Solar shading for Thermal Resilience in Buildings:
An overview and gap analysis

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Acknowledgment

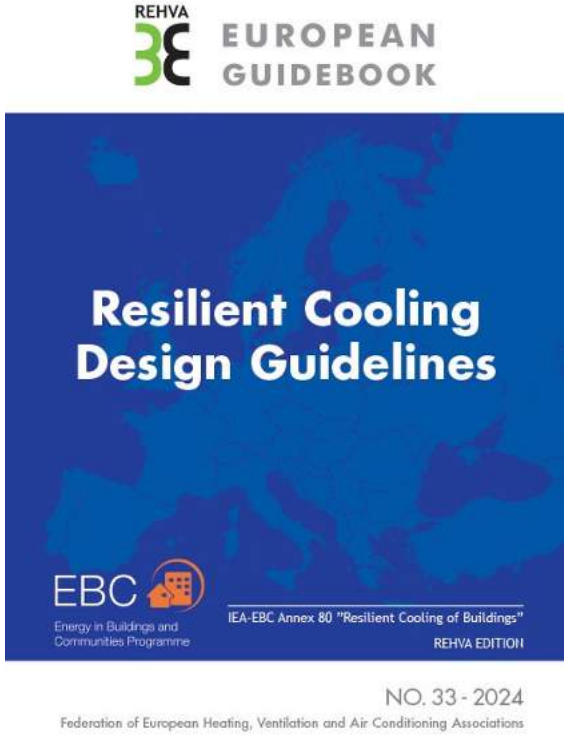
Resilient Cooling (2019-2023) Advanced Solar Control

EUROPEAN SOLAR SHADING ORGANISATION

EBC

Energy in Buildings and Communities Programme

IEA Annex 80

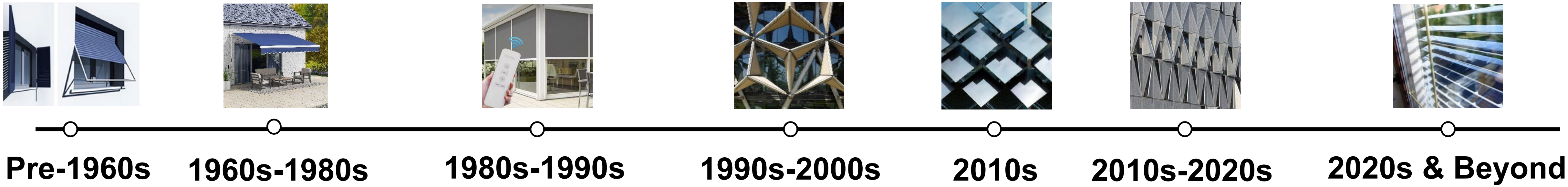


Attia, S., Psomas, T. (Ed.), & Corrado, V. (Ed.). (2024). *Resilient Cooling Design Guidelines*. (33). Brussels, Belgium: REHVA: Federation of European Heating, Ventilation and Air Conditioning Associations. https://orbi.uliege.be/handle/2268/320775

Solar Shading Research

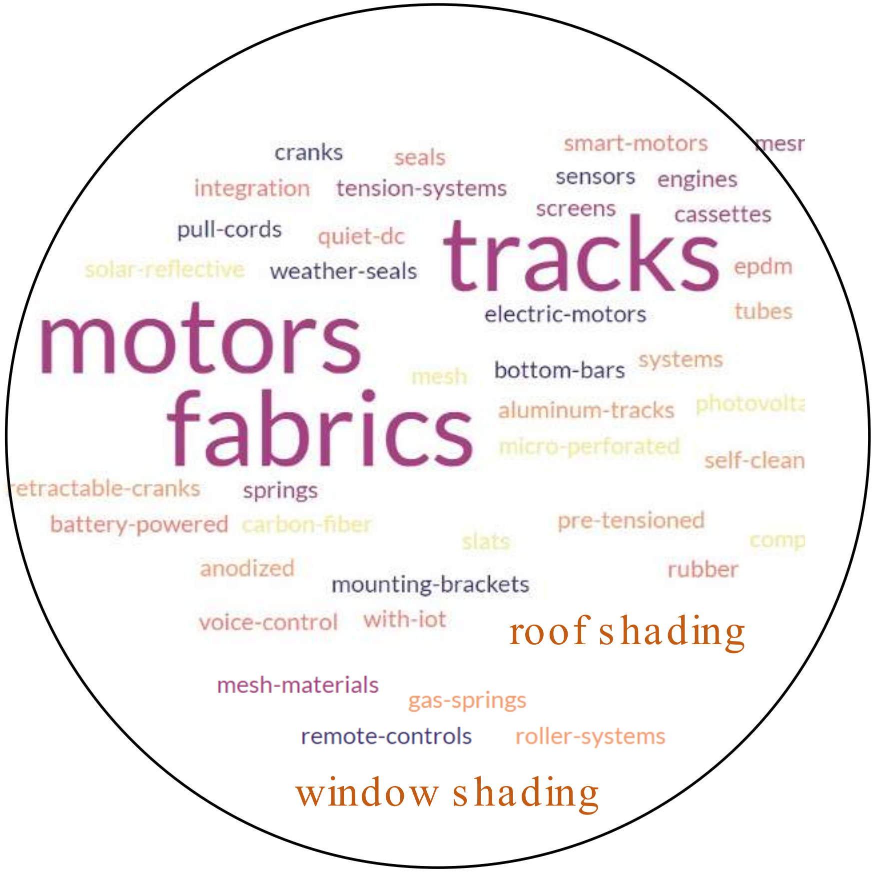
Evolution of facades shading systems

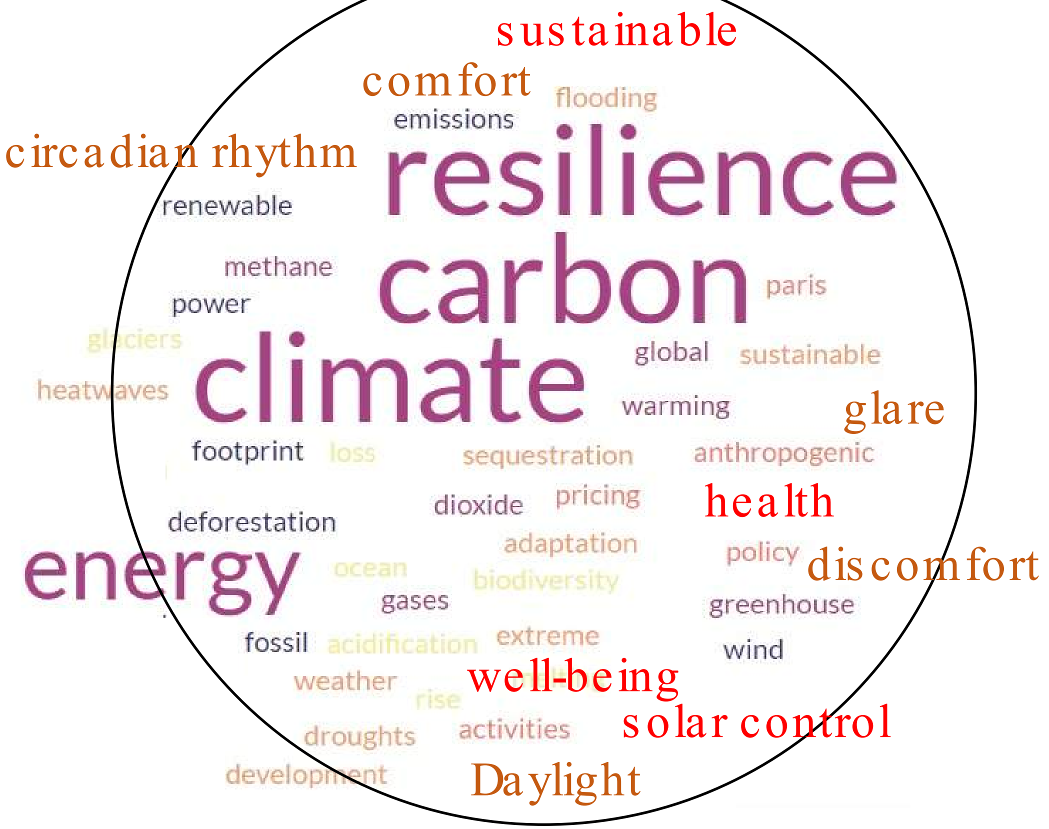
Application: Residential and Commercial



1. **Traditional Static Shading Systems** (Pre-1960s): Passive, fixed overhangs, pergolas.
2. **Adjustable Manual Shading Systems** (1960s–1980s): Manually operable blinds, louvers.
3. **Automated Shading Systems** (1980s–1990s): Motorized systems with basic sensors.
4. **Smart and Responsive Shading Systems** (1990s–2000s): Sensor-driven, integrated with building management.
5. **Adaptive Shading Systems (2010s)**: Dynamic, kinetic, and predictive systems.
6. **Adaptive and Predictive Facades** (Late 2010s–2020s): Fully adaptive facades with smart materials.
7. **Energy-Harvesting and Sustainable Shading Systems** (2020s and Beyond): energy-generating shading, sustainable materials, and AI-driven systems.

Matter vs. Impacts





Go deeper and deeper into the matter to create the next generation of solar shading inventions with intended consequences.

Dealing with the problems created by unintended consequences. Solving eminent emerging problems. Discovering terrible dangers that are facing us, like climate change, week by week.

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Resilience against short term events

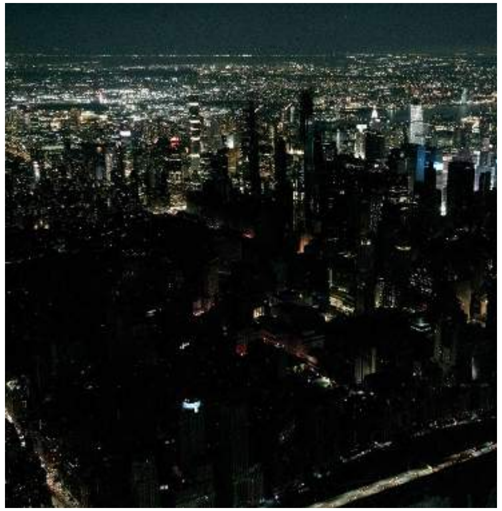
Disruptions

Drought

Flood

Heatwave

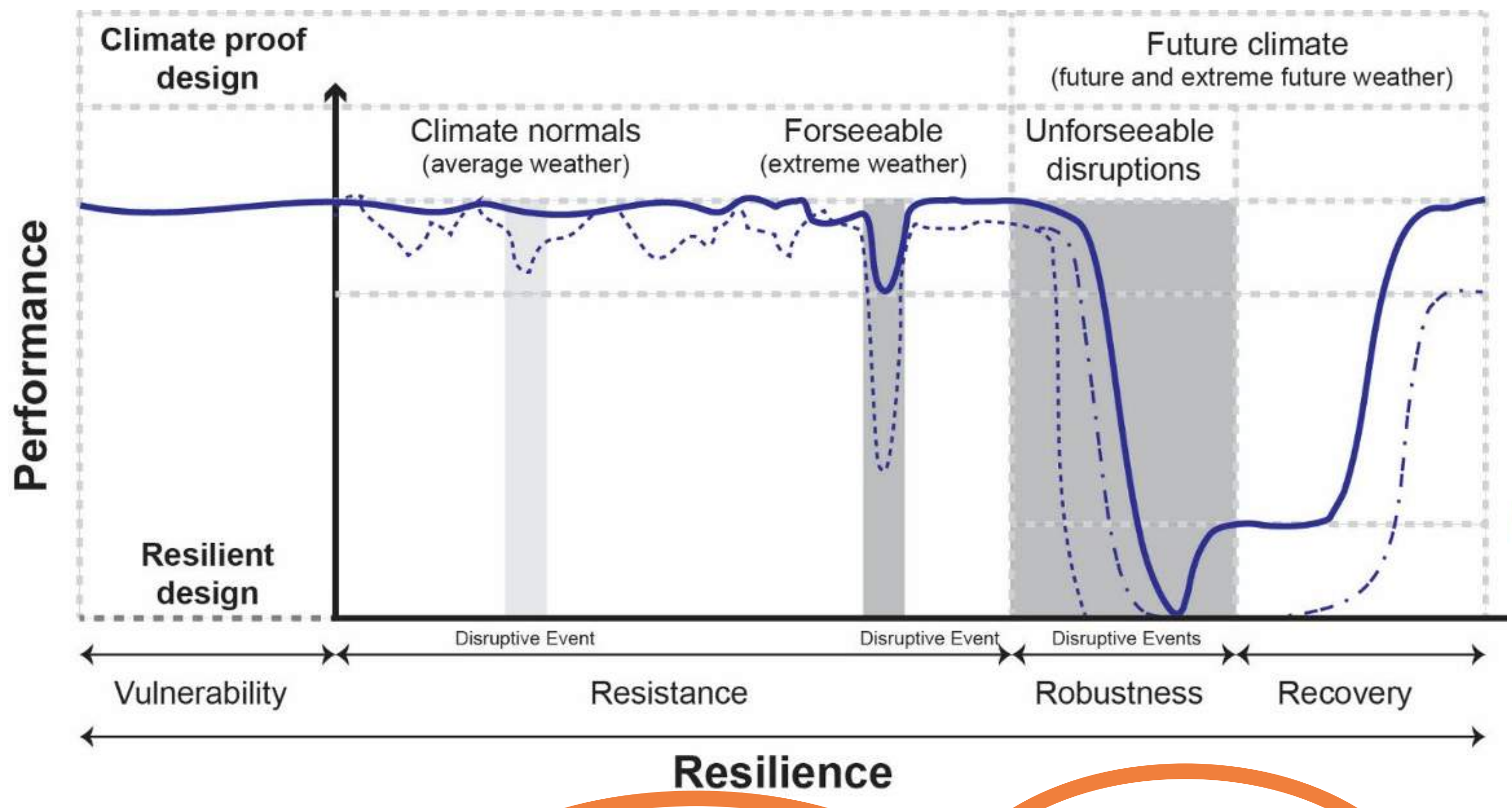
Fire



Power Outage

Air Pollution

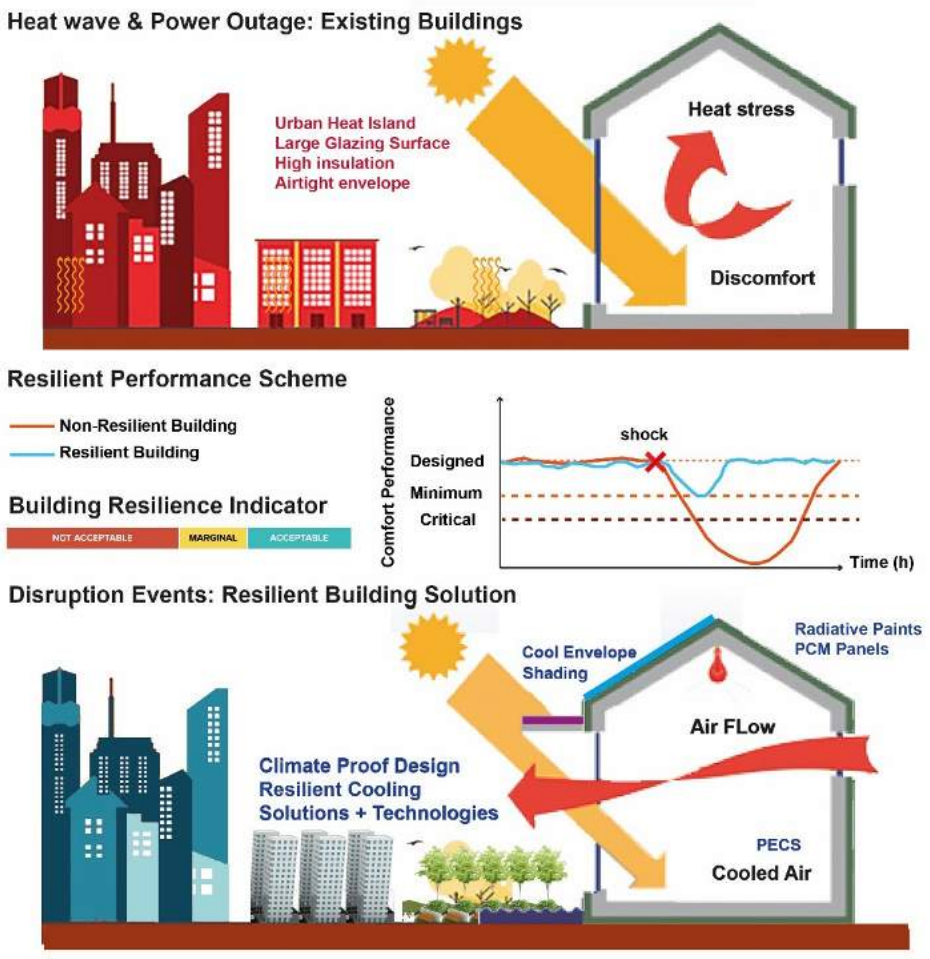
Definition: Resilience vs. Shock = FAILURE



1. designed thermal conditions
2. minimum thermal conditions
3. critical thermal conditions

1. weather files: extreme weather
2. weather files: average weather
3. weather files: future weather
4. weather files: worst future weather

Event 1: short extensive heatwave
Event 2: short intensive heatwave
Event 3: long extensive heatwave
Event 4: long intensive heatwave
Event 5: power outage



Non-Resilient and Resilient Performance Curve during heat waves and power outage events.

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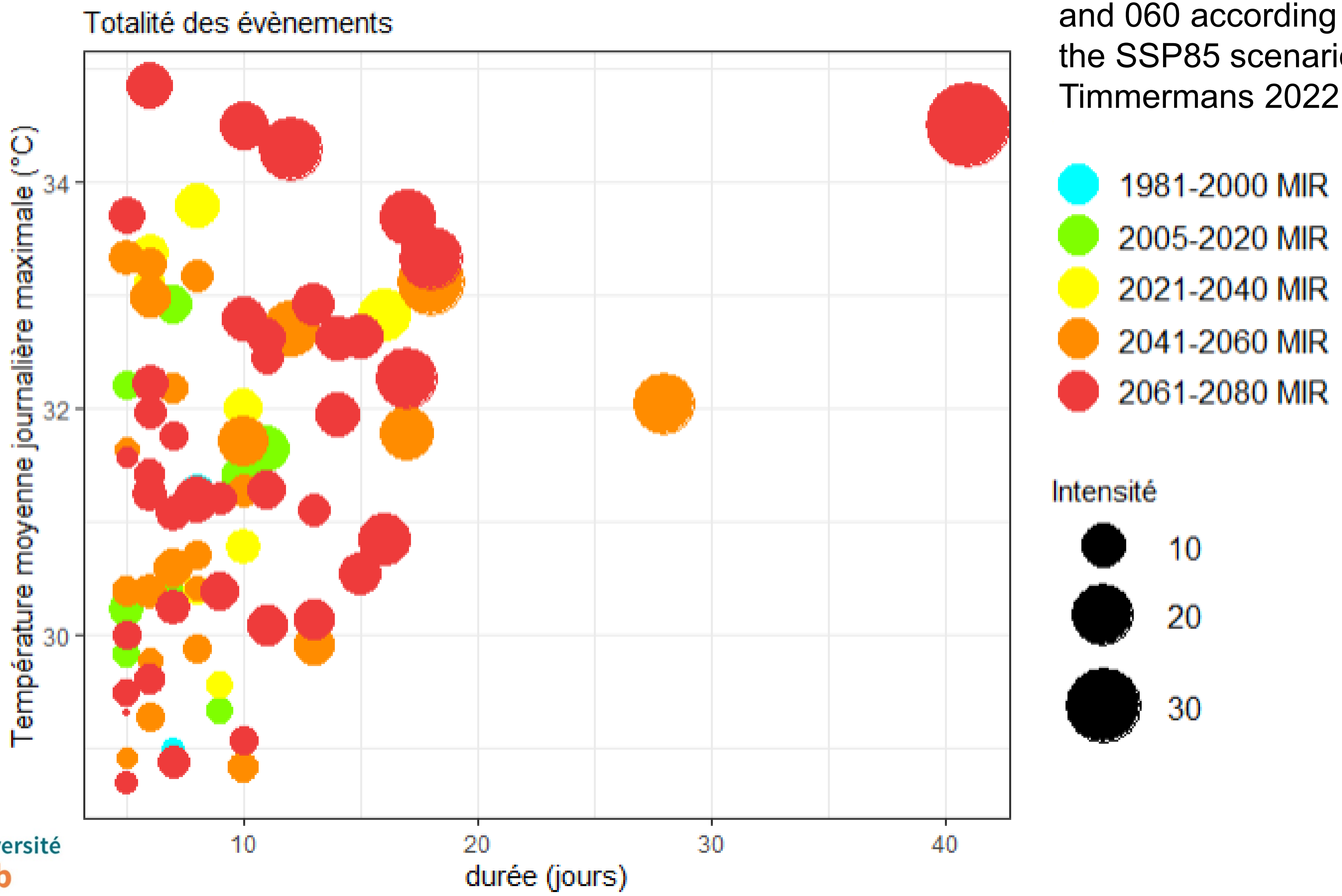
doi.org/10.1016/j.egypro.2016.06.218

Heat Waves in Liège 1981-2080



Intensity of heat waves in Liege between 1981 and 060 according to MAR-MIR in the case of the SSP85 scenario. Source: Guillaume Timmermans 2022.

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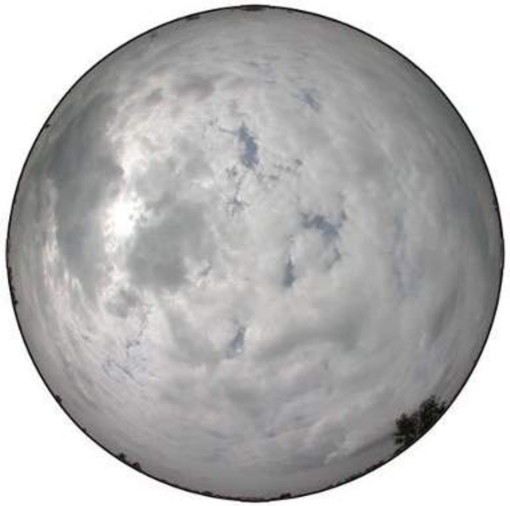
CIE Standardized Skies in Brussels



overcast sky

intermediate sky

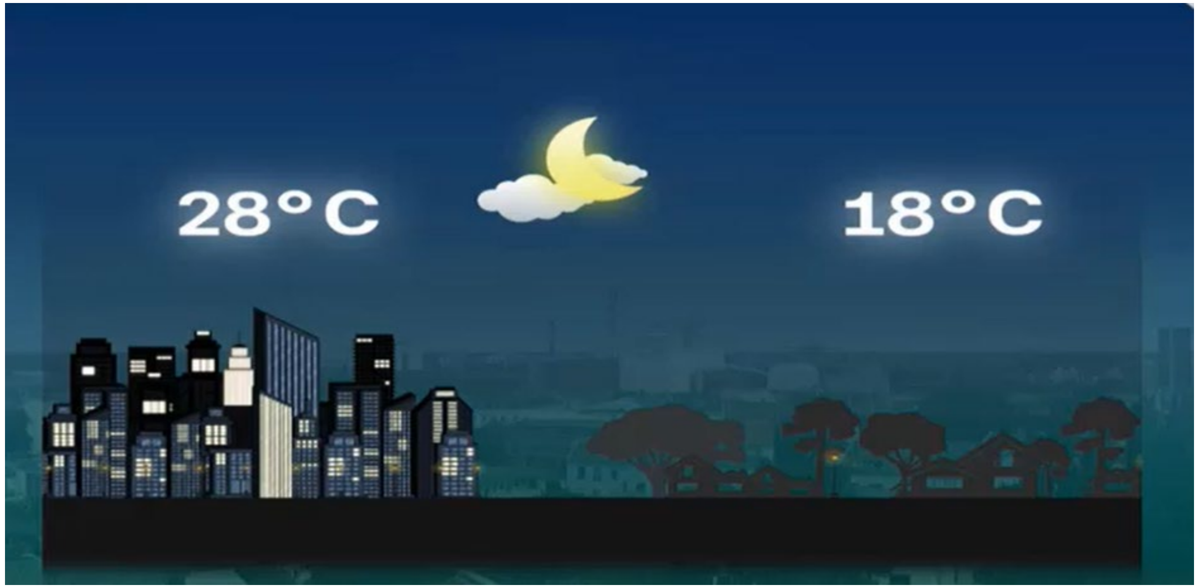
clear turbid/turbulent

clear sky

Source: Wyard, C (2018). Global radiative flux and cloudiness variability for the Period 1959–2010 in Belgium: a comparison between reanalyses and the regional climate model MAR. Atmosphere, 9(7), 262.

Tropical Nights in Brussels

Urban heating during the day and night is visible



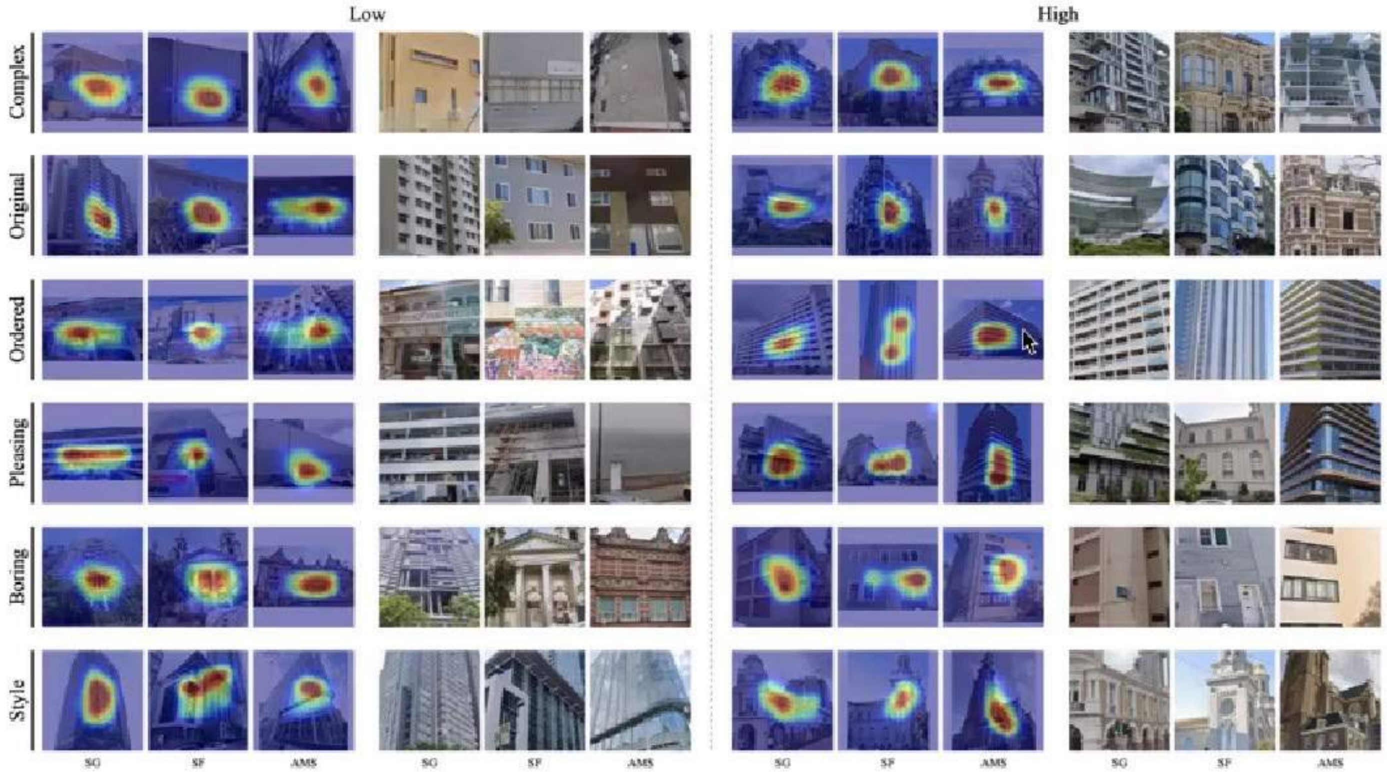
Temperature variation between night and day

Solar Shading and Resilience Research

1. Thermal Impact of Solar Shading

Shading devices influence the amount of solar heat that enters a building, directly affecting indoor temperatures and energy consumption.:

- **Heat Maps are effective in detecting and showing the density and intensity of facade heat patterns.**
- **Studies have shown that solar shading can lower surface temperatures on façades by 5-8°C during summer, which substantially reduces cooling loads in buildings, improving thermal comfort and energy efficiency.**



-**Liang Xiucheng**, 2024, Shenzhen University China.

-Brown, C. (2023). Solar Shading Design and Implementation in UK Housing as a Tool for Advancing Sustainable Development. In The Role of Design, Construction, and Real Estate in Advancing the Sustainable Development Goals (pp. 63-83). Cham: Springer .

-Barbero-Barrera, M. D. M., Tendero-Caballero, R., & García de Viedma-Santoro, M. (2024). Impact of Solar Shading on Façades' Surface Temperatures under Summer and Winter Conditions by IR Thermography. Architecture, 4(2), 221-246.

2. Shading and Building's Resilience

The Role of Shading Systems in Buildings Thermal Resilience:

- **Thermal Autonomy is the ability to maintain safe indoor conditions in the event of extended energy outage or loss of energy supply.**
- **Advanced shading systems can reduce the thermal heat load by up to 50%, thus enhancing energy efficiency.**
- **Strong resilience measures in building energy codes to minimize energy use, maximize comfort, and enhance potentially life-saving resilience benefits.**

-Gare Maritime, Bureau Bouwtechniek, Neutelings Riedijk Architects
-EFI Foundation, Modernizing the U.S. Electricity Grid for Resilience, Load Growth, the Clean Energy Transition, and Energy Security, 2024.
-Franconi, E, E Hotchkiss, T Hong, M Reiner et al. 2023. Enhancing Resilience in Buildings through Energy Efficiency. Richland, WA: Pacific Northwest National Laboratory. PNNL-32737, Rev 1.

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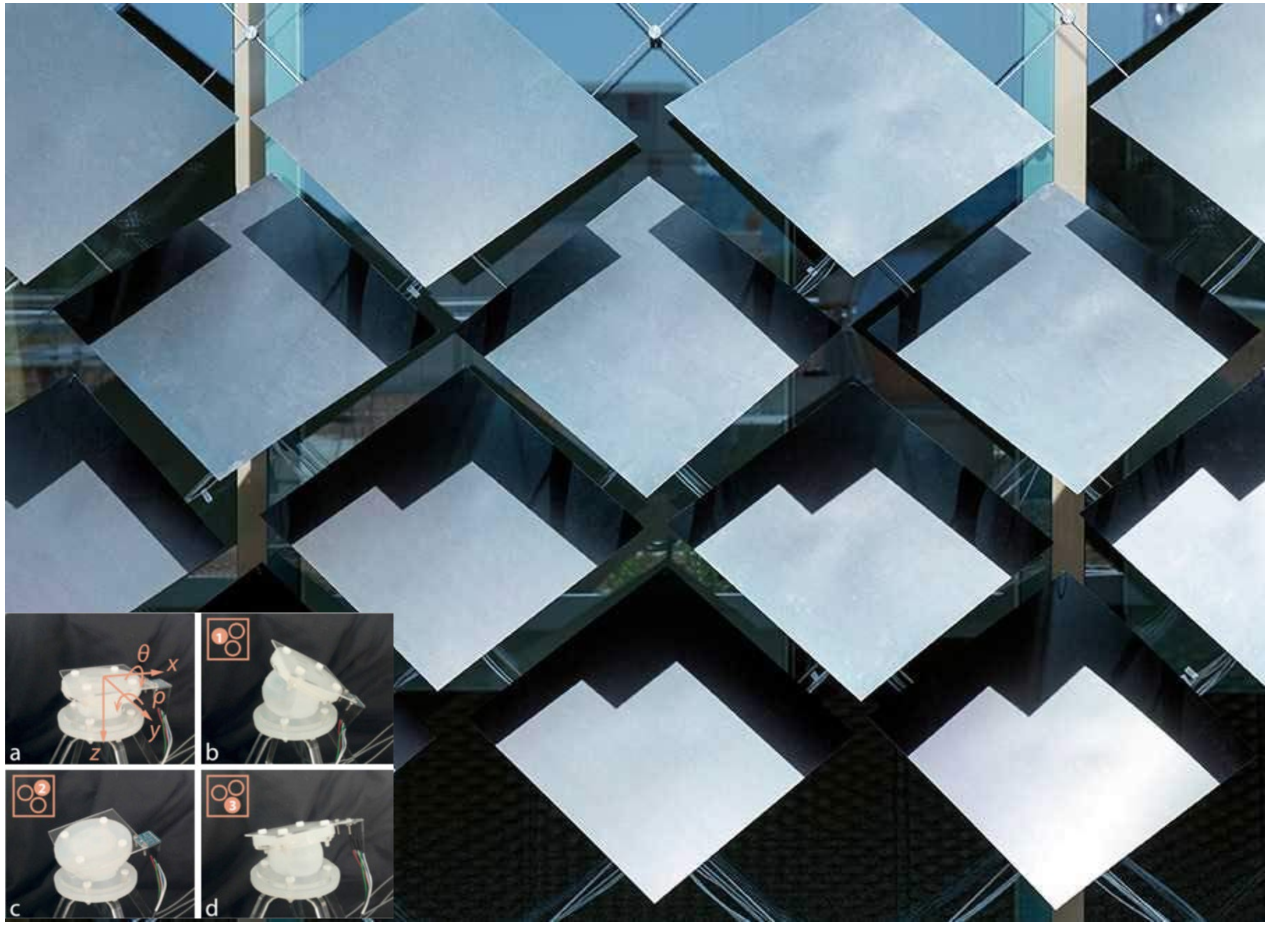
3. Dynamic Shading Systems

Dynamic shading systems are increasingly incorporating artificial intelligence (AI) and machine learning to optimize shading based on real-time data:

- **Photovoltaic-Integrated Shading Systems**
- **Kinetic Shading Systems and kinetic actuator**
- **ISO 52016-3 calculation procedures regarding adaptive building envelope elements**
- **High-performance facades**



-The adaptive solar façade is assembled on the south side of the House of Natural Resources. (Photo: Marco Carocari) Prof. Arno Schlüter, ETH Zürich

-Nagy, Z., Svetozarevic, B., Jayathissa, P., Begle, M., Hofer, J., Lydon, G., ... & Schlueter, A. (2016). The adaptive solar facade: from concept to prototypes. Frontiers of Architectural Research, 5(2), 143-156.

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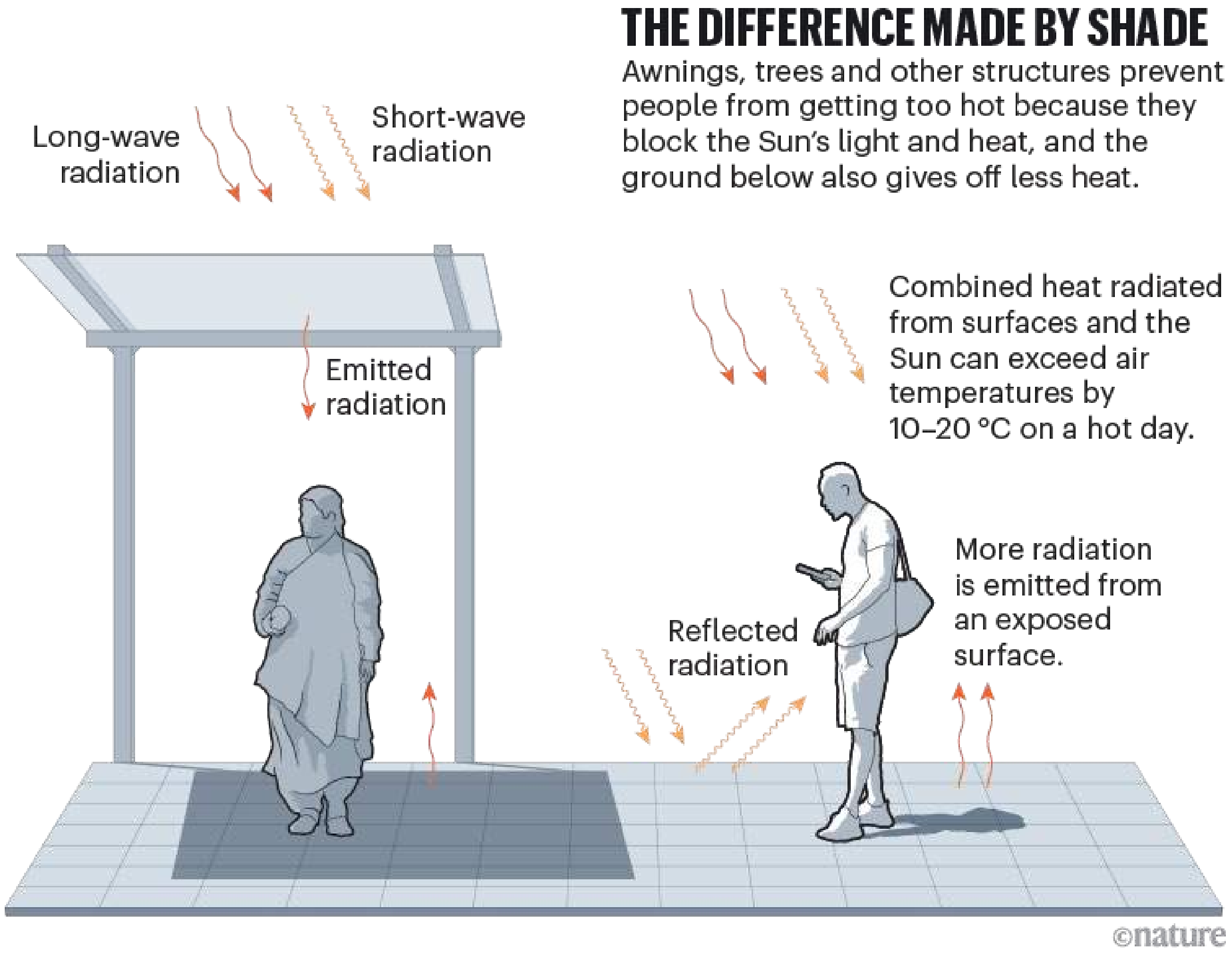
4. Shading in Climate Adaptation Strategies

Advancements in shading technologies for climate adaptation strategies to reduce urban heat islands and enhance building resilience :

- **Automated louvers and blinds**
- **External shading systems for outdoor spaces, such as verandas, retractable and motorized awnings, bioclimatic pergolas, sail shades and decks.**
- **Deep overhangs, brise-soleil, and external louvers**



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Research Gaps on the Role of Solar Shading

1. Long-Term Performance-based Design

Lack of Strong Regulations

The often-overlooked role of shading in building energy efficiency regulation relates mainly to:

- **Shading technologies can be associated with both geometry and the envelope, creating confusion about design responsibility and integration into standards.**
- **Building energy standards focus primarily on insulation, HVAC systems, and other aspects of the building envelope.**

NPO, HUMAN 2024, Wat houdt ons tegen? Seizoen 3, Cooler zonder airco, 17 July 2024

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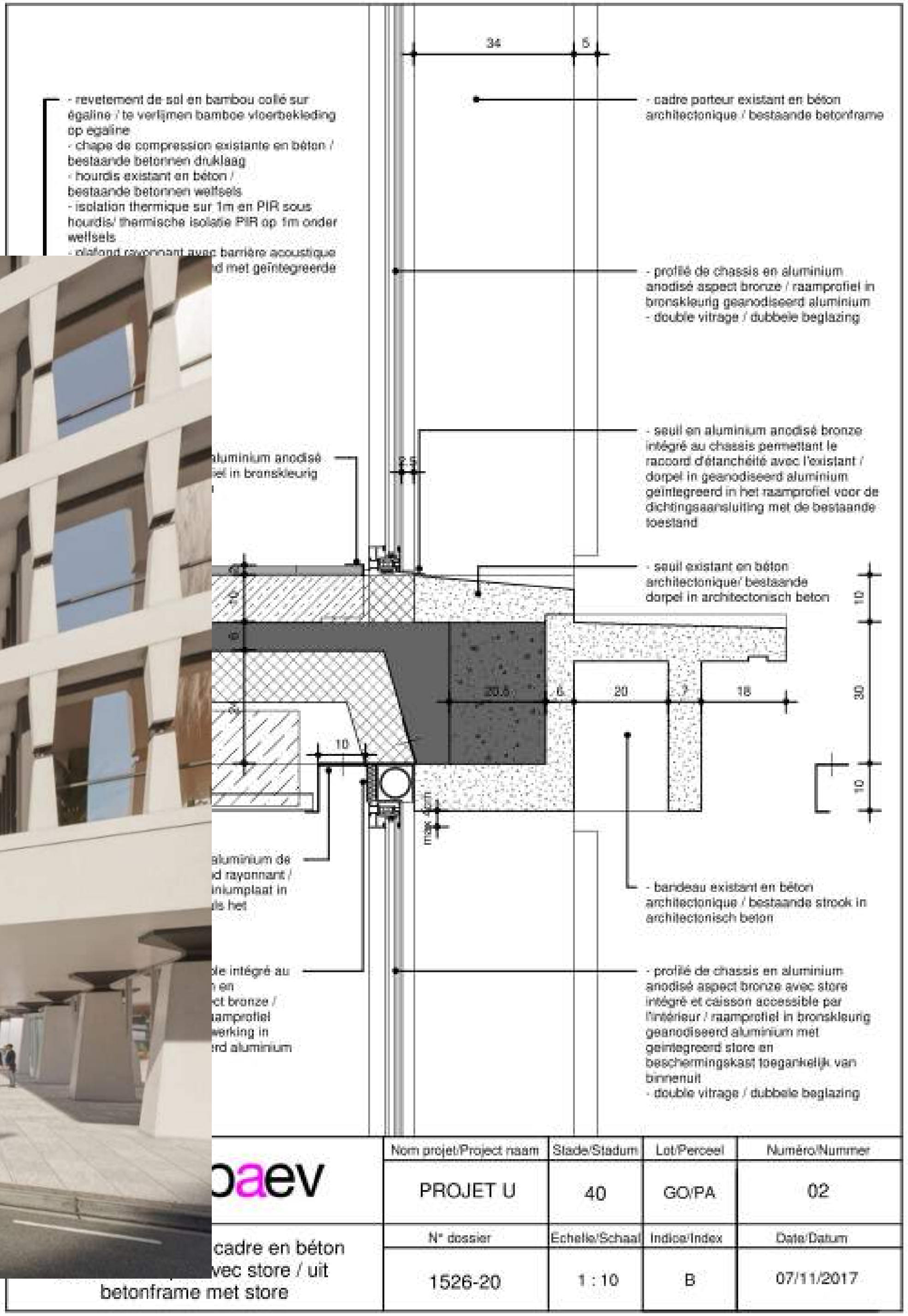
Performance Liability

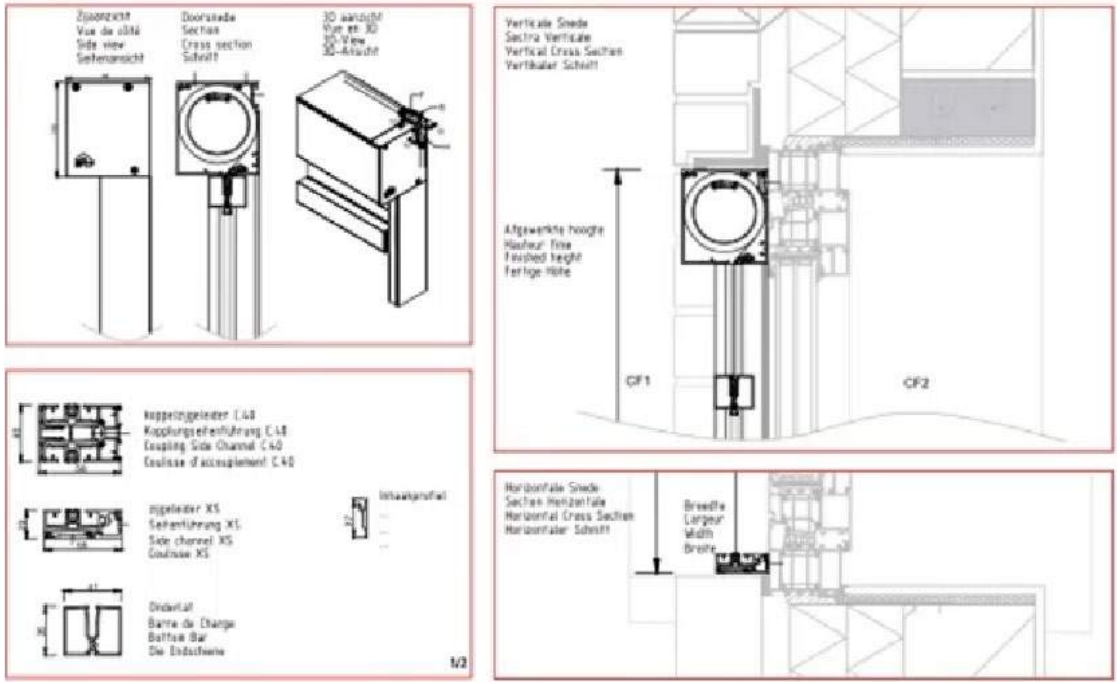
Centre administratif Uccle

Centre administratif Uccle , MK Engineering 2023



2. Durability & Sustainability

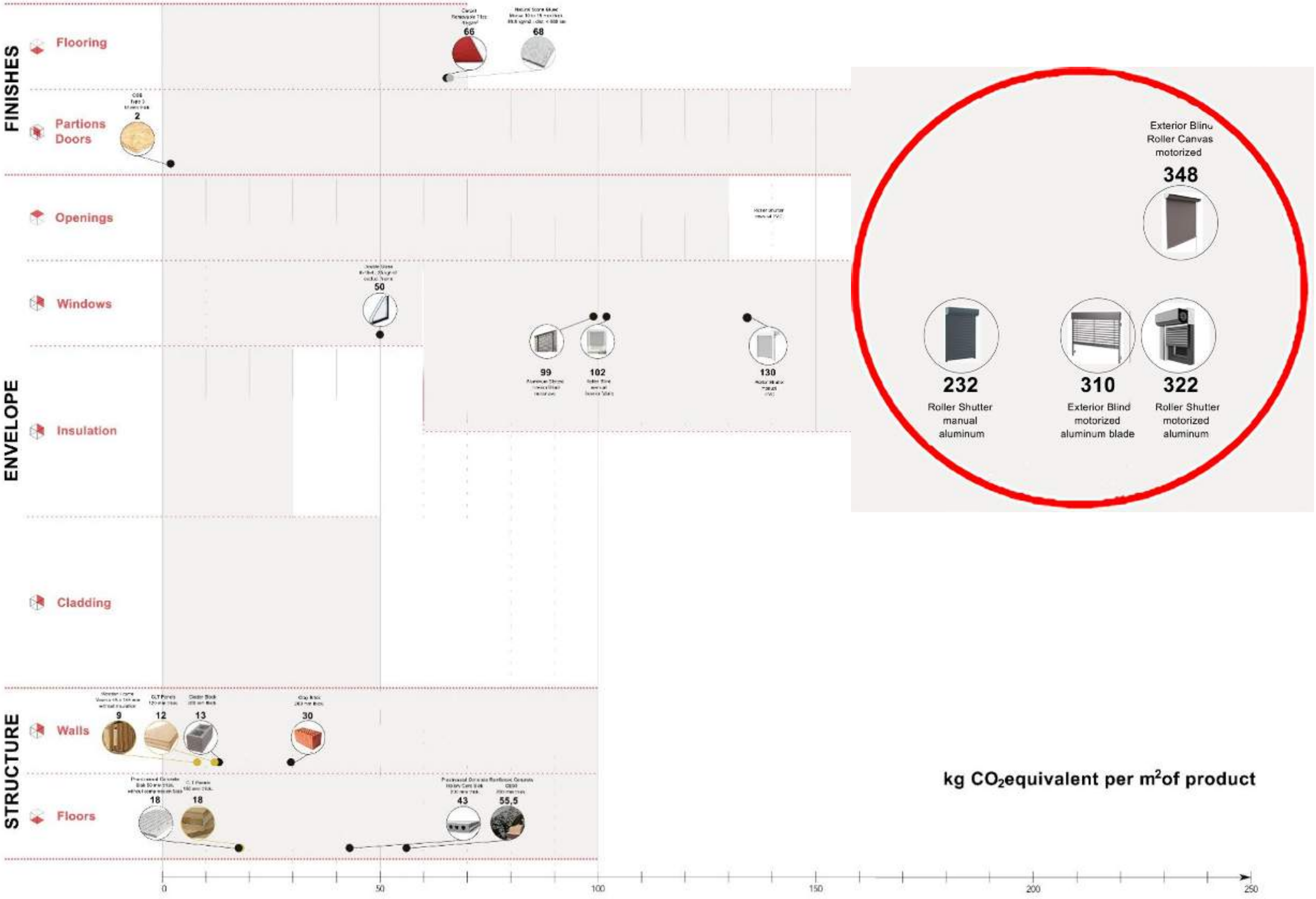
More research is needed on the long-term performance of shading devices under varying climate conditions and how factors such as weather, degradation, and maintenance affect their thermal efficiency. Studies on the resilience of shading systems under extreme weather conditions (e.g., storms, high winds (e.g., 130 km/h), and UV degradation (blocking 95-100% of radiation) (fiberglass, polyester, and PVC-coated polyester,) are crucial for understanding their long-term reliability and cost-effectiveness.



Matisse 16 - Projet immobilier mixte à Evere, BESIX

2. Durability & Sustainability

- Taking a Broader View of Carbon
- Whole life carbon Assessment
- Environmental Product Declarations



Matisse 16 - Projet immobilier mixte à Evere, BESIX

https://www.kpf.com/story/the-climate-ready-city-how-sustainability-is-shaping-architecture-in-2024

3. Integration with Smart Systems

Dynamic solar shading systems are under-researched in terms of their integration with smart building technologies. More work is needed to explore how these systems can interact with building automation and IoT-based controls to optimize performance based on real-time environmental data. The development of cost-effective, fully automated shading systems, which adjust based on both occupant behavior and external weather conditions, represents an emerging area of interest.

Nieuw Brugge Kavel 3B - BINST ARCHITECTS, Stefan Schoonderbeek

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4. Integration with Other Passive Cooling Strategies

Few studies investigate how solar shading can be combined with other passive design strategies, such as natural ventilation, cool roofs, or green walls, for a holistic approach to thermal resilience. Research is needed to explore synergies between these strategies to maximize thermal comfort while minimizing energy use.

Renson Fixvent Mono AK

AIRRIA, https://www.airria.be/

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Conclusions

Research Needed to Bridge the Gaps:

1. **Field Studies and Post-Occupancy Evaluations**: More field-based studies are required to validate simulation models with real-world performance data.

2. **Innovations in Dynamic Shading**: Research on cost-effective and energy-efficient automated shading systems integrated with smart technologies is necessary.

3. **Policy and Market Research**: Investigating the social and economic factors hindering the adoption of solar shading and developing policy measures and incentives to encourage broader implementation.

4. **Climate-Specific Design Guidelines**: Developing shading solutions tailored for different climate zones, focusing on year-round performance for both cooling and heating needs.

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