A WEB-BASED SIMULATION PLATFORM FOR THE ENERGY, DAYLIGHT AND GLARE EVALUATION OF FENESTRATION SYSTEMS

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Radiance Workshop

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Fraunhofer Institute for Solar Energy Systems ISE

www.ise.fraunhofer.de

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Performance evaluation of fenestration systems: problem statement

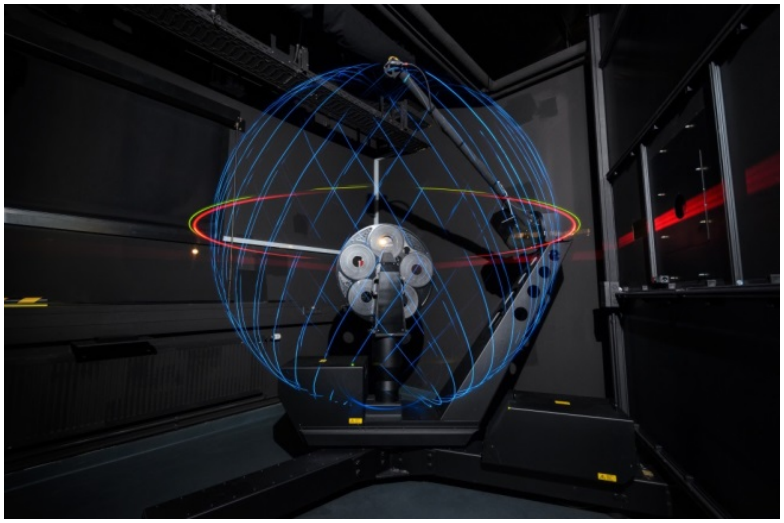
- Fenestration systems have opposing effects on solar heat gains, daylight availability, glare control and view contact.
- The balance between these aspects depend on:
  - Building and surrounding geometry
  - Building operation (dynamic)
  - Size, position and orientation of fenestration systems
  - Optical and thermal properties of systems
  - Control of systems (dynamic)
  - Climate (dynamic)

Performance evaluation of fenestration systems: problem statement

- The performance evaluation of fenestration systems requires:
  - Definition of evaluation criteria.
  - Characterization of their optical and thermal properties.
  - Dynamic simulations to evaluate the performance under specific climate and boundary conditions.

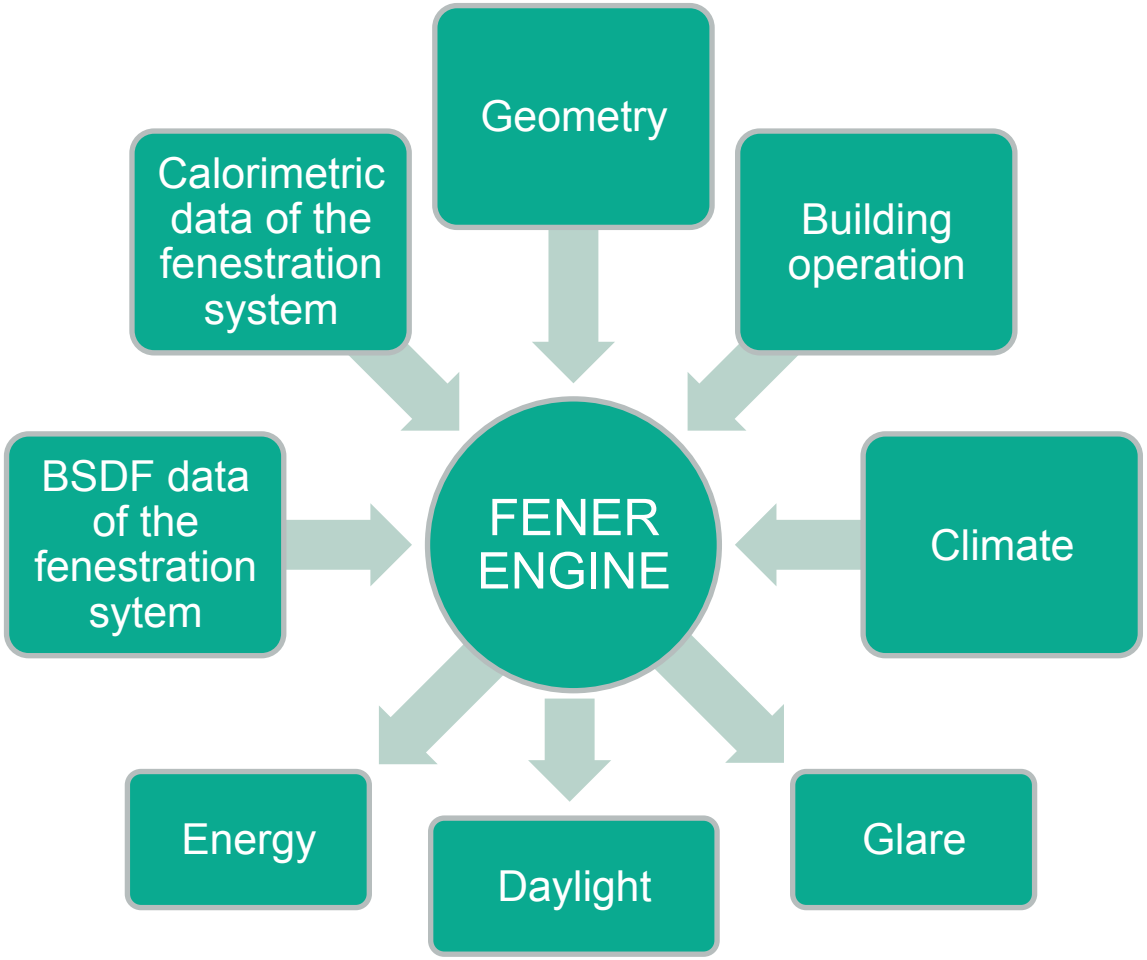
Characterization of optical and thermal properties

- Photogoniometer: bidirectional scattering distribution function (BSDF)
- Calorimeter: U-value and angle-dependent solar heat gain coefficient (g-value)



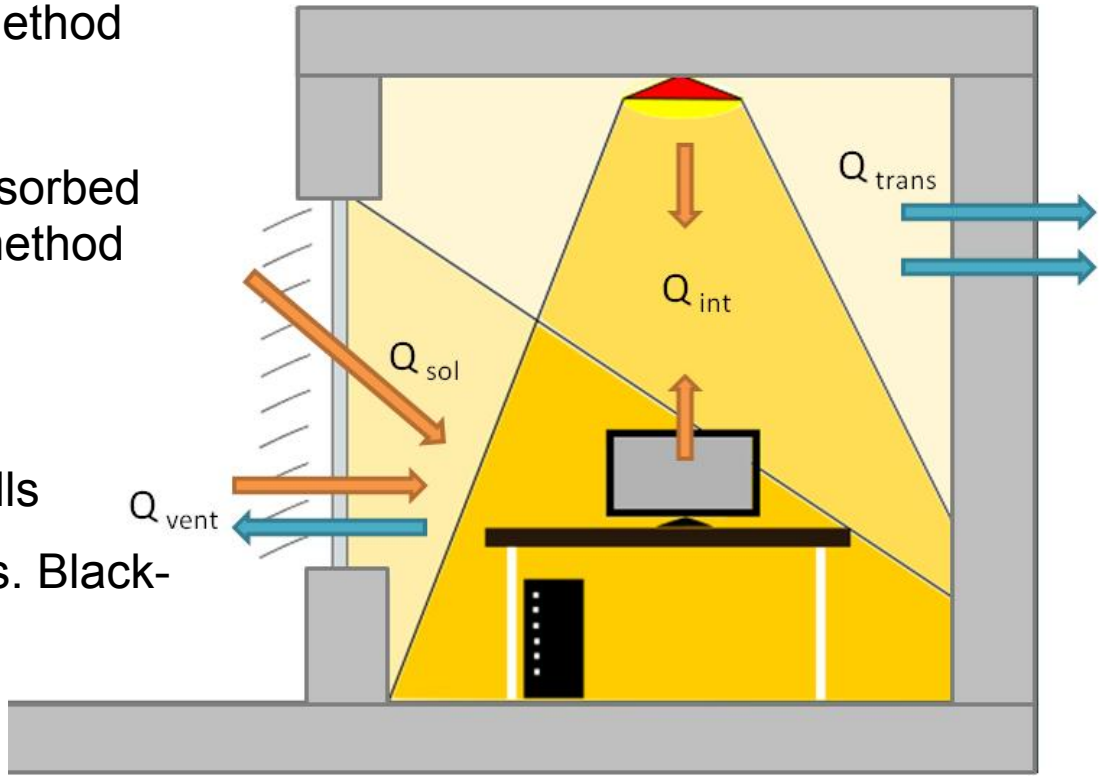
(left) Photogoniometry laboratory; (right) Colometric Outdoor test Facility for Real-size building Envelope Elements. Fraunhofer ISE

Performance evaluation based on dynamic simulations

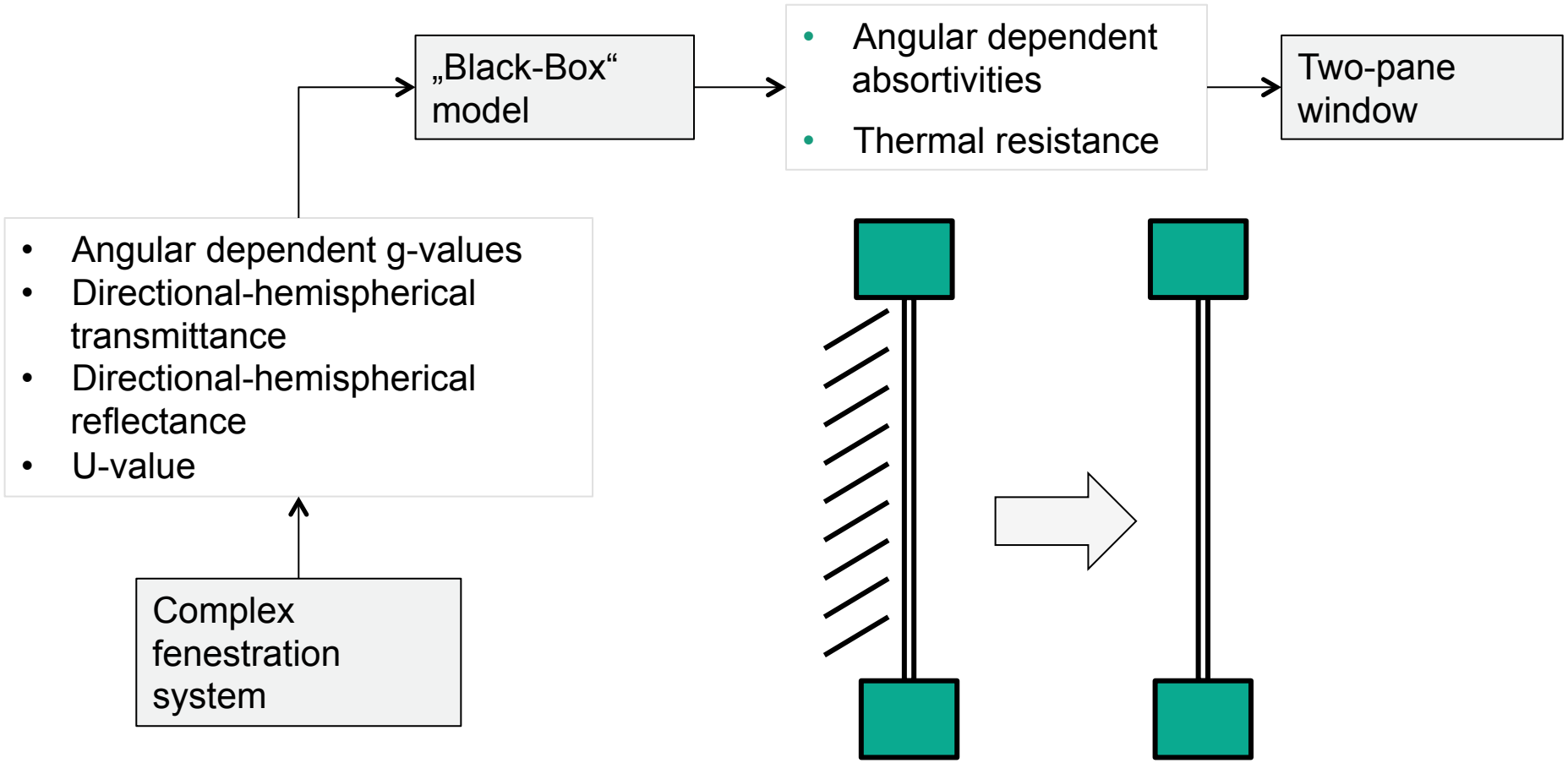


Performance evaluation based on dynamic simulations

- Shading operation according to a control algorithm.
- Indoor illuminance. 3-phase method
- Artificial lighting requirements.
- Transmitted solar radiation absorbed by indoor surfaces. 3-phase method
- Outdoor energy balance.
- Indoor energy balance.
- Heat transmission through walls
- Heat transfer through windows. Black-Box model



Performance evaluation based on dynamic simulations
Black-Box model (Kuhn et al 2011)



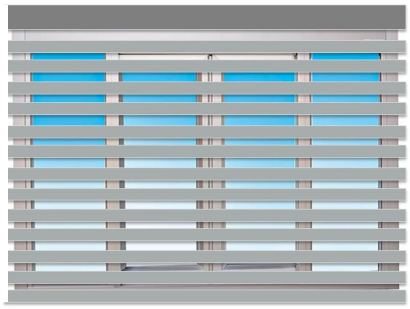
Kuhn T.E., Herkel S., Frontini F., Strachan P., Kokogiannakis G., 2011. Solar control: A general method for modelling of solar gains through complex facades in building simulation programs, Energy and Buildings 43(1), 19-27.

Model evaluation

- Building energy demand ⇒ FENER vs EnergyPlus
- Transmitted solar irradiance ⇒ FENER vs EnergyPlus vs Radiance
- Average work-plane illuminance ⇒ FENER vs Radiance

Simulations are carried out for:

✓2 different Fenestration systems



✓2 different days of the year

Bueno, B., J. Wienold, A. Katsifaraki, T.E. Kuhn, 2015. Fener: a Radiance-based modelling approach to assess the thermal and daylighting performance of complex fenestration systems in office spaces. Energy and Buildings 94 10–20.

FENER-WEBPORT

https://fener-webport.ise.fraunhofer.de

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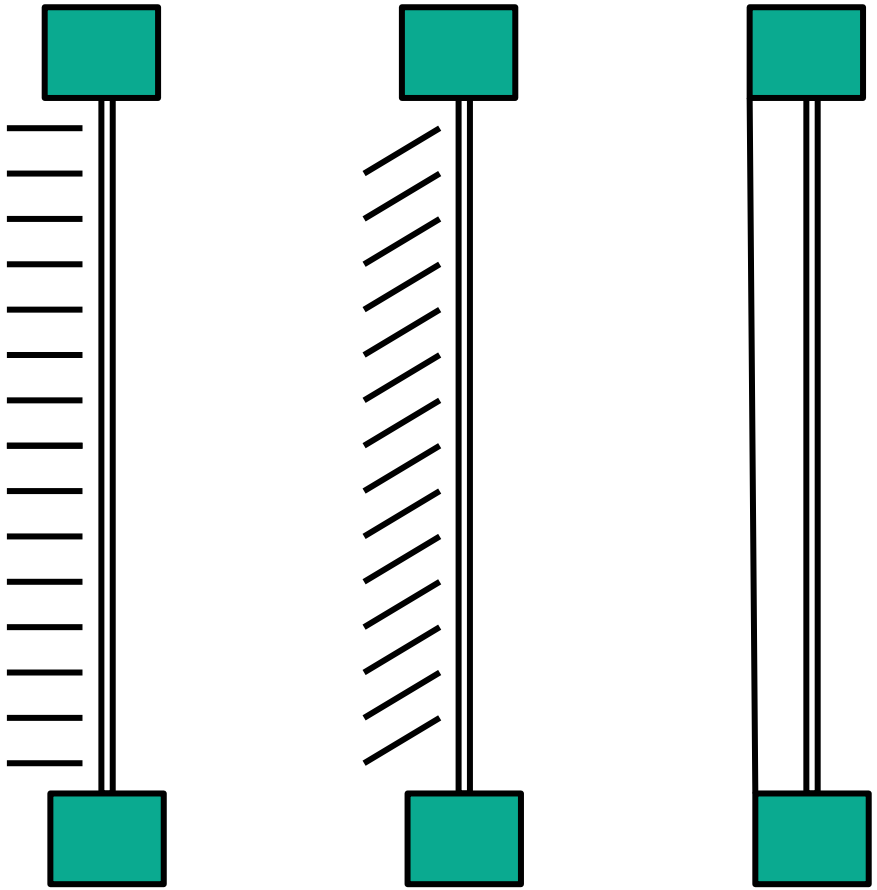
WORKOUT EXAMPLE: CONTROL STRATEGY



Tilt	0°	45°	90°
U	1.2	1.2	1.1
g_0	0.60	0.13	0.02
tau_{v0}	0.74	0.13	0.00

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1. Scenario | 2. Simulation setup | 3. Review

Overview

User guide

Daylight simulation **Glare simulation** **Thermal simulation**

Name Name **Compare** Fenestration system + Add − Remove

	Name	Comparison
	Reference	Choose what you want to compare
☐	radiation	
☐	daylight	
☐	temp	

Setup

1. Scenario | 2. Simulation setup | 3. Review

Climate | Geometry | Fenestration system | Inputs

User guide

Reference

Simulation period From 01/01 to 31/12

Climate Lyon(France) [admin] Upload .epw file

Latitude 45.72 **Longitude** 4.95

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1. Scenario | 2. Simulation setup | 3. Review

Climate | Geometry | Fenestration system | Inputs

User guide

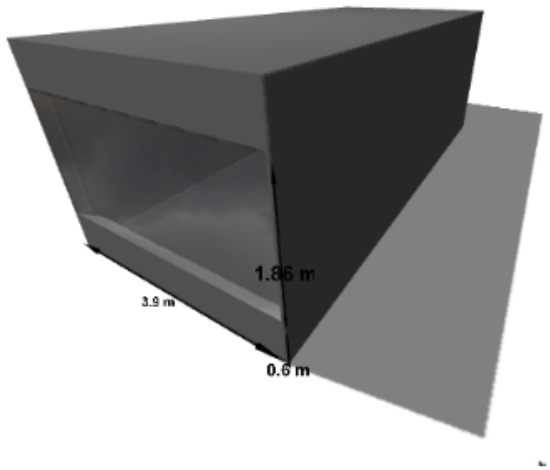
Reference

Configuration Reference office (W 3.9m x D 8.5m x H 3.1m)

Orientation South

Glazing-to-facade ratio 60%

3D model



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Next

1. Scenario | 2. Simulation setup | 3. Review

Climate | Geometry | Fenestration system | Inputs

User guide

Reference | radiation | daylight | temp

Upload a light scattering system | Upload a non-scattering system | Introduce control states

- ○ Fixed system — Solar control glazing unit and exterior perforated screen
- ◉ Control state matrix — VBA - Based on energy, daylight and glare

◀ Back | Next ▶

Introduce control states

Name: VBA - Based on exterior irradiance on building facade

Default: VBA-0

Number of variables: 2

Number of condition lines: 1

Create matrix | Explanation

Based on exterior ir | Load matrix

Variables:

Occupation | Exterior irra

Setpoint (more or equal):

1 | 150

Fill the control state matrix under the following conditions:

☑	☑	VBA-45

Save | Close

Introduce control states

Control matrix has been loaded.

Name: VBA - Based on daylight

Default: VBA-0

Number of variables: 2

Number of condition lines: 1

Create matrix | Explanation

Based on glare [adı | Load matrix

Variables:

Occupation | Average wc

Setpoint (more or equal):

1 | 2500

Fill the control state matrix under the following conditions:

☑ ☑ VBA-45

Save | Close

Introduce control states

Name: VBA - Based on indoor temperature

Default: VBA-0

Number of variables: 2

Number of condition lines: 2

Create matrix | Explanation

Based on indoor tei | Load matrix

Variables:

Occupation | Indoor air te

Setpoint (more or equal):

1 | 26

Fill the control state matrix under the following conditions:

☐	☑	VBA-90
☑	☑	VBA-45

Save | Close

Introduce control states

Name: VBA - Based on energy, daylight and glare

Default: VBA-0

Number of variables: 4

Number of condition lines: 7

Create matrix | Explanation

Based on energy, | Load matrix

Variables:

Occupatior	Average wc	Exterior irra	Indoor air t

Setpoint (more or equal):

1	1000	150	26

Fill the control state matrix under the following conditions:

☐	☑	☑	☑	VBA-90
☐	☐	☑	☑	VBA-90
☐	☐	☐	☑	VBA-90
☐	☑	☐	☑	VBA-90
☑	☑	☐	☐	VBA-45
☑	☑	☑	☐	VBA-45
☑	☑	☐	☑	VBA-45

Save | Close

1. Scenario | 2. Simulation setup | 3. Review

Climate | Geometry | Fenestration system | Inputs

User guide

Working hours

6 18

Light control

Illuminance setpoint (lux) 500.0

Control type ON/OFF

Thermal

Equipment watts per zone floor area (W/m2) 5.0

People watts per zone floor area (W/m2) 10.0

Lights watts per zone floor area (W/m2) 10.0

Infiltration/ventilation (ACH)

During working hours 2.0 Outside working hours 0.5

Heating thermal setpoint (°C)

During working hours 21 Outside working hours 17

Cooling thermal setpoint (°C)

During working hours 27 Outside working hours 30

Construction type Heavy

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1. Scenario | 2. Simulation setup | 3. Review

Name of the simulation: Radiance_workshop_2016 **Notify me about progress via e-mail** ☐ Save

	Reference	radiation	daylight	temp
Simulation period	From 01/01 till 31/12			
Climate	Lyon(France) [admin]	Lyon(France) [admin]	Lyon(France) [admin]	Lyon(France) [admin]
Room orientation	South	South	South	South
Room type	Reference office	Reference office	Reference office	Reference office
Room dimensions (width x depth x height) (m)	3.9 x 8.5 x 3.1	3.9 x 8.5 x 3.1	3.9 x 8.5 x 3.1	3.9 x 8.5 x 3.1
Glazing-to-facade ratio	60%	60%	60%	60%
Glazing area dimensions (width x height) (m)	3.8 x 1.86	3.8 x 1.86	3.8 x 1.86	3.8 x 1.86
Fenestration system	VBA - Based on energy, daylight and glare	**VBA - Based on exterior irradiance on building facade**	**VBA - Based on daylight**	**VBA - Based on indoor temperature**
Fenestration control	Control state matrix	Control state matrix	Control state matrix	Control state matrix
Working hours	6-18 LT			
Illuminance setpoint (lux)	500.0			
Lighting control	ON/OFF			
Equipment watts per zone floor area (W/m2)	Inside working hours: 5.0 Outside working hours: 0.0			
People watts per zone floor area (W/m2)	Inside working hours: 10.0 Outside working hours: 0.0			
Lights watts per zone floor area (W/m2)	Inside working hours: 10.0 Outside working hours: 0.0			
Infiltration/ventilation (ACH)	Inside working hours: 2.0 Outside working hours: 0.5			
Heating thermal setpoint (°C)	Inside working hours: 21 Outside working hours: 17			
Cooling thermal setpoint (°C)	Inside working hours: 27 Outside working hours: 30			
View position from the window (m) (view direction parallel to the window)	1.5			
View height (m)	1.65			

◀ Back Run sumulation ▶

Results of the simulation: Radiance_workshop_2016

Your simulation is running...

Finished: 0 / 4

Reference

radiation

daylight

temp

Results | Review

Daylight

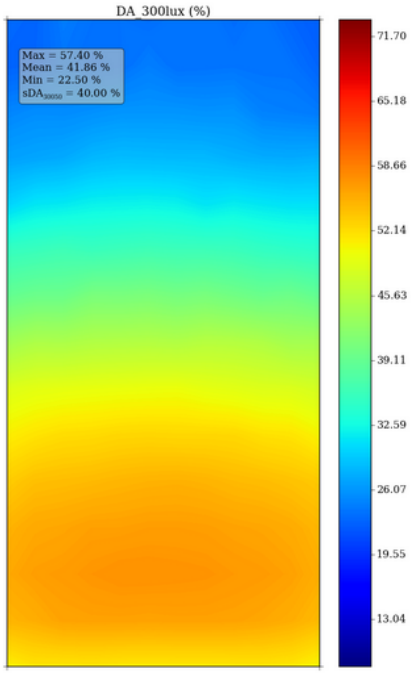
- Horizontal illuminance distribution
- Daylight autonomy
- Daylight factor
- Average horizontal illuminace (lux)

Glare

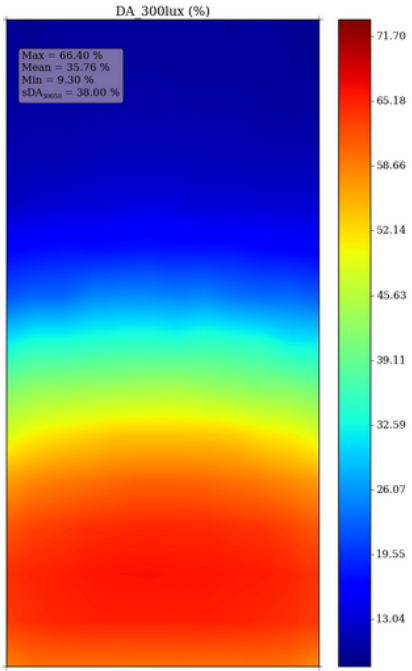
- Temporal map of daylight glare probability
- Daylight glare probability
- Vertical illuminance

Thermal

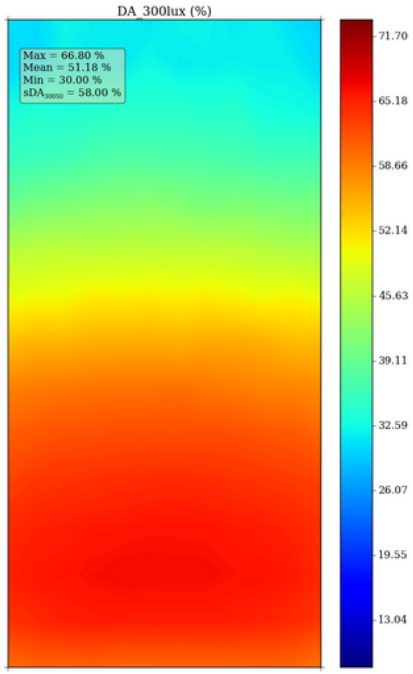
- Heating/cooling energy load
- Lighting energy load
- Transmitted solar irradiance
- Bar plot: lighting, heating and cooling energy demand



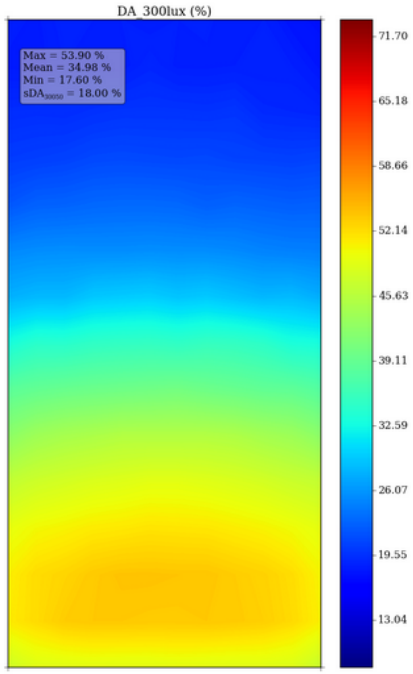
Reference



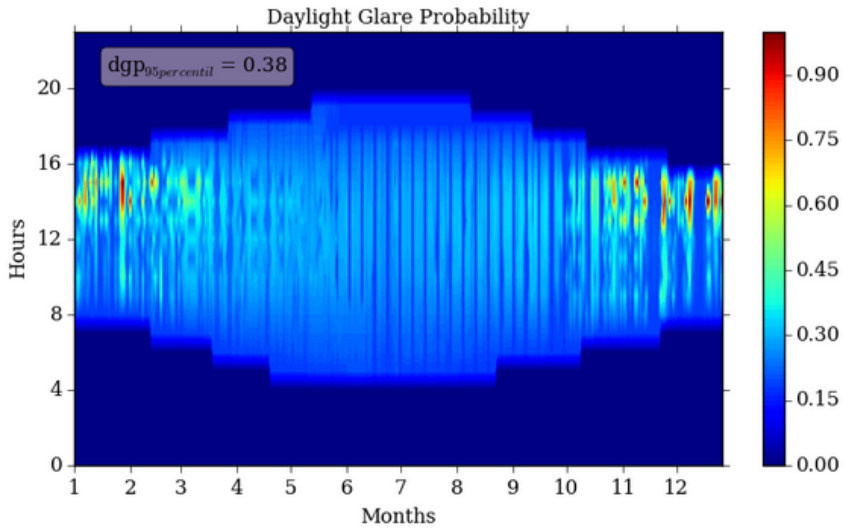
radiation



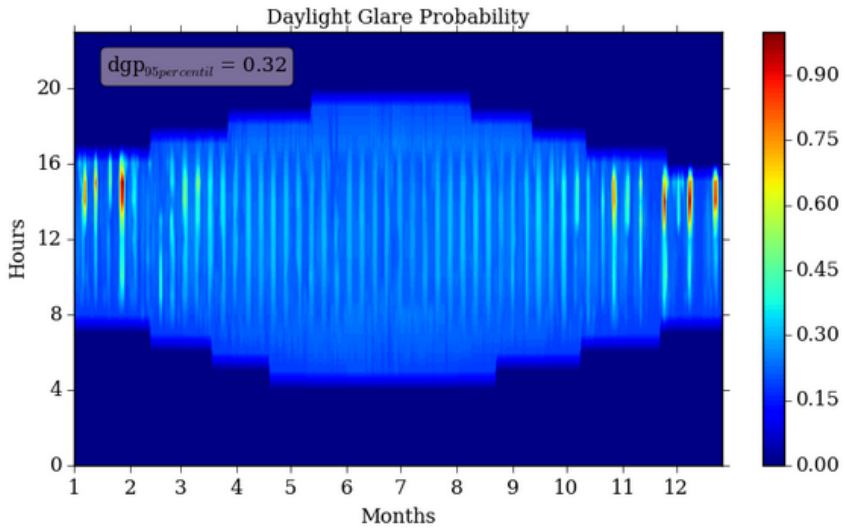
daylight



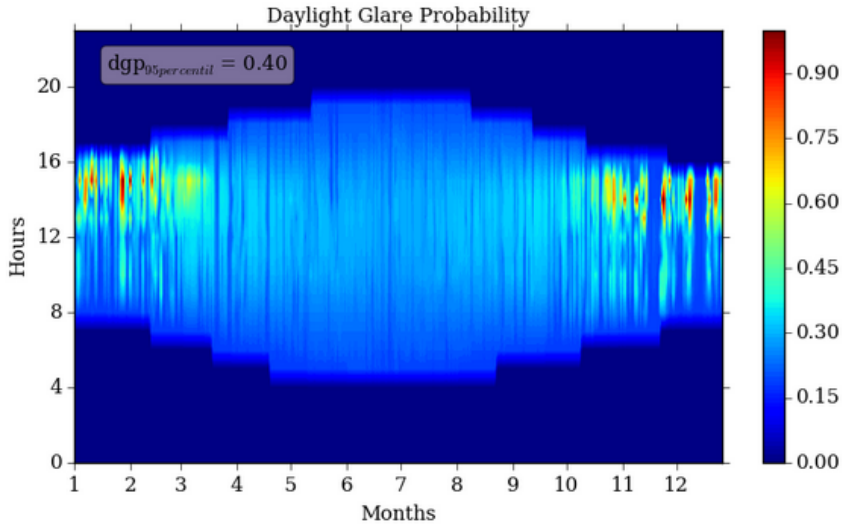
temp



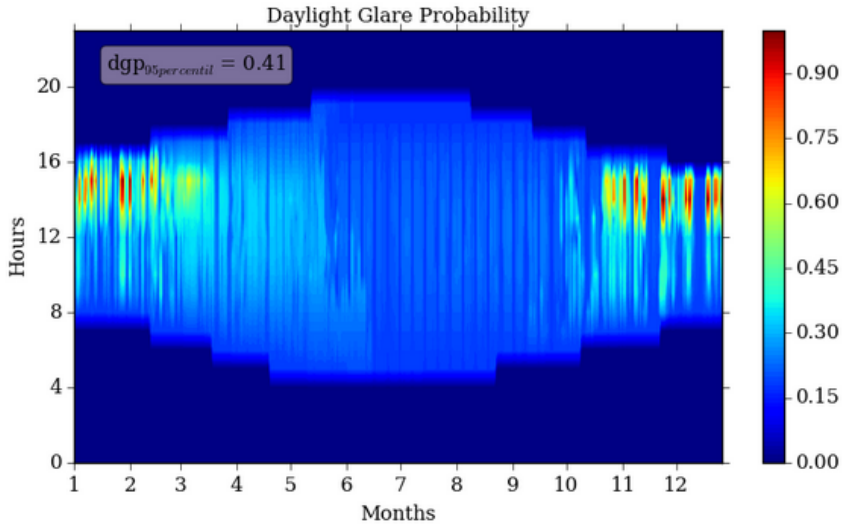
Reference



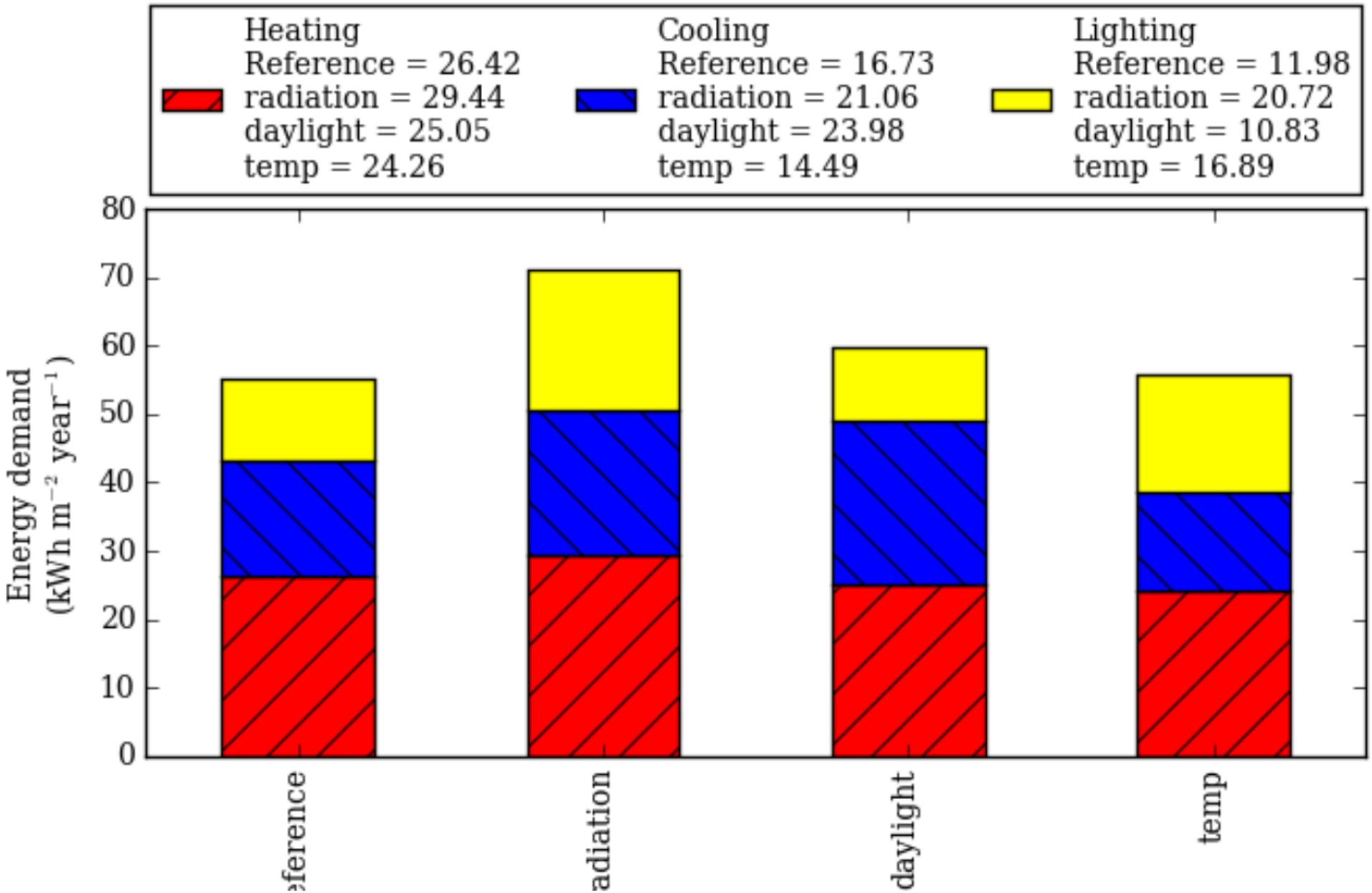
radiation



daylight



temp


Heating
Reference = 26.42
radiation = 29.44
daylight = 25.05
temp = 24.26
Cooling
Reference = 16.73
radiation = 21.06
daylight = 23.98
temp = 14.49
Lighting
Reference = 11.98
radiation = 20.72
daylight = 10.83
temp = 16.89
Energy demand
(kWh m^{-2} year^{-1})
0
10
20
30
40
50
60
70
80
eference
adiation
daylight
temp

FENER-WEBPORT: Highlights

- Specific for the evaluation of fenestration systems and their control
- Allows the assessment of advanced shading control strategies
- Allows the evaluation of a broad variety of fenestration systems
- Allows a permanent communication between numerical models and measurements

FENER-WEBPORT: Highlights

- Specific for the evaluation of fenestration systems and their control
- Allows the assessment of advanced shading control strategies
- Allows the evaluation of a broad variety of fenestration systems
- Allows a permanent communication between numerical models and measurements

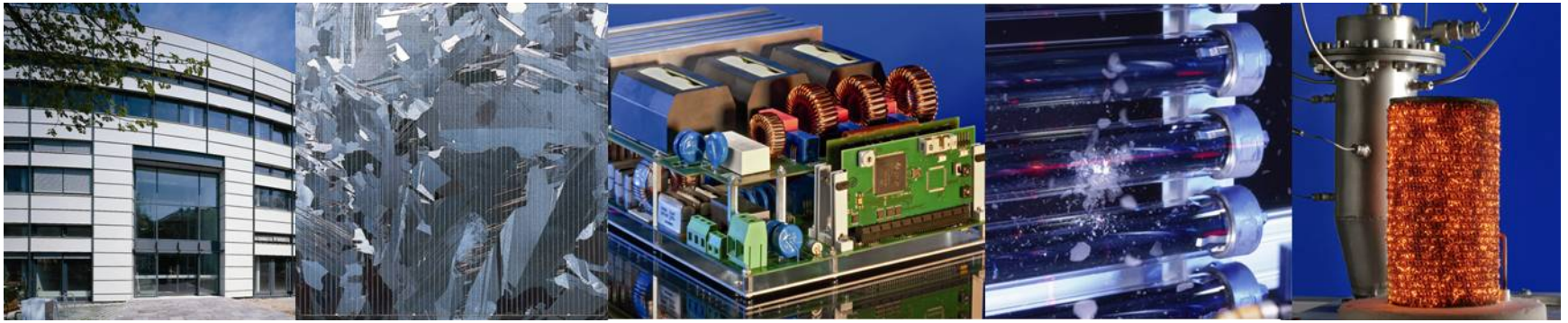
- Simplicity vs Flexibility

Essential for a correct interpretation of model results and to avoid human and numerical errors

FENER-WEBPORT: Next steps

- Import geometry in IFC format (Building-Information-Modeling compatible)
- Link with Complex Glazing and Shading Database CGDB

Thank you for your attention!



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