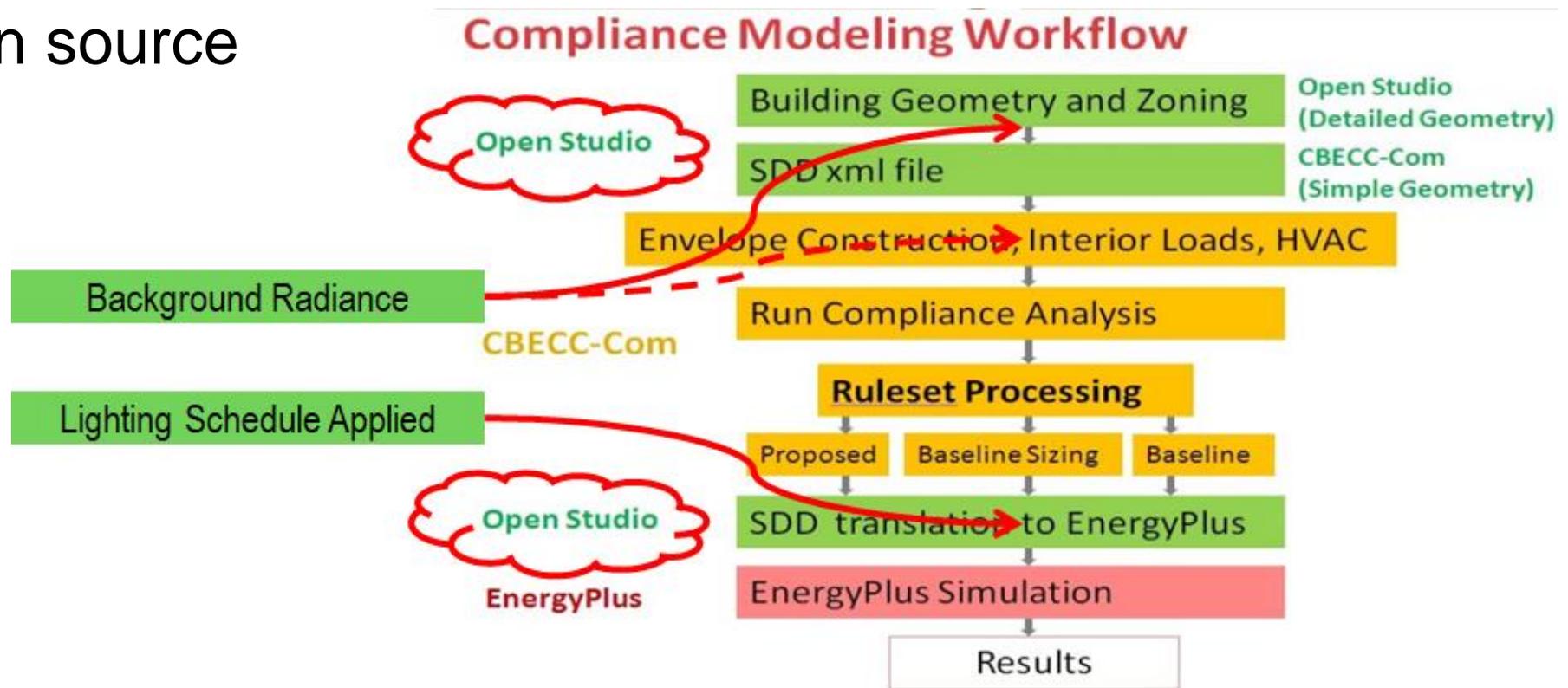
# OpenStudio Radiance Measure Verification

- BSDFs from official library: geometry or make/model
- OpenStudio outputs plan and elevation view for simulated spaces
- Plan Checker compares to construction documents



# OpenStudio Radiance Measure Workflow

- Already in CBECC-Com
- Open source



# Radiance Software

- Annual simulation?
- Daylight/Glare metrics?
- Blinds control?
- BSDFs?
- Accuracy vs. Speed?
- **Open source?**



# Thank You

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