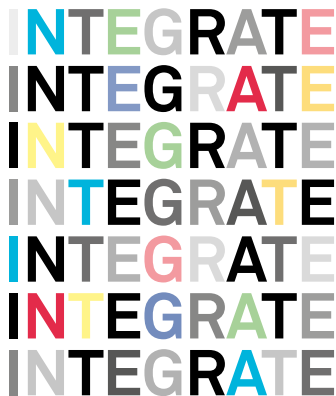


The Zero Carbon Building Systems Lab in daylight research at ETHZ

LO Grobe, R Sogno, I Hirschier, S Crosby, A Schlueter
23. International Radiance Workshop, 27.8.2025, Lausanne (CH)

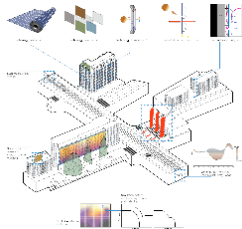




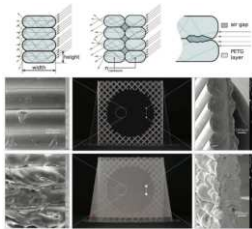
- **Aims:** Reduce emissions, transition to renewables, and address climatic extremes
- **Fields of action:** Integrate energy, material, and human response in building design in research & teaching

Arno Schlueter et al. *Integrate: Architecture under the influence of climate change*. Zurich, Switzerland: vdf Hochschulverlag an der ETH Zürich, 2022.
doi: 10.3218/4100-2 [🔗](https://doi.org/10.3218/4100-2)

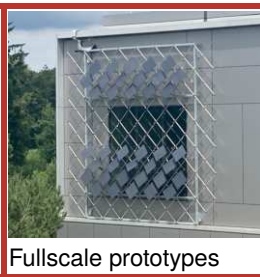
Modes of research



Modelling¹



Experiments²



Fullscale prototypes



Living Labs³

¹ Justin McCarty. "Solar energy in the city: Localised urban integrated photovoltaic deployment". PhD thesis. ETH Zurich, Department of Architecture, 2025. doi: [10.3929/ethz-b-000738738](https://doi.org/10.3929/ethz-b-000738738)

² Valeria Piccioni et al. "Tuning the solar performance of building facades through polymer 3D printing: Toward bespoke thermo-optical properties". In: *Advanced Materials Technologies* 8 (2023). doi: [10.1002/admt.202201200](https://doi.org/10.1002/admt.202201200)

³ Alberto Silvestri et al. "Real building implementation of a deep reinforcement learning controller to enhance energy efficiency and indoor temperature control". In: *Applied Energy* 368 (2024). doi: [10.1016/j.apenergy.2024.123447](https://doi.org/10.1016/j.apenergy.2024.123447)

The Zero Carbon Building Systems Lab



- Dedicated to research and teaching
- Filling the gap between small-scale experiments and living labs
- Hosting test rooms and solar simulator for testing at full scale
- Located at ETH Hönggerberg Campus – Right next to the Institute for Technology in Architecture / DFAB

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Testing under local climate conditions



- Two South-oriented test cells
- Configurable facade and ceiling/roof
- Hosted initial studies in the first year of operation, e.g., in building control, VR for thermal and visual comfort assessments, and the ongoing testing of the Adaptive Solar Facade.

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First studies in the outward-facing test cells



- Testing cloud-connected smart thermostatic valves
- VR for thermal and visual comfort assessments
- Testing the Adaptive Solar Facade / Solskin AI

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Testing the Adaptive Solar Facade

Individually oriented solar panels generate electric energy and provide shading.

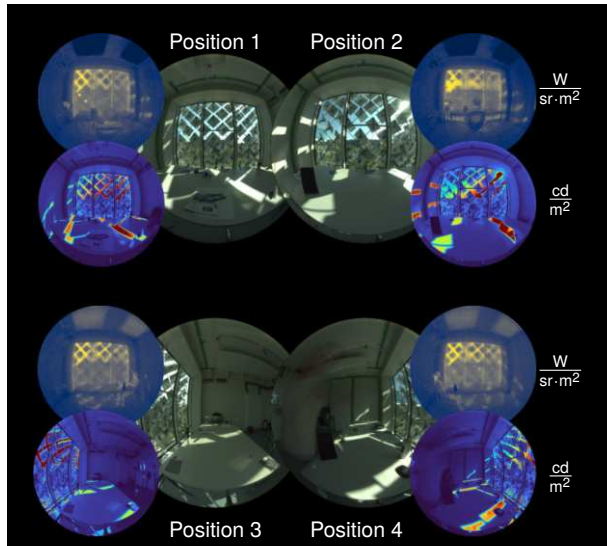
- Intentionally set uncomfortable visual and thermal conditions
- Observe operation of controls by study participants
- Recording radiance and luminance maps

Aim: Inform the development of a machine-learning driven control system

For details please address Dong Hyun Kim.



Solskin



Testing under emulated global climate conditions



- One test cell exposed to emulated climate
- Configurable facade, similar are exterior-facing cells
- *How to emulate the sun?*

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Setting up the LED-based solar simulator LEDSS



Assembly of LED modules by apprentices.

Design targets:

- One sun irradiance on large specimen,
- Low divergence,
- Tuneable spectrum,
- Emulate all solar geometries to model direct sunlight on a facade.



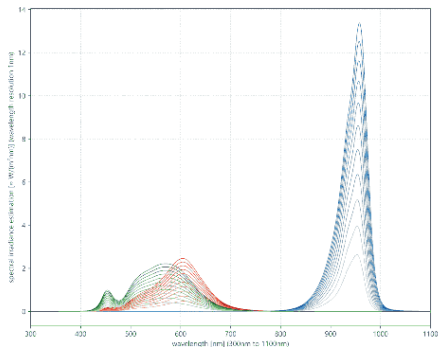
a/s team folding compound parabolic reflectors.

The LED-based Solar Simulator



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Characterisation of the LEDSS: Module output



Spectral tuning

Infrared (blue), warm white (red), and cold white (green) LEDs at setpoints 10 % to 60 % in increments of 5 %

Set-point 50%

R2	3.5% ±0.1%	1.5% ±0.1%	0.4% ±0.0%
R3	-1.9% ±0.1%	2.4% ±0.0%	2.0% ±0.0%
R4	-1.0% ±0.0%	1.7% ±0.0%	-2.1% ±0.0%
R5	0.7% ±0.0%	-0.8% ±0.0%	-4.6% ±0.0%
R6	0.9% ±0.0%	-2.6% ±0.0%	0.1% ±0.0%
	C4	C3	C2

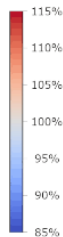
infrared

R2	-1.9% ±0.0%	1.9% ±0.1%	2.2% ±0.0%
R3	0.1% ±0.0%	2.6% ±0.0%	0.1% ±0.0%
R4	1.4% ±0.0%	-0.5% ±0.0%	-1.5% ±0.0%
R5	-1.2% ±0.0%	0.1% ±0.0%	-1.0% ±0.0%
R6	2.1% ±0.0%	-5.3% ±0.0%	0.9% ±0.0%
	C4	C3	C2

warm white

R2	-1.8% ±0.0%	1.0% ±0.0%	2.9% ±0.0%
R3	1.4% ±0.0%	4.5% ±0.0%	-2.6% ±0.0%
R4	0.9% ±0.0%	1.6% ±0.0%	-2.5% ±0.0%
R5	-1.4% ±0.0%	-0.1% ±0.0%	-2.6% ±0.0%
R6	3.6% ±0.0%	-3.3% ±0.0%	-1.5% ±0.0%
	C4	C3	C2

cold white

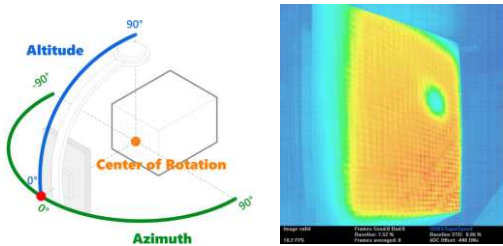


Relative irradiance deviation per module
Normal angle of incidence, average per module
of 5 × 5 boards / reflectors.



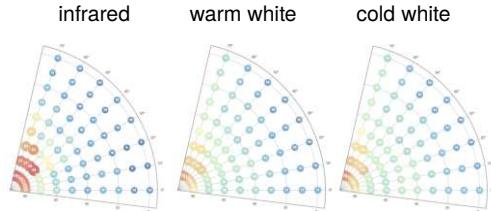
Rino Sogno. "Characterisation and calibration of a novel LED based solar simulator". MA thesis. ETH Zurich, Department of Architecture, 2024

Characterisation of the LEDSS: Spatial uniformity

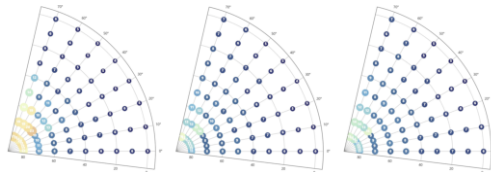


Solar coordinate system (left), HDR image of illuminated screen acquired by luminance camera (right)

- Image-based acquisition of local irradiance
- Coverage (almost) half incident hemisphere
- Non-uniformity $snu = \frac{E_{\max} - E_{\min}}{E_{\max} + E_{\min}}$



Not aggregated (per pixel) $snu \approx 29$



Aggregated to 157 mm x 157 mm: $snu \approx 21$

Non-uniformity snu as function of incident direction

Rino Sogno. "Characterisation and calibration of a novel LED based solar simulator". MA thesis. ETH Zurich, Department of Architecture, 2024

First studies in the global climate test cell

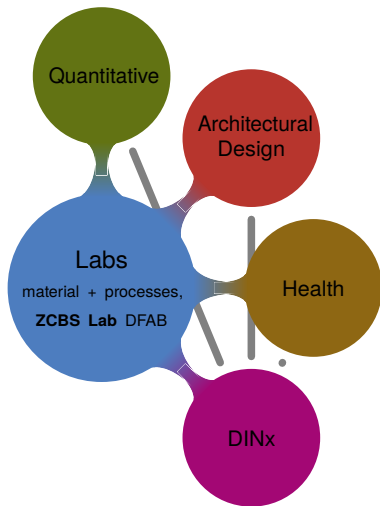


- Solar transmission through a translucent, 3D-printed facade (Valeria Piccioni)
- Measurement of dynamic solar gains
- Thermal effects by BIPV (Justin McCarty)



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Daylight Integration Nexus (DINx)



- Three-years initiative 2026-2028
- Chairs of Architecture and Building Systems Arno Schlueter and Architecture and Urban Design Hubert Klumpner
- Integration and translation of research in daylight and health in building design
- Postdoctoral fellowships in three focus areas:
Architectural design, Health, and Quantitative methods
- Relate to Material and processes by DFAB (fabrication) and ZCBS Lab (testing)
- DINx connects to teaching and research at ETH Department of Architecture and external partners and stakeholders

Supported by VELUX STIFTUNG

Daylight Integration Nexus (DINx)



Opportunities for postdoctoral research, collaboration, exchange!
Stay tuned & contact me directly: grobe@arch.ethz.ch