
Bartenbach
research & development

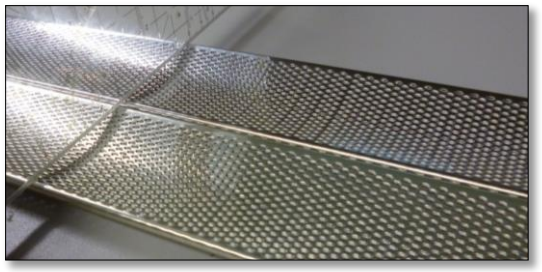
DALEC

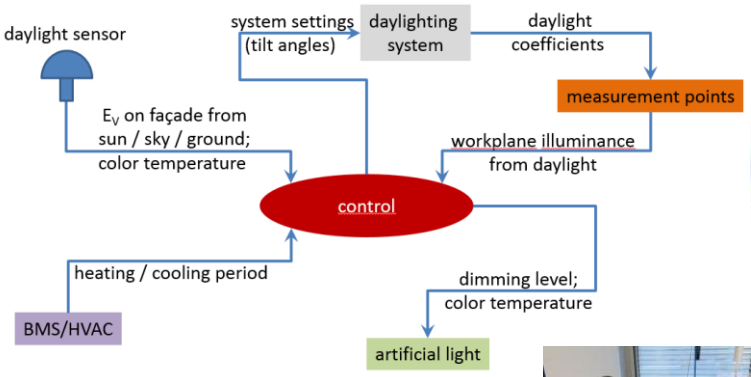
Day- and Artificial Light with Energy Calculation

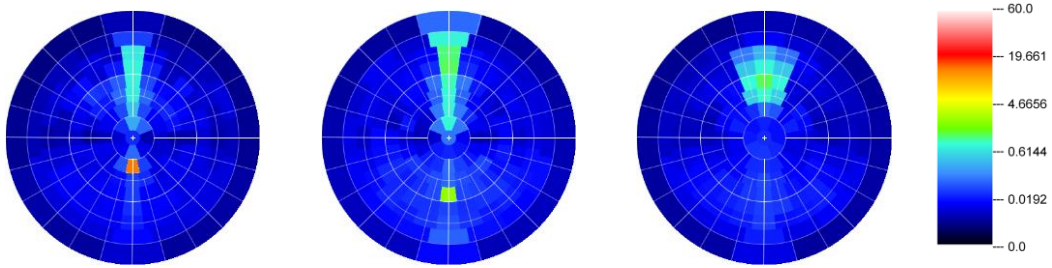
Motivation 1

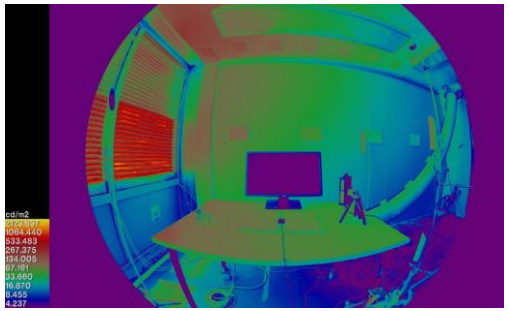
Research Project „Integrated Day- and Artificial Light“

(see talk from 2012 workshop…)

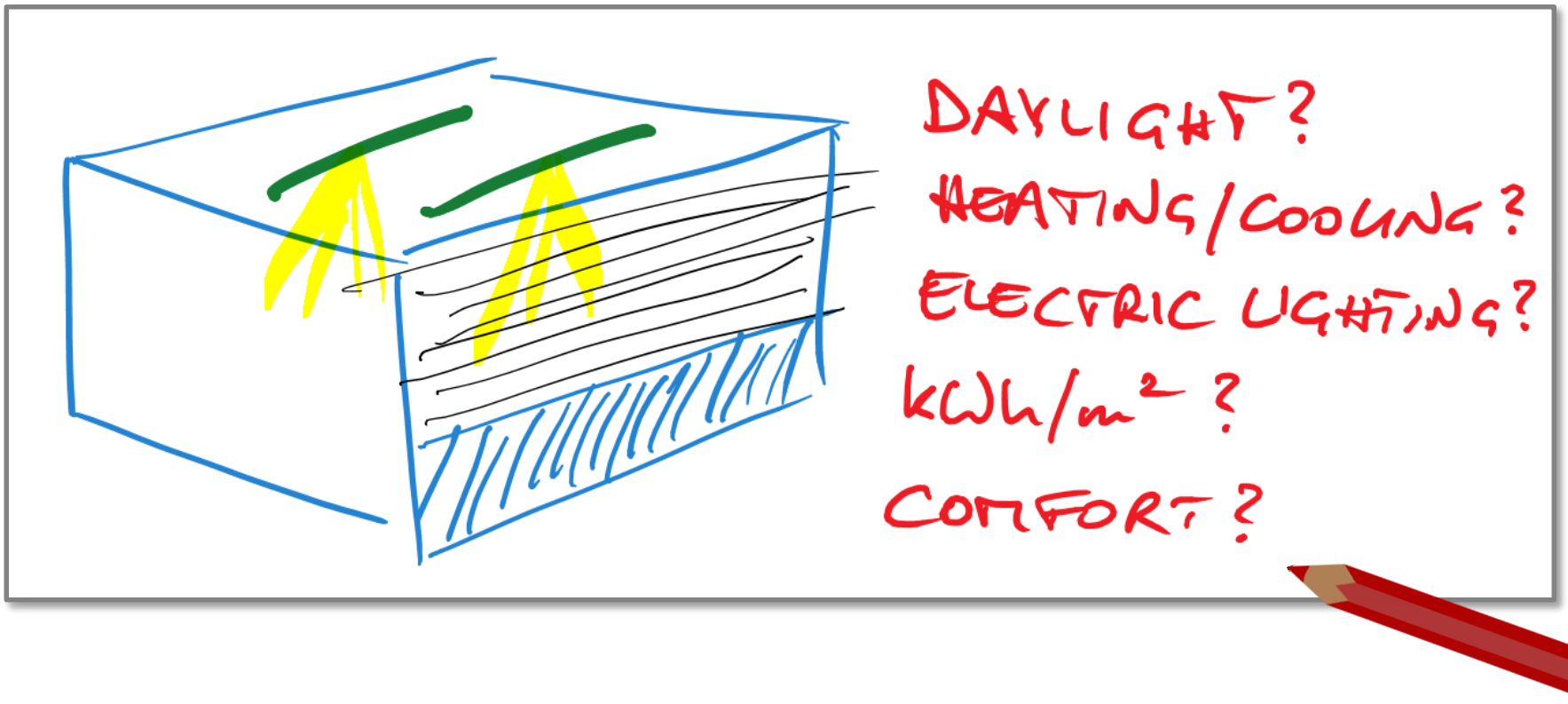




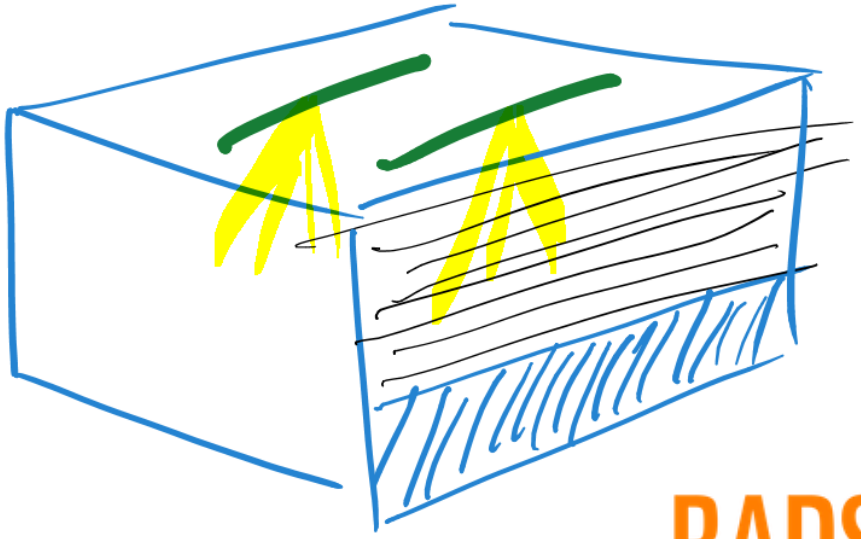




Motivation 2



Motivation 2



DIALux
made by DIAL.

EnergyPlus

RADSITE | radiance-online.org

RELUX
light simulation tools

TRNSYS 17

AGi32
lighting software
by Lighting Analysts

Vision

Evaluation of

- façade and
- electric lighting systems

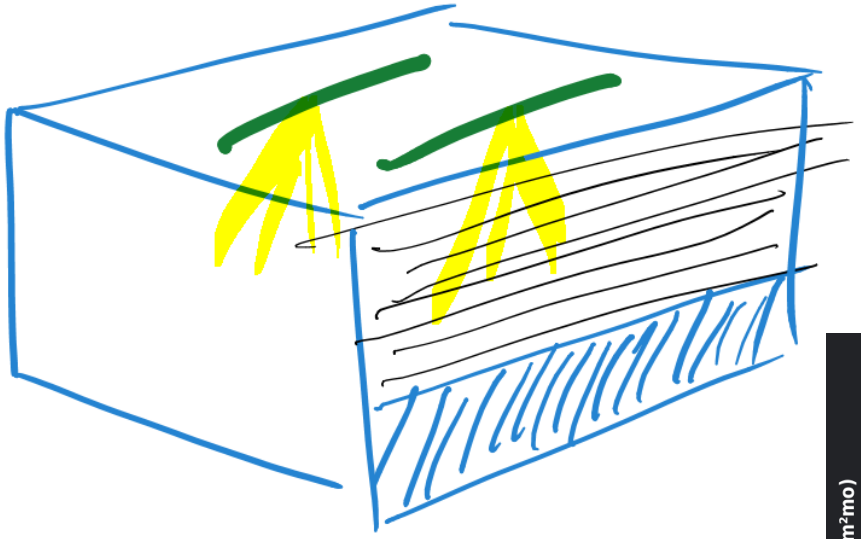
in early design phases for

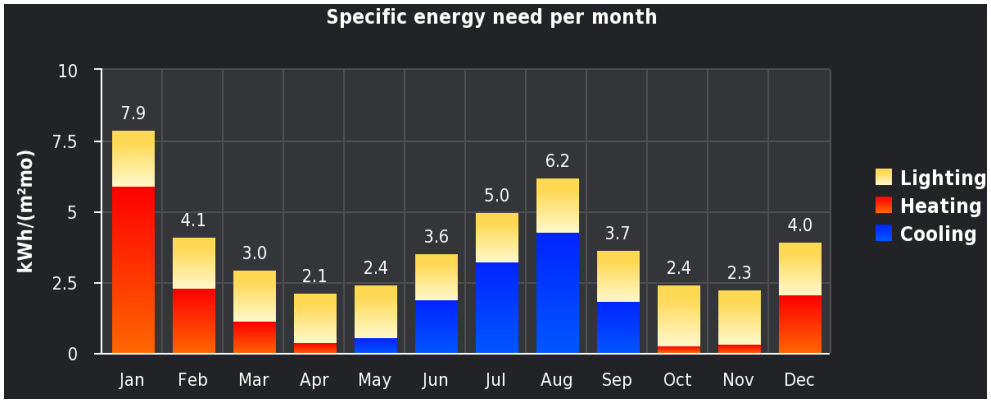
- annual daylighting
- annual demand for electric lighting
- annual demand for heating and cooling
- visual and thermal user comfort

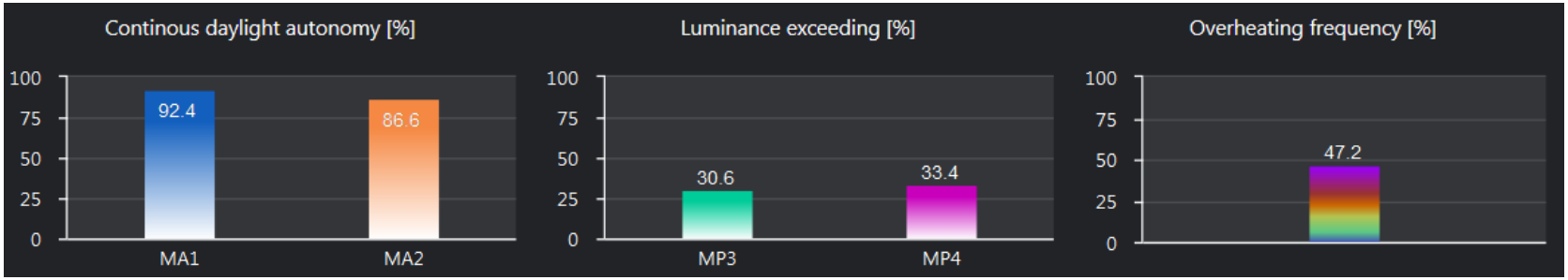
by means of a tool with

- simple input and
- short calculation times
- that can be handeled without strong expertise.

Vision




Specific energy need per month
kWh/(m²mo)
10
7.5
5
2.5
0
7.9
4.1
3.0
2.1
2.4
3.6
5.0
6.2
3.7
2.4
2.3
4.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Lighting
Heating
Cooling


Continous daylight autonomy [%]
100
75
50
25
0
92.4
86.6
MA1
MA2
Luminance exceeding [%]
100
75
50
25
0
30.6
33.4
MP3
MP4
Overheating frequency [%]
100
75
50
25
0
47.2

DALEC

Day- and Artificial Light with Energy Calculation

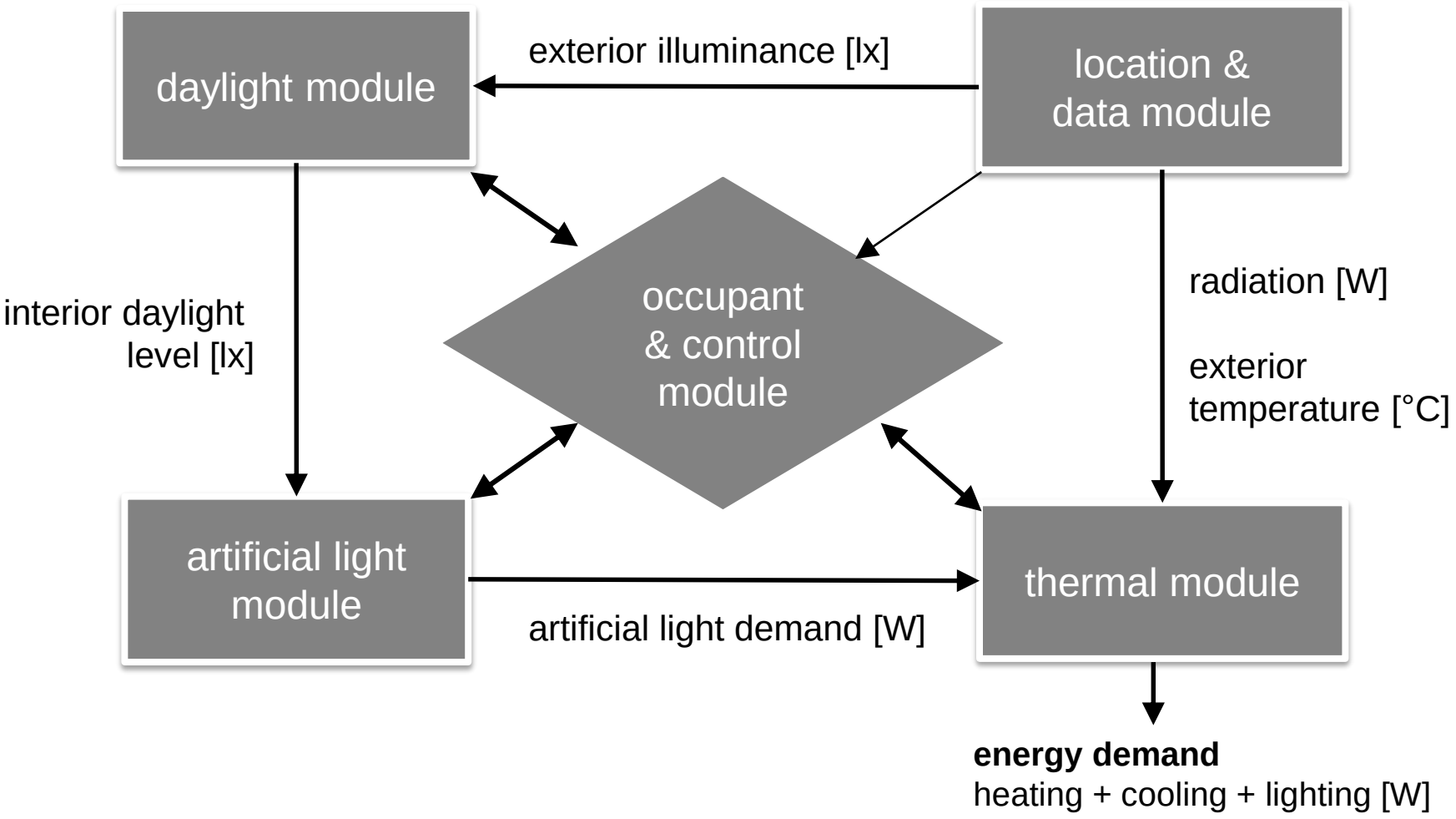
online concept evaluation tool for holistic lighting design

Bartenbach
David Geisler-Moroder

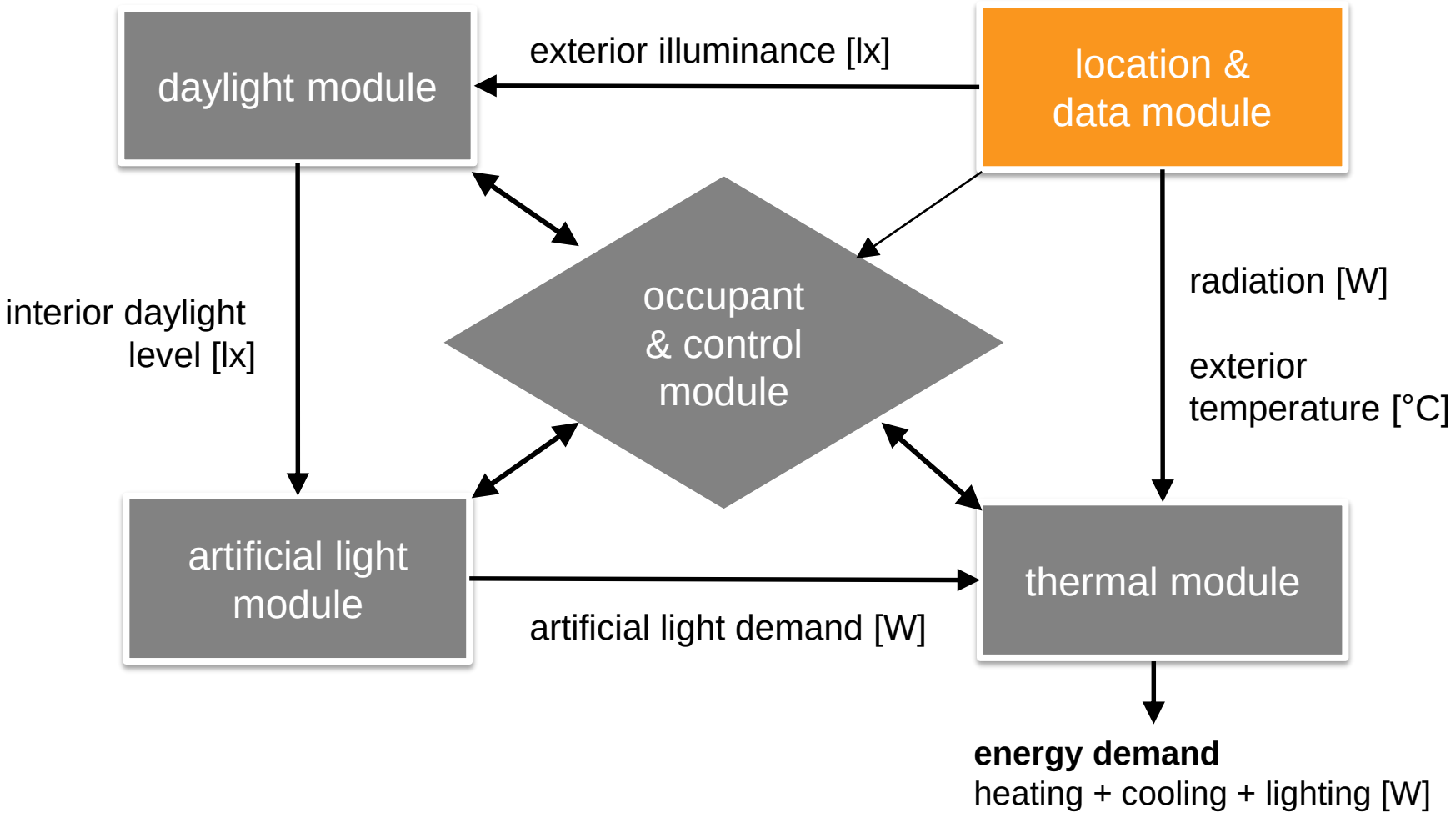
universität innsbruck
Matthias Werner

ZUMTOBEL
Bert Junghans
Oliver Ebert

Concept


daylight module
exterior illuminance [lx]
location &
data module
occupant
& control
module
interior daylight
level [lx]
radiation [W]
exterior
temperature [°C]
artificial light
module
artificial light demand [W]
thermal module
energy demand
heating + cooling + lighting [W]

Concept


daylight module
exterior illuminance [lx]
location & data module
occupant & control module
interior daylight level [lx]
radiation [W]
exterior temperature [°C]
artificial light module
artificial light demand [W]
thermal module
energy demand
heating + cooling + lighting [W]

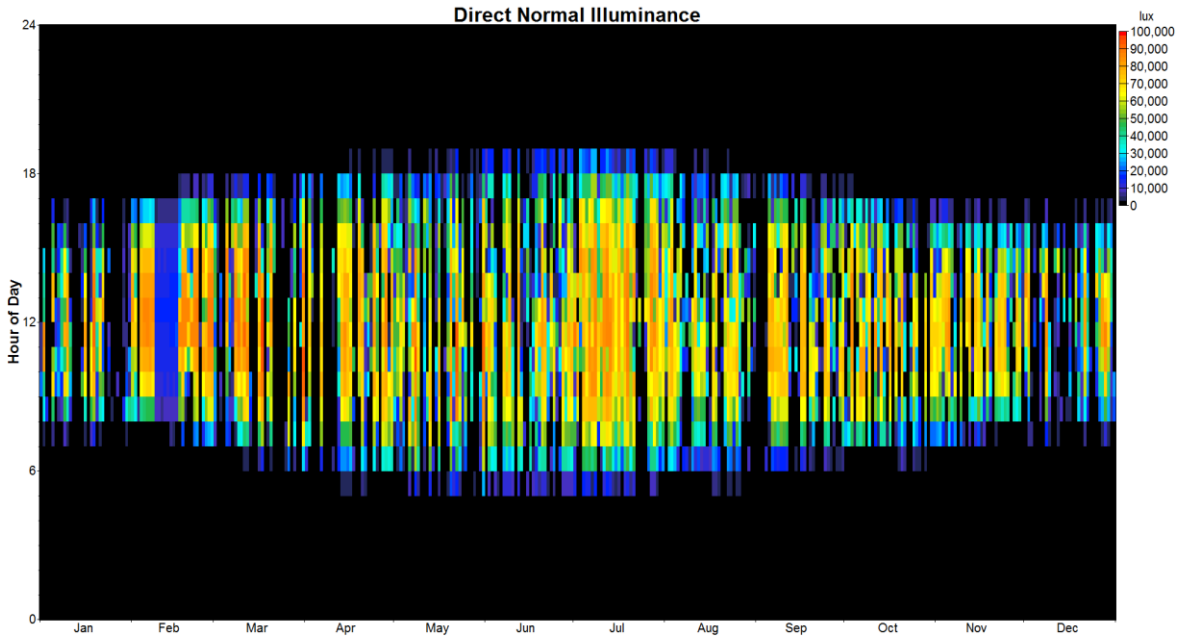
Location & Data Module

DALEC calculations are based on

- **IWEC2**
- **TMY3** and
- **CWEC**

weather data sets for

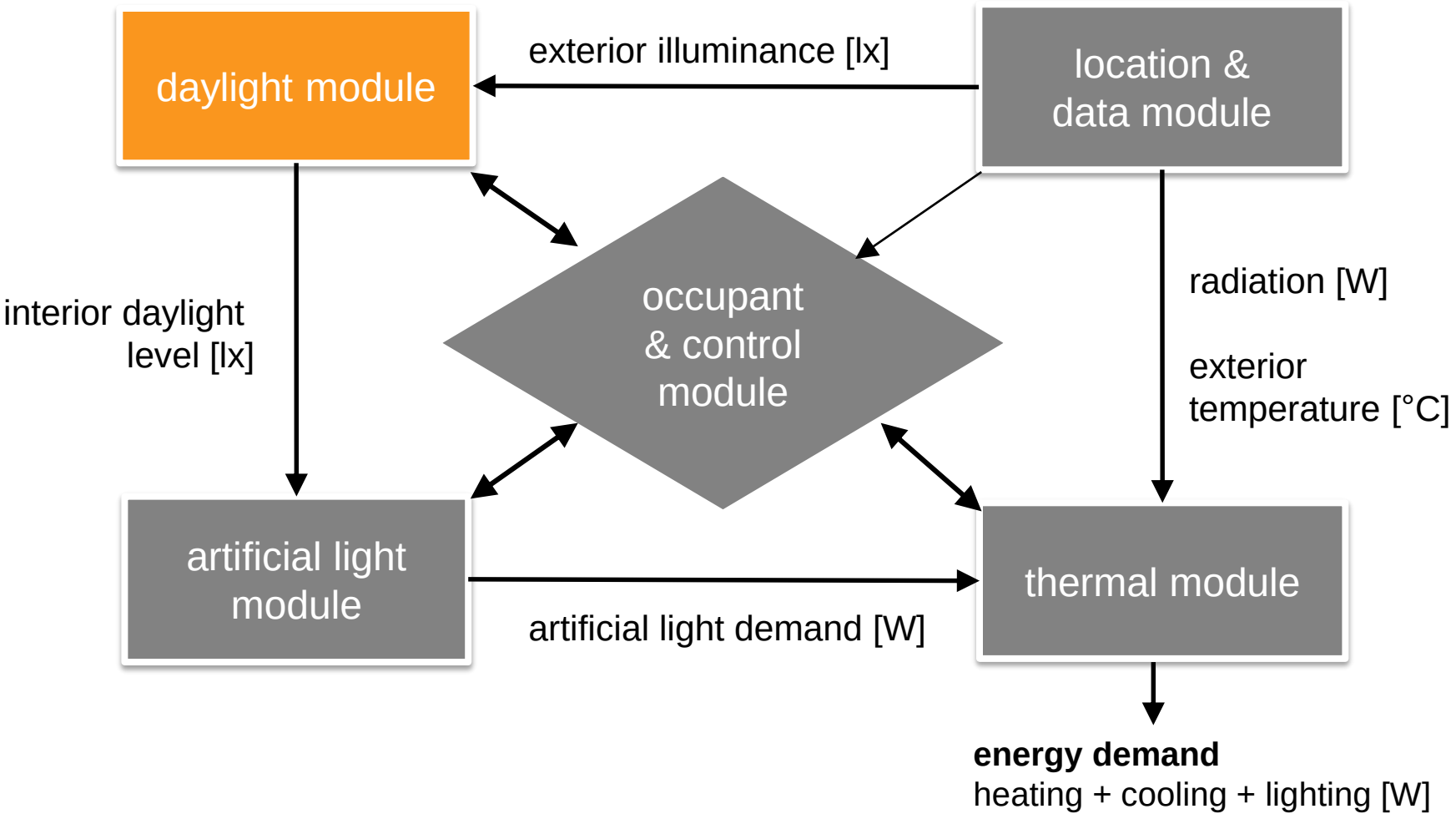
- **> 3100 sites** worldwide



Data used:

- Location → daylight module
- Horizontal illuminance [lx] (diffuse, direct) → daylight module
- Irradiation [W/m²] (diffuse, beam) → occupant & control
- Outdoor temperature [°C] → thermal module

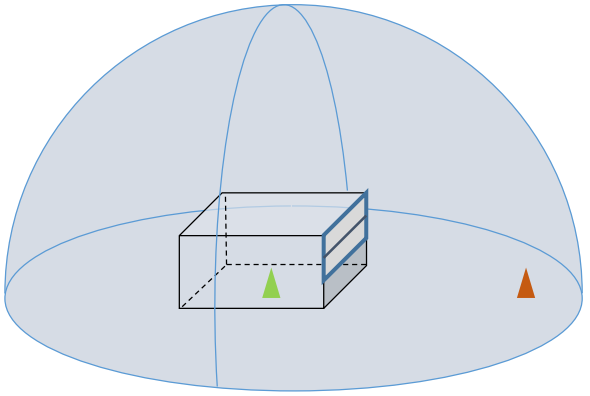
Concept


daylight module
exterior illuminance [lx]
location &
data module
occupant
& control
module
interior daylight
level [lx]
radiation [W]
exterior
temperature [°C]
artificial light
module
artificial light demand [W]
thermal module
energy demand
heating + cooling + lighting [W]

Daylight Module

Daylight coefficient approach

- 1 factor for diffuse sky
- 145 sun factors (Tregenza / CIE 108-1994)

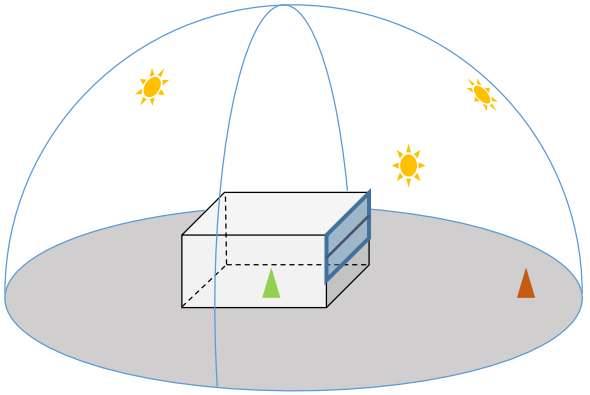


$f_D = E_{measurement\ point} / E_{h,\ exterior,\ diffuse\ sky}$

Time step evaluation

$$E_{measurement\ point} = f_D * E_{h,\ diffuse} + f'_S * E_{h,\ direct}$$

f'_D	factor for diffuse sky
$E_{h,diffuse}$	diffuse illuminance from weather data
f'_S	sun factor for current sun position
$E_{h,direct}$	direct illuminance from weather data



$f^i_S = E_{measurement\ point} / E_{h,\ exterior,\ sun\ position\ i}$

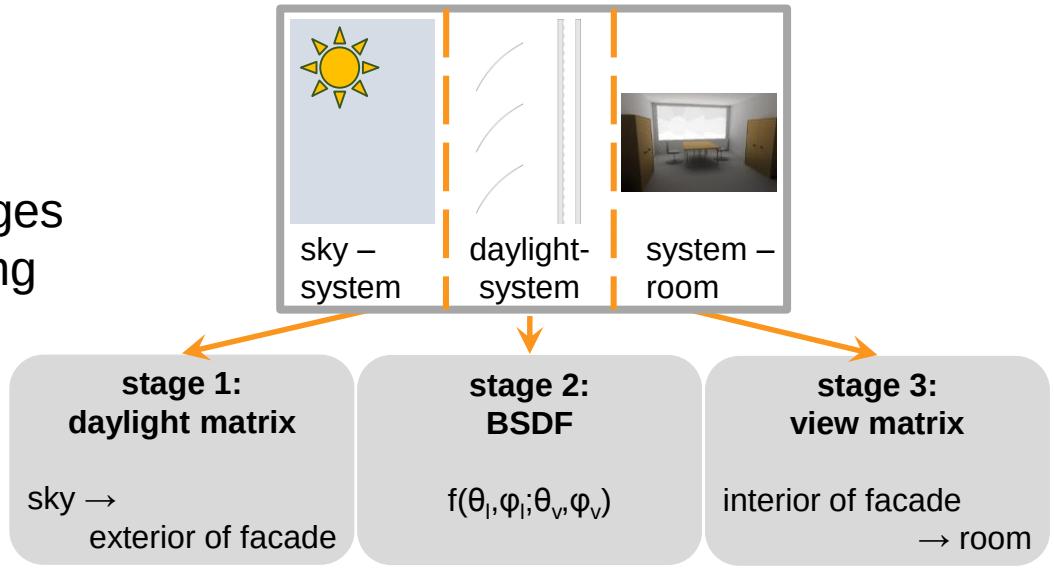
for i = 1, … ,145

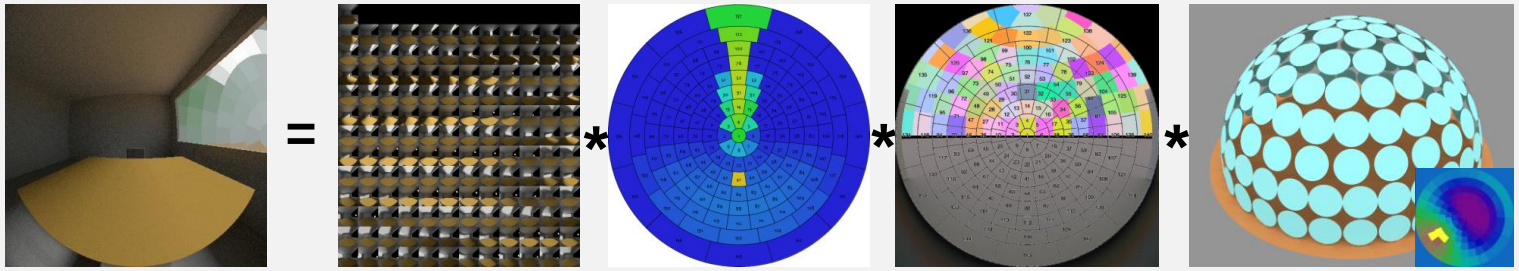
Daylight Module

Factor calculation using the 3-phase-method

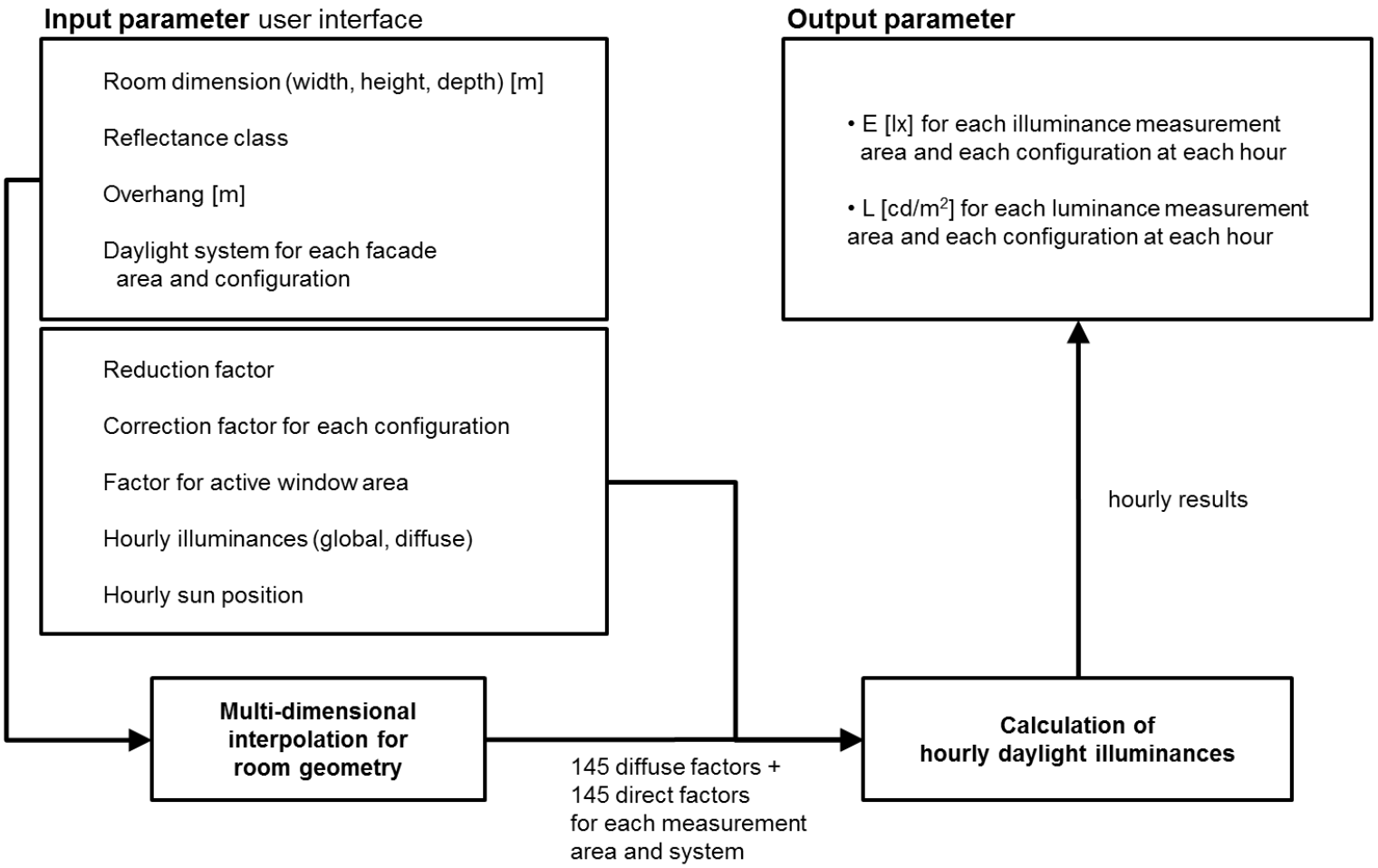
(thanks to G.W. and A.McN.!)

- division of flux transfer into 3 stages
- time consuming simulations during pre-calculation
- fast calculation for single sky distributions
- factors stored in database



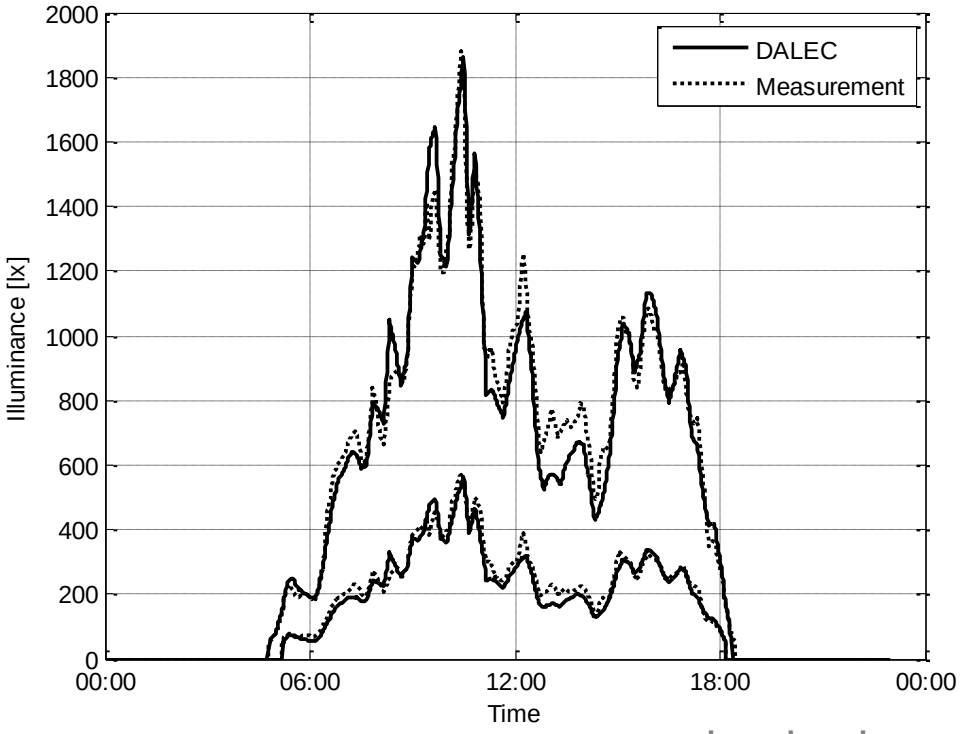


Daylight Module



Daylight Module

Validation



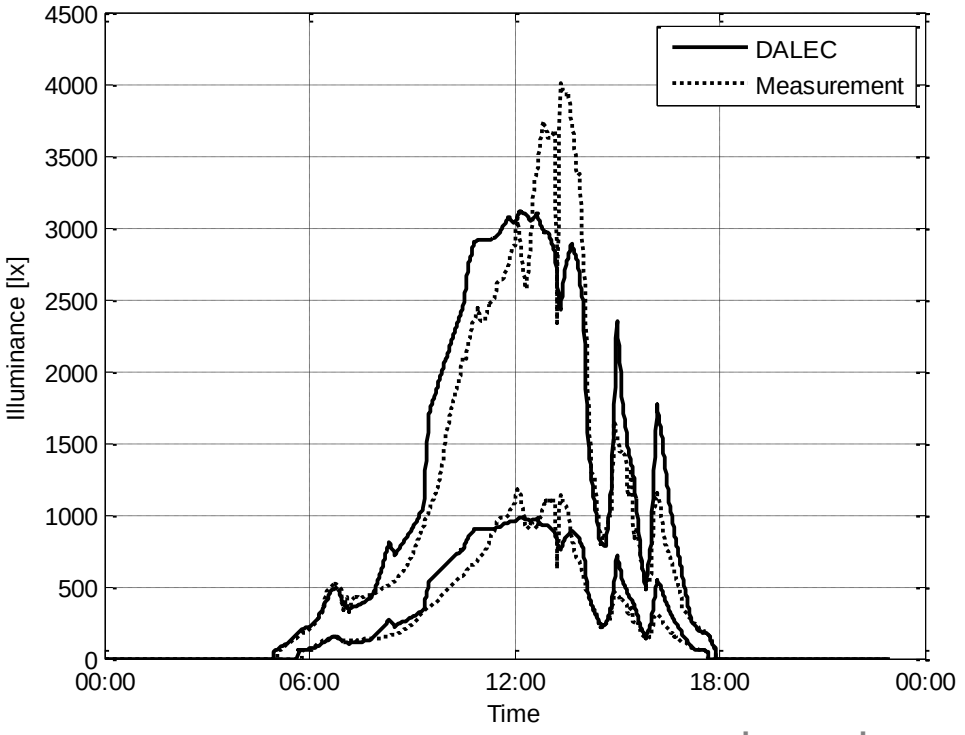
cloudy sky

Comparison measurement vs. DALEC simulation

- **Monitoring** in course of research project „Integrated Day- and Artificial Light“
- **Illuminance calculation with DALEC** based on measured exterior levels

Daylight Module

Validation

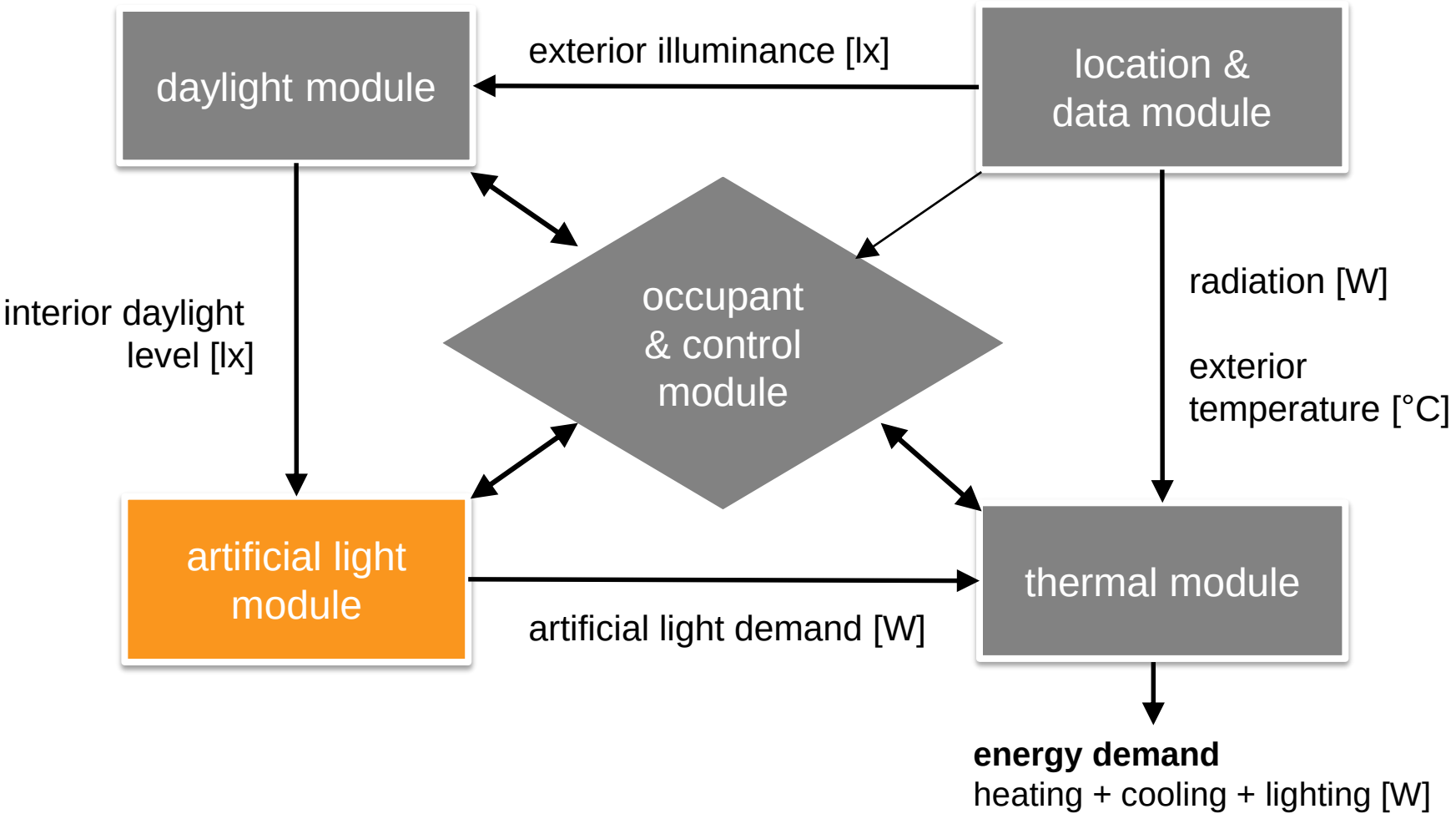


clear sky

Comparison measurement vs. DALEC simulation

- **Monitoring** in course of research project „Integrated Day- and Artificial Light“
- **Illuminance calculation with DALEC** based on measured exterior levels

Concept


daylight module
exterior illuminance [lx]
location & data module
occupant & control module
interior daylight level [lx]
radiation [W]
exterior temperature [°C]
artificial light module
artificial light demand [W]
thermal module
energy demand
heating + cooling + lighting [W]

Artificial Light Module

Lumen efficiency method for

- number of luminaires
- resulting average illuminance

Database with precalculated factors for

- normalized lumen output

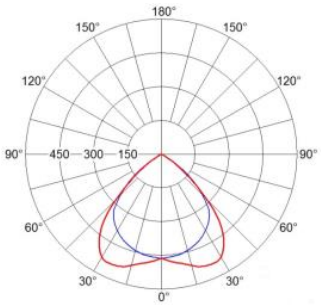
Input

- required illuminance
- flux and power per luminaire
- maintenance factor
- direct light ratio
- lamp dimming characeristic
- switching mode

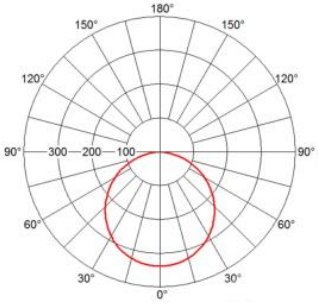
Available light intensity distributions

Direct

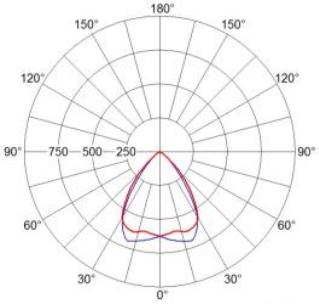
wide beam



diffuse

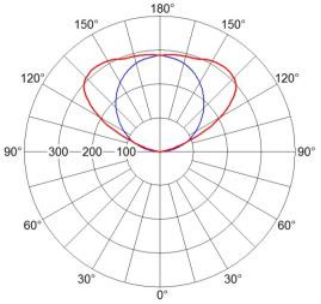


narrow beam

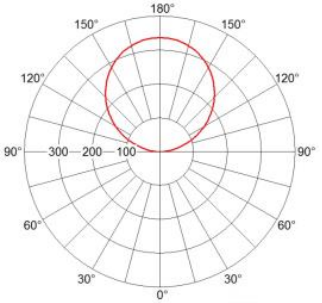


Indirect

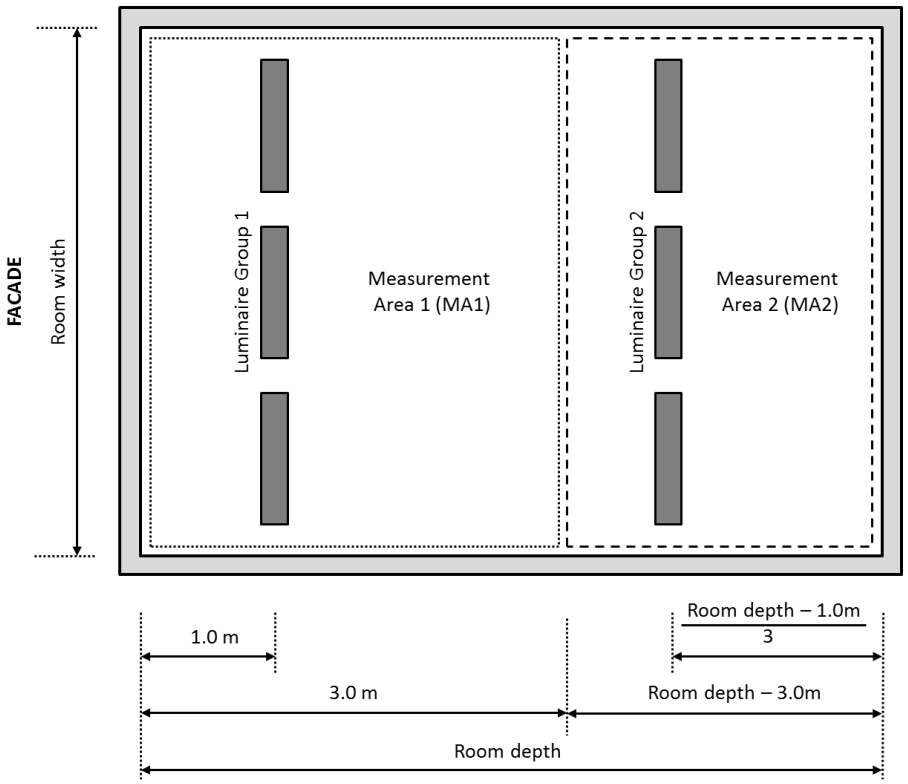
wide beam



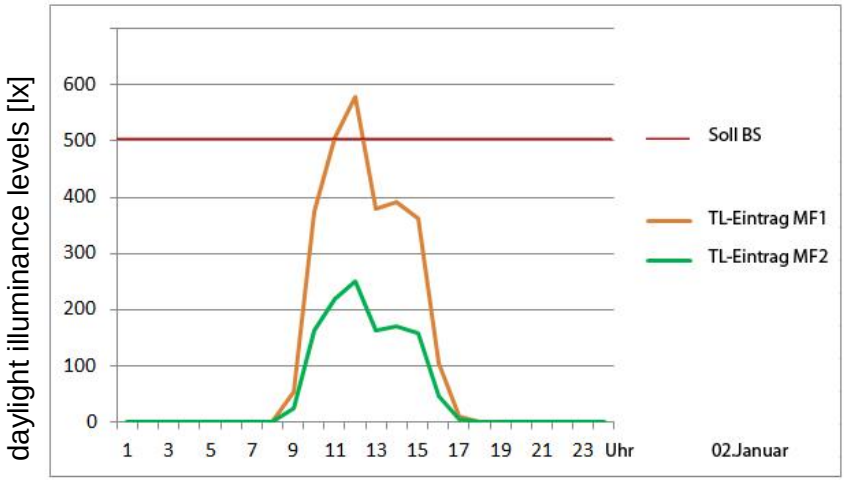
diffuse

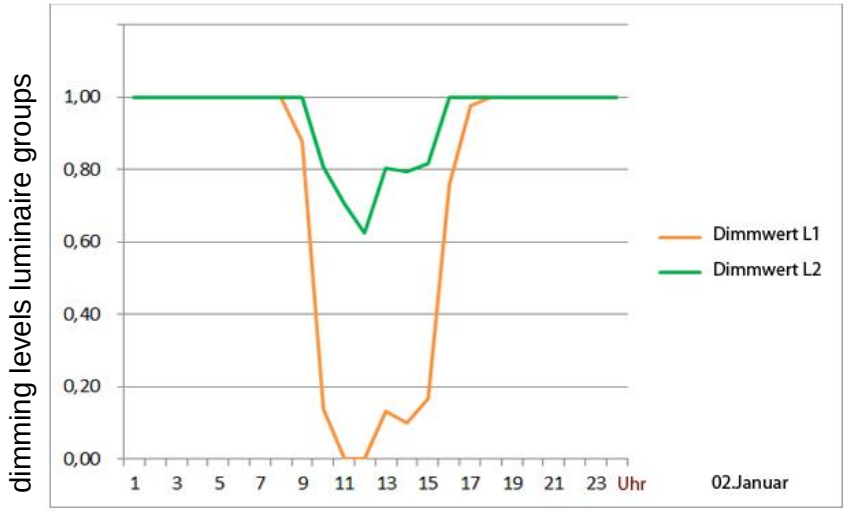


Artificial Light Module

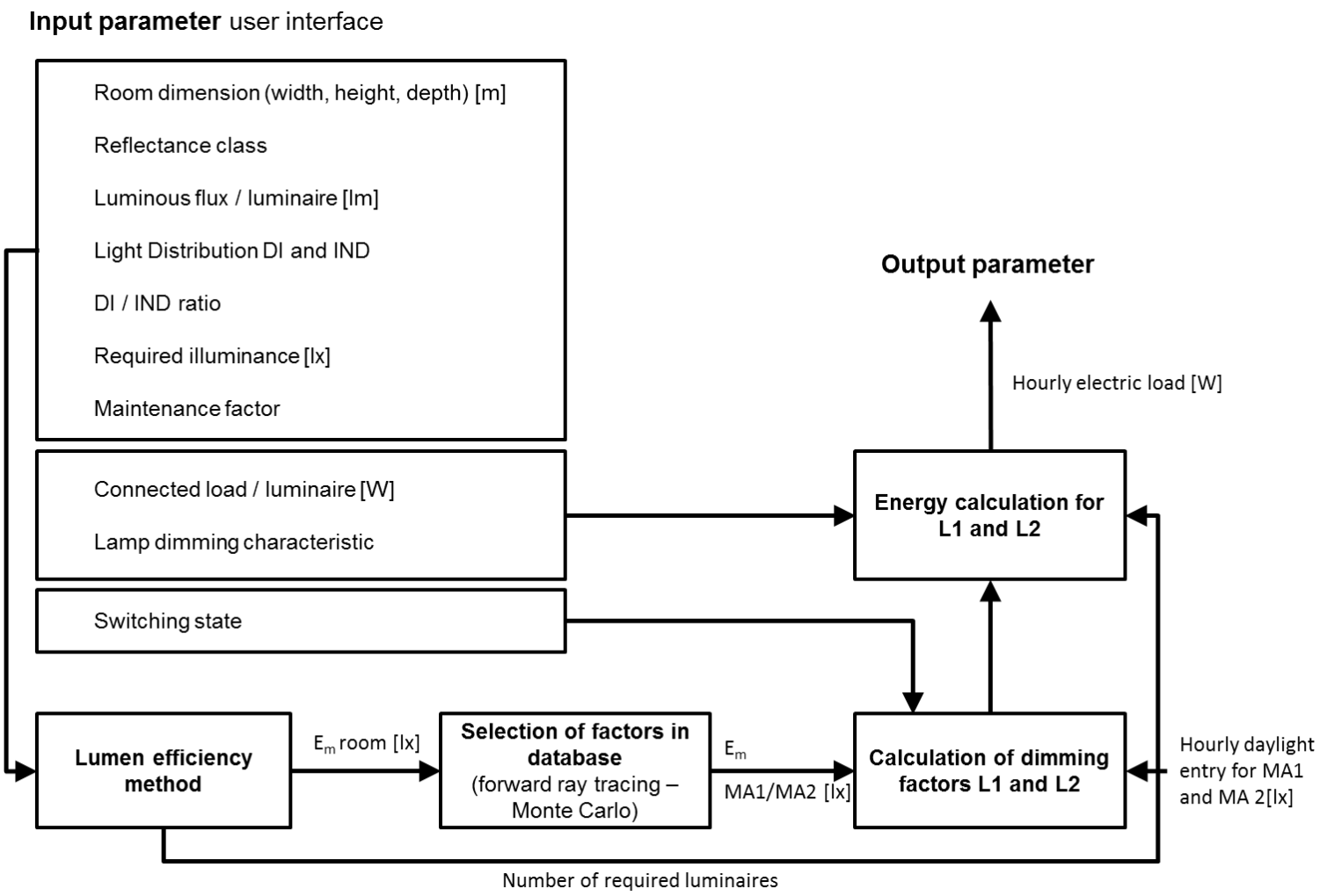


Measurement areas (for daylight and artificial light) and luminaire positions

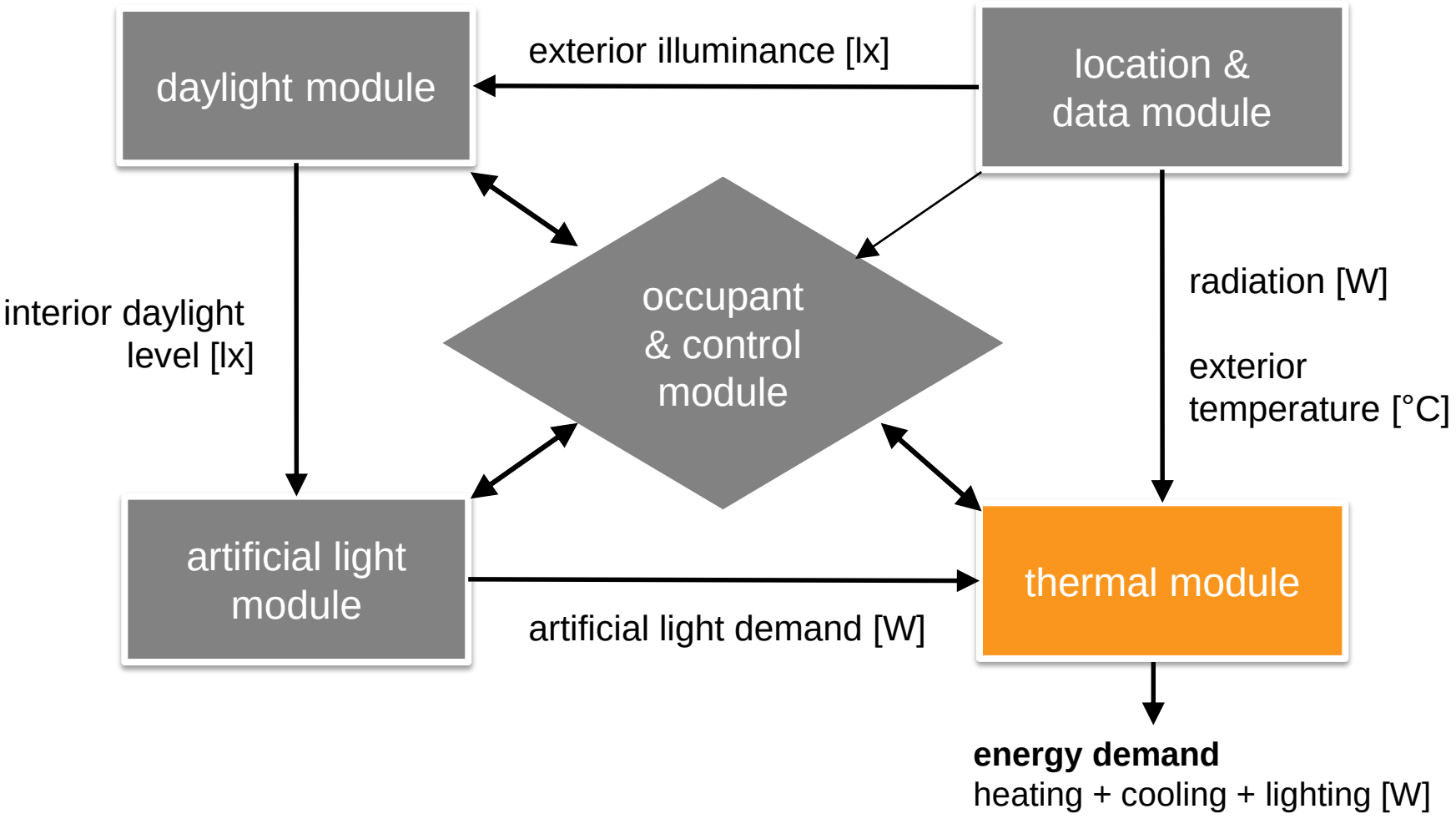




Artificial Light Module



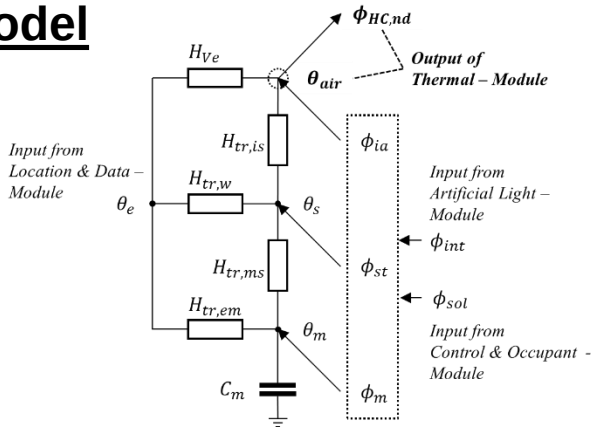
Concept


daylight module
exterior illuminance [lx]
location & data module
occupant & control module
interior daylight level [lx]
radiation [W]
exterior temperature [°C]
artificial light module
artificial light demand [W]
thermal module
energy demand
heating + cooling + lighting [W]

Thermal Module

Dynamic building model

- **EN ISO 13790**
- default values

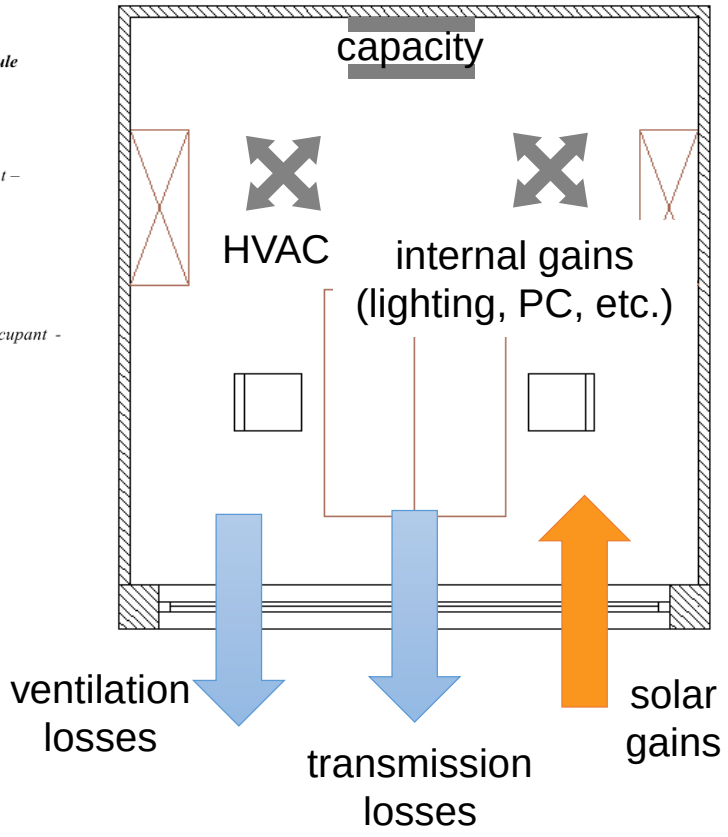


Input:

- weather data
- **artificial light** (internal gains)
- **solar heat gain** (through facade)

Output:

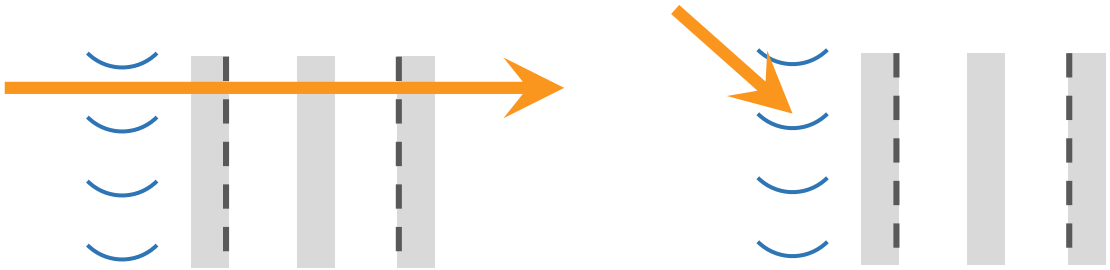
- **energy demand for heating and cooling**
- interior temperatures
- overheating frequency



Thermal Module

Thermal characterisation of the facade system

- **angular dependency** known for glazings
- unkown for daylight systems → cannot be neglected



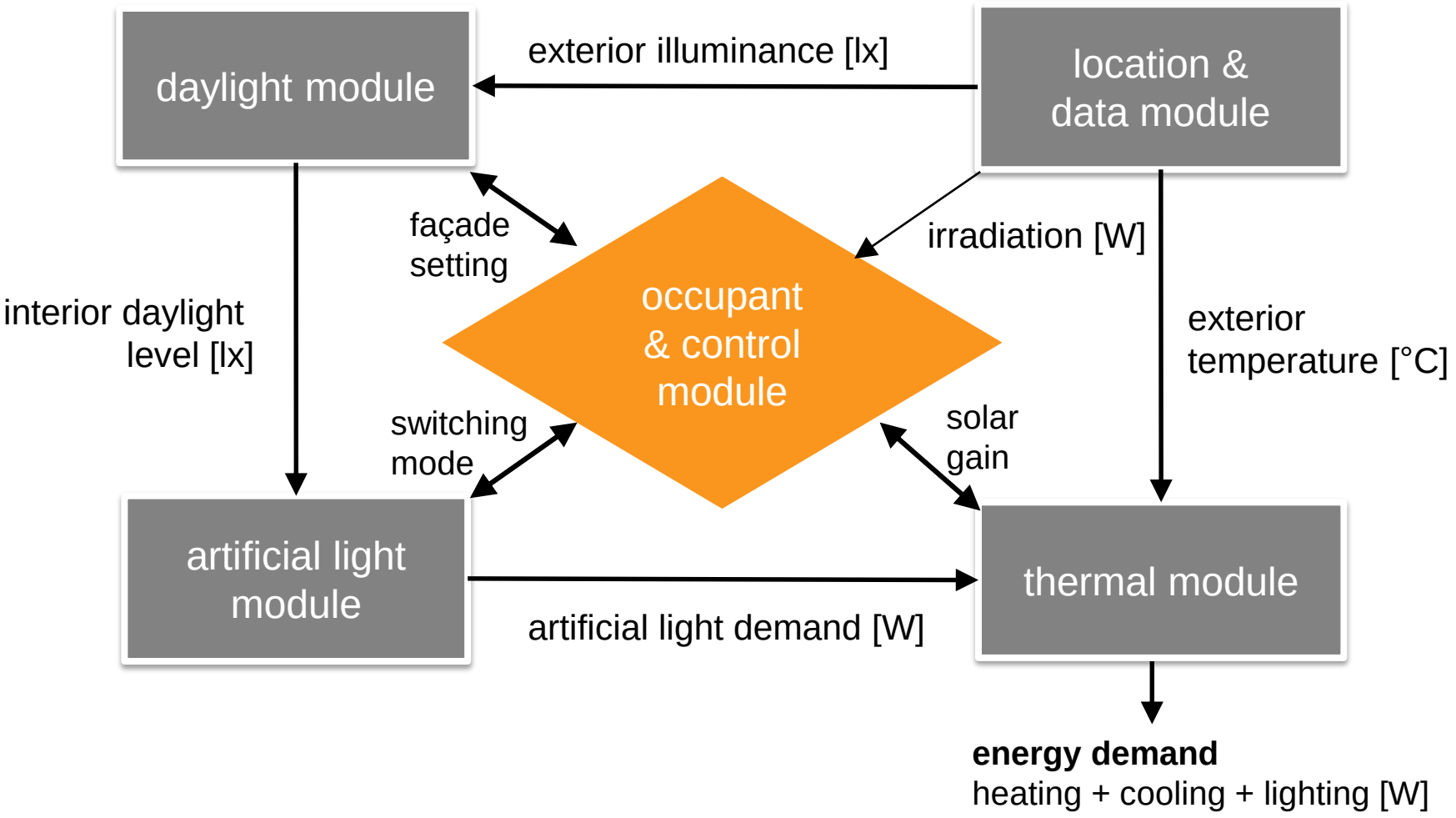
Database:

- angular dependent SHGC (145 Klems directions)

Input:

- SHGC of glazing at normal incidence

Concept


daylight module
exterior illuminance [lx]
location &
data module
façade
setting
irradiation [W]
interior daylight
level [lx]
occupant
& control
module
exterior
temperature [°C]
switching
mode
solar
gain
artificial light
module
thermal module
artificial light demand [W]
energy demand
heating + cooling + lighting [W]

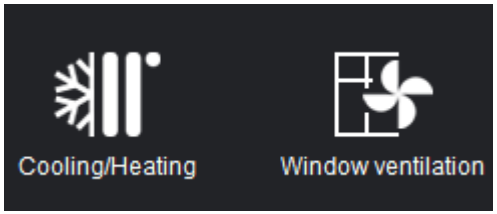
Occupant & Control Module

Thermal control:

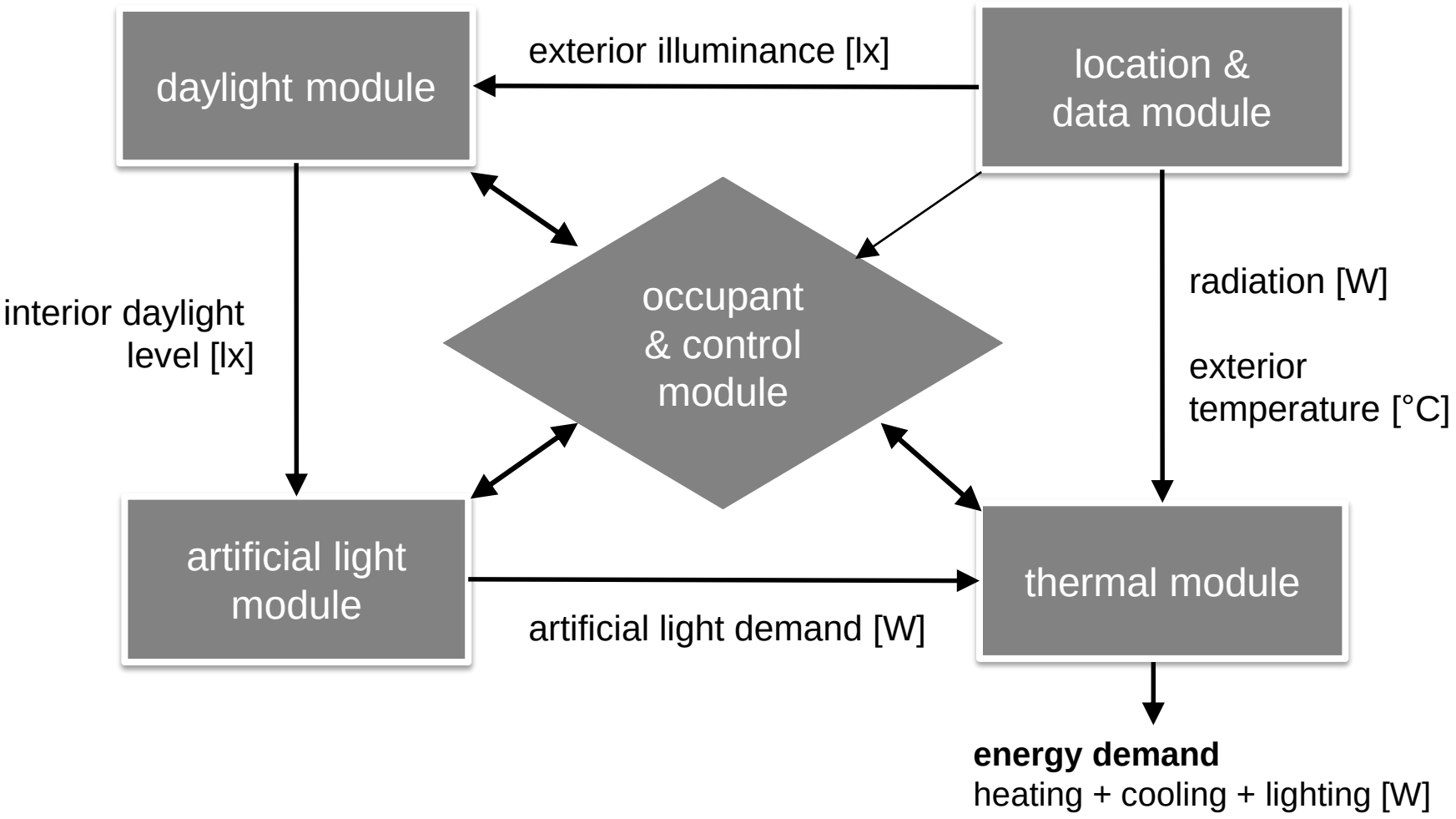
- **radiation limit at façade (outside)** → façade setting
- **interior temperature** → heating / cooling / night ventilation

DALEC controls mimicking occupants:

- **luminance threshold at façade (inside)** → façade setting
- **interior temperature** → window ventilation



Concept


daylight module
exterior illuminance [lx]
location &
data module
occupant
& control
module
interior daylight
level [lx]
radiation [W]
exterior
temperature [°C]
artificial light
module
artificial light demand [W]
thermal module
energy demand
heating + cooling + lighting [W]

DALEC Excel Prototype

dalec.xlsx

DALEC

Day- & Artificial Light + Energy Calculation

05.06.2014 | Eingabefeld | Berechnungsfeld | Deutsch

Allgemeine Parameter

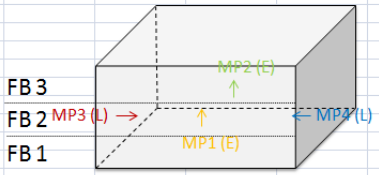
Raumbreite	5	2.5 - 10m
Raumtiefe	5	4 - 8m
Raumhöhe	3	2-4m
Reflexionsgrad Umgebungsflächen (Decke/Wand/Boden)	2	1 = dunkel (70/50/20); 2 = mittel (80/50/20); 3=hell (90/60/40)
Überstand	1	0-2m
Abminderungsfaktor	0,8	
horizontale Verbauung	0	0 - 45°
Orientierung	180	0°=Nord; 90 = Ost; 180° = Süd; 270° = West;

	Beginn	Ende	
Belegungszeit	8	18	Uhr
Werktage pro Woche	5	d	
Sommerzeit	ja		

Anfang Kühlperiode [d]: 100
Ende Kühlperiode [d]: 300

Fassadengestaltung

Bezeichnung Fassadensystem ID:
0: opak
1: kein System (nur Verglasung)
2: klarer Screen
3: diffuser Screen
4: Außenraffstore (fix 0°)
5: Außenraffstore (fix 45°)
6: Außenraffstore (Cut-Off-Steuerung)
7: Umlenklamelle + Prallscheibe (fix 0°)
8: Umlenklamelle + Prallscheibe (Cut-Off)
9: Umlenklamelle + Prallscheibe (Retro)



Fassadenkonfiguration	FB1 (0 - 1m) K1 ("unverschattet")	FB1 (0 - 1m) K2 ("verschattet Heizperiode")	FB1 (0 - 1m) K3 ("verschattet Kühlperiode")	FB2 (1m - 2m) K1 ("unverschattet")	FB2 (1m - 2m) K2 ("verschattet Heizperiode")	FB2 (1m - 2m) K3 ("verschattet Kühlperiode")	FB3 (2m - Raumhöhe) K1 ("unverschattet")	FB3 (2m - Raumhöhe) K2 ("verschattet Heizperiode")	FB3 (2m - Raumhöhe) K3 ("verschattet Kühlperiode")
Fassadensystem ID:	0	0	0	1	8	8	1	8	8
tau Verglasung	0,9			0,8			0,8		
g-Wert Verglasung (0.4-0.7)	0,4			0,5			0,5		
0/1 = 2-/3-Scheibenverglasung	0								
Screeneigenschaften nur bei ID 2/3 nach EN 13363-1									
tau Screen [0-0.5] nur bei System 2/3	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4
rho Screen [0.1-0.8] nur bei System 2/3	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
0/1 = außen-/ innenliegend nur bei System 2/	0	0	0	0	0	0	0	0	0
Faktor aktive Fensterflächen	0			0,8			0,5		

Schaltparameter für verschattete Fassadenkonfiguration

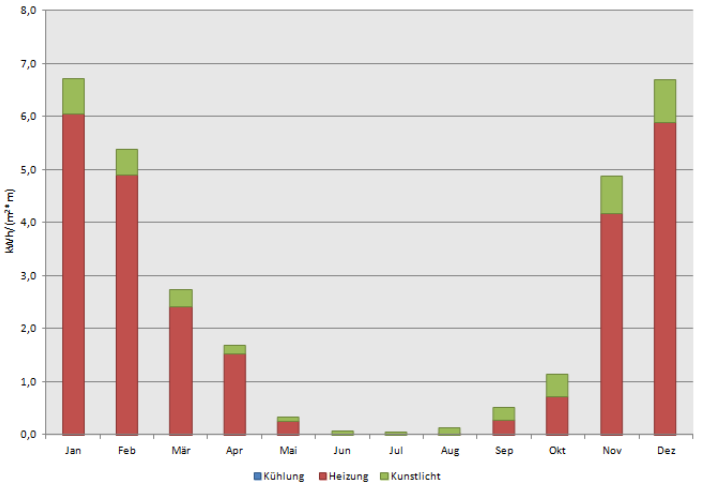
Abfragen werden mit -1 deaktiviert

Ergebnisse & Diagramme

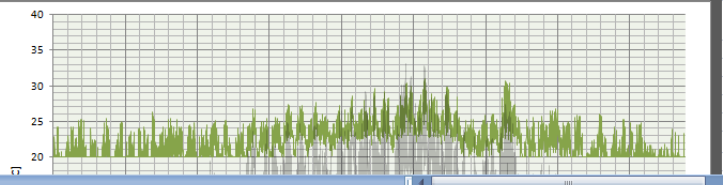
CARPET-Plots befinden sich im Blatt "Plots"

Energiebedarf Kühlung, Heizung und Kunstlicht [kWh/(m²*m)]

	Jan	Feb	Mär	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Dez	Summe
Kühlung	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Heizung	6,05	4,90	2,41	1,52	0,24	0,00	0,00	0,00	0,27	0,71	4,17	5,89	26,16
Kunstlicht	0,65	0,47	0,34	0,16	0,09	0,06	0,04	0,13	0,25	0,42	0,71	0,80	4,13
											Jahressumme		30,30



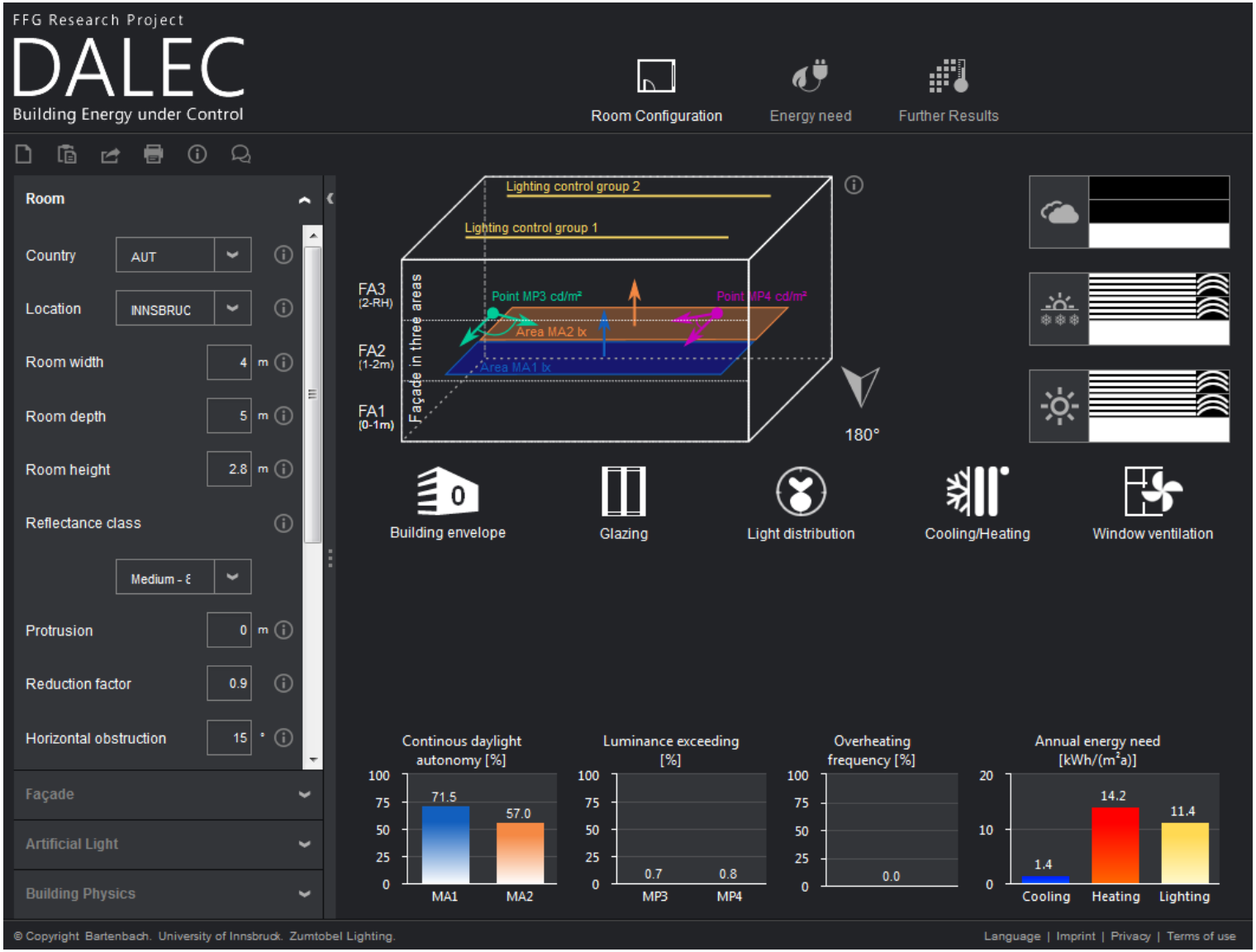
Temperaturen



Weather File | In- Output | Plots | IO_tl | IO_kl | IO_th | Calc | SHGC_Calc | SHGC-2 | SHGC-3 | Languages | epw_IBK | epw_Sydney

DALEC Online Tool

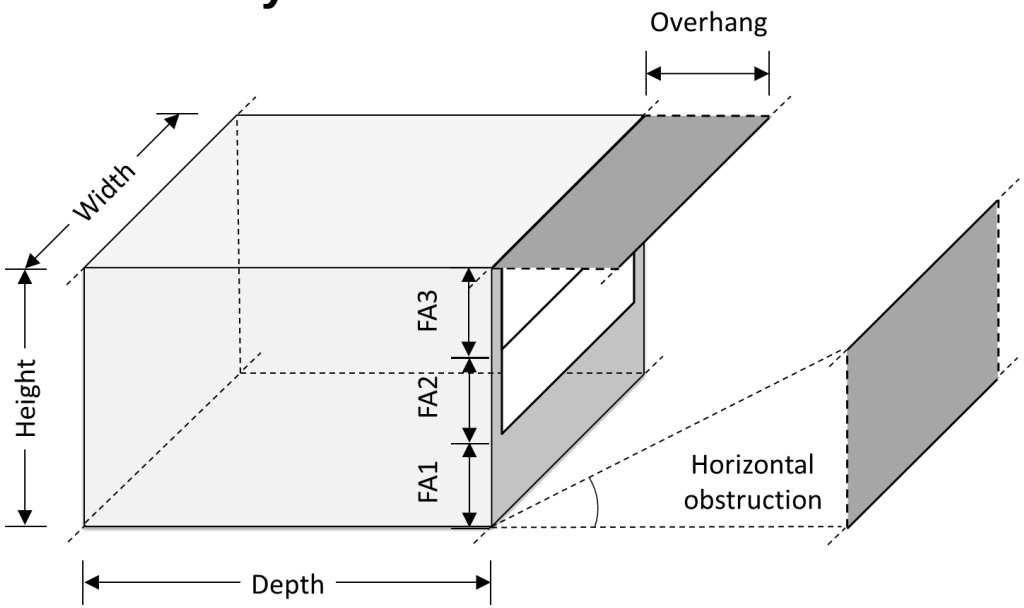
www.dalec.net



DALEC Online Tool

Inputs

Geometry



Facade (3 areas):

- opaque
- glazing
- glazing +
  - screens
    (int./ext., diffuse/clear)
  - venetian blinds
    (fix 0°/45°, cut-off)
  - redirection blinds
    (fix 0°, cut-off, retro)

Artificial light:

- required illuminance
- luminaire properties
- lamp properties
- switching mode

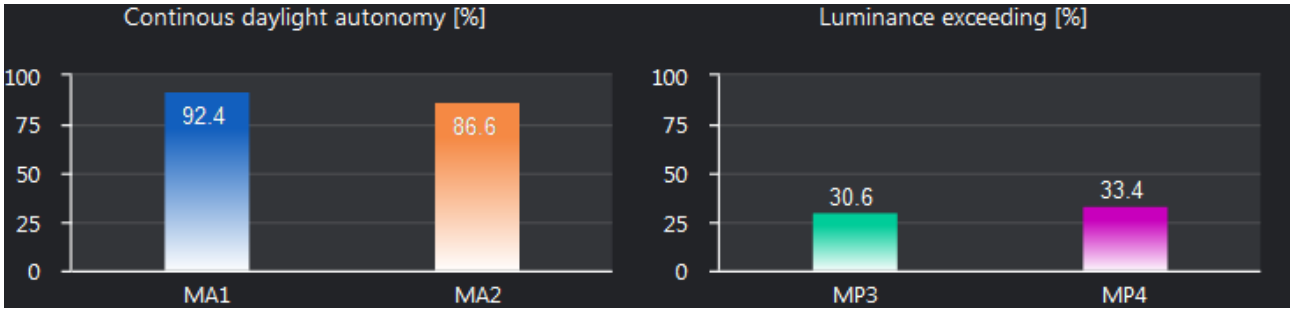
Building physics

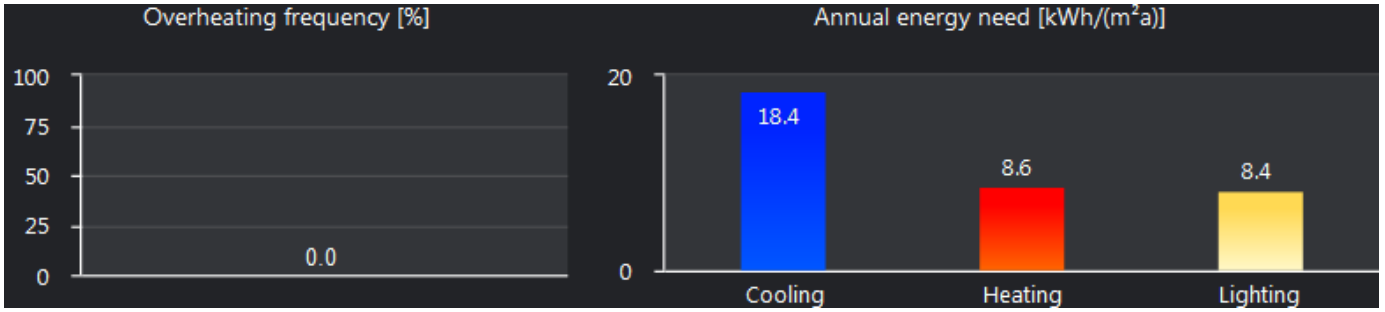
- building standard
  - old, new, passive house, own
- heating / cooling
- ventilation
- internal loads

DALEC Online Tool

Outputs

Annual results

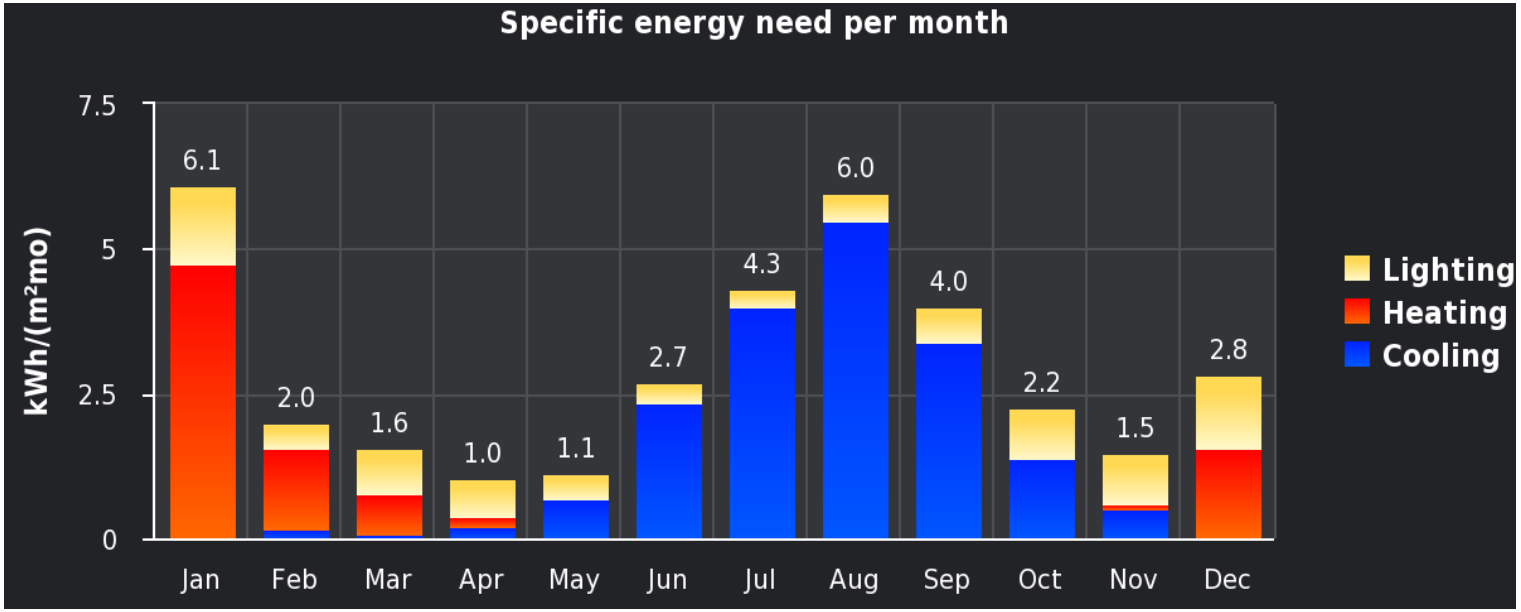




DALEC Online Tool

Outputs

Monthly results

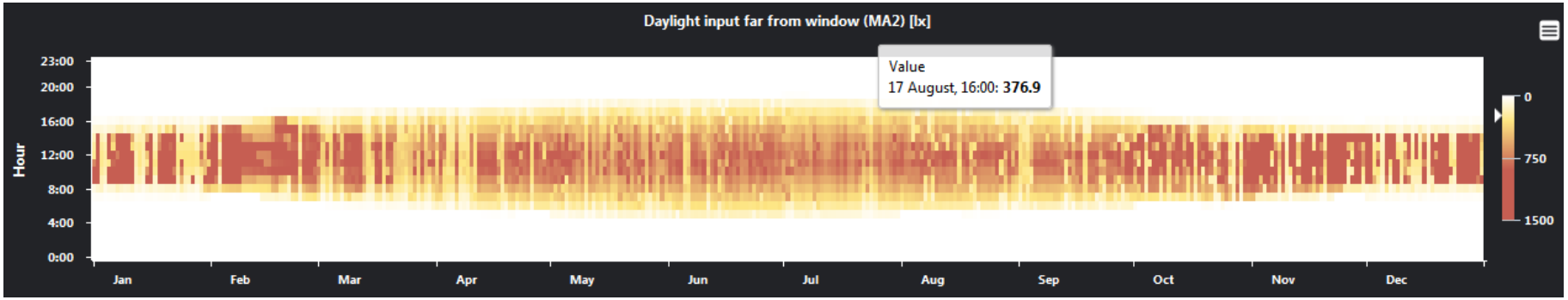


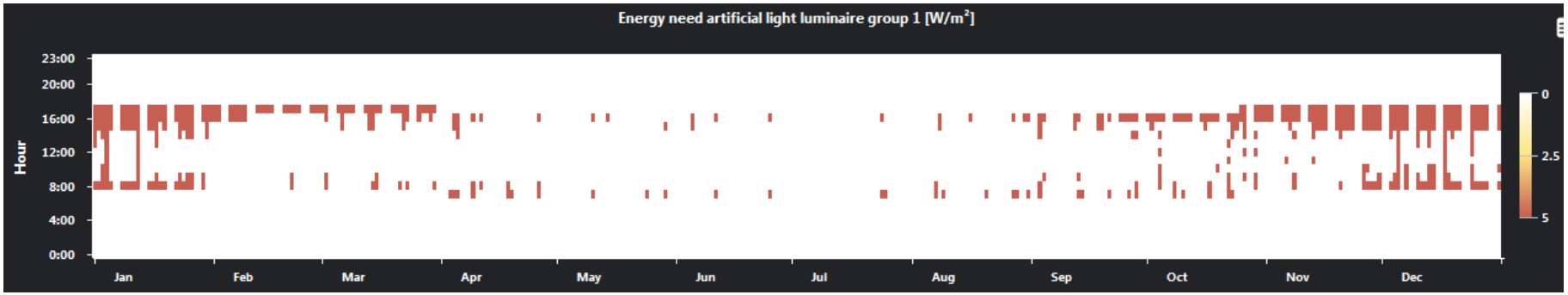
Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Cooling [kWh/(m²mo)]	0.0	0.2	0.1	0.2	0.7	2.4	4.0	5.5	3.4	1.4	0.5	0.0	18.4
Heating [kWh/(m²mo)]	4.8	1.4	0.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.5	8.6
Lighting [kWh/(m²mo)]	1.3	0.4	0.8	0.6	0.4	0.3	0.3	0.5	0.6	0.9	0.9	1.3	8.4

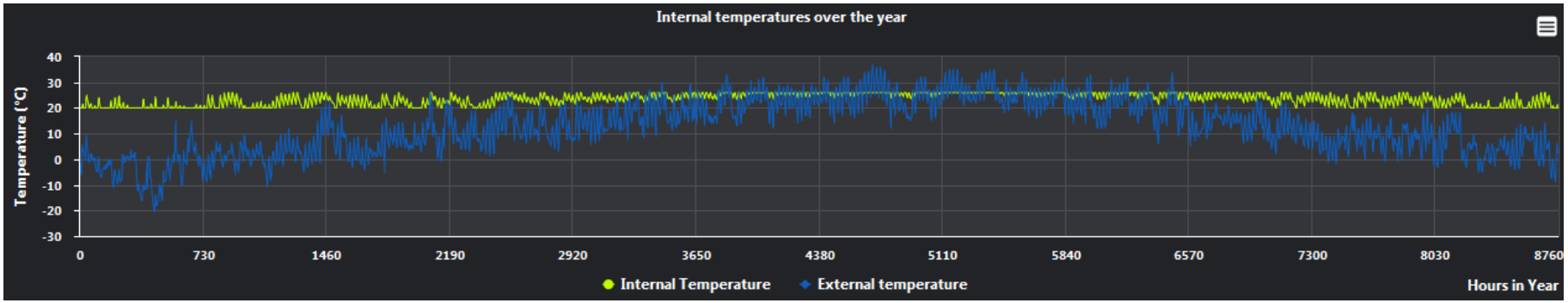
DALEC Online Tool

Outputs

Hourly results



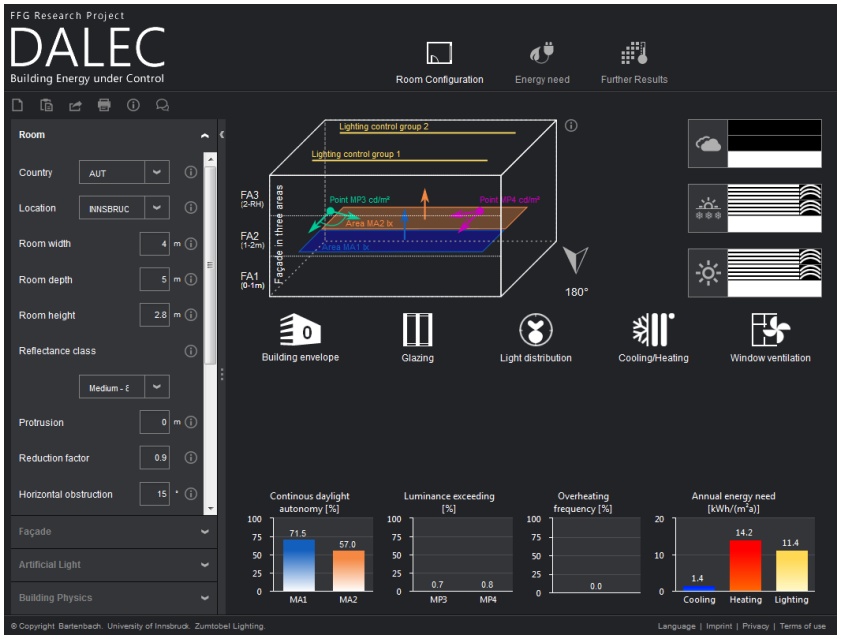




DALEC Online Tool

Tool for holistic design in early planning phases

- evaluation of annual daylighting, demand for artificial light, heating and cooling
- worldwide sites, arbitrary orientations
- coupled light and thermal simulation
- evaluation of comfort criteria
- easy to use even without deep expertise
- low input effort
- short calculation times
- online @ www.dalec.net
- free to use ~~$ € £ ¥~~



Live Demo

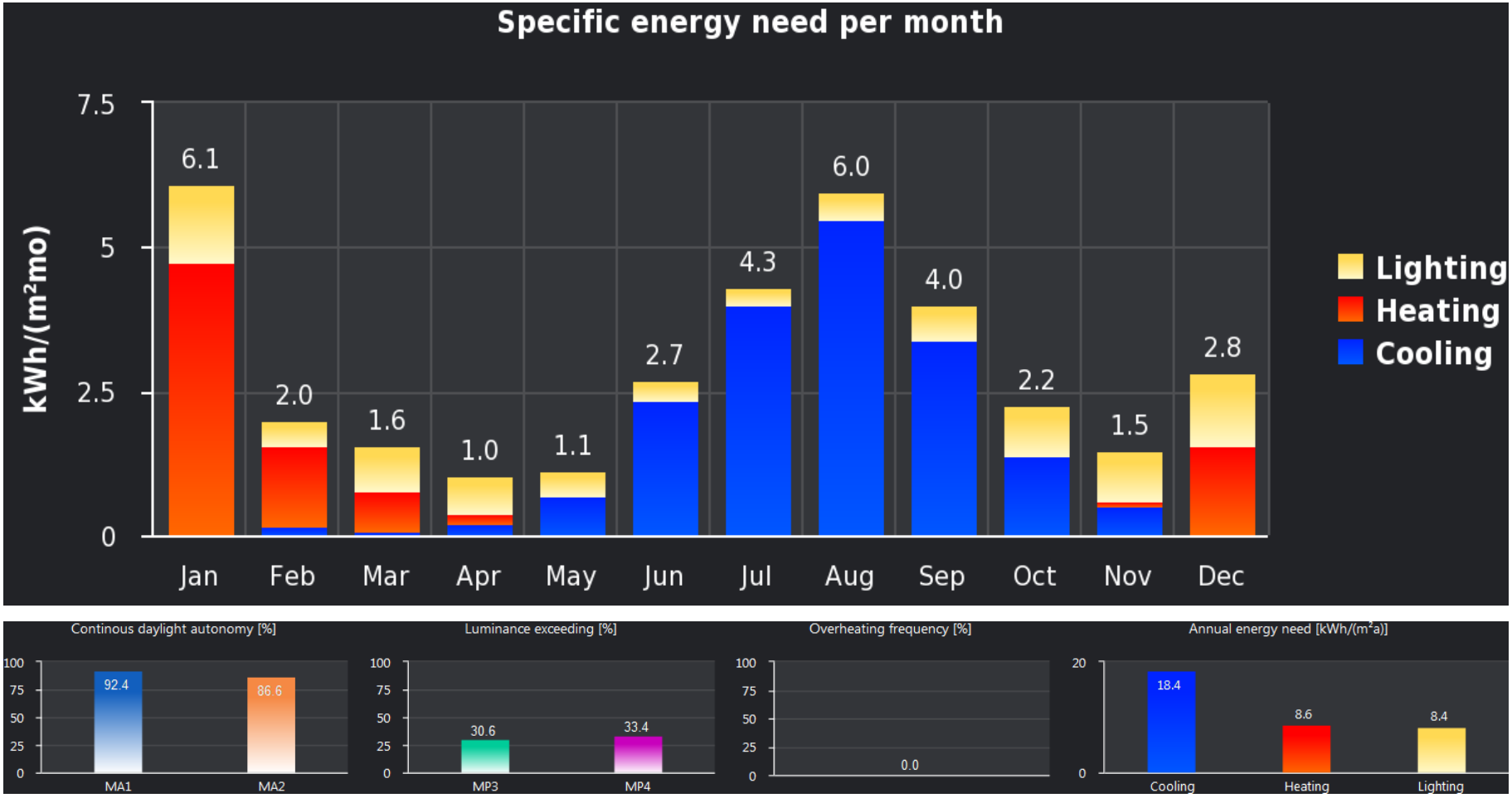
www.dalec.net

Example: South-oriented room 8m x 7m x 3.2m

1. Philadelphia, Clear Glazing
2. Philadelphia, Glazing + interior screen
3. Philadelphia, Glazing + exterior venetian blinds
4. Philadelphia, Glazing + redirecting blinds in closed cavity facade

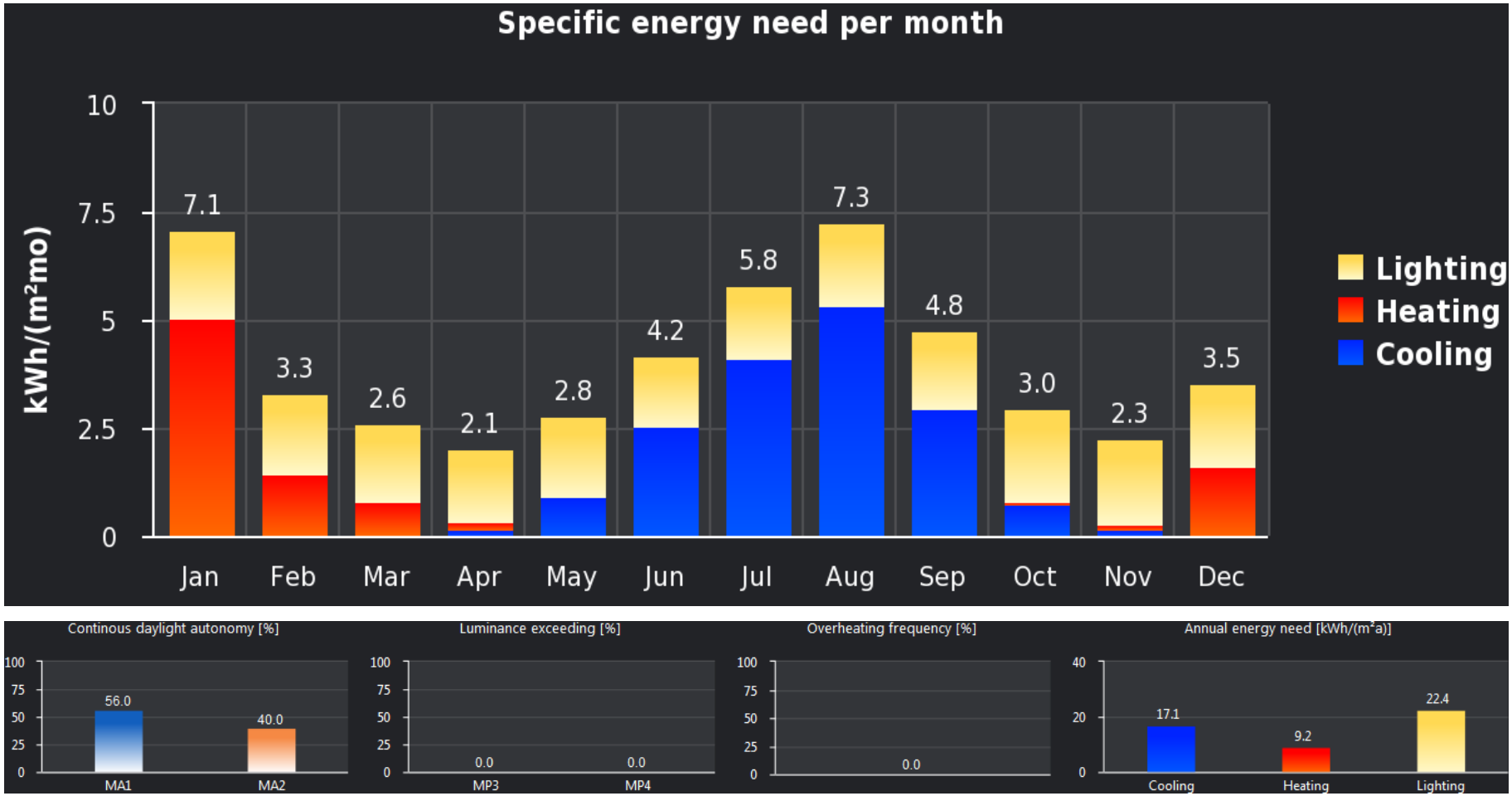
Example Calculation

[Philadelphia, Clear Glazing]



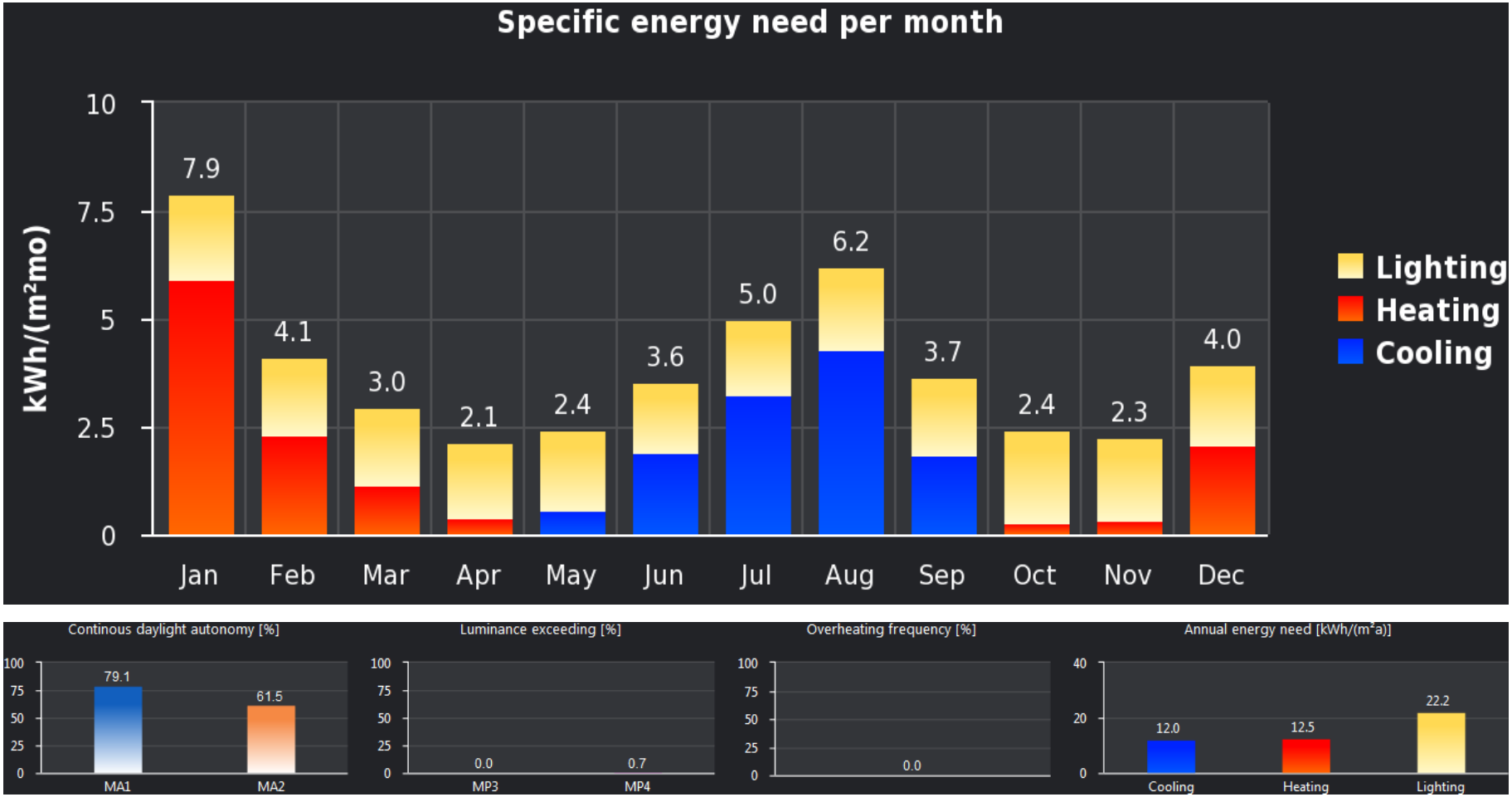
Example Calculation

[Philadelphia, Glazing + diffuse interior screen]



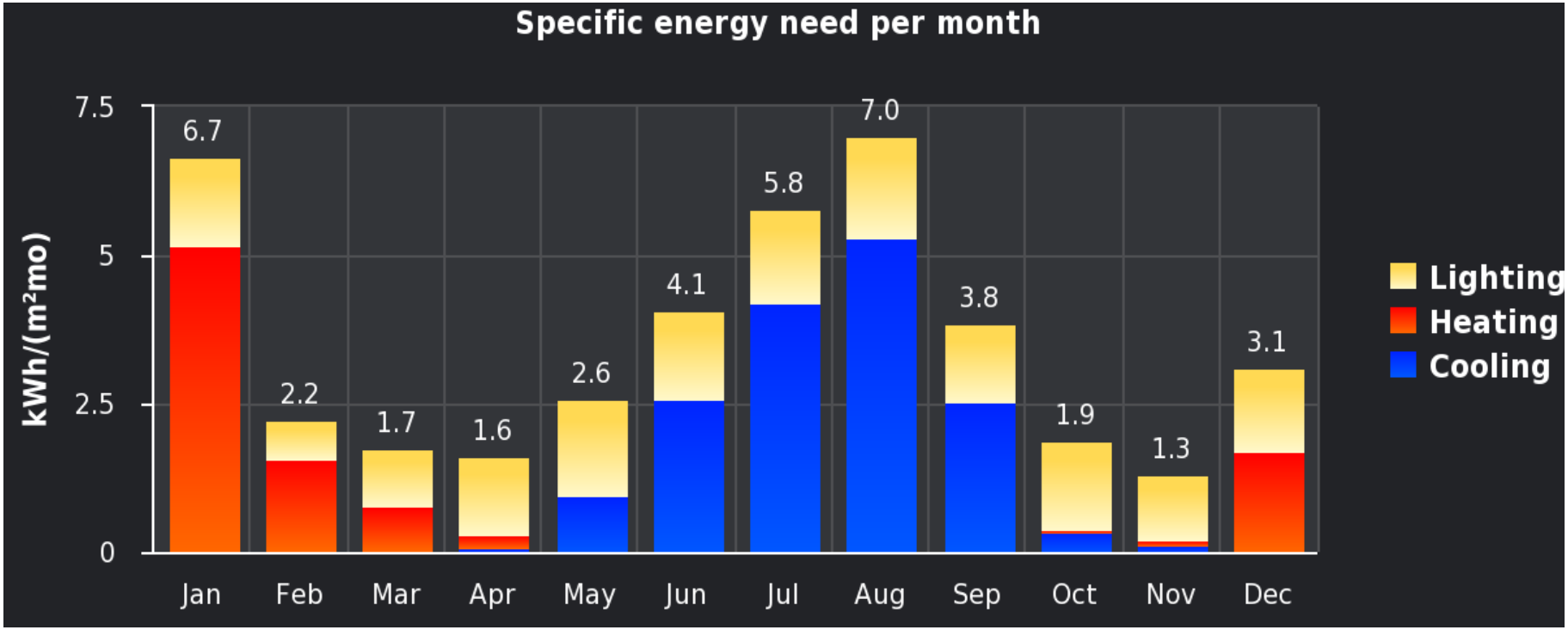
Example Calculation

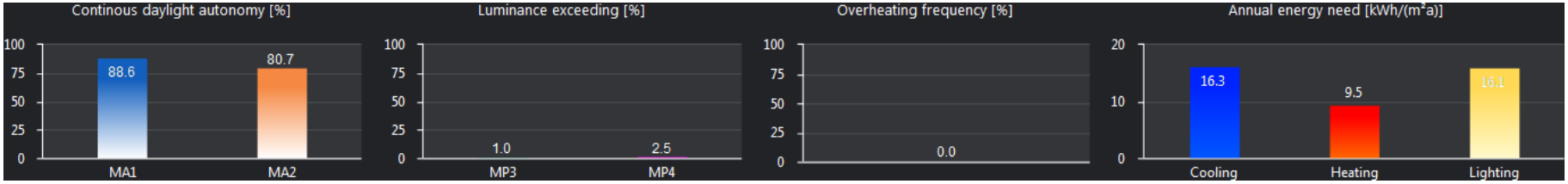
[Philadelphia, Glazing + exterior venetian blinds]



Example Calculation

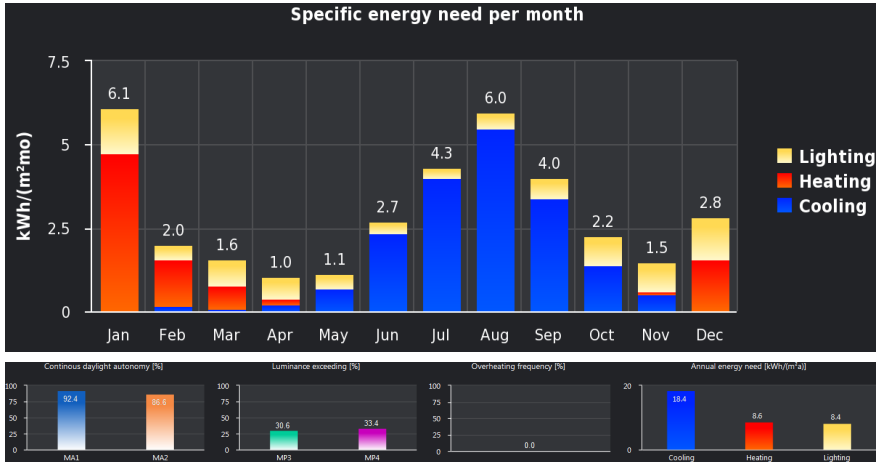
[Philadelphia, Glazing + redirecting blinds in closed cavity facade]



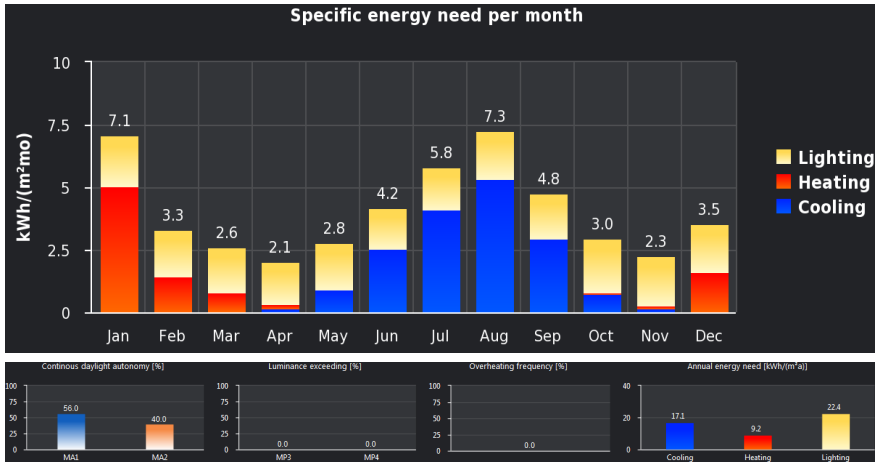


Comparison

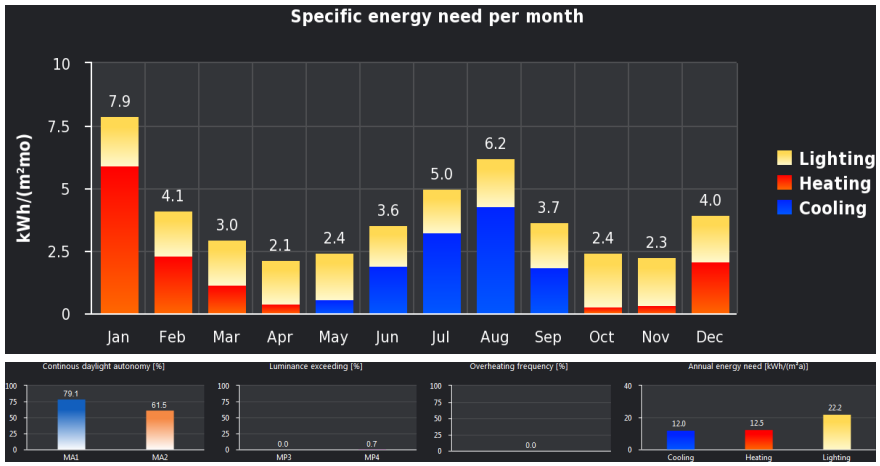
Philadelphia, Clear Glazing



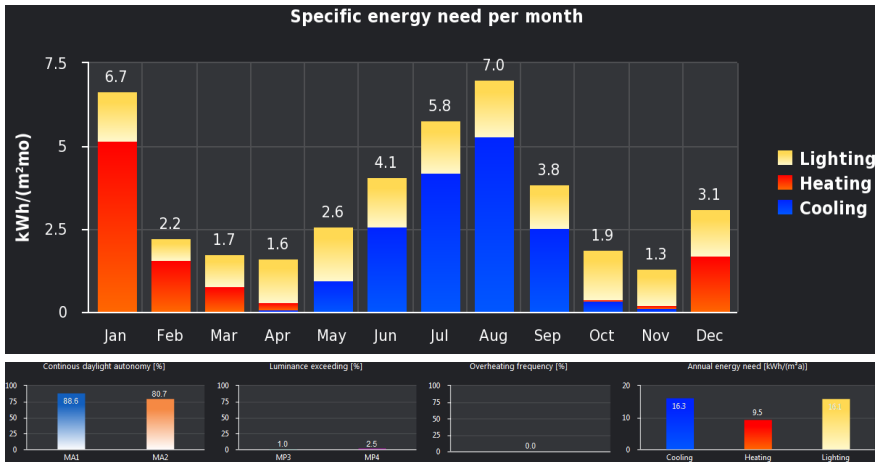
Philadelphia, Glazing + diffuse interior screen



Philadelphia, Glazing + exterior venetian blinds



Philadelphia, Glazing + redirecting blinds in closed cavity facade



DALEC – next steps

- **Improvement of the calculation method and practicability**
  - room by room evaluation → whole buildings
  - halls (industry, sports, …)
  - additional electric lighting controls (e.g. maintenance control)
  - data interfaces for weather data, daylighting and artificial lighting systems (BSDFs, IES/LDT)
- **Comfort criteria**
  - evaluation scheme for visual and thermal comfort (DGP, PMV, …)
  - “quality traffic lights”
- **Extended evaluations**
  - design comparisons
  - “optimizer” function
- **Improvement of user interface** based on user feedback
- **Further validation** against advanced scientific simulation methods

Acknowledgement

The development of DALEC is supported by the Austrian research funding association (FFG) through the programme “City of Tomorrow”, a service of the Austrian Ministry for Transport, Innovation and Technology.

Q&A

Thank you for your attention!

Any questions?

www.dalec.net

David Geisler-Moroder
Bartenbach GmbH
David.Geisler-Moroder@bartenbach.com
www.bartenbach.com