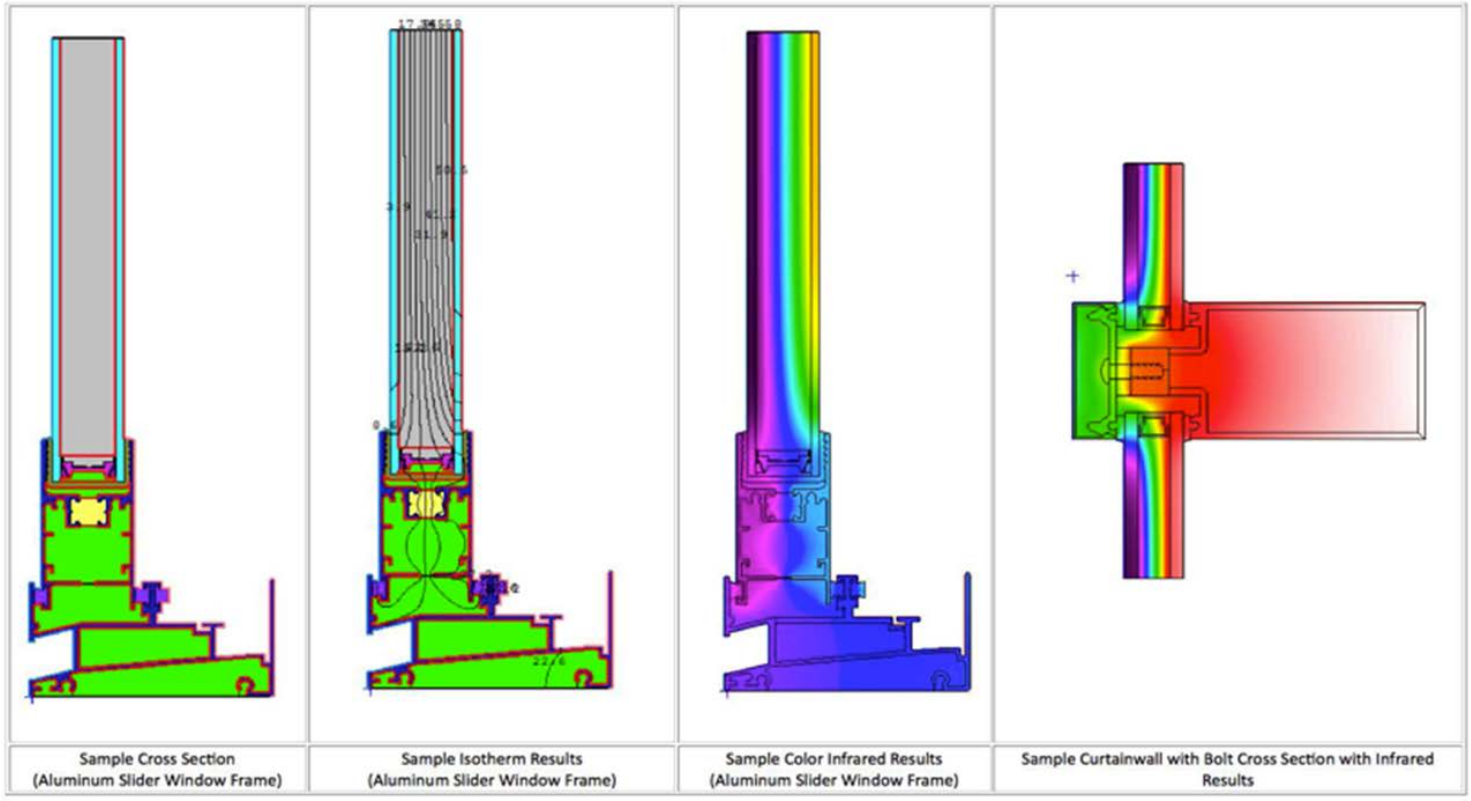
Fenestration Modeling Tools

2017 Building Technologies Office Peer Review



Sample Cross Section (Aluminum Slider Window Frame)

Sample Isotherm Results (Aluminum Slider Window Frame)

Sample Color Infrared Results (Aluminum Slider Window Frame)

Sample Curtainwall with Bolt Cross Section with Infrared Results

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Charlie Curcija, dccurcija@lbl.gov
LBNL

Project Summary

Timeline:

Start date: 10/1/2015

Planned end date: 9/30/2018

Key Milestones:

1. International Glazing Database (IGDB)/Complex Glazing and shading database (CGDB) Releases – IGDB every 2 months, CGDB ever 6 months.
2. XML Schema for IGDB/CGDB – 4/30/17
3. Design and planning document for next gen WINDOW/THERM – 9/30/17
4. EPCalc release to industry – 5/15/17, version 1.1 - 9/30/17

Budget:

Total Project $ to Date:

- DOE: $500K (Last 12 months: $275K)
- Cost Share: $470K (Last 12 months: $210K)

Total Project $:

- DOE: $800K
- Cost Share: $770K

Key Partners:

NFRC - National Fenestration Rating Council	AAMA – American Architectural Manufctg. Association
AERC - Certification & Rating of Attachment Fenestration Technology	Luca Papaz / Pellini
CBERD – Joint US/India Energy Research Center	Chris Mackey / Performance Network
PPG/Vitro – Major glass manufacturer	PassivHaus – Passive House Rating
International partners: Australia, Brazil, South Africa, India, China, EU	

Project Outcome:

Suite of interconnected tools capable of accurately modeling prime fenestration systems, integrated shading systems and window attachments and coverings

Purpose and Objectives

Problem Statement: The window industry needs accurate, independently verified tools—and associated measurement facilities—to move toward a paradigm of virtual, rapid product design, development, and rating. Specifically, manufacturers need tools to accelerate design-to-market delivery of new energy efficient window technologies and products. These tools also form the foundation for rating fenestration products and attachments through NFRC, AERC and AAMA.

Target Market and Audience: Window and attachment manufacturers, window rating organizations.

Impact of Project: Technical potential for energy savings by 2030 from windows is 2 quads (commercial and residential) and an additional 1.0 quad for daylighting.

World class modeling tools form the basis for building energy codes for fenestration in the US, as well as helping national fenestration manufacturers innovate and sell their products globally.

Prime window

Window attachments

Approach

Approach: Develop a suite of interconnected credible modeling tools capable of accurately modeling prime fenestration systems, integrated shading systems and window attachments/coverings.

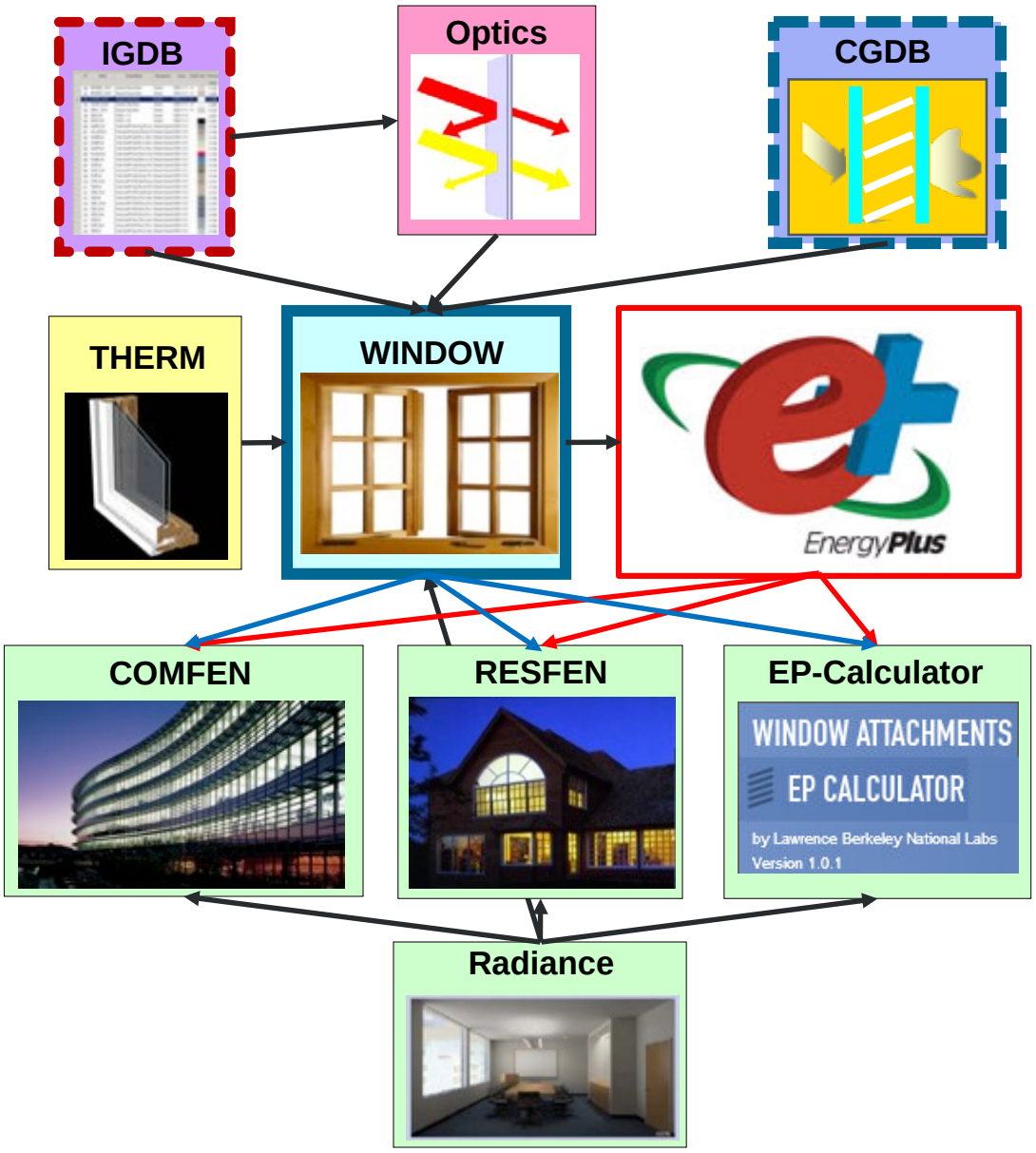
Key Issues:

- Enable rapid development of new technologies, such as vacuum glazing, window attachments & shades, chromogenic glazing, PV integration, Hi-R windows, etc.
- Enable cost-effective rating/certification of prime windows with or without integrated shades (NFRC) and window attachments/coverings (AERC).
- Provide wider access to software tools by building and related industries beyond fenestration. Examples are PassivHaus, opaque envelope, appliance industry.
- Convert to open source model and greater input from third-party contributors.

Distinctive Characteristics:

- Long-running project.
- Supports whole-building codes, product ratings, and product development.
- Serves broad audience in building industry, both in US and internationally.

Current Fenestration Software Tools Ecosystem



IGDB: specular glazing database

CGDB: complex glazing & shading database

Optics: virtual glass lab

Angular SHGC/U/VT: design

THERM: window frame heat transfer

WINDOW: glazing, shading, whole-window

Radiance: detailed lighting/daylighting

EnergyPlus: whole-building energy

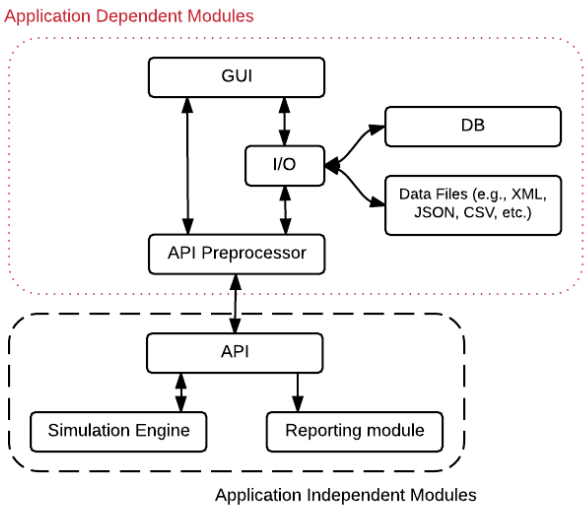
COMFEN: commercial fenestration design

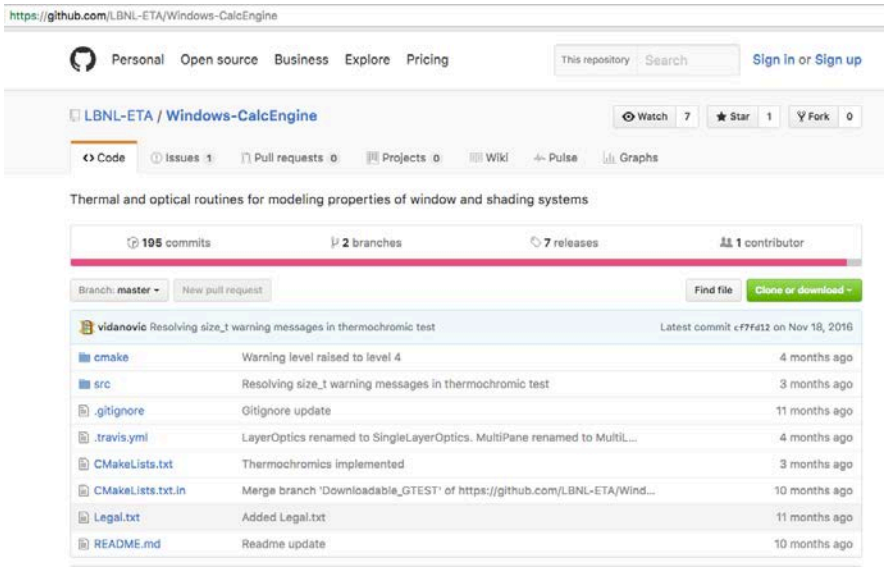
RESFEN: residential fenestration design

EP-Calculator: attachment energy indices

Open-Source

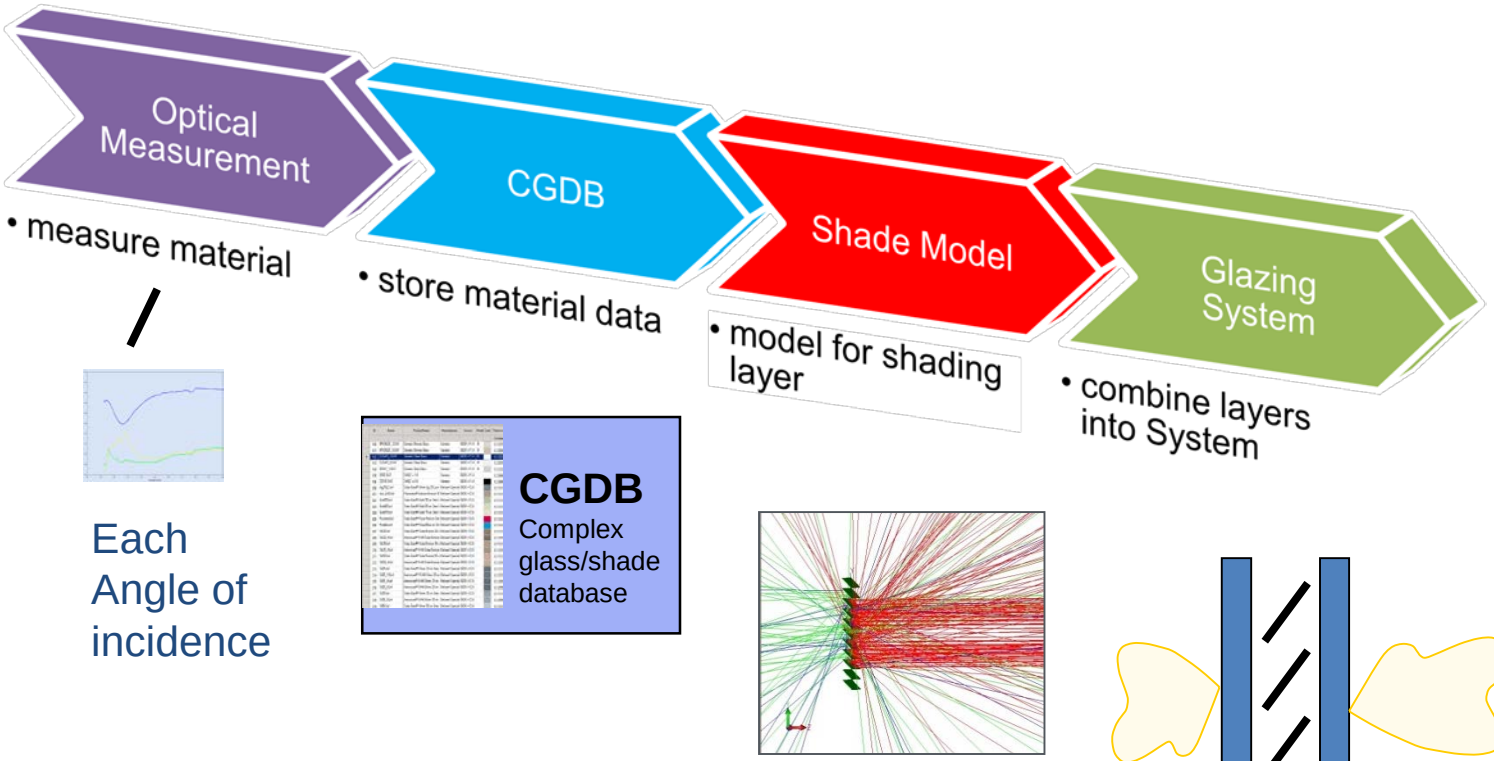
- WinCalc engine
  - Refactored simulation engine for Berkeley Lab WINDOW
  - C++ programming language (was a mix of FORTRAN and Visual Basic)
  - Integration with E+
- WINDOW and THERM transition to open source model
  - Public vs proprietary code
  - Licensing





IGDB/CGDB Material Database

- Current state and data flow for Complex Glazing and shading DataBase (CGDB)

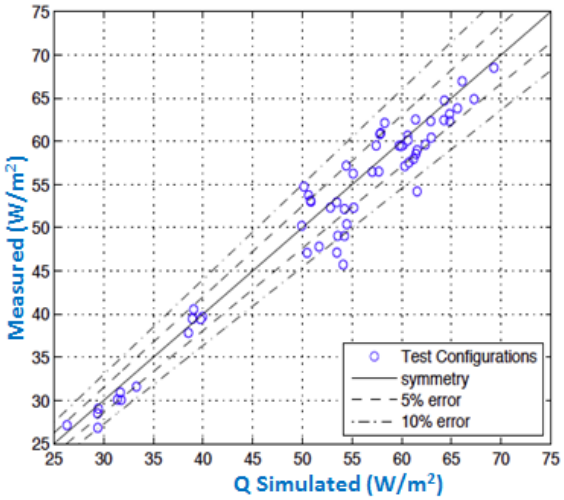


- **Current and future work:**
  - Transition to Cloud-based unified IGDB/CGDB database
  - API for data access
  - Regional Data Aggregation (RDA) model to accomplish decentralized management and support of IGDB/CGDB

WINDOW and THERM – Air Flow

Air flow around shading systems

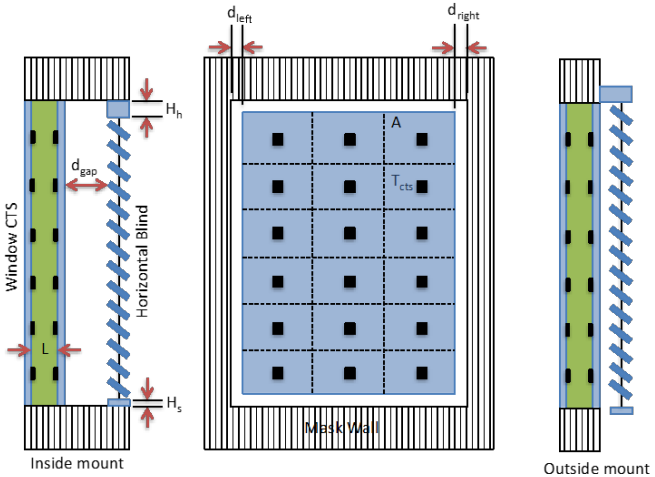
- Edge gaps, top and bottom gaps
- Validated existing algorithms ➔ no change



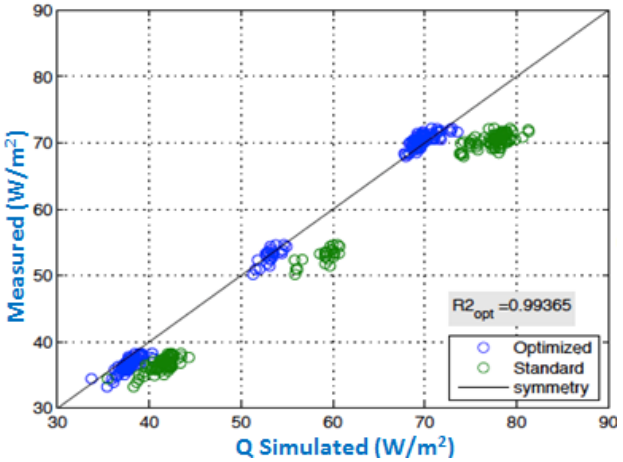
Validation of airflow around attachments

Air flow through venetian blinds

- Developed new algorithms
- Implemented in WINDOW



Experimental setup for validation and development of new algorithms



Green circles – existing algorithms

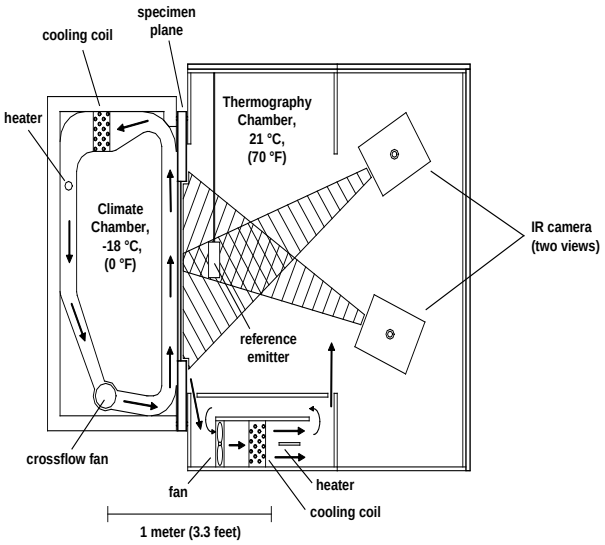
Blue circles – new algorithms

WINDOW and THERM – Permeability

Heat transfer effects from fabrics and perforated shading devices

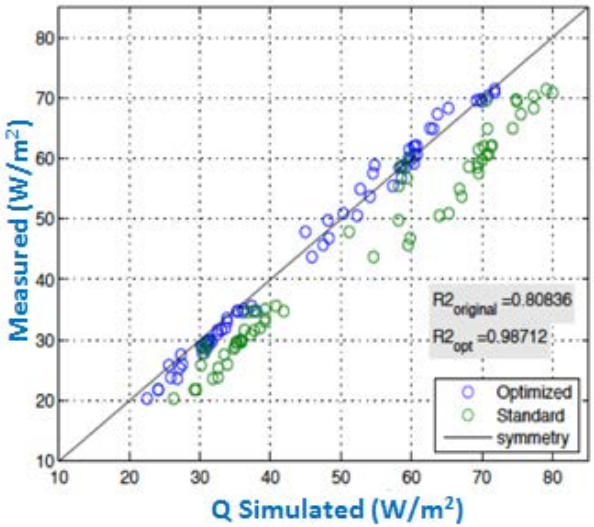
- New Permeability Factor (PF)
- New heat transfer equations based on PF
- PF is used in calculating velocity in a cavity between the attachment and window, which in turn is used in heat transfer correlation

$$\mathrm{PF} = \left(\frac{K}{3.44x10^{-9}}\right)^{1/1.6}$$



LBNL Thermal IR Test Facility

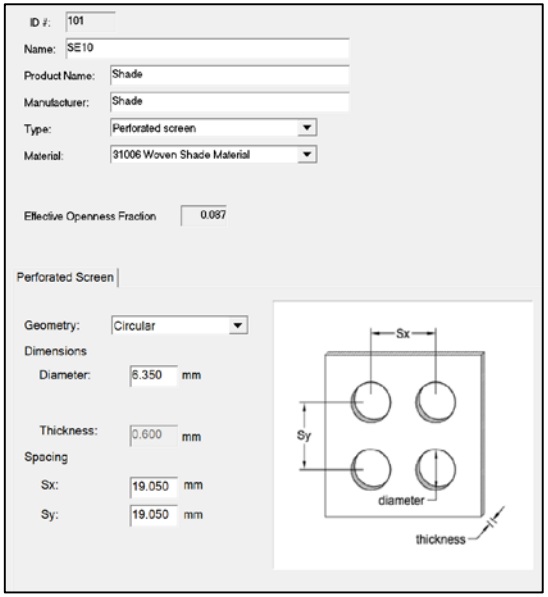
Measurement vs simulation



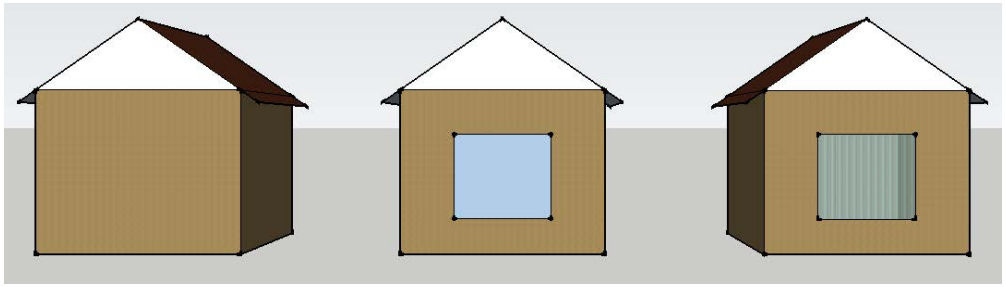
Green – existing algorithms

Blue – new algorithms

WINDOW Shading Library



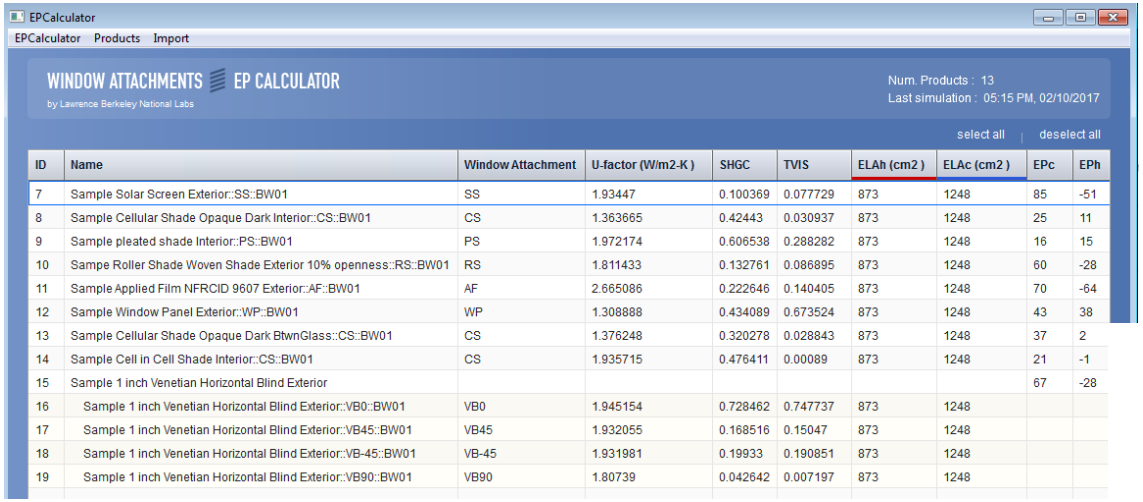
EP-Calculator – Energy Performance for Attachments



A (“Adiabatic” window) B (Baseline window) S (Window + Shade/attachment)

EP-Calculator: annual energy performance indices for window attachments (AERC)

- EP_C (cooling) & EP_H (heating) - Ratios of annual energy saving resulting from the addition of attachment to annual energy use caused by window. $(E_B-E_S) / (E_B-E_A)$
- Based on COMFEN (EnergyPlus), beta released Feb. 2017, final release Sep. 2017.
- Expand to include commercial window attachments to meet AERC needs in 2 years.
- Cost shared by Window Attachments Project

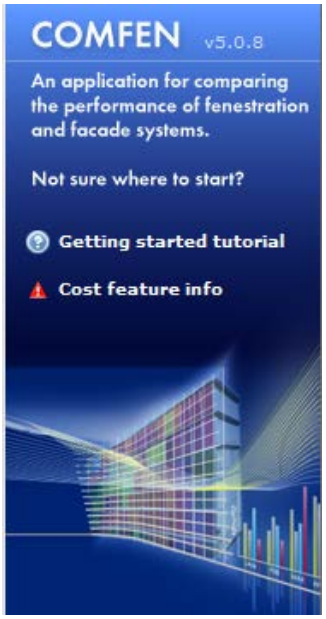


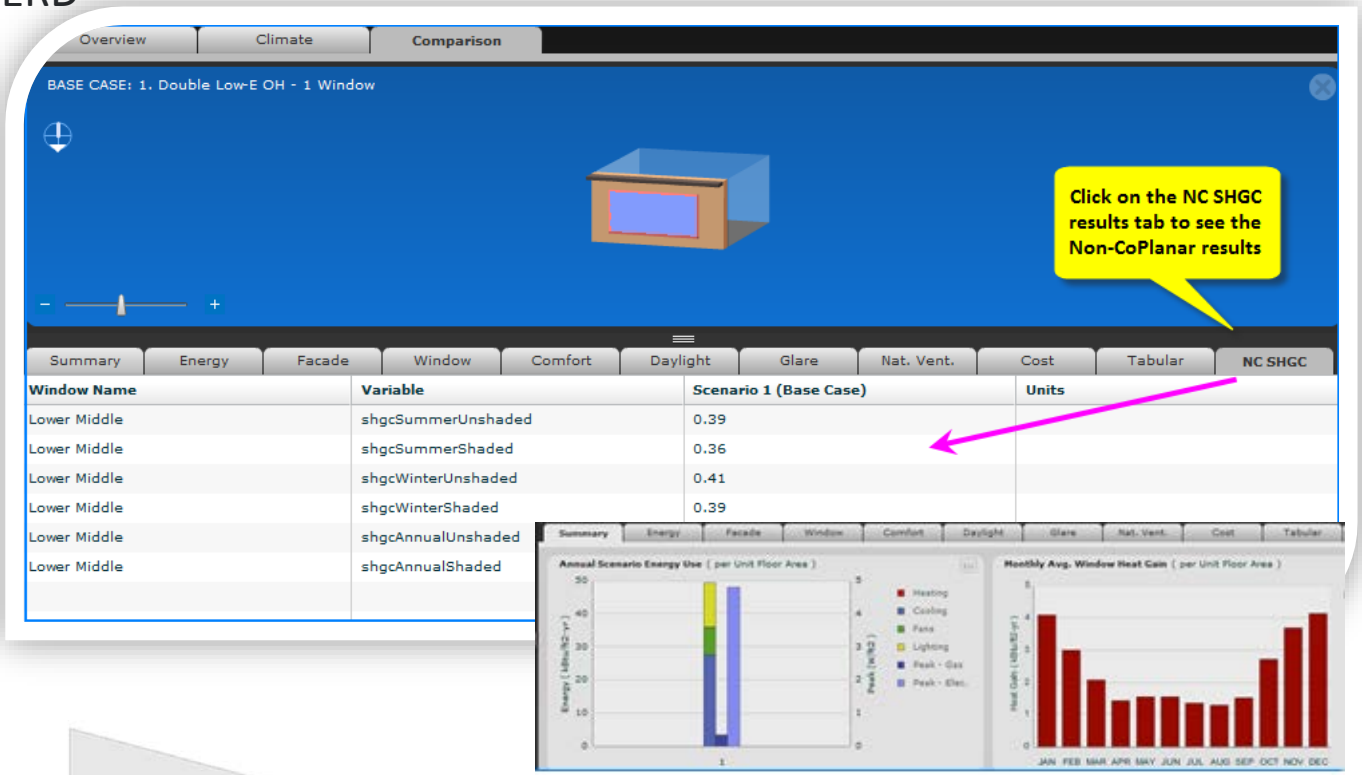
ID	Name	Window Attachment	U-factor (W/m2-K)	SHGC	TVIS	ELAh (cm2)	ELAc (cm2)	EPc	EPh
7	Sample Solar Screen Exterior::SS::BW01	SS	1.93447	0.100369	0.077729	873	1248	85	-51
8	Sample Cellular Shade Opaque Dark Interior::CS::BW01	CS	1.363665	0.42443	0.030937	873	1248	25	11
9	Sample pleated shade Interior::PS::BW01	PS	1.972174	0.606538	0.288282	873	1248	16	15
10	Sampe Roller Shade Woven Shade Exterior 10% openness::RS::BW01	RS	1.811433	0.132761	0.086895	873	1248	60	-28
11	Sample Applied Film NFRCID 9607 Exterior::AF::BW01	AF	2.665086	0.222646	0.140405	873	1248	70	-64
12	Sample Window Panel Exterior::WP::BW01	WP	1.308888	0.434089	0.673524	873	1248	43	38
13	Sample Cellular Shade Opaque Dark BtwnGlass::CS::BW01	CS	1.376248	0.320278	0.028843	873	1248	37	2
14	Sample Cell in Cell Shade Interior::CS::BW01	CS	1.935715	0.476411	0.00089	873	1248	21	-1
15	Sample 1 inch Venetian Horizontal Blind Exterior							67	-28
16	Sample 1 inch Venetian Horizontal Blind Exterior::VB0::BW01	VB0	1.945154	0.728462	0.747737	873	1248		
17	Sample 1 inch Venetian Horizontal Blind Exterior::VB45::BW01	VB45	1.932055	0.168516	0.15047	873	1248		
18	Sample 1 inch Venetian Horizontal Blind Exterior::VB-45::BW01	VB-45	1.931981	0.19933	0.190851	873	1248		
19	Sample 1 inch Venetian Horizontal Blind Exterior::VB90::BW01	VB90	1.80739	0.042642	0.007197	873	1248		

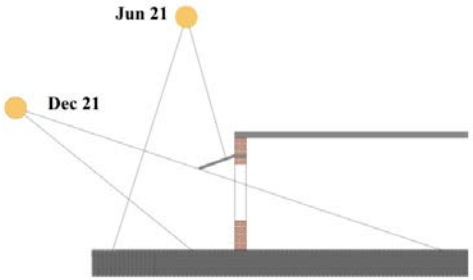
EP-Calculator/COMFEN/RESFEN – Non-Coplanar Shading

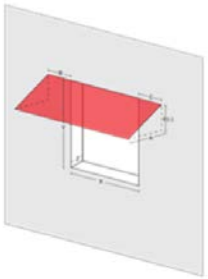
Non-coplanar shading (e.g., awnings)

- Current work: add models and interface EP Calculator/COMFEN/RESFEN
- COMFEN CBERD with Getting Started Guide (https://windows.lbl.gov/projects/CBERD/)
- Cost share by DOE CBERD









Project Integration and Collaboration

Project Integration:

- NFRC collaboration (monthly calls)
- AERC coordination and support (multiple weekly calls)
- User support and education
- CRADA and non-CRADA collaboration with manufacturers
- Standards development (ISO 15099, NFRC, AERC, ASTM, ASHRAE)

Partners, Subcontractors, and Collaborators:

- Rating organizations
- Trade associations
- Window/Glazing manufacturers
- AEC companies: Arup, HOK, Parmastelisa, Enclos
- Media companies: BuildingGreen, US Glass
- International partners: Brazil, Mexico, South Africa, India, China, Australia, UK, Thailand, ES-SO (European Solar-Shading Organization)
- Subcontractors: Daniel McQuillen

Communications:

- e-mail/phone user support
- web-based software support forum
- Conferences
- Webinars

Progress and Accomplishments

Accomplishments

- WINDOW and THERM 7.5 released:
  - New algorithms for louvered blinds
  - Refined modeling of air flow around shading device
  - New model for permeability of shading devices
- Release of new and updated CGDB content every six months.
- Release of new and updated IGDB content every 2 months
- Open source plan

Market Impact

- Tools used by all major fenestration manufacturers
- Compliance with standards, codes, & above code programs
- Global user base

Recognition

- Consistently among the top 3 requests from industry when DOE asks for input

Lessons Learned

- Open-source transition substantially slowed-down due to sub-module licensing issues that need to be resolved, sometimes on a module-by-module basis

Next Steps and Future Plans

FY17

- Develop optical and thermal models for window quilts and awnings (non-coplanar shades) - Software tools affected: THERM, WINDOW and EP Calculator
- Extend improved algorithms for modeling air flow around shading devices (effects of edge gaps, shade porosity/openness) into EnergyPlus through updating WinCalc open source engine.
- Add shading and window-attachment content to CGDB in support of AERC
- Develop WINDOW/THERM plan to handle new IGDB/CGDB and greater model complexity
- Release EP-Calculator 1.0

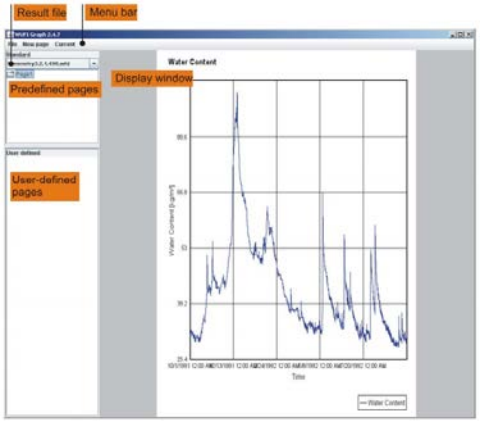
Out Years

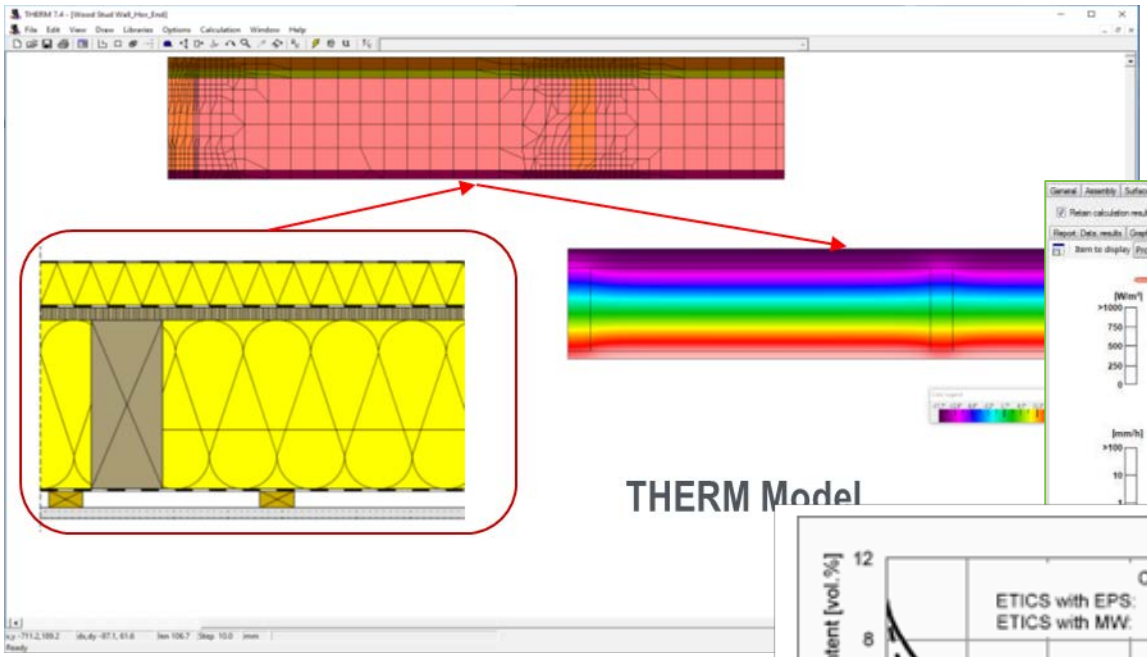
- Extend WINDOW, THERM, EP Calculator, COMFEN, RESFEN and EnergyPlus to model full set of window attachments and shades
- Cloud-based unified IGDB/CGDB and connection to DOE's Building Component Library (or TPEx)
- Develop models for fenestration-integrated PV as part of BIPV and implement in WINDOW
- Integration with THERMM
- Complete transition to open-source

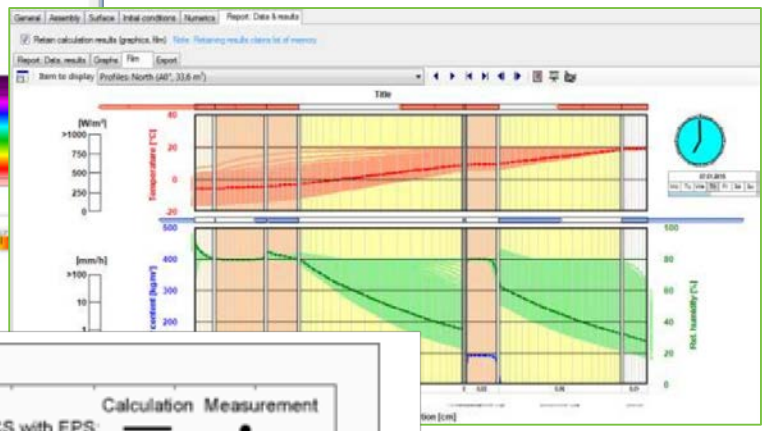
Related Project – THERMM

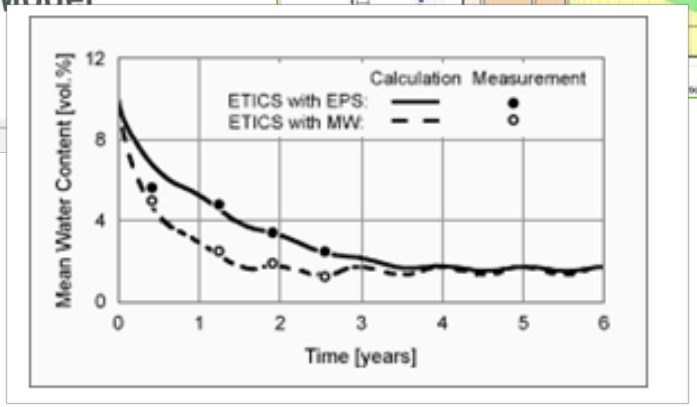
THERMM: enhance THERM with moisture modeling

- BTO BENEFIT FOA award FY17-FY19
- 20% cost share from California Energy Commission (CEC)
- Joint project with ORNL









REFERENCE SLIDES

Project Budget

Project Budget: 3 year project with DOE budget of $800K and cost share of $770K
Variances: Long history of fenestration software tools development. Current budget is substantial decrease from past funding.
Cost to Date: Current year's budget is $300K. S far, $130K?? was expended
Additional Funding: Cost shared by industry at almost 50%

Budget History					
FY 2016 (past)		FY 2017 (current)		FY 2018 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$200K	$200K	$300K	$270K	$300K	$300K

Project Plan and Schedule