COMFEN
A Commercial Fenestration/ Façade Design Tool

Stephen Selkowitz
Head, Building Technologies Dept, LBNL

Rob Hitchcock, Robin Mitchell, Mehry Yazdanian
Lawrence Berkeley National Laboratory
Charlie Huizenga
CBE – University of California Berkeley
Background and Context

• Role of Fenestration in Building Energy Use
• Residential
  – Book
  – Efficient Window Collaborative website www.efficientwindows.org
  – Tool: RESFEN (DOE2 with a 2 screen interface)
• Commercial
  – Similar suite of tools
  – Different users- professionals
  – More complex alternatives
  – New concerns to optimize energy performance
  – Energy plus Daylight, View, Comfort, Task Visibility, …….
• New Interest, New Drivers
  – Global Warming, Carbon, Zero Energy Buildings
  – Highly Glazed Buildings
Optimizing Energy in Integrated Facades

- **Ideal**: Integrated approach to façade-lighting-HVAC building systems to achieve optimum energy-efficiency and comfort.

  - Climate
  - Orientation
  - Building Type
  - Fenestration area
  - Glass type
  - Operations
  - Daylight
  - Shading
  - ……

Slopes vary depending on efficiency of lighting and HVAC systems

- Energy Use
- Increased lighting energy use and heat gains
- Minimum energy use
- Increased solar heat gains

- Energy
- Demand
- Carbon
- Peak Cooling
- Comfort: visual/thermal
- View
- Appearance
Solar versus daylighting trade-offs


Figure 9. Thresholds for various window sizes as a function of shading coefficient and visible transmittance. The threshold is defined as the combination of values of window-to-wall ratio, shading coefficient, and visible transmittance that yields net zero incremental electricity. Glazing efficacy (Ke) and solar (SC*WWR) and effective aperture (Tvis*WWR) values of the five sample glazings used in our analysis are shown.
Optimizing Fenestration/Facade Design

- Complex tradeoffs between:
  - Cooling and daylighting; peak cooling
  - Energy and comfort, amenity, architectural “style”
- Optimum solutions dependent on:
  - Building type (loads)
  - Climate
  - Orientation
- Many choices for fenestration design and glazing/shading technologies; increasing complexity of solutions, e.g. blinds, light shelves; more dynamic solutions
- Designs evolve from concept phase to construction; limited ability to assess and then “re-assess” impact of design changes
- Designers opting for “more glazing”- load impacts will be greater
- Commercial book and web site provide basic information resources but not project-specific solutions, which is what designers need
Commercial Window Website

Windows for High Performance Commercial Buildings

Windows Systems for High-Performance Buildings

This web site provides information on windows for high-performance commercial buildings. It includes design issues, materials and assemblies, window design decisions, and case studies.

This web site is sponsored by the U.S. Department of Energy's Windows and Glazings Program.

A sustainable design process is intended to produce high-performance buildings that are energy-efficient, healthy, economical in the long run, and use resources wisely to minimize the impact on the environment. Properly designed windows play an important role in achieving these energy and environmental goals and contribute to the comfort, satisfaction, and productivity of building occupants as well.

The challenge in designing facades and selecting windows in commercial buildings is balancing many issues and criteria. This fact-packed guide provides critical information and performance data on the energy efficiency, interior environment, and technical considerations that drive window design decisions.

Authors: John Carmody, Stephen Sekowitz, Eleanor S. Lee, Darush Arasteh and Todd Wilmert

January 2004 / 400 Pages
Available from Norton Professional Books. Single copy price: $50.00 USA; volume discounts available from publisher.

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This site was developed jointly by the University of Minnesota and Lawrence Berkeley National Laboratory.
Facade Design Tool: Compare Performance Options in Los Angeles, California

Case 1
- Orientation: South
- Window Area: WWR=0.15
- Daylight Controls: No
- Interior Shades: No
- Exterior Shades: None
- Window: Clear (2)

Case 2
- Orientation: South
- Window Area: WWR=0.30
- Daylight Controls: No
- Interior Shades: No
- Exterior Shades: None
- Window: Low-E Clear (2)

Case 3
- Orientation: South
- Window Area: WWR=0.45
- Daylight Controls: Yes
- Interior Shades: No
- Exterior Shades: Overhang 1
- Window: Low-E Clear (2)

Case 4
- Orientation: South
- Window Area: WWR=0.60
- Daylight Controls: Yes
- Interior Shades: Yes
- Exterior Shades: Overhang 2
- Window: 2 Low-E Clear (4)

Run Comparison  Clear
4 Modes: Analyze, Compare, Find, Optimize

http://www.commercialwindows.umn.edu/
COMFEN: Project Goals

- Easy-to-use tool providing **design guidance** on commercial building glazing and façade options
- Early design but ability to drill deeper
  - **Interactive Tradeoffs:** Energy Consumption, Demand, Visual and Thermal Comfort, CO₂ Emissions
  - Underlying Sophisticated Annual Simulation
  - Focused Input: glazing/façade, location, orientation, and daylighting options for **comparative cases**
  - **Easily Interpreted Output:** primary end-use energy consumption, peak demand, CO₂ emissions, daylight illuminance, visual glare, thermal comfort; annual, monthly, hourly (illuminance)
COMFEN Differentiation

• Other similar tools exist
  – e.g., EFEN, SPOT, Daylight 1-2-3, MIT Design Advisor
• COMFEN differentiation
  – Link to broad “knowledge base” - website and book, case studies
  – Link to field test data
  – Focused access to a rich set of façade design variables
    • Full set of performance parameters: e.g. energy, peak, comfort, ….
    • Concept <-- detailed design
    • EnergyPlus engine
    • Radiance Daylighting engine
  – Comparative analysis based on a “room” module
  – Limit non-façade variables (e.g., HVAC system)
  – Target specific tool audiences (e.g., Architect, Glazing Manufacturer, Engineer, Owner)
COMFEN: Version 1.0 Objectives

• Façade Analysis Tool
  – Up to four comparative façade cases
  – Multiple glazing and exterior shading options on each façade
  – EnergyPlus V2.0 simulation engine
  – Graphical Output
    • Energy Consumption (Heating/Cooling/Fans/Lighting)
    • Peak Demand
    • CO₂ Emissions
    • Daylighting Illuminance
    • Visual and Thermal Comfort Indices

• Excel Development Platform
  – Familiar user environment
  – Rapid prototyping

• Public release of COMFEN V1.0 October 2007
  – windows.lbl.gov/software/comfen/1
COMFEN Current and Future Work

• Collect user feedback regarding V1.0 Release
  – windows.lbl.gov/software/comfen/1/COMFENSurvey.asp

• Develop comprehensive development plan for future
  – Extend fenestration input and analysis options
    • More glazing systems, frame types, shading options
    • Lighting and shading control options
    • Optically complex fenestration systems
  – Increased flexibility for user input (exploring existing tools such as Google SketchUp)
  – Tailored output for targeted audiences (e.g., architects, glazing manufacturer representatives, etc.)
  – Methods to carry-forward façade designs to detailed design phase
  – Plan for incremental development over time

• Enhanced COMFEN release FY08
Glazing, Frame, Shading Enhancements

• Future methods for user-defined glazing systems
  – Select material layers from IGDB to create desired system
  – Auto input to EnergyPlus using full spectral data sets
  – Optically complex glazing systems (when available in EnergyPlus)

• Additional frame types
  – Including highly insulated frames

• Variety of shading options
  – Venetian blinds, translucent shades, bug screens, switchable glazing
  – Inside, outside, or between glass layers
  – Shading control options
    • interior daylight illuminance levels
    • glare
    • block beam solar
    • etc.
Using COMFEN v1.0

- Two worksheets: Façade Library and Project
- Step 1. Define Façade Library Entries
  - Define simple zone geometry and internal loads
  - Define façade windows, glazing system, frame type
  - Add overhangs and fins
- Step 2. Select Project Façade Options
  - Select location
  - Select up to four façade modules
    - Facade
    - Orientation
    - Daylighting control option
- Step 3. Run Analysis
- Step 4. View Comparative Results
Façade Library – Define Module

Windows for High Performance Commercial Buildings

FAÇADE LIBRARY

Project

Room Information

Façade Design Name

Double Clear - Transom

Geometry

<table>
<thead>
<tr>
<th>Width</th>
<th>Depth</th>
<th>Height</th>
<th>Room Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>20</td>
<td>10</td>
<td>400</td>
</tr>
</tbody>
</table>

Loads

- Lighting: 1.2% Wf/floor
- Equipment: 0.75 Wf/floor
Façade Library – Define Windows

### Overhangs

<table>
<thead>
<tr>
<th>Window</th>
<th>Hgt above</th>
<th>Dist From</th>
<th>Length</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor (D)</td>
<td>Left Wall &quot;C&quot; (A)</td>
<td>(feet)</td>
<td>(feet)</td>
<td>(feet)</td>
</tr>
<tr>
<td>1</td>
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### Left Fin

<table>
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<td>(feet)</td>
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### Right Fin

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<td>(feet)</td>
<td>(feet)</td>
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### Dimensions

<table>
<thead>
<tr>
<th>Window</th>
<th>Sill Height</th>
<th>Left Wall</th>
<th>Height</th>
<th>Width</th>
<th>Area (TQ)</th>
<th>Glazing System</th>
<th>Frame Type</th>
<th>Frame Width</th>
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<tbody>
<tr>
<td>1</td>
<td>30</td>
<td>30</td>
<td>5</td>
<td>2</td>
<td>6</td>
<td>DoubleSpecLowE Tint (F)</td>
<td>Aluminum w/Thermal Break</td>
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<td>30</td>
<td>30</td>
<td>5</td>
<td>2</td>
<td>6</td>
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<td>30</td>
<td>30</td>
<td>5</td>
<td>2</td>
<td>6</td>
<td></td>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>

*All windows have same glazing system and frame type as Window 1.*

Note: Maximum of 4 windows per façade.
Façade Library – Add Overhangs
Façade Library – Add Fins

Façade Layout

Elevation

Section

Overhangs

<table>
<thead>
<tr>
<th>Window</th>
<th>Hgt above</th>
<th>Dist From Left Wall (C)</th>
<th>Length (A)</th>
<th>Depth (B)</th>
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<td>1</td>
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<td>0.5</td>
<td>20</td>
<td>3</td>
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<tr>
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<td>9.5</td>
<td>0.5</td>
<td>20</td>
<td>3</td>
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</table>

Left Fin

<table>
<thead>
<tr>
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<th>Hgt above</th>
<th>Dist From Left Wall</th>
<th>Height</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0.5</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>0.5</td>
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<tr>
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<td>0</td>
<td>0.5</td>
<td>12</td>
<td>3</td>
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</table>

Right Fin

<table>
<thead>
<tr>
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<th>Dist From Left Wall</th>
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<th>Depth</th>
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</thead>
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<tr>
<td>4</td>
<td>0</td>
<td>10.5</td>
<td>12</td>
<td>3</td>
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</tbody>
</table>

Plan

<table>
<thead>
<tr>
<th>Window</th>
<th>Sill Height</th>
<th>Left Wall (feet)</th>
<th>Height</th>
<th>Width</th>
<th>Area (ft²)</th>
<th>Window setback (feet)</th>
<th>Glazing System</th>
<th>Frame Type</th>
<th>Frame Width (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>10</td>
<td>0</td>
<td>DoubleClearAir-Gem (B)</td>
<td>Aluminum</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>5</td>
<td>54</td>
<td>0</td>
<td>QuadSpecSemiClear (I)</td>
<td>Aluminum</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>7.6</td>
<td>4</td>
<td>5</td>
<td>54</td>
<td>0</td>
<td>QuadSpecUltraClear (I)</td>
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<td>4</td>
<td>1</td>
<td>14</td>
<td>4</td>
<td>5</td>
<td>54</td>
<td>0</td>
<td>QuadSpecSemiClear (I)</td>
<td>Aluminum</td>
<td></td>
</tr>
</tbody>
</table>

Note: Maximum of 4 windows per façade.
Project Façade Comparison

Windows for High Performance Commercial Buildings

PROJECT

- Project Name: Grace College Study
- Location: AZ Phoenix
- Building Type: Small Office
- Vintage: New (ASHRAE 90.1 2004)
- Project North: 0 (degrees east of true north)
- Run Period: Annual
- Start Day: Jan 1
- Stop Day: Dec 31

Facade Design Comparison

- Room Orientation: North
- Façade Design Name: Single Clear - Transom
- Daylighting Control Name: None

Results

- Comparison Target: Architecture 2030
- Chart Style: Stacked

Energy Comparison

- Case
  - 1: 10, 15, 20, 25
  - 2: 5, 10, 15, 20

Peak Energy Comparison

- Case
  - 1: 10, 15, 20, 25
  - 2: 5, 10, 15, 20

CO2 Comparison

- Case
  - 1: 10, 15, 20, 25
  - 2: 5, 10, 15, 20
## COMFEN Monthly Results

### Monthly Values

<table>
<thead>
<tr>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Energy Use (kBtu/ft²)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Electric Peak Demand (kWh/ft²)

<table>
<thead>
<tr>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Peak Electricity</strong></td>
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<td></td>
<td></td>
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</table>

### Thermal Comfort

<table>
<thead>
<tr>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>% Comfortable</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
COMFEN Daylighting Results
Glazing and Shading Example
(Sacramento daylight illuminance)
COMFEN Comfort Results
COMFEN v1.0 Glazing and Shading Example (Sacramento)
Glazing and Shading Example (Chicago)
Orientation Example
Glazing and Shading Example (Sacramento monthly graphs)
Glazing and Shading Example (Sacramento thermal comfort)
Glazing and Shading Example (Chicago monthly graphs)
Enhancements for COMFEN v2.0

• User defined Glazing Systems
  – Imported from WINDOW 6
  – Or created in COMFEN from IGDB glazing layers

• User defined Shading Layers
  – Venetian Blinds, Woven Shades, Exterior Screens

• User defined Shading Control Schemes
  – Shading Type
    • Interior, Exterior, or Between Glass Blind or Shade
    • Exterior Mesh Screen
    • Electrochromic Switchable Glazing
  – Control Type
    • Scheduled, Horizontal Solar or Solar on Window, Block Beam Solar, Glare, Daylight Illuminance, Outside or Inside Temperature, Zone Cooling, and more
V2.0 Blind Shading Layer Library
## V2.0 Shading Control Scheme Library

**Name:** Venetian, White, Shade Control

### Shade Description

**Shading Type:** Venetian Blind - Interior

**Shading Type Locations:**
- Interior
- Exterior
- Between glass

**Shading Device:** Venetian, White Metal, 90 degrees (slats Vertically/Closed)

### Shading Control

- **Shade Control:**
  - **Control Type:** Always on
  - **Control Setpoint:**
    - Limits
    - Schedule (if applicable): None
  - **Slat Angle Control for Venetian Blinds:**
    - Slat Angle Schedule: Solar
    - Schedule (if applicable): None

---

*SimBuild 2008*
Enhancements for COMFEN v3.0+

- New User Interface
  - 3-D Model- Sketchup
- Access to More Detailed Daylight Data
  - More detailed hourly/annual options, e.g. Daylight Autonomy
  - New Radiance simulation results
- Access to more detailed Thermal Comfort Data
  - CBE Comfort Model
- Green Building Ratings e.g. LEED
- Building Code Compliance links

- Links to Case study performance data
  - LBNL Testbed Field test performance results
  - Building Performance Data
Enhancements for COMFEN v3.0+

- Collaborative University Development Network
  - U. Minn.- John Carmody
  - UCB/CBE - Charlie Huizenga
  - Technion- Israel: Guedi Capeluto, Prof.
  - DTU - Denmark: Steffen Petersen, PhD student
  - Victoria Univ, NZ- Michael Donn
  - Harvard Univ.,- Christoph Reinhart

- Open Development Platform
  - For R&D exploration
  - For Tool enhancement
Time Lapse of Interior Room Luminance with Dynamic Shading
Split blind In LBNL Test Facility

Upper: -45° / Lower: 0°
Upper: horiz/ Lower: +30°
Upper: +60° / Lower: +closed
ARCHITECTURAL IDEAS

CODE COMPLIANCE

Design Solutions as OUTPUT

EnergyPlus Results

PhD Dissertation by C. Ochoa, Technion Israel Institute of Technology
Advisor: Guedi Capeluto
Potential Daylight Autonomy Output
Steffen Petersen, DTU, Denmark, IDBuild

Parameter variation: Window height [m]
Max. limit [lux] 500
Evaluation point Task

Daylight Autonomy:
- Variation 1: 0.58
- Reference: 0.69
- Variation 2: 0.76

Note: Daylight Autonomy is the fraction of the total working hours (user defined) in which the amount of lux is equal to or above the "maximum lux limit".

NB: The steps between contours in the plots are automatically set to 10% of the 'Maximum lux limit'.

Variation 1
Reference
Variation 2
Adding Daylight Data to COMFEN via Radiance results

Full Radiance ray-tracing simulation of Venetian blinds

Second (much quicker) rendering using the supplied BSDF from Window6
Assessing Sun Penetration Using **SunTools**

SketchUp Plug-ins by Guedi Capeluto – arrguedi@technion.ac.il
Sunpath Diagram Superimposed on Skyvault from Room Perspective
Assessing Sun Penetration Using **SunTools**
SketchUp Plug-ins by Guedi Capeluto – arrguedi@technion.ac.il
Modifying the Design >> Horizontal louver
Assessing Sun Penetration Using **SunTools**
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More Info?

Stephen Selkowitz
Building Technologies Department
Lawrence Berkeley National Laboratory
Building 90-3111
Berkeley, CA 94720   USA
SESelkowitz@lbl.gov

http://windows.lbl.gov/software/comfen/1/

New Façade Project Website:
http://windows.lbl.gov/comm_perf/facade-solutions/

More Project Info:
http://windows.lbl.gov
Commercial systems R&D
http://buildings.lbl.gov/hpcbs
Electrochromics
http://windows.lbl.gov/comm_perf/electrochromic
New York Times project
http://windows.lbl.gov/comm_perf/newyorktimes.htm

Resource Materials:


IEA Daylight in Buildings Source Book:
http://gaia.lbl.gov/iea21

High Performance Building Facades: http://gaia.lbl.gov/hpbf

Commercial Windows Website: http://www.commercialwindows.umn.edu