SIMULATION-BASED WORKFLOWS FOR THE DESIGN OF TEXTILE SHADING SYSTEMS WITH ENHANCED FUNCTIONALITY

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Fraunhofer Institute for Solar Energy Systems ISE

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Requirements for shading and daylighting systems
Building level

- Daylight provision
- Glare protection
- Solar heat gain management
- Visual contact preservation

These functions oppose each other… aargh!

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Requirements for shading and daylighting systems
Building level – component level

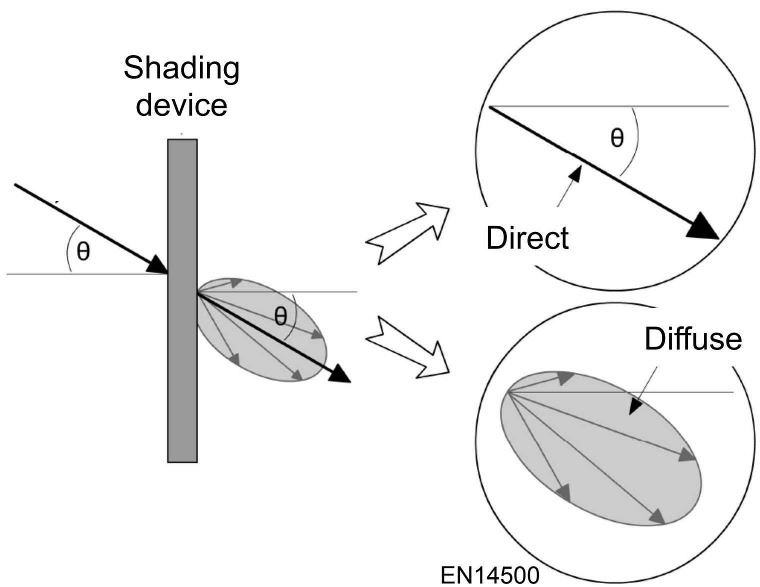
- Daylight provision
- Glare protection
- Solar heat gain management
- Visual contact preservation

High diffuse-diffuse transmittance (visible)

Very low direct-direct transmittance (visible) (positive altitude angles)

Switchable transmittance (solar)

High direct-direct transmittance (visible) (negative altitude angles)



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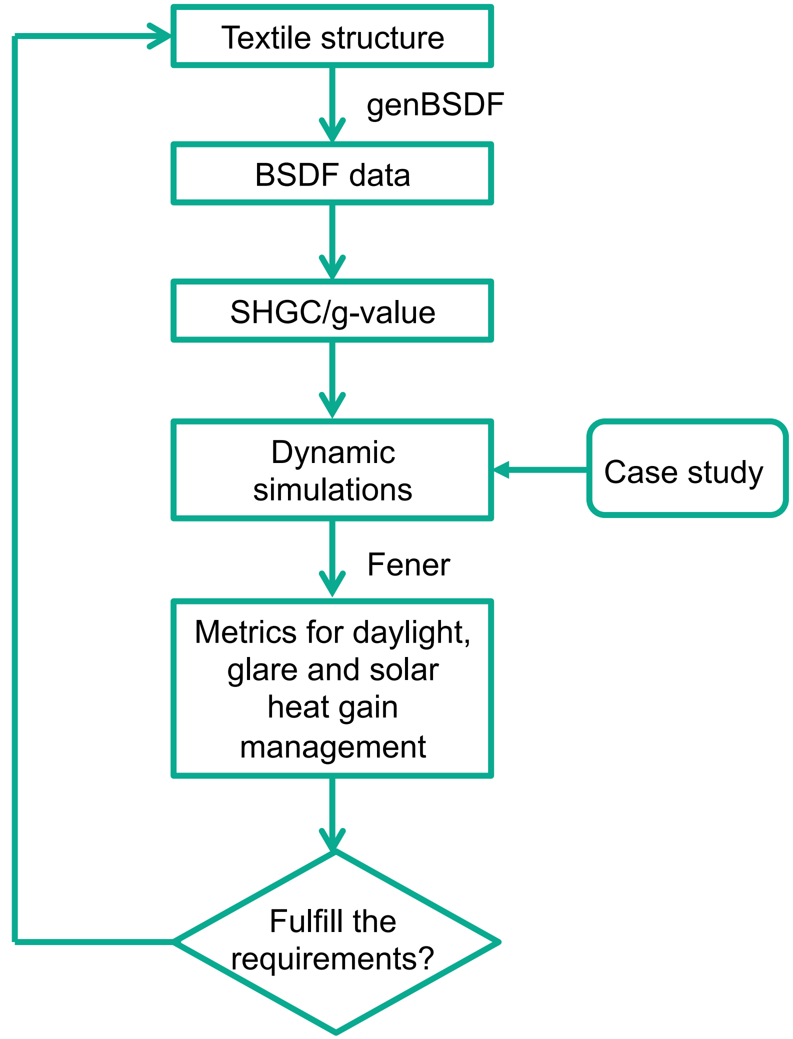
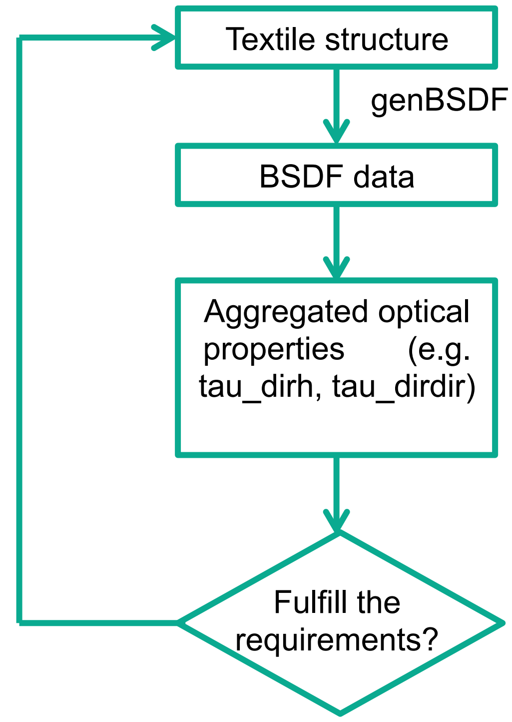
Workflow for the design of textile shading systems
Building level

- Takes into account the specific building context in which the textile shading device will be applied.
- However, there isn't a direct link between design parameters (textile geometry) and evaluation parameters (metrics)
  - Errors are difficult to identify.
  - Assumptions of models and metrics are difficult to interpret (and easy to forget).



Workflow for the design of textile shading systems
Component level

- There is a direct link between design parameters (textile geometry) and evaluation parameters (optical properties).
- However, the final performance of the shading device for a certain building application and a control strategy is unknown.



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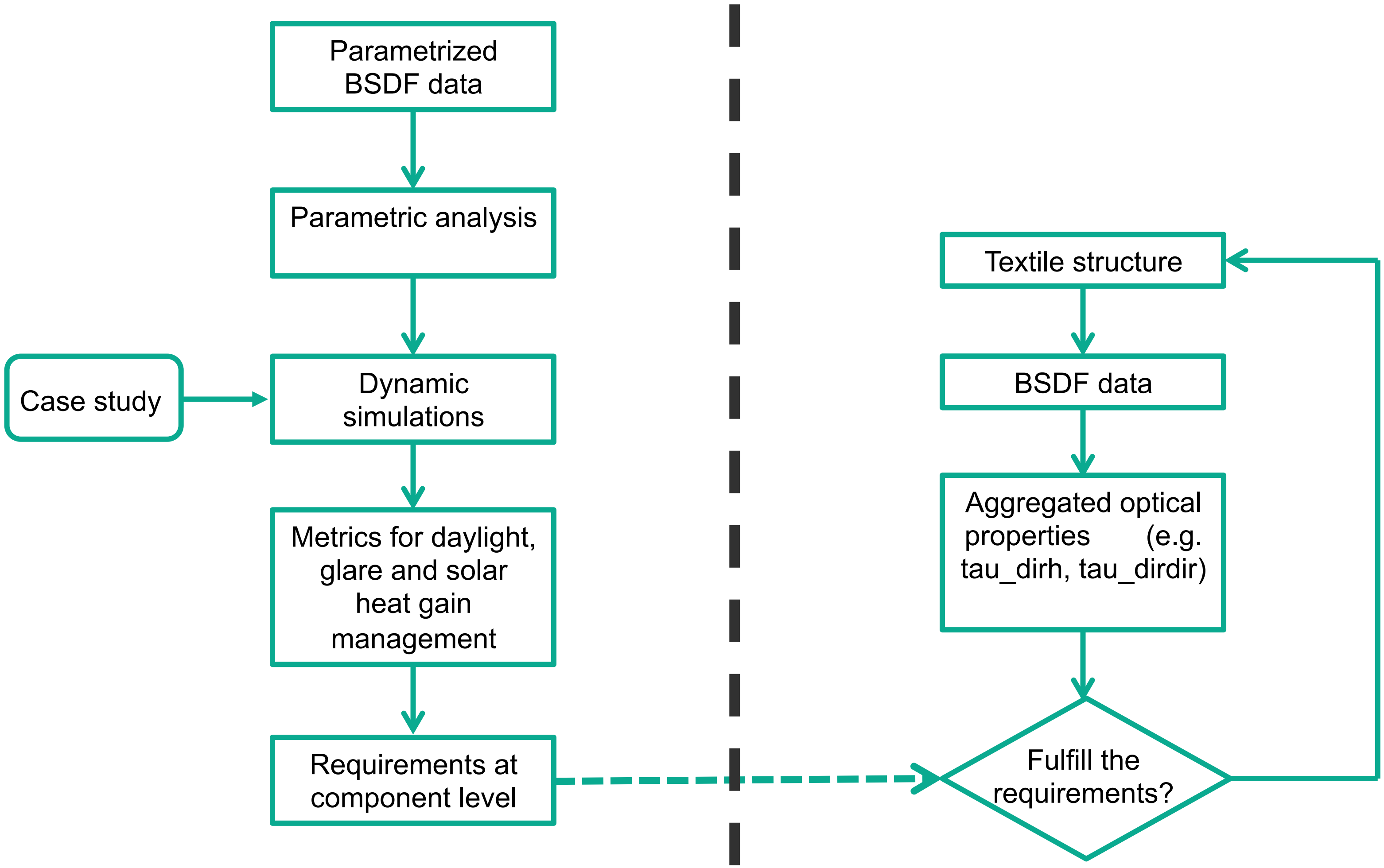
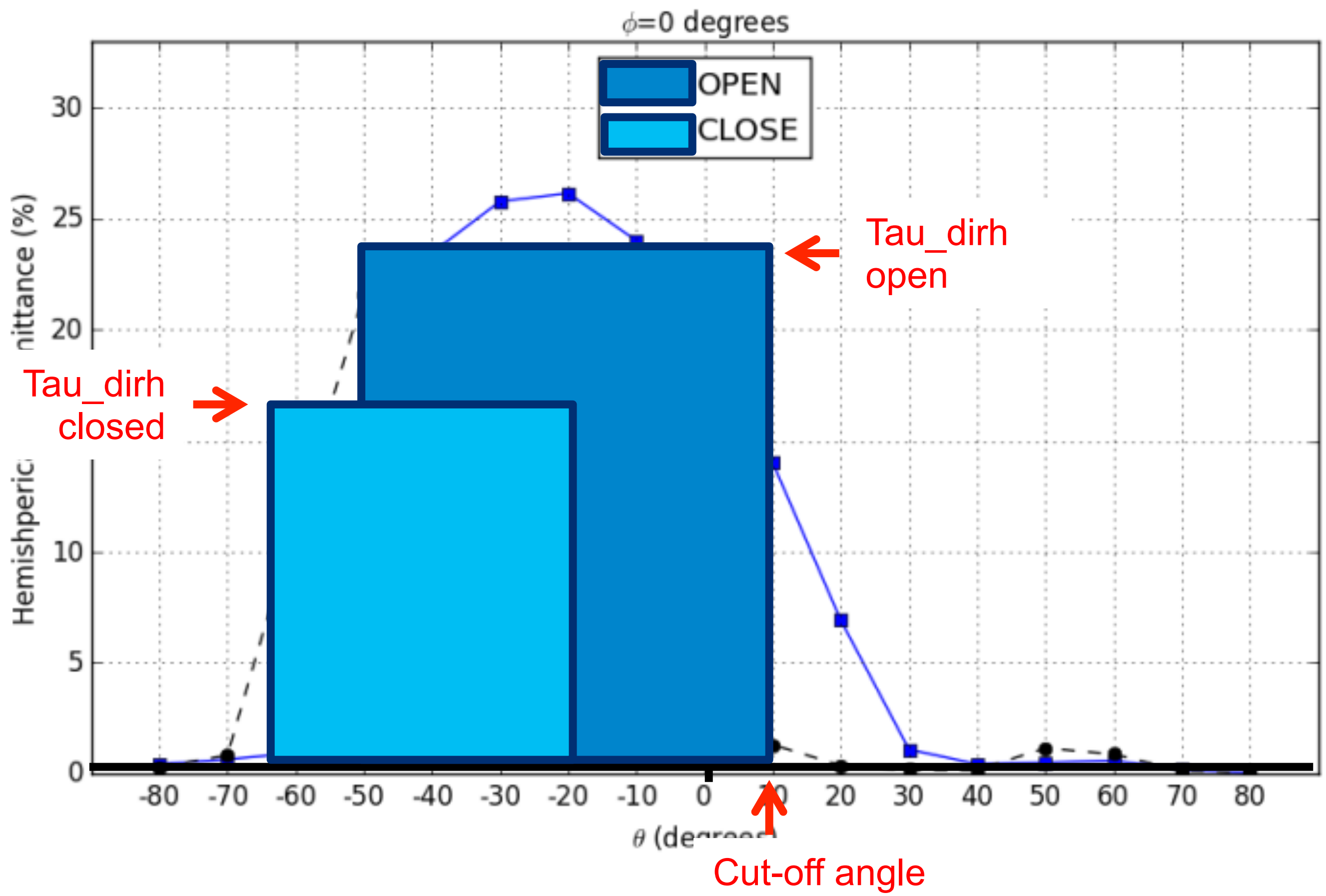
Workflow for the design of textile shading systems
Building level <> Component level

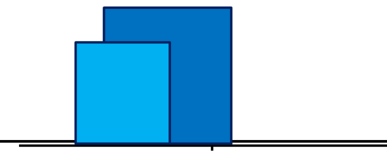
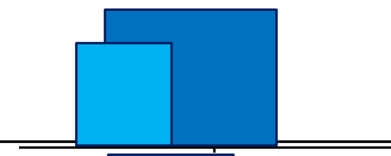
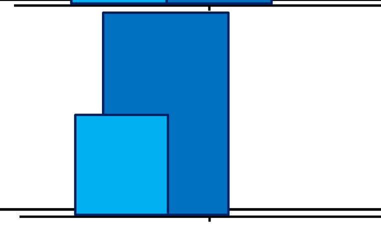
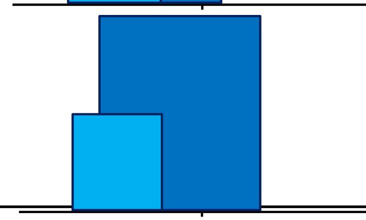


Workflow for the design of textile shading systems
Parametrization of the angular behavior of a CFS



Workflow for the design of textile shading systems

Parametric analysis

Cases	Tau_dirh open (%)	Tau_dirh closed (%)	Cut-off angle (deg)	Parametrized angular performance
1 (ref)	20	15	10	
2	20	15	30	
3	30	15	10	
4	30	15	30	

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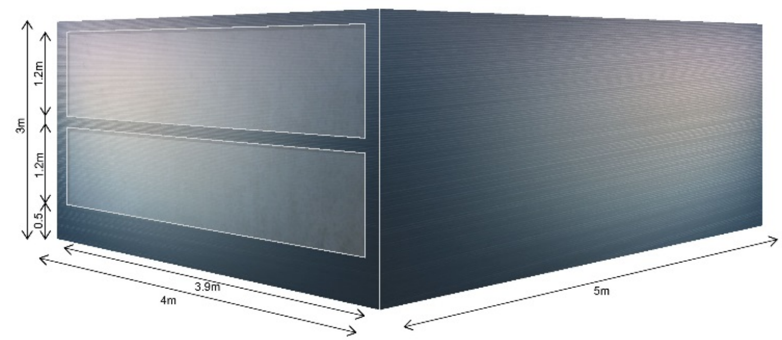
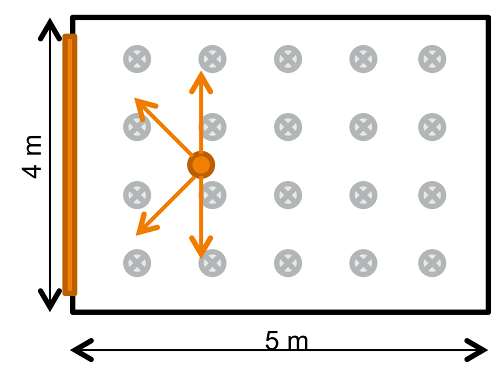
Workflow for the design of textile shading systems
Definition of the case study

Building type	Office
Climate	Frankfurt
Orientation	South
Glazing ratio	80%
Room dimensions	4 m x 5m x 3 m
Occupation schedule	8-18 LT
Infiltration	0.6/0.2 ACH
Internal heat gains	12 W m-2
Heating thermal setpoint	21°C/17°C
Cooling thermal setpont	24°C/28°C
Construction type	heavy
Surface albedos	0.7 (fl = 0.2)





Workflow for the design of textile shading systems
Definition of the case study – control strategy

	`If occupation:`

■ Primary glare control	`if max_vertical_illuminance > 3473lux:`
	`Upper window: Textile in open position`
	`Lower window: Textile in closed position`

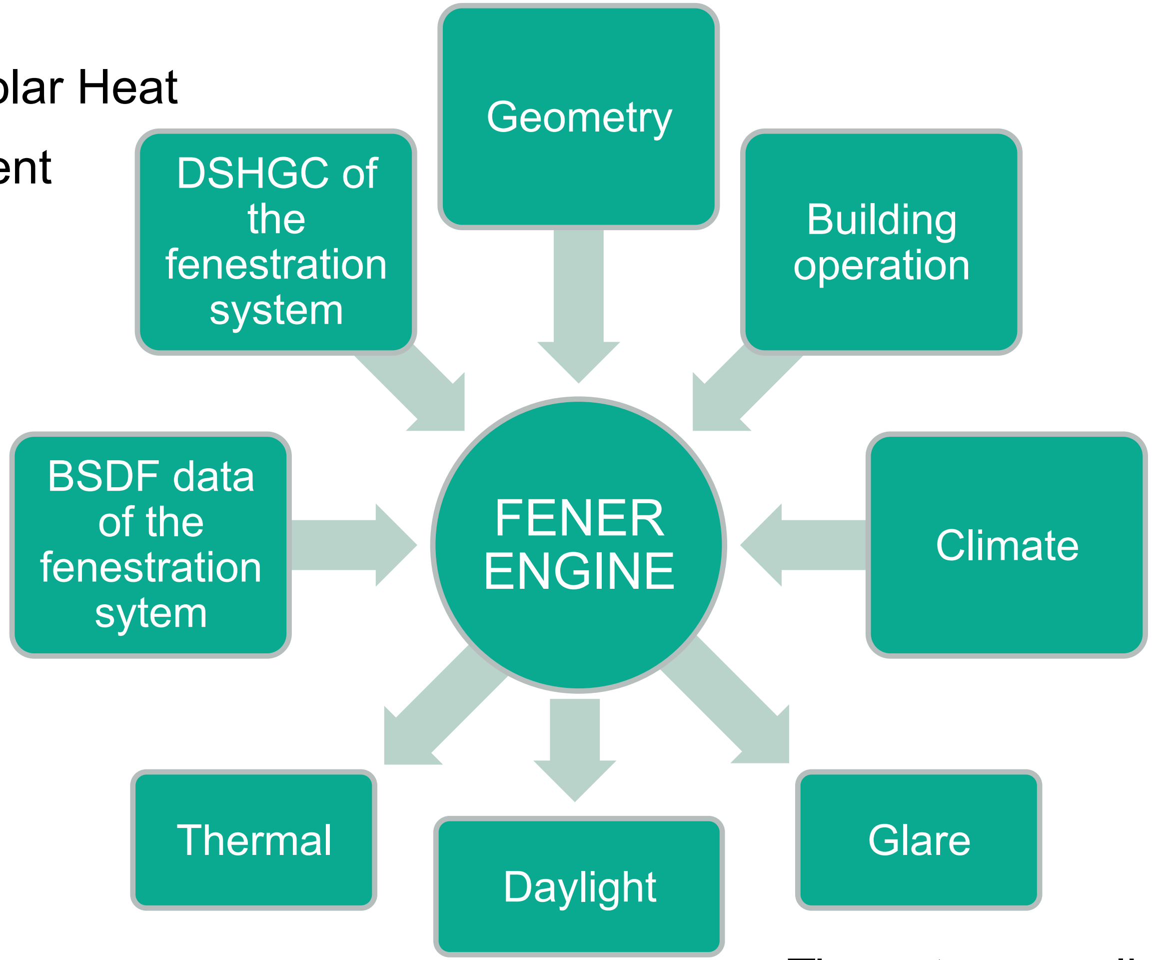
■ Secondary glare control if enough daylight	`elif max_vertical_illuminance > 2670lux:`
	`if average_horizonal_illuminance > 400 lux:`
	`Upper window: Textile in open position`
	`Lower window: Textile in open position`
	`else:`
	`Upper window: Textile is retracted`
	`Lower window: Textile in open position`

■ Temperature control if enough daylight	`else:`
	`if indoor_temp > 23°C:`
	`if average_horizonal_illuminance > 400 lux:`
	`Upper window: Textile in open position`
	`Lower window: Textile in open position`
	`else:`
	`Upper window: Textile in open position`
	`Lower window: Textile is retracted`

Workflow for the design of textile shading systems
Dynamic simulations

Directional Solar Heat Gain Coefficient

Bi-directional Scattering Distribution Functions



Time-step coupling

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

B. Bueno, J.-M. Cejudo-Lopez, T.E. Kuhn, A general method for the evaluation of the thermal impact of complex fenestration systems in building zones, Energy and Buildings 155 (2017) 43-53

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Workflow for the design of textile shading systems
Definition of evaluation criteria - metrics

Function	Metric
Daylighting	Percentage of daylighting hours (Ratio of occupied hours with <u>average</u> horizontal illuminance > 400 lux)
Glare	Percentage of „visual comfort“ hours (Ratio of occupied hours with <u>maximum</u> vertical illuminance < 3473 lux)
Solar heat gain management	Percentage of heating energy demand savings with respect to the maximum heating demand (the heating energy demand of the same case with an opaque window)
	Percentage of cooling energy demand savings with respect to the maximum cooling demand (the cooling energy demand of the same case with a transparent window)

Workflow for the design of textile shading systems
Comparison of design alternatives – case Frankfurt

Cases	Tau_dirh open (%)	Tau_dirh closed (%)	Cut-off angle (deg)	Daylight (%hours)	Visual comfort (%hours)	Heating saving (%)	Cooling savings (%)
1	20	15	10	56	96	62	95
2	20	15	30	70	96	64	95
3	30	15	10	64	96	64	94
4	30	15	30	75 (sDA=100%)	96	64	94

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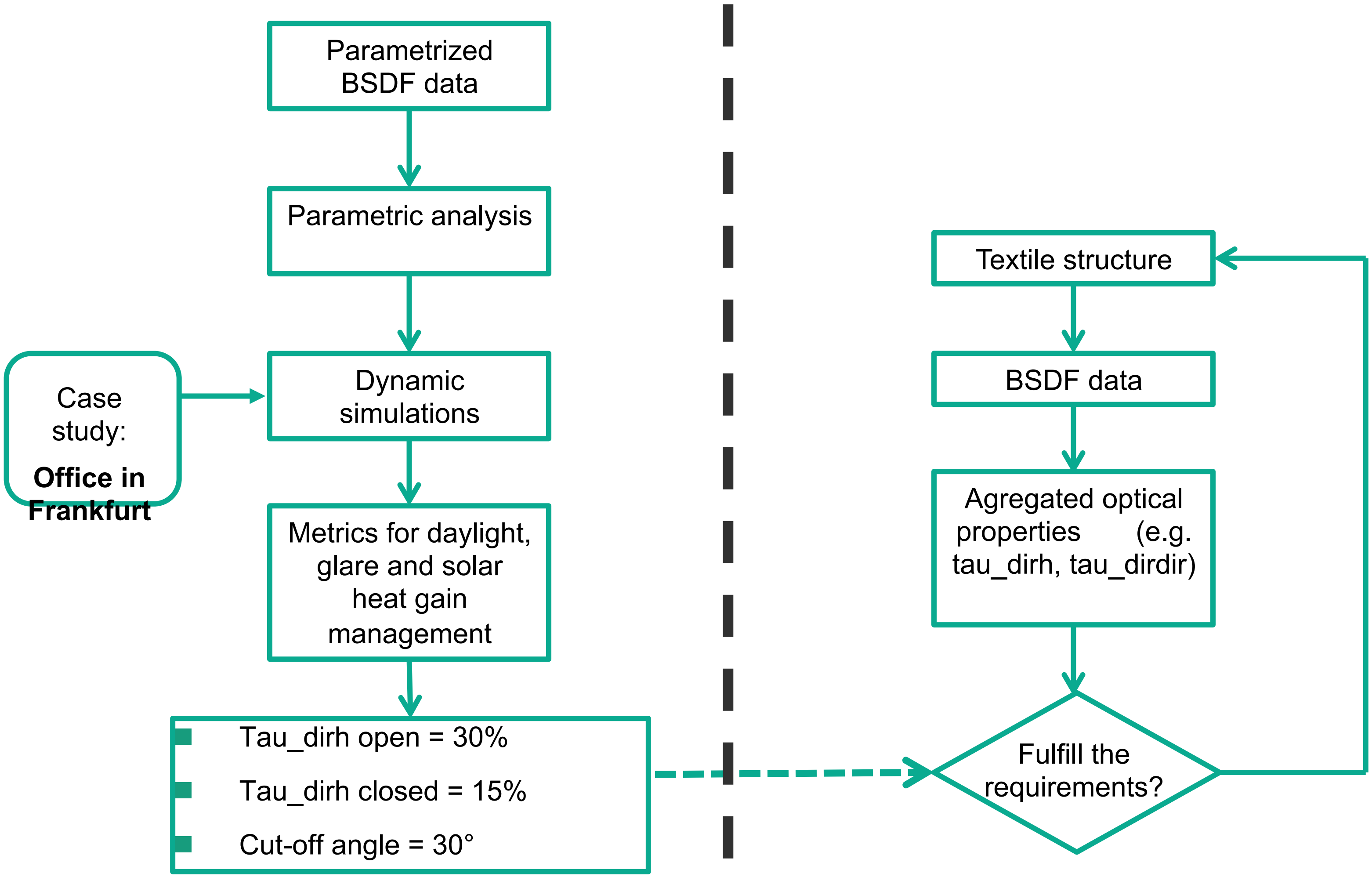
Workflow for the design of textile shading systems
Establishment of requirements at component level



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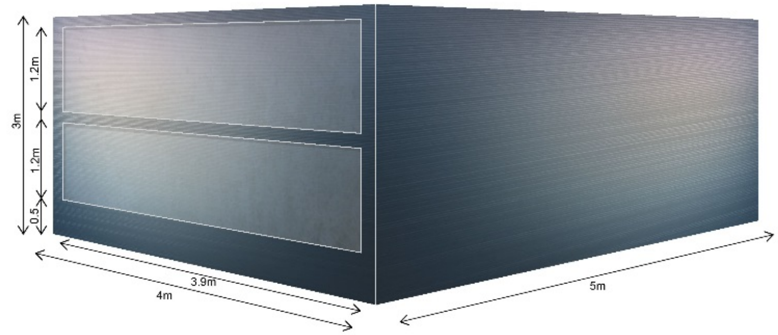
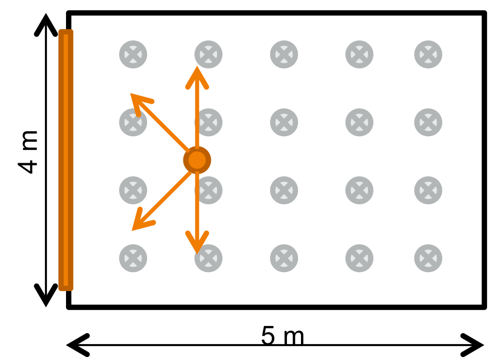
Workflow for the design of textile shading systems
Definition of the case study– case Rome West

Building type	Office
Climate	**Rome**
Orientation	**West**
Glazing ratio	80%
Room dimensions	4 m x 5m x 3 m
Occupation schedule	8-18 LT
Infiltration	0.6/0.2 ACH
Internal heat gains	12 W m-2
Heating thermal setpoint	21°C/17°C
Cooling thermal setpont	24°C/28°C
Construction type	heavy
Surface albedos	0.7 (fl = 0.2)





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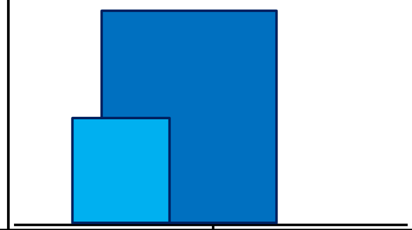
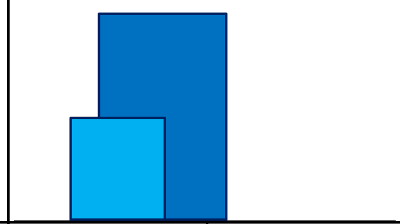
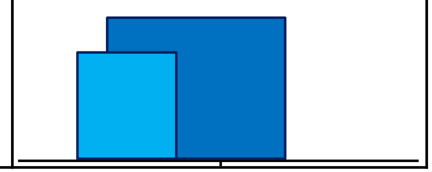
Workflow for the design of textile shading systems

Comparison of design alternatives – case Rome West

Cases	Tau_dirh open (%)	Tau_dirh closed (%)	Cut-off angle (deg)	Daylight (%hours)	Visual comfort (%hours)	Heating saving (%)	Cooling savings (%)
1	20	15	10	63	99	69	88
2	20	15	30	84 (sDA=100%)	97	72	86
3	30	15	10	79 (sDA = 90%)	99	69	88
4	30	15	30	86 (sDA=100%)	95	73	86

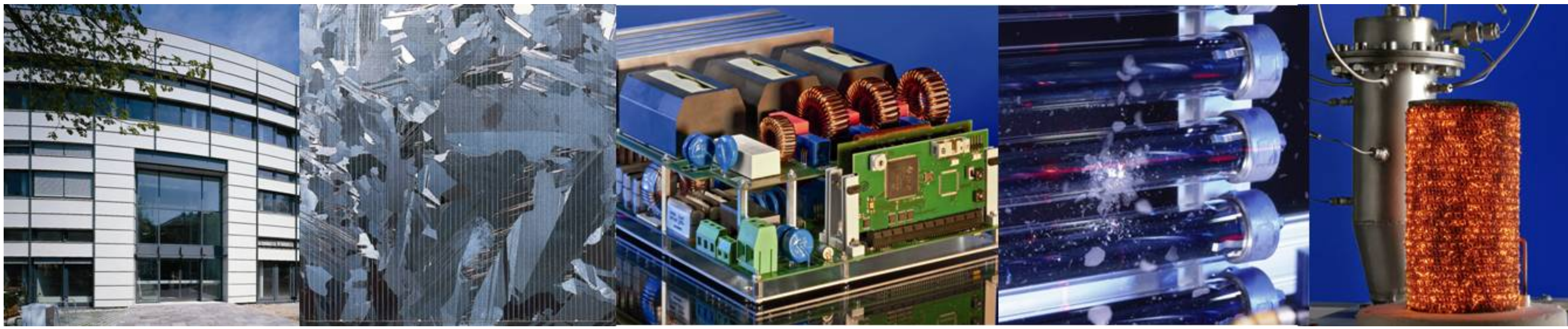
Workflow for the design of textile shading systems
Case-specific requirements at component level

Case studies	Climate	Facade orientation	Tau_dirh open (%)	Tau_dirh closed (%)	Cut-off angle (deg)	
1	Frankfurt	South	30	15	30	
2	Rome	West	30	15	10	
3	Rome	South	20	15	30	

Conclusions

- Simulation-based workflows for the design of angular selective, switchable textile shading systems have been presented.
- Workflows that aim to fulfill requirements at component or at building level have different pros and cons.
- A hybrid workflow is proposed.
  - The requirements of the shading system at component level are determined by the analysis of the case study at building level.
- The hybrid workflow allows a case-specific design of textile shading systems.

Thank you for your attention!



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