19TH ANNUAL INTERNATIONAL RADIANCE WORKSHOP, BILBAO, 2021

CONTROL STRATEGIES FOR INTERIOR ROLLER SHADES TO IMPROVE VISUAL COMFORT IN EDUCATIONAL BUILDINGS AT HIGH LATITUDES

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FIN EST Twins

European Union
European Regional Development Fund

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20.08.2021

BACKGROUND

- University Grade in Industrial Technologies (2010-2015) [Mechanical branch]
- Master in Industrial Engineering (2016-2017) [Energy branch]

- Research assistant and researcher in Fraunhofer ISE (2018) [Shading systems to improve indoor comfort in office buildings]
- Visitor researcher in Fraunhofer ISE (2019-2021) [Methods to speedup annual glare calculations]

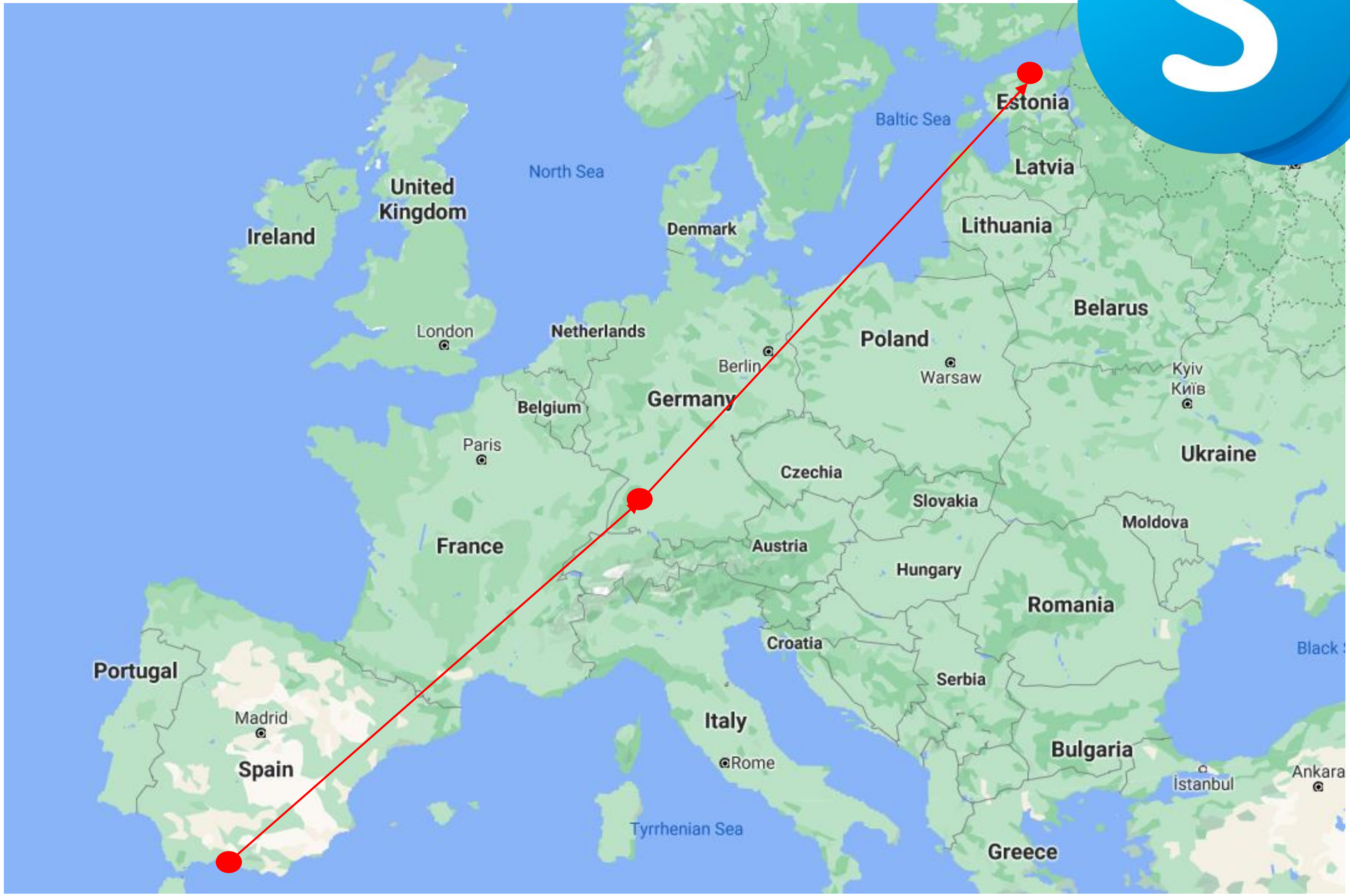
- PhD studies in Tallinn University of Technology (2019- July 2022) [Performance-driven and Integrated Design Methods and Solutions for Architecture and Urban Design]

UNIVERSIDAD DE MÁLAGA

Fraunhofer ISE

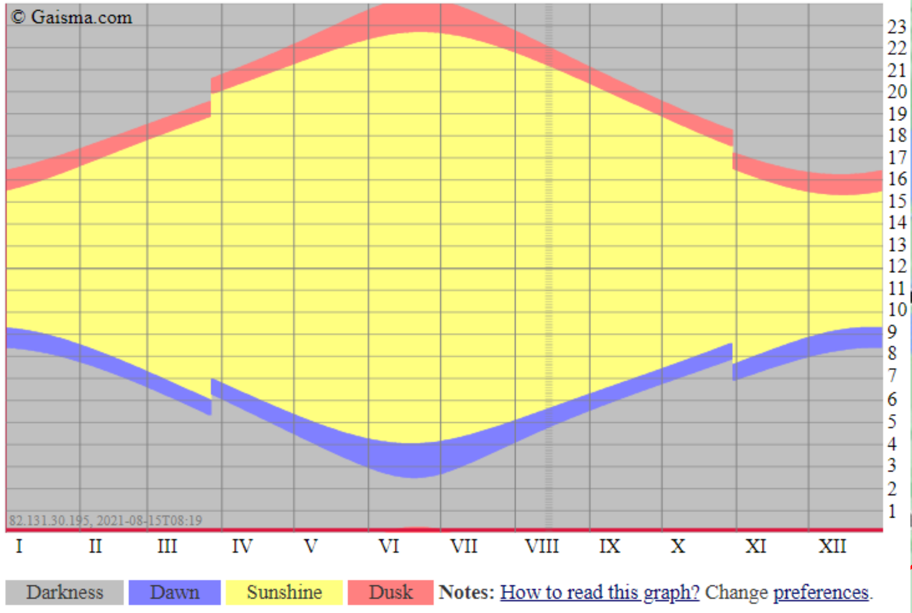
TAL TECH

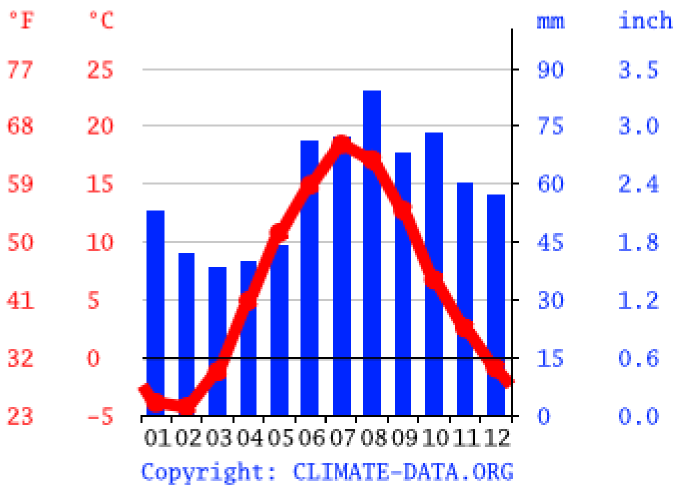
ESTONIAN CONTEXT

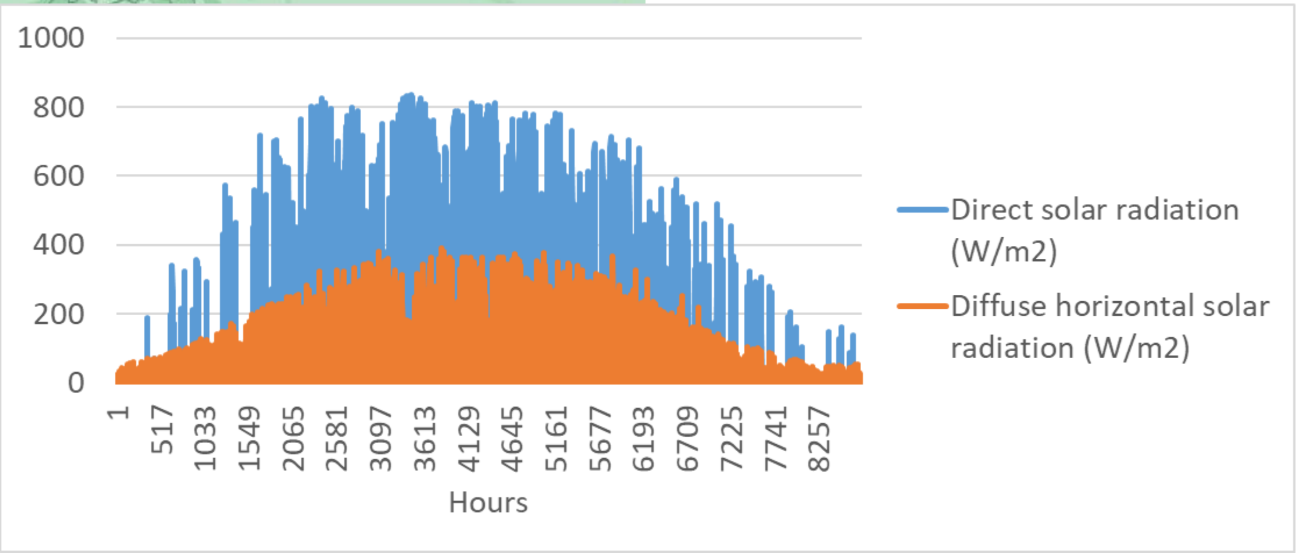


ESTONIAN CONTEXT

Latitude: 59.436962 N
Longitude: 24.753574 E



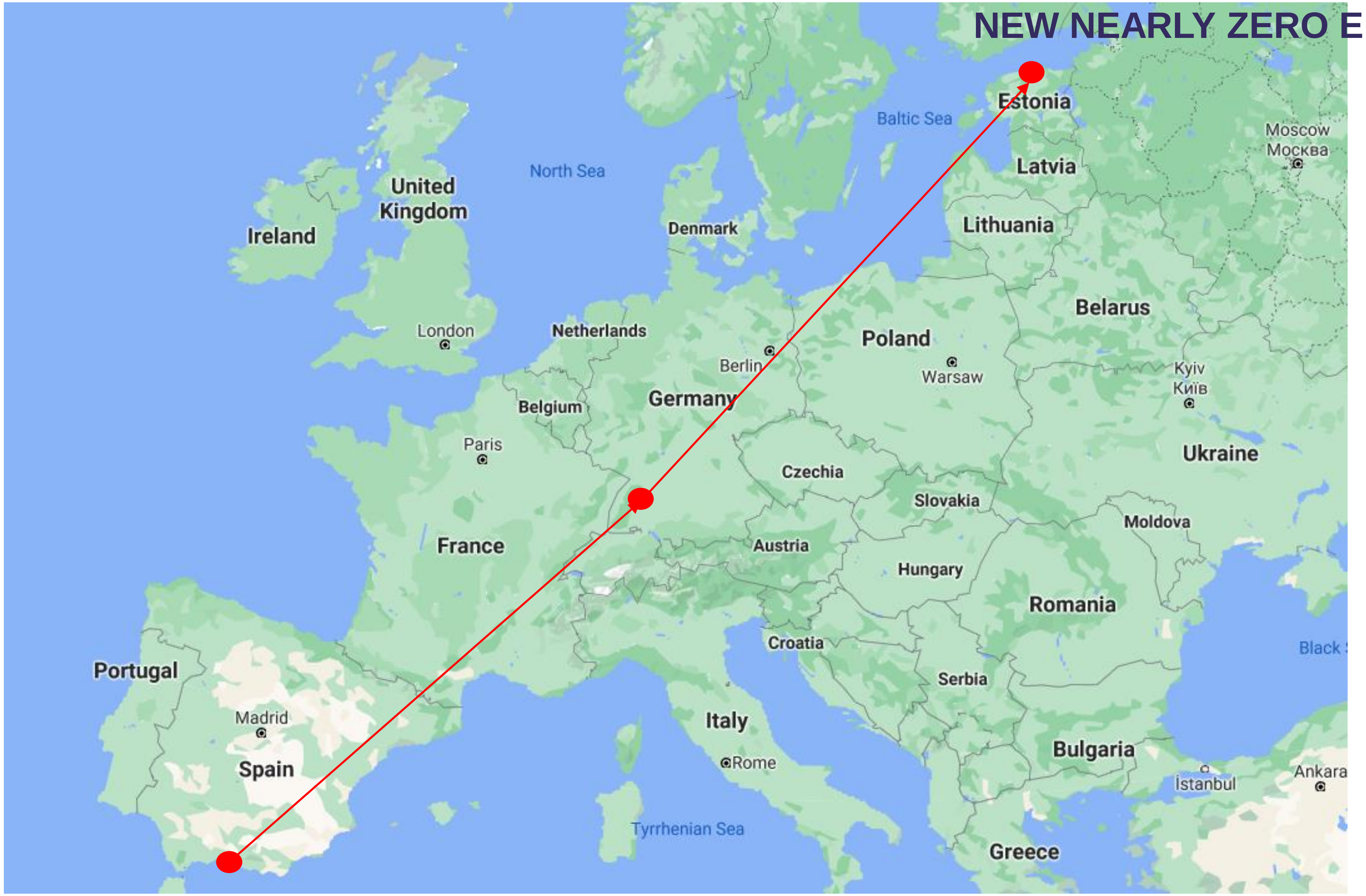




ESTONIAN CONTEXT

After 15 years of research...

ESTONIA HAS THE MOST ENERGY EFFICIENT NEW NEARLY ZERO ENERGY BUILDINGS



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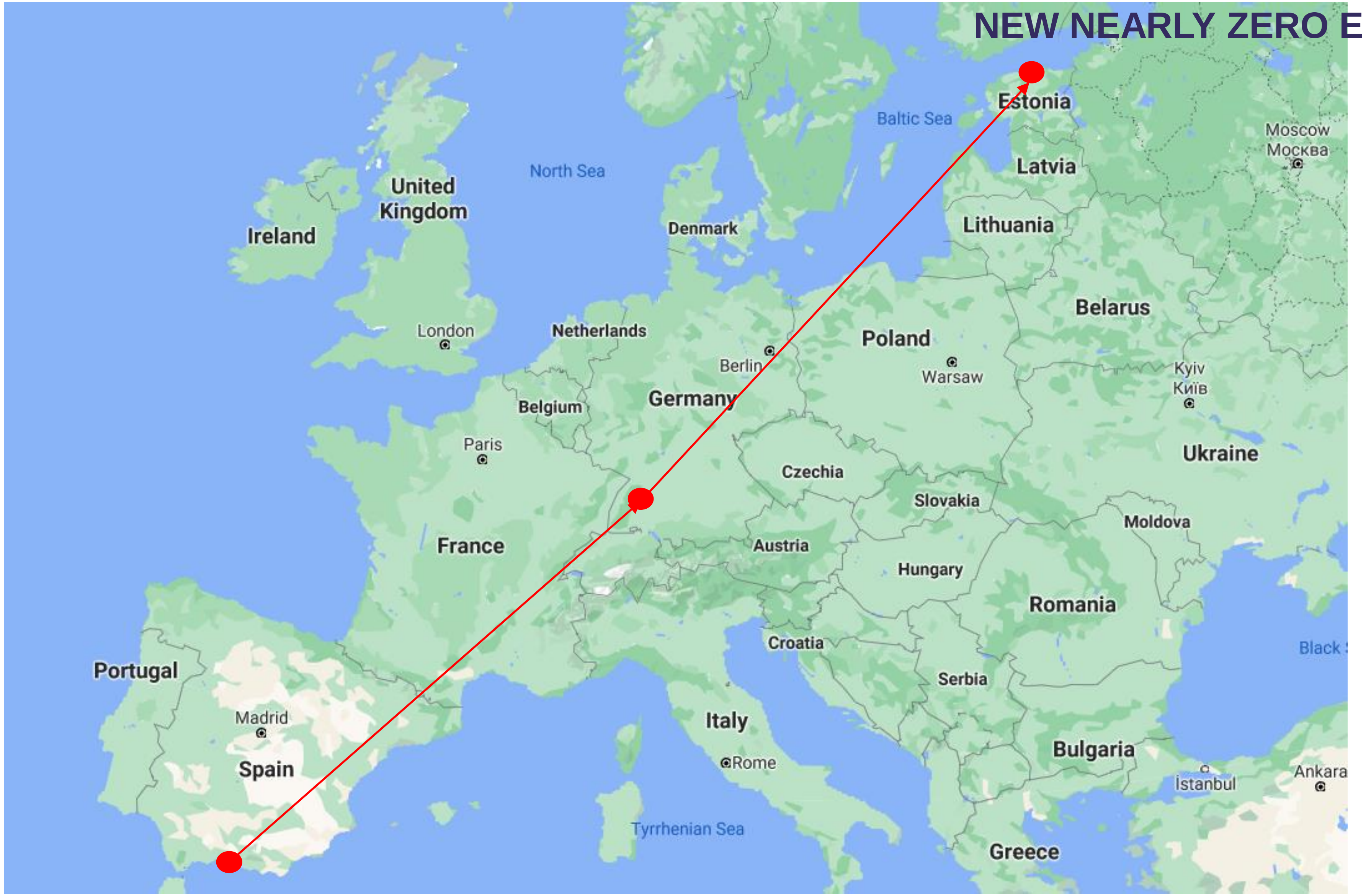


What about visual comfort in buildings?

- High WWRs often provoke overheating issues during the warm season,
- Daylight glare is often underestimated but present,
- Not reasonable criteria for the selection/sizing of shading systems.
- Strict standards to ensure solar access for new residential buildings but lack of tools to conduct these analyses

GENERAL FRAMEWORK

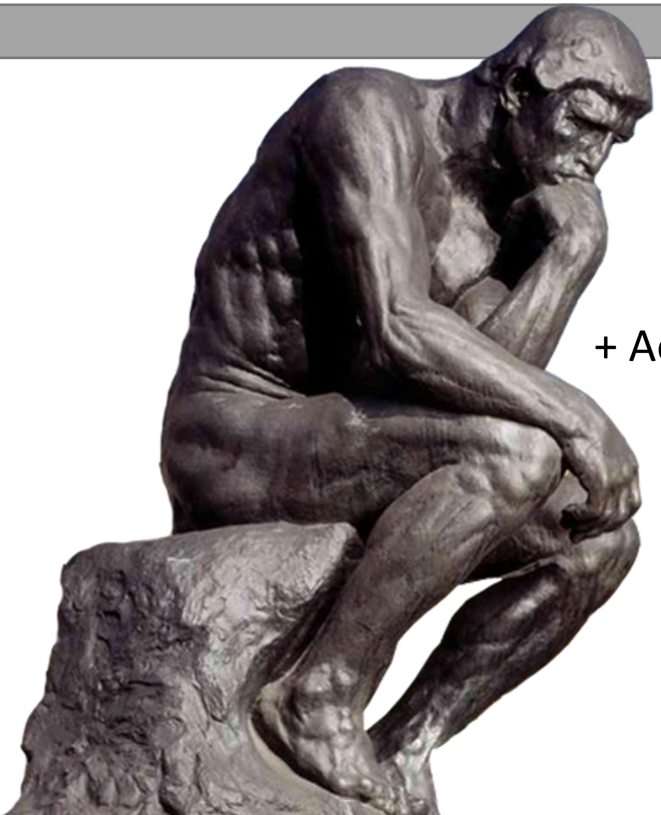
BUILDING PERFORMANCE

Standards and regulations

- Indoor visual comfort:
  - Solar access
  - Daylight provision
  - Glare protection
- Indoor thermal comfort:
  - Overheating
- Energy performance

ASSESSMENT PROCESS

PERFORMANCE-DRIVEN DESIGN PROCESS



+ Aesthetics

DECISIONS

- Building level:
  - Building volume
  - Building orientation
  - Floor plan
- Façade level:
  - Windows location
  - Windows size
  - Windows construction
- Window level:
  - Shading system
  - Shading control
  - Ventilation control

VISUAL COMFORT IN ESTONIAN EDUCATIONAL BUILDINGS

- Main building functions in efficient buildings with active cooling systems:

Daylight provision vs daylight glare (the eternal fight)

- In Estonia there are two standards for daylight in buildings:

The novel **European standard EN 17037:2018** and the old Estonian standard based on mean Daylight Factor requirements,

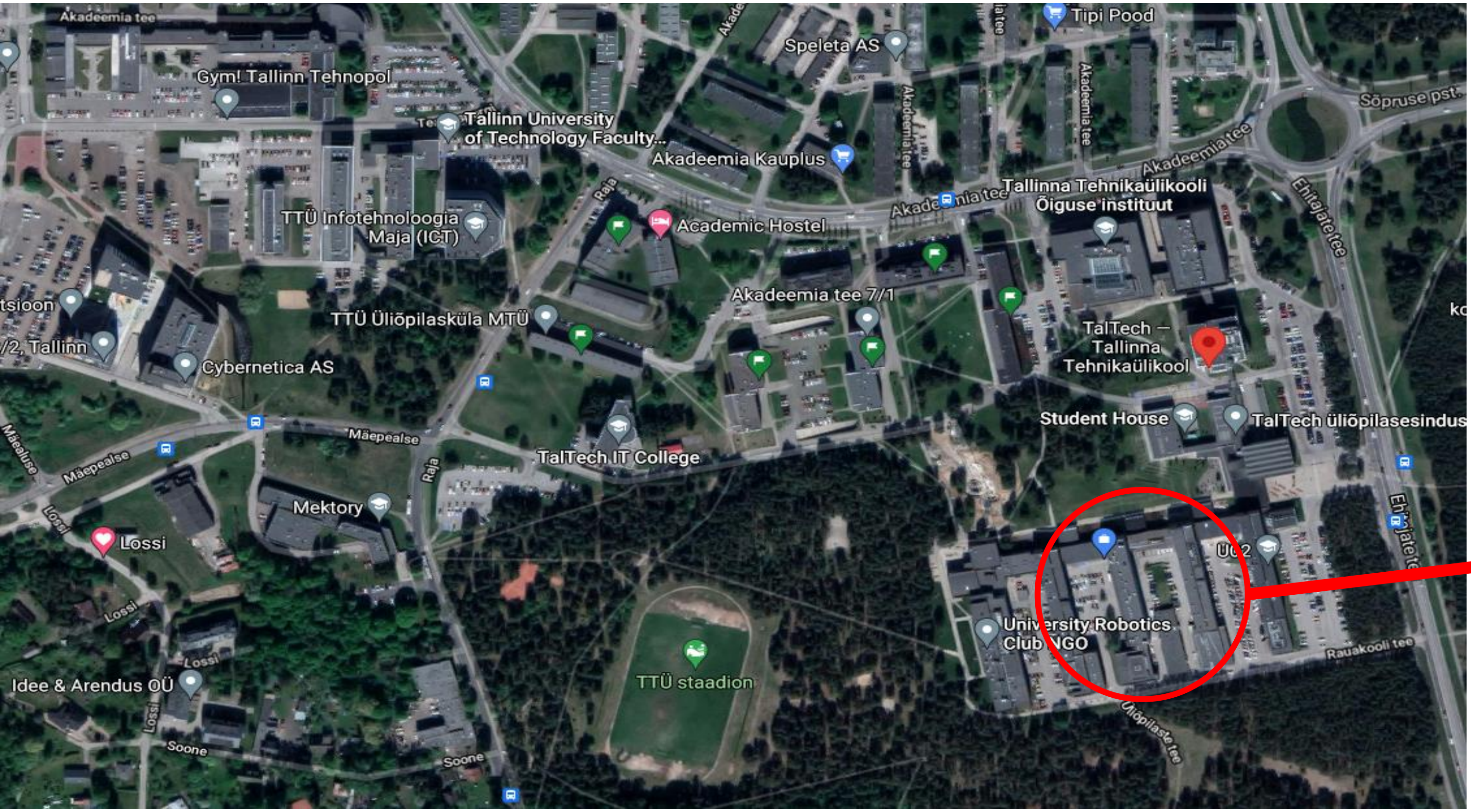
The use of the EN 17037:2018: Estonian architects/practitioners are not fully aware of this,

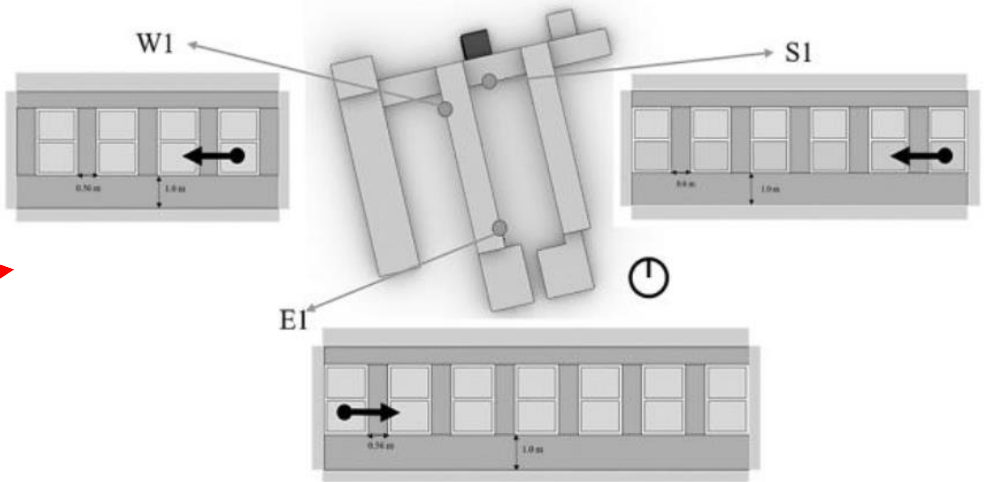
AIM OF THE INVESTIGATION

- To propose a workflow for the definition of shading control strategies to improve visual comfort in Estonian educational buildings

CASE STUDY

- 3 auditoriums located at TalTech Campus, Tallinn, Estonia





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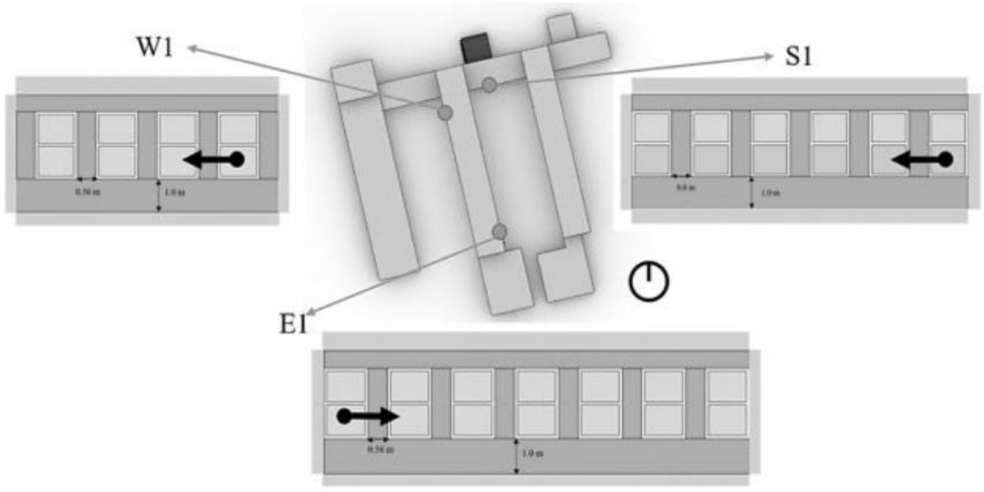
CASE STUDY

- 3 auditoriums located at TalTech Campus, Tallinn, Estonia
- 5 interior roller shades

Table 2: Optical properties of the interior roller fabrics considered. Where td=direct-direct transmittance, td=direct-diffuse transmittance, and rd=direct-diffuse reflectance.

Fabric	ts (-)	td (-)	rd (-)	Cut-off angle (°)
s1d25	0.01	0.25	0.60	50
s2d20	0.02	0.20	0.60	50
s3d20	0.03	0.20	0.60	50
s4d6	0.04	0.06	0.60	50
s5d6	0.05	0.06	0.60	50

Auditorium	**E1**	**S1**	**W1**
Orientation	North-east	South-east	South-west
Floor level (m)	11.25	0	7.5
Zone height (m)	3.15	3.15	3.15
Zone width (m)	5.2	5.4	3.05
Zone length (m)	12.11	10.2	7.8
Window width (m)	1.25	1.2	1.25
Window height (m)	2.0	2.0	2.0
Floor Area (m²)	62.97	55.08	23.79
Win. Frame ratio (%)	23.3	23.8	**24.7**



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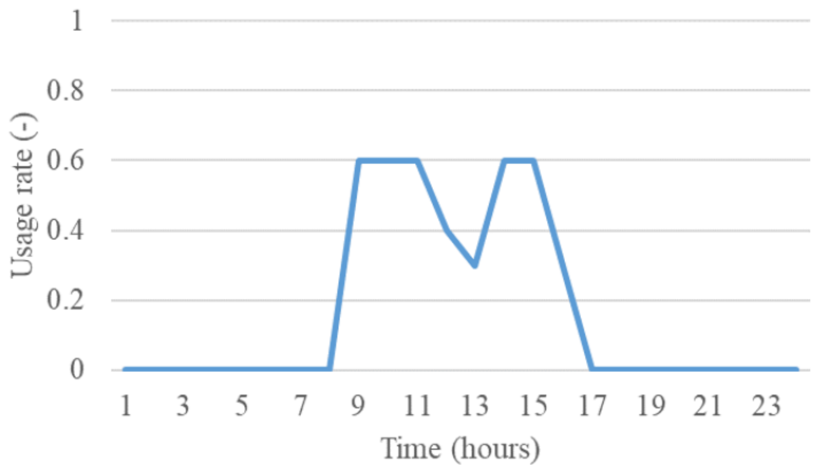
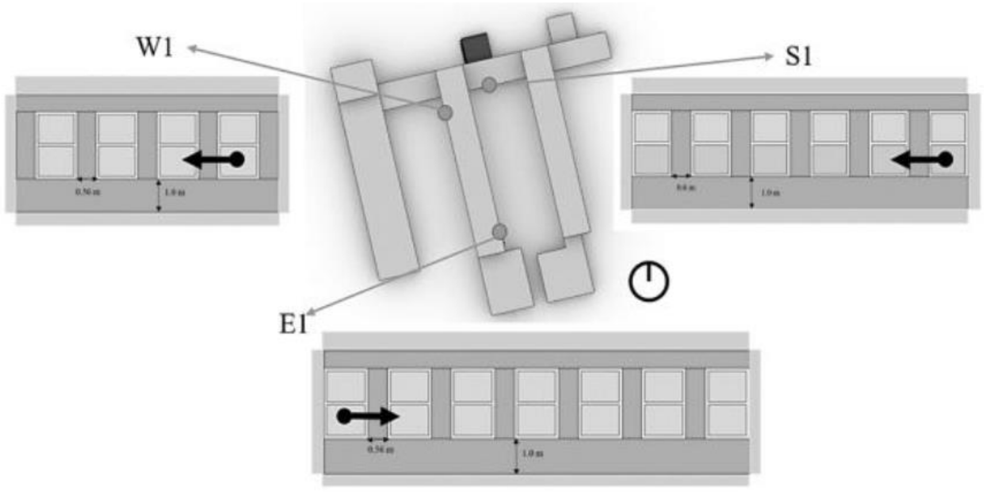


Figure 3: Occupancy schedule for educational buildings in Estonia.



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CASE STUDY

- 3 auditoriums located at TalTech Campus, Tallinn, Estonia
- 5 interior roller shades →
- 3 control variables: Vertical illuminance (Ev), DGP and global irradiance (Girr)

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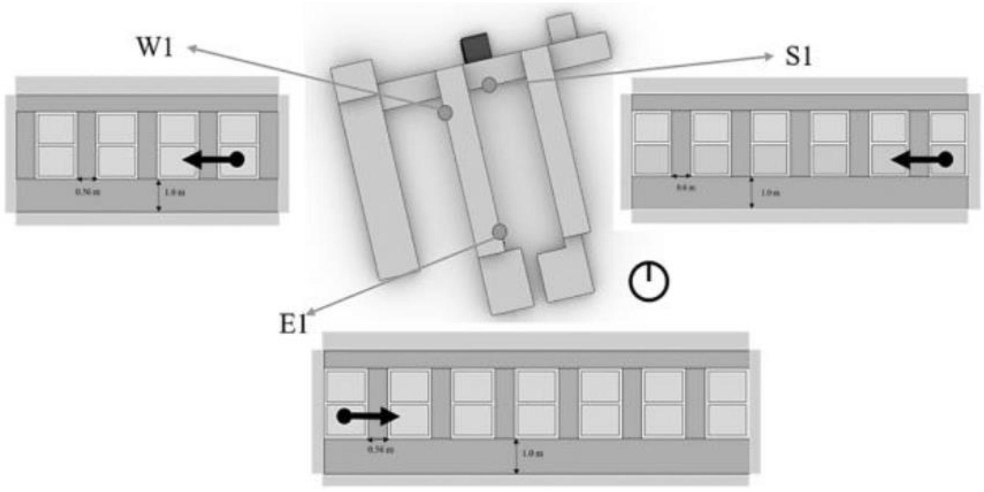
s4d6	0.04	0.06	0.60	50
s5d6	0.05	0.06	0.60	50

Table 4: Radiance parameters used in daylight and glare simulations.

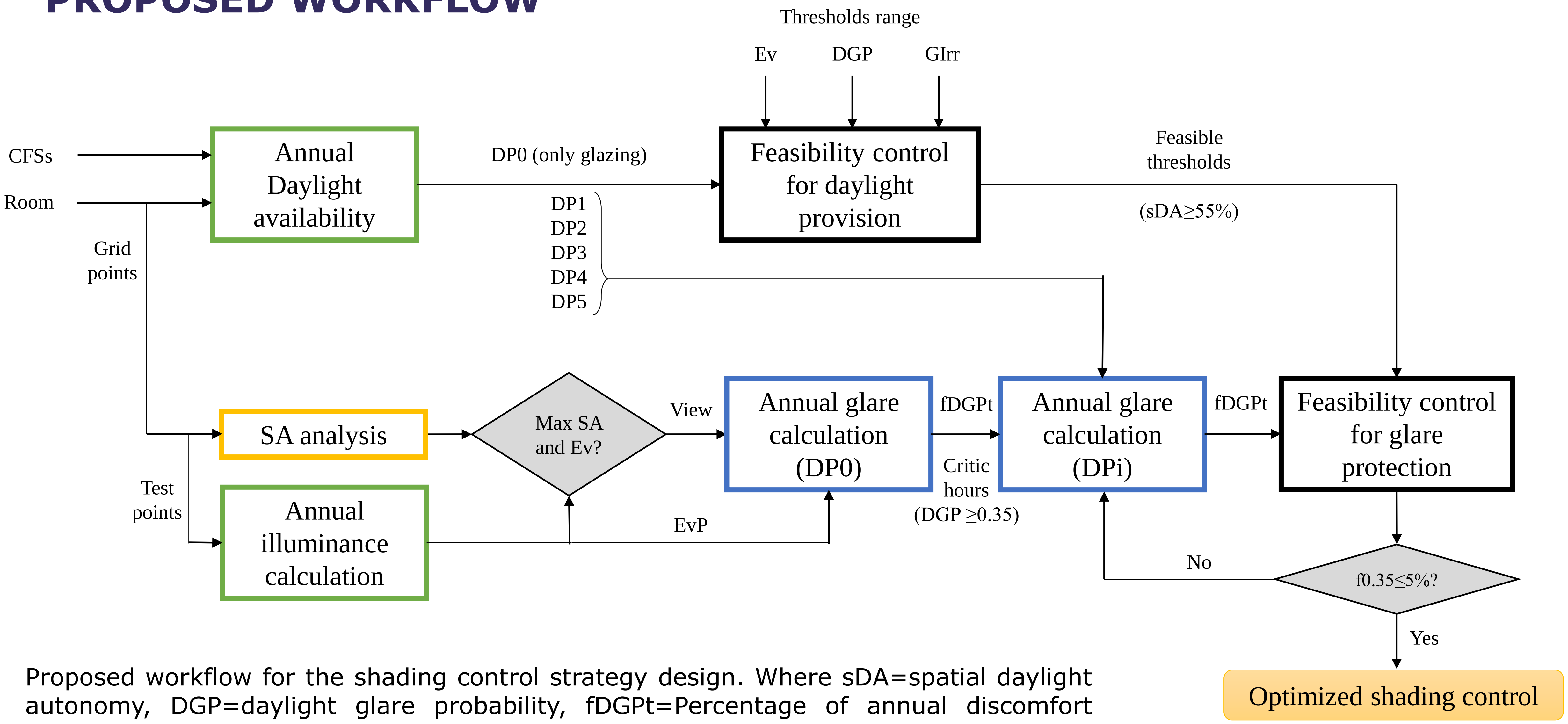
3pm	Sky generation: -m 6 (MF=6)
	Daylight matrix: -c 2e4 -ab 2 -ad 512 -lw 1.95e-3
	View matrix: -c 10 -ab 10 -ad 65536 -lw 1.53e-5 -pj 0.7
rtrace	-ab 0 -ad 1024 -lw 1/1024 -aa 0.15 -st 0.15 -as 512 -x 900 -y 900

Table 5: Reflectance values for the main opaque surfaces in each room study.

Surface\Auditorium	E1	S1	W1
Interior walls	0.69	0.32-0.72	0.65
Floor	0.32	0.30	0.49
Ceiling	0.79	0.79	0.76
Slab	0.30	0.3	0.3



PROPOSED WORKFLOW

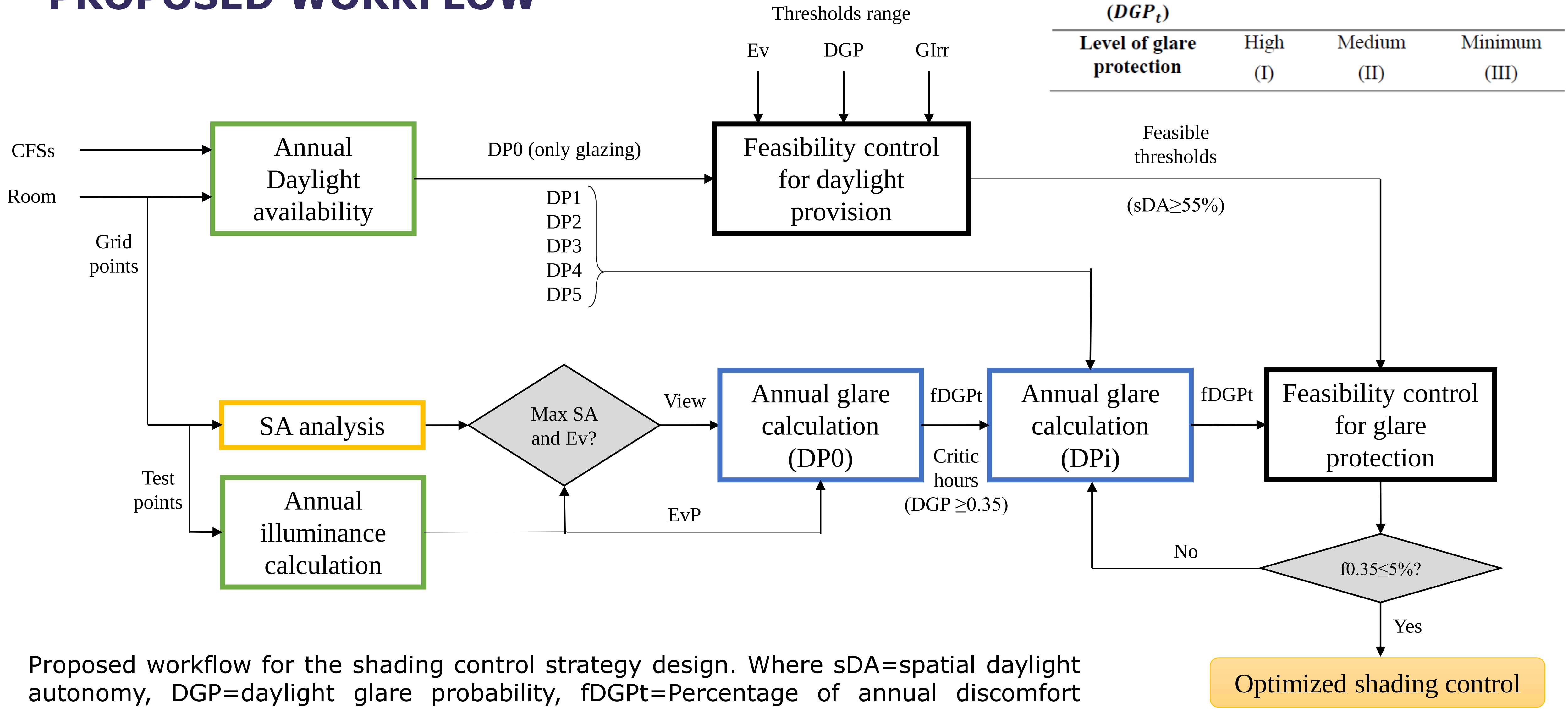


Proposed workflow for the shading control strategy design. Where sDA=spatial daylight autonomy, DGP=daylight glare probability, fDGPt=Percentage of annual discomfort hours above a threshold DGPt, Ev=Vertical illuminance, Girr=Global irradiance

PROPOSED WORKFLOW

Table 3: Annual glare protection classes according to the European standard EN 17037.

DGP threshold (DGP_t)	0.35	0.40	0.45
Level of glare protection	High (I)	Medium (II)	Minimum (III)

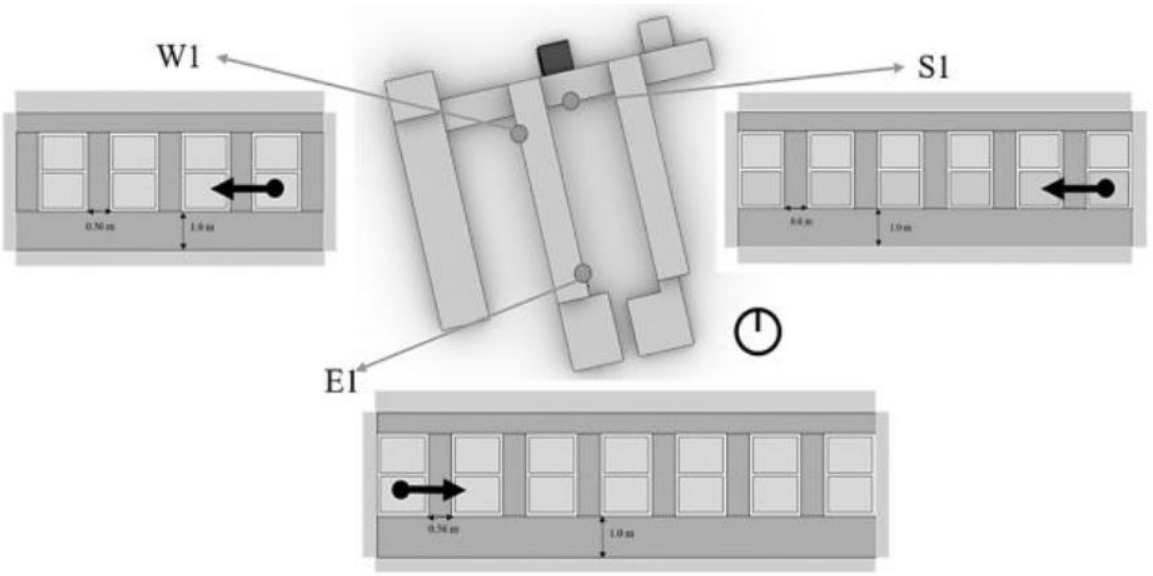


Proposed workflow for the shading control strategy design. Where sDA=spatial daylight autonomy, DGP=daylight glare probability, fDGPt=Percentage of annual discomfort hours above a threshold DGPt, Ev=Vertical illuminance, Girr=Global irradiance

DAYLIGHT AVAILABILITY AND DAYLIGHT GLARE PROTECTION ASSESSMENT

Table 8: Annual overall performance of the three auditoriums without shading device.

Room	$sDA_{300, 50\%}$ (%)	$fDGP_t$ (%)		
		$f0.35$	$f0.40$	$f0.45$
E1	38.3	8.0	4.0	2.8
S1	35.0	42.9	40.0	35.8
W1	87.5	0	0	0



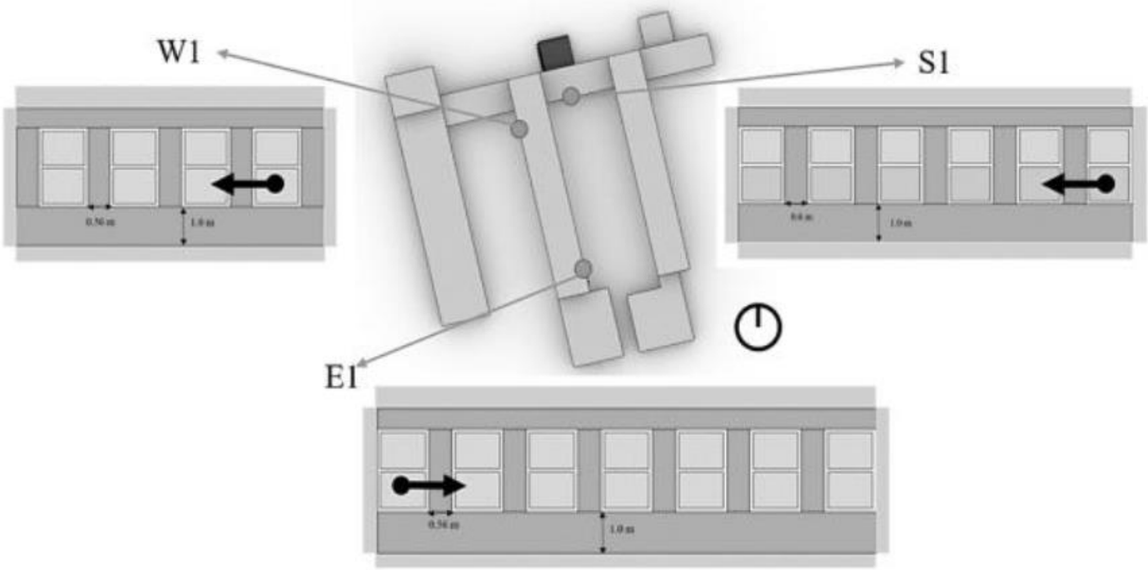
FEASIBLE THRESHOLDS

Auditorium E1

Fabric	Ev_x		DGP_x		$GIrr_x$	
	x	sDA	x	sDA	x	sDA
s1d25	4000	38.3	0.4	38.3	600	7.5
s2d20	4000	38.3	0.4	38.3	600	5.8
s3d20	4000	38.3	0.4	38.3	600	5.8
s4d6	4000	37.9	0.4	37.9	600	2.5
s5d6	4000	37.9	0.4	37.9	600	2.9

Auditorium S1

Fabric	Ev_x		DGP_x		$GIrr_x$	
	x	sDA	x	sDA	x	sDA
s1d25	3500	35	0.4	34.5	400	17.7
s2d20	3500	35	0.4	32.3	400	14.1
s3d20	3500	35	0.4	32.7	400	14.1
s4d6	3500	14.5	0.4	13.2	400	4.1
s5d6	3500	16.8	0.4	13.6	400	4.1



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s2d20	4000	38.3	0.4	38.3	600	5.8
s3d20	4000	38.3	0.4	38.3	600	5.8
s4d6	4000	37.9	0.4	37.9	600	2.5
s5d6	4000	37.9	0.4	37.9	600	2.9

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s3d20	**3500**	**35**	0.4	32.7	400	14.1
s4d6	3500	14.5	0.4	13.2	400	4.1
s5d6	3500	16.8	0.4	13.6	400	4.1

Optimized shading control

Table 12: Maximum feasible (when $sDA_{300,50\%} \geq 55\%$) glare protection level and recommended fabric and control strategies for each room study.

Room	$sDA_{300,50\%}$ (%)	Maximum glare protection	Fabric	Control strategy
E1	38.3	I	s3d20	Ev4000
S1	35.0			Ev3500
W1	87.5	I	-	-

- High openness factor to improve visual contact with the outside,

- High diffuse transmittance to maximize daylight availability in the rooms.

FEASIBLE THRESHOLDS

Auditorium E1

Fabric	Ev_x		DGP_x		$GIrr_x$	
	x	sDA	x	sDA	x	sDA
s1d25	4000	38.3	0.4	38.3	600	7.5
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E1	s3d20 Ev4000	38.3	4.0	0.0	0.0
S1	s3d20 Ev3500	35.0	4.0	1.1	0.6

CONCLUSIONS

- The proposed optimization workflow can help architects and practitioners with the selection of the shading device and its control strategy to achieve good balance between visual comfort in buildings.

- The use of interior roller fabrics with openness factors of 3% (and diffuse transmittance of 20%) have a significant potential to protect against daylight glare without compromising daylight provision and energy performance in educational buildings in Estonia,

- Shading control strategies based on vertical illuminance at eye level with single threshold are highly recommended to achieve a satisfactory visual comfort levels.

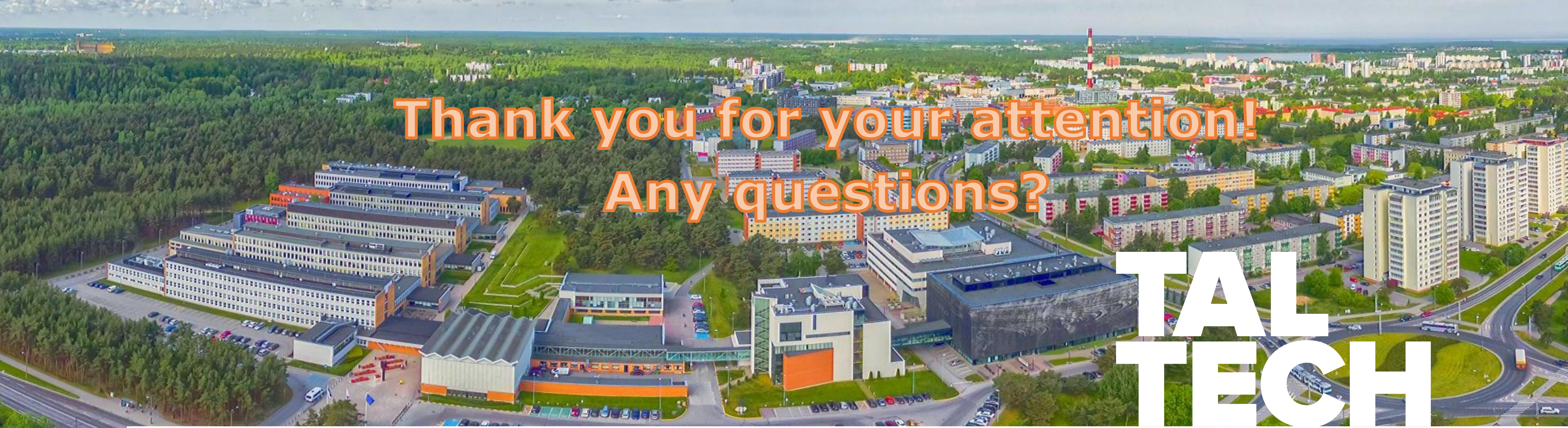
- The optimal illuminance threshold value depends on the orientation and the surrounding obstructions of each room. It can be calculated using the proposed workflow. The illuminance thresholds 4000 lux and 3500 lux were found optimal for north-east and south-east auditoriums, respectively.

FUTURE STEPS

- Different type of shading devices within the optimization workflow,

- Efficiency of this workflow to design shading control strategies for different type of buildings and climates,

- The evaluation of the subjective building user’s perception of daylighting and glare.



Thank you for your attention!
Any questions?

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