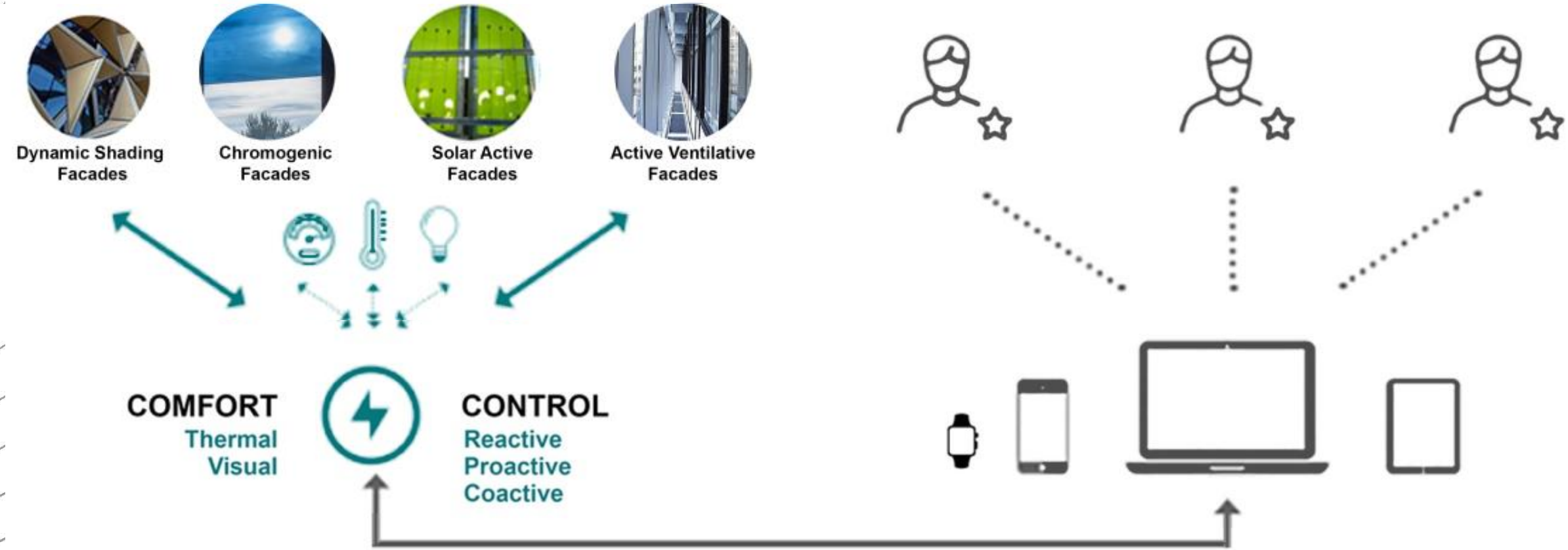
User control of adaptive facades:

Observations from case studies on users' interaction



Prof. Dr. Shady Attia
Sustainable Building Design Lab, UEE,
Applied Sciences, University of Liège, Belgium
shady.attia@uliege.be

/in/shady-attia-14352a7
/www.sbd.ulg.ac.be/

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Acknowledgment

COST Action TU14030

ISO/AWI 52016-3

ISO/TC 163/SC2/WG 15

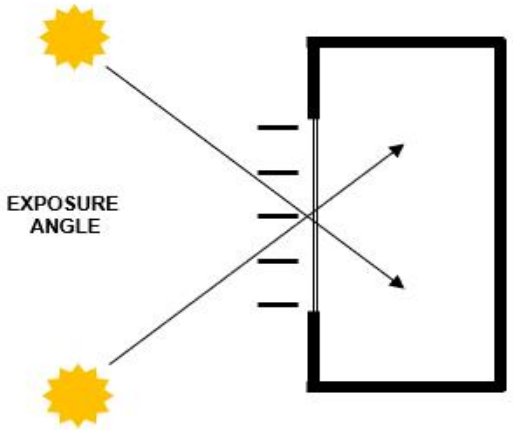
IEA Annex 80

Resilient Cooling (2019-2023) Advanced Solar Control

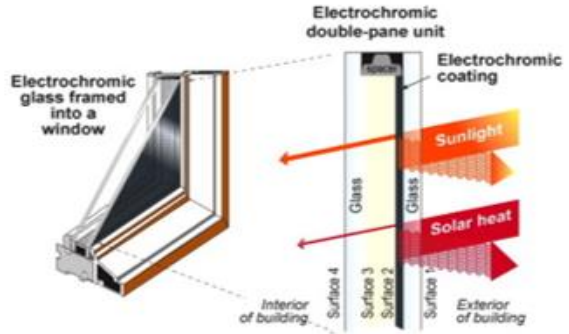
Architectural Facades and Products research group

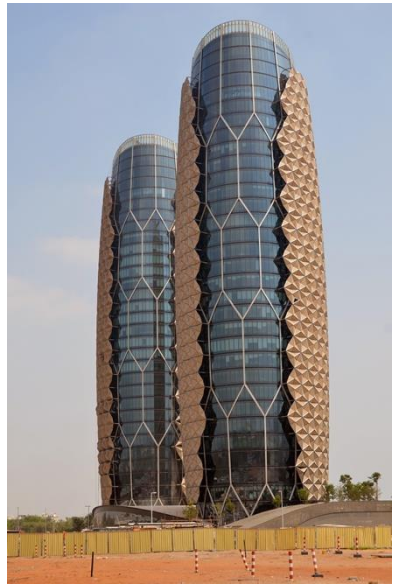
To what extent are occupants satisfied with blind/glazing control strategies ?

OPTION 1 – DYNAMIC SHADING DEVICE



OPTION 3 – ELECTROCHROMIC GLAZING





Attia, S. (2018). Evaluation of adaptive facades: The case study of Al Bahr Towers in the UAE.
Bilir, S., & Attia, S. (2018). Performance Evaluation of Adaptive Façades: A case study with electrochromic glazing

Adaptive Facades

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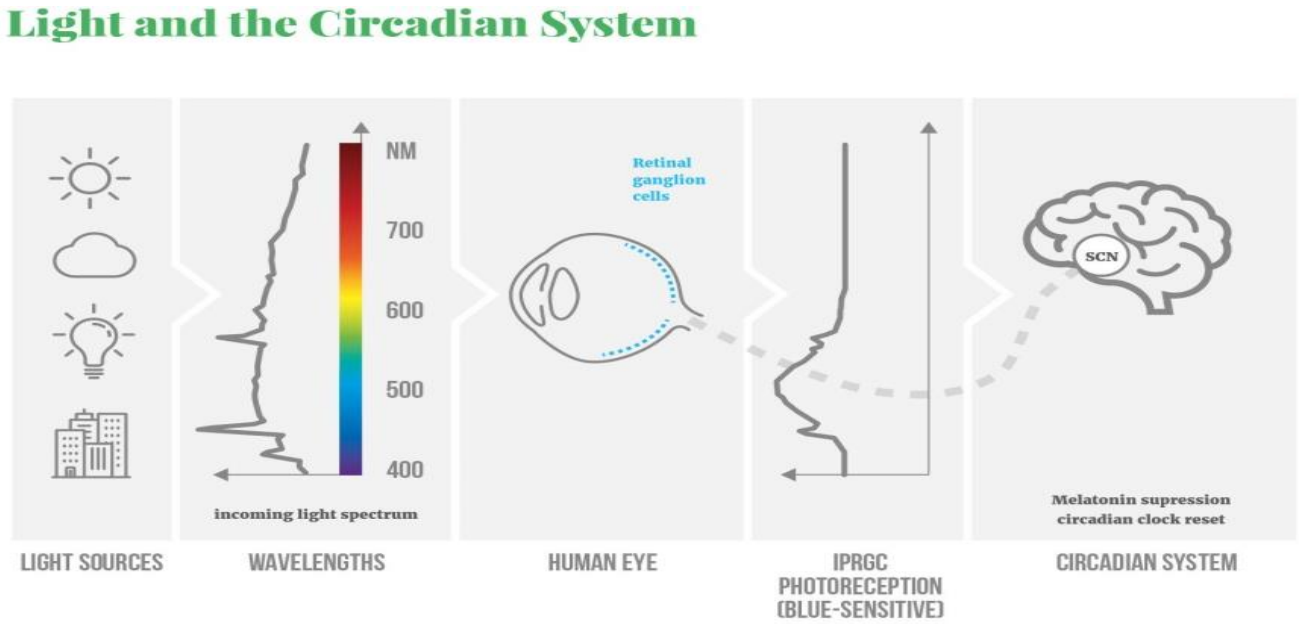
Smartness: The Great Disruptor

Cyclical Trends: **Well-being** (light: circadian rhythm), **User Interaction, Augmented Reality, IoT**: smart workspace



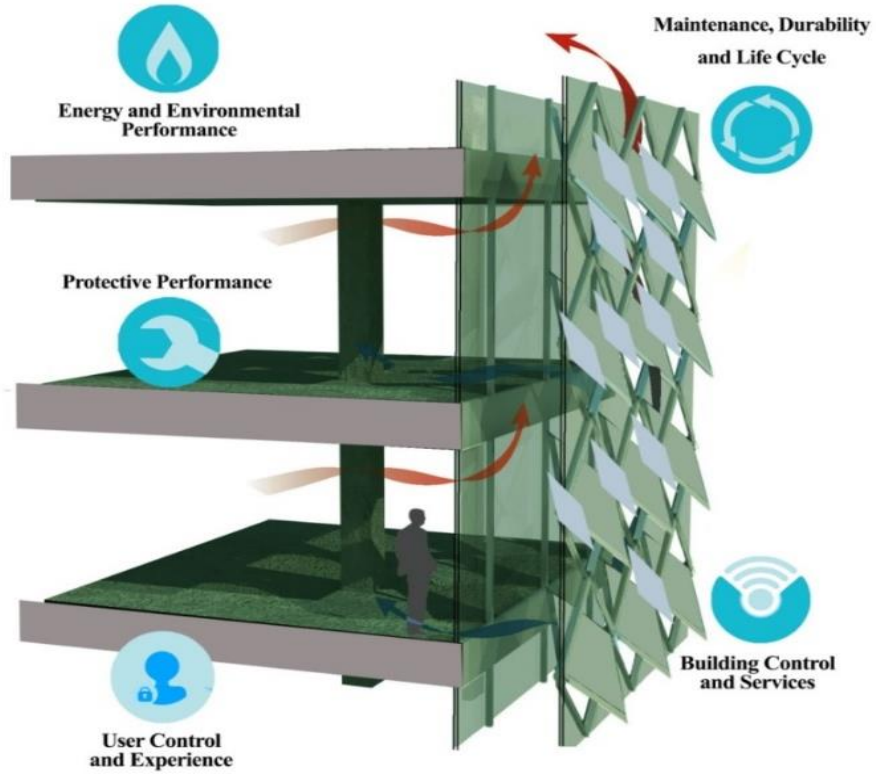
- ❑ Personalized dynamic building envelopes
- ❑ Advanced Sensor Technology (Measure more accurate occupant satisfaction)

Structural Trends: Personalization & Artificial Intelligence

personalized conditioning systems, envelope control, comfort models and connected homes

Future trends and main concepts of adaptive facade systems

Regulation Landscape, State of Technology Advancement, Future Market Technology



adaptive façades families

Dynamic Shading Facades

Chromogenic Facades

Solar Active Facades

Active Ventilative Facades

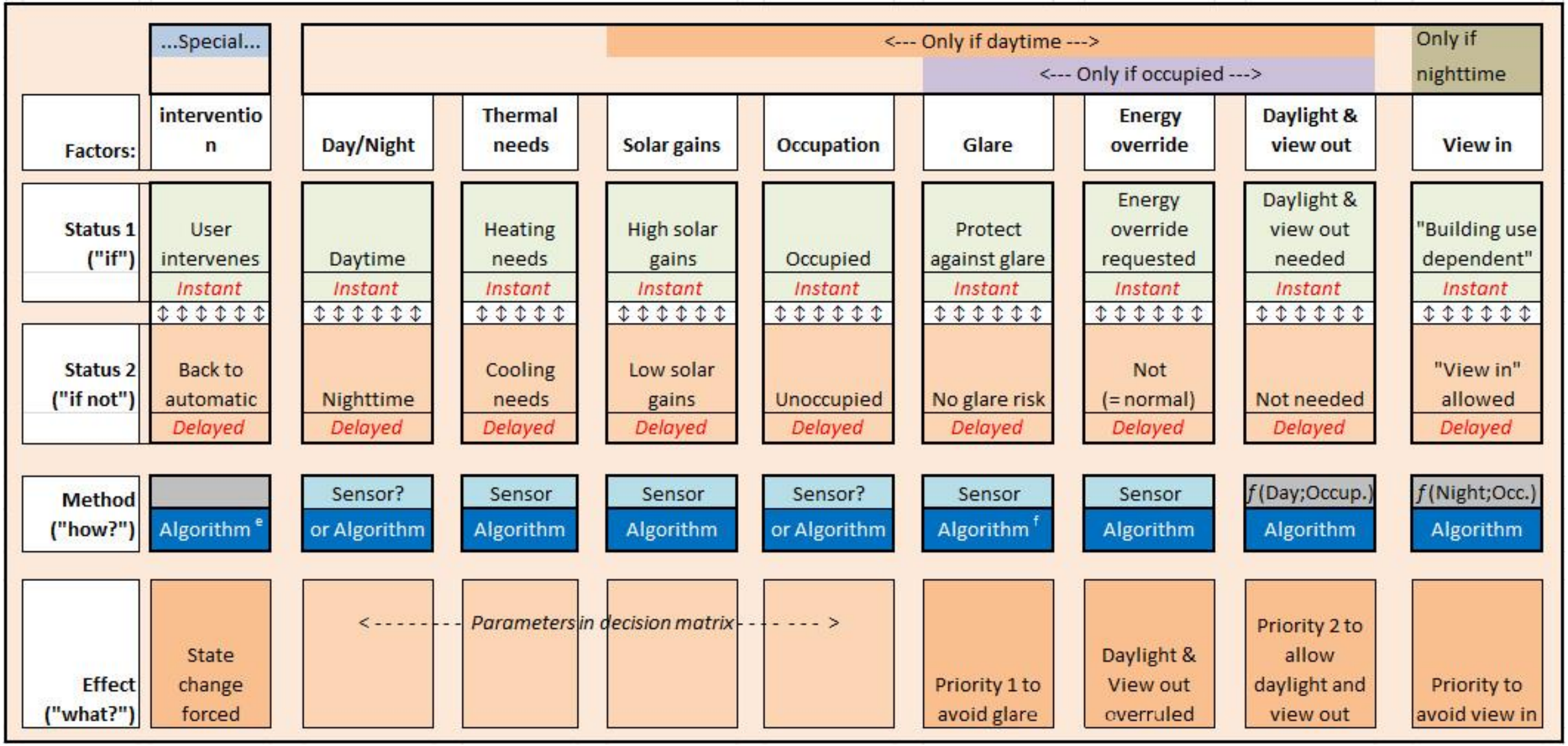
AF technologies, categories & characteristics

TABLE 1 Adaptive facade technologies, categories, and characteristics

	Application/purpose	Control	Building type	Technology/materials
Dynamic shadings				
Shutter or equivalent	Obstruction of sunlight, thermal insulation, security, summer comfort, cooling savings, security, heat retention	Manual, motorized or automated (with different levels of automation)	Residential and nonresidential (schools, hospital, offices, public buildings)	Often large wood or PVC, aluminum, integrated blinds in the ceiled glazing
Roller blinds or equivalent	Obstruction of sunlight, thermal insulation, summer comfort, privacy, glare protection, cooling savings			Cellular shades and fabrics (different types and properties)
Venetian blinds or equivalent	See above			Tilting slats and glare control, aluminum and ceiled glazing
CCF: natural ventilated	Sunlight adjustment, daylight control, summer comfort, glare protection, privacy, cooling savings	Electric (motorized) or magnetic	Office buildings	Venetian blinds: aluminum Electrostatic: thin film
Chromogenic glazing				
Electrochromic glazing	Solar gain and daylight control, reduce cooling needs, summer comfort, glare reduction	On demand (active), automated (different levels of automation)	Residential and nonresidential (schools, hospital, offices, public buildings)	Suspended particles, organic and nonorganic coating, colloidal nanocrystal
Liquid crystal glazing	Create privacy spaces, projection screen, and control (solar heat, visible light)			
Thermochromic glazing	Solar gain and daylight control, reduce cooling needs, summer comfort, glare reduction	Environmentally activated (passive)		Thin film or interlayer which changes its crystal structure
Solar active facades				
Double skin facade	Solar gain and daylight control, reduce cooling needs, summer and winter comfort, glare reduction	Active control, environmentally activated, automated	Residential and nonresidential buildings	Two skins with a ventilated cavity (natural or mechanical)
Green facade and roof	See above	Environmentally activated (passive)		Different foliage layers and functional substrates for plant growing
Phase change materials	Solar gain control, reduce cooling needs, winter and summer comfort, heat and solar energy store	Environmentally activated (passive)		Salt or paraffin materials, micro or macro encapsulated into building components
AVF				
CCF: active ventilated	See above	On demand (active), automated (different levels of automation)	Office buildings	

Façade Functions & Control Strategies

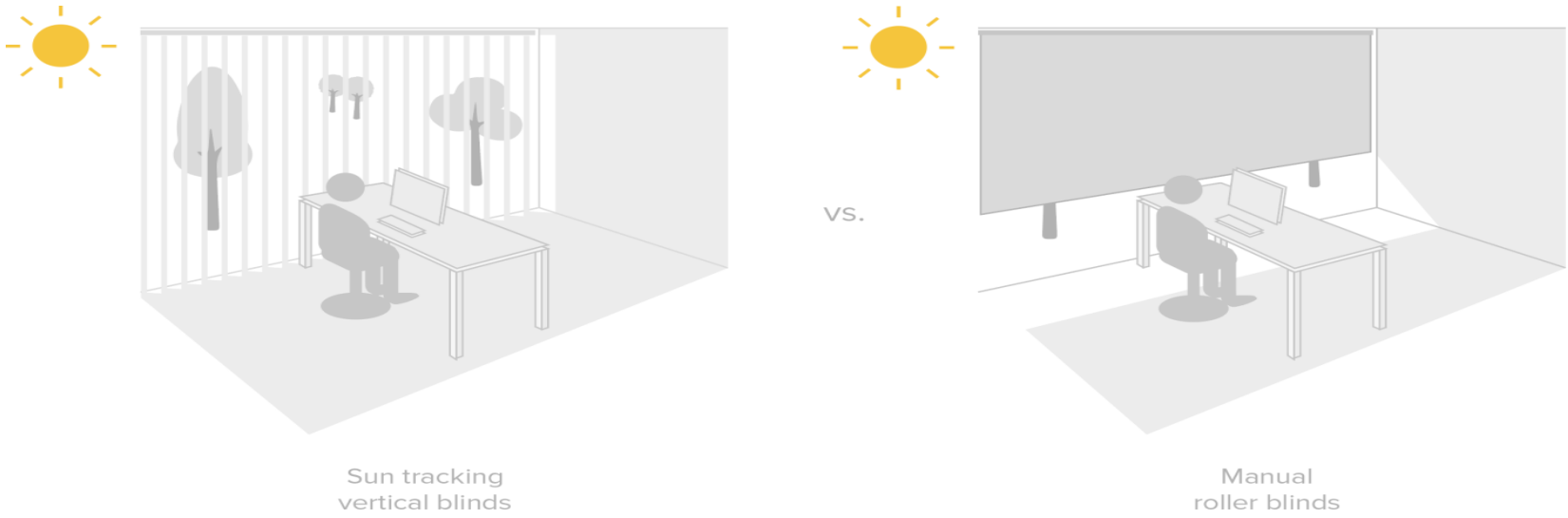
ISO 52016-3 – Control Factors (draft)



Façade Functions & User Experience

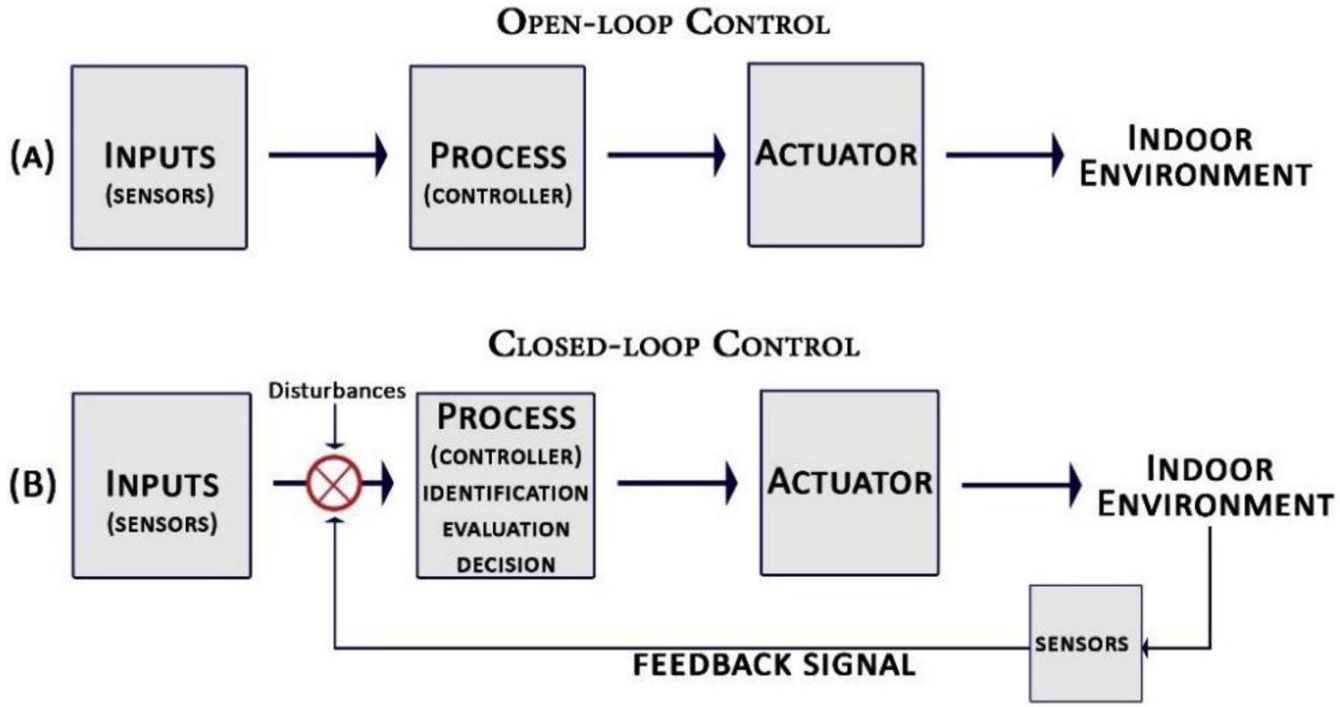
Adaptive facades may include functionalities like:

- **External shading for solar energy control**
- **Internal shading for daylighting and glare control**
- Demand controlled ventilation
- Window opening for ventilation and cooling

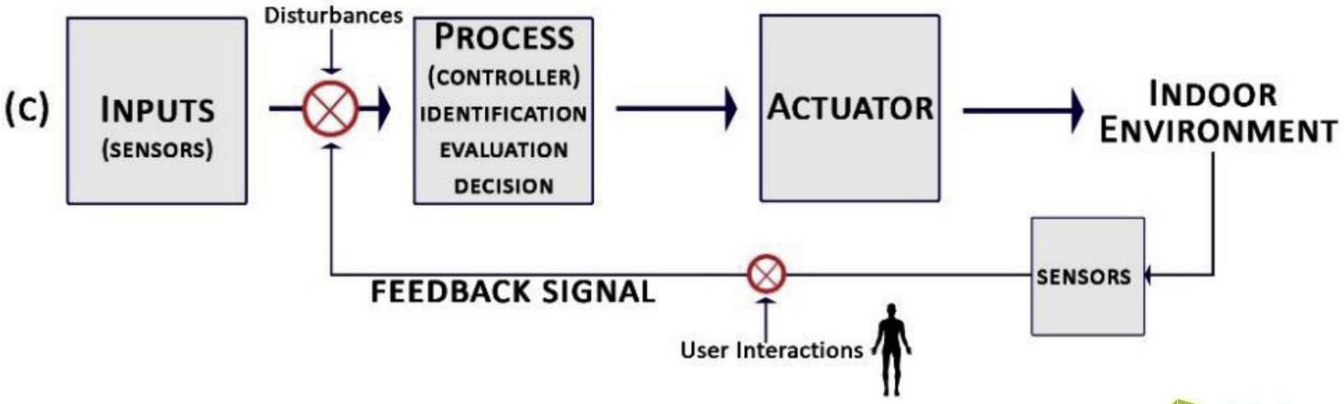


Control strategies

1. **Automated control** (programmed)
   a. User Profiles and Occupancy Modes
   b. Sensor based
      i. Predictive Model Control
      ii. Artificial Intelligence models



2. **Automated + Manual** (human user action)
   a. Manual controller
   b. Graphical User Interface (GUI)
   c. Voiceover technology



Key Elements of Control Strategies

1. **Automated control** (programmed)
   a. User Profiles and Occupancy Modes
   b. Sensor based
      i. Predictive Model Control
      ii. Artificial Intelligence models

   i. If unoccupied: Energy saving mode
   ii. If occupied after sunrise: comfort mode
      -Glare safe mode
      -Thermal comfort mode
      -Daylight mode
      -View mode
      -Energy saving mode
   iii. If occupied after sunset: depend on building function
   iv. Safety
   v. Privacy
   vi. Energy Saving

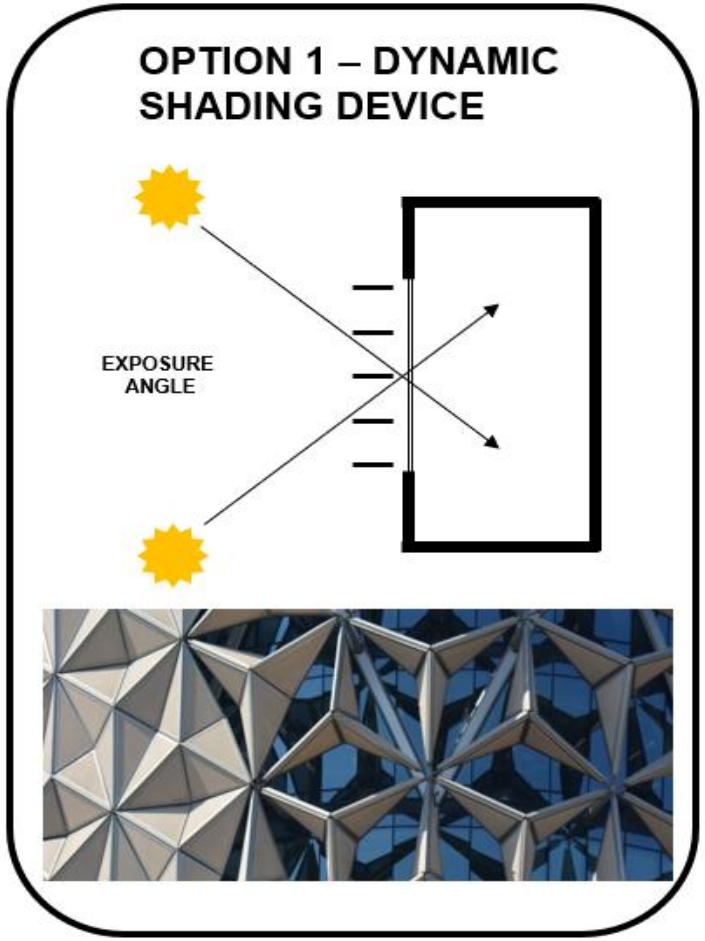
2. **Automated + Manual control** (human user action)
   a. Manual controller
   b. GUI / Dashboard
   c. Voiceover technology

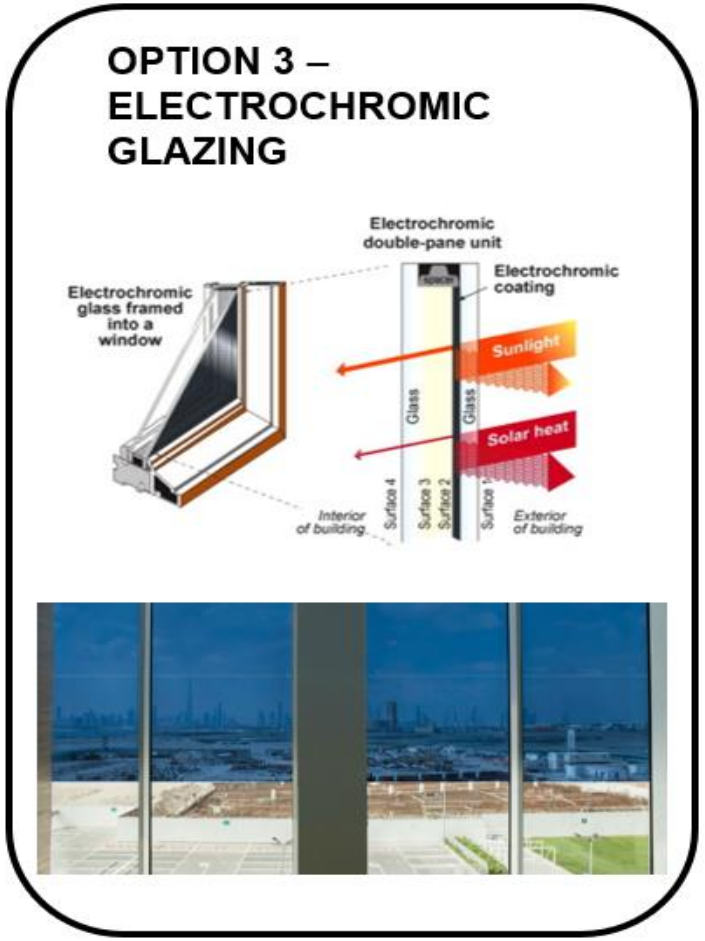
   i. Hysteresis and/or delay in reponse
   ii. Only during assumed actual occupany
   iii. Manual or motorized operation

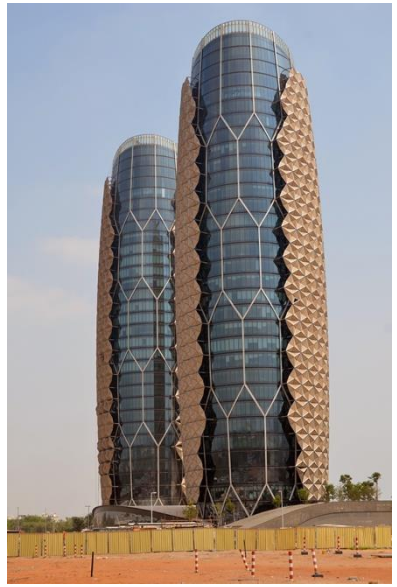
User Interaction & experience

To what extent are occupants satisfied with blind/glazing control strategies ?

Smart Shading vs. Chromogenic Glazing: Façade Strategy for West Side







Al Bahr Towers, Abu Dhabi

Photo Courtsey: Terry Boake
Architect: Aedas UK

Swiss School in Dubai

Photo Courtsey: Reynaers
Architect: U+A Architecture

Attia, S. (2018). Evaluation of adaptive facades: The case study of Al Bahr Towers in the UAE.
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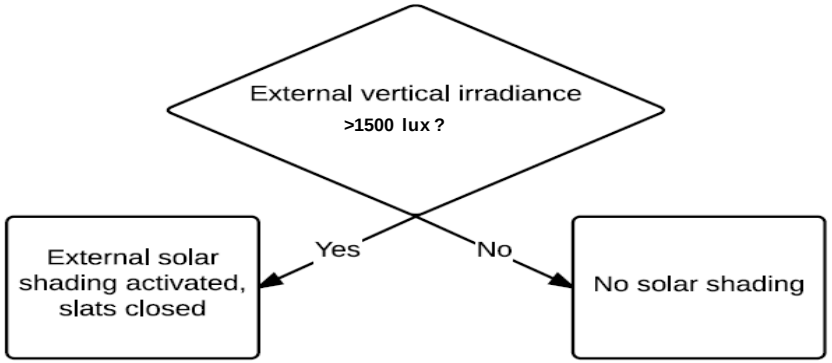
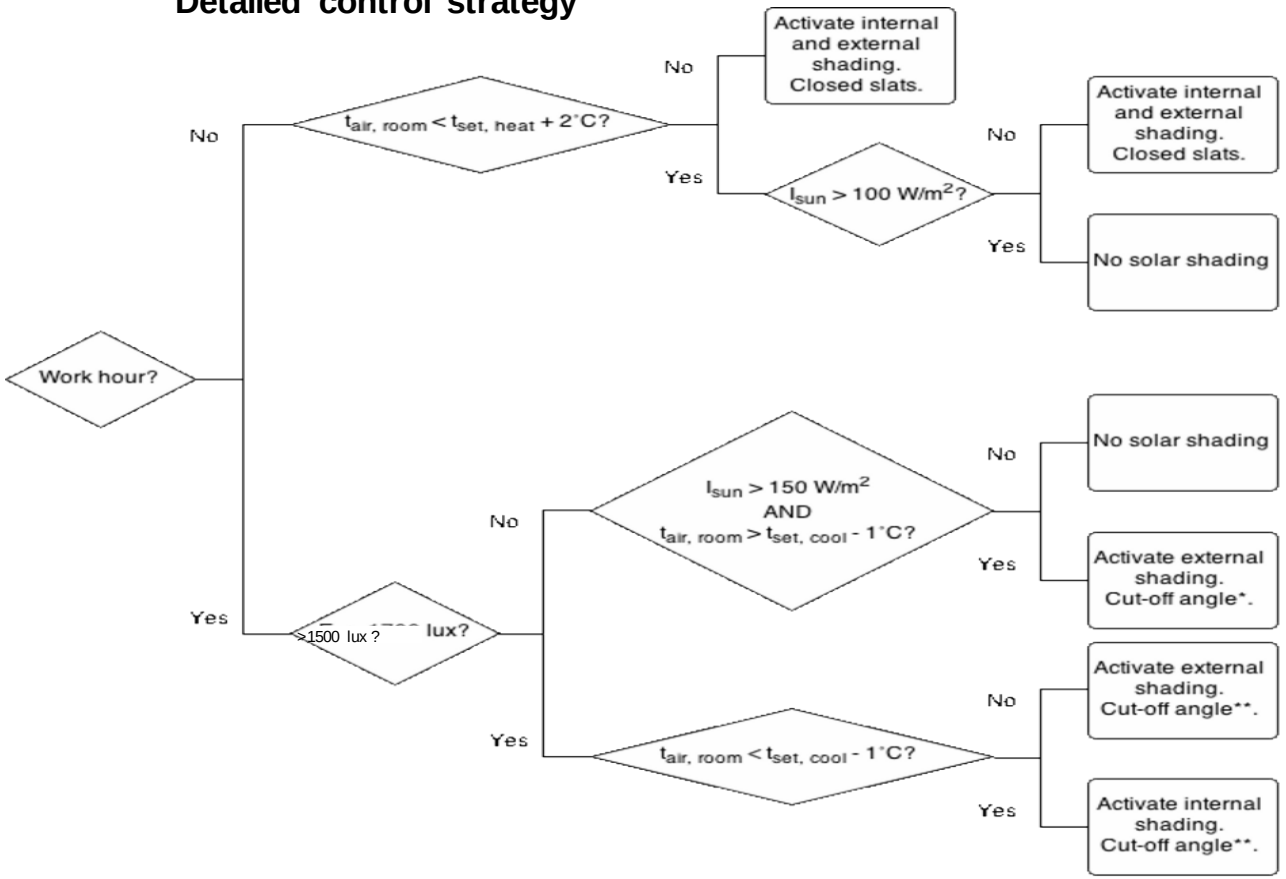
Control strategies

Simple control strategy



Detailed control strategy

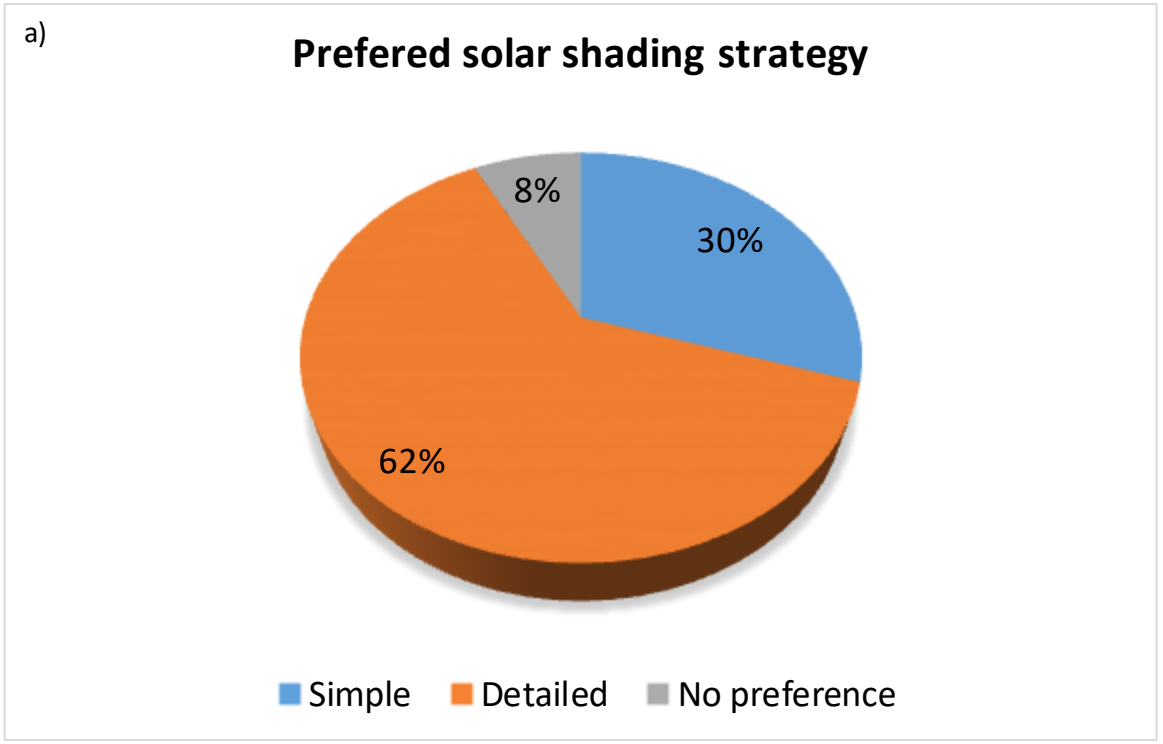


Optimized control strategy with respect to visual and thermal comfort and energy use.

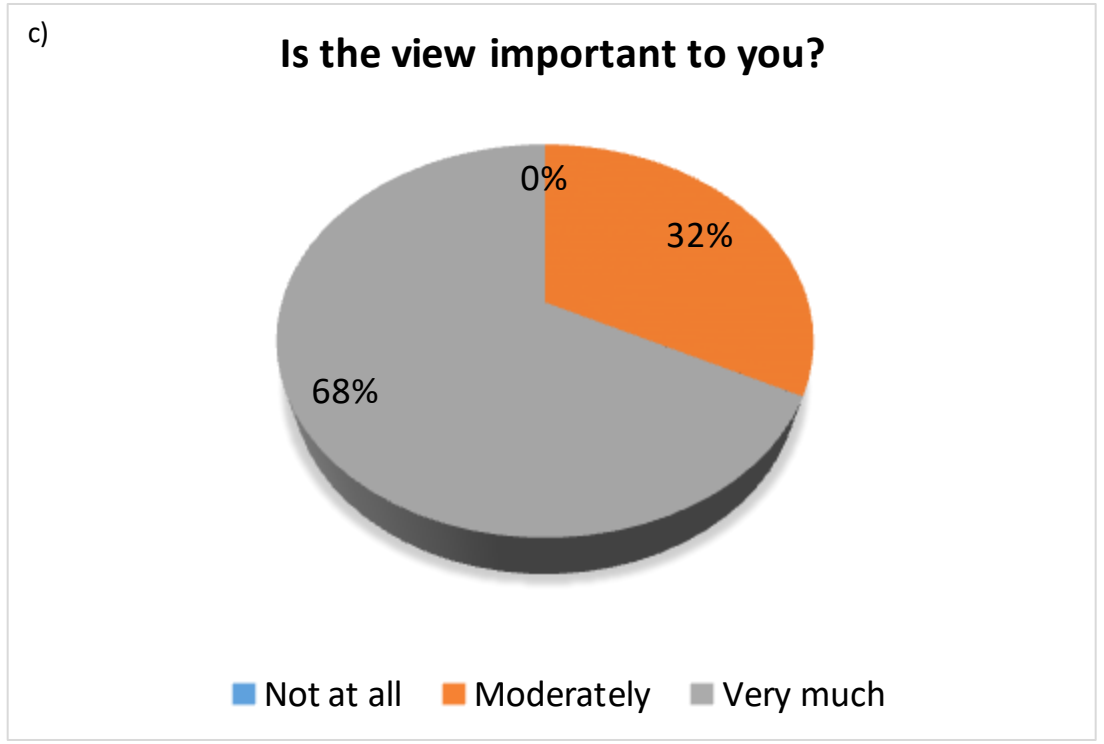
- ** Cut-off angle, with minimum tilt angle of 15˚.*
- *** Cut-off angle, with minimum tilt angle of 15˚ and stepwise increase of 10˚ until E_V< 1500 lux.*

Occupant satisfaction with blind control strategies

a)



c)



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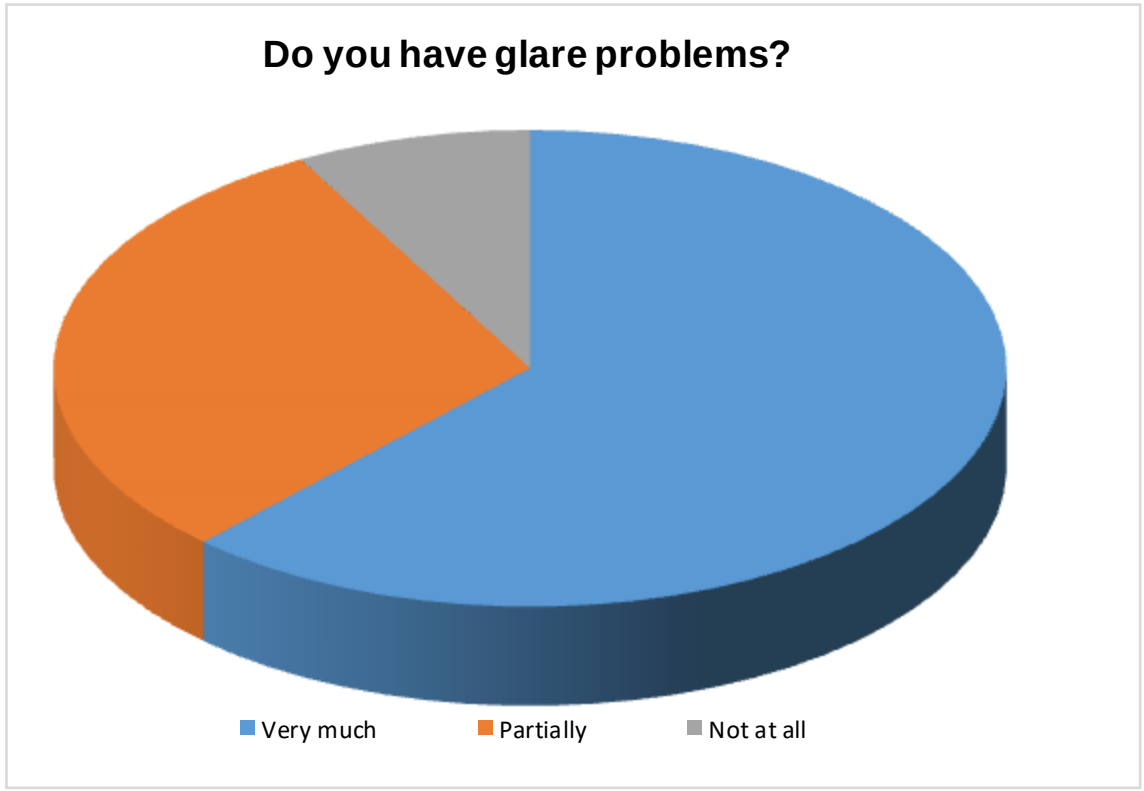
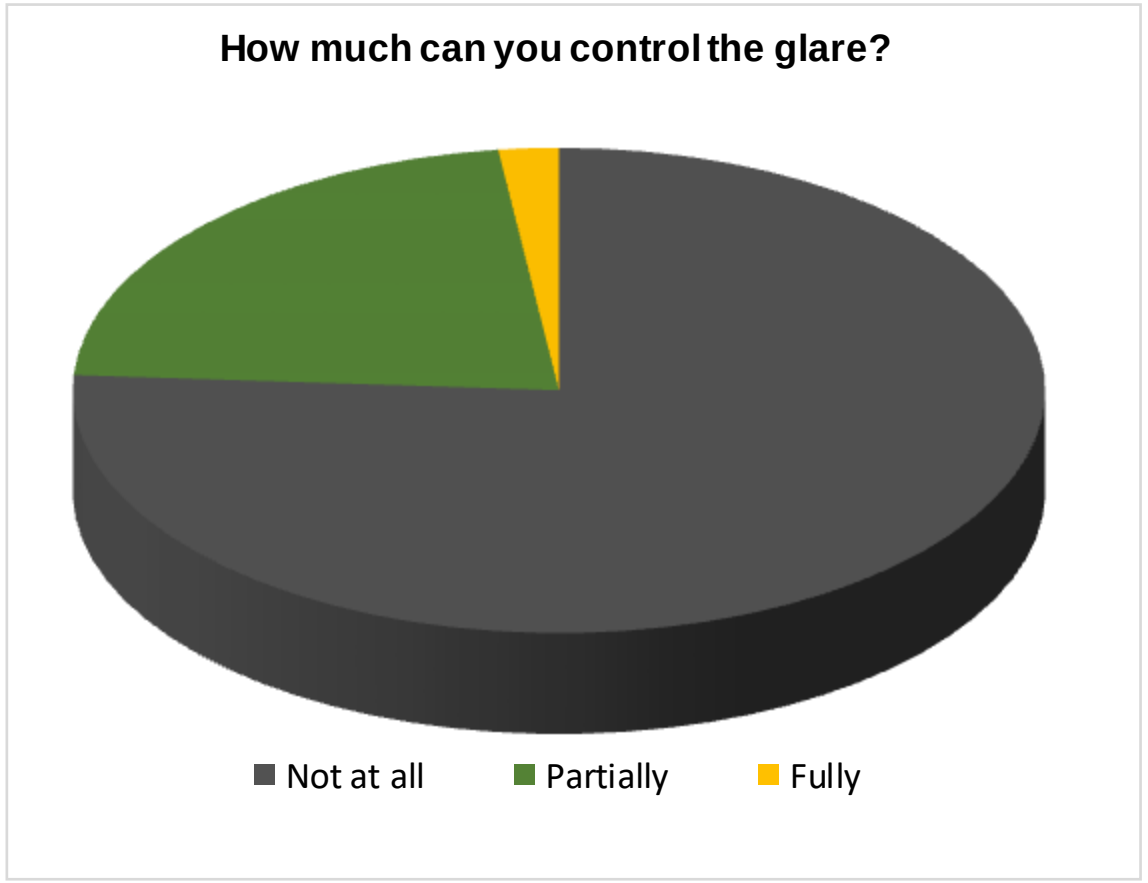
Occupant satisfaction with glazing control strategies





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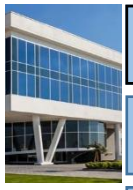
Average weighted percent of number of blind/glazing movement/switches in different study periods

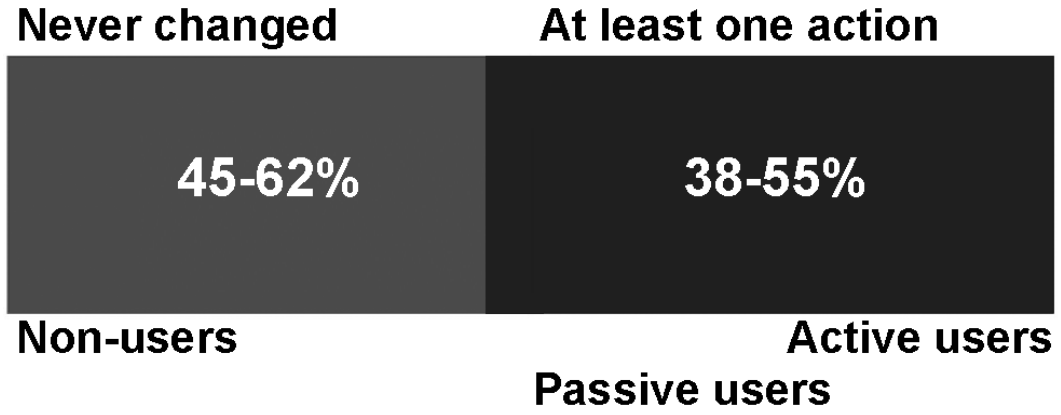
Average percent of blinds that moved once during the season	55%
Average percent of blinds that moved at least once per day	16%
Average percent of blinds that moved at least once per hour	9%



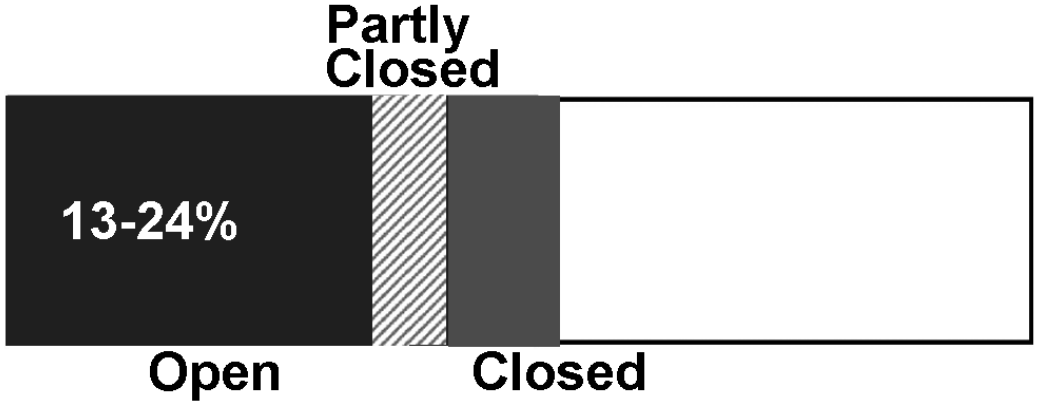
Average percent of glazing that switched once during the season	38%
Average percent of glazing that switched at least once per day	9%
Average percent of glazing that switched at least once per hour	4%

User and adaptation control ‘clusters’

- There is a slight positive correlation between clear sky conditions and closing/switching of blinds/glazing.
- A remarkable share of occupants tends to not interact with automatically controlled adaptive facades
- When users lower the blinds (occlusion) or switch the glazing, most of the time, they don’t raise them again until the end of the day.



Distribution of “non-users,” and “passive and active users” in the dataset.

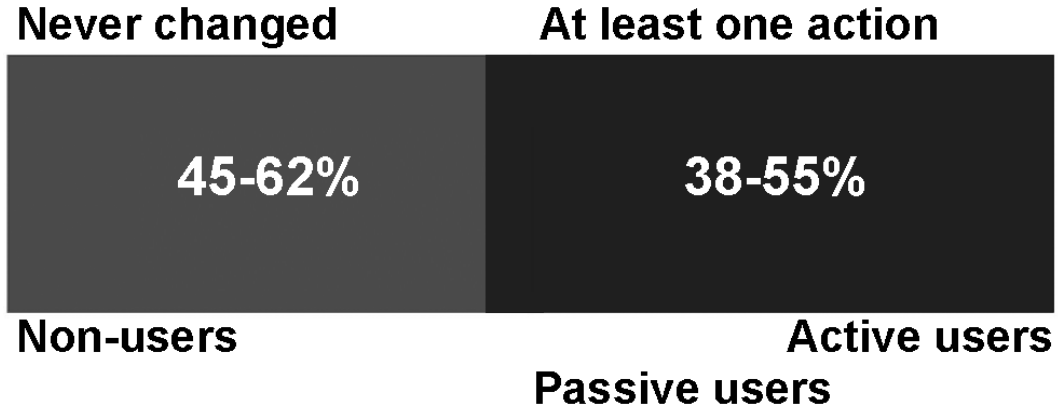


Distribution of observed occlusion/tint in “active users” category.

User and adaptation control ‘clusters’

- **Users override solar shading control to enjoy view or improve privacy (increase risk of overheating as well as larger heating energy use)**

- **According to our observations, shading blinds are more frequently closed/switched than EC glazing.**



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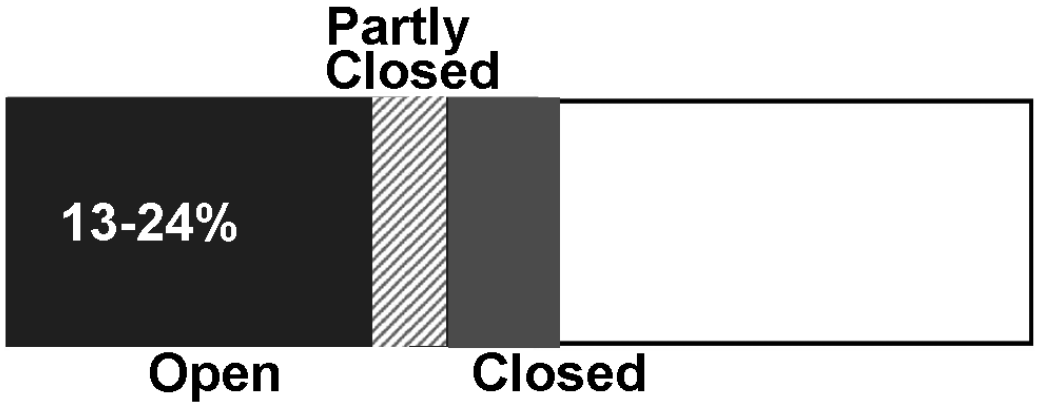

Distribution of observed occlusion/tin in “active users” category.

Conclusions

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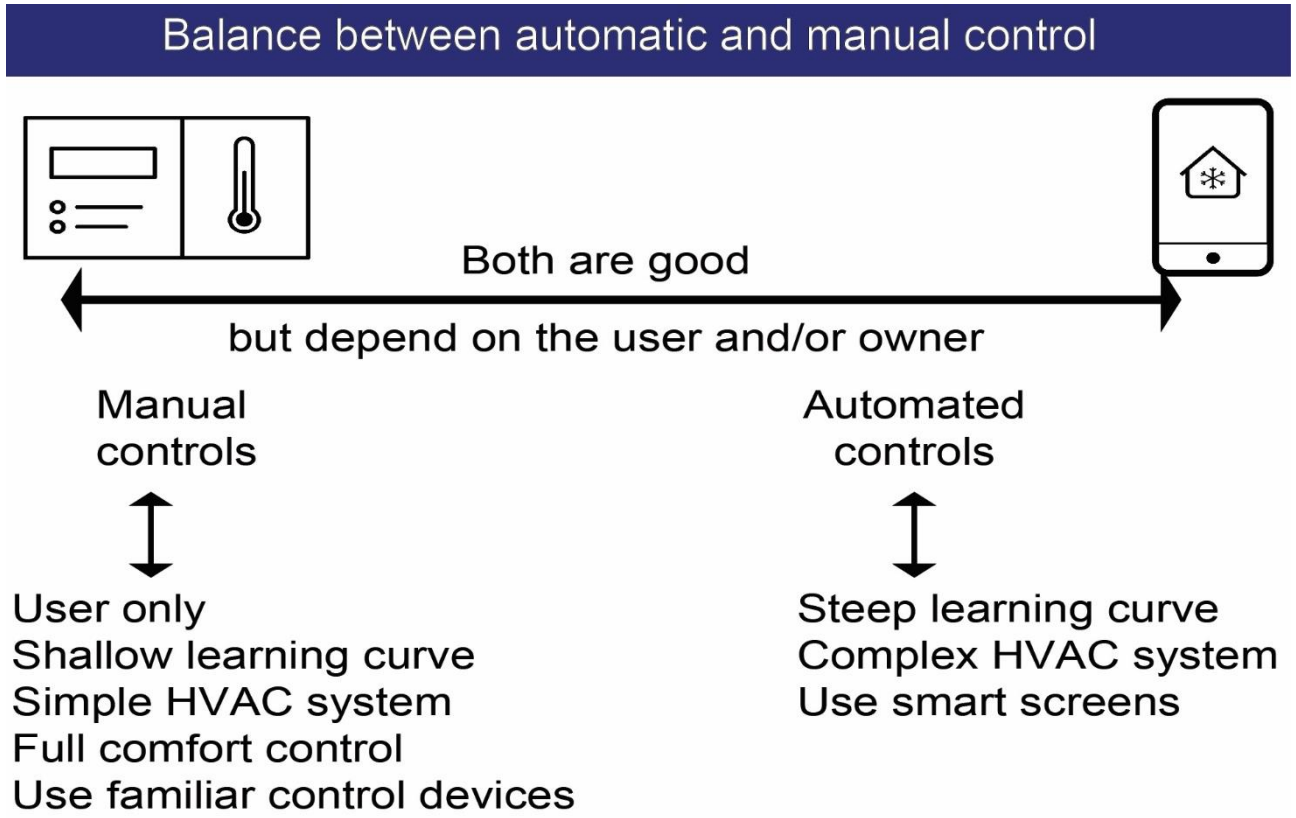
Conclusion and Recommendations

There is low interaction between occupants and adaptive facades

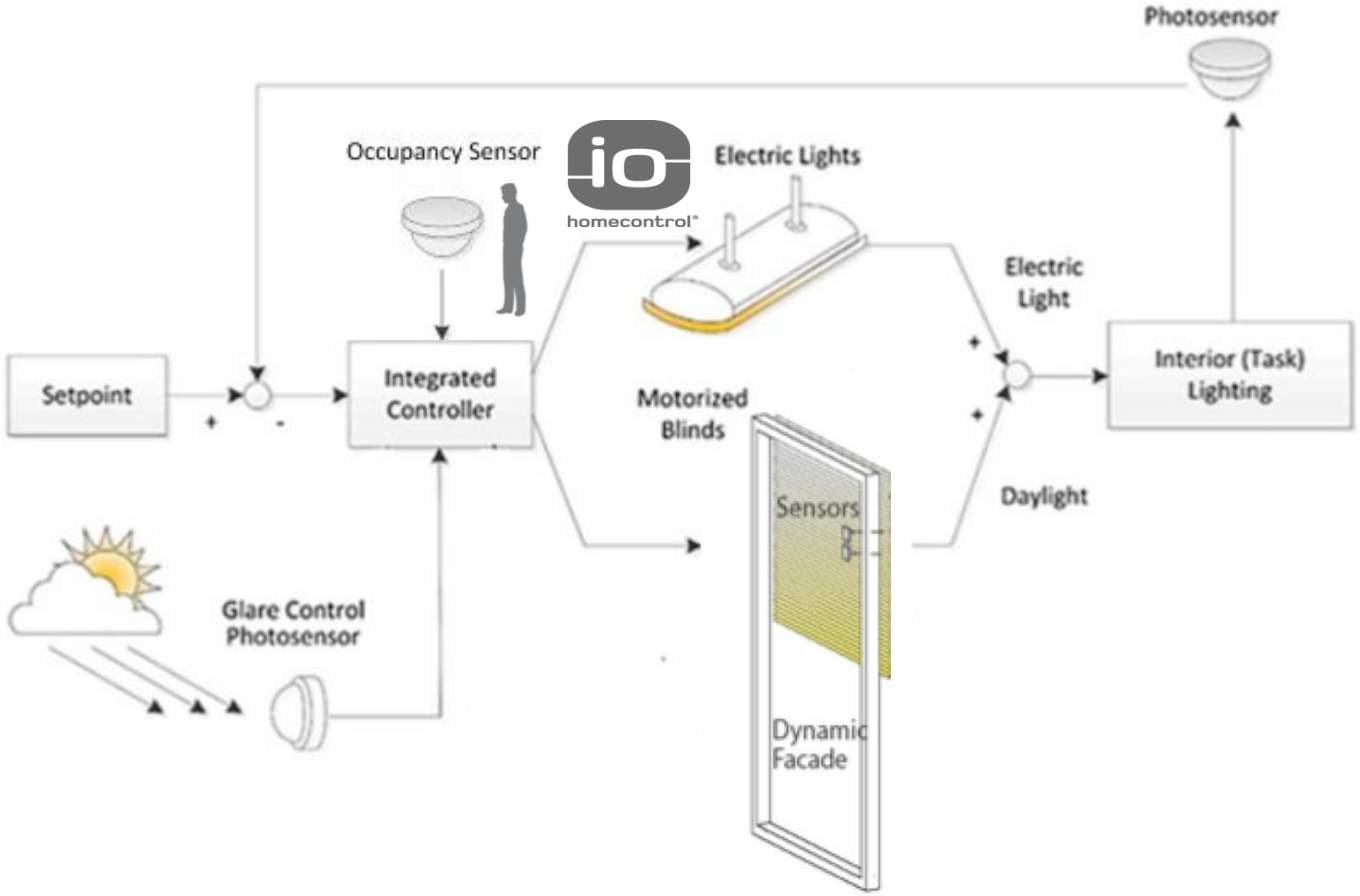
- **Make users feel in control by encouraging the possibilities to override and interact. Empower users** (displays, dashboard, personalization)
- **We must cluster users according to the usage intensity and preferences patterns. (active, passive users)** allow different degrees of **user interaction**
- **Self-learning automated control** and **advanced control algorithms** require more attention

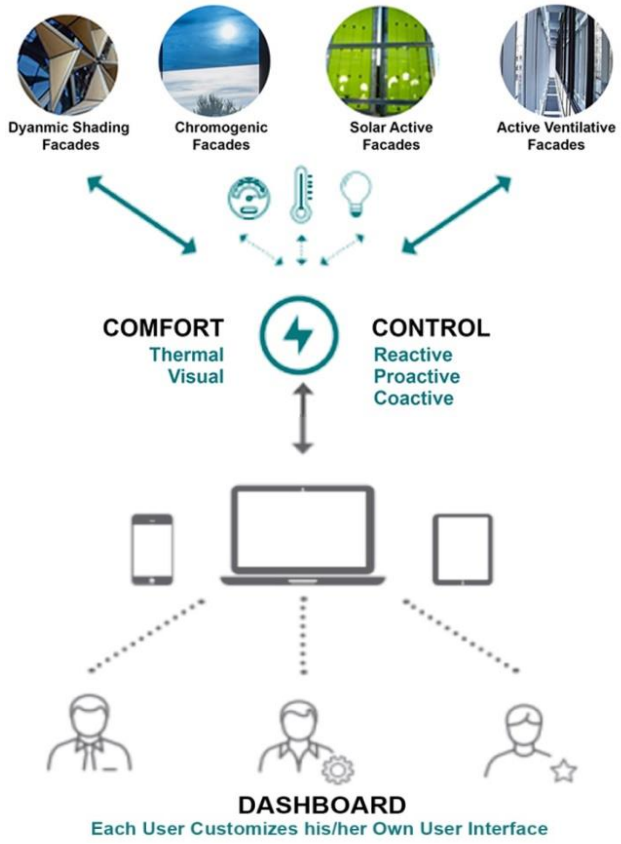


Attia, S. (2018) Net Zero Energy Buildings (NZEB) , Elsevier

Future Work: Adaptive Façade Control Framework

- Occupant-centered controller framework with reminders based on mobile devices with notifications and alerts.





The Adaptive Facades Control Framework modifying the work of Shen et al. (2014). Energy and visual comfort analysis of lighting and daylight control strategies

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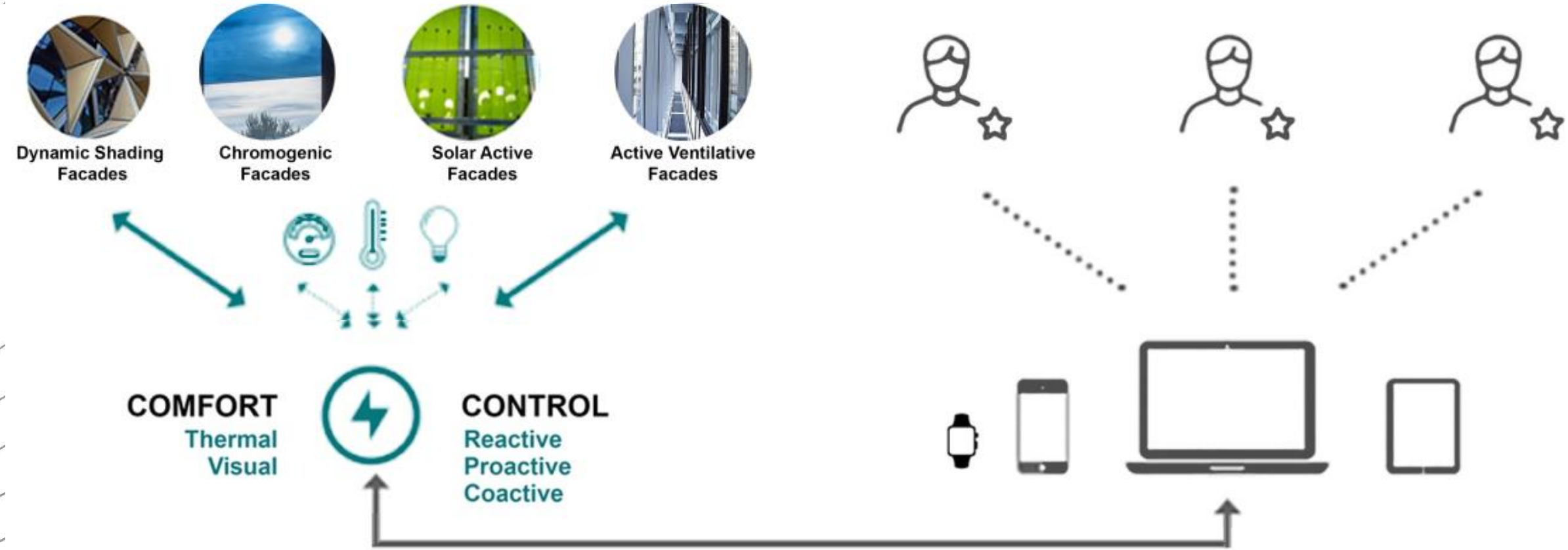

Prof. Dr. Shady Attia
Sustainable Building Design Lab, UEE,
Applied Sciences, University of Liège, Belgium
shady.attia@uliege.be

/in/shady-attia-14352a7
/www.sbd.ulg.ac.be/

30.03.2021

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