eQUEST
Panel #3 : Bridging the Gap

Marlin Addison
eQUEST Development Team
and School of Architecture, Arizona State University

Daylighting Forum 2010
May 14th – 15th 2010
Las Vegas, NV
‘Whole Building’ Analysis, what/why?

A building is a system of systems … optimum performance requires whole building analysis

Source: Savings By Design
‘Whole Building’ Simulation Tools

What are the ‘specs’ of a Whole Building Energy Simulation tool?

- feasible to model the entire building, small (~20 zones), medium (~100 zones), large (~1000 zones)
  - necessary to interact core and perimeter areas, differing orientations, complex HVAC, controls and operations
  - required by ASHRAE 90.1 and Title 24
- feasible to model dozens of EEM’s
- feasible to make many ‘runs’ (100’s?) per project

... therefore, to make ‘whole building’ analysis feasible, we have some constraints on run time
Why do we need WBES?

Rule: *make things as simple as possible, but not too simple*

Example: Is HVAC load linear with OA temp?

Simple steady-state model with t-stat = 78F

The slope of this line represents the overall UA of the building envelope.
Why do we need WBES?

Is HVAC load linear with OA temp?

Simple steady-state model with t-stat = 78F
+ ignore effects due to: internal loads, wind, long wave radiant losses from ext surfaces, slab losses, infiltration, envelope mass, ext surface solar absorbtance, interior mass, window solar gain, and natural ventilation

- simplified engineering methods (not simulation) assume heating/cooling energy is linear with outdoor air dry bulb temperature.

The slope of this line represents the overall UA of the building envelope.
Is HVAC load linear in OA temp?

Why do we need WBES?

WBES model with t-stat = 78F + effects due to the items listed below

Additional effects included above: internal loads, wind, long wave radiant losses from ext surfaces, slab losses, infiltration, envelope mass, ext surface solar absorbtance, interior mass, and window solar gain

The ‘real world’ is a complicated place. WBES can help.
Efficiency Ratings: need WBES?

Why do we need WBES?

Note the significant scatter in the SEER versus EER plot above. **WBES can help sort this out.**
Rated SEER versus Simulated

Why do we need WBES?

Even sophisticated ratings or ‘metrics’ cannot ignore the context. WBES can help address this.

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Rated SEER versus Simulated

Why do we need WBES?

Even sophisticated ratings or ‘metrics’ cannot ignore the context. **WBES** can help address this.

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EEM Interaction

Try this “experiment”…

- Run several EEMs one-at-a-time
- Sum the predicted benefits
- Run the same EEMs in one run
- Compare the sum of benefits from one-at-a-time runs with the run that combines all EEMs
EEM Interaction

Why do we need WBES?

Our EEMs:

- Ext Wall from R-11 to R-19
- Roof from R-12 to R-21
- Low-e windows
- Reduced lighting power
- Daylighting in perimeter spaces
- Chiller efficiency from 0.84 to 0.6 kW/ton
EEMs Run One-at-a-time

Why do we need WBES?

Sum of independent EEM runs ≈ 339,500 kWh

<table>
<thead>
<tr>
<th>Annual Energy Use</th>
<th>Lights</th>
<th>Misc Equip</th>
<th>Space Heating</th>
<th>Space Cooling</th>
<th>Heat Reject</th>
<th>Pumps &amp; Aux</th>
<th>Vent Fans</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 Base Case</td>
<td>300,862</td>
<td>183,038</td>
<td>1,091</td>
<td>216,406</td>
<td>3,868</td>
<td>51,606</td>
<td>73,146</td>
<td>829,017</td>
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<tr>
<td>1 0 + Wall R11 to R19</td>
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<td>183,038</td>
<td>1,056</td>
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<td>51,598</td>
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<tr>
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<td>183,038</td>
<td>1,646</td>
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<td>49,995</td>
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<td>1,850</td>
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<td>200,573</td>
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</table>

Annual Incremental Savings (negative values indicate increased use)

<table>
<thead>
<tr>
<th>Annual Cumulative Savings (negative values indicate increased use)</th>
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<tbody>
<tr>
<td>0 Wall R11 to R19</td>
</tr>
<tr>
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<td>0 Low-E Windows</td>
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<td>0 Reduced LPD</td>
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<tr>
<td>0 Side Daylighting</td>
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<tr>
<td>0 Chiller 0.84 to 0.6 kW-ton</td>
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</tbody>
</table>

SUM of independent Savings: 200,813 0 -2,029 114,107 1,519 4,357 20,697 = 339,461
# EEMs Run Cumulatively

## Why do we need WBES?

Last run with all EEMs ≈ 281,200 kWh (~20% less)

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<tr>
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<td>183,038</td>
<td>2,009</td>
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<td>183,038</td>
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<td>120,650</td>
<td>2,564</td>
<td>47,683</td>
<td>55,645</td>
<td>547,808</td>
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</table>

## Annual Incremental Savings (negative values indicate increased use)

<table>
<thead>
<tr>
<th></th>
<th>Lights</th>
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<tbody>
<tr>
<td>1 0 + Wall R11 to R19</td>
<td>0</td>
<td>35</td>
<td>20</td>
<td>0</td>
<td>8</td>
<td>1</td>
<td>64</td>
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<td>2 1 + Roof R12 to R21</td>
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<td>371</td>
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<td>7</td>
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<td>0</td>
<td>-1,939</td>
<td>12,797</td>
<td>308</td>
<td>1,015</td>
<td>4,795</td>
<td>63,270</td>
<td>(35% less)</td>
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<td>187</td>
<td>508</td>
<td>0</td>
<td>48,939</td>
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</table>

## Annual Cumulative Savings (negative values indicate increased use)

<table>
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<td>35</td>
<td>20</td>
<td>0</td>
<td>8</td>
<td>1</td>
<td>64</td>
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<td>2 1 + Roof R12 to R21</td>
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<tr>
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<td>-2,857</td>
<td>94,756</td>
<td>1,304</td>
<td>3,923</td>
<td>17,501</td>
<td>281,209</td>
<td></td>
</tr>
</tbody>
</table>

SUM of independent savings: 200,813 0 114,107 1,519 4,357 20,697 339,461

% SUM overpredicts 21% n/a -29% 20% 16% 11% 18% 21%
eQUEST Usage

How widely used is eQUEST?

- 25,000 eQUEST downloads in 2009
- USGBC LEED™ NC submittals
  - 65% eQUEST
  - 20% Trane Trace
  - 5% Carrier HAP
  - 10% VisualDOE, EnergyPro, others

  source: survey conducted by Rocky Mountain Institute

- 2010 AIA COTE Top Ten Award
  - 60 of 63 finalist submissions used eQUEST

  source: personal correspondence, COTE ‘Top Ten’ judging panel
Runtime versus Accuracy Trade-Off

You can have it …

Good
Fast
Cheap

(pick two)

Selecting the right WBES tool…
Common WBES Compromises

- one-dimensional heat flow through solids
- average zone air temperatures, i.e., assumes well mixed air (no buoyancy or stratification)
- surface average temperature
- convex spaces with no internal obstructions
- assumes ideal HVAC control
- no site microclimate effects
- simplified ground coupling
- simplified infiltration / natural ventilation
- simplified lighting / daylighting

- being addressed in WBES tools such as EnergyPlus & ESP-r
Daylighting in eQUEST

Clear Sky (20 pts) + Overcast Sky (1 pt)

weighted by cloud cover
Daylighting in eQUEST

Direct Component        Indirect Component (split flux)
Daylighting in eQUEST

Direct Component

Limitations:
- determined for \( \leq 2 \) interior workplane points
- no internal obstructions
- limited resolution due to 20 point sun position interpolation table

Indirect Component (split flux)

Limitations:
- average internally reflected component for a spherical room
- no internal obstructions
- diffuse interior surfaces
Side lighting, conventional window

June 21 noon, 10 ft ceiling, total workplane illuminance

DOE-2 compared with Radiance & Superlite

Source: A. Dang, 2003
Side lighting, conventional window

June 21 noon, 10 ft ceiling, **direct workplane illuminance**

June 21 noon, 10 ft ceiling, **indirect workplane illuminance**
Side lighting, conventional window

Dec 21 noon, 10 ft ceiling, direct workplane illuminance

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Side lighting, light shelf

June 21 noon, 12 ft ceiling, direct workplane illuminance

June 21 noon, 12 ft ceiling, indirect workplane illuminance
Top lighting, no light well

June 21 noon, 10 ft ceiling, total workplane illuminance

![Graph showing total workplane illuminance over depth]

- Superlite
- Radiance
- DOE 2
Top lighting, with light well

June 21 noon, 10 ft ceiling, total workplane illuminance
Daylighting error, decision impact

June 21 noon, 10 ft ceiling, total workplane illuminance

DOE-2 compared with Daysim

Source: R. Koti, 2006
Daylighting error, decision impact

June 21 noon, 10 ft ceiling, total workplane illuminance

DOE-2 compared with Daysim

Source: R. Koti, 2006
Title 24 Daylight Control Zones

Title 24 Daylight Control Zones

Zones and daylighting reference points in eQUEST 2-D view

Title 24 control zones in eQUEST 2-D view
eQUEST Parametric Skylights

Optimized Skylight Roof Ratio

DOE-2 LS-M report
Questions?

Source: Overview of Simulation presentation, IBPSA-USA
Daysim 3.0 and looking forward...

Welcome to DAYSIM

Daysim 3.0

Climate-based Daylighting Metrics
Electric Lighting Energy USE

Christoph Reinhart
Daylighting Forum Las Vegas
Daysim ...

- is a validated RADIANCE-based daylighting analysis software
- is available from www.daysim.com since 2001 (Windows and Linux)
- has originally been developed at the Fraunhofer ISE and NRC Canada
- current development at Harvard, Fraunhofer ISE, Penn State
- is open source (custom versions at Transsolar & Arup)
- features a basic JAVA graphical user interface
- calculates climate-based daylight performance metrics

*) Architecture: Pratt & Whitney; Simulation Kalwall

Daysim user forum at http://groups.google.com/group/group/daysim
Validation of dynamic RADIANCE-based daylight simulations for a test office with external blinds

Christoph F. Reinhart*, Oliver Walkenhorst

Solar Building Design Group, Fraunhofer Institute for Solar Energy Systems, Gimmeldinger Straße 5, 79108 Freiburg, Germany

Received 2 August 2000; accepted 2 January 2001
This slide was made in 2001.
Daysim also...

- features an **user behavior model** that predicts occupant use of personal lighting and shading controls
- has been coupled with thermal simulations EnergyPlus, ESP-r, TRNSYS

Daysim Plug-ins for

Rhinoceros

Ecotect

SketchUp
GSD Daylighting Analyzer
Grasshopper/Rhino & Radiance/Daysim

Project: Zollverein Essen
by SANAA

www.gsd.harvard.edu/research/gsdsquare/ABPS.html
New Features in 3.0

- Expected Release Date July 2010
- Annual daylight glare probability profiles.
- New DDS daylight coefficient file format
- Photon mapping integrated
Towards an Holistic Computer-based Analysis of Daylit Spaces

A space that is primarily lit with natural light and that combines a high occupant satisfaction with the visual and thermal environment with low overall energy use for lighting, heating and cooling.

<table>
<thead>
<tr>
<th>Daylight Availability</th>
<th>Visual Comfort</th>
<th>Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occupant behavior and/or automated control systems link the three criteria together.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Joined study with Jan Wienold; Supported by Autodesk and Milton Foundation

Daylight Factor Analysis - Example

Harvard Design School
How to analyze for visual discomfort?

Glare ‘imperceptible’

DGP = 22%

CIE overcast sky
March 21st 3PM

CIE clear sky
March 21st 3PM

Glare ‘intolerable’

DGP = 41%
Discomfort Glare – Annual Analysis

Intolerable glare for 1000 hours per year.
Adding Occupant Behavior

Intolerable glare for zero to 50 hours per year.
Daylight Availability

South Office - No Blinds

active blind use

South Office - Blinds

passive blind use
Daylighting Dashboard

### Daylight Availability
- South Office - No Blinds
- Active blind use
- Passive blind use

### Comfort
- Glare (% of occupied times)
  - Potentially "intolerable" glare
  - Potentially "disturbing" glare
- View (% of occupied times)

### Energy
- Energy end use (kWh/m²-yr)
  - Heat generation (gas)
  - Chiller (electricity)
  - Lighting
  - Office equipment
- Costs ($/m²-yr)
- Carbon emissions (kg/m²-yr)
# Daylighting Dashboard

<table>
<thead>
<tr>
<th>name</th>
<th>daylight</th>
<th>comfort</th>
<th>energy</th>
<th>costs</th>
<th>co₂e</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>autonomy</td>
<td>glare</td>
<td>view</td>
<td>(kWh/m²)</td>
<td>($/m²)</td>
</tr>
<tr>
<td>South Office-Blinds</td>
<td>80</td>
<td>59</td>
<td>50</td>
<td>100</td>
<td>92-102</td>
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<tr>
<td>South Office-No Blinds</td>
<td>18-30</td>
<td>0-1</td>
<td>1-3</td>
<td>0-41</td>
<td>105-114</td>
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<td>Design Option 3...</td>
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<tr>
<td>Design Option 4...</td>
<td></td>
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</tbody>
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**Target Levels**

- **Daylight Availability**: % of space with a daylight autonomy larger than
  - **48 %**
- **Overlit Area**: % of space that is overlit should be smaller than
  - **10 %**
- **Glare**: % of occupied time during which the occupant experiences disturbing/intolerable glare should be smaller than
  - **5 %**
- **View**: % of occupied time when the occupant can look out should be larger than
  - **50 %**
- **Energy**: Overall energy use should be less than
  - **kWh/m²yr**
- **Costs**: Operational Energy costs should be less than
  - **$/m²yr**
- **CO₂e**: Equivalent carbon dioxide emissions should be less than
  - **kg/m²yr**
Executive Education Workshop
Daylighting Buildings

Rhino - Radiation Maps
Ecotect- Daysim
SketchUp/Daysim

July 14 -16 2010
Harvard University
Graduate School of Design

Google: ‘Harvard GSD Executive Education’
Daysim 4.0 (2011)

Panel #3 : Bridging the Gap

Richard Mistrick, Ph.D.
Penn State University

Daylighting Forum 2010
May 14th – 15th 2010
Las Vegas, NV
Daysim 4.0 – General Info

- **Software Status:** In use at Penn State and Harvard. The software will be open-source in early 2011.
- **Analysis** is via the Radiance ray-tracing software using daylight coefficients.
- **Occupancy schedule (by file)** is very flexible.
- **Climate Data**
  - .EPW and .WEA files
  - Time steps can be 5 to 60 minutes.
- **Space Geometry**
  - Arbitrary. All basic Radiance material types are available (including non-Lambertian).
- **Blinds/Shades**
  - 3 different blind/shade configurations can be applied to 2 different window groups.
  - Blind/shade control is via an open-loop sensor, solar profile angle, or both.
Daysim 4.0
Input
Electric Lighting System Integration

- Applies IES photometric data.
- Photosensor-controlled lighting zone is entered, along with non-controlled equipment in additional zones.
- Photosensors are located and analyzed using a directional response data file.
- A critical work plane point is selected for system calibration.
- Current photosensor control algorithms include:
  - Open-loop dimming and switching
  - Closed-loop proportional dimming (sliding set point)
  - Closed-loop integral reset dimming (constant set point)
  - Closed-loop switching
- A single daylight condition is selected for photosensor system calibration. The user then enters control algorithm parameters.
Photosensor Control
Daysim 4.0 Output

- Room *illuminance* at any time, under any blind/shade condition (daylight, electric, or daylight + electric).*
- *Daylight autonomy.*
- *Continuous daylight autonomy.*
- *Useful daylight illuminance.*
- *Annual fraction of time* work plane points meet or fall below target illuminance.*

- Dimming level, power level, or illuminance across the day or week: *optimum performance vs. photosensor control.*
- *Histograms* - illuminance, dimming level. (day, week, month, year).
- Photosensor signal to optimum dimming level *scatter plot.*
- *Monthly and annual energy use* and savings under optimum and photosensor control. *Contour plots*
Pros and Cons

- Flexible (space, occupancy, system layout).
- Space specific.
- Addresses multiple blind conditions.
- Most output is graphical.
- Hourly dimming levels are accessible.
- Some photosensor control system knowledge is necessary. System layout is under user control.
- Considers a single control zone.
- User must calibrate system, which is then compared to optimum control for calibration point.
Next steps in software development

- Customizable control algorithms.
- Multiple control zones within a space.
- Formatted numerical output.
- Additional shade control options (Lightswitch).
- Links to Revit/BIM.
- Additional automation of system layout and calibration processes.
- Integrate latest Radiance enhancements (BSDF’s).
EnergyPlus
Panel #3 : Bridging the Gap

Nicholas Long
National Renewable Energy Laboratory

Daylighting Forum 2010
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Annual Daylighting Simulation Capabilities

- **EnergyPlus**
  - Team consists of several national laboratories, universities, and private developers
  - Released twice a year with new features and fixes
  - Not a user interface, simulation engine only

- **Users**
  - Over 1,500 downloads of Version 5.0 (released 4/26/2010)

- **User Types**
  - Engineers / Architects
  - Third-party software developers
  - Codes and Standards Analysis
  - National Laboratories
  - Universities
  - International
Annual Daylighting Simulation Capabilities

- Time-step driven analysis
- Advanced windows integration (Windows 5/6)
- Two methods for daylighting calculations
  - Simple – split flux
  - DElight – radiosity based
- 2 control sensors per zone (measuring illuminance)
- Illuminance maps with variable gridding (only simple)
- Electrochromic windows, scheduled blinds, controls, and fully integrated analysis with building systems
  - EMS
  - Operable windows and AirFlow network
  - Glare control with window shades
- Uses custom weather format (EPW) generated from NSRDB database (NOAA, NREL, NASA)
  - Calculates illuminance from sky condition, sun position, ground reflectance, and external shading
Annual Daylighting Simulation Capabilities

- Quantifying Annual Daylighting Illuminance
  - Flexible reporting using EMS
  - Common Variables
    - Lighting Energy Use
    - Workplane Illuminance
    - Whole-building energy use

- EnergyPlus fully integrates lighting, HVAC, utility demand
Pros and Cons

● **Pros**
  - “Quick” setup of daylight model
  - Early design impact of daylighting
  - Fully integrated analysis with Envelope, Plugs, Lighting, HVAC, etc.

● **Cons**
  - Development time of whole building model
  - Simplicity in daylight model (e.g. furniture, reflections, sensor options)
  - Simulation Time
Pros and Cons

- EnergyPlus vs Radiance
- Simple Window

EnergyPlus

Radiance
Pros and Cons

● EnergyPlus vs Radiance

● Modeling furniture and clerestory.

EnergyPlus

Radiance
Next steps in software development

- Continued EnergyPlus development
- OpenStudio / Google SketchUp
- HVAC GUI
- Abstraction layer of EnergyPlus analysis engine (open source, cross-platform, strong API)
  - Integration of Radiance output into EnergyPlus input
  - More sensor options
- Codes & Standards Analysis
Next steps in software development

- Web Interfaces & Internet Data Mining
- OpenStudio & Other GUIs
- Pre-processor & Analysis Support Tools

- Input & Visualization Tools
- Abstraction Layer (ZeroKit)
- EnergyPlus / Radiance

Beginners → User Expertise → Experts

Daylighting Forum 2010 Las Vegas, NV
Daylight and Whole-Building Energy Analysis Using Radiance in IES <Virtual Environment>

Panel #3 : Bridging the Gap

Dimitri Contoyannis, PE
Integrated Environmental Solutions, Ltd.

Daylighting Forum 2010
May 14th – 15th 2010
Las Vegas, NV
Annual Daylighting Simulation Capabilities

**Methodology:**

- Radiance (ray-tracing) simulation data is used for annual daylight simulations.
- User places a sensor in each daylit room.
- Radiance illuminance reading is taken at each sensor.
  - Hourly readings taken for a representative day of each month to capture impact of sun position.
  - 3 sky conditions (sunny sky/clear sky/overcast sky) simulated for a representative reading of weather conditions and direct beam and diffuse lux values are recorded.
  - The sensor readings are saved in a data file for review and for use in the annual whole building simulation.
- At time of annual simulation, illuminance values are calculated at each time step by interpolating from data in the weather file.
  - Solar angle variables determine which radiance time/date data to use.
  - Solar irradiance variables (direct/diffuse) determine which sky condition and luminous efficacy to use.
- Illuminance values are used for dimming control at each simulation time step. Customizable/user-defined formula allows for a high level of control. Typical applications include step dimming and proportional dimming. Interaction with blinds can be defined by a similar method.
- Dimming control modulates the electrical energy consumption and lighting gains to the rooms.
- Impact of reduced lighting gains due to daylight dimming will impact heating and cooling system loads and energy consumption.
Calculation of Daylight Illuminance Values for Annual Simulation

Sensor placed in model

Illuminance readings taken at sensor for multiple sky positions and conditions

For the annual simulation, hourly illuminance values are determined from sensor calculations and hourly weather data

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<th>Time</th>
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<th>Diffuse Irradiance (kW/m²)</th>
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</table>
Daylight Sensor Placement Analysis

Sample Zone – 2nd Floor North Wing Open Office Area

**Lighting Controls Design Criteria:**
- **Illuminance Target:** 50 Ft-c
- **% of Lamps Controlled:** 100%

**Radiance Images Generated:**
- **Times of year:** September 21, June 21, Dec 21
- **Times of day:** 9am, 12pm, 3pm
- **Sky conditions:** Overcast, Clear, Cloudy
- **View:** Plan View, Working Plane Level
  (30” above floor to represent typical desk height)

**Sensor Location Analysis:**
The room experiences an even lighting distribution throughout the year. Therefore, we conclude that 100% of the lights should be dimmable. The sensor is located near the center of the room.

**Daylight Design Features:**
- **Louvered sun shades on South facade**
- **High-level clerestory on North facade**

**Illuminance (ft-c) at working plane (plan view) – Sep 21, 9am, overcast**
Daylight Sensor Placement Analysis

2nd Floor North Wing Open Office Area – Detailed Radiance Results

Illuminance (ft-c) at working plane level (plan view)

Sep 21, 9am, overcast
Sep 21, 12pm, overcast
Sep 21, 3pm, overcast
Dec 21, 9am, overcast
Dec 21, 12pm, overcast
Dec 21, 3pm, overcast

June 21, 9am, overcast
June 21, 12pm, overcast
June 21, 3pm, overcast

Sep 21, 12pm, overcast – 2.6% area < 20 FC
Jun 21, 12pm, overcast – 1.0% area < 20 FC
Dec 21, 12pm, overcast – 14.4% area < 20 FC
Model Setup Overview

Lighting Control Strategies Setup

Daylight Dimming:
For Spaces with daylight dimming, a dimming profile is applied to the lighting controls. Lighting gains to the space and lighting power consumption are reduced when adequate daylight levels are available. Daylight levels are determined by a sensor in the space which takes readings from Radiance illuminance calculation, and weather data.

Two dimming strategies have been modeled – proportional dimming and step dimming. Sensor placement is determined by performing initial Radiance simulations to find appropriate location. Lighting design calls for 50 foot-candles.

<table>
<thead>
<tr>
<th>No Dimming</th>
<th>Step Dimming</th>
<th>Continuous Dimming</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Building schedules are modelled using default schedules from ASHRAE 90.1 User’s Manual, Table G-I – Office Occupancy</td>
<td>• 3-Lamp Fixtures</td>
<td>• Ballast allows lighting to be reduced down to 15% energy consumption</td>
</tr>
<tr>
<td></td>
<td>• Last “step” does NOT turn off</td>
<td>• % of lighting controlled is determined per zone from initial Radiance sims</td>
</tr>
</tbody>
</table>
Daylight – Impact on Building Performance

Sample Zone – 2nd Floor North Wing Open Office Area

Lighting Gains (Btu/hr)

Cooling Loads (Btu/hr)
(Greater negative values indicate greater cooling loads)

Daylight Reading (ft-c)

Date: Wed 23 Jun

Lighting gain: sp-239-NORTH_WING_OPEN_OFFICE_AREA (ifaw_step_dimming_v1.aps)
Lighting gain: sp-239-NORTH_WING_OPEN_OFFICE_AREA (ifaw_prop_dimming_v1.aps)
Lighting gain: sp-239-NORTH_WING_OPEN_OFFICE_AREA (ifaw_no_dimming_v1.aps)
Daylight illuminance 1: sp-239-NORTH_WING_OPEN_OFFICE_AREA (ifaw_step_dimming_v1.aps)
Daylight illuminance 1: sp-239-NORTH_WING_OPEN_OFFICE_AREA (ifaw_prop_dimming_v1.aps)
Daylight illuminance 1: sp-239-NORTH_WING_OPEN_OFFICE_AREA (ifaw_no_dimming_v1.aps)
Space conditioning sensible: sp-239-NORTH_WING_OPEN_OFFICEAREA (ifaw_step_dimming_v1.aps)
Space conditioning sensible: sp-239-NORTH_WING_OPEN_OFFICE AREA (ifaw_prop_dimming_v1.aps)
Space conditioning sensible: sp-239-NORTH_WING_OPEN_OFFICE_AREA (ifaw_no_dimming_v1.aps)
Approach for Operable Blinds

**Formula Profiles:**
As with daylight dimming, modulation of lighting energy and gains to the space are specified by a formula profile.

**Step Dimming Profile:**

\[
\text{if}(e1 > \frac{2}{3} \text{ ill target}), [\text{power output at } \frac{2}{3} \text{ ill target}], \text{if}(e1 > \frac{1}{3} \text{ ill target}), [\text{power output at } \frac{1}{3} \text{ ill target}], 1))
\]

**Proportional Dimming Profile:**

\[
\text{ramp}(e1,0,1, [\text{ill target}*(1–\text{min turndown})], [\text{power output at min turndown}])
\]

**Dimming Profile with Operable Blinds:**

**Questions:**
When to assume the blinds are closed? (assume 80 ft-c for this example)
How much light do the blinds allow to pass (transmittance)? (assume 50% for this example)

Modifiers applied to appropriate dimming control profile (assume proportional dimming profile for this example)

\[
\text{if}(e1 > 80, \text{ramp}(e1*[\text{transmittance}],0,1, [\text{ill target}*(1-\text{min turndown})]), [\text{power output at min turndown}]), \text{ramp } (e1, 0,1, [\text{ill target}*(1-\text{min turndown})], [\text{power output at min turndown}]))
\]
Daylight – Impact on Building Performance

Sample Zone – 2nd Floor North Wing Open Office Area

Lighting Gains (Etu/hr)
- Proportional Dimming (no shading)
- Proportional Dimming (add’l gain when blinds closed)

Daylight Reading (ft-c)
Daylight – Impact on Building Performance

Sample Zone – 2nd Floor North Wing Open Office Area

Solar Gains (Btu/hr)
- No operable shades
- With operable shades

Lighting Gains (Btu/hr)
(see prev. slide for enlarged view)

Cooling Loads (Btu/hr)
(Greater negative values indicate greater cooling loads)
- With operable shades & prop dimming
- No operable shades & prop dimming

Daylight Reading (ft-c)
Closing Remarks:

•Pros and Cons of Methodology
•Software Development
Daylight Simulation Technologies in Autodesk Products
Panel #3 : Bridging the Gap

Pierre-Felix Breton
Autodesk

Daylighting Forum 2010
May 14th – 15th 2010
Las Vegas, NV
Revit MEP
Ecotect
BIM + Analysis
Considering Many Aspects of Performance

- Solar Position
- Overshadowing
- Shading Design
- Envelope Design
- Shading Optimization
- Solar Availability
- Incident Radiation
- Daylight Analysis
- Acoustic Design
- Rights-to-Light
- Visual Impact
- Whole Building Energy
Revit MEP
Key Analysis Features

- Shadow Studies
- Load Calculations
- Artificial Lighting Calculations (Zonal Cavity Method)
- gbXML / Analytical model export
- Ecotect interoperability
- 3ds Max interoperability
Ecotect	
Key Analysis
Features

- Shadow Studies
- Load Calculation
- Daylight Factors / Insolation
- Acoustical Simulation
- gbXML / Analytical model import
3ds Max Design
Pretty Pictures & Analysis
Winter Solstice (fc) 13:00
3ds Max Design
Daylight Simulation Validation

CNRC Lab

National Research Council Canada

DAYSIM version 2.0
Indoor Sensors
Outdoor Light Sensors
Windows and blinds configurations
Results: Outdoor Sensors

FG Diffuse Bounces: 6
FG Density: 1.0
Rays Per FG Point: 2500
Interpolate over Num. Points: 5

Total Render Time: 78.336 seconds

Current Simulation  | Benchmark Data  | Radiance Data  | Max Illuminance: 65000  | TC0 Outside Sensor  | Outside Sensor  | May 17, 2007
Results: Indoor Sensors
No Shading Device
Results: Indoor Sensors
Light Shelf
Results: Indoor Sensors
Translucent Glazing
3ds Max Design
Real-Time Graphics
3ds Max Design
Key Analysis
Features

- Rich Interop with Revit and AutoCAD
- Daylighting and Artificial Lighting
- Object and Parameter Animation
- Real Time Viewport Capabilities
- Multicore Processing
3ds Max Design Key Analysis Features

- Light Meter Object
- Image Overlay Light Metering
- Export Light Levels to CSV files
- Presentation and Analysis Reports Combined
- CIE Sky model
- Perez All Weather Sky Model
- Weather Data Support
- Fully Scriptable
3ds Max Design
Key Features

- Light Meter Object
- Image Overlay Light Metering
- Export Light Levels to CSV files
- Presentation and Analysis Reports Combined
- CIE Sky model
- Perez All Weather Sky Model
- Weather Data Support
- Fully Scriptable
3ds Max Design Limitations / Downsides

- No out of the box statistical analysis functionality
- Not an optical simulator
- User interface complexity
Panel 4: 
Next Steps for Programs and Codes  

Daylighting Forum, May 14, 2010 
Springs Preserve, Las Vegas  

Lisa Heschong 
Heschong Mahone Group 
Gold River, Ca 
www.h-m-g.com
Problem Statement:

“In order to establish requirements for daylit buildings, there needs to be a performance standard that ensures that occupants’ needs for visual comfort will be met that allows designs to be optimized for the most energy efficient means to deliver that comfort”
Consistently heard comments:

- **We need to talk like this more often**
  - resolve issues, build consensus
    - Convene forum every 12-18 months?
    - DOE to take the lead?

- **We have to make analysis simpler**
  - so designers can get meaningful answers
    - Accurate, fast, user-friendly tools
    - Libraries of product performance data
    - Agreed upon default values
    - Optimization of design strategies
Key Players – each has a role

- researchers
  - university
  - national labs
  - private
- software developers
  - energy analysis
  - lighting analysis
  - daylight analysis
- manufacturers
  - blinds & attachments
  - skylights
  - windows
  - lighting controls
- efficiency program managers
  - utilities & NGOs
  - state and federal
- code and standards
  - ASHRAE & IES & IECC
  - LEED, CHPS, IgCC
  - NFRC
  - CEC & other states
- designers and engineers
  - lighting designers
  - architects
  - energy consultants
California Utility Efficiency Programs

Basic structure:

- **Emerging Technology (demonstration) Programs**
  - Product evaluation
    - field tests to assess performance
    - evaluate user acceptance
    - feedback for further product development
  - Tools and advanced practices
    - to support adoption of new design methods

- **Efficiency (incentive) Programs**
  - accelerate adoption of new measures
    - increase market share for efficiency measures
    - help to drive down costs
  - market transformation
    - build experience with new methods
California Utility Efficiency Programs
What is needed to support them?

- **Emerging Technology (demonstration) Programs**
  - Product evaluation
    - monitor energy savings of advanced daylighting products
    - user acceptance of new systems
    - feedback for product refinement and positioning
  - Tools and advanced practices
    - support development of professional grade tools

- **Efficiency (incentive) Programs**
  - accelerate adoption of new measures
    - incentives based on energy savings of advanced systems
  - market transformation
    - professional education
Wish List for Building Design Team:

- Architects
  - use simulation tools to optimize performance
- Lighting designers
  - trust daylight – learn where the sun is...
- Mechanical engineers
  - learn about visual quality!
Wish List for Software Developers

- **Lighting Analysis Tools** (space level)
  - use annual, climate-based simulations
  - enable hourly blinds operation
  - incorporate complex optical performance data

- **Energy Analysis Tools** (building level)
  - support easy import/export to lighting tools
  - coordinate fenestration controls
  - coordinate lighting controls
Wish List for Manufacturers:

- Blinds are ubiquitous
  - make “daylight optimized” blinds
- Provide more fenestration performance
  - light, view, air, thermal comfort, and low maintenance, and fashion, and …
- Provide light distribution data
  - industry wide standard format reports
  - ease of import into simulation software
Wish List for NFRC:

- Develop testing and reporting standards for daylighting products
  - public libraries of product performance data
    - enable evaluation of system level performance
    - multi-angle, 3D light distribution
  - default values for generic products
    - to be used in professional grade analysis tools
- Rating systems can come much later…
  - and are least important
Wish list for IES:

- Advocate for visual comfort research
  - set research agenda for daylight perception
  - understand physiology
    - understand glare
    - understand view
    - understand circadian needs
  - create predictive models
- Coordinate visual comfort recommendations with other bodies
  - AIA, ASHRAE, NFRC, etc.
Wish List for Codes and Standards Bodies:

- Progress towards shared language and methodology
  - Agree on “evidence based” standards
    - as opposed to political (power-based) process
  - OK to set different criteria based on goals and market
- Daylighting recognized as primary, no longer falls between stools
  - resolve issues between lighting and envelope committees
  - consider all inputs:
    - view, lighting preferences, controls operation, and thermal impacts
A Code Analysis Hierarchy

Determine Needs
Meet Needs & Minimize Loads
Meet Loads as Efficiently as Possible
Daylighting Program Development Diagram
Daylighting Program Development Diagram

- Can we refine this diagram?
  - Simpler is better....

- Can we fill in the needed actions?
  - Can we identify the key players?
    - Yes...many of them were here today!

- Can we accelerate the schedule?
  - Can we identify the funding sources?
    - LBNL has $16-18 million...
  - Can we agree on the basic formats?
  - Can we agree on the necessary research agenda?
Delight + Efficiency
Panel #4: Accelerating daylight as a light source for net zero buildings

Matthew Tanteri
Tanteri & Associates
School of Constructed Environments, Parsons New School of Design
IALD Educator

Kevin Van Den Wymelenberg
University of Idaho – Integrated Design Lab

Daylighting Forum 2010
May 14th – 15th 2010
Las Vegas, NV
Building Net Zero

“The Confusion of Tongues” by Gustave Doré, 1865
Teaching daylighting

Are these the basics of daylighting?

- Speed
- Accuracy
- Cost

- Adoptable
- Usable
- Enforceable
Teaching daylighting

Or is it more about the subjective?

“the handling of forms, the meaning of a room, have to relate to daylight”

– Richard Kelly
Physical Modeling

Outdoor Scale Model Testing on the East Coast
Studio 2, S09, SCE Parsons New School, Instructor: M. Tanteri

Outdoor Scale Model Testing on the West Coast
DES 137A, S08, UC Davis  Instructor: K. Papamichael
Physical Modeling

Model by Young Hee Min and Jie Soo Tchah, Studio 2, S07, SCE Parsons New School, Photo by M. Tanteri
Tools and Methods

EQUIDISTANT PROJECTION EXERCISE SEQUENCE

Daylighting Forum 2010    Las Vegas, NV
Simulation

Radiance

Synthetic Imaging System
Daylighting ‘delight’

University of Washington, Research Assistant Professor Chris Meek

Daylighting Forum 2010     Las Vegas, NV
Daylighting ‘delight’

University of Washington, Research Assistant Professor Chris Meek

Daylighting Forum 2010     Las Vegas, NV
Daylighting ‘delight’

University of Washington, Research Assistant Professor Chris Meek
Daylighting ‘delight + efficiency’

© Chris Meek & Kevin Van Den Wymelenberg

Daylighting Forum 2010     Las Vegas, NV
Daylighting ‘delight + efficiency’

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Daylighting Forum 2010     Las Vegas, NV
‘delight + efficiency’

• **Educational Needs**
  * Visual teaching methods
  * Integration of academia + practice + industry
  * Demonstration facilities
Pattern 4: Glass Area Ratios
Fenestration Patterns from 2+ Sides

Overview

Successful daylight from the side begins with maintaining a relationship between window head height and section depth. Generally speaking, the effective distance of daylight penetration is roughly two times the head height of the perimeter window. In buildings with traditional floor to ceiling heights (~10') this translates to about 20'-0' of section depth. It should be noted that the configuration and size of interior furnishings, and the presence and use patterns of blinds may substantially reduce this distance.

Once an interior section depth exceeds 25'-0' the contrast between perimeter zone and core of the building begins to increase substantially during daylight hours. Since the human eye tends to adjust to the brightest location within a space this can cause the perception of darkness in the interior section, and glare due to the lack of luminous uniformity across the section.

There are two primary strategies to address this condition. First, section depths can be kept narrow to ensure both daylight performance and relative uniformity. Alternatively, a second (or multiple) source of daylight can be added to provide supplemental illumination. In this case additional sources are provided in the form of daylight apertures on multiple sidewalls.

Our case study example is the 2 Rector Street building in New York City, designed by the Xxoo. This pattern sequence highlights simulations under survey sky conditions during September at noon with workspace illumination data represented in Lux. Other daylight performance metrics are included in the appendix. Typical office lighting criteria range from 300-400 Lux and 300 Lux was selected as one of the daylighting design criteria examined herein. The percentage of floor area above or below this value is presented for each permutation.
Pattern 4-2.2: 30% Glass Area (1 Side)

These data illustrate debilitating glare from three perimeter windows comprising 30% of the wall area on the end wall. The daylight zone is restricted to the area within the first 15-20 ft from the windows and the majority of the open office space is subject to glare. In a space such as this, blinds would be drawn closed to reduce glare, even on these north-facing windows, much of the time. Approximately XXX% of the floor area meets the targeted lighting criteria from daylight alone.
Pattern 4-5.2: 30% Glass Area (2 Sides)

Windows comprising 30% of the wall area on of the long walls (in addition to the end wall) dramatically reduces the perception of glare experienced. Providing daylight from two directions is an important strategy to create spaces with both functional daylight illumination and with lower contrast. Here, the light from the windows on the long wall can be seen illuminating the third wall opposite. Approximately XXX% of the floor area meets the targeted lighting criteria from daylight alone.

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Pattern 4-7.2: 30\% Glass Area (3 Sides)

Windows comprising 30\% of the wall area are utilized on all three major walls (N, E, W) within this space. Contrast is reduced because there is light from three sides and walls are painted white to increase interreflection. Furthermore, deep window reveals, orientation and building self-shading (atrium at east) serve to minimize direct sun penetration. Approximately XXX\% of the floor area meets the targeted lighting criteria from daylight alone.

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- **Human Factors Research Needs**
  - What daylight luminance patterns are preferred, accepted and refused?
  - How do people interact with manual and automated blinds?
  - How does view quantity and quality modulate daylight luminance acceptance, preference and blind use?
  - Others: circadian, fatigue, stress, pain, performance, productivity, well-being…
<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Strongly Agree</th>
<th>Strongly Agree</th>
<th>Strongly Agree</th>
<th>Strongly Agree</th>
<th>Strongly Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using the blinds, I was able to create a visually comfortable environment for computer work.</td>
<td>I am pleased with the visual appearance of the office</td>
<td>I like the vertical surface brightness</td>
<td>I am satisfied with the amount of light for computer work</td>
<td>I am satisfied with the amount of light for paper based reading work</td>
<td>The computer screen is legible and does not have reflections</td>
<td>The lighting is distributed well</td>
</tr>
</tbody>
</table>

7 - preferred

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Daylighting Forum 2010  Las Vegas, NV
7 – just disturbing

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● “do these code folks ‘get it’?” – David Cohan
● “be careful that daylight is not legislated out of our buildings” – Chalres Eley
● “plan for the future!” – Steve Selkowitz
● “the future of green buildings is high density urban developments…” – Jack Bailey
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- “let’s differentiate VT & SHGC by façade - Lisa Heshcong
- “Yes! Let’s do it!” – Mark Frankle
- “Hey IES - get Involved!” – Michael Lane
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- “the logical conclusion of efficiency is windowless buildings” – Prasad Vaidya
- “building codes are about minimum quality standards, energy codes are about efficiency” – John Hogan
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- “what is role of daylight in a 0.3 w/sf LPD future?” – Eleanor Lee
- Energy is driving the equation.
- We need to make new friends!
  - CDC, NIH, NIOSH
- IES DMsC Sufficiency Metric is a QUALITY metric.
The Manufacturer’s Perspective

Panel 4: Next Steps – Accelerating Daylight as a Light Source

Amy Keller, MIES, Principal
Kalwall Corporation

Neill Digert, Ph.D., MIES
Solatube International, Inc.

Daylighting Forum 2010
May 14th – 15th 2010
Las Vegas, NV
Current State of the Industry

- A Case of Apples and Oranges
  - Competing Codes
  - Competing Design Standards
  - Lack of Technology Understanding
  - Difficulty in Comparing and Choosing Between Product Options
  - Non-uniform Test Standards
Accelerating Daylight – Manufacturer’s Perspective

- Factors Influencing Product Adoption, Application, and Innovation
  - Research & Education
    - Manufacturers must educate customers on the behavior of light within a space
    - Uncertainty about what is “desired” goal. Need more research to quantify...
  - Design: Modeling and Simulation
    - Software now enables us to show effect of different product options in design phase!
Factors Influencing Product Adoption & Application

● Codes & Standards
  ● Lighting is complicated: IES central to standards development
    ● Multifaceted / Multidisciplinary
  ● Level playing field, need consistent performance standards, must avoid value engineering out daylight!

● Testing and Compliance

● Incentive Programs
  ● Reward use of highest performance technologies
  ● Cash for clunkers, Washing machines, replacement of windows and furnaces
Current Status

● Competing Codes & Standards Cause Confusion in the Market
  ● Competing Directives to Code Officials and Designers
  ● Unclear Goals for Product Performance

● Oversimplification of Codes Hinders Product Innovation
  ● WWR, VLT, SHGC, Sun Penetration, Contrast Ratios, Uninformed Aperture Area Requirements for Toplighting Systems, etc..
  ● Simplified, Prescriptive Code Language Disadvantages Product Innovation
Modeling & Simulation

● Current Status
  ● Many Modeling and Simulation Options:
    ● Energy
    ● Lighting
    ● Visualization
  ● Lack of uniform simulation parameters
  ● Not enough skilled modeling technicians! Expertise resides in specialty firms, not quick and dirty for design phase. Or seen as too much $$$
Next Steps

- Consult with Industry Organizations (Lighting and Research) for Uniform/Consistent Language Development
- IES as “the Lighting Authority” must be central!
- IES is the technical resource for lighting issues
  - Watch the science of Light and Health….
  - Remember the PEOPLE inside of the buildings!
Next Steps (Cont’d.)

- **Testing & Compliance**
  - Adopt Global Standards for Product Testing and Compliance
    - But this must first be informed by further lighting research and performance metrics. Do not rush into this too quickly!
  - Develop Test Protocols and Standards that Embrace New Technology and which Accurately Evaluate Existing Technology
    - Complex fenestration databases
    - Validated materials libraries for accurate simulation
Conclusions

● Develop and Apply Informed, and Integrated Code Language (Energy, Envelope, Lighting, Sustainable Practices)
  • Implement Biannual Daylighting Forum Meetings (LIGHTFAIR / Greenbuild)
  • DOE Needs to Support Long-term Vision and Research Support

● Deploy Codes that Encourage adoption of best technologies and design solutions

● Product Performance Requirements will Drive Innovation from Manufacturers. Offer competitive solutions or lose sales
• **Doug Mahone:**
  - one more endemic problem: daylighting myopia. the problem is defined by where you are from, city type where you live and work. we need to recognize broader range of problems, range or products, etc.

• **Owen Howlett:**
  - understand how occupant lighting preferences will drive energy use, for task lighting, blinds operation, etc. WE need more data on behavior actions, and visual cues that drive those actions, the better we can model performrance
• **Mark Frankel:**
  
  Codes are just the backstop. becoming a juggernaut. the design community needs to get out ahead. daylighting has most promise, but needs better info

• **Jim Edelson**
  
  2015 is wide open. those codes could be drivers. you all need to join in crafting those codes
• **Charel Knuffke**
  - “Daylighting is the architect’s opportunity to communicate with God.”
  - make sure you consider human performance, far more valuable than energy
  - Likes that Title 24 offers a carrot, with power adjustment factors. could be adopted by other codes

• **Nicholas Roy**
  - Beware of Sick Building Syndrom. We need to diligently avoid recreating problems

• **John Hogan**
  - Designers not paying enough attention, thus causing problems. It is a lot for them to deal with.
Fred Oberkircher:
- Daylighting needs to become equal partner, with a team influencing design, instead of architect at top of hierarchy of design. All orgs need to promote integrated design

Bill Worthen
- Yes, mission of sustainability requires team effort. Engineers have enabled architects to do whatever architects have wanted to do. Only limits have been “I don’t know how to model it”
- I need help communicating that design is an art to code officials.
• **Nancy Clanton:**
  - what if we started over with codes? get away from power restrictions, and instead based them on energy use? We need better information to do this.

• **Randall Higa**
  - Code officials have strong preference for LPDs for lighting. So, why not do the same thing for HAVC? i.e. tons/sf, then add power adjustment factors in for economizers. But statistically don’t work, so will only get 10% credit...
    - We have a mismatch with how we regulate lighting v HVAC. How to get past that?
    - We will need way to easily verify lighting designs based on energy instead of connected loads
● Jim Benya
  ● the performance method is an energy budget method. New idea is to recognize dynamics of lighting energy use better for prescriptive measures. Code officials demand simple metrics, since they don’t have the manpower to enforce.

● Matt Tanteri
  ● There seems to be a consensus from this meeting that simulation is the path forward. And that performance path should be based on energy use intensity.
  ● If we just control daylight with a quality metric, then we have the two forces.
  ● Need to overlay prescriptive formulas onto simulation output to refine the prescriptive methods. (We do need the prescriptive paths for now....)
  ● The problem right now is the metrics are coming after the codes.
• Ross McCluney
  • completely insufficient knowledge among general public about glare. suggests IES takes on a public education campaign

• Prasad Vaidya
  • Problem: performance method does not allow you to use operable shades for any of your compliance runs

• Michael Lane
  • Suggesting moving towards kWh/sf as std. 90.1 code goal. Lighting committee is trying....

• Fred Oberkircher
  • IES has new process: has posted two position papers in past year. We are taking a more active role. I will suggest that IES write a position paper on daylighting
● **Todd Reed**
  - provide more occupant education on glare and visual quality

● **Charles Eley**
  - all designers can do is produce a building that is capable of sustainability. therefore occupant training is critical to achieve potential.
  - consider asset rating and operational ratings (benchmarking)
  - As we move towards lower energy use, it is inevitable that standards will have to become more complex. More stringent goals mean codes will have to be more context sensitive, not simpler.
● **Davidson Norris**

  - don’t just focus on the building. Inner: The interior design is also critical.
  - also can’t control what is around us. Outer: We need solar access as a part of zoning controls. Another building can destroy an owner’s investment. Very real issue in dense urban environments, especially for solar redirection

● **Steve Selkowitz**

  - We won’t get to zero energy buildings with codes. Codes don’t push towards optimized design.
  - How to close the loop so that occupant operation is reported. Design teams and owners could sign a document promising to fix a building if it does not meet energy codes. Someone has to be held RESPONSIBLE for the energy performance of buildings.
● Fred Oberkircher
  ● I will pass information onto IES committees

● Christoph Reinhart
  ● I will teach all Harvard Students how to do climate based design analysis

● David Cohan
  ● ACEEE paper request. folks from NW are working on an outcome based code. City of Seattle will pilot. Building code officials have no access to building performance data to enforce a code. That is a huge structural problem.

● John Mardaljevic
  ● Old DF approach has “infected” our thinking about daylight
● Harvey Bryan
  ● We are not going to building a lot of new buildings. There may be major “re-cladding” of existing. Need approaches to help that market

● Richard Wilson
  ● Mfgr of “shading projects”, which have a poor relationship to the design of the project. Be sure that you are not being forced down to cheapest product.

● Nancy Clanton
  ● Existing building have not been discussed much here. Should have to supply your energy data yearly so can flag problems, then start to fix them.
  ● LEED is considering asking for survey data form occupants to get feedback loop on how buildings are performing for the occupants
• Keith Yancey
  • Higher energy costs would help drive the equation

• Nicholas Roy
  • Will be another Velux symposium soon