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London, 1st -3rd September 2014

Coupling Energy and Daylighting Simulation for Complex Fenestration Systems

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EURAC Research (Italy)

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RE-CONCEPTUALIZING SHOPPING MALLS

from consumerism to energy conservation

A task:

- DEVELOPMENT OF SHARED TRNSYS "DECK" TO INTEGRATE DIFFERENT BUILDING SUB-SYSTEMS SIMULATION "TYPES" (HVAC, ENVELOPE, DL, ...)

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Motivation

enable DayLight simulation of CFS in Trnsys

Goal

- climate-based analysis/optimization of the building with respect to selected objectives
  - ❑ visual comfort
  - ❑ thermal comfort
  - ❑ energy
  - ❑ a combination of above

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Motivation

enable DayLight simulation of CFS in Trnsys

Wishlist

- dynamic interaction between thermal and DL
- keep it accurate but flexible (custom controls design possible for energy/lighting optimization, codes/standard verification...)
- should not require a Radiance guru (reduced user effort in pre-processing)

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Motivation

enable DayLight simulation of CFS in Trnsys

State of the art

D. Geisler-Moroder, C. Knoflach, W. Pohl, M. Hauer, D. Neyer, W. Streicher

Integrated Thermal and Light Simulations for Complex Daylight Systems Using TRNSYS and RADIANCE. Preliminary results from the project „Light From Façade“. 10th Intl. Radiance Workshop, August 24-26, 2011

- “artlight” dll with three-phase method implementation was developed. Not published...

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Main output of this work

"Type_DLT.dll" for Trnsys:

- ✓ C++ coded
- ✓ Three Phase Daylight Coefficient Method
- ✓ *Open source*

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Tool-chain 1/2

pre - processing

Window 6.3 → - BSDF (or from *genBSDF*)
- glazing parameters

Google SketchUp → - geometry
- physical properties

A text editor → - config. files with basic Radiance param. (view, windows, glow)

⇒ Input data

yet not 100% automatic...

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Tool-chain 2/2

Input data → Trnsys 17 (each simulation step: run Radiance through the Type_DLT) → Output data

Annual building simulation

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Manual configuration files

CFS1.rad

```
void glow CFS1
0
0
4 1 1 1 0
CFS1 polygon f_16_0
0
0
12
    -23.095208  130.979431
4.100000
    -23.095208  130.979431
10.400000
    -0.173648  0.984808
10.400000
    -0.173648  0.984808
4.100000
```

windows geometry (one file per each windows group)

win.dat

```
1 # number of windows groups
CFS1 0.984807729721 0.173648163676 0 0 0 1
```

window group list file:
window modifier + view direction + view up

Simulation tests. Two control approaches

Assumptions

- variable geometry shading (e.g. venetian blinds angles)
- dimming lights

Tested approaches to control design:

1. optimal daylighting approach: “DLT”
2. optimal energy approach: “Th”

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Simulation tests. Two control approaches

DLT approach

maximise visible light transmission while keeping visual comfort

inputs

- current shading state
- computed average illuminance on working planes
- maximum illuminance (comfort target)

output

optimal shading state

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Simulation tests. Two control approaches

Th approach

maximise thermal comfort optimizing solar gains

inputs

Winter

- current shading state
- target comfort temperature

Summer

- current shading state
- total radiation on façade

output

optimal shading state

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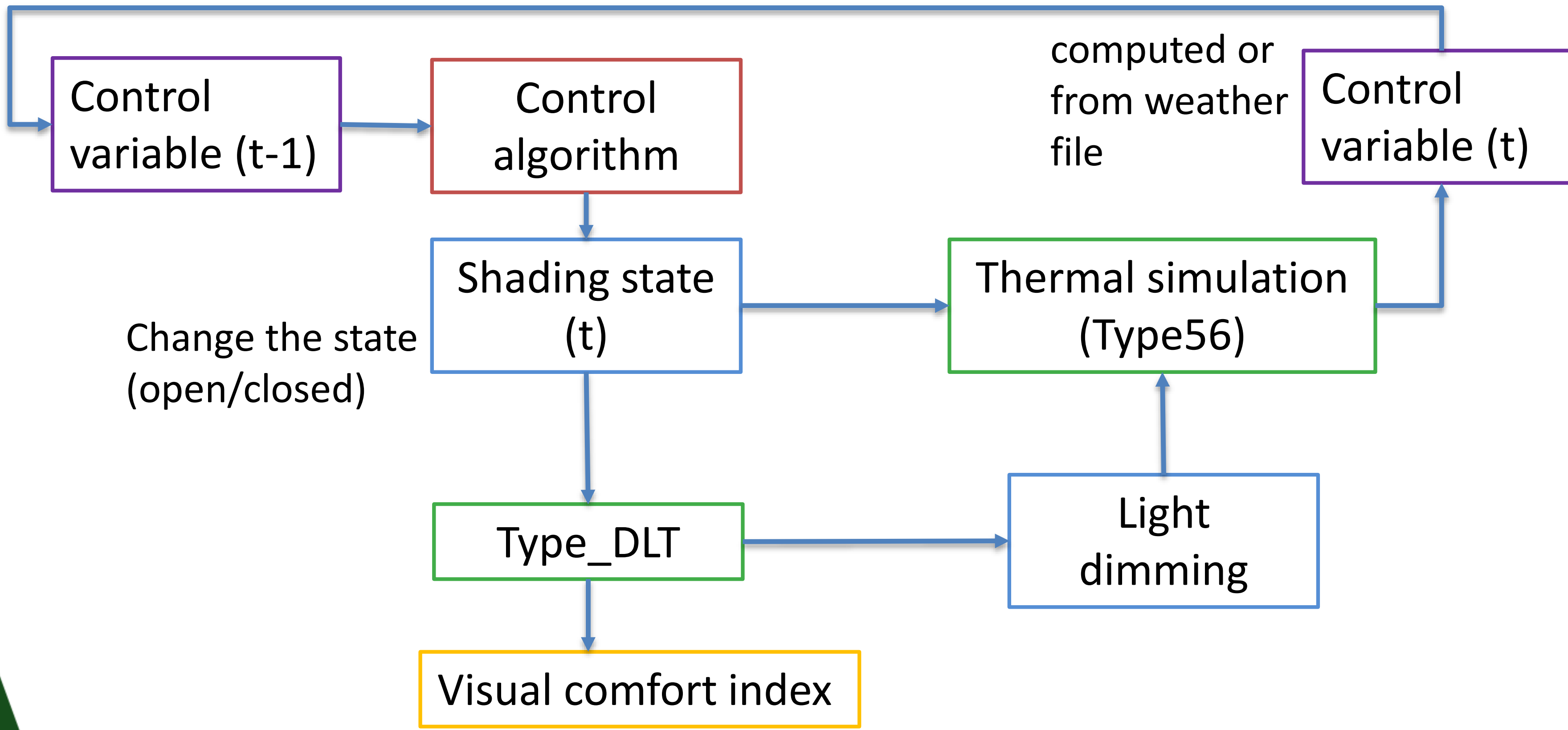
Simulation approach Th. Variable shading

EACH SIM STEP

THERMAL FEEDBACK CONTROL



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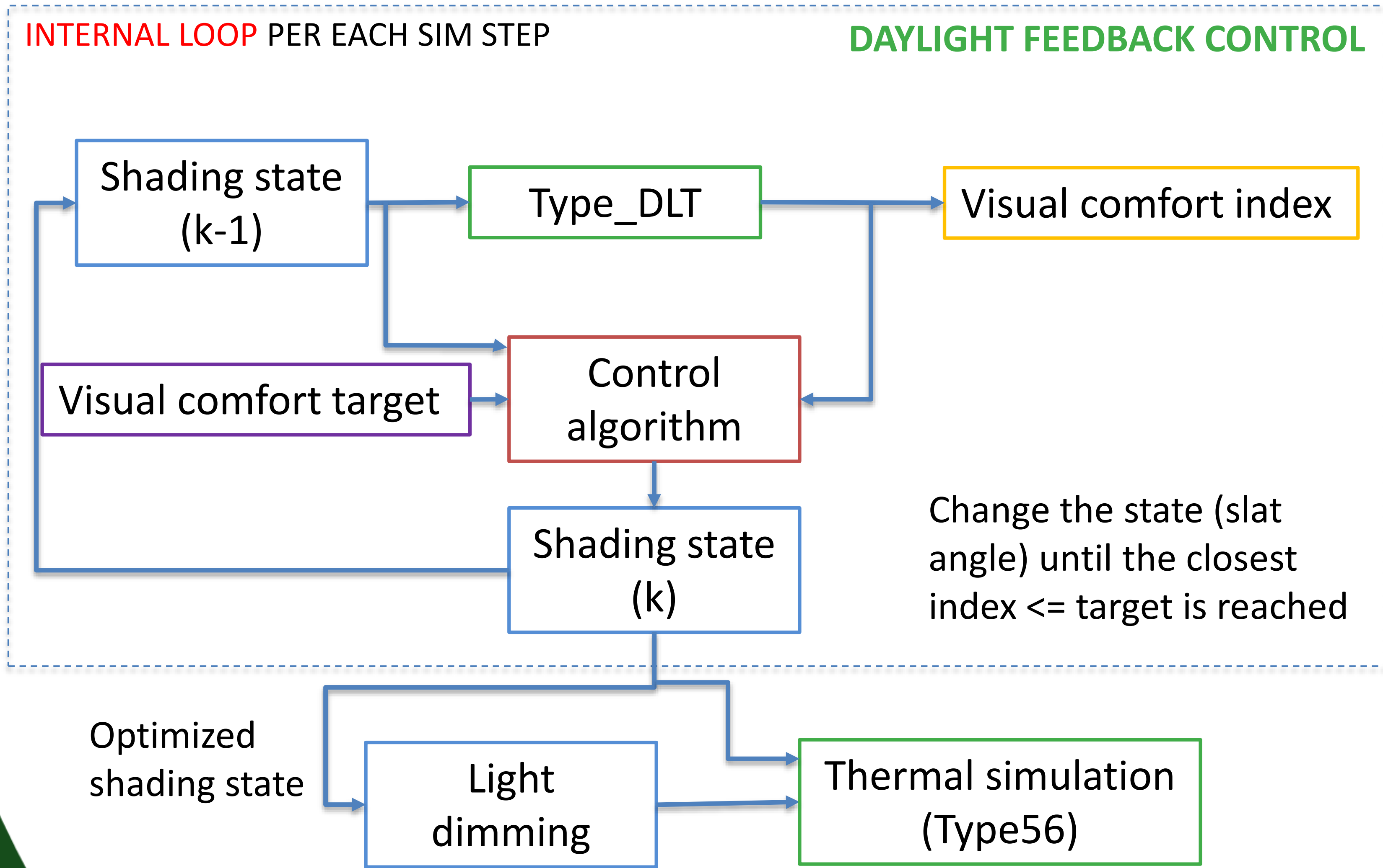
Simulation approach DLT. Variable shading



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Thermal model of the CFS

- In this work:
  - Shading factor computed from SHGC (still not angle dependent):

$$Fc = (SHGC(clear\_glass) – SHGC(CFS)) / SHGC(clear\_glass)$$

- Next step: implementation of ISO 15099 detailed calculation (uses BSDF)

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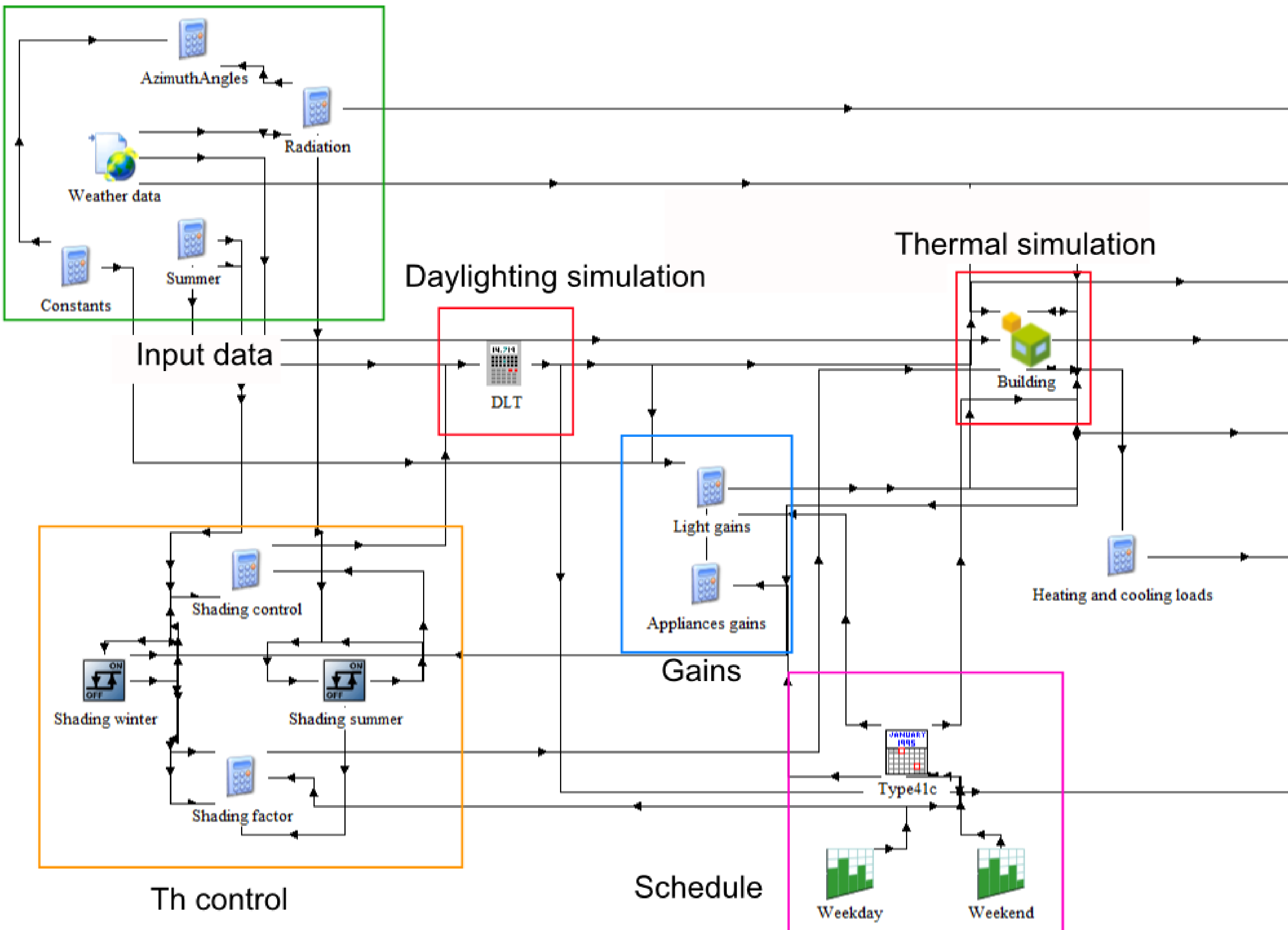
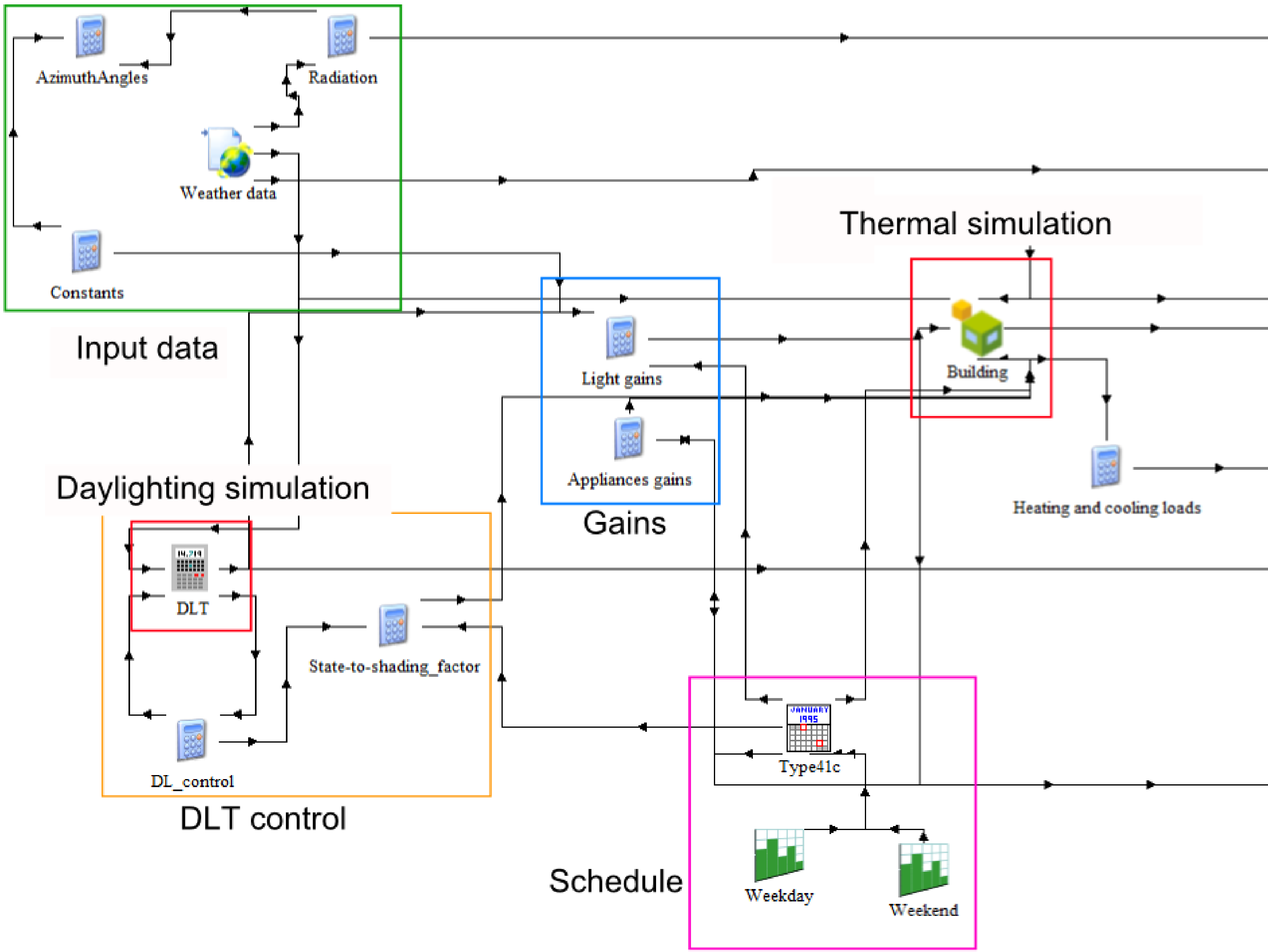
Trnsys deck implementation. Th

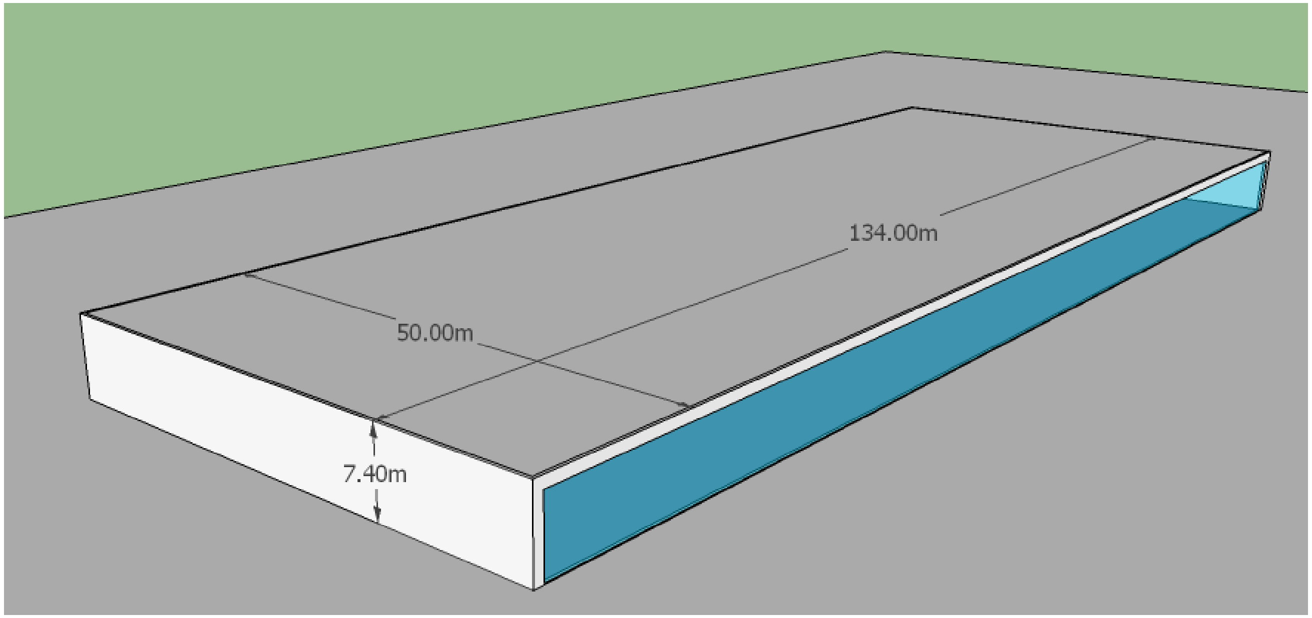


Trnsys deck implementation. DLT



The demo test

Shopping mall area. Large supermarket



	Reflection factor
Internal wall	0.5
Ceiling	0.8
Floor	0.2
External wall, ground	0.35

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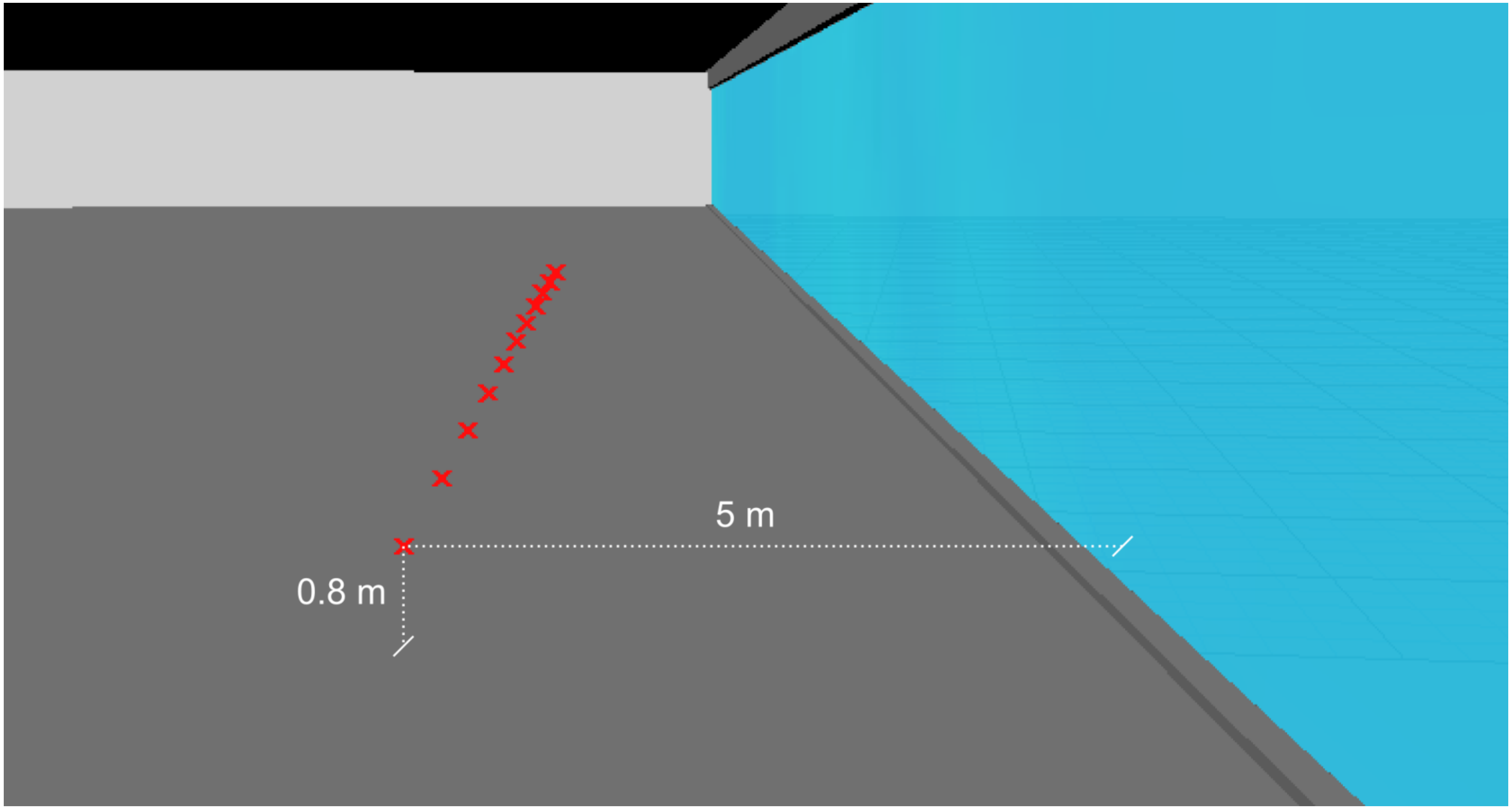
The demo test

Sensor grid. 11 sensors on a row on cash registers



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The demo test

Solar control glazing (double pane)

Glazing System Library

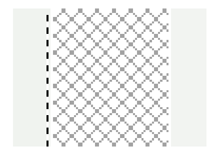
ID #: 1 Name: clearglass_solar_control

Layers: 2 Tilt: 90 ° IG Height: 1000.00 mm

Environmental Conditions: NFRC 100-2010 IG Width: 1000.00 mm

Comment:

Overall thickness: 20.000 mm Mode: #



	ID	Name	Mode	Thick	Flip	Tsol	Rsol1	Rsol2	Tvis	Rvis1	Rvis2	Tir	E1	E2	Cond	Comment
Glass 1	7110	ip_ipl4E.ipe	#	4.0	X	0.588	0.246	0.312	0.889	0.055	0.048	0.000	0.837	0.037	1.000	
Gap 1	2	Argon		12.0												
Glass 2	7197	ip_fl_4.ipe	#	4.0		0.842	0.076	0.076	0.900	0.082	0.082	0.000	0.837	0.837	1.000	

Center of Glass Results | Temperature Data | Optical Data | Angular Data | Color Properties

Ufactor	SC	SHGC	Rel. Ht. Gain	Tvis	Keff	Gap 1 Keff
W/m2-K			W/m2		W/m-K	W/m-K
1.360	0.653	0.568	422	0.810	0.0218	0.0218

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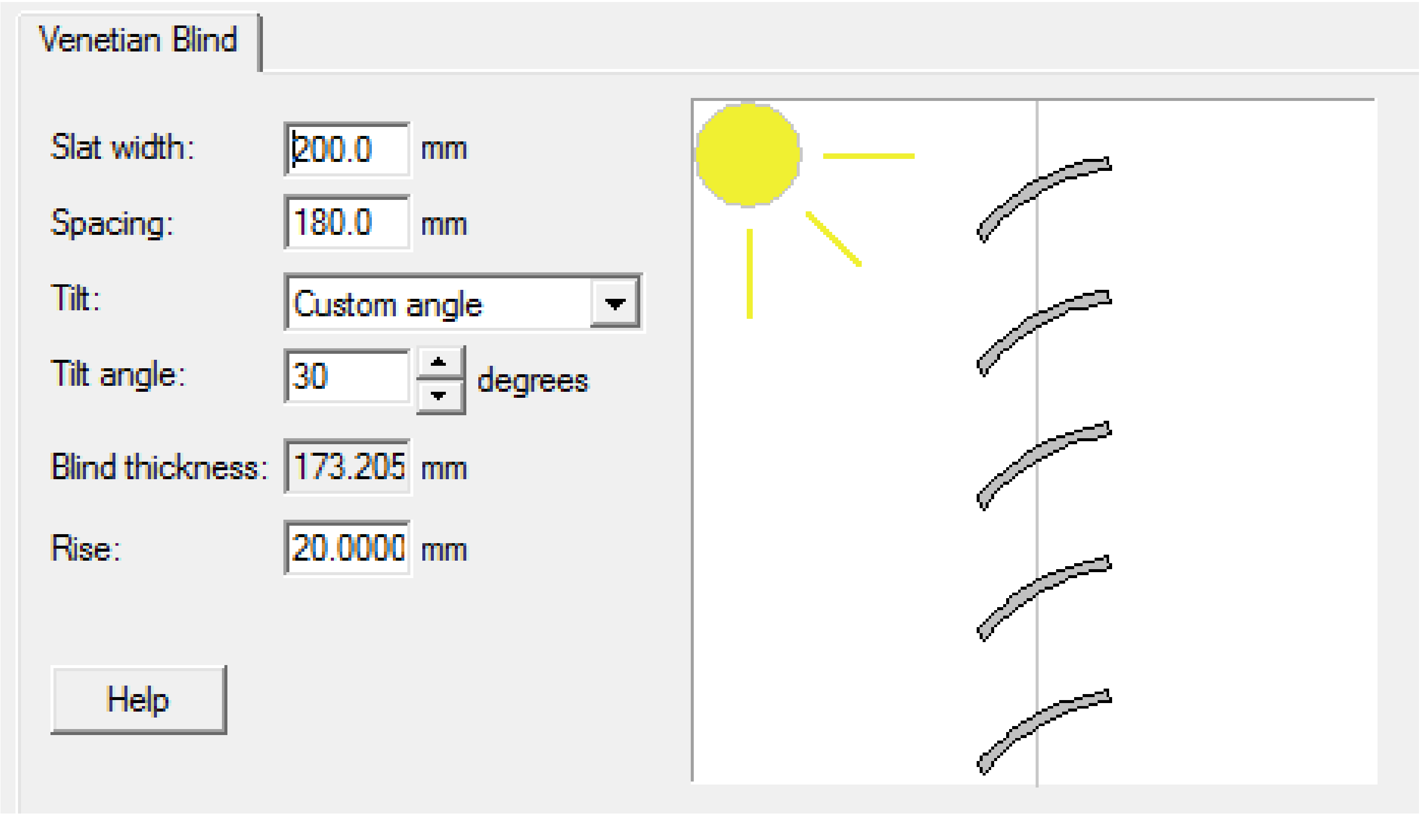
The demo test

Exteriori venetian blinds (variable tilt angle)



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Simulation baseline

- Time step: 1h
- Simulation period: 1 year
- Climate data source: Meteonorm
- Winter period: 15th October – 15th April
- Temperature setpoint: Tmin = 17 ˚C; Tmax = 24 ˚C (all seasons)
- Target comfort temperature: 23 ˚C (winter)
- Visual comfort target range: 300 – 2000 lux
- Total radiation on façade: 55 W/sqm (summer)
- Internal loads:
  - electric lights
  - 1000 people
  - cooling devices (food)
  - thermal losses through: main transparent façade, floor, ceiling, back wall
- Dimming parameters: from A. Mc Neil, *Tutorial on three-phase method for complex fenestration system*

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Simulation baseline

- Comparison of DLT and Th control approaches

❑ DLT control. 5-position tilted slats

State	Shading state
0	clear glass
1	tilt angle 15°
2	tilt angle 30°
3	tilt angle 45°
4	tilt angle 60°

❑ Th control. 2-state shading

State	Shading state
0	clear glass
1	tilt angle 60°

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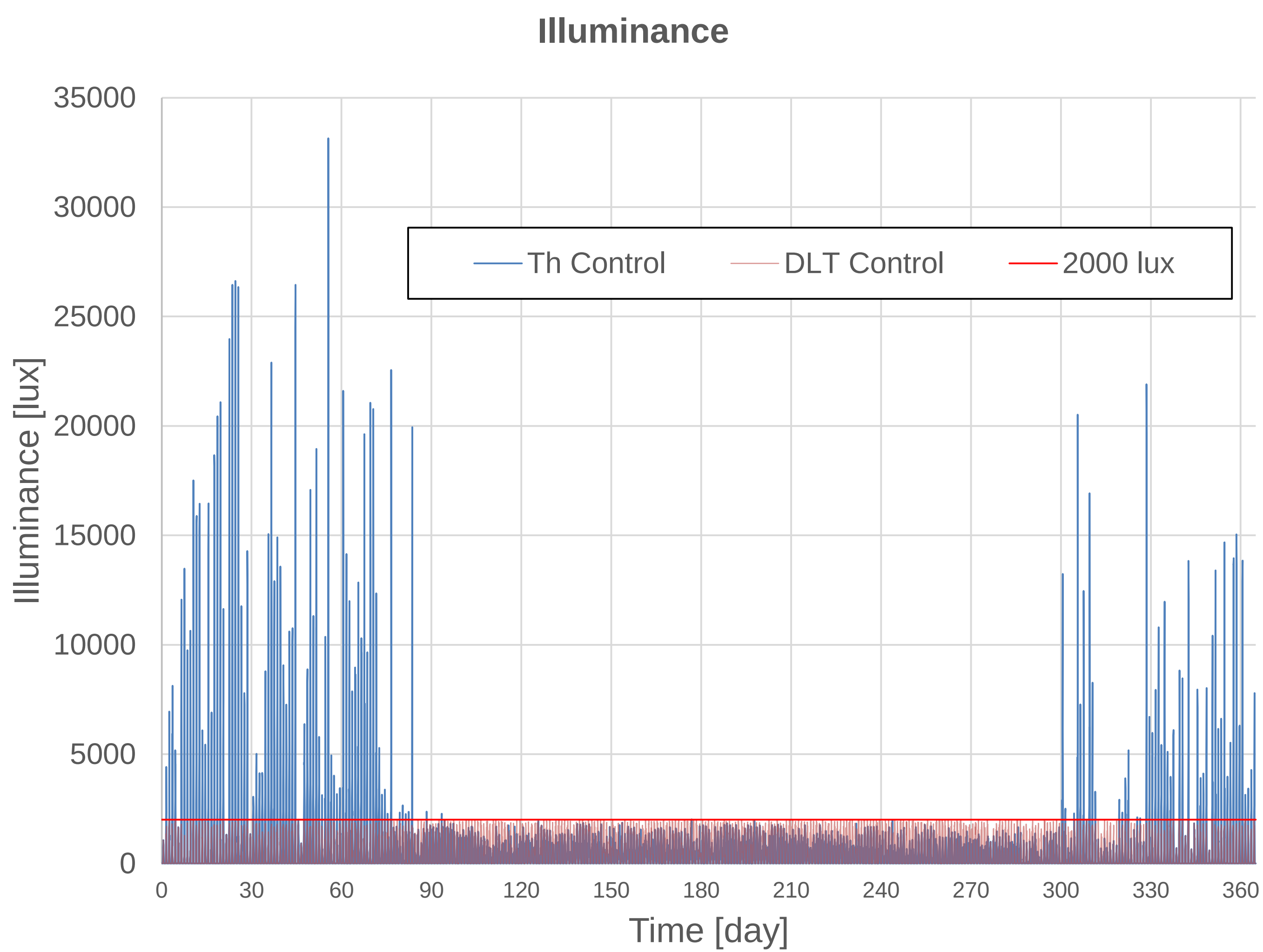
Results



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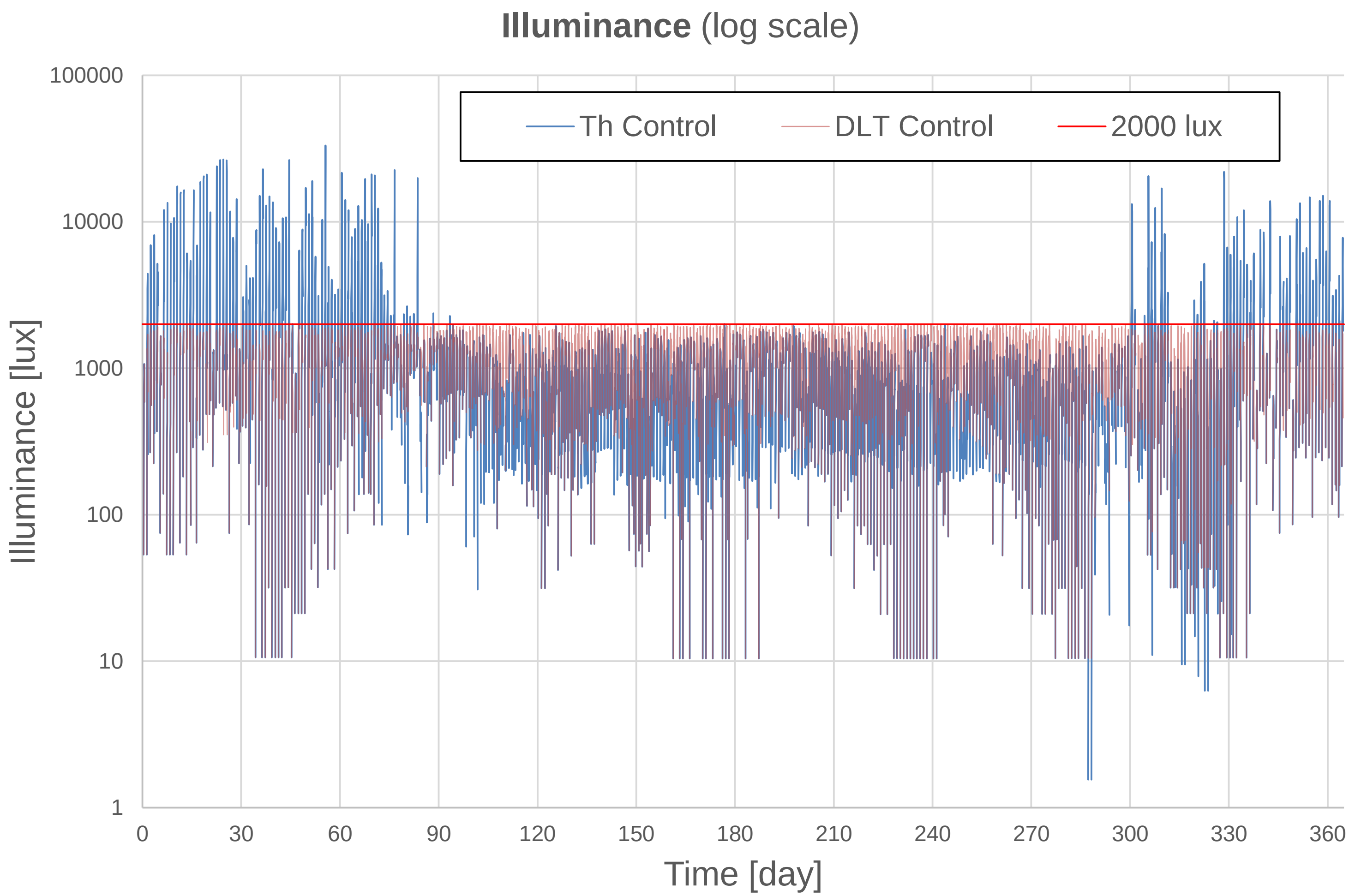
Results



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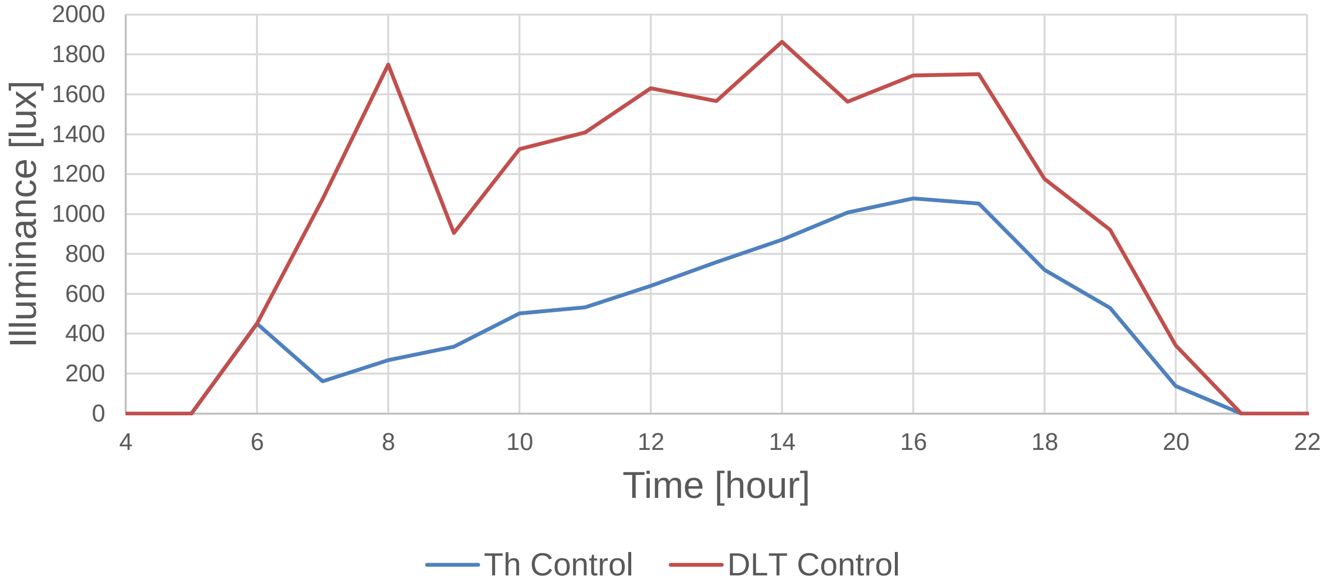
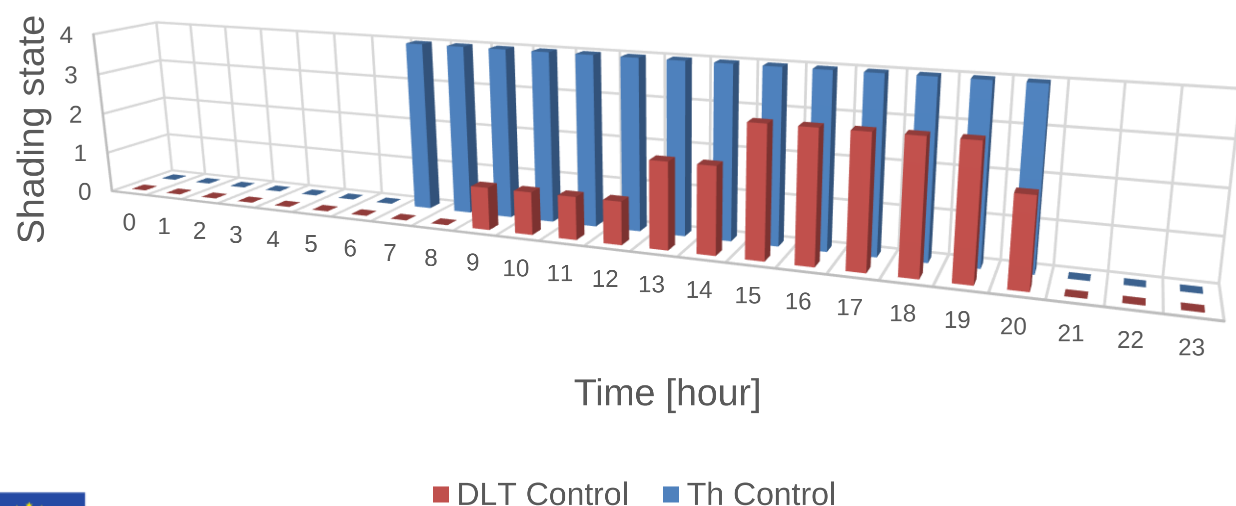
regime: summer

Illuminance - 17th June



Shading Control - 17th June



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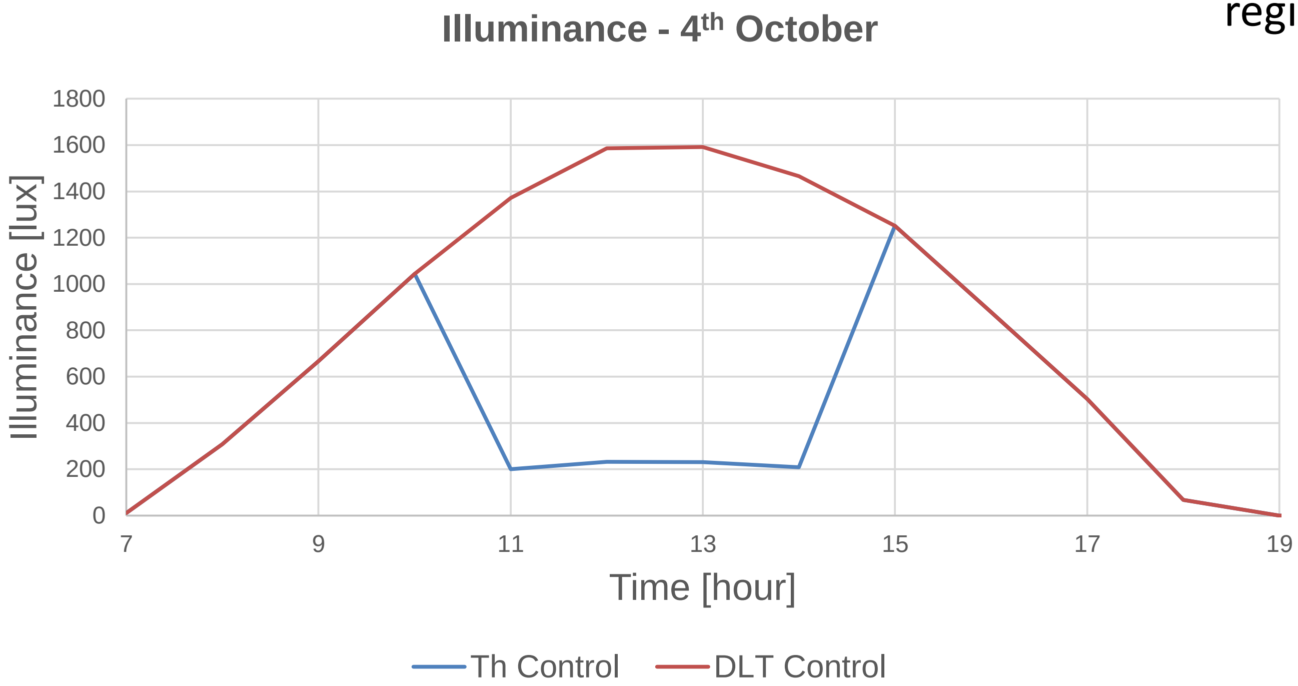
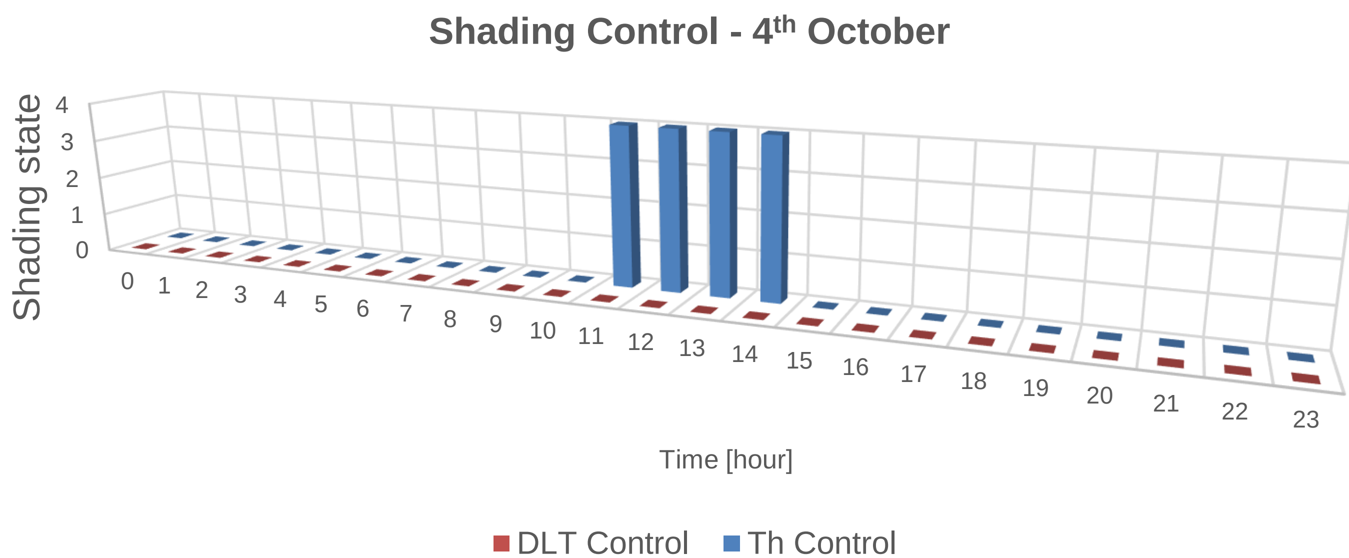
regime: summer





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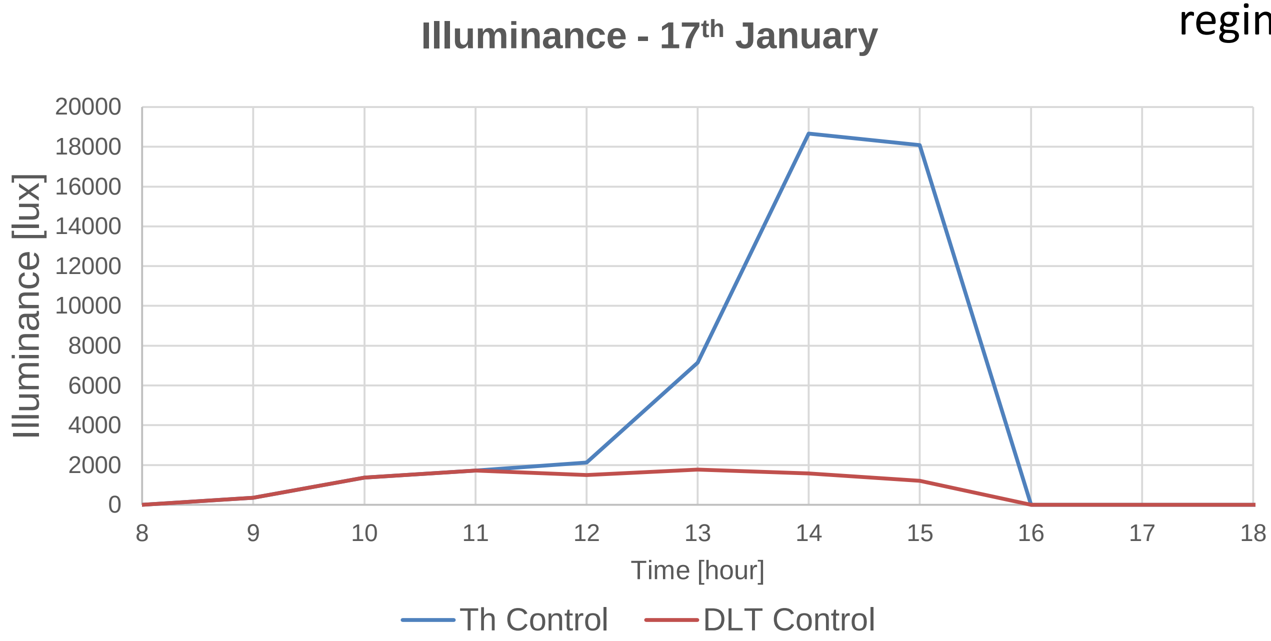
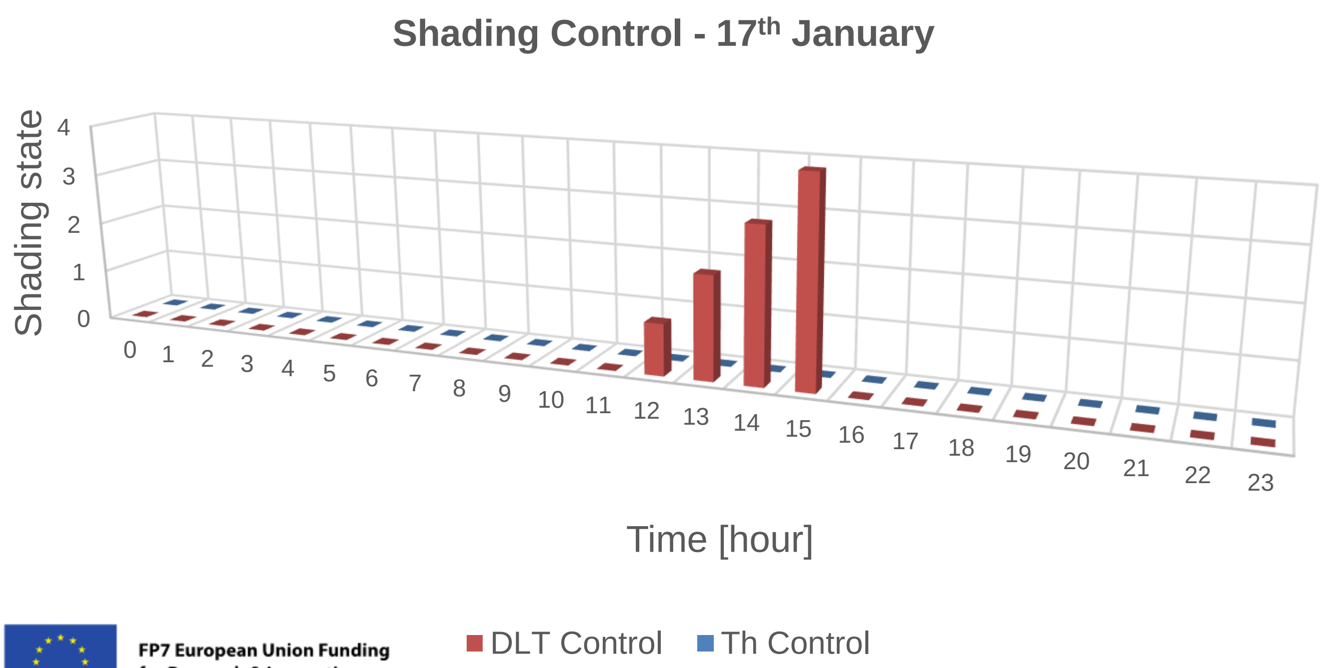
regime: winter





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Results

Comparison of annual energy consumption

	Heating demand kWh	Cooling demand kWh	Total power demand kWh	
TH Control	1385.8	539061.8	540447.6	
DLT Control	3315.4	572007.3	575322.7	
		Difference [GWh]	**-34.875**	-6%

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Conclusions

“type_DLT.dll” enable daylighting simulation and control design in Trnsys:

- ✓ Preliminary tests consistent
- ➢ Actual façade to be implemented
- ➢ Multi-objective optimization algorithms to be explored
- ➢ Source code and examples to be published

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THANK YOU!

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