



Federation of European Heating, Ventilation and Air Conditioning Associations

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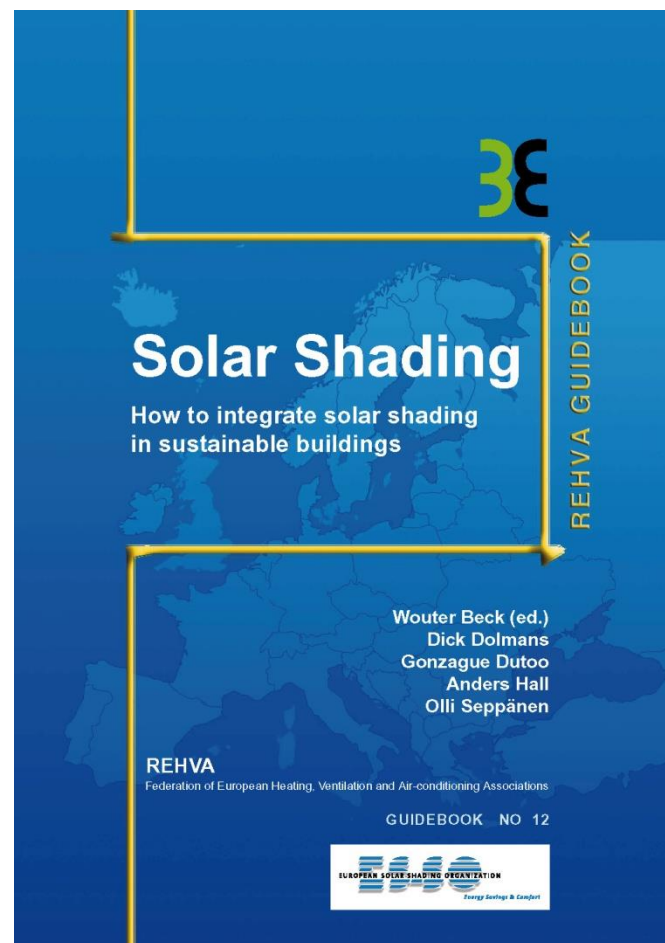
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Solar Shading

by

Wouter Beck (ed.),
Dick Dolmans,
Gonzague Dutoo
Anders Hall
Olli Seppänen



Task force Solar Shading started 2008



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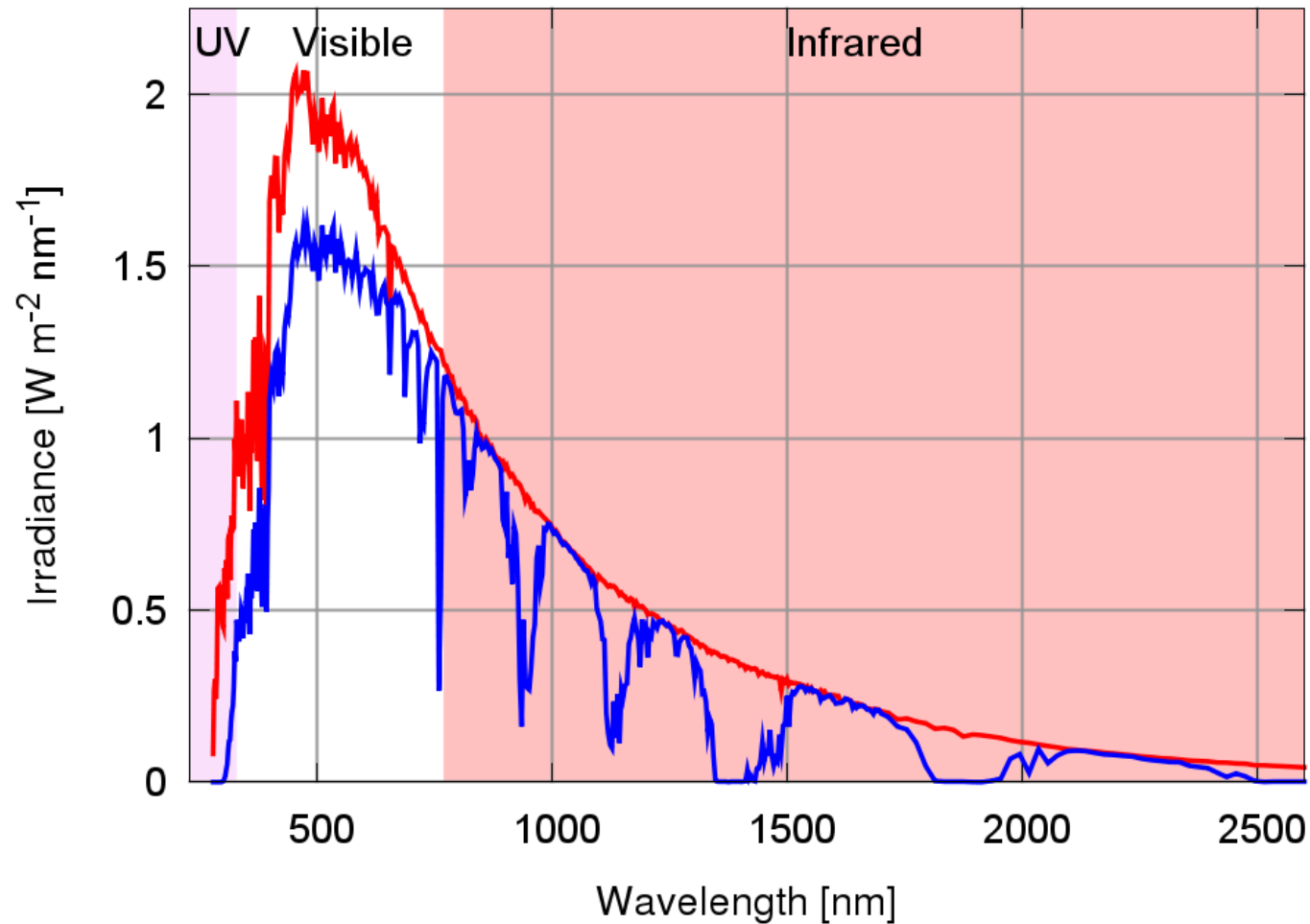
- **Terminology**
- **Solar radiation**
- **Effect of windows on indoor environment**
- **Window systems**
- **Energy effects of solar shading**
- **How to choose a shading solution**
- **Automating and integrating solar shading**
- **Existing buildings**
- **Double-skin facades**
- **Maintenance of solar shading systems**
- **Cases**

Reviewers

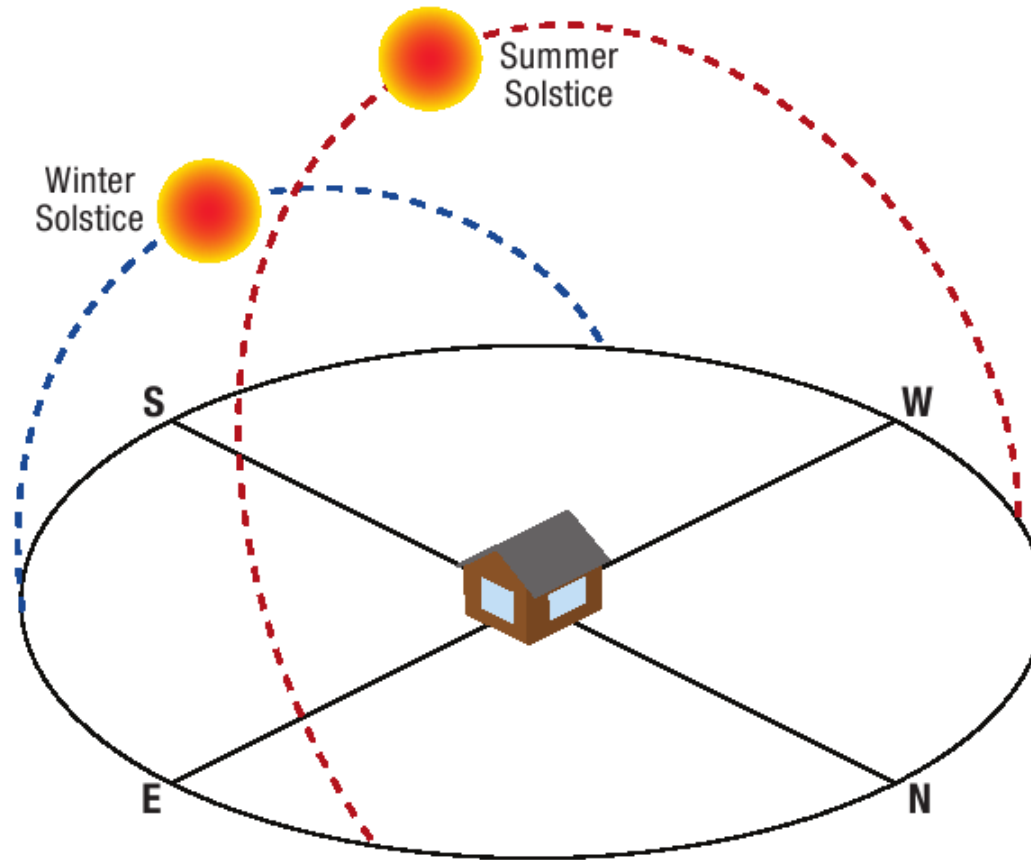
- **Prof. Jan Hensen, Eindhoven University of Technology, The Netherlands**
- **Prof. Mat Santamouris, University of Athens, Greece**
- **Hervé Lamy, SNFPSA, Paris, France**
- **Prof. Michael G Hutchins, Sonnergy Ltd, Abingdon, UK**
- **Dr. Thanos Tzempelikos, Purdue University, West Lafayette, IN, USA**

Solar radiation

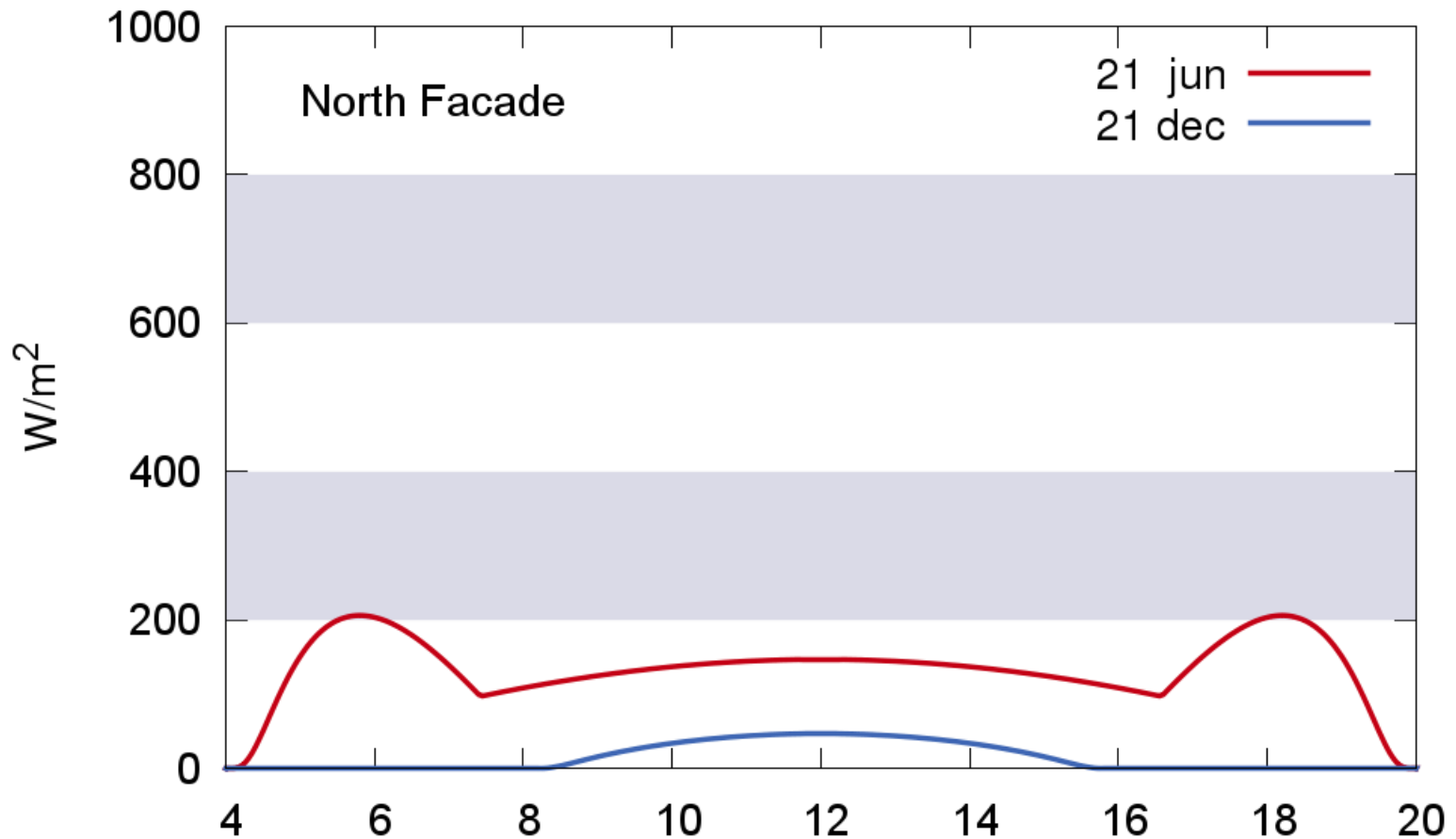
Solar radiation



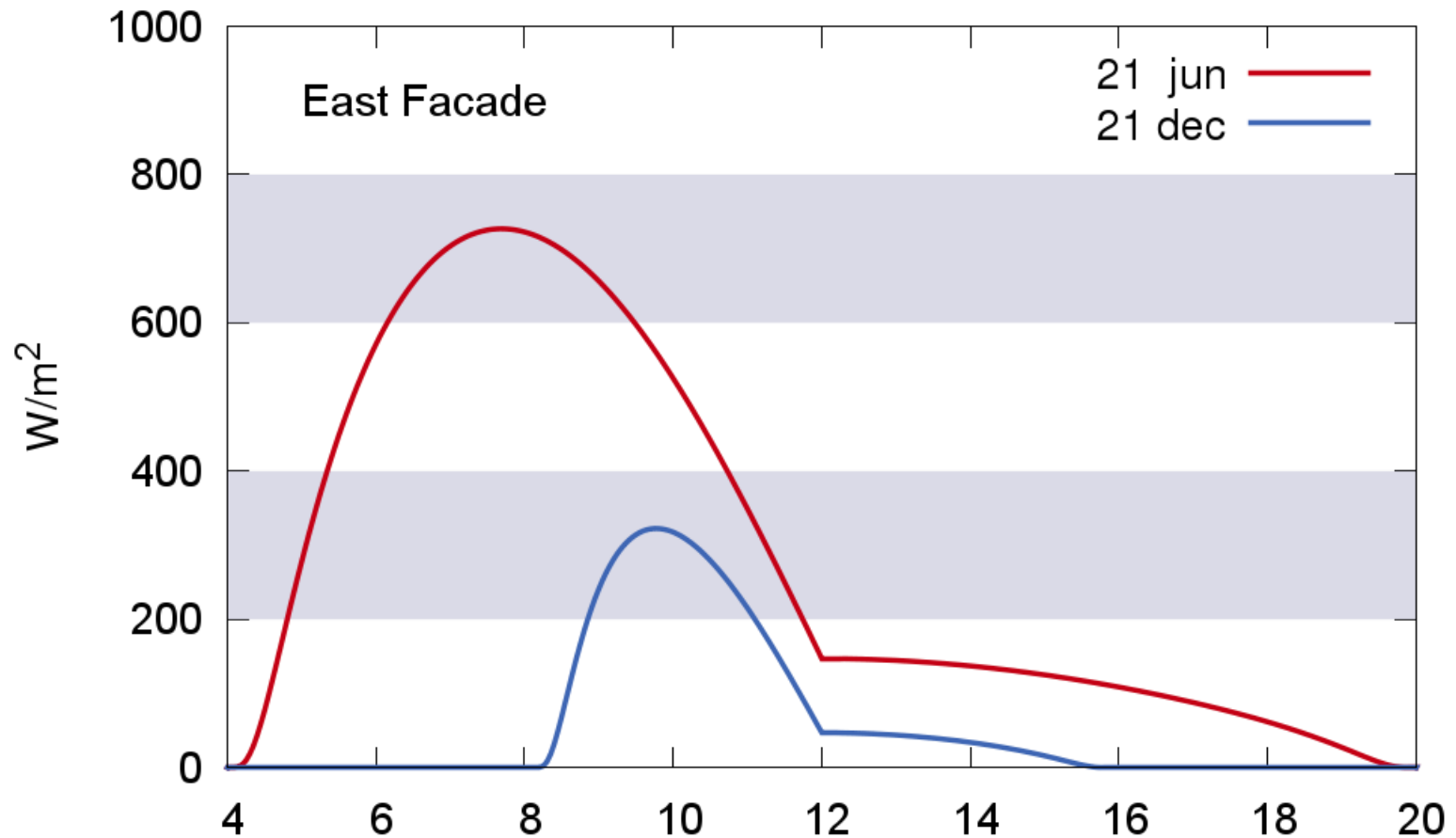
Solar paths



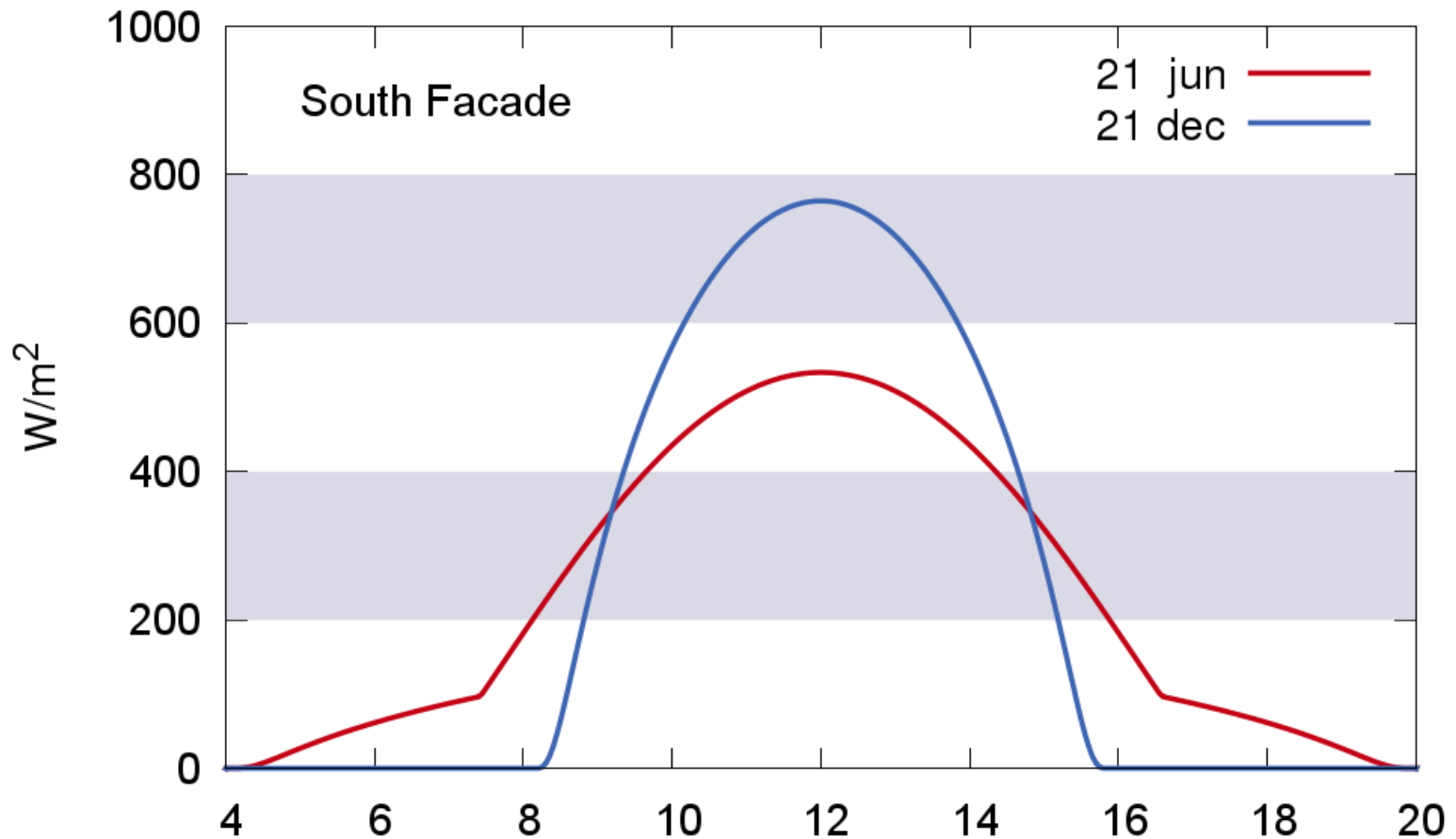
Solar irradiance on a façade (lat. 50 N, clear sky)



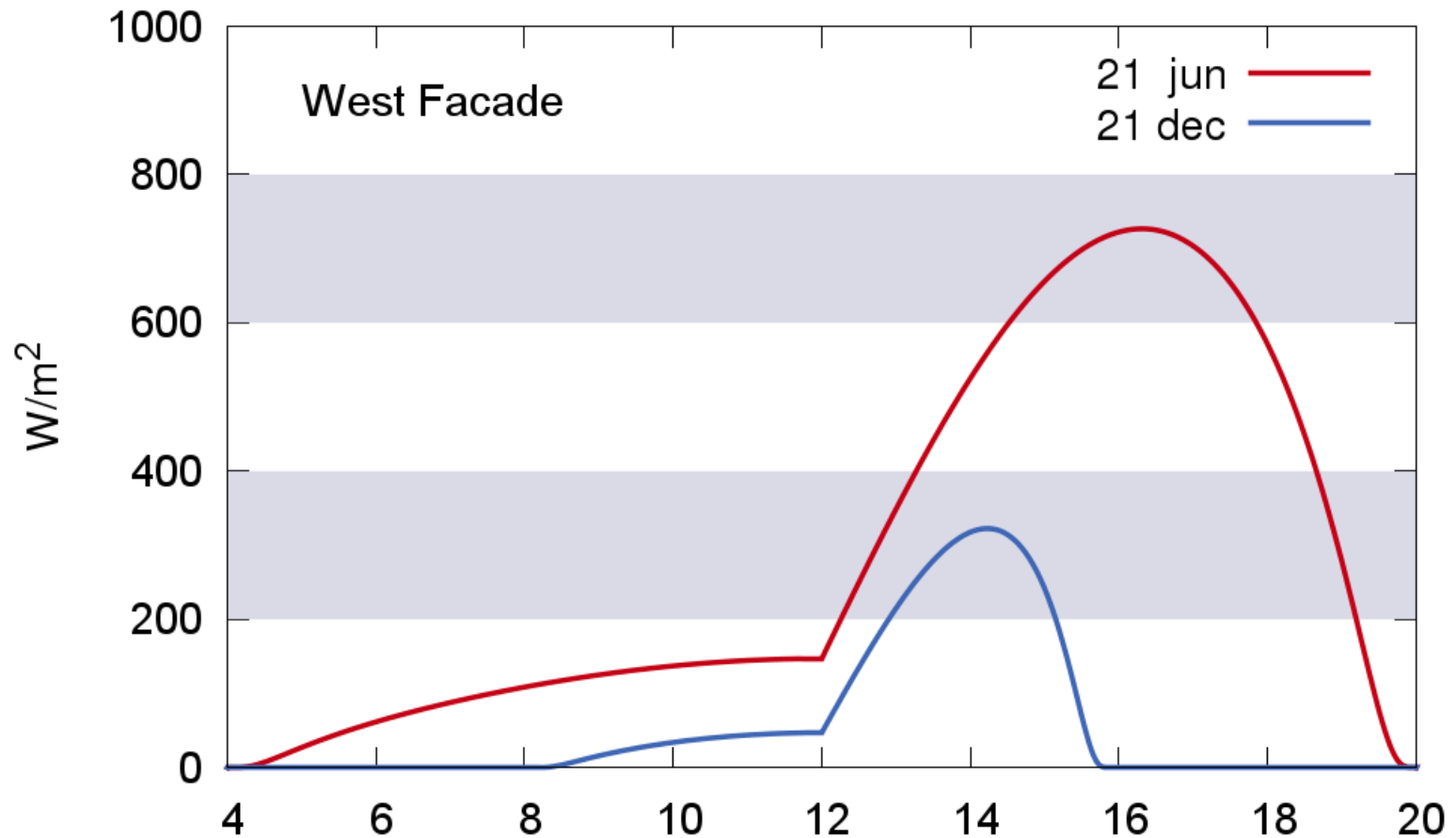
Solar irradiance on a façade (lat. 50 N, clear sky)



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



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



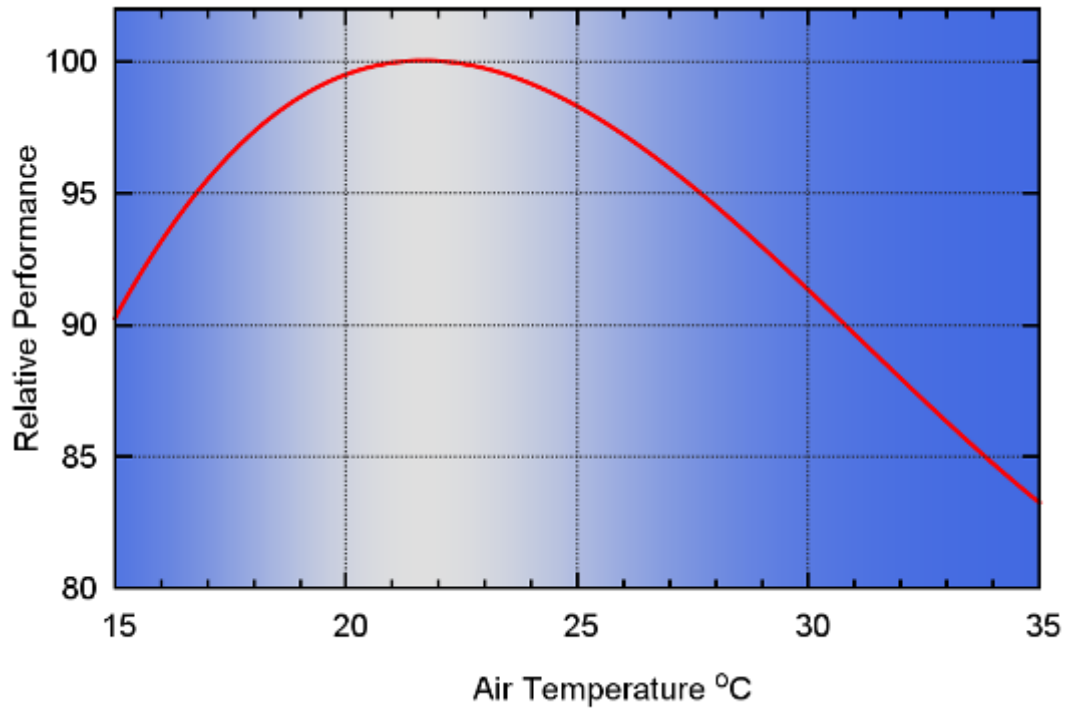
Effect of windows on indoor environment

Effect of windows on indoor environment

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

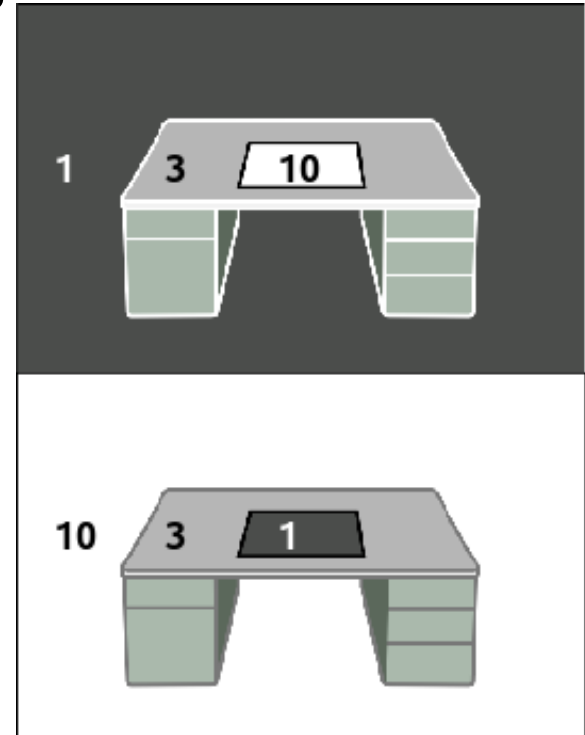
Thermal comfort

- 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

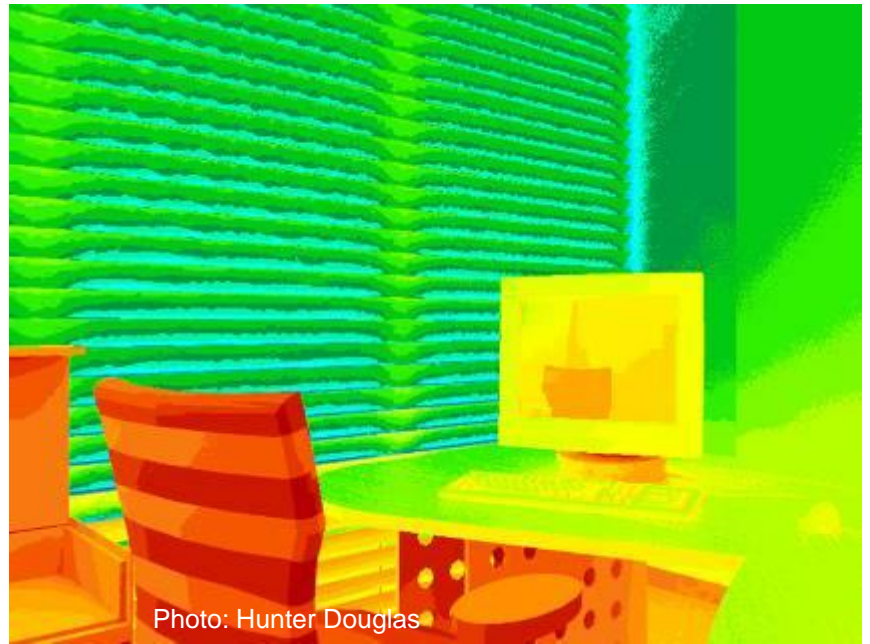
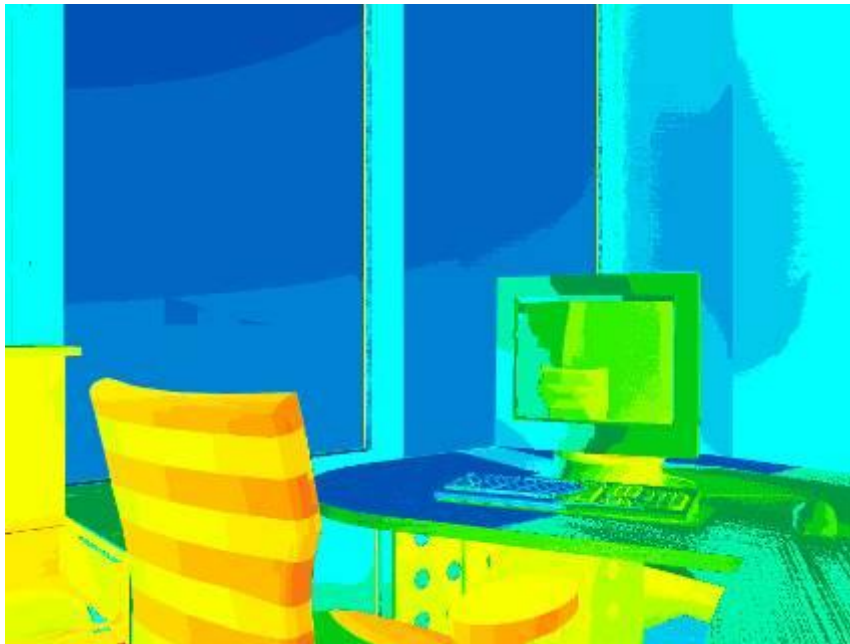
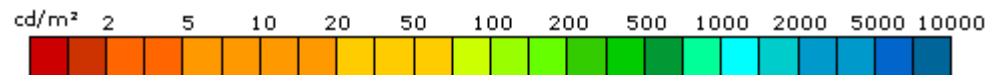
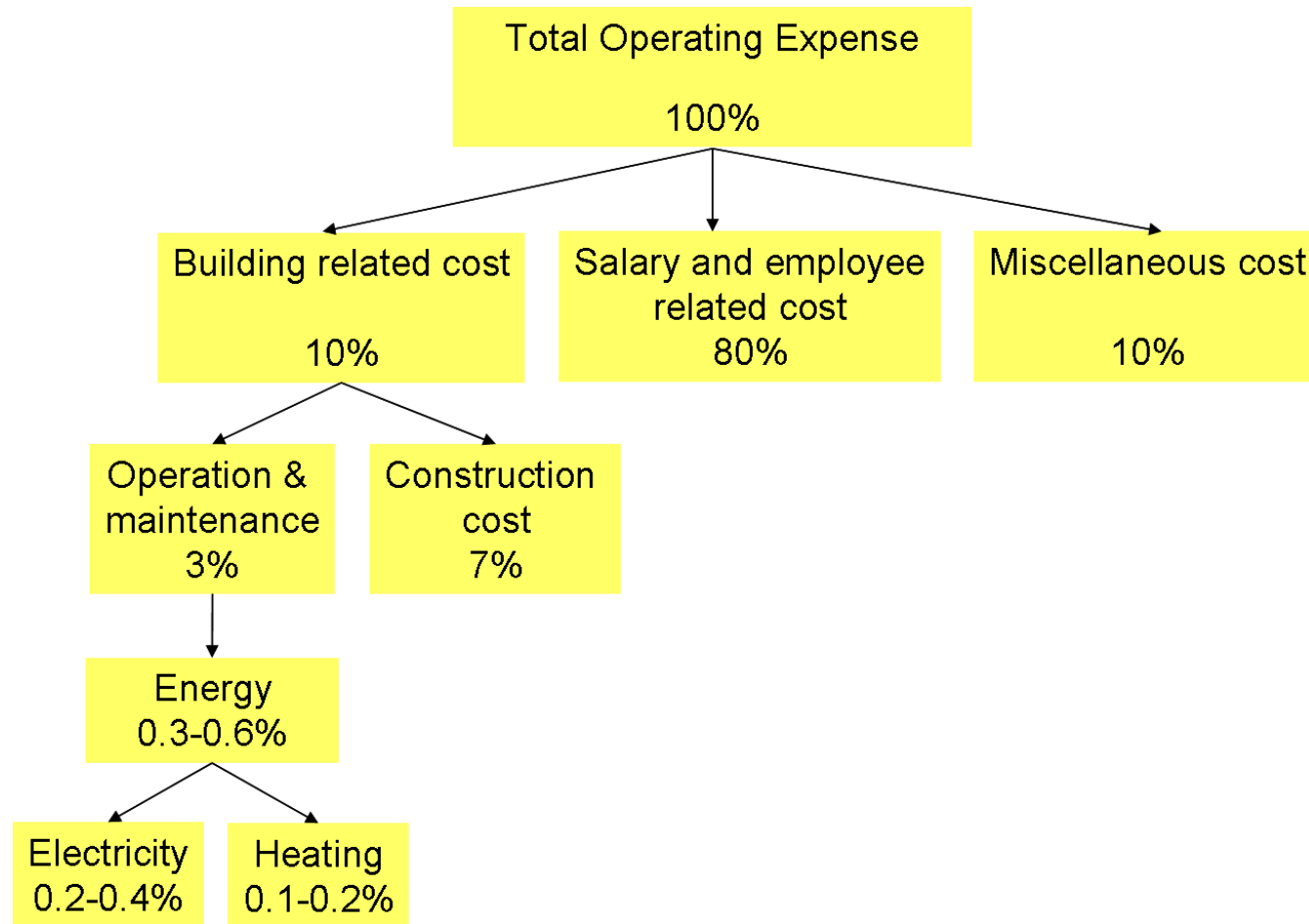


Photo: Hunter Douglas



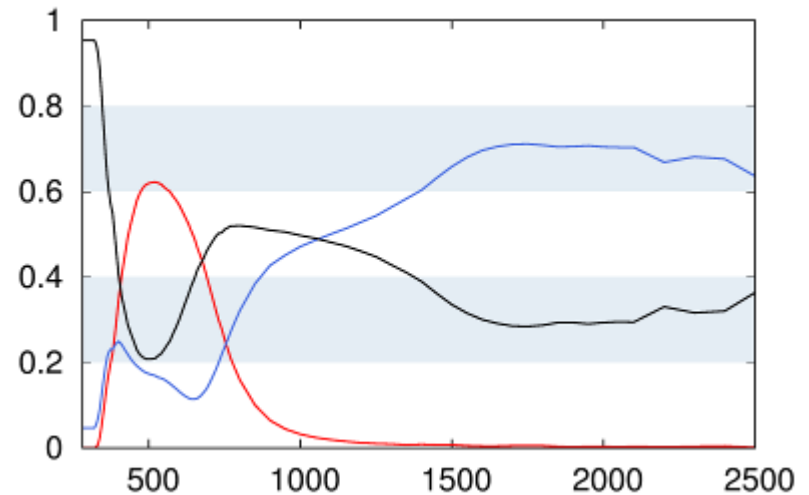
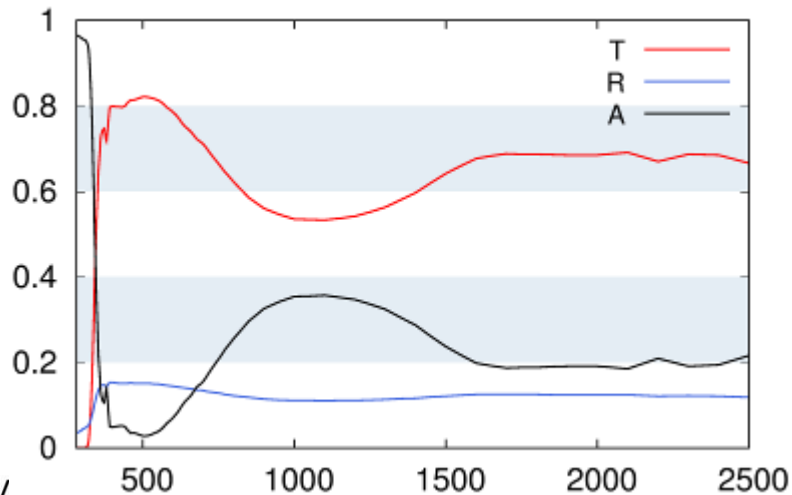
The economic impact of productivity



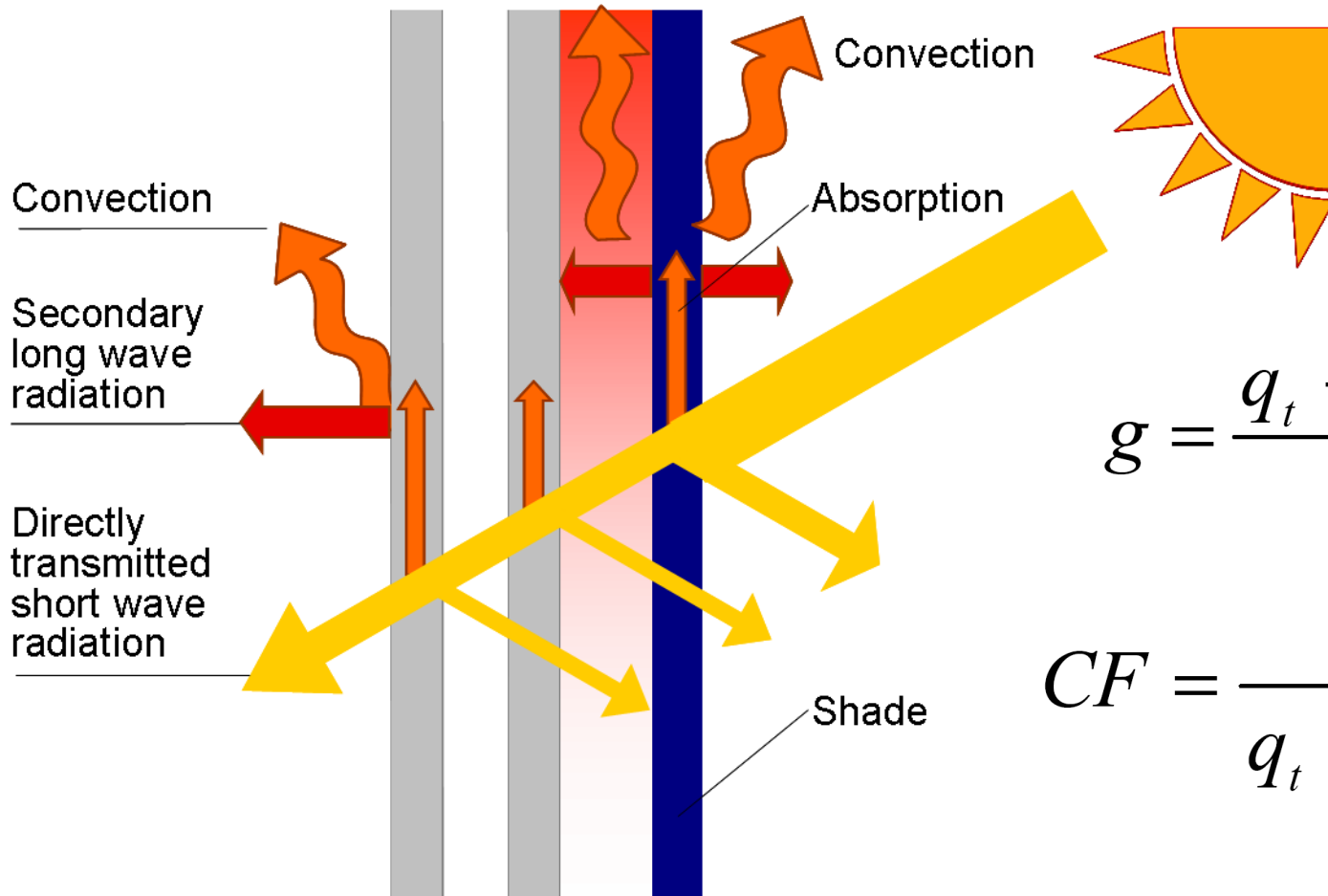
Window systems

Glazing properties

- Thermal transmittance U [W/m²K]
- Light transmittance T_v [-]
- g-value [-]



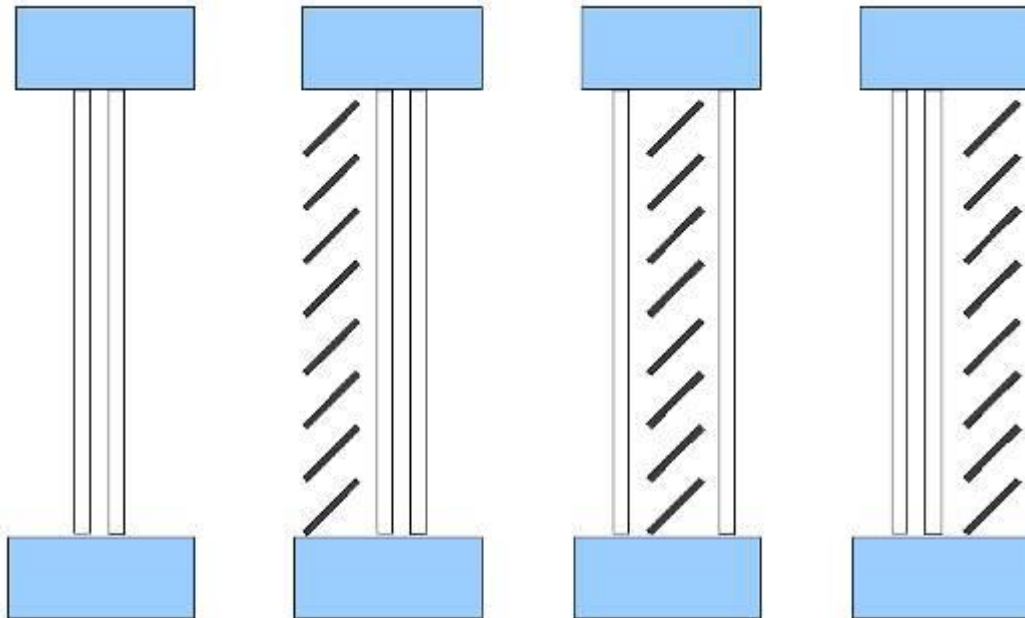
Energy flows



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

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

Convection loads



$g = 0.63$
 $CF = 0.04$
 $RF = 0.09$
 $DF = 0.86$

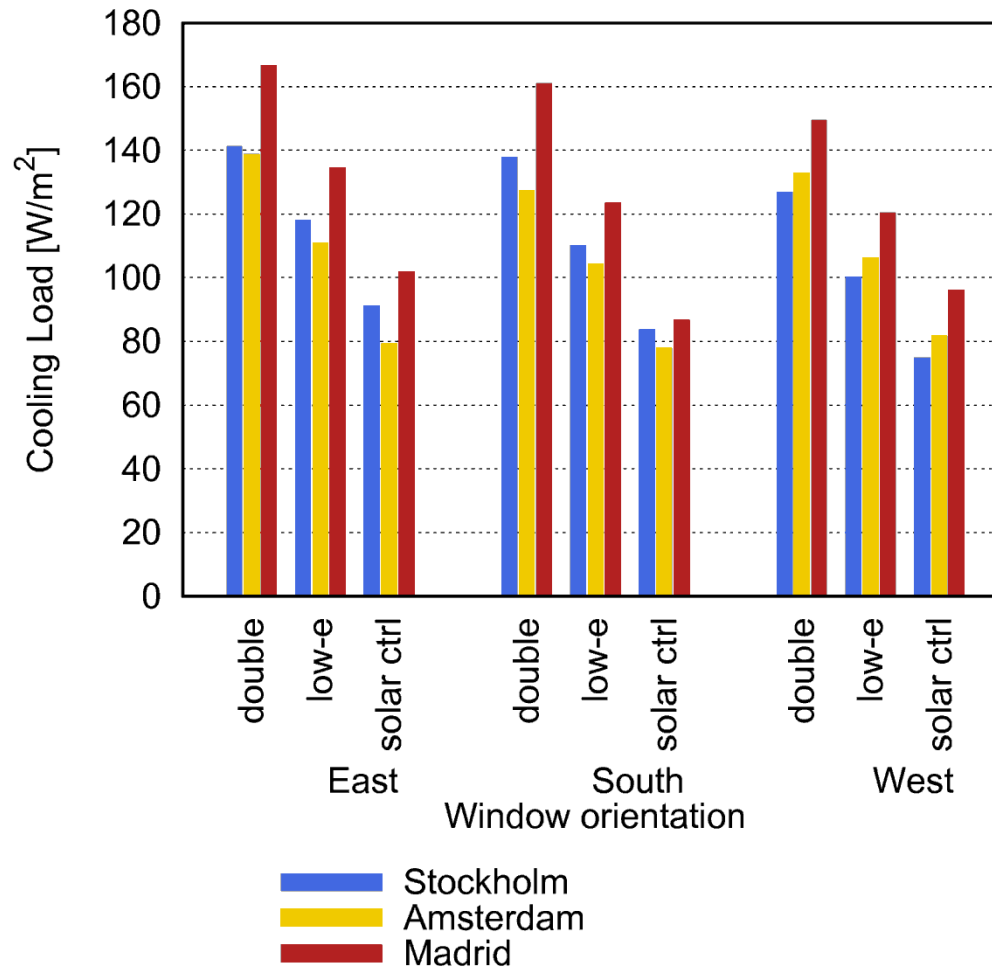
$g = 0.09$
 $CF = 0.01$
 $RF = 0.22$
 $DF = 0.77$

$g = 0.23$
 $CF = 0.21$
 $RF = 0.46$
 $DF = 0.32$

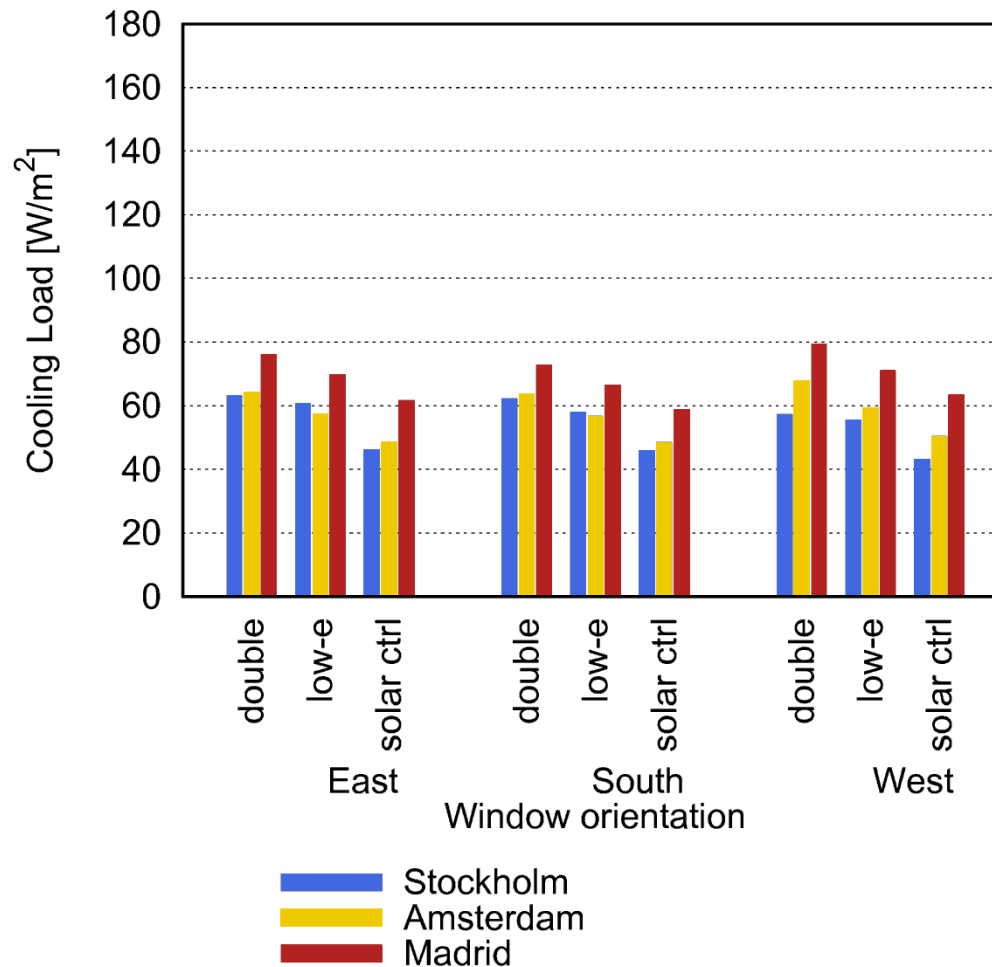
$g = 0.49$
 $CF = 0.45$
 $RF = 0.39$
 $DF = 0.16$

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

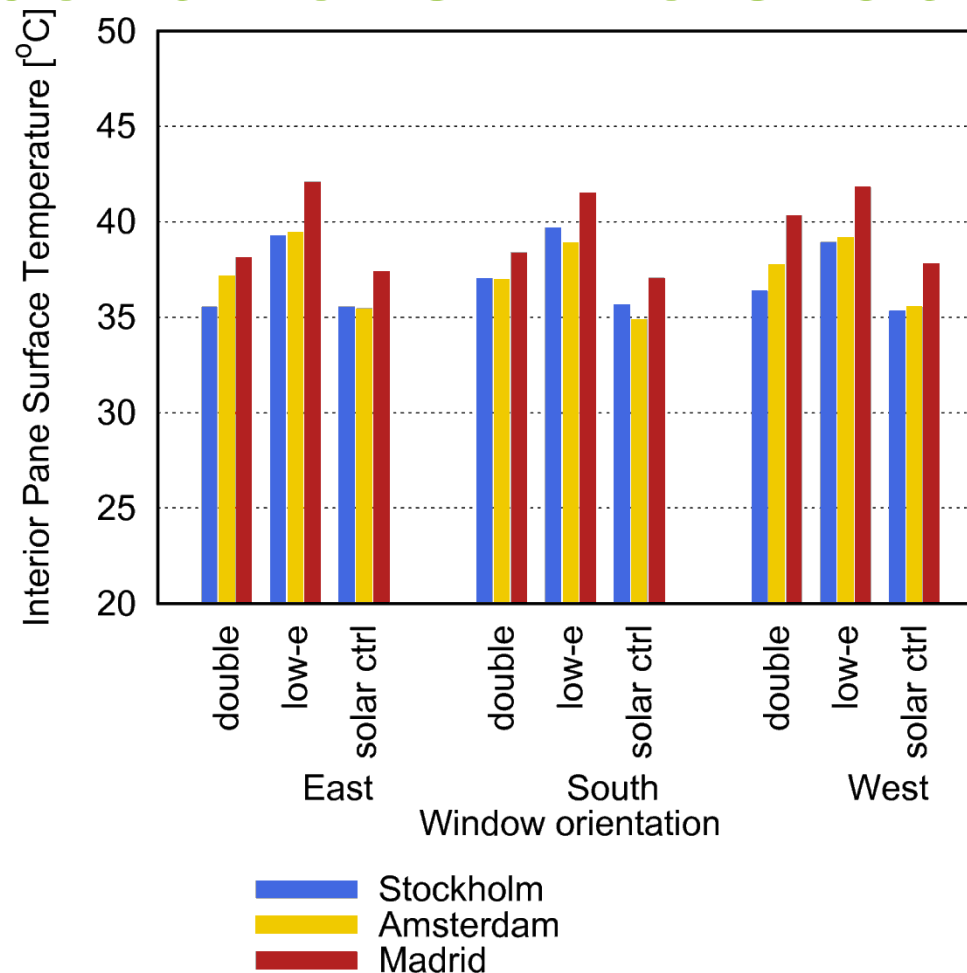
Cooling loads – no shading



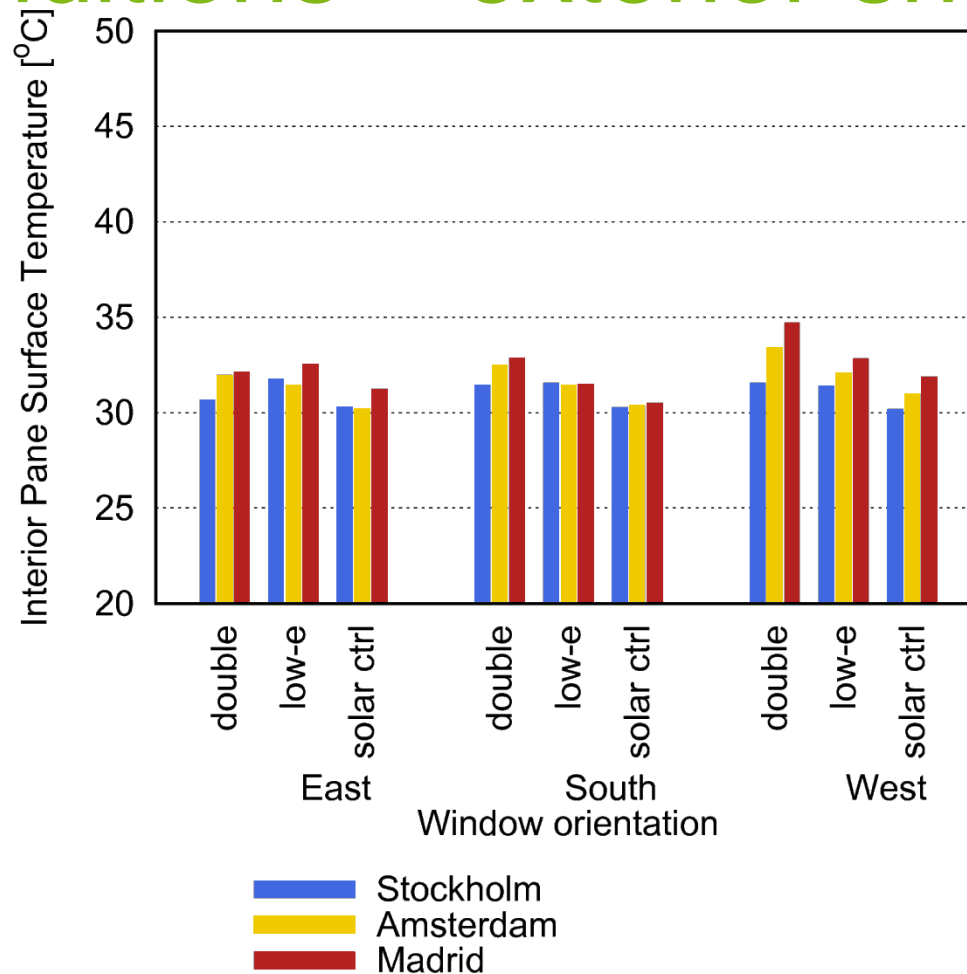
Cooling load – exterior shading



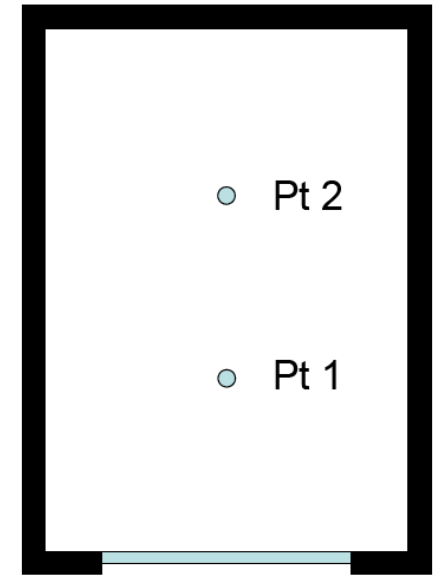
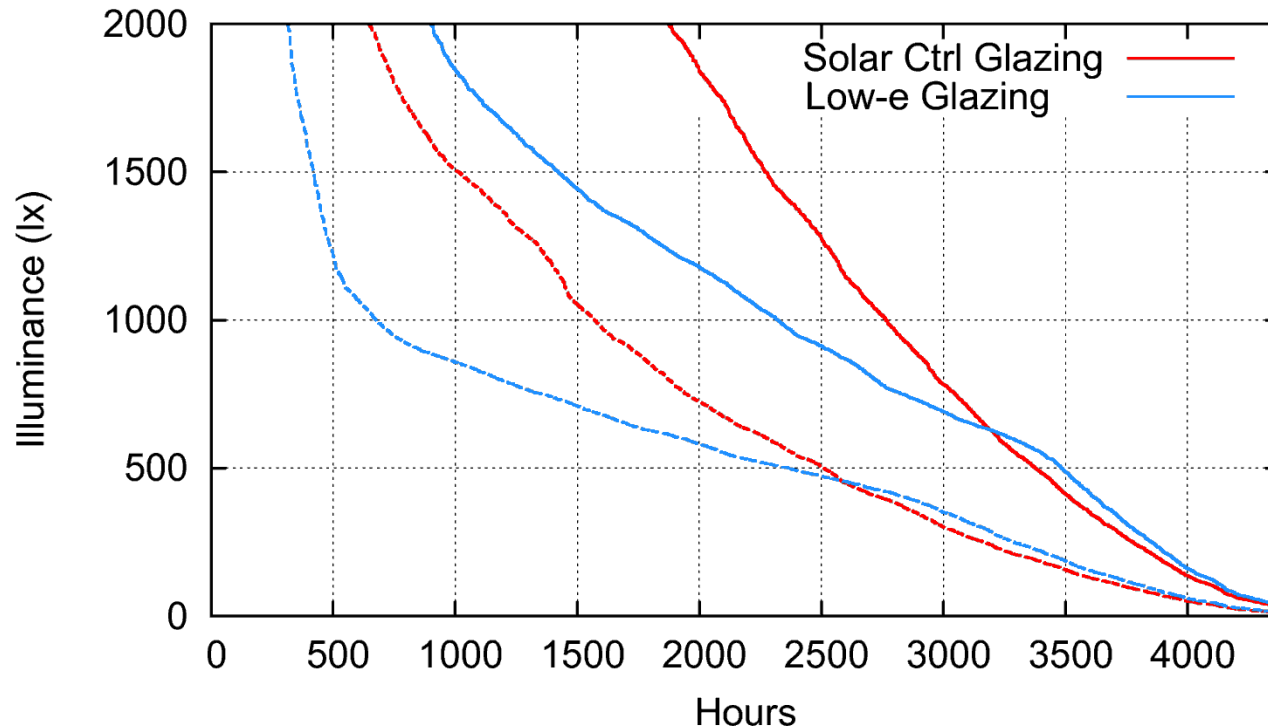
Surface temperature interior window pane under peak load conditions – no shading



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

Energy effects of solar shading

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

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

Standard office

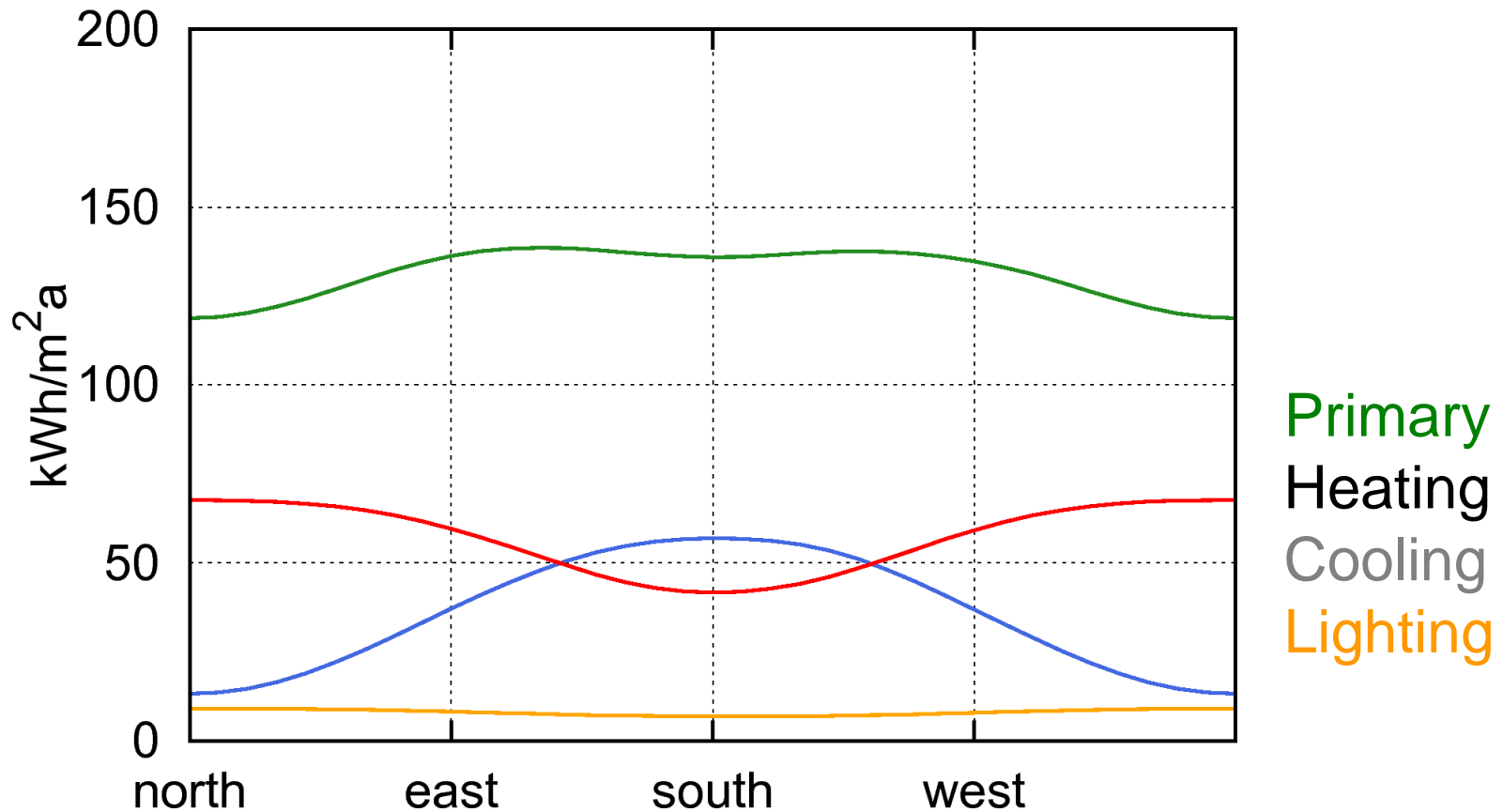
• dimension	3.6 x 5 x 3 m
• ventilation	1.5 dm ³ /m ² s
• infiltration	0.1 ACH
• daylight dependent lighting	500 lx
• max. internal load art. lighting	12 W/m ²
• internal loads people	10 W/m ²
• internal loads equipment	15 W/m ²
• thermostat cooling	25/30 °C (8-18/otherwise)
• thermostat heating	21/15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

Conversion to primary energy

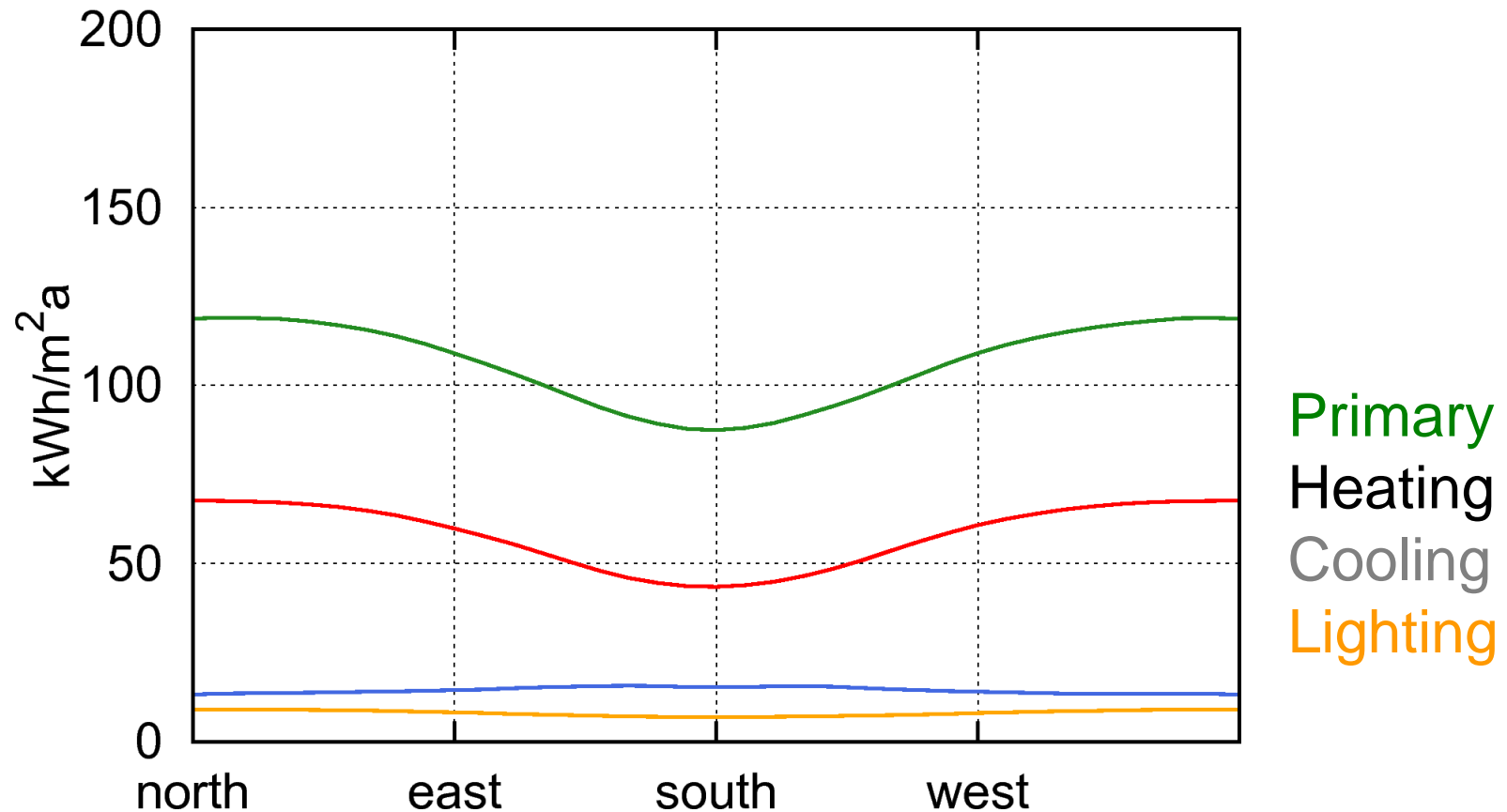
$$E_{\text{Prim}} = \frac{1}{A} \left(\frac{E_{\text{light}}}{\eta_e} + \frac{E_{\text{cool}}}{\eta_e \eta_c \text{COP}} + \frac{E_{\text{heat}}}{\eta_h} \right)$$

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

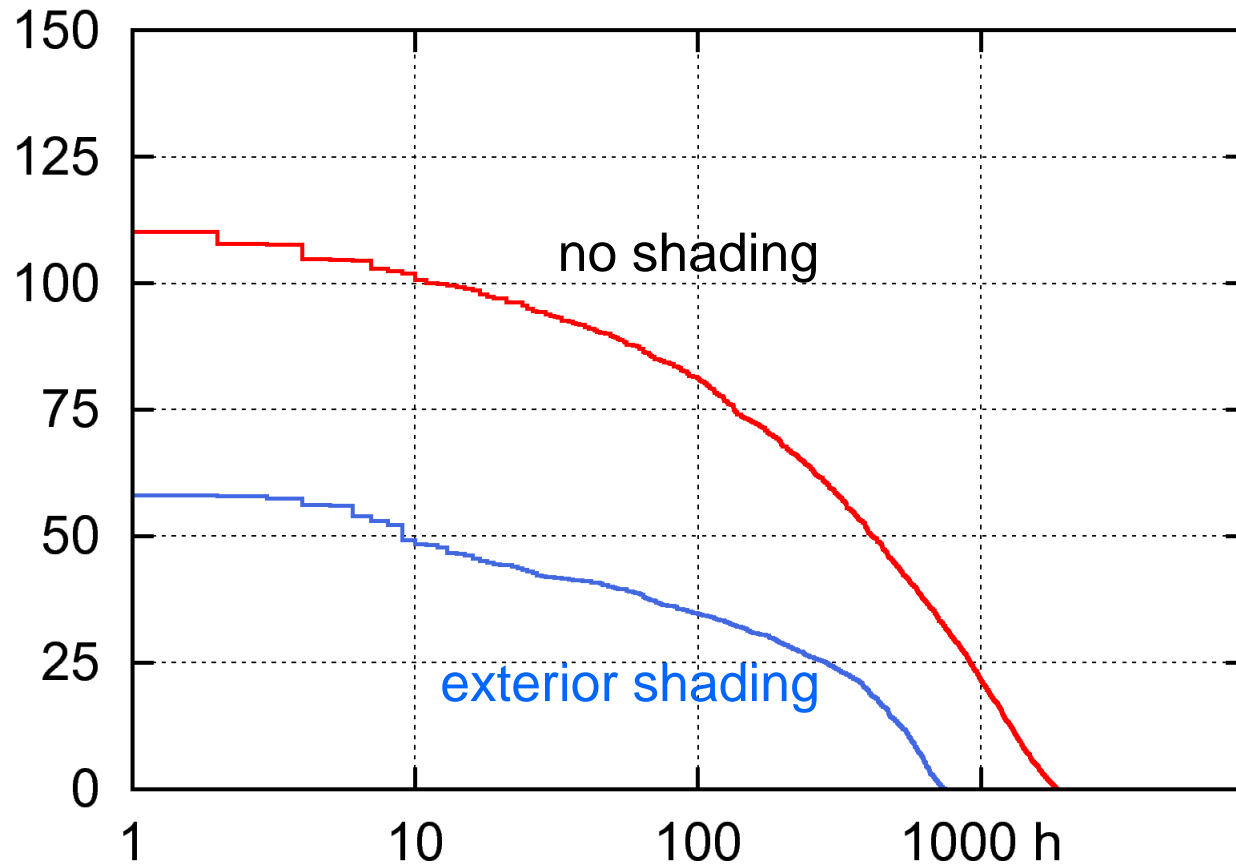
Stockholm – low-e glazing, no shading



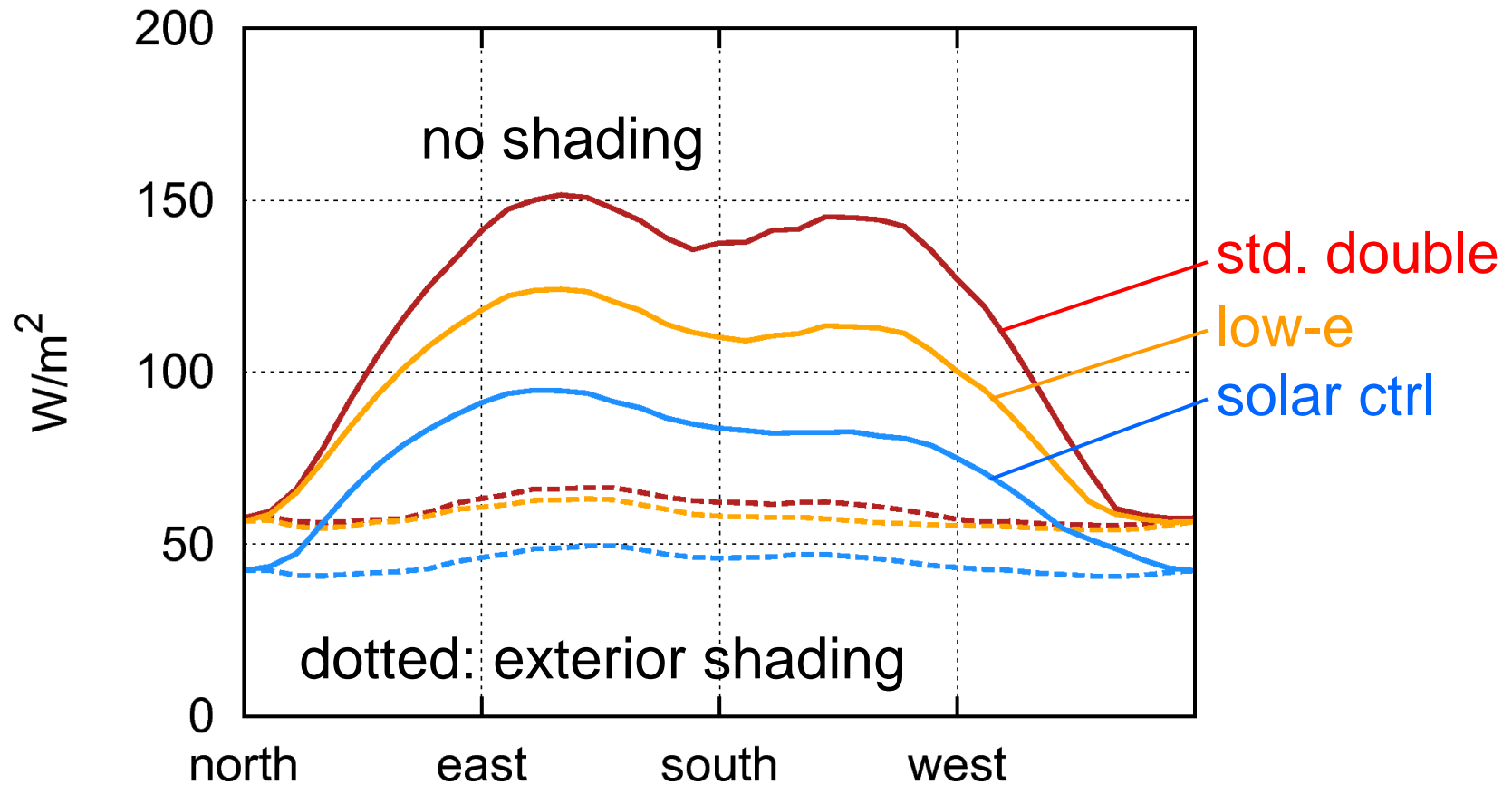
Stockholm – low-e glazing, with shading



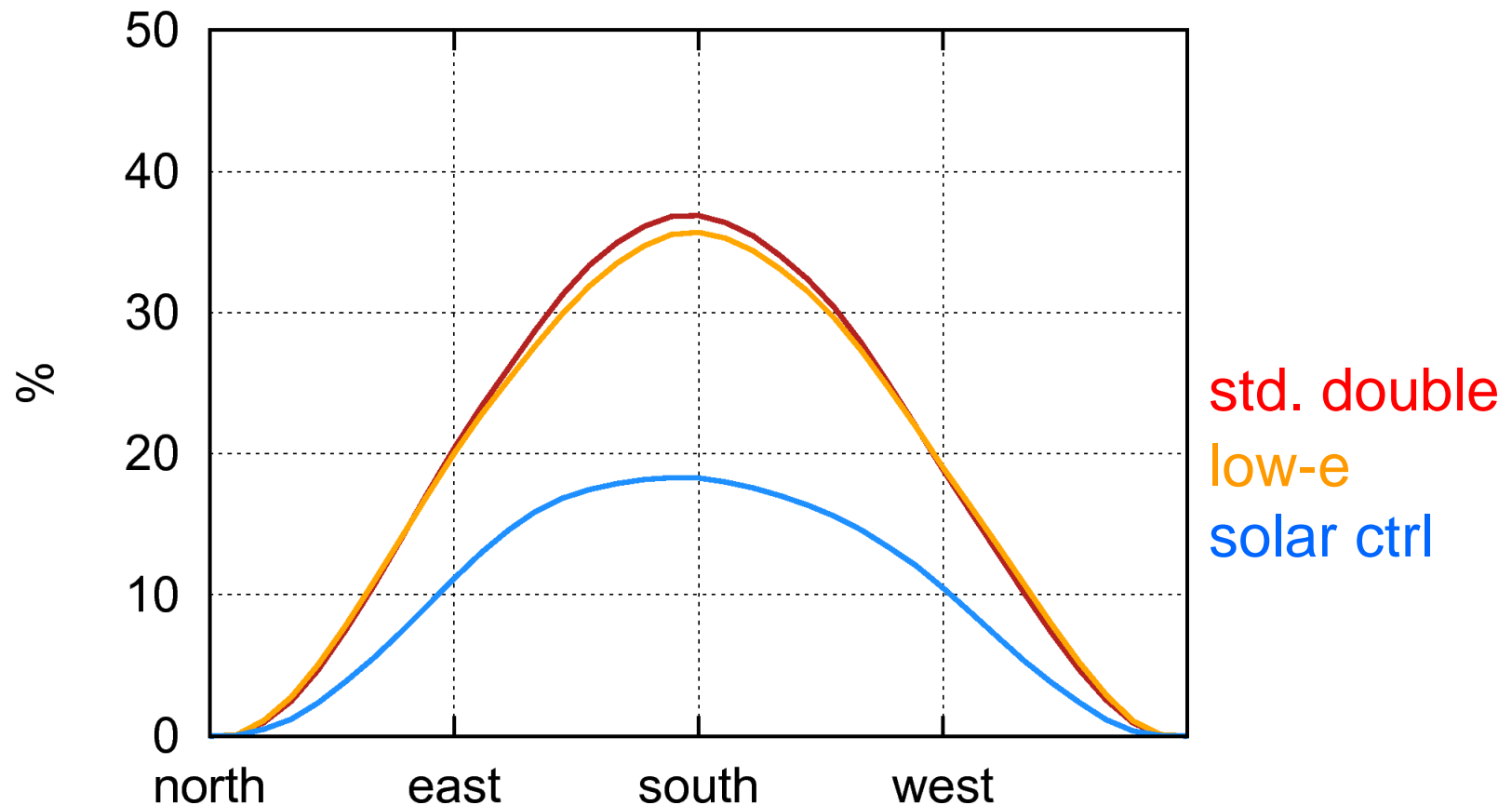
Stockholm – cooling load, low-e glazing, orientation: south



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			
<i>Investment cost</i>	<i>Quantity</i>	<i>Unit</i>	<i>Cost €</i>	<i>Quantity</i>	<i>Unit</i>	<i>Cost €</i>	<i>Delta €</i>
HVAC	1548	W	1769	1064	W	1431	338
Solar shading	6.48	m ²		6.48	m ²	626	- 626
Glazing	6.48	m ²	791	6.48	m ²	441	350
Total investment			2560			2498	62
<i>Recurring cost</i>	<i>Quantity</i>	<i>Unit</i>	<i>Cost €</i>	<i>Quantity</i>	<i>Unit</i>	<i>Cost €</i>	<i>Delta €</i>
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

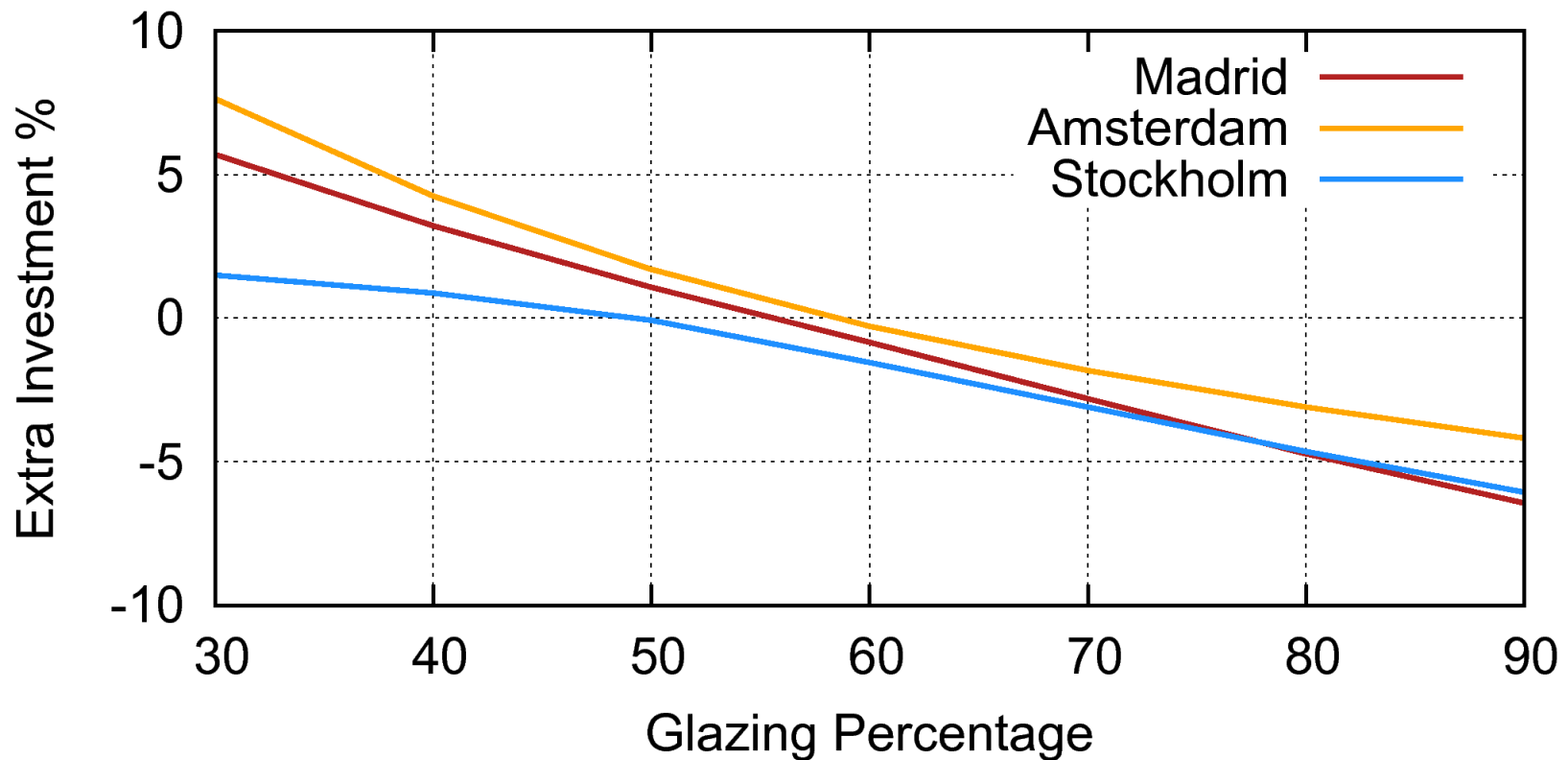


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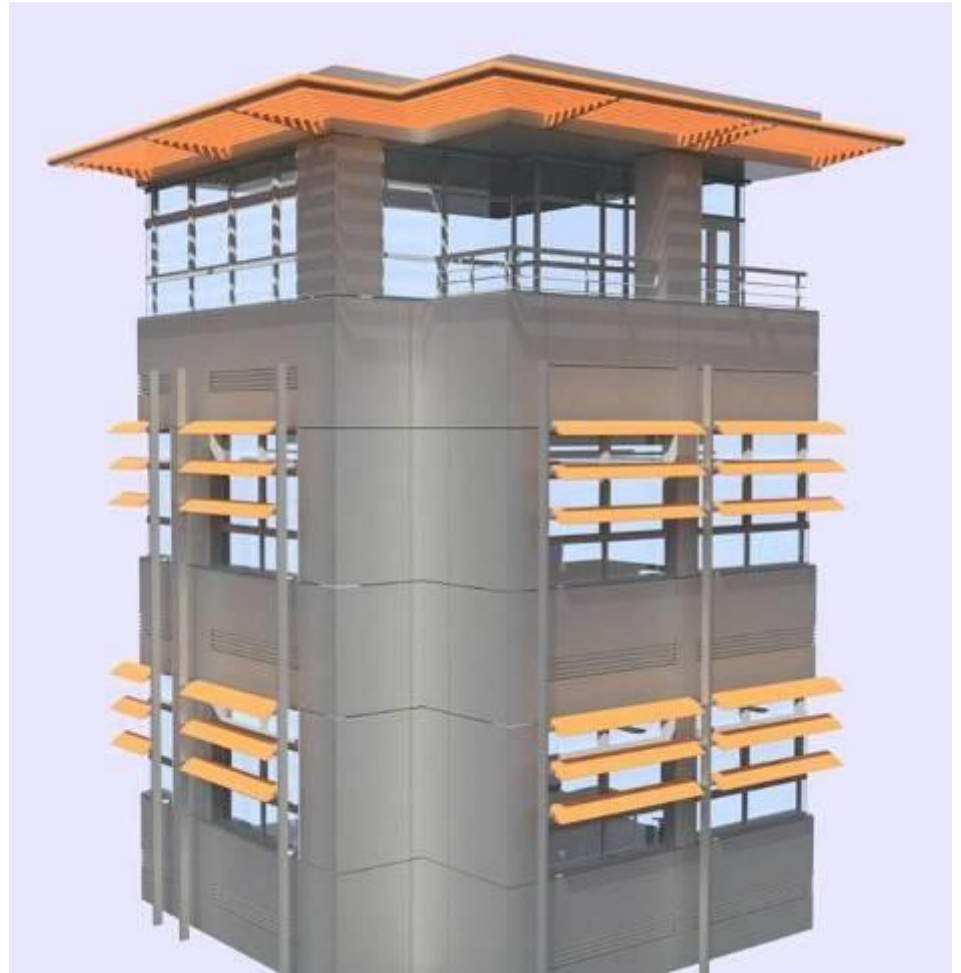
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Cases

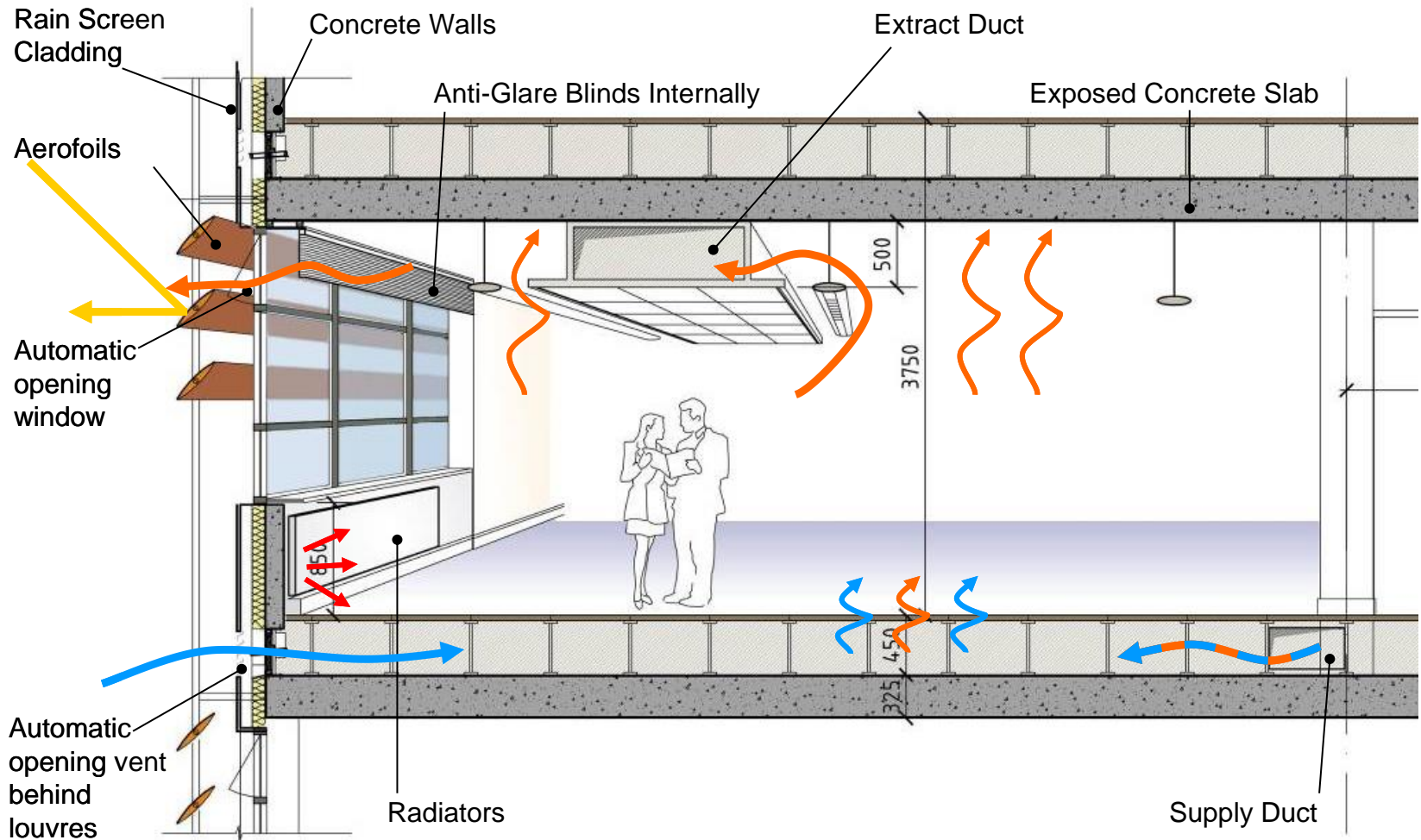
Trafalgar House, Croydon



Photo: Hunter Douglas



Trafalgar House, Croydon



Central Plaza Brussels



Photo: Hunter Douglas

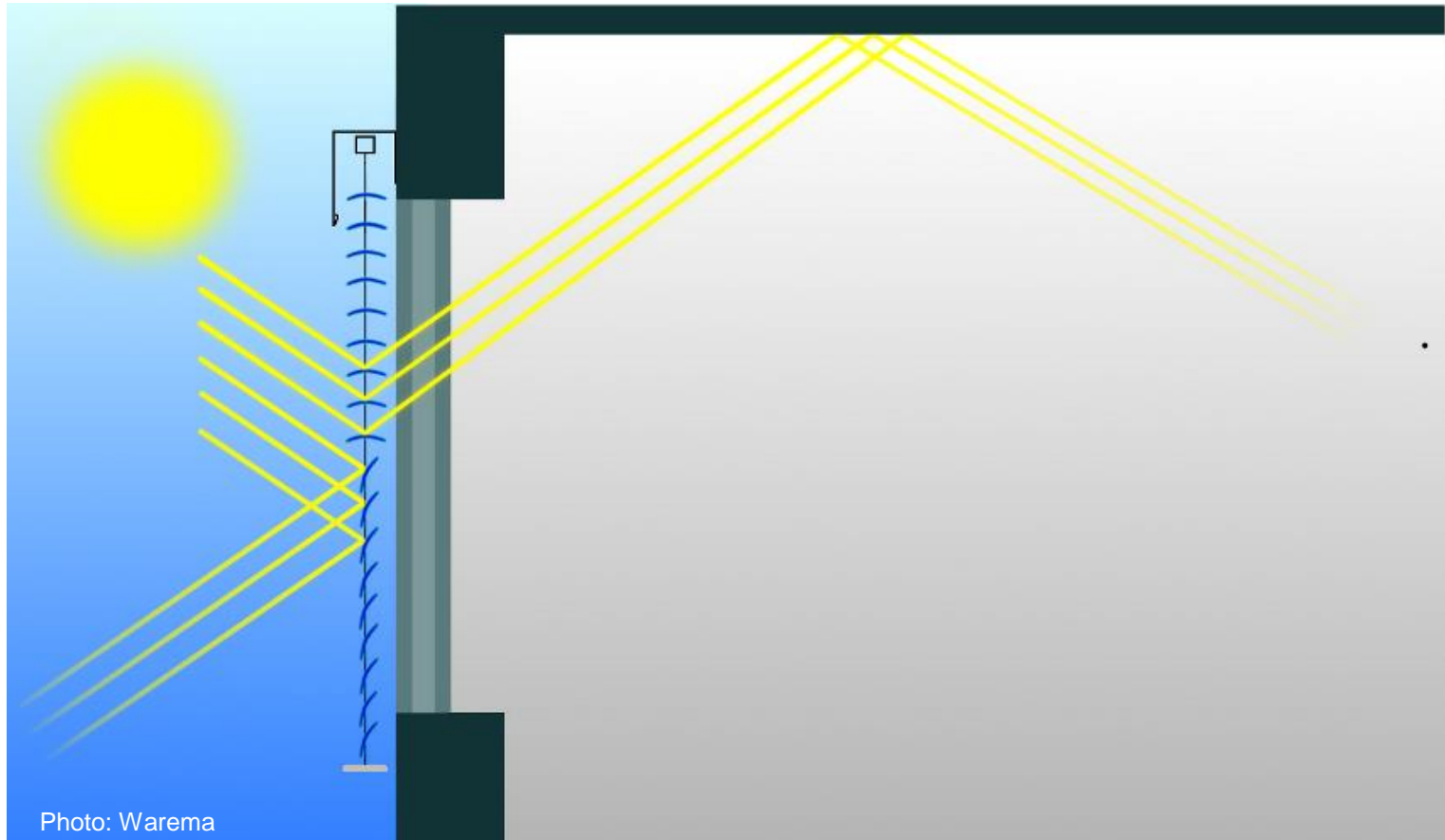


Allianz, Frankfurt am Main



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),**
- **Maaïke Berckmoes (Scheldebouw-Permasteelisa),**
- **Risto Kosonen (Halton),**
- **Bernard Gilmont (European Aluminium Association),**
- **Maija Virta (Halton),**
- **Prof. Dirk Saelens (Catholic University of Leuven, Belgium)**
- **Prof. Zoltan Magyar (University of Pécs, Hungary)**

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