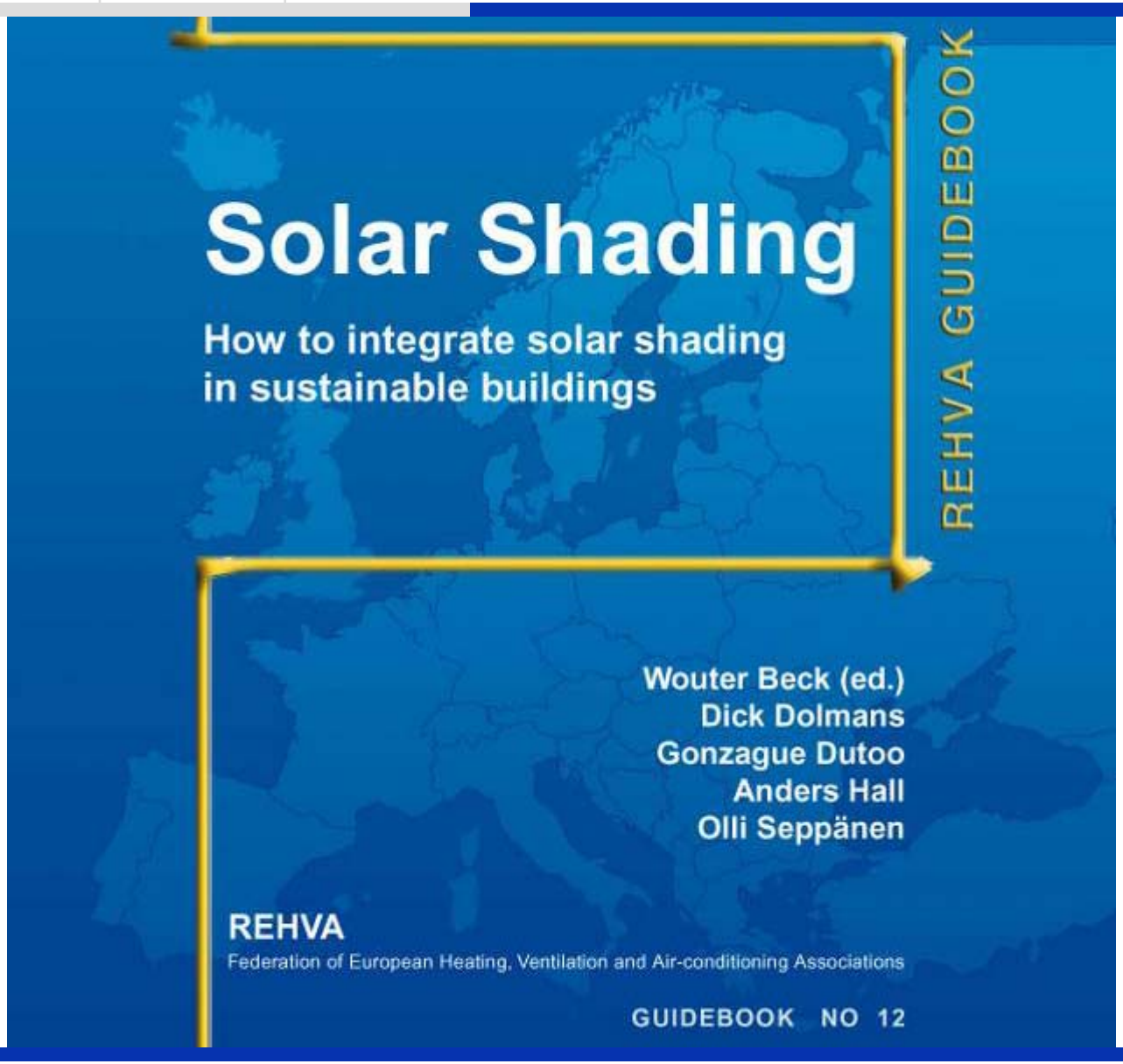
REHVA GUIDEBOOK
Solar Shading
How to integrate solar shading in sustainable buildings
Wouter Beck (ed.)
Dick Dolmans
Gonzague Dutoo
Anders Hall
Olli Seppänen
REHVA
Federation of European Heating, Ventilation and Air-conditioning Associations
GUIDEBOOK NO 12

Task force Solar Shading started 2008

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Reviewers

- Prof. Jan Hensen, Eindhoven University of Technology, The Netherlands
- Prof. Mat Santamouris, University of Athens, Greece
- Hervé Lamy, SNFPSA, Paris, France
- Prof. Michael G Hutchins, Sonnergy Ltd, Abingdon, UK
- Dr. Thanos Tzempelikos, Purdue University, West Lafayette, IN, USA

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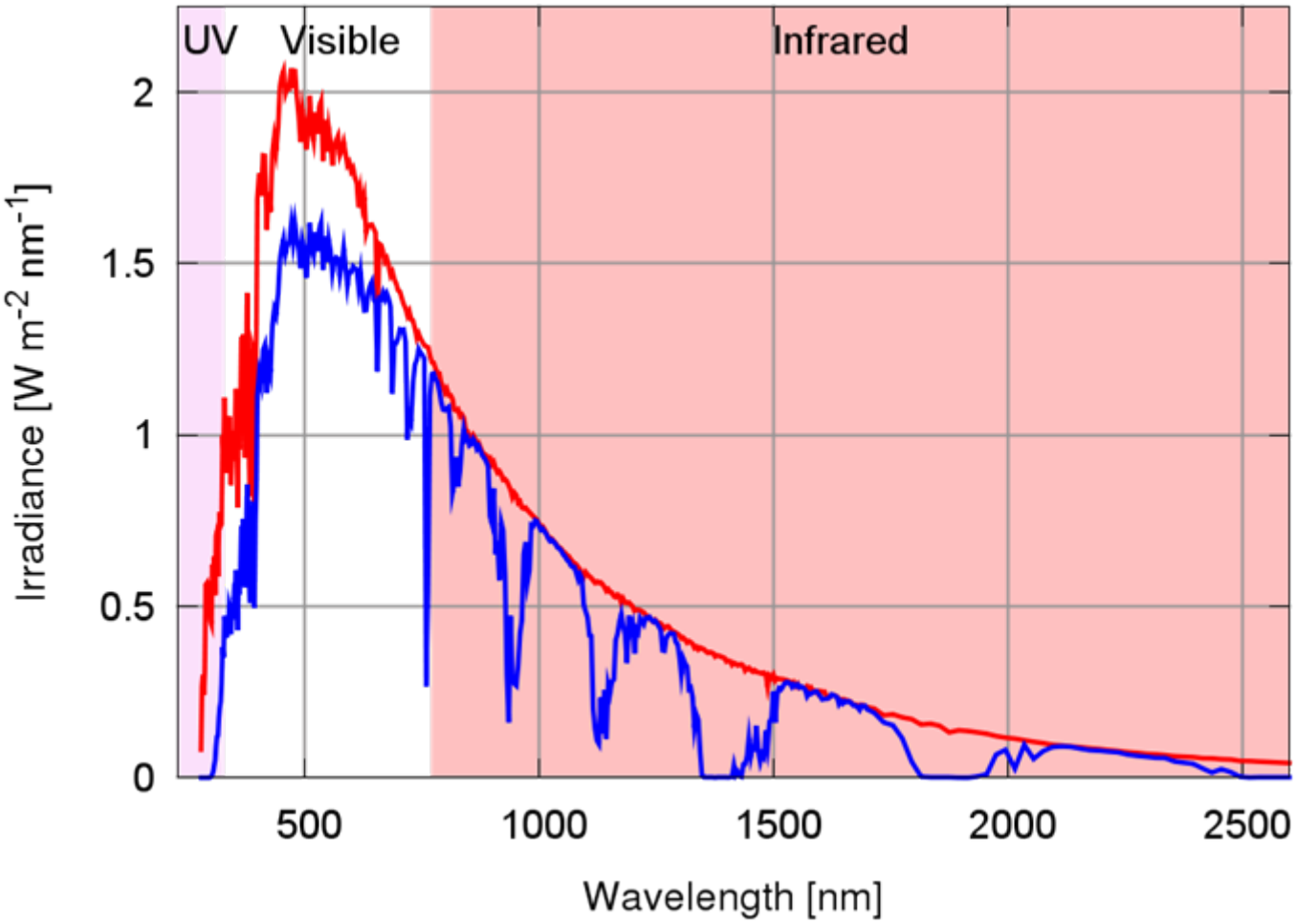
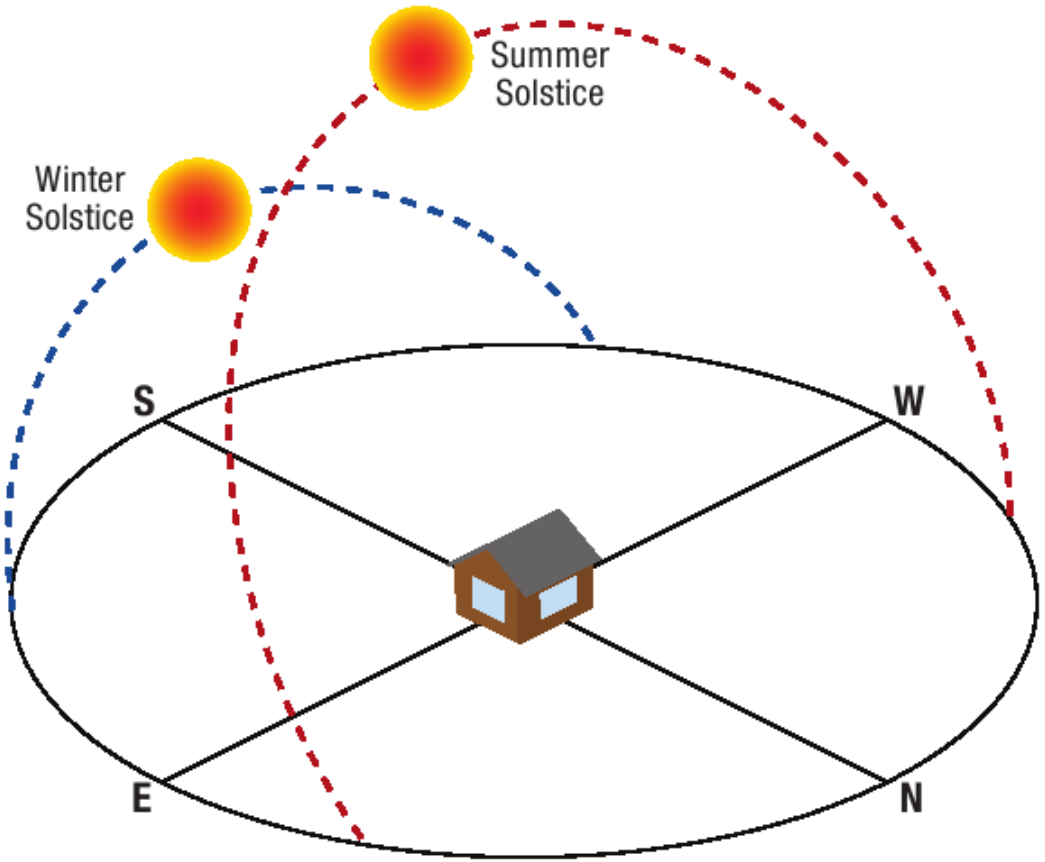
Solar radiation

HunterDouglas
WINDOW COVERINGS

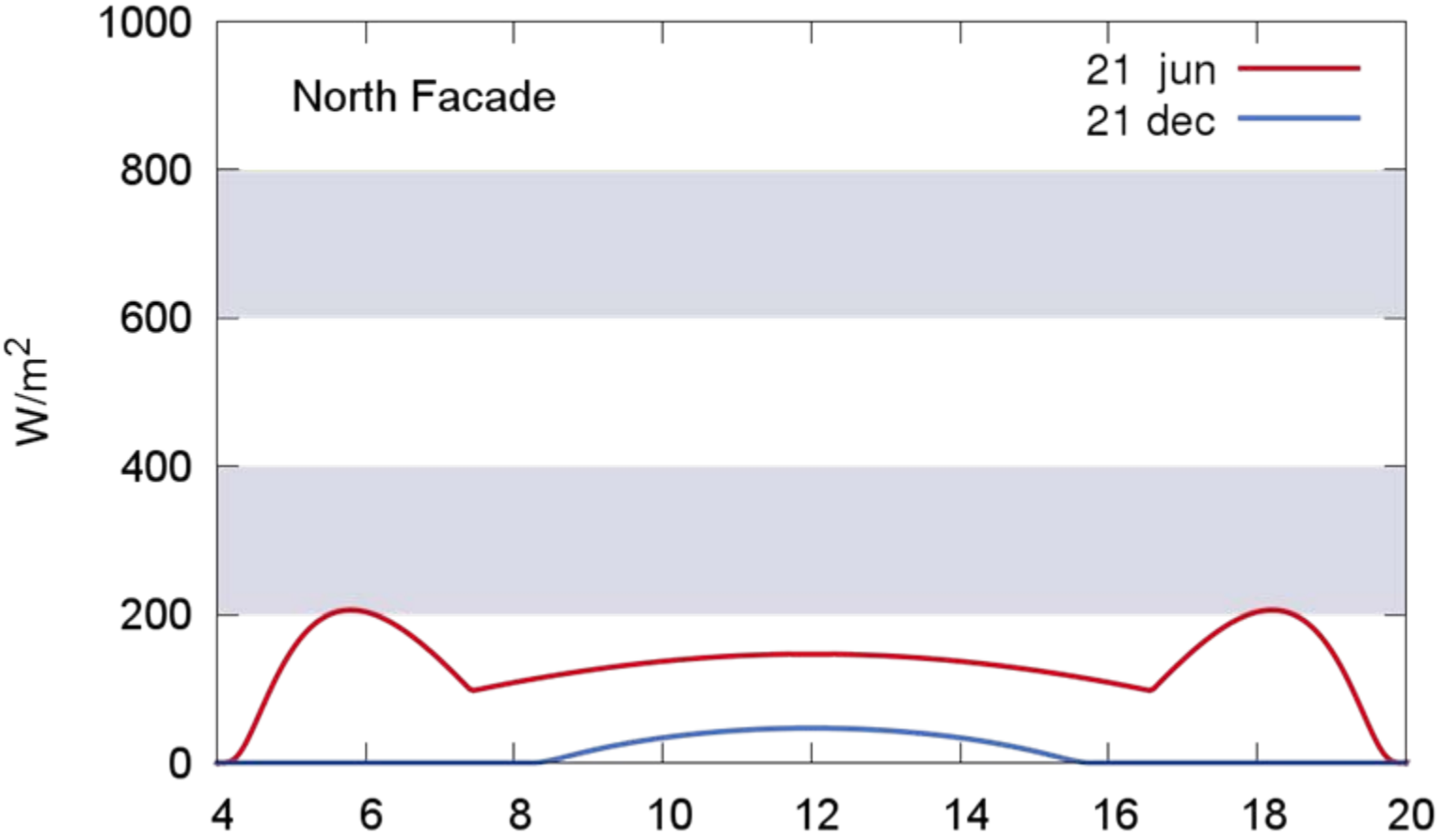
Solar radiation



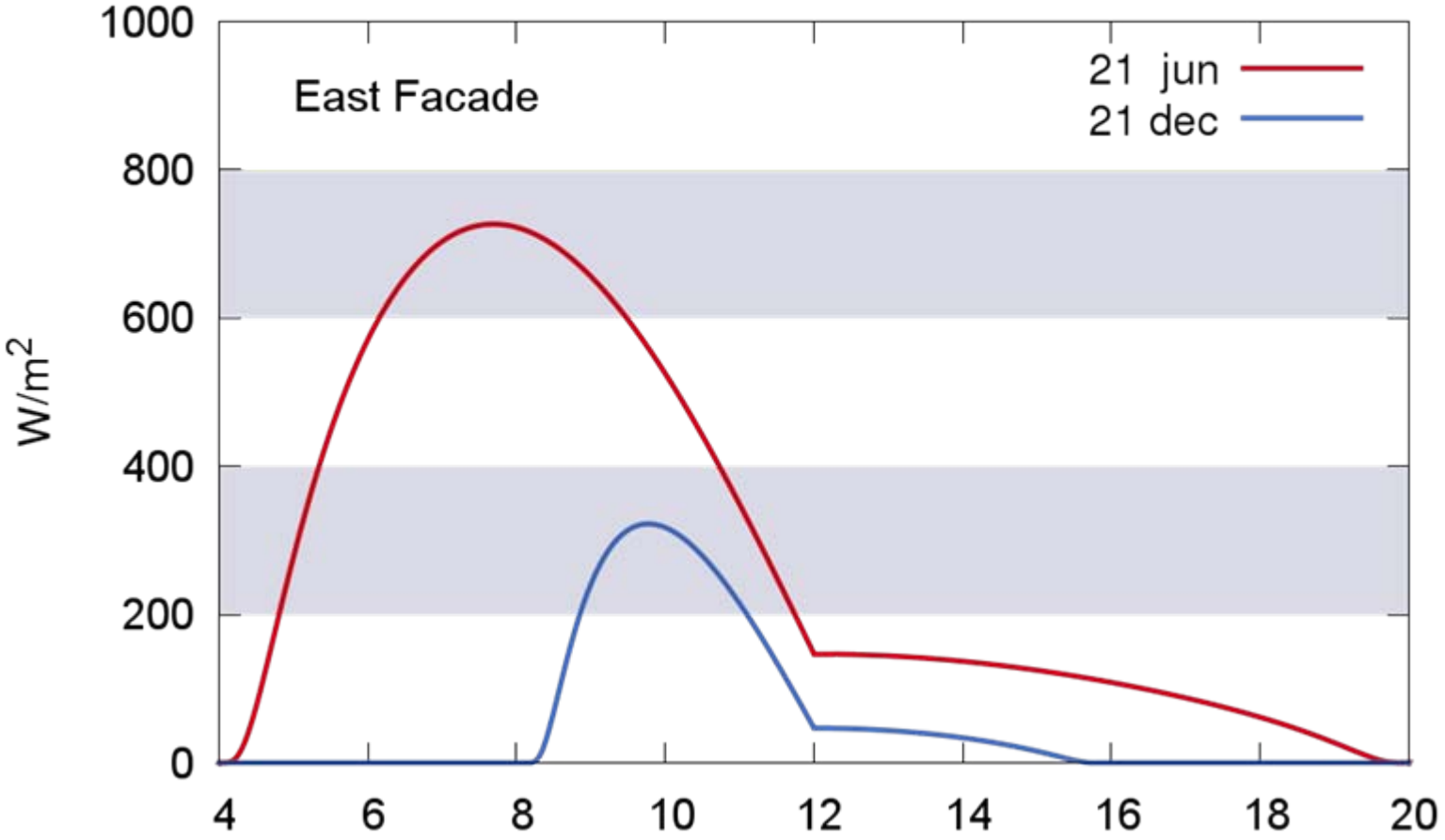
Solar paths



Solar irradiance on a façade (lat. 50 N, clear sky)



Solar irradiance on a façade (lat. 50 N, clear sky)



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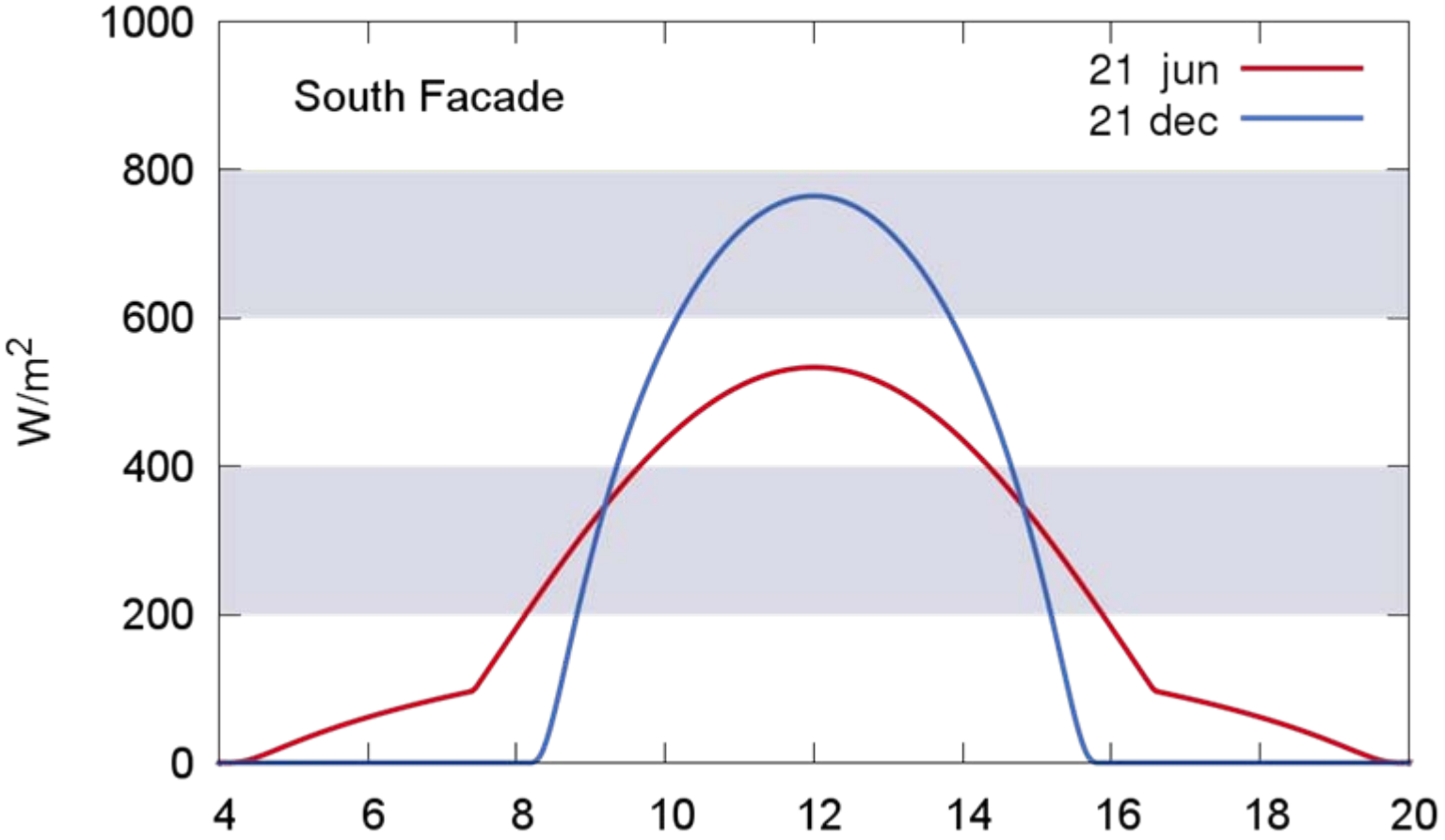

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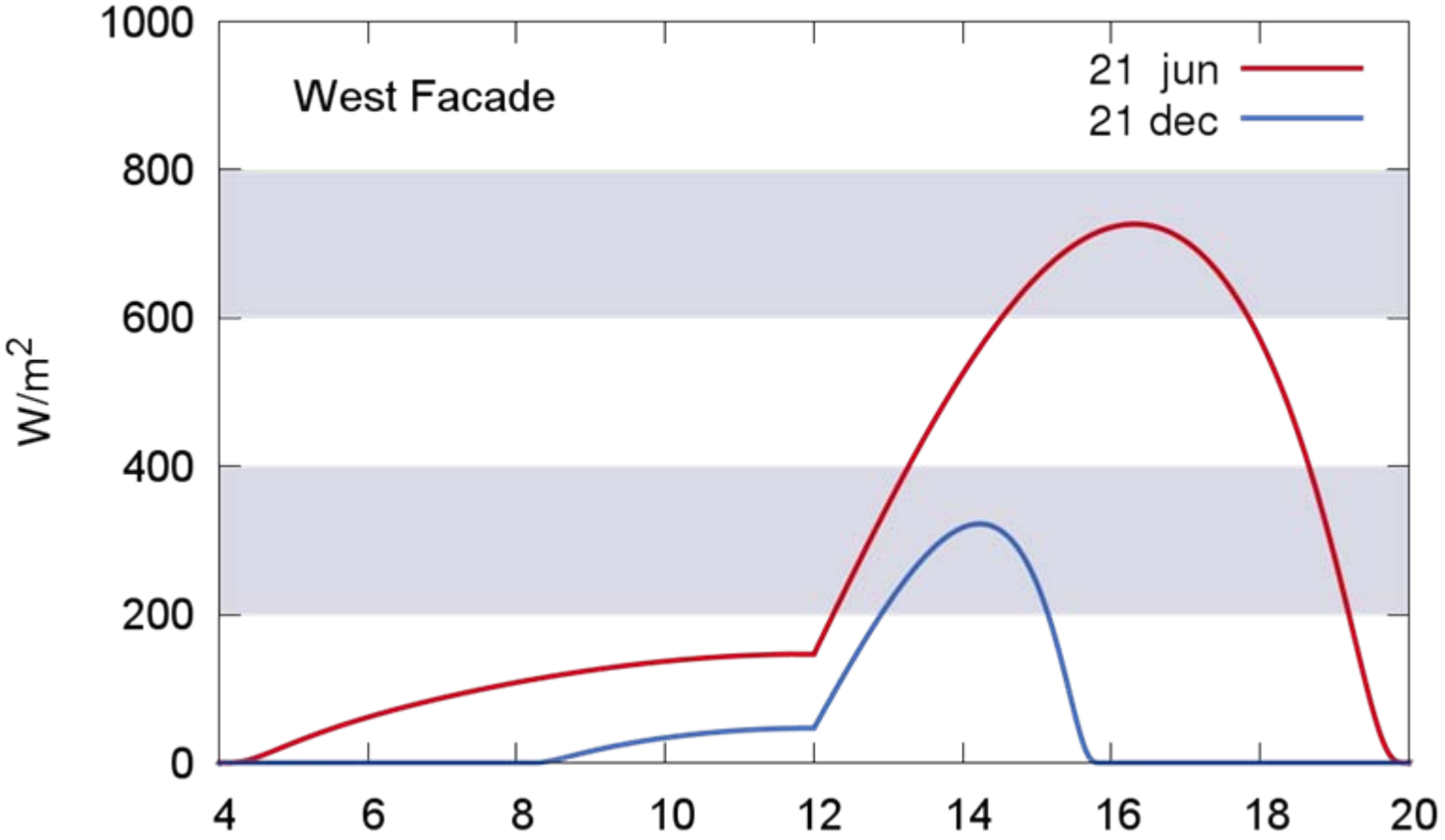


Effect of windows on indoor environment

HunterDouglas
WINDOW COVERINGS

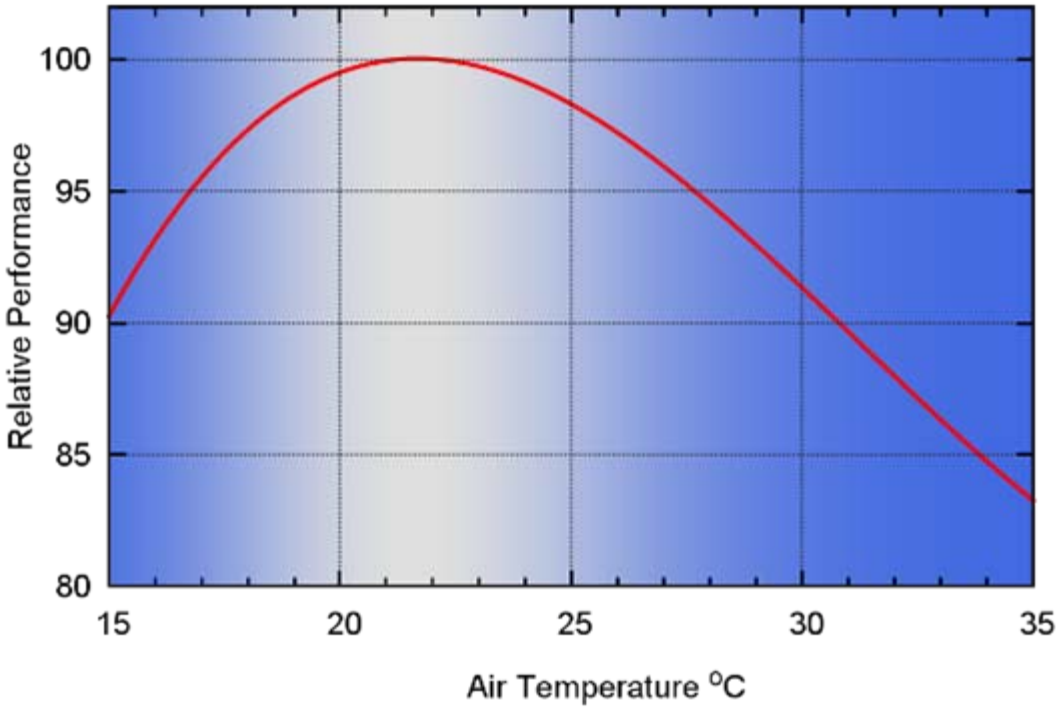
Effect of windows on indoor environment

- Thermal comfort
- Visual comfort
- Acoustic comfort
- Indoor air quality
- Daylighting
- Impact of productivity

Thermal comfort

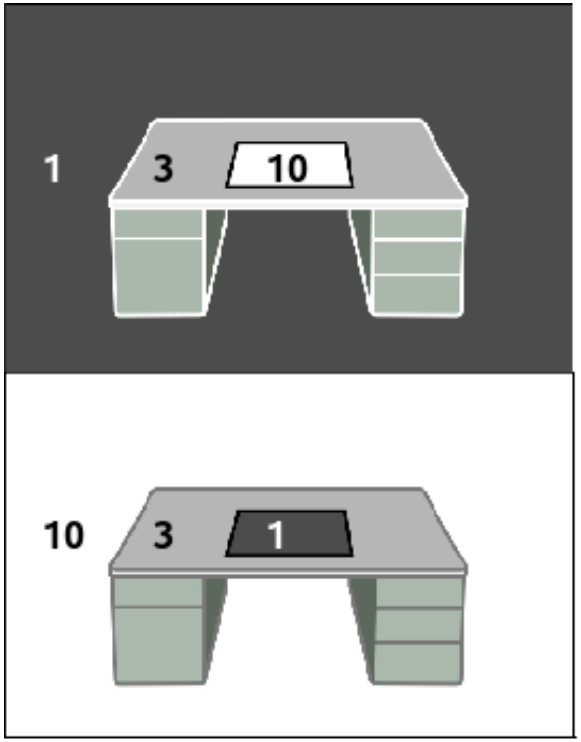
- Air temperature
- Radiant temperature
- Operative temperature

- Relation to office worker productivity



Visual comfort

- Contact with the outdoors
- Absolute brightness
- Luminance ratios
- Color rendition

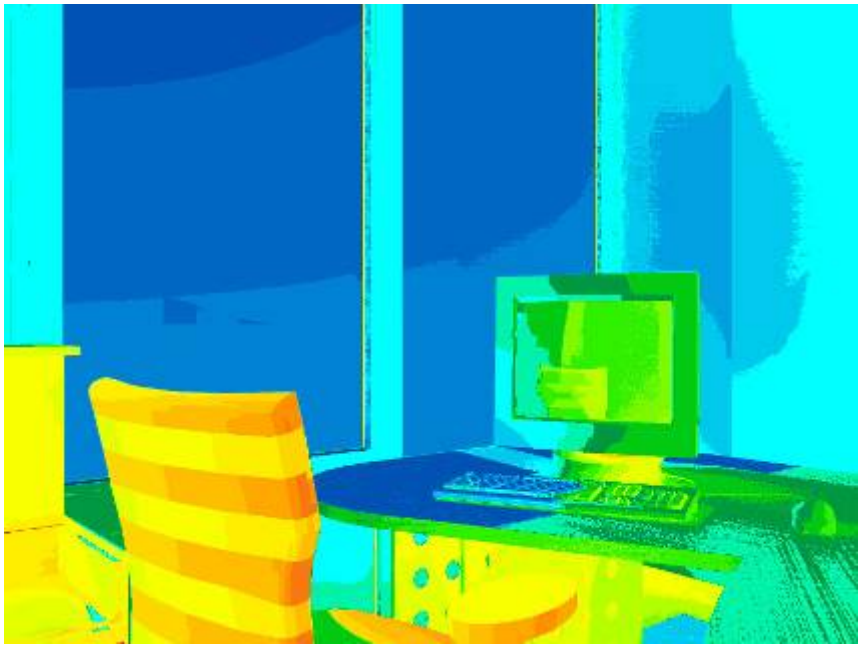


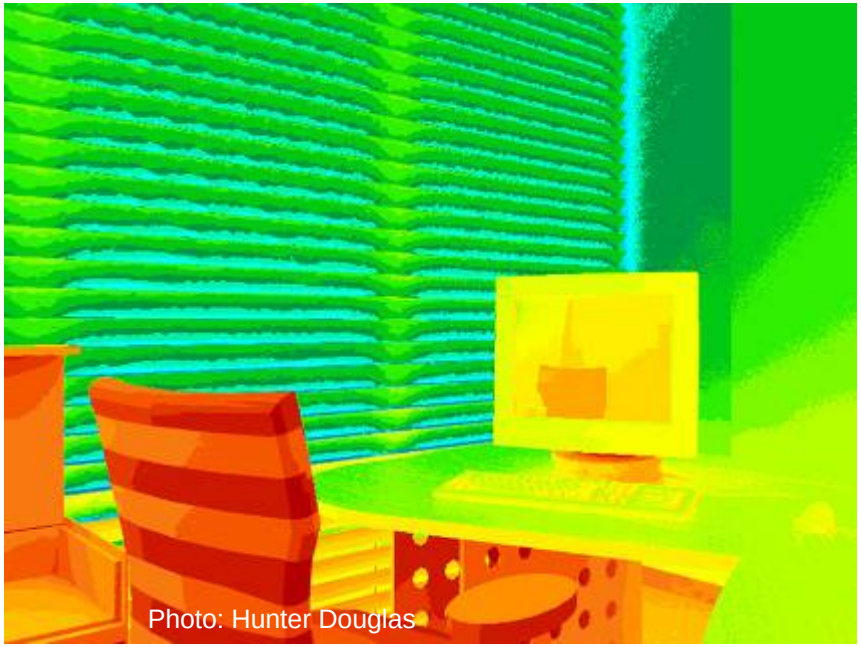
Effect of good visual comfort

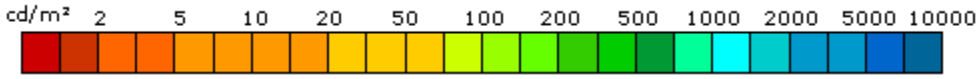
- 3.75% median productivity increase [CMU]
- 20 to 25% less health complaints [Hartkopf]
- 15% reduced absenteeism [Thayer]
- 10 to 25% better performance on test of mental function
- 20 to 26% faster progress of students [Heshong]

Predicting visual comfort

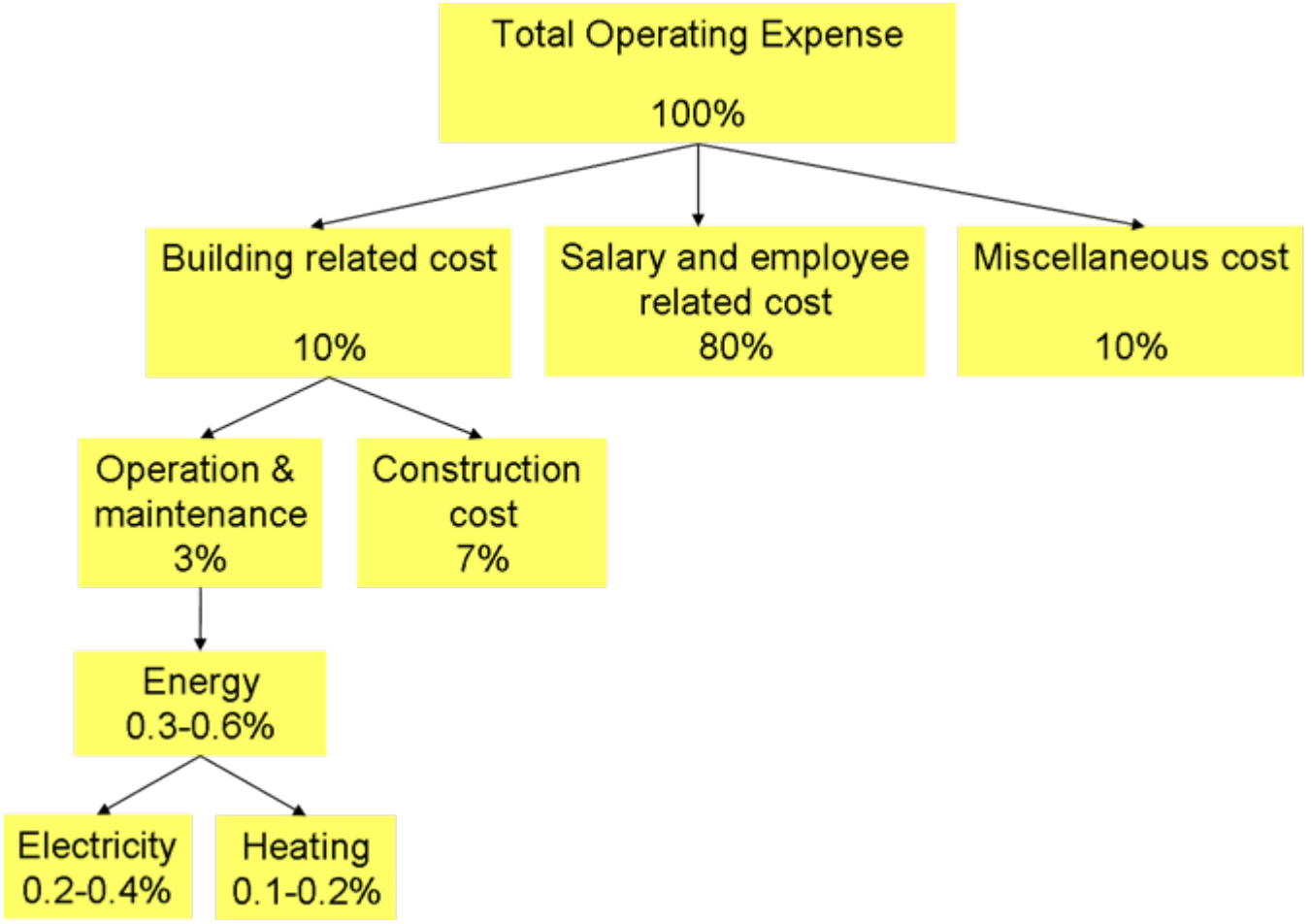
Predicting visual comfort







The economic impact of productivity



Window systems

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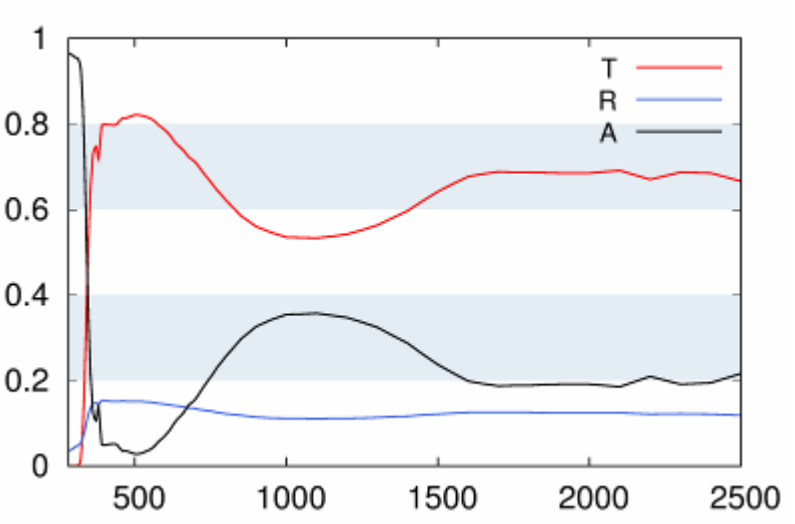
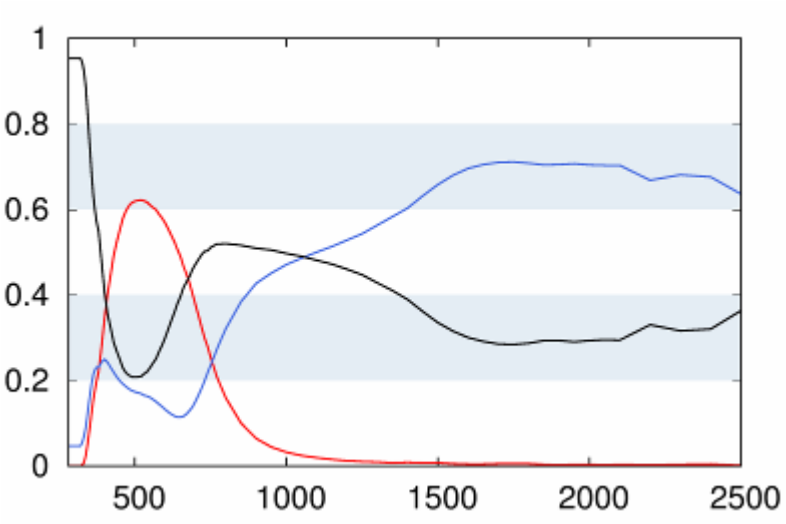
WINDOW COVERINGS

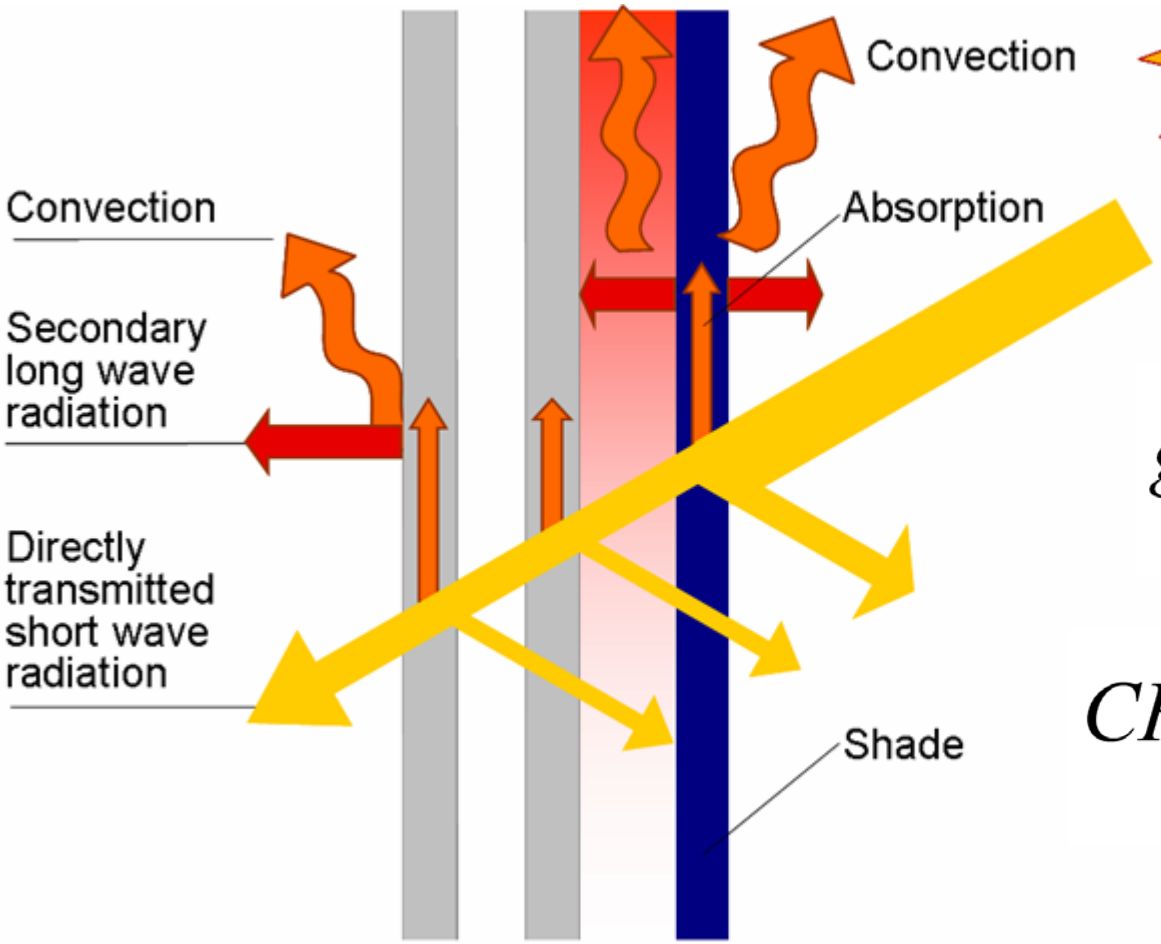
Glazing properties

- Thermal transmittance U [W/m^{2}K]
- Light transmittance T_v [-]
- g-value [-]





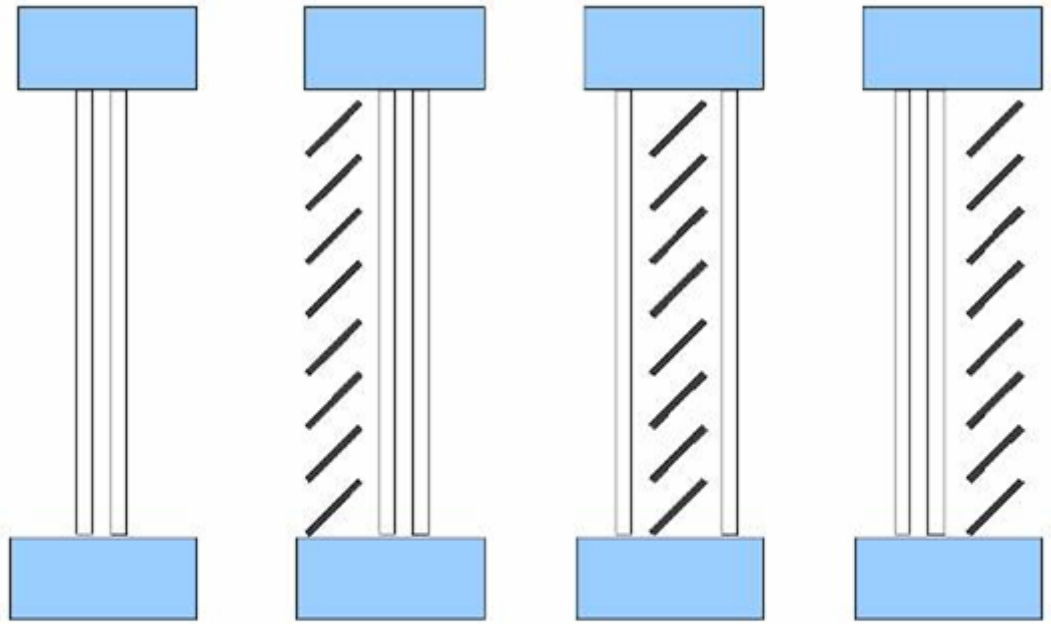
Energy flows



$$g = \frac{q_t + q_{ci} + q_{ri}}{q_i}$$

$$CF = \frac{q_{ci}}{q_t + q_{ci} + q_{ri}}$$

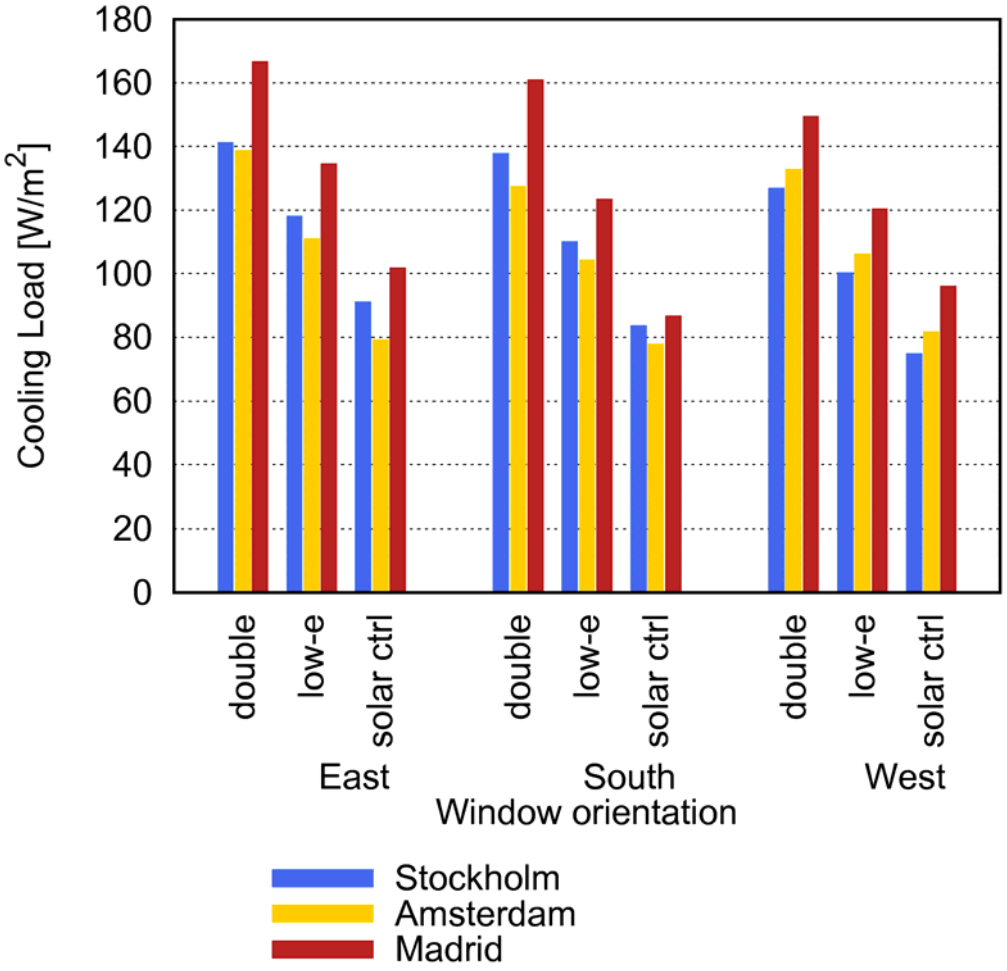
Convection loads



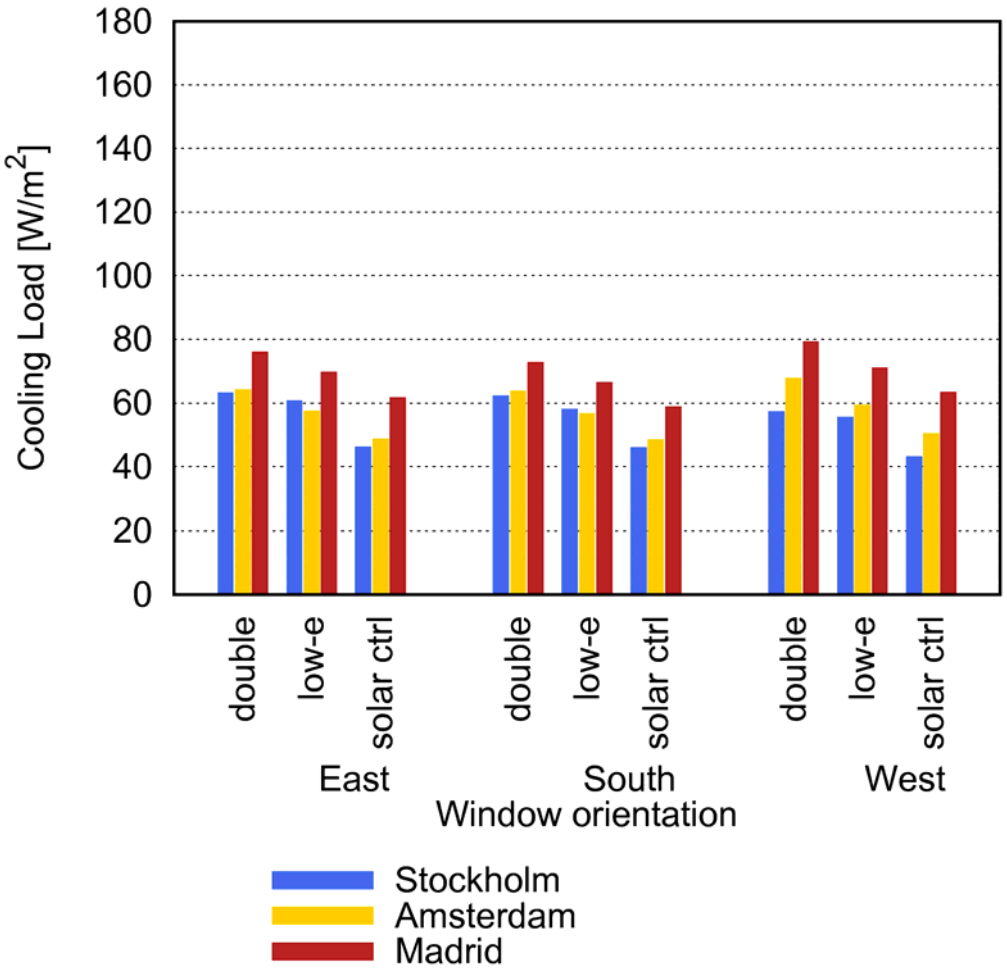
g = 0.63	g = 0.09	g = 0.23	g = 0.49
CF = 0.04	CF = 0.01	CF = 0.21	CF = 0.45
RF = 0.09	RF = 0.22	RF = 0.46	RF = 0.39
DF = 0.86	DF = 0.77	DF = 0.32	DF = 0.16

$$CF = \frac{q_{ci}}{q_t + q_{ci} + q_{ri}}$$

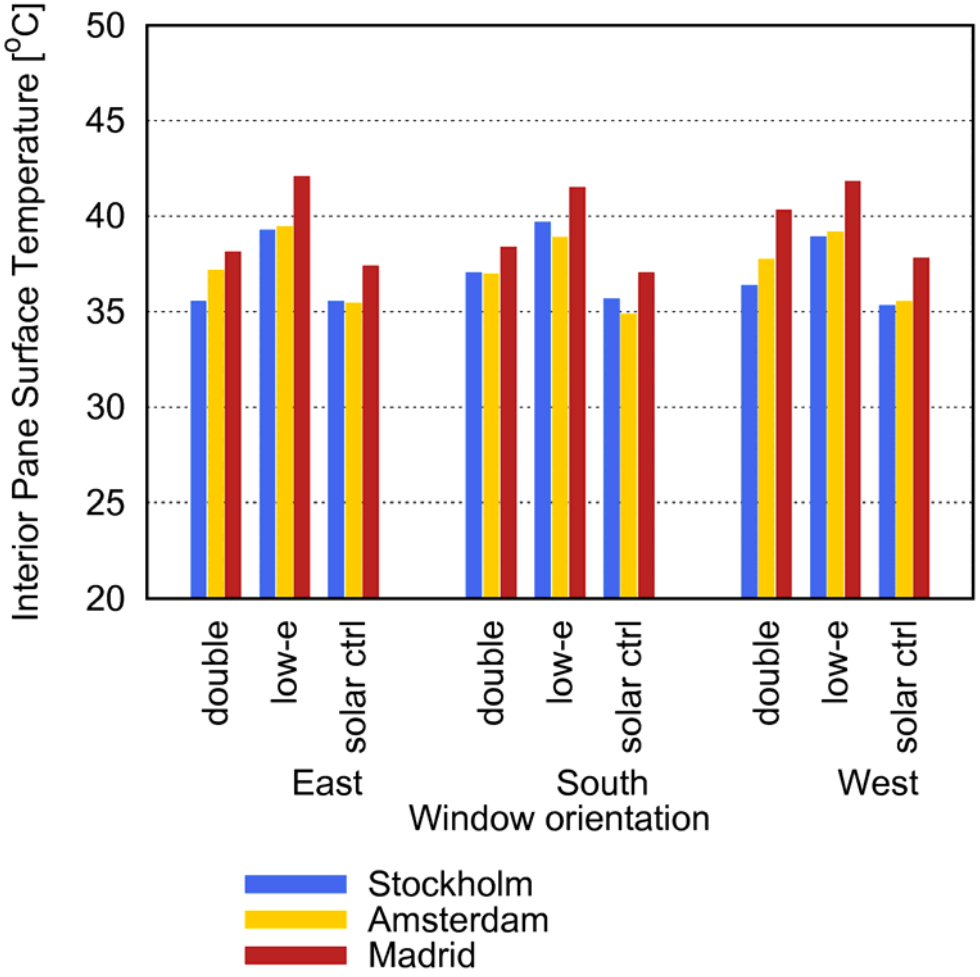
Cooling loads – no shading



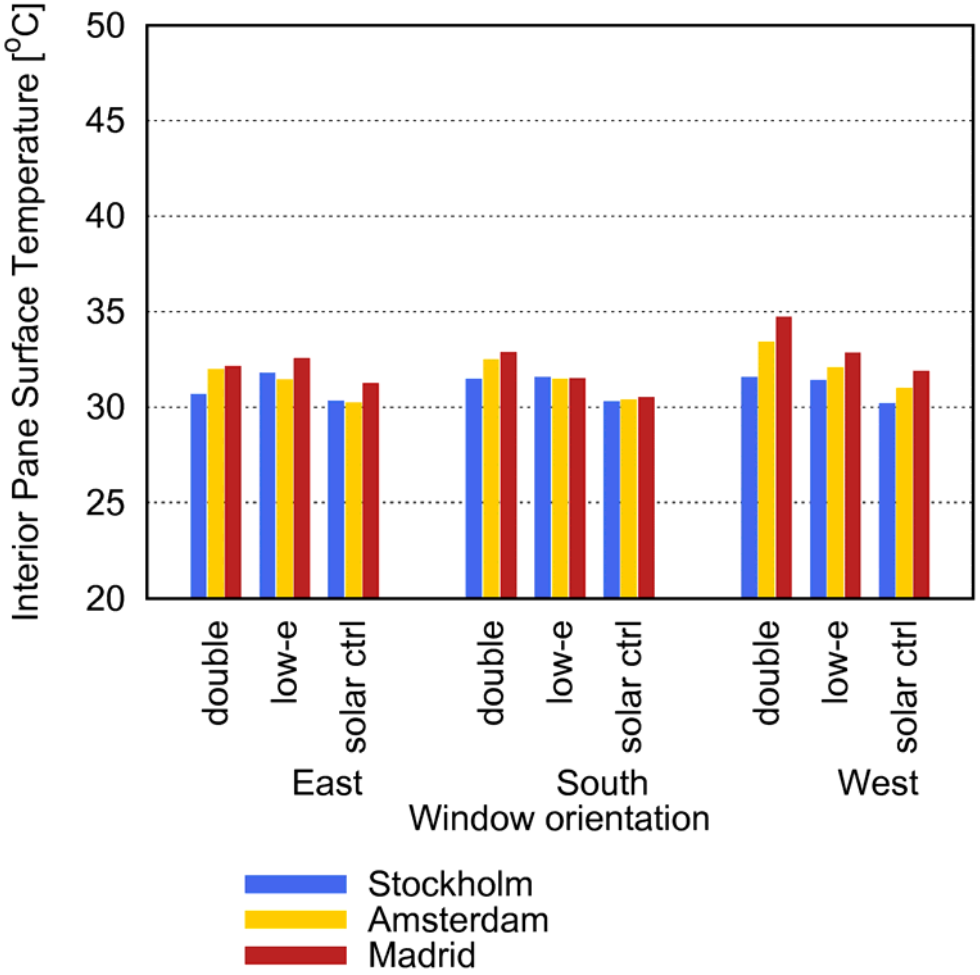
Cooling load – exterior shading



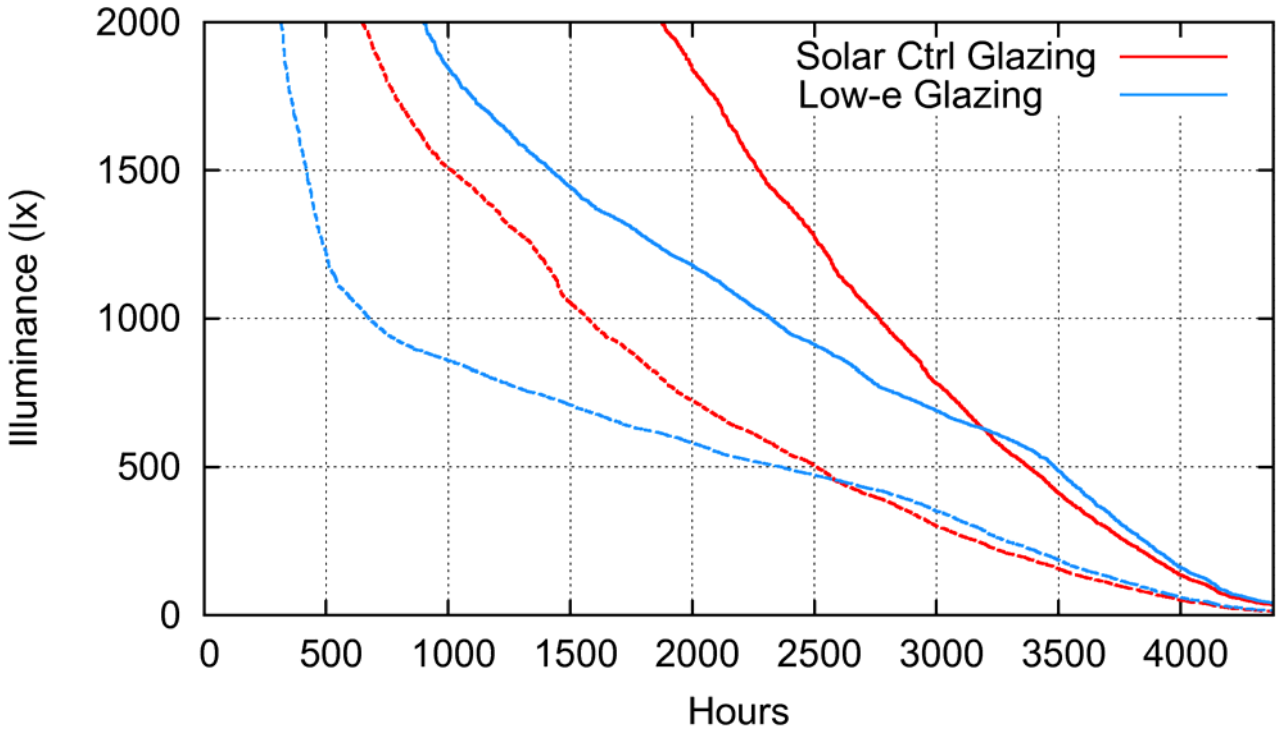
Surface temperature interior window pane under peak load conditions – no shading

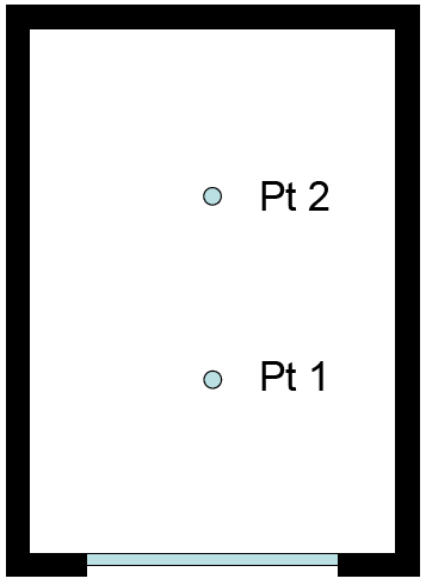


Surface temperature interior window pane under peak load conditions – exterior shading



Influence of shading on lighting needs





- Daylight illuminance in a south oriented office automatic Venetian blind @ 200 W/m²

Energy effects

HunterDouglas
WINDOW COVERINGS

Energy effects of solar shading

- Orientation dependent energy balance of an office for
- Stockholm
- Amsterdam
- Madrid

- Three glazing types
- Standard double glazing (U = 2.9 W/m^{2}K)
- Low-e (U = 1.2 W/m^{2}K)
- Solar control glazing (U = 1.1 W/m^{2}K)

Standard office

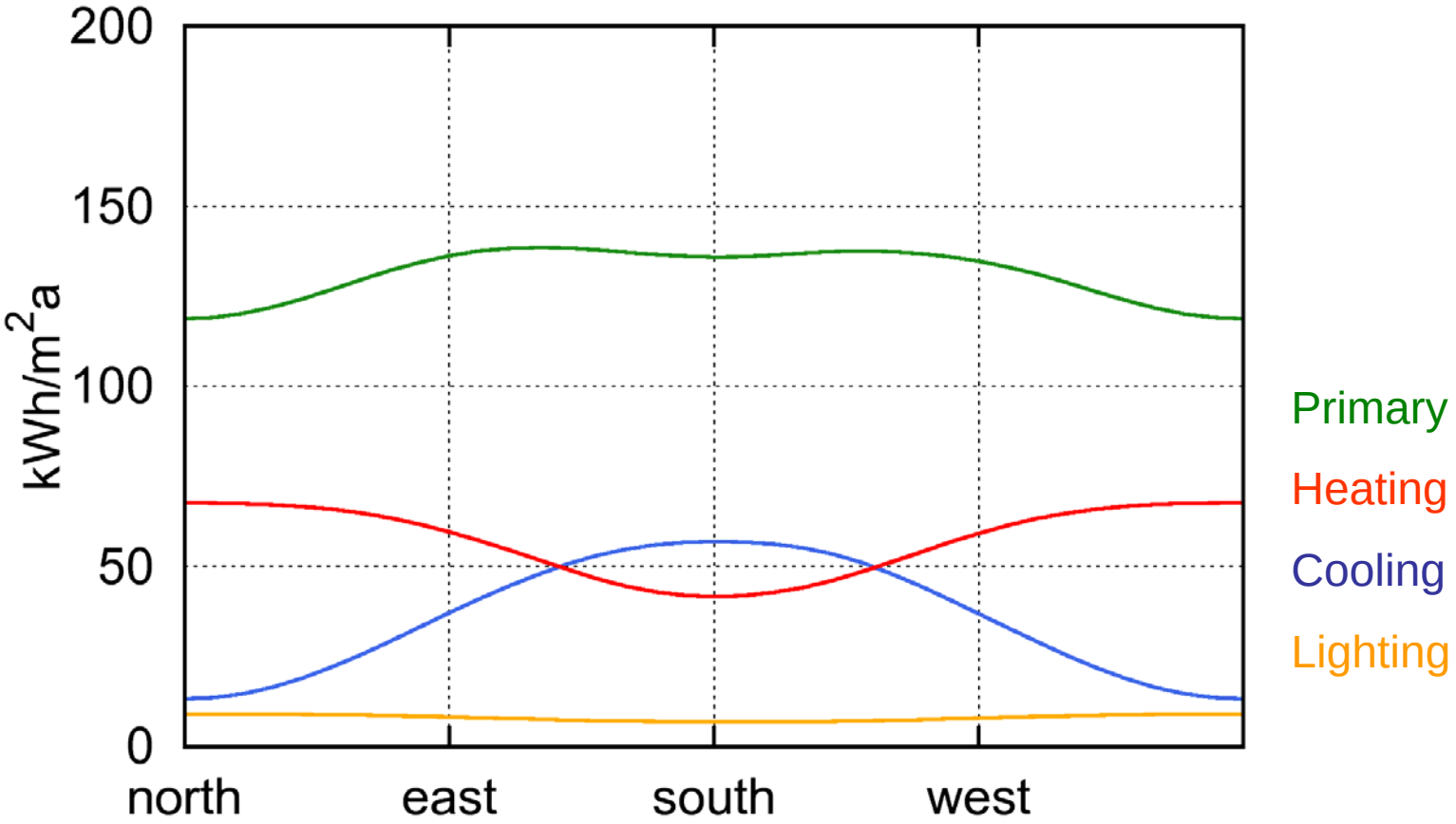
dimension	3.6 x 5 x 3 m
ventilation	1.5 dm^3/m^2s
infiltration	0.1 ACH
daylight dependent lighting	500 lx
max. internal load art. lighting	12 W/m^2
internal loads people	10 W/m^2
internal loads equipment	15 W/m^2
thermostat cooling	25/30 ºC (8-18/otherwise)
thermostat heating	21/15 ºC (8-18/otherwise)
shading set point	200 W/m^2

Conversion to primary energy

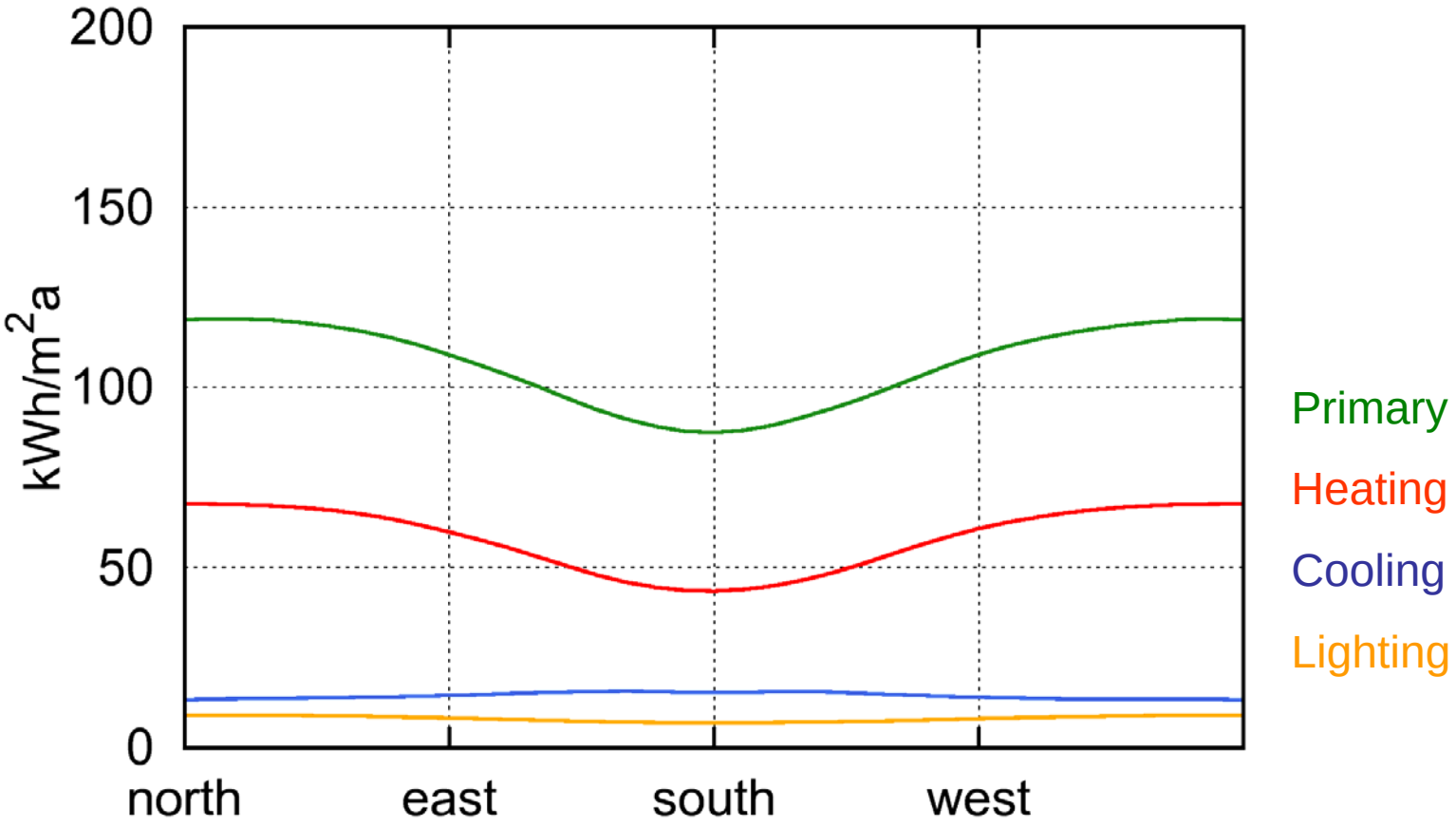
$$E_{\text{Prim}} = \frac{1}{A}\left(\frac{E_{\text{light}}}{\eta_e} + \frac{E_{\text{cool}}}{\eta_e \eta_c \text{COP}} + \frac{E_{\text{heat}}}{\eta_h}\right)$$

	Symbol	Value
Heating (natural gas)	η_h	85%
Electricity	η_e	39%
System efficiency for cooling	η_c	70%

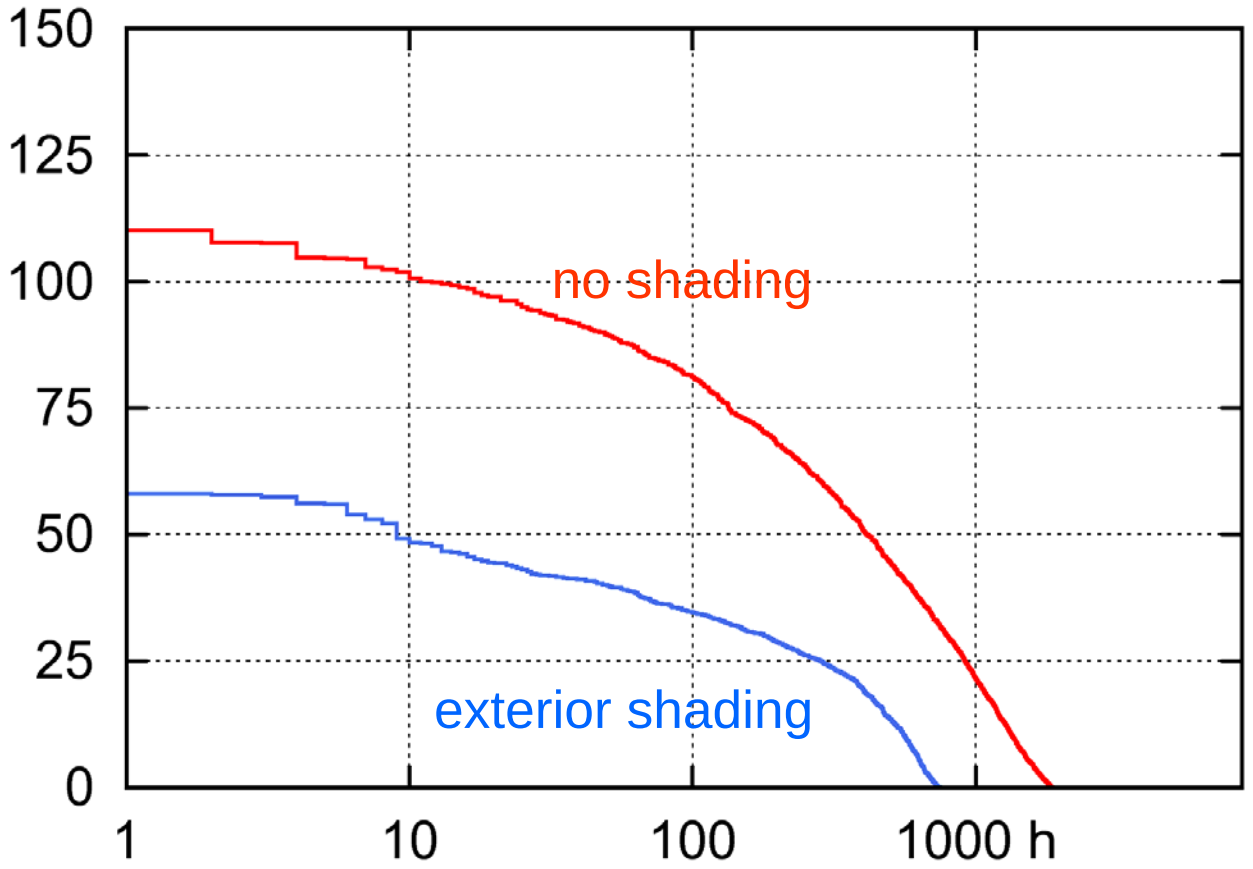
Stockholm – low-e glazing, no shading



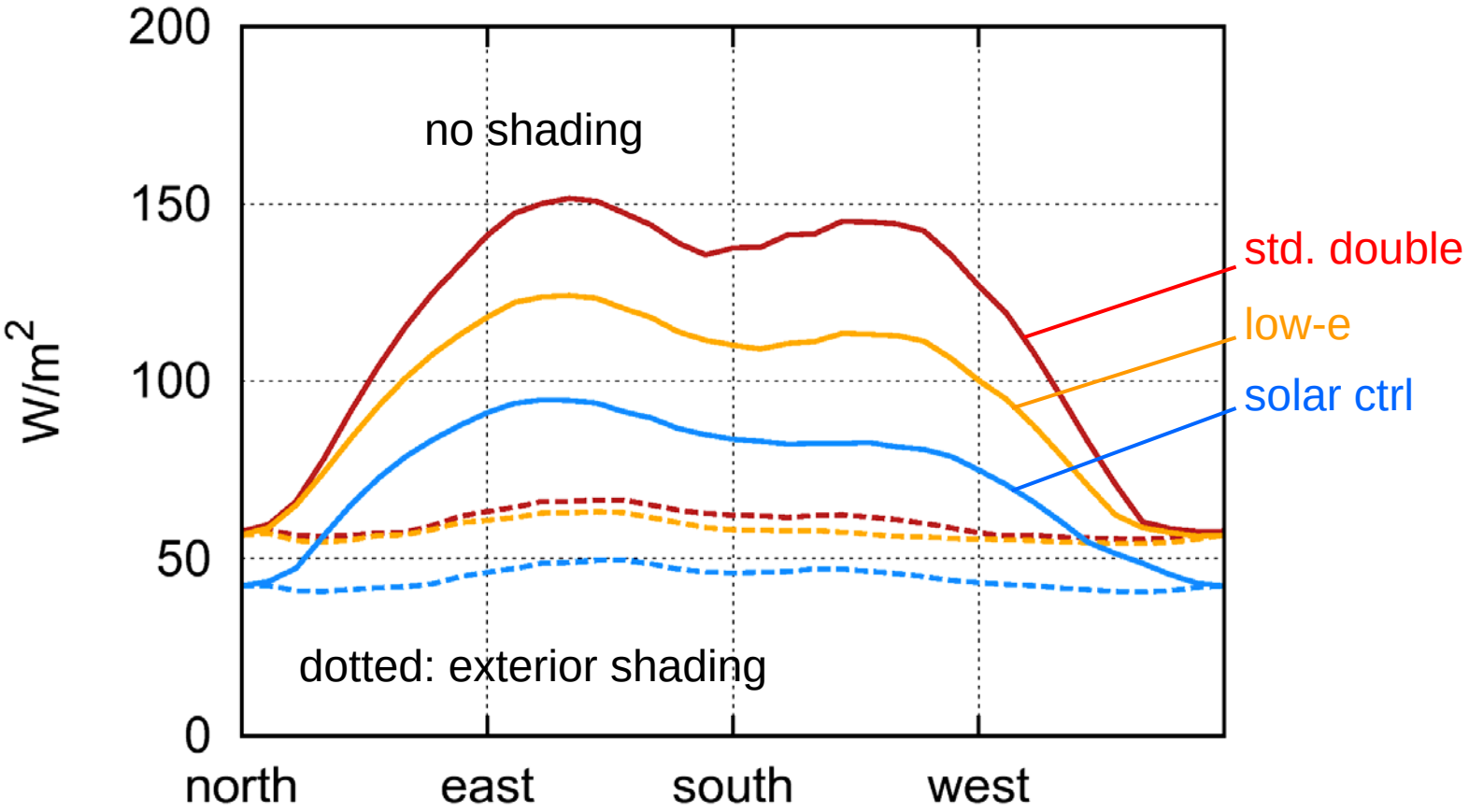
Stockholm – low-e glazing, with shading



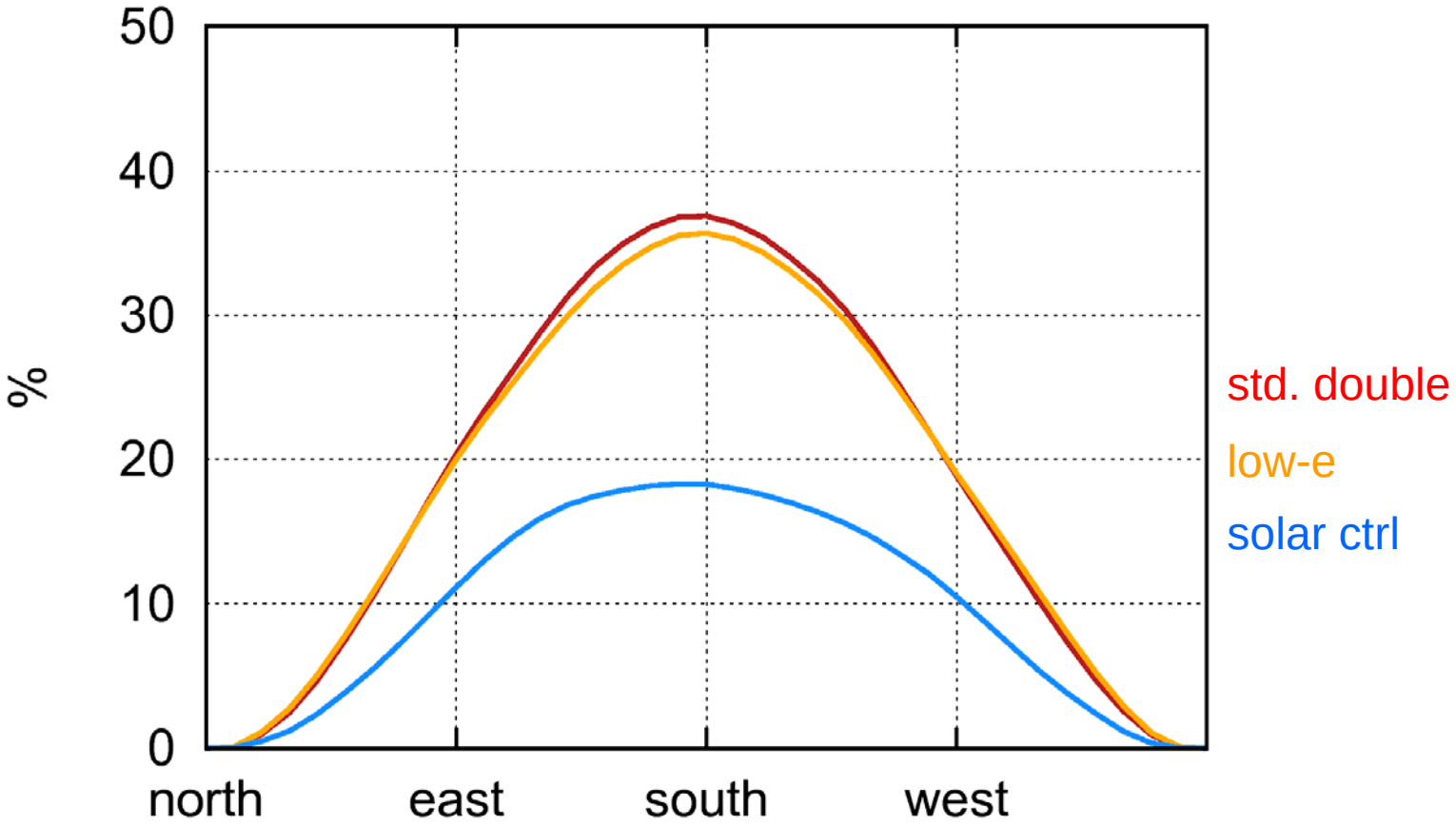
Stockholm – cooling load, low-e glazing, orientation: south



Stockholm – cooling load reduction through shading



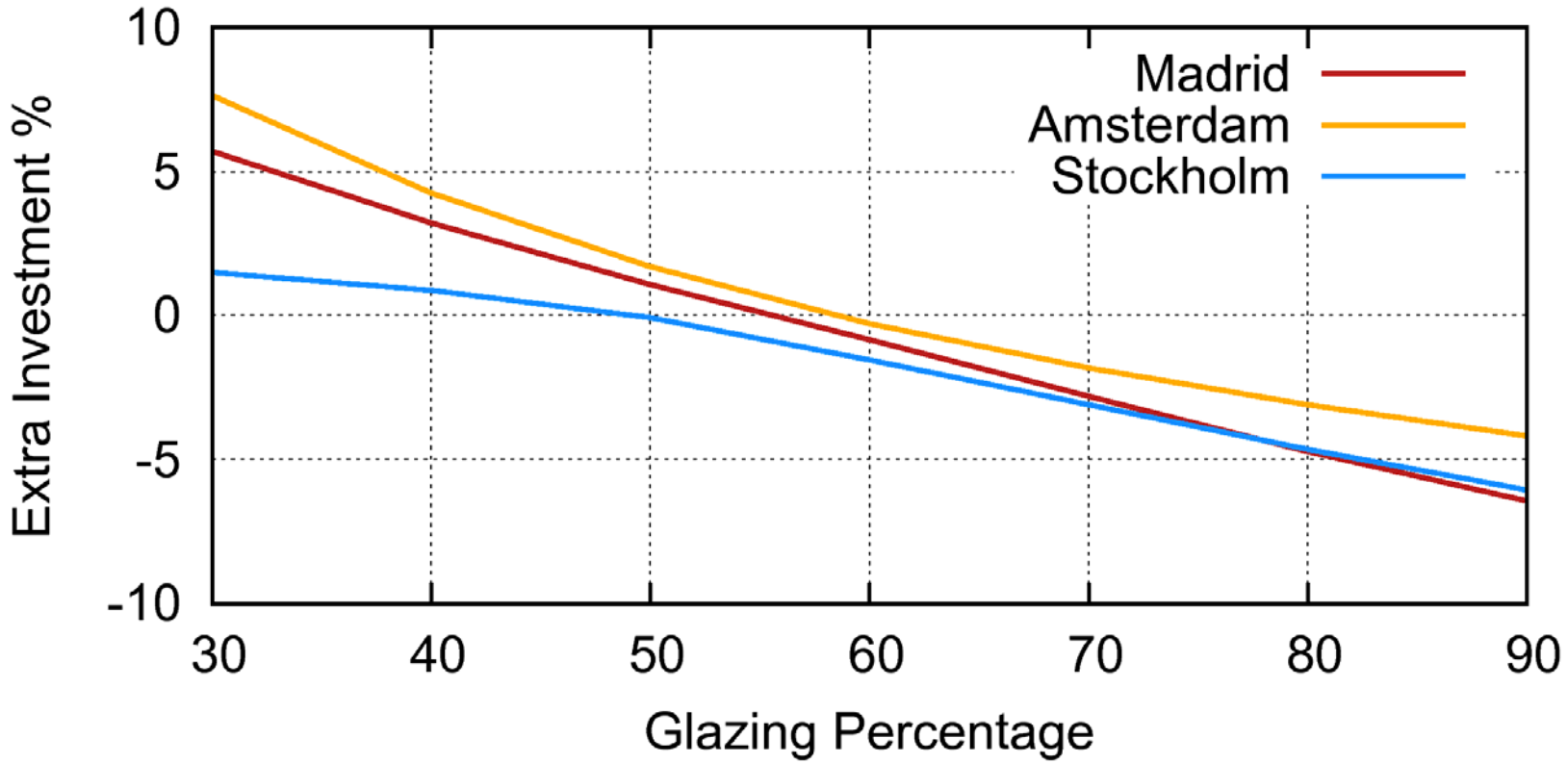
Reduction in primary energy use for heating, cooling and lighting through shading



Cost benefit analysis of solar shading

Stockholm	Solar control glazing			Low-e glazing with solar shading			
Investment cost	*Quantity*	*Unit*	*Cost €*	*Quantity*	*Unit*	*Cost €*	*Delta €*
HVAC	1548	W	1769	1064	W	1431	338
Solar shading	6.48	m²		6.48	m²	626	- 626
Glazing	6.48	m²	791	6.48	m²	441	350
Total investment			2560			2498	62
Recurring cost	*Quantity*	*Unit*	*Cost €*	*Quantity*	*Unit*	*Cost €*	*Delta €*
Electricity for lighting	141	kWh	17	133	kWh	16	1
Cooling	451	kWh_{th}	26	270	kWh_{th}	16	10
Heating	1017	kWh_{th}	71	921	kWh_{th}	64	7
Total recurring per year			114			96	18
						Simple payback period (years)	0

The extra investment in solar shading as a function of glazing percentage



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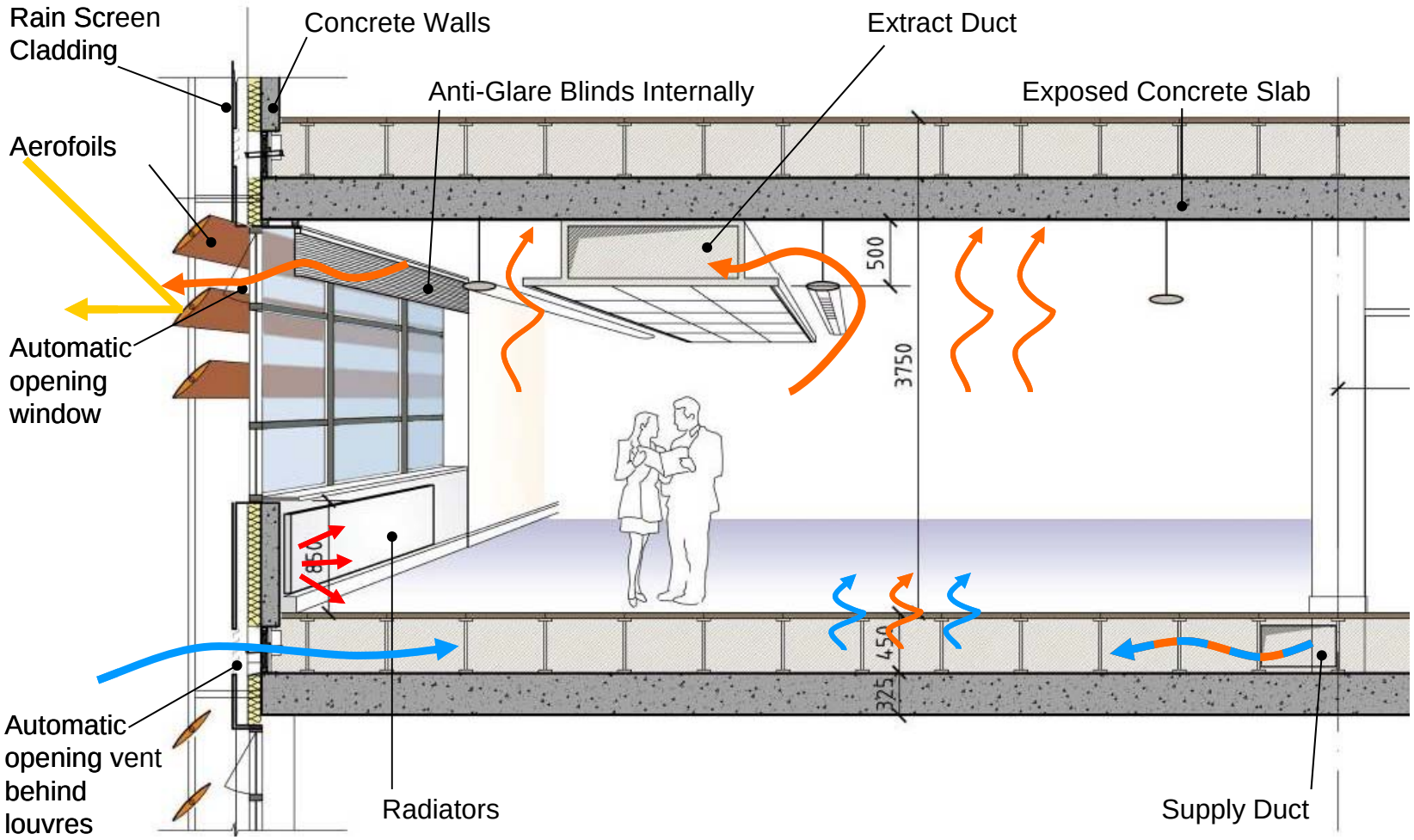
WINDOW COVERINGS

Trafalgar House, Croydon

Trafalgar House, Croydon



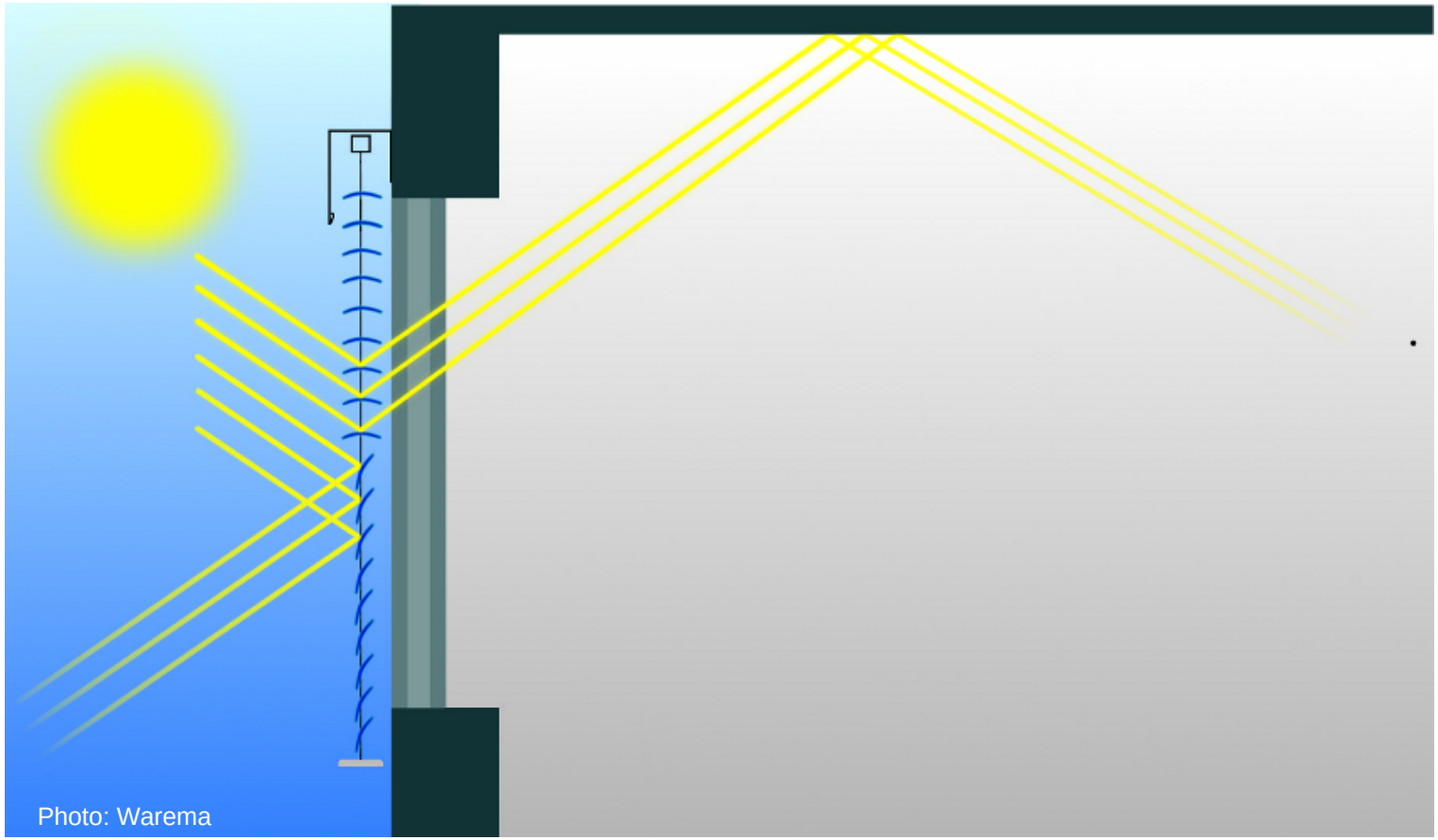
Central Plaza Brussels


Photo: Hunter Douglas

Allianz, Frankfurt am Main

Photo: Warema

Allianz, Frankfurt am Main



Mediathèque Marguerite Yourcenar

Photo:Dickson Constant

Appendices

- EU standards concerning shutters and blinds
- Specification example
- Matrix of responsibilities

Acknowledgements

- Ellen Kohl (Warema),
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- Prof. Zoltan Magyar (University of Pécs, Hungary)