NEARLY ZERO ENERGY BUILDING CONSTRUCTIONS

ADAPTIVE SOLAR SHADING OF NEARLY ZERO ENERGY BUILDINGS

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Module 2, chapter 5

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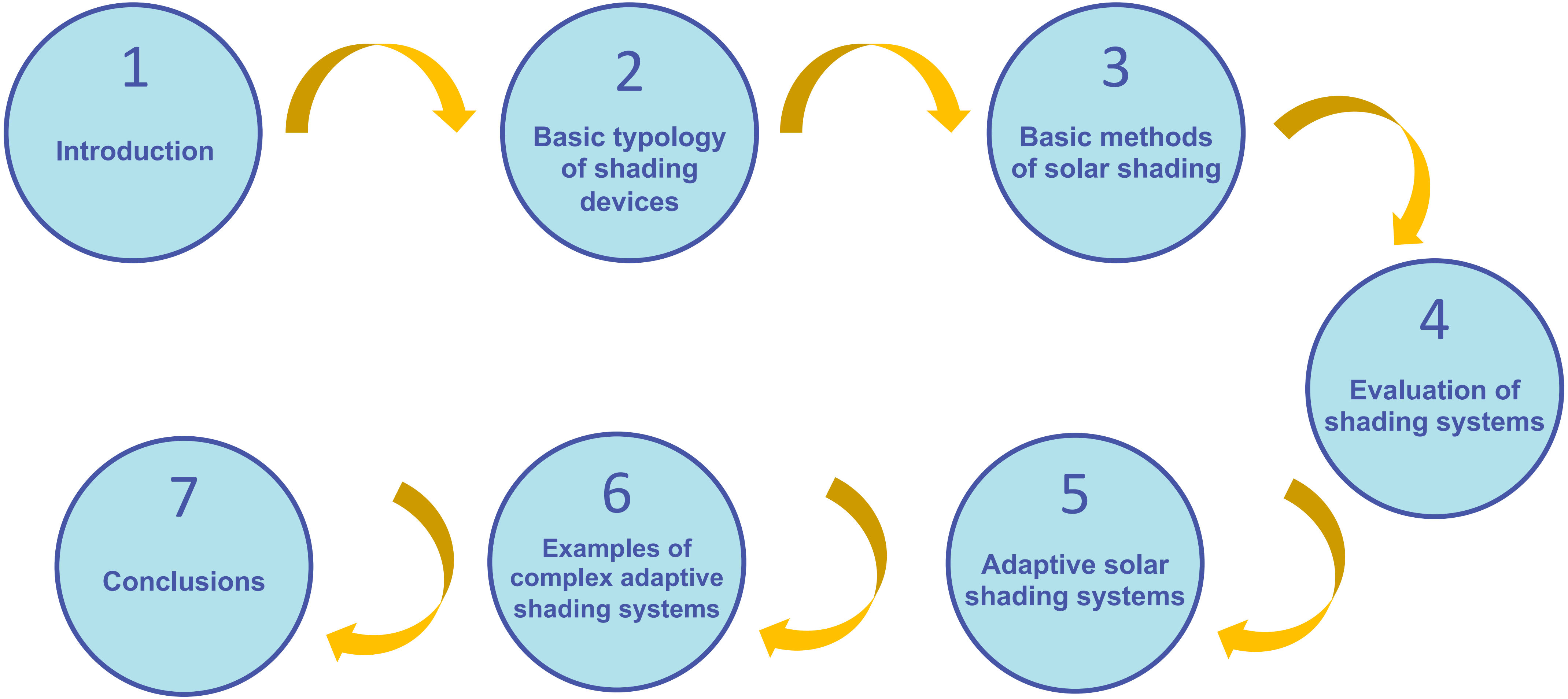
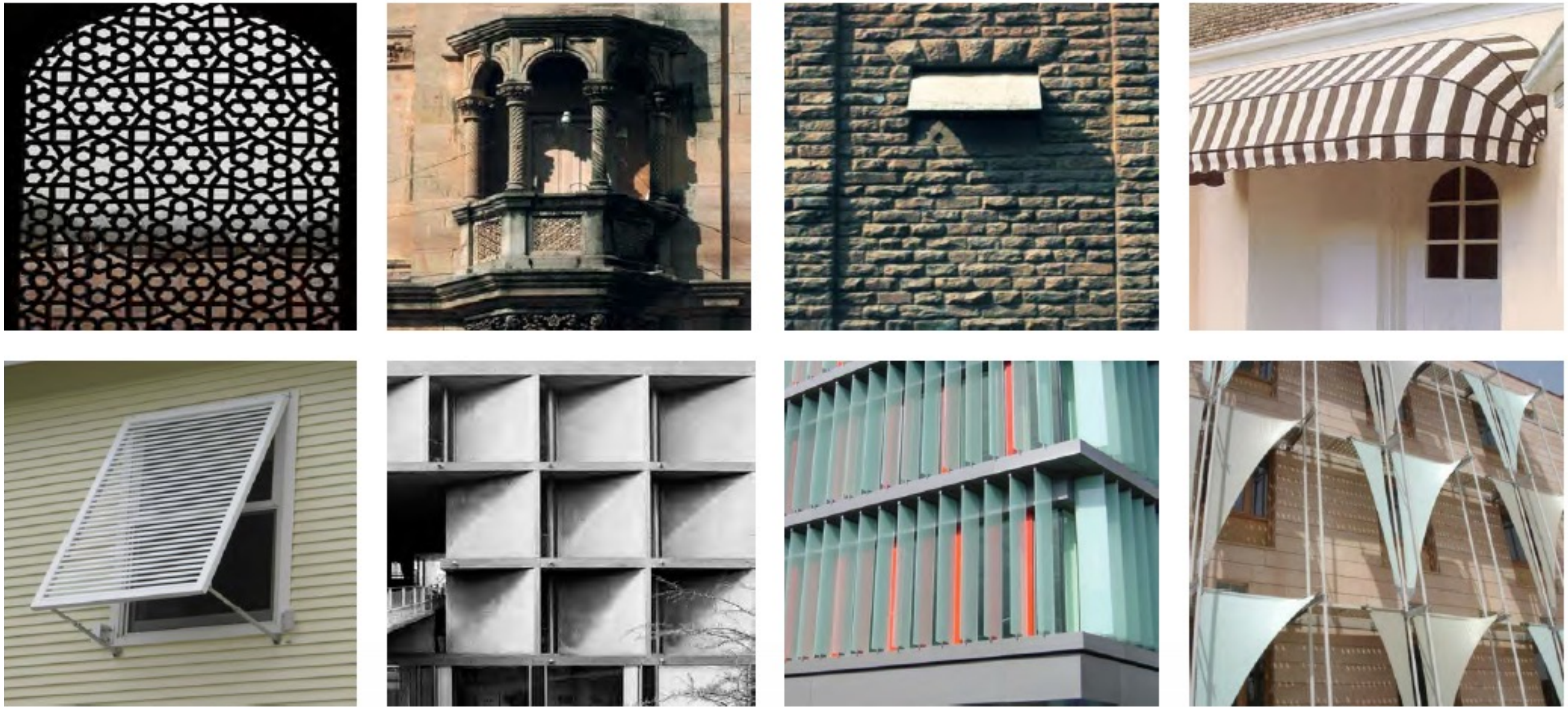
Structure and content of the presentation



INTRODUCTION

Building shading technology is vital in warm and sunny locations, concerning glare, a su protection is necessary in almost all climate conditions



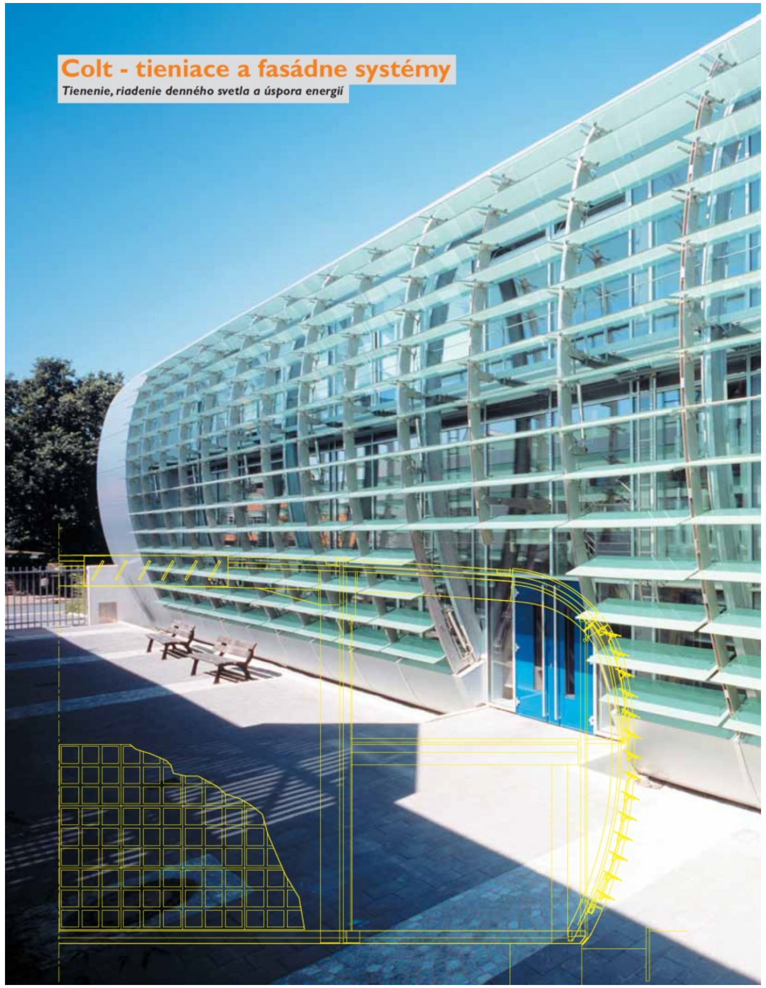
It is evident that modern buildings in a mild climate also need to be shaded

Modern buildings are not always equipped with effective shading technology

Chambre de Commerce, Luxembourg

Sky-Office, Düsseldorf, Germany

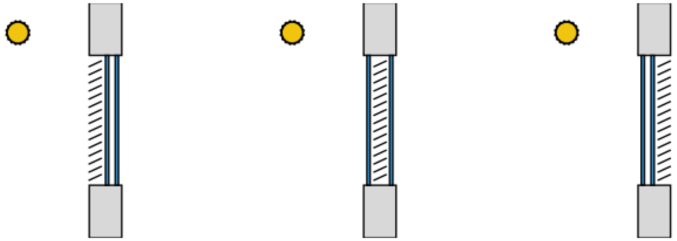
Shading technology is often a significant architectural element and as such is sometimes abused, respectively it is used redundantly



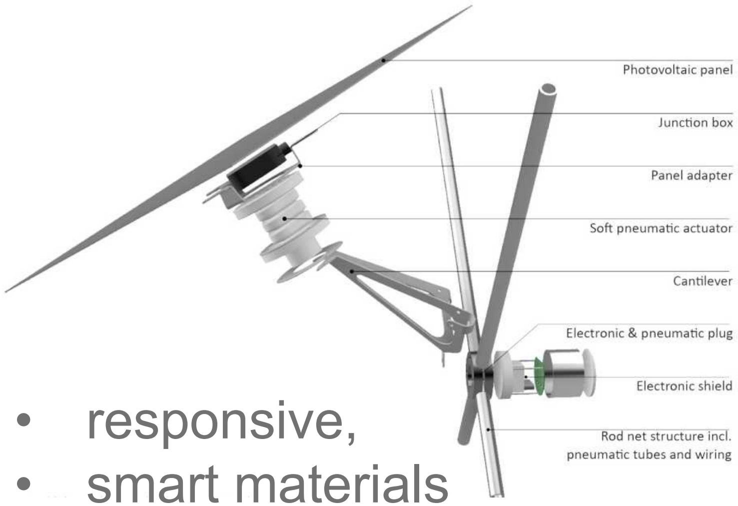
BASIC TYPOLOGY OF SHADING DEVICES

Basic typology of shading devices

Static/fixed	Dynamic/mobile	other

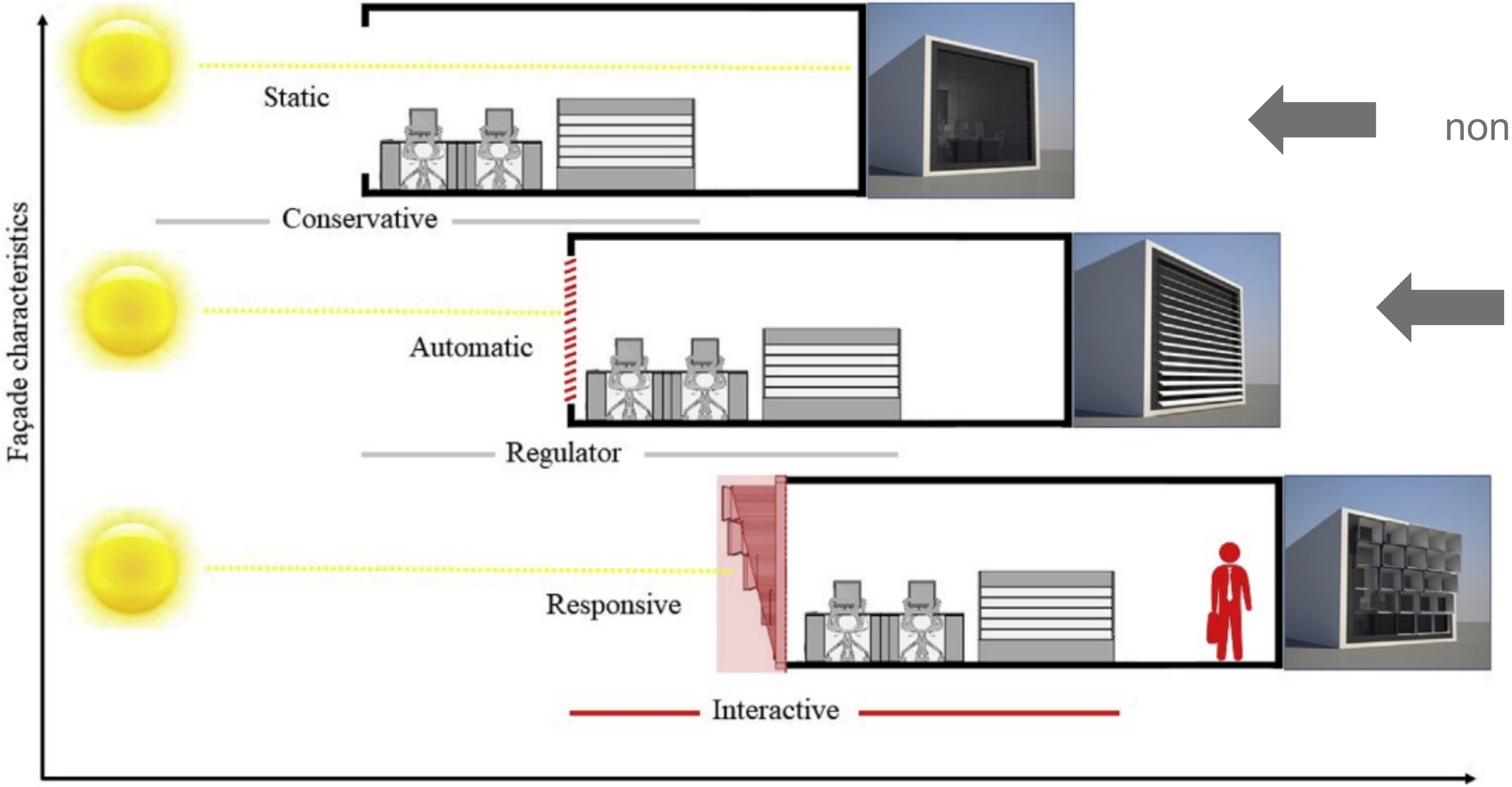


All types of shading devices can be external, internal or located in a shaded element.



- responsive,
- smart materials

Facade functions based on the relation among dynamic shading, properties of glazing system and interior space, and active occupant engagement



non-adaptable measures

automated response

intelligent response

Adaptive shading devices are included in this category.

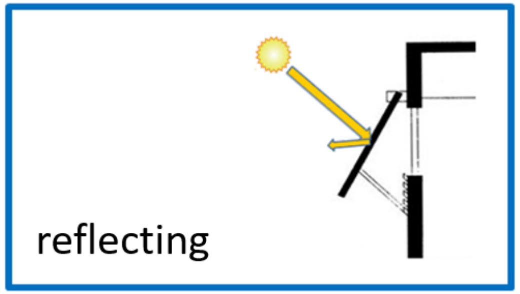
HI-SMART

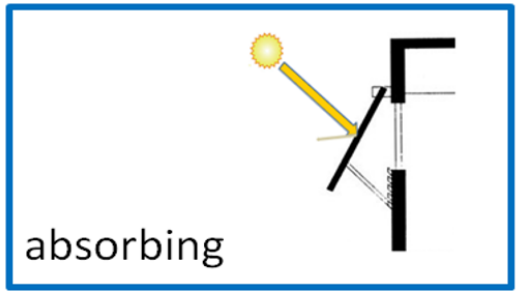
Erasmus+

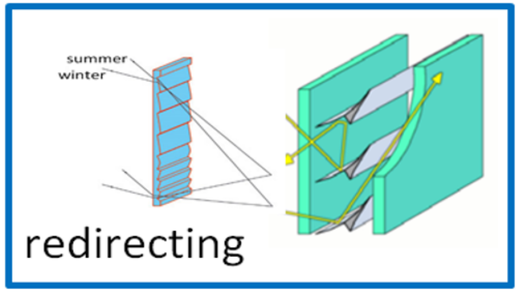
Hosseini et ali., 2019

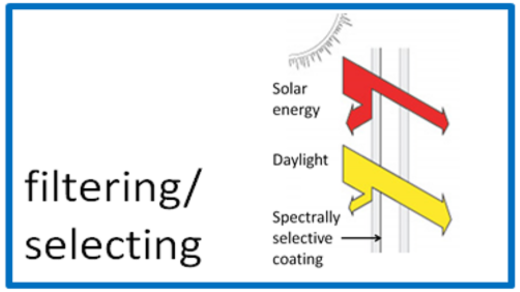
BASIC METHODS OF SOLAR CONTROL AND SEVERAL WAYS TO MAKE THE CONTROL MORE EFFECTIVE

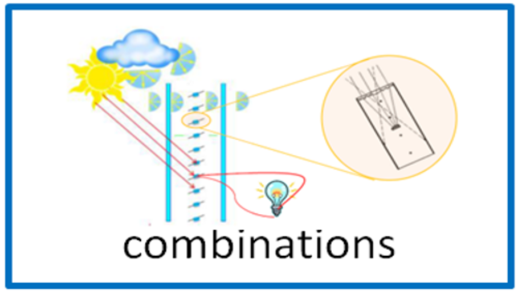
Basic methods of solar control











Shading systems can regulate solar energy by:

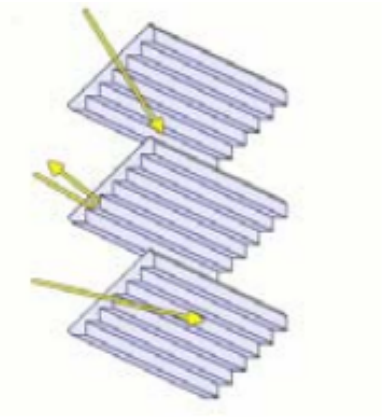
- reflecting (specular or diffuse),
- absorbing,
- redirecting,
- filtering,
- and by combination of these possibilities.

Absorbed solar energy is mainly transformed into thermal energy.

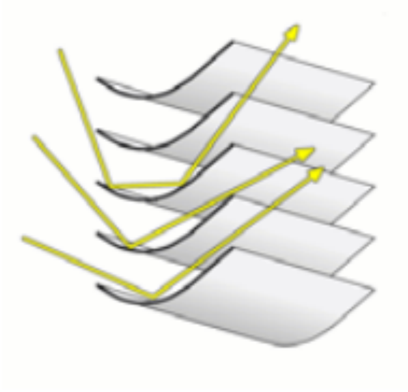
Part of the absorbed energy can be converted into other forms of energy, for example electricity, chemical energy, biofuel, and accumulated heat.

3
Basic methods

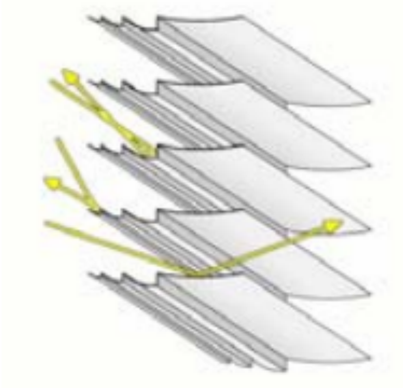
Improving the efficiency of shading lamellas by shaping them



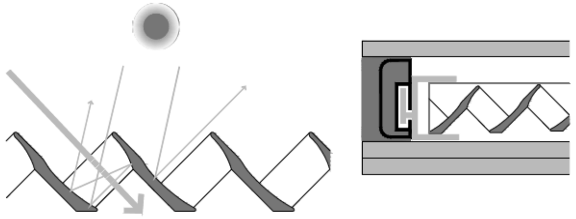
Prismatic acrylic elements



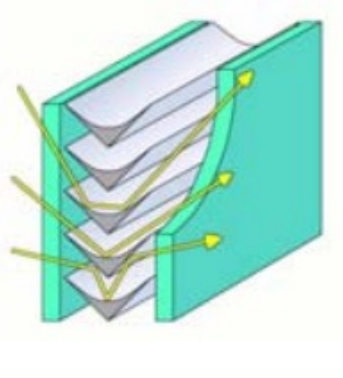
Bent metal slats



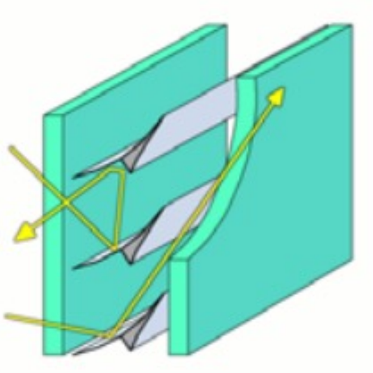
Metal slats with protrusions



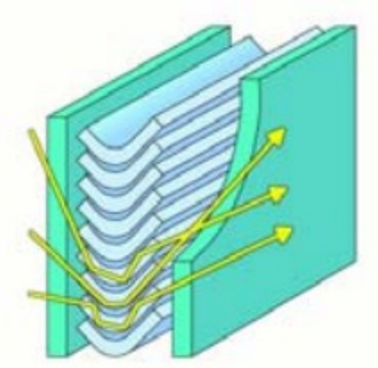
Micro lamellas in glazing



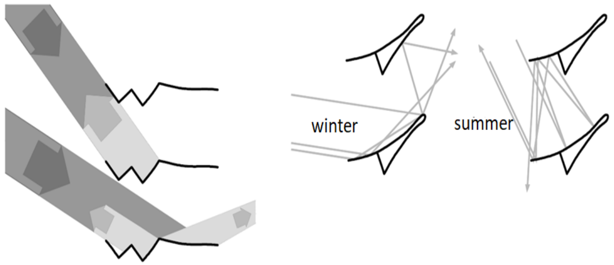
Symmetrical metal profiles



Asymmetric metal profiles

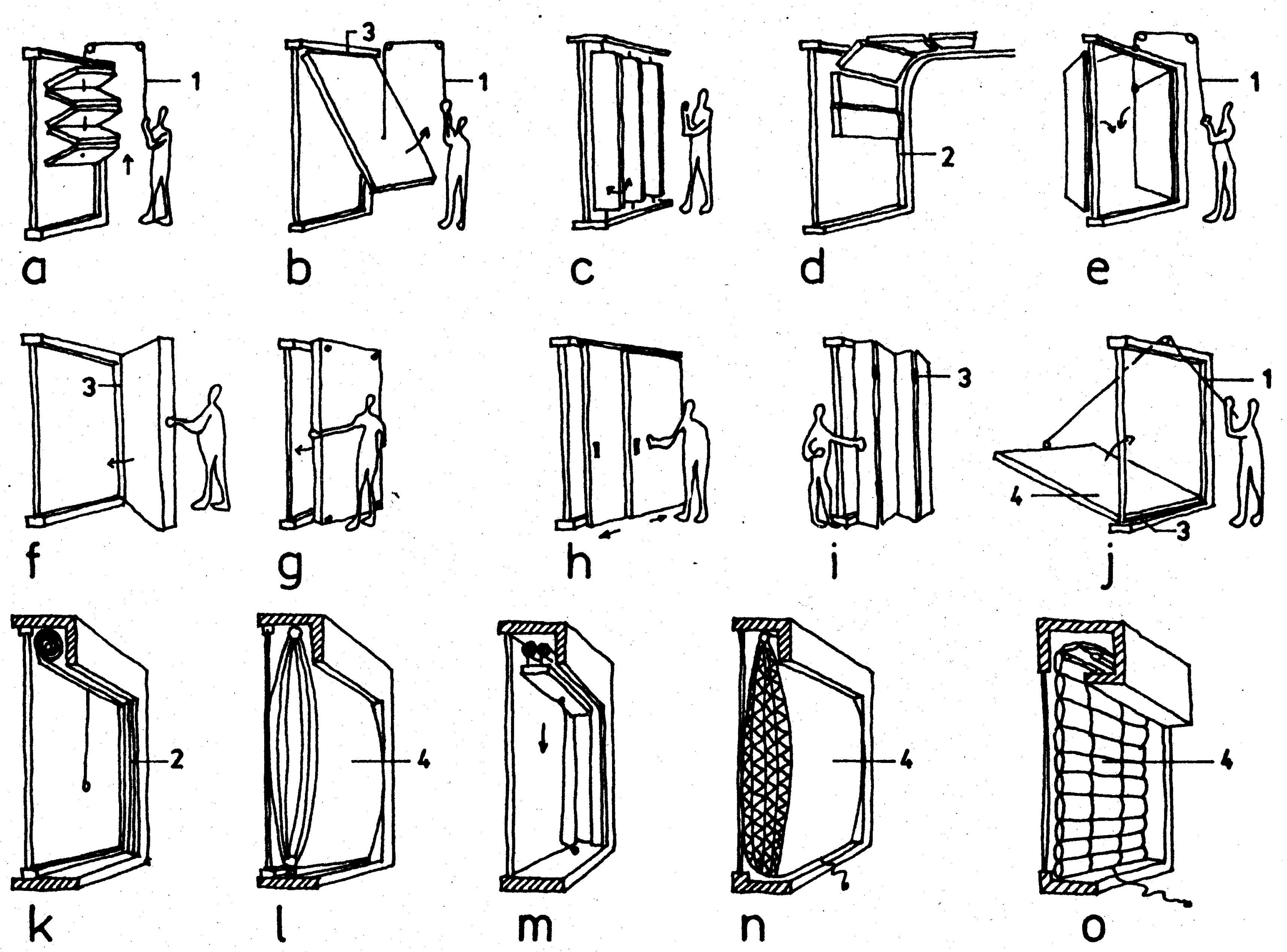


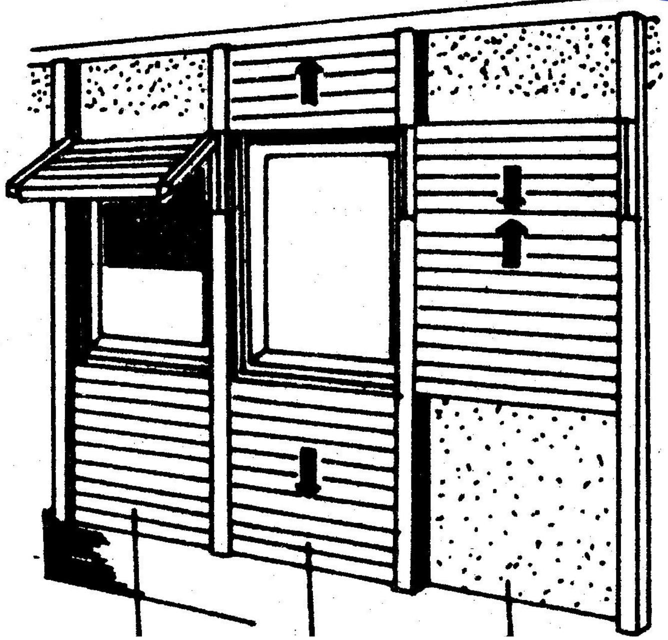
Bent acrylic slats



RETRO blinds (on left), asymmetric metal profiles (on right)

Mobile shading systems with additional thermal insulation function





All systems can be operated manually or mechanically. Several systems can be made adaptable.

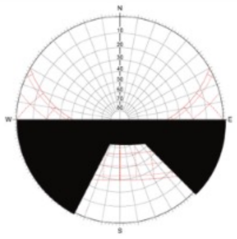
EVALUATION OF THE SHADING EFFECT OF SUN SHADES

Geometric and numerical evaluation of the shading effect of simple sunshades

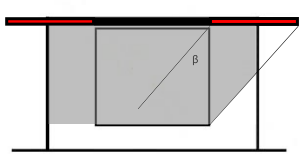
4
Evaluation

Geometric methods

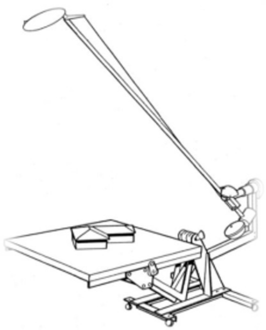
- shading masks



- cast shadows on glazing



- heliodons

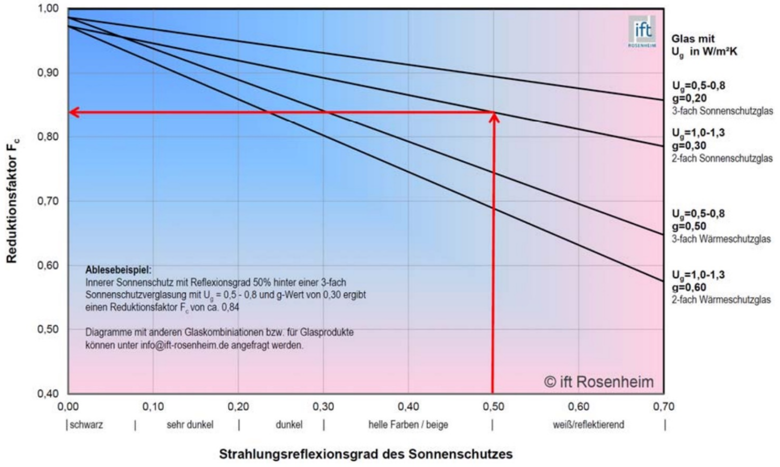


Simple numerical methods

- F_c = reduction factor

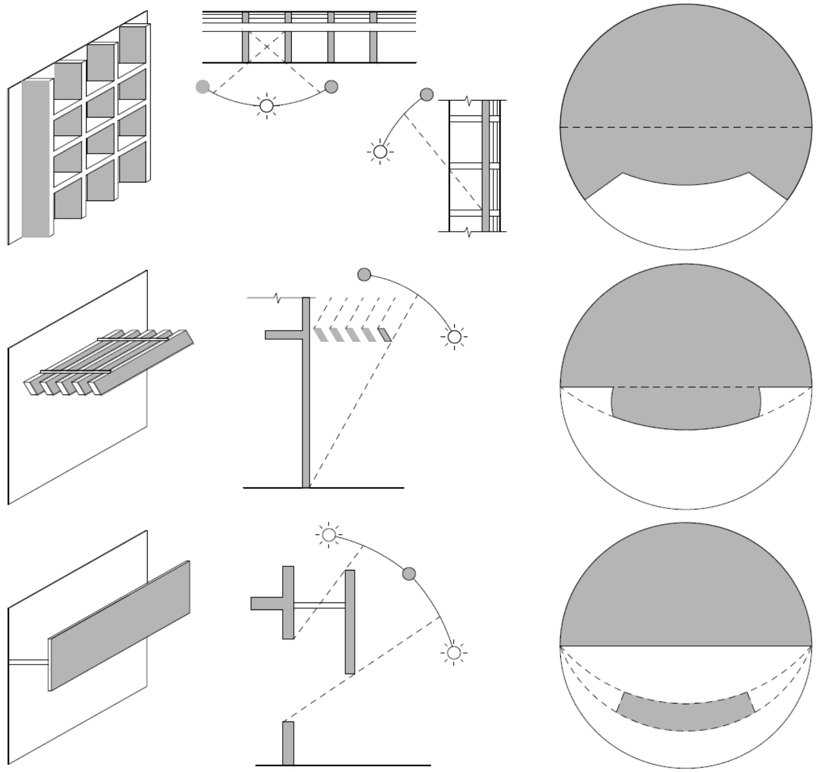
solar irradiation with shading (g_{tot}) / solar irradiation without shading (g) = reduction factor Fc

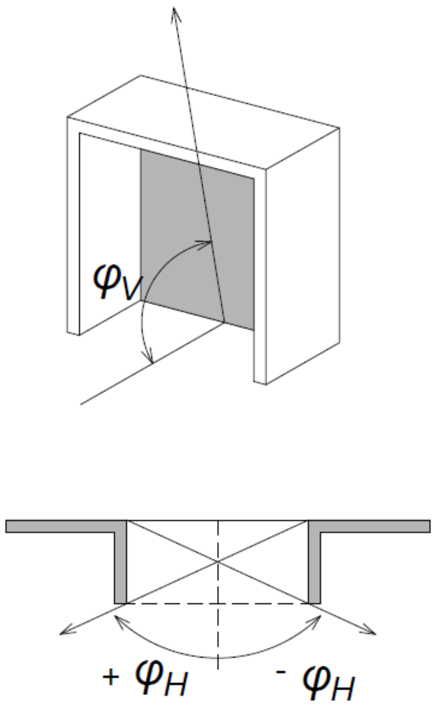
$$g_{tot} = g \cdot F_c \quad (-) \quad F_c = g_{tot} / g$$

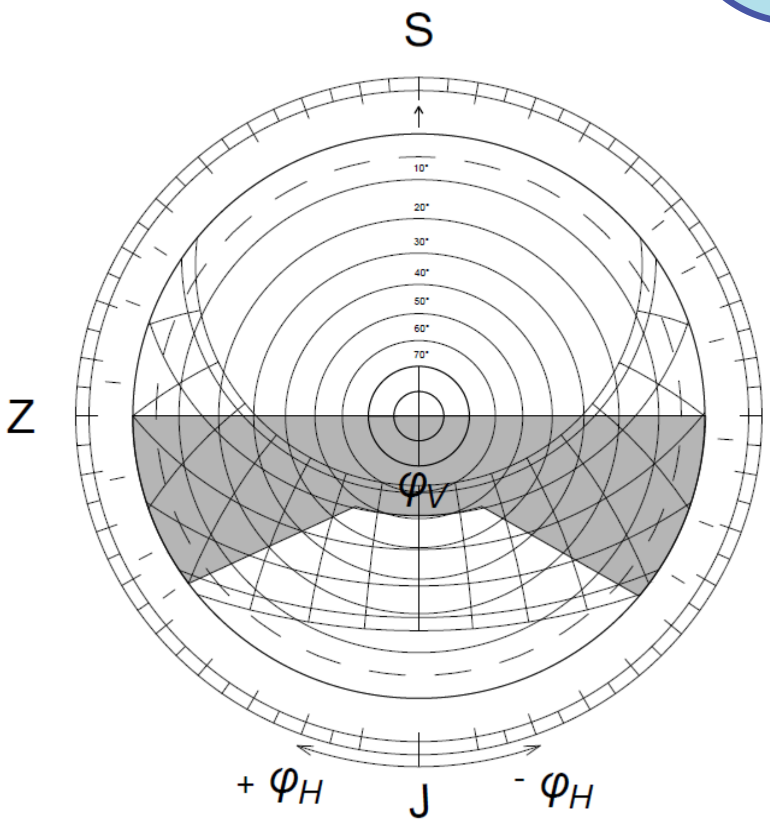


Graph for determining the reduction factor F_c for internal shades according to EN 13363-1 for various types of glazing systems

Shading masks

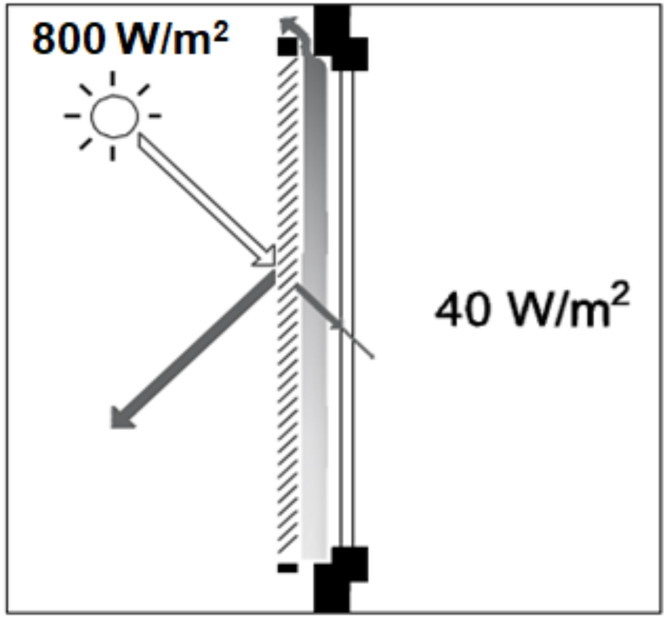




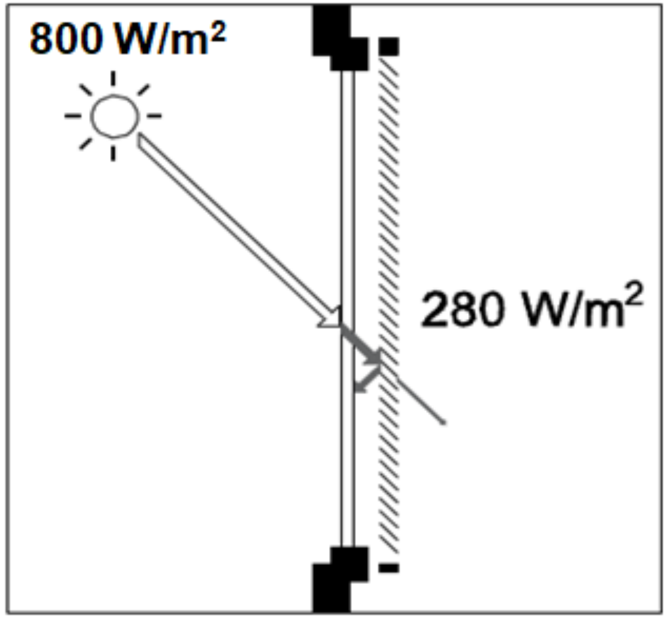


With shading masks, we can determine the shading of a certain point with almost any shading device. By plotting the shading angles in the solar diagram (in this case stereographic), we obtain a year-round overview of the shading of the point under consideration.

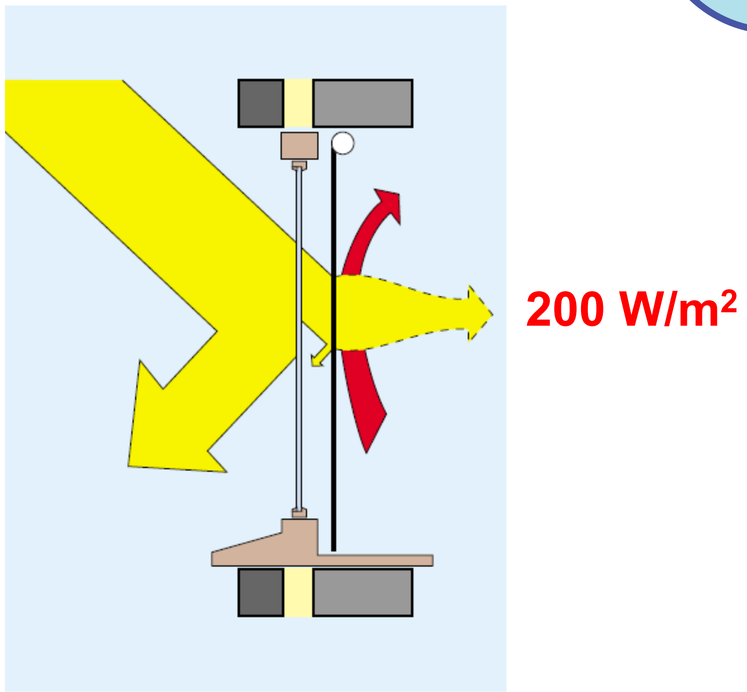
Application of reduction factor F_c, which considers both shortwave and longwave transmitted radiation



$g_{tot} = 0,05$

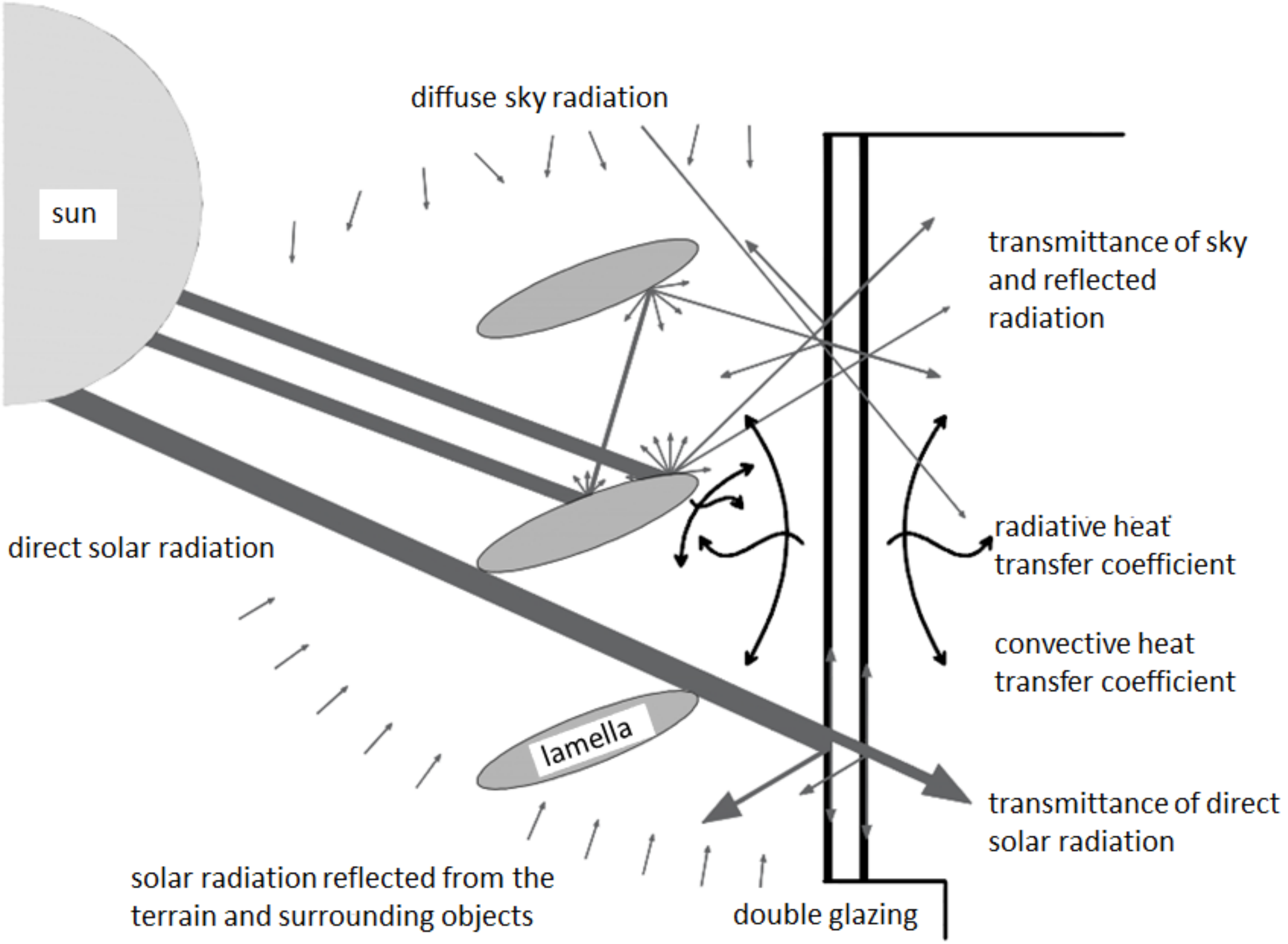


$g_{tot} = 0,35$



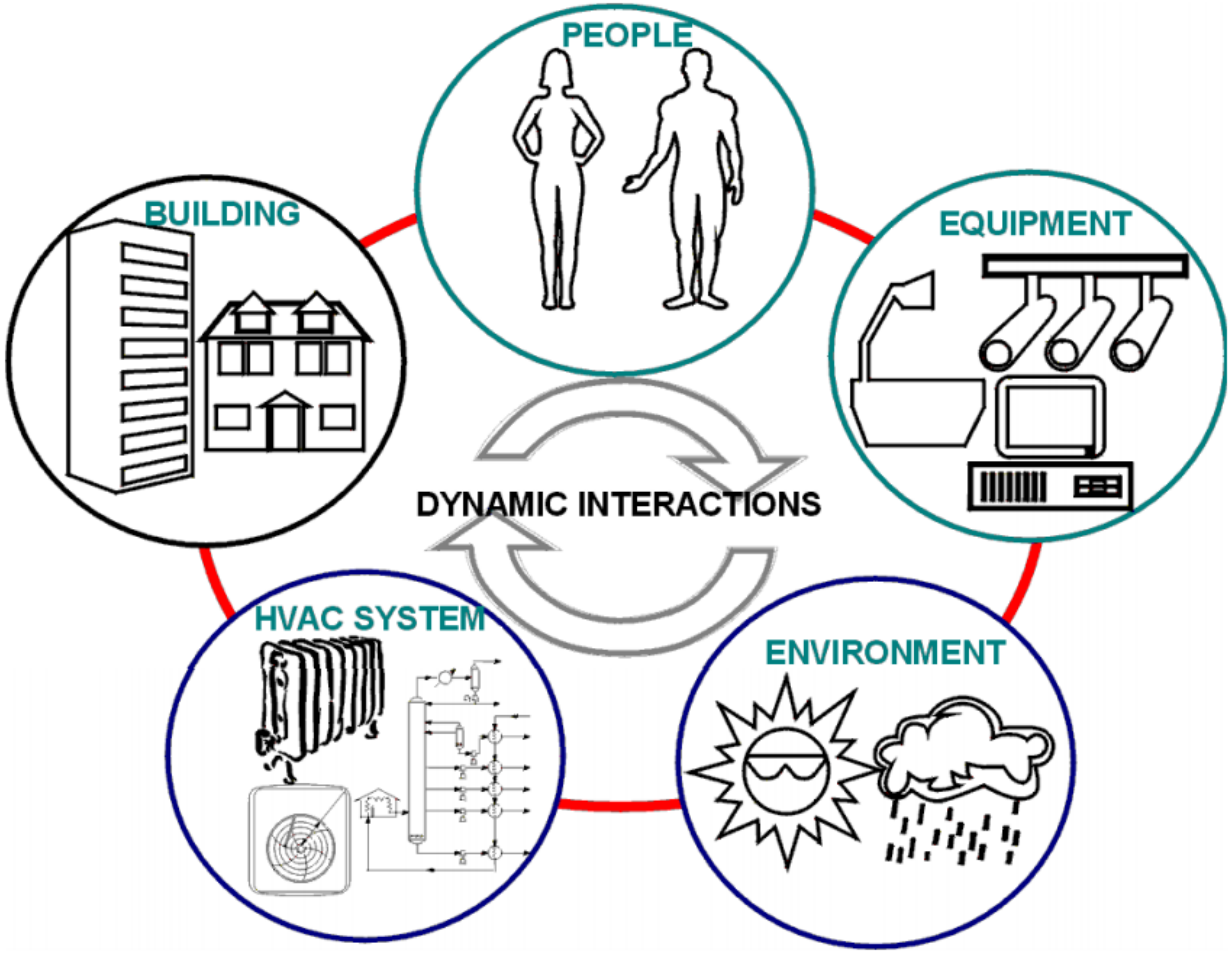
According to Slovak legislation (Decree no. 259/2008 Coll.) the total radiant heat on the heads of people in fixed worked positions must not exceed 200 W/m^2 ... for more than 10 minutes.

Solar gain through window with shading device



- Although external and internal slat-type blinds (such as venetian blinds) are used frequently to reduce the solar load on windows, there are only few calculation models for such shading devices.
- The effectiveness of the shading device must be assessed in conjunction with the type of glazing.
- The efficiency of the shading device is partly influenced by the thermal parameters of the indoor and outdoor environment, which usually change dynamically.

Simulation methods



- Simulation programs are used for solving the complex relationships between climate, occupancy requirements, mechanical and electrical systems, energy-efficiency issues and other design characteristics of buildings.

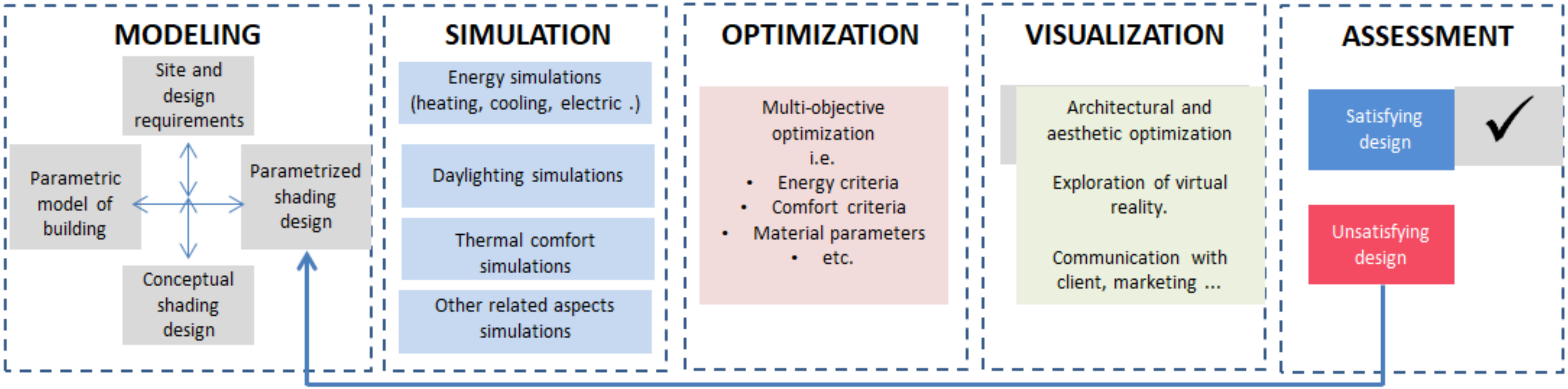
- Virtually all above mentioned relationships in a building are affected by shading systems.

Computer simulations and optimized shading devices design

4
Evaluation

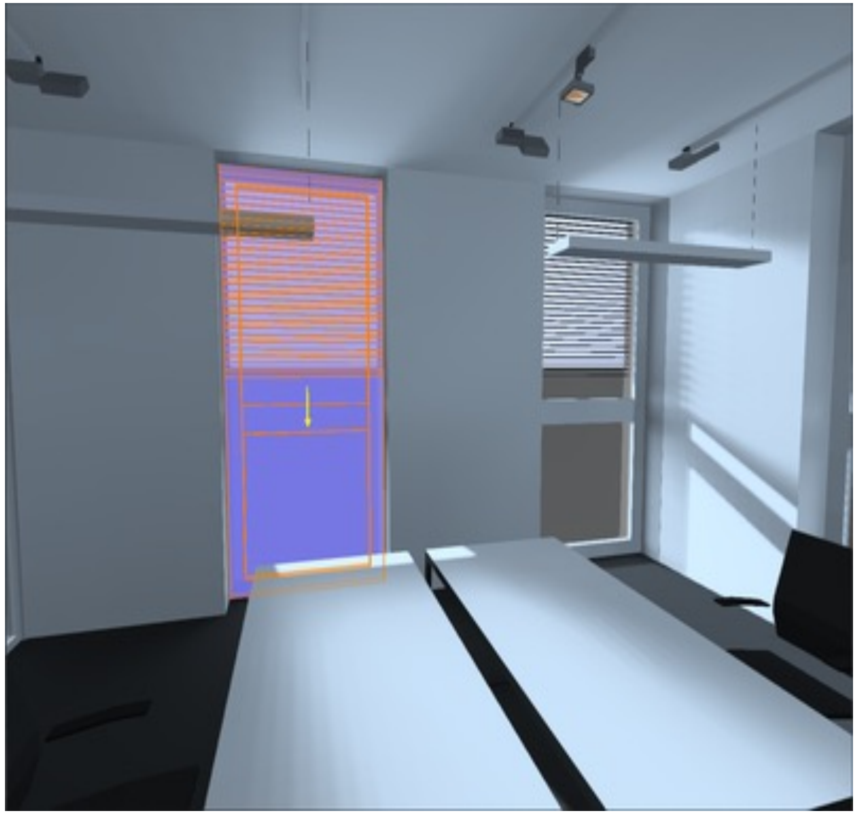
There are currently a large number of simulation programs that can be used to assess the effects of shading devices on various building functions:

Radiance, DOE-2, Daysim, ENER-LUX, MIDAS, COMFORT, TRNSYS, ADELINE, IENUS, ESP-r, WIS, LIGHTSCAPE, Phoenix, TAS, Simulink, IDR Block, Energy Plus, Ecotect, Autodesk VIZ, VE for Revit, Matlab, EES, IES– VE, iD-build, WINDOW, DIVA for Rhino, Design Builder, Sun-Shade, Radlink in Adeline, Fener, Evalglare, Bsim and others.



4
Evaluation

Visualization of daylighting of the room by partially shaded windows in the DIALux evo 6 – advanced simulation program



Visualization of daylighting of the room in an older program (radiosity method)

Recommendation for glare protection in EN 17037

4
Evaluation

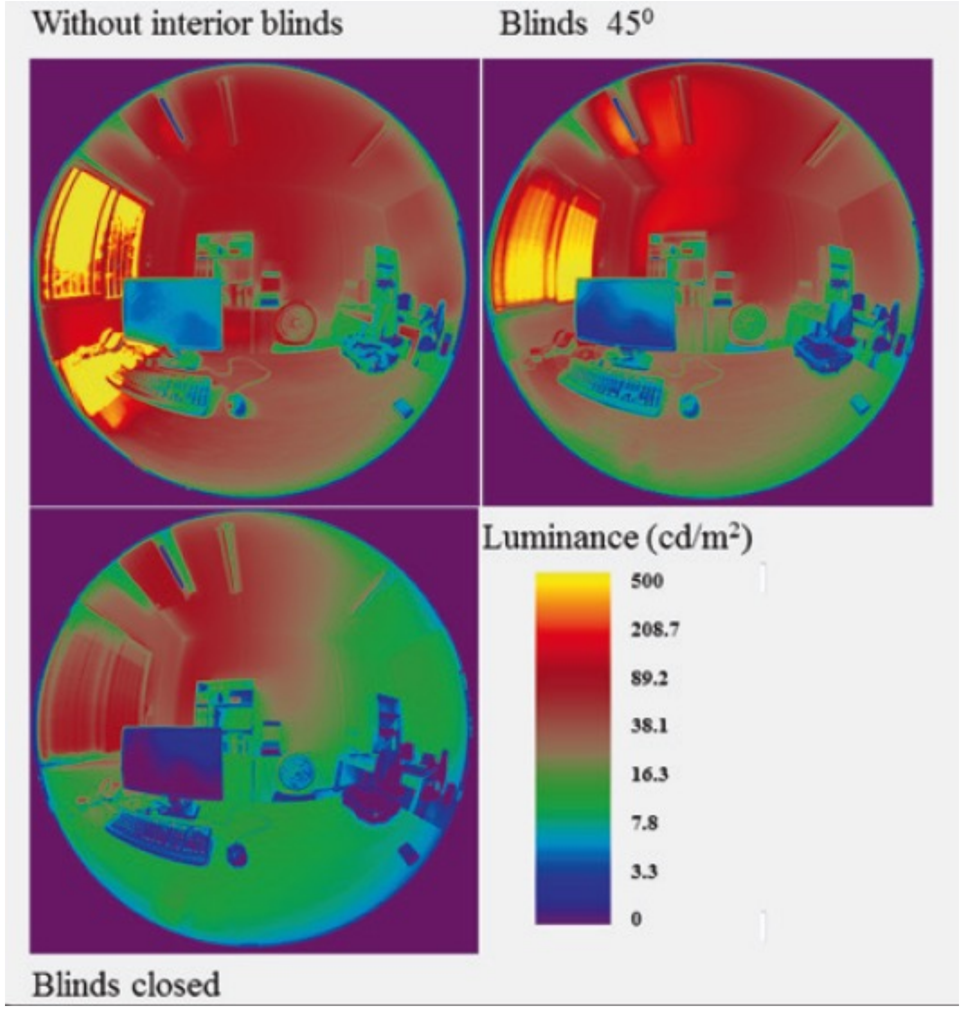
$$DGP = 5{,}87 \times 10^{-5} \times E_v + 9{,}18 \times 10^{-2} \times \log\left(1 + \sum_i \frac{L_{s,i}^2 \times \omega_{s,i}}{E_v^{1.87} \times P_i^2}\right) + 0{,}16$$

E_v is the illuminance at eye level [lux]. L_s is the luminance of glare source [cd/m^2]. P is the position index [-]. ω_s is the solid angle subtended by the glare source [-]. i is the number of glare sources.

Criterion	Daylight Glare Probability (DGP)
Glare is mostly not-perceived	DGP ≤ 0,35
Glare is perceived but mostly not disturbing	0,35 < DGP ≤ 0,40
Glare is perceived and often disturbing	0,4 < DGP ≤ 0,45
Glare is perceived and mostly intolerable	DGP ≥ 0,45

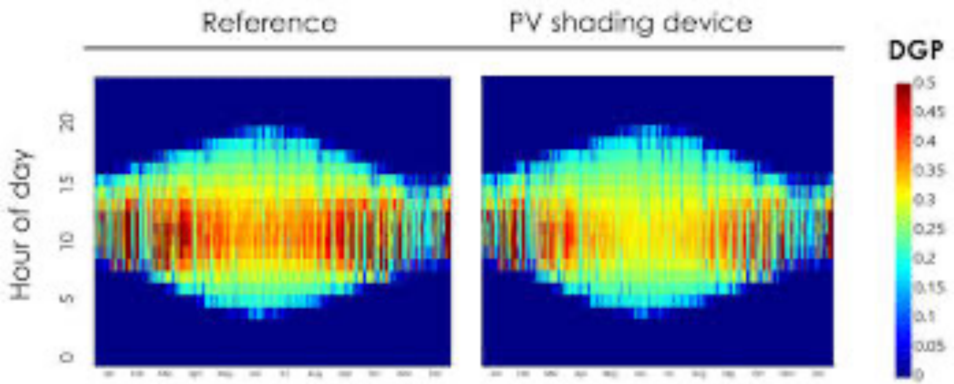
The minimum recommendation for glare protection is that of DGP (Daylight Glare Probability) for the occupied space does not exceed a value of 0,45 in more than 5 % of the occupation time of the relevant space.

Simulations of glare



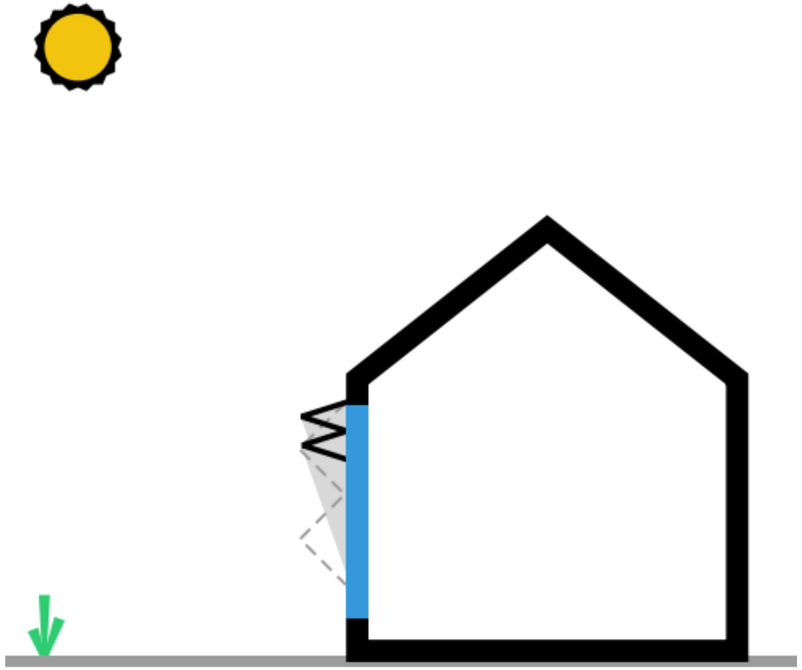
An example of a graphical output from the simulation of glare:

- Without interior blinds,
- The interior shaded by interior vertical slats rotated at an angle of 45°,
- And in the state with the slats completely closed.



PV shading device reduces glare throughout the year.

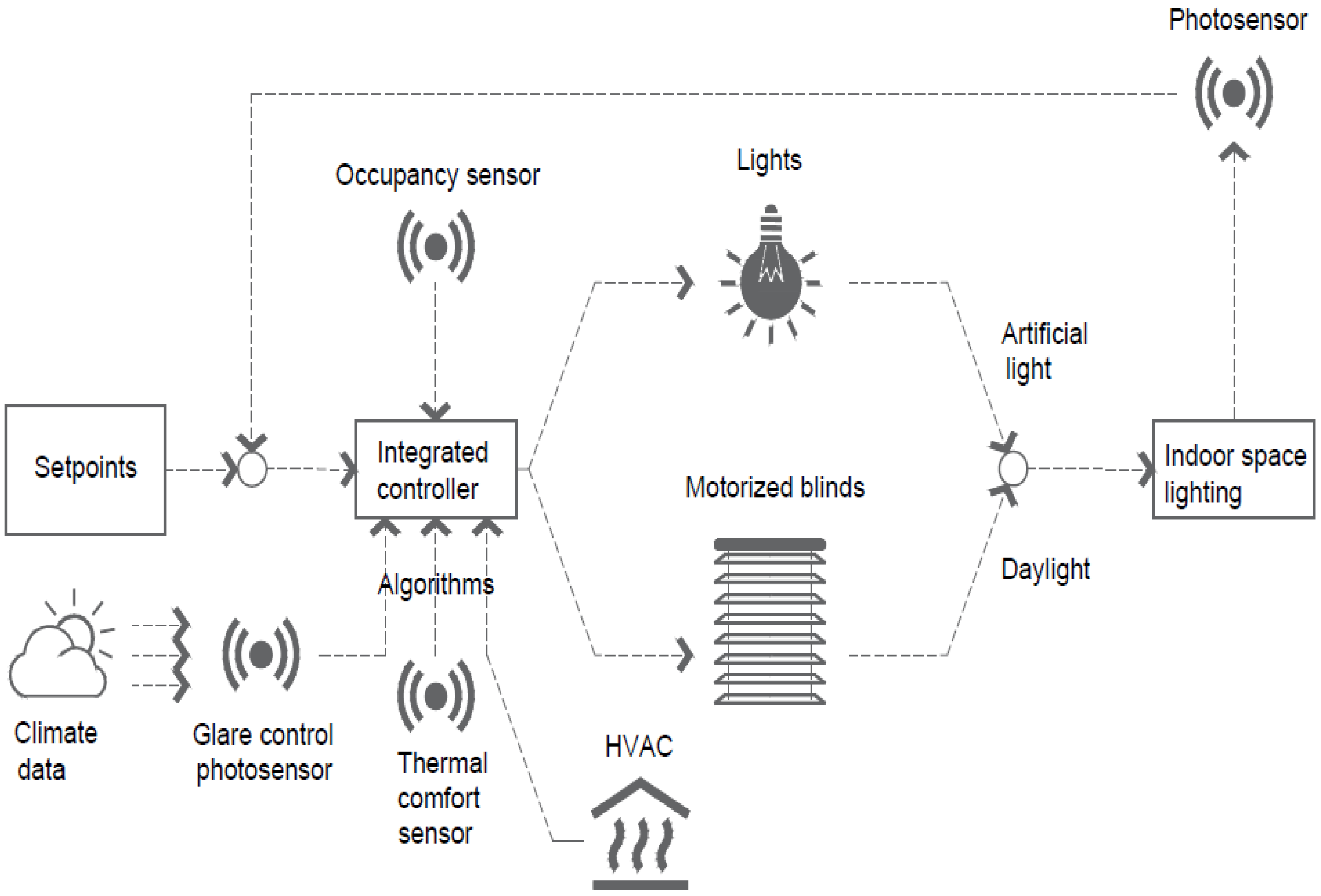
ADAPTIVE SOLAR SHADING SYSTEMS



Is the shutter "static" shading system?

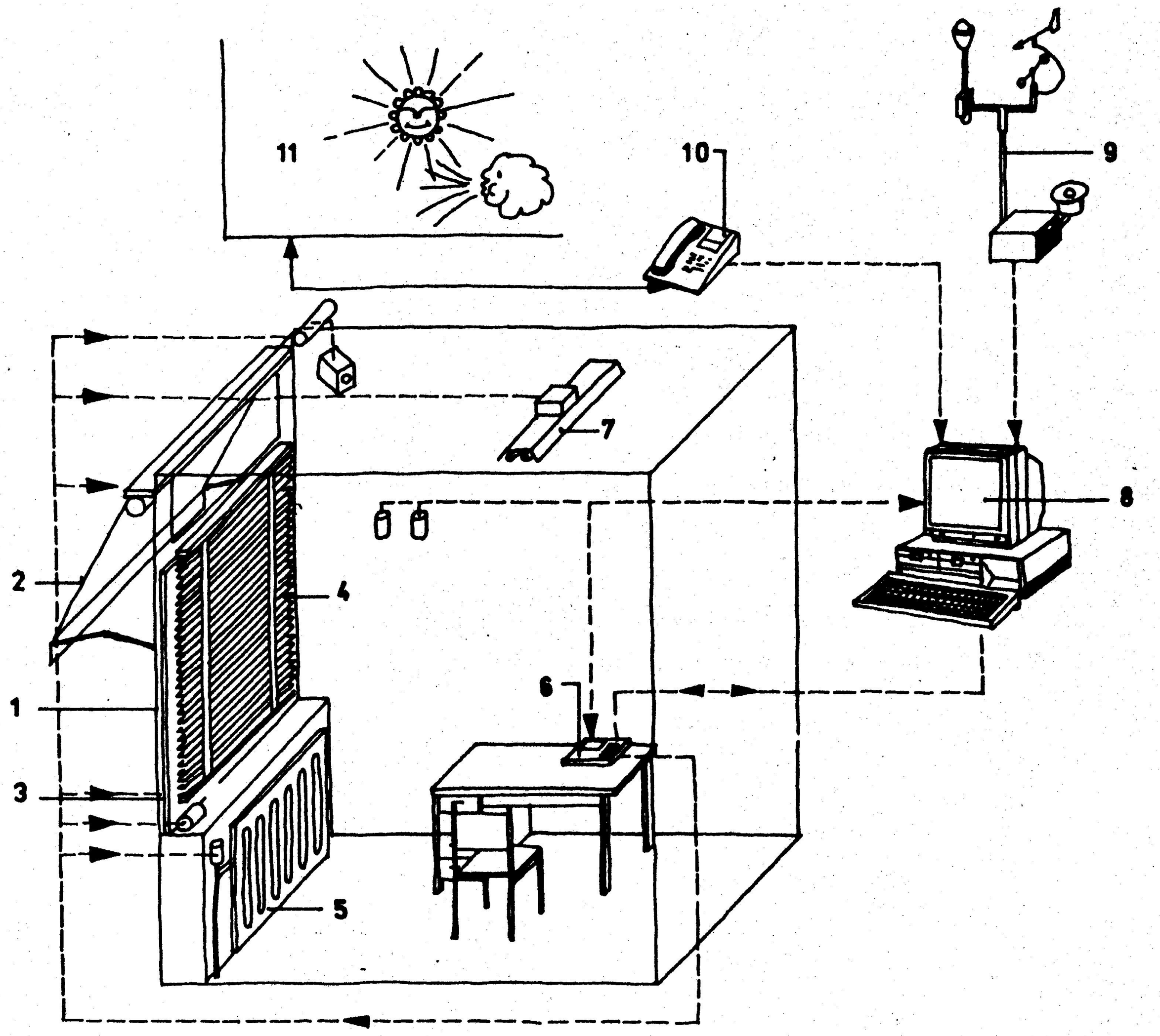
Proponents of dynamic building facades often argue that traditional facades are not capable of adapting and responding to various changes that they are exposed to.
These claims are rather false myths, as is shown in figure below.
But it should be considered that in some "advanced" modern buildings people don't have control over windows and shading systems.

Interactions of adaptive shading device with HVAC and artificial lighting of an „intelligent” building



- An adaptive shading device includes functionalities such real-time sensing, kinetic elements, automation and the ability for user override.
- Advanced adaptive shading devices as a part of “intelligent” building skin need computational algorithms that allow the building systems to self-adjust and to control indoor environmental conditions.
- Information should be provided to the building’s users so they can modify their actions relative to indoor occupant comfort parameters and energy use.

Adaptive shading needs a lot of information



1 - window,

2 - awning,

3 - control of shading devices,

4 – venetian blinds,

5 - room control unit, 6 – radiator,

7 - lamp,

8 - central computer,

9 - local meteorological station,

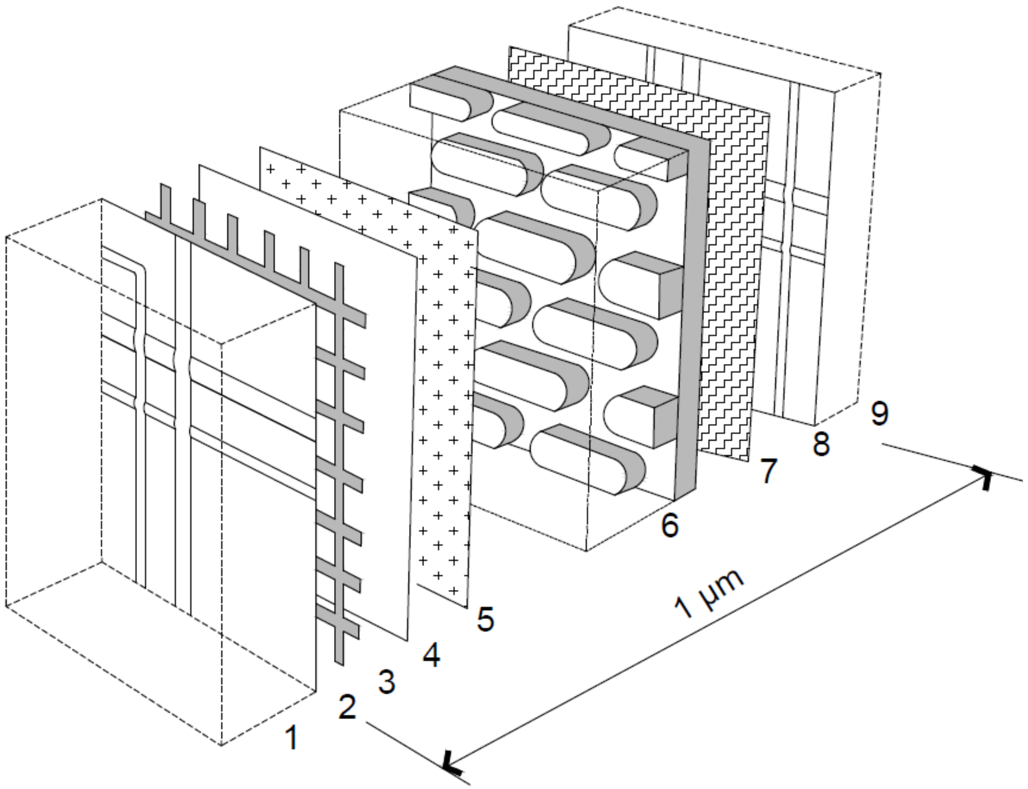
10 - communication with meteorological station,

11 - weather forecast ,

+ lots of sensors and cameras.

TYPOLOGY OF ADAPTIVE SHADING SYSTEMS

Brief history of adaptive shading devices



Polyvalent wall (Davies, 1981)

1 - clear glass,
2 - outer sensor and control logic layer,
3 - photoelectric grid,
4 - selective heat absorber,
5 - electro-reflective coating,
6 - microporous gas-permeable layer,
7 - electro-reflective coating,
8 - inner sensor and control logic layer,
9 - clear glass

Polyvalent wall

Mike Davies (Davies, 1981) presents the high-tech concept of dynamic façade which called “polyvalent wall”. He himself described his concept as follows:

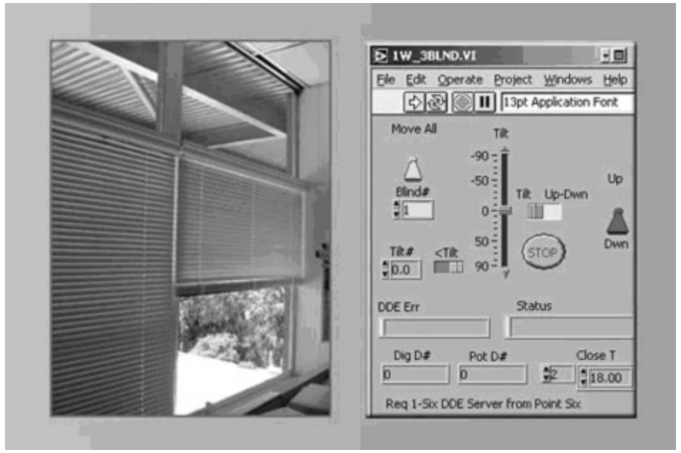
“What is needed is an environmental diode, a progressive thermal and spectral switching device, a dynamic interactive multi-capability processor acting as a building skin. The diode is logically based on the remarkable physical properties of glass, but will have to incorporate a greater range of thermal and visual adaptive performance capabilities in one polyvalent product. This environmental diode, a polyvalent wall as the envelope of a building, will remove the distinction between solid and transparent”.

This idea was never realized, but the concept is still very inspiring.

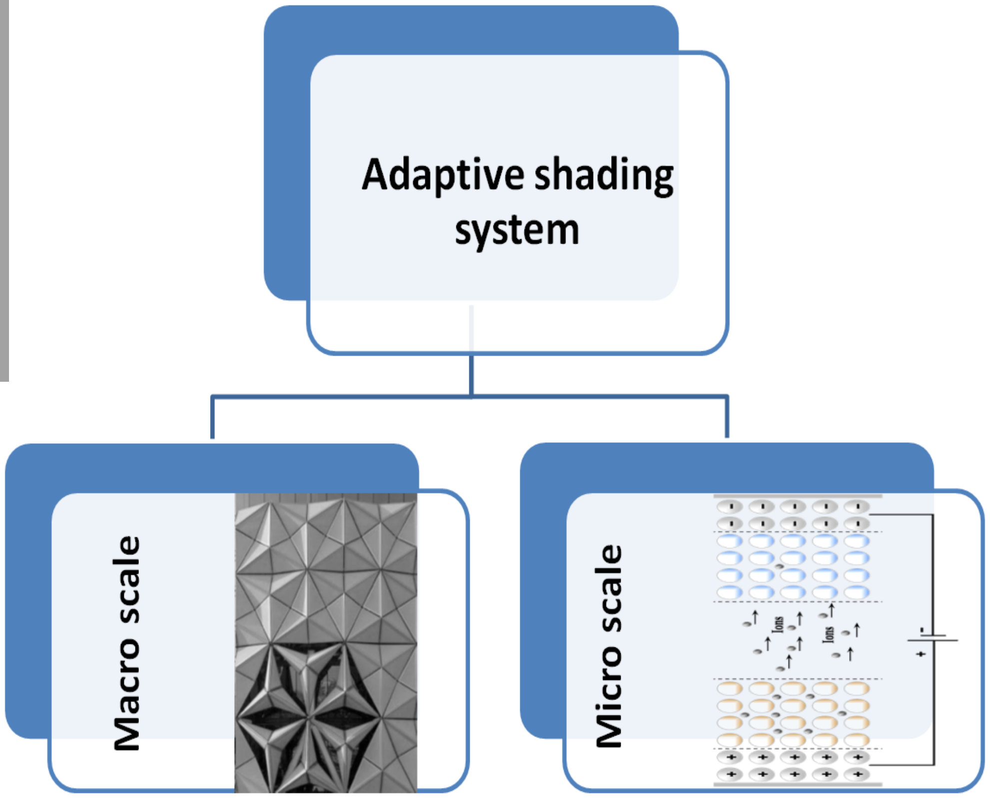
Davies, 1981

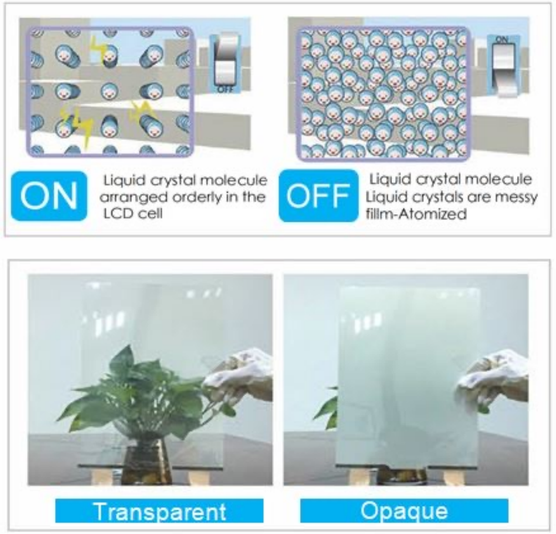
TYPOLOGY OF ADAPTIVE SHADING SYSTEMS

Basic typology of adaptive shading systems



A venetian-blind system at a Berkeley Lab office building is equipped with a “virtual instrument” panel for IBECS control of blinds settings.





PDLC Smart Film (polymer dispersed liquid film). It is transparent when power on and back to opaque when power off.

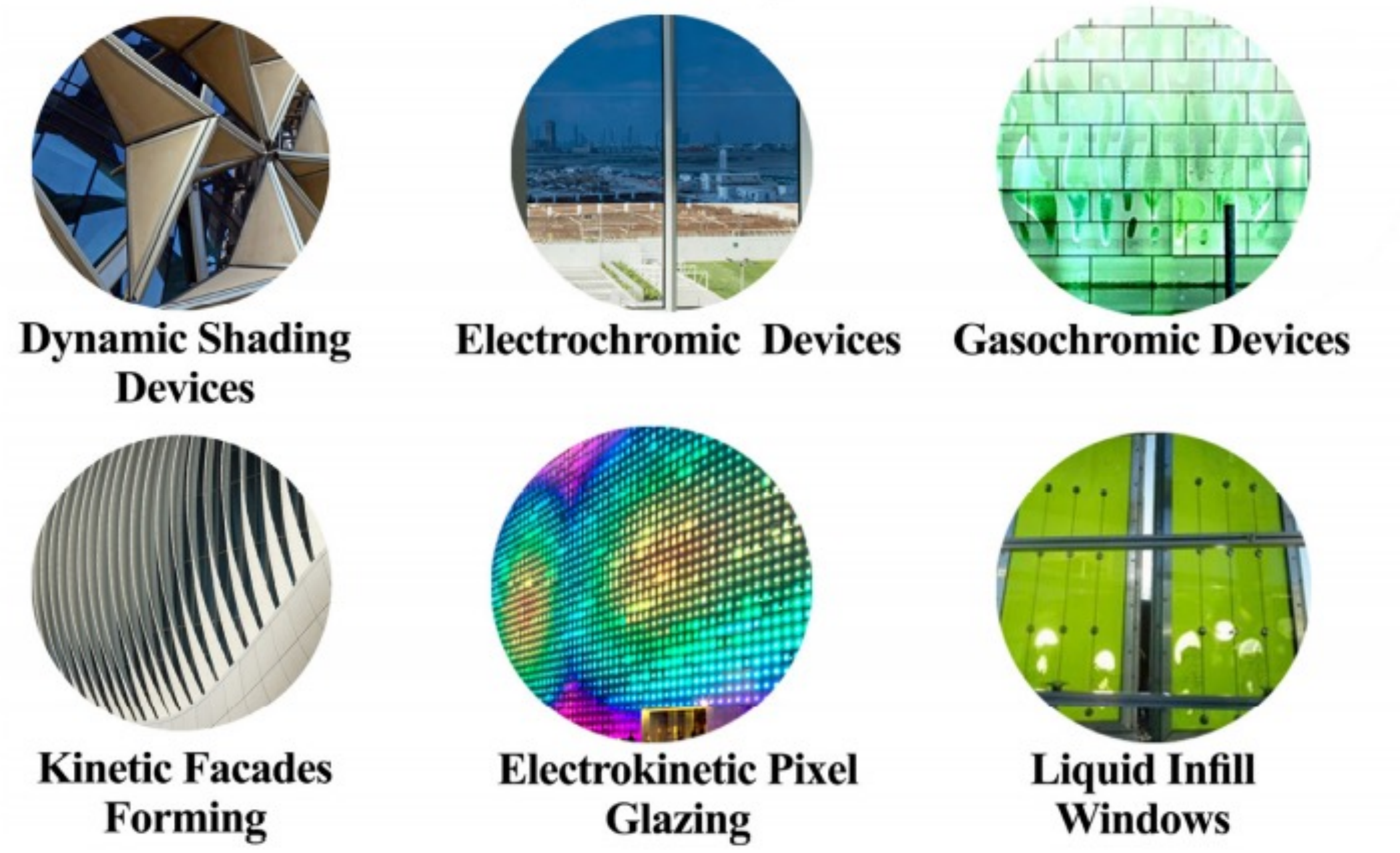
HI-SMART

Erasmus+

https://www.sciencedirect.com/topics/engineering/shading-device

https://www.abcblinds.com.tw/page_1.php?TVcode=8&TVcode1=50&Vcode=544

Some of new technologies of adaptive shading



Shady et al., 2018

TYPOLOGY OF ADAPTIVE SHADING SYSTEMS

Adaptive solar shading systems

Kinetic systems

- Any movable shading device (e.g. Venetian blinds, plantation shutters, roller shutters, moveable origami structures ...)
- Elastic shading systems
- Pneumatic systems with different shapes and transparencies
- Mechanical smart windows (e.g. Vistamatic [Web 1], SunValve [Web 2], SmarterShade [Web 3], adaptive fritting [Web 4])
- Transformable structures
- Other shape morphing shading systems

Switchable glazing

- Electrochromic
- Gasochromic
- Suspended particle devices
- Liquid crystal devices
- Micro-blinds [Web 5]
- Nanocrystals embedded in glass [Web 6]

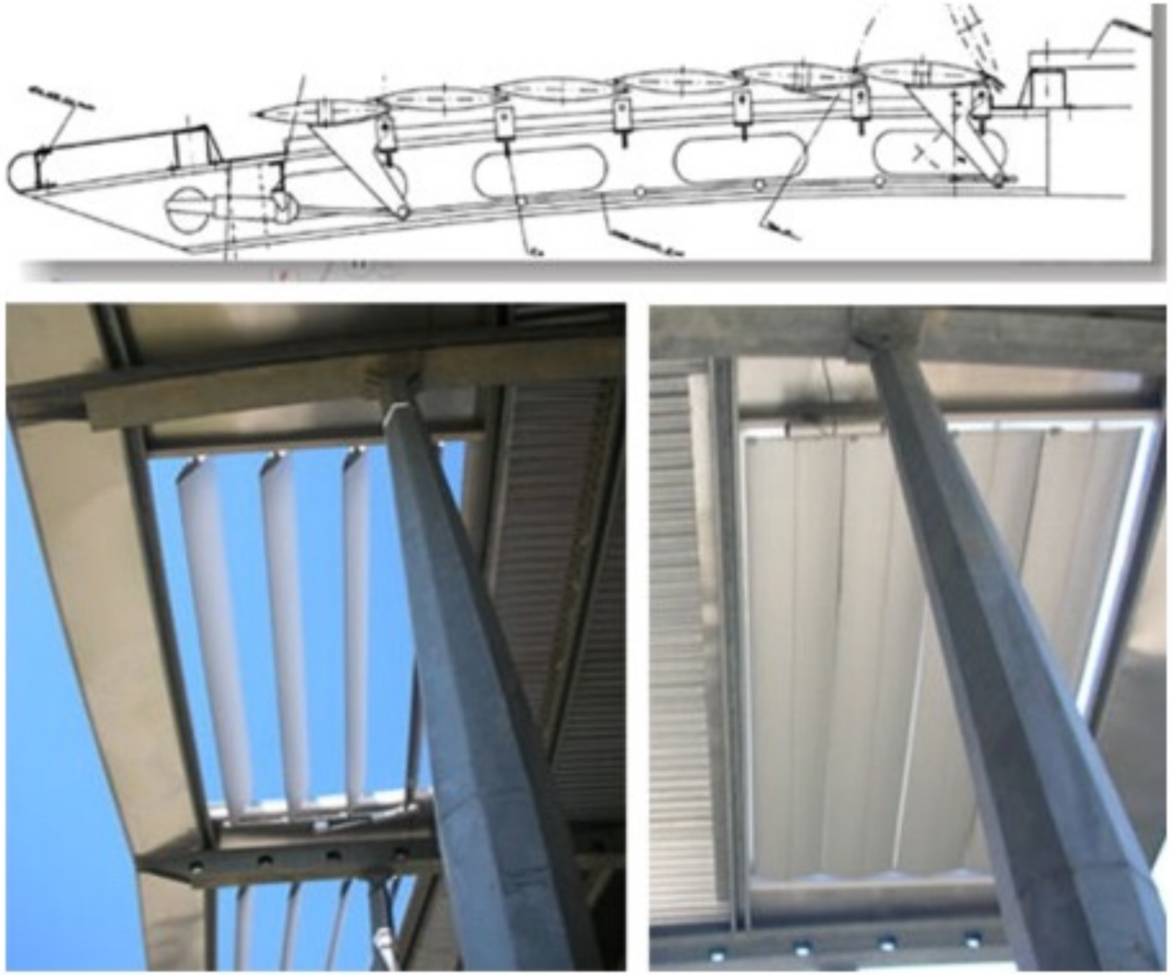
Multifunction systems

- Systems with supplementary thermal insulation
- Systems that improve daylighting quality
- Systems coupled with photovoltaic devices
- Systems coupled with thermal solar collectors
- Systems coupled with bioreactors (e.g. microalgae façade system [Web 7])
- Systems that enhance natural ventilation of buildings

Specific systems

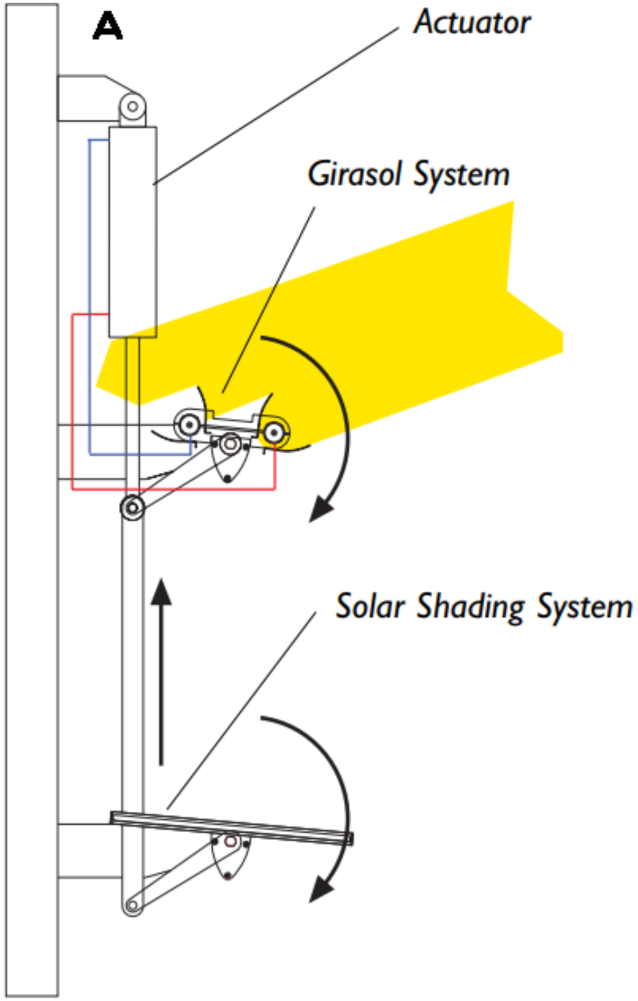
- Colored liquid-shaded glazing
- Homeostatic [Web 9]
- Specific "bio-facades" (e.g. BIOS-FIN [Web 11]),
- Water spray
- Dynamically injected gas or bubbles into pneumatic systems

An example of a simple adaptive shading device



- General technical progress has expanded the possibilities of designing and operating building envelopes that can dynamically change their properties.
- Adaptive shading systems (also known as dynamic, kinetic, responsive, active, adjustable, smart, advanced, intelligent, switchable, interactive and suchlike) are usually an integral part of adaptive (dynamic) facade.
- In many cases, just adaptive shading device is the essence of a dynamic facade.

Colt Girasol control system – an example of advanced control system

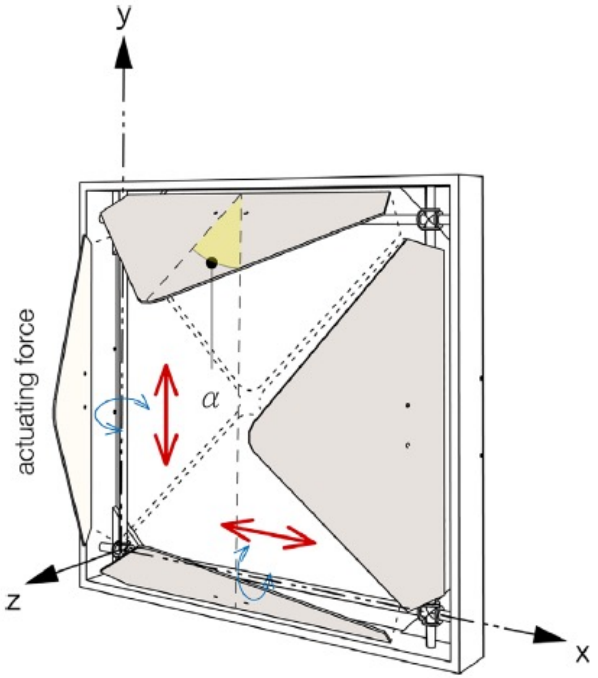


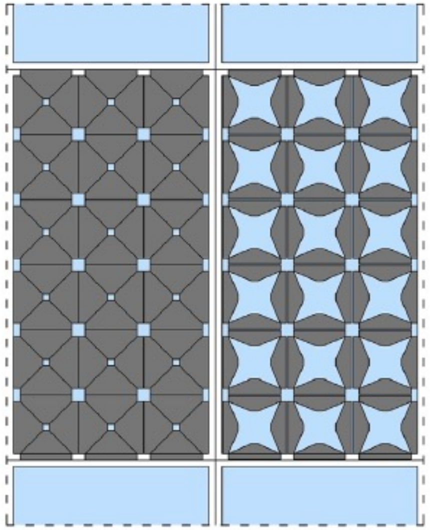
Girasol (innovative thermohydraulic system) operates solar shading louvres without the need for electrical power or a sophisticated control system.

Absorber tubes, enclosed by mirrors, force a hydraulic cylinder to open or close the louvres according to the position of the sun.

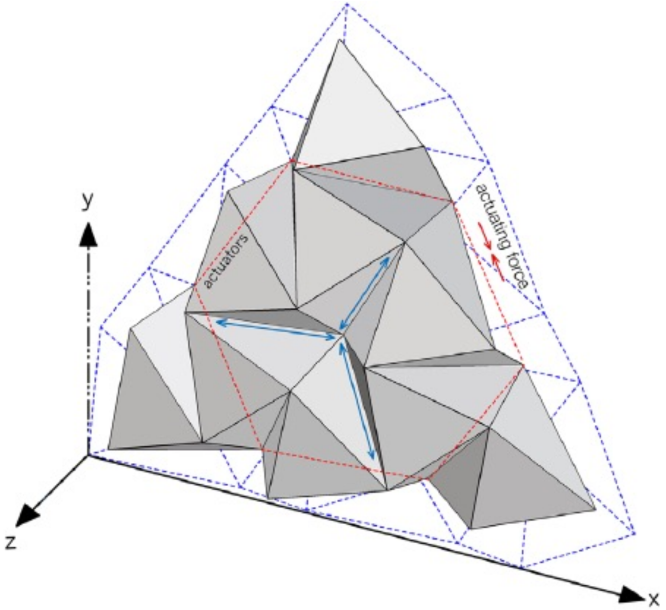
Tubes are filled with a special hydraulic fluid and as the sun moves over the building, there will be an imbalance of heat between the two tubes and the louvres will open or close as appropriate

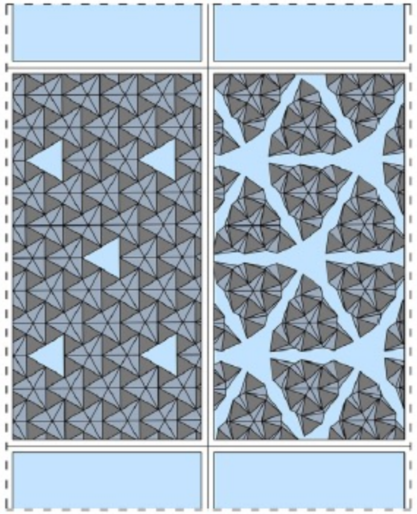
Kinetic shading systems – „kinetic solar skin“





Payne AO, Johnson JK. Firefly: interactive prototypes for architectural design. Archit Des 2013;83:144–7.





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Perforated or twisted metal contributes to a decorative effect. Kinetic solar skins often link back to the two directional shading devices of the Middle Eastern (mashrabiya tradition). This type of shading device is being used also in less sunny locations, especially for architectural and aesthetic reasons.

Kinetic shading system – „kinetic architecture“

Kinetic shading system of Pfalzkeller Emergency Service Centre in Saint Gallen (Switzerland) by architect Santiago Calatrava (in the picture).

The shading slats are mechanically closed as required. The aim is to eliminate the penetration of direct sunlight and to transmit diffused daylight into Emergency Service Centre.

Amount of material is very high.

http://www.worldarchitecturemap.org/buildings/pfalzkeller-emergency-centre

Architectural shutters – simple kinetic shading device

- Recently, shading devices called architectural shutters have been used very often. The most commonly used are simple architectural shutters, which can be seen in the photo on the left.
- The shutters are usually moved horizontally by hand, but can be operated automatically (with manual override). In this case, however, their application becomes much more expensive.
- The architectural shutters can effectively shade the glazed parts of the façade, regulate daylight and eliminate glare. There are also more sophisticated versions of architectural shutters that increase the thermal and acoustic insulation of the facades and their airtightness.

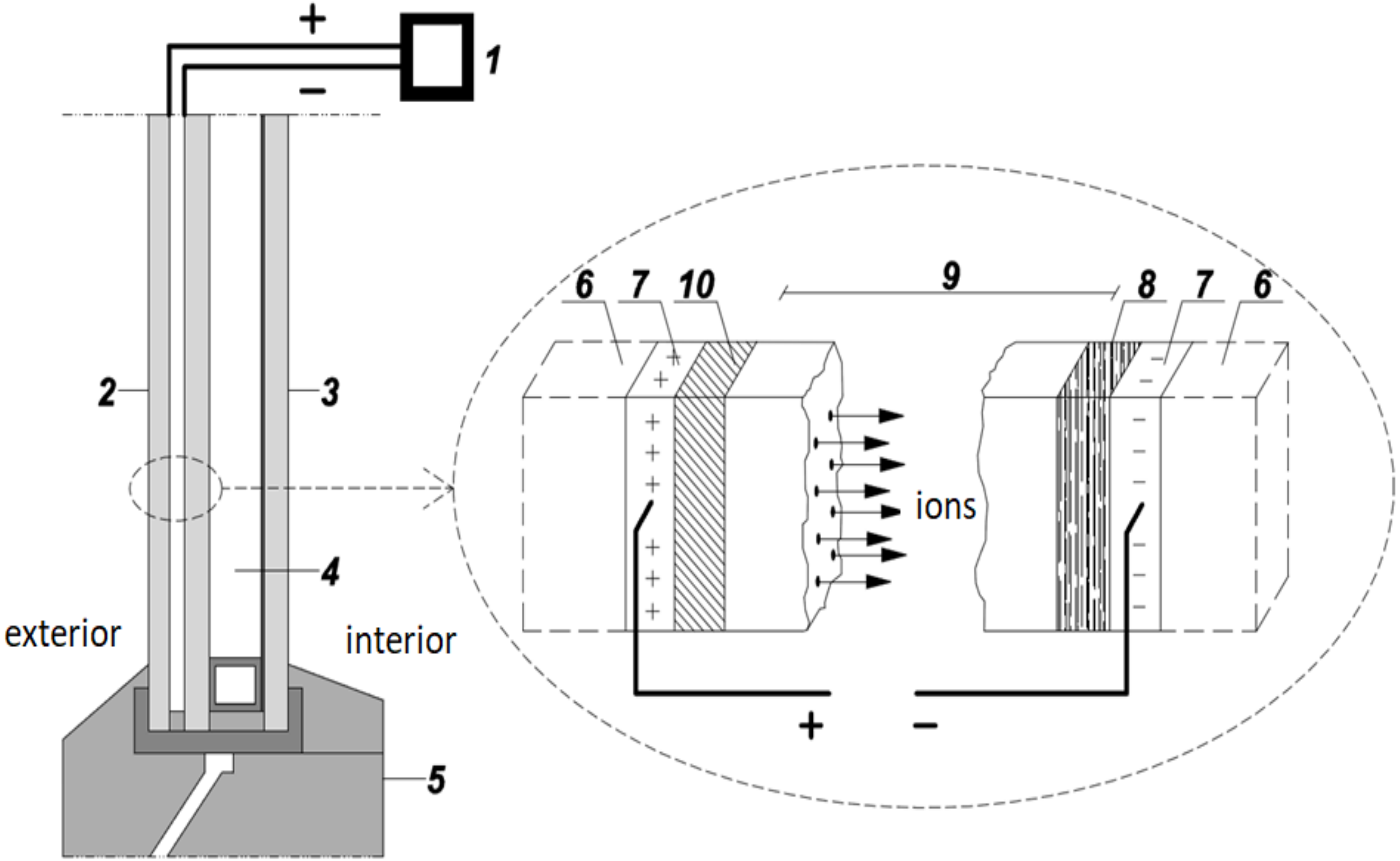
Shading fabrics – another simple kinetic shading device

Automatized interior shading fabric in office complex Cassovar in Košice (Slovakia).

Motorized shading fabrics belong to adaptive solar shading systems.
These smart motorized shades can be programmed as a part of a home or office automation system.

Automatized interior shading fabric in office complex Cassovar in Košice (Slovakia) is in the figure on the left. On cloudy days, the fabric shadings are rolled up in the pipes and unfolded on sunny days.

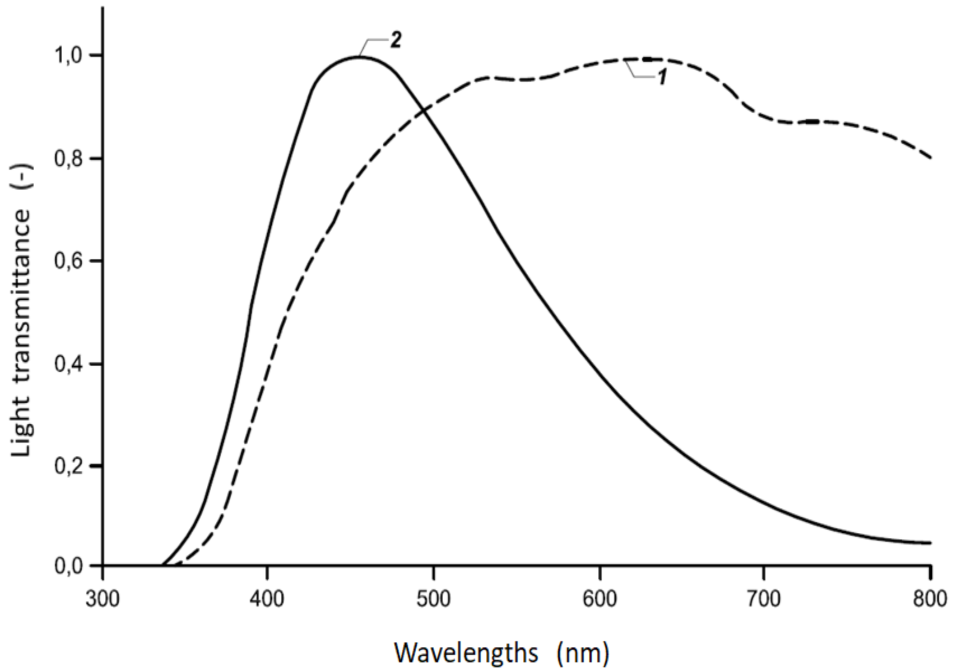
Switchable glazing



Electrochromic triple glazing system

1 - power supply,
2 - electrochromic pane glass,
3 - inner panel with low-emission surface treatment,
4 - cavity filled with noble gas,
5 - window frame,
6 - glass,
7 - transparent electrical conductor,
8 - electrochromic layer,
9 - ion conductor (electrolyte),
10 - electrochromic layer (ion accumulator)

Electrochromic glazing



Relative spectral transmittance of light through electrochromic glazing

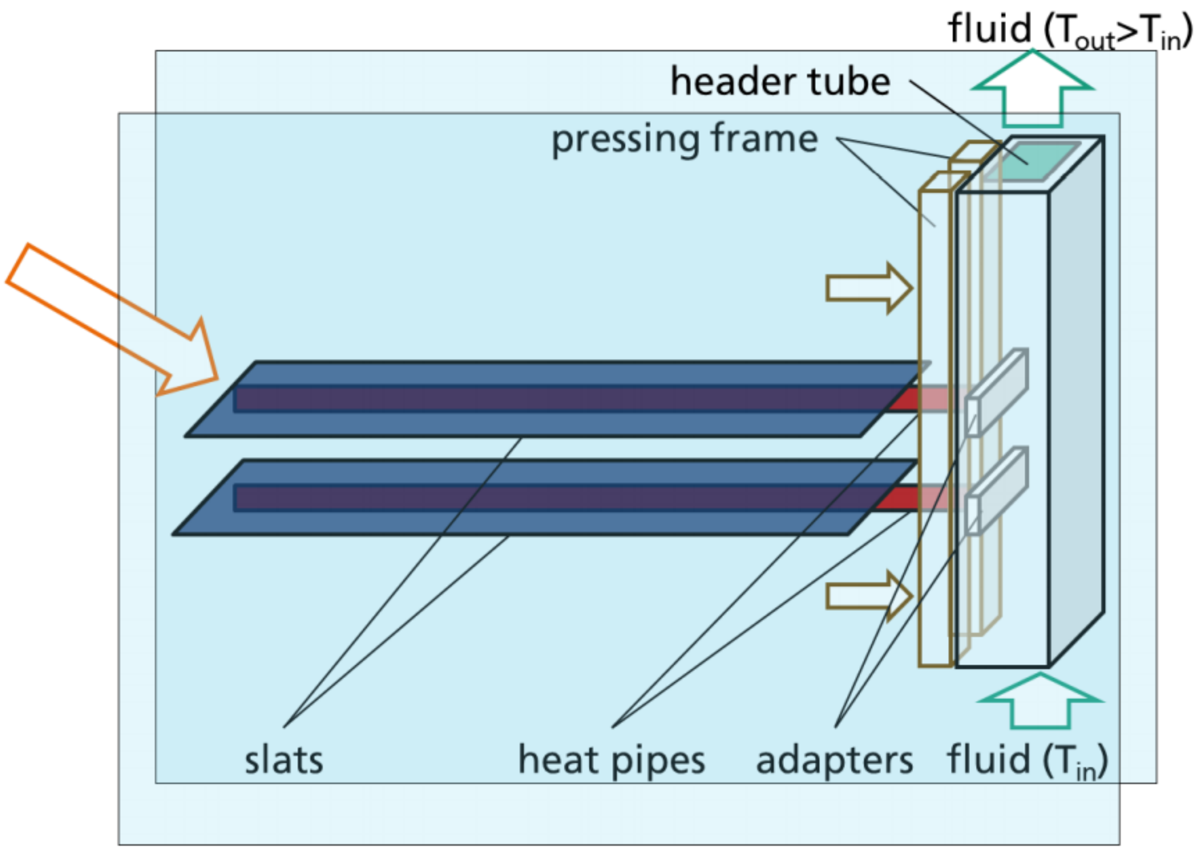
1) clear state, 2) maximum coloring state

Interior view of an electrochromic glazing with panes in fully clear (left) and fully dark (right) states

More detailed and broader information on switchable glazing can be found in Module 2, Chapter 4

Multifunction systems

5
Adaptive shading systems



Solar thermal venetian blinds

- Heat pipes are integral part of conventional venetian blinds.
- The heat pipes transfer heat to the collecting pipe, which is part of the building hydraulic loop.
- The rotation of the blinds can be controlled automatically based on instructions from the central control system. It is a complex moving mechanical system with many components and fluid.
- Such systems are costly, maintenance-intensive, and less effective than the expected efficiency, which is usually based on optimistic theoretical assumptions.

Specific adaptable shading systems

The flat photobioreactor

‘The bioenergy facade’ or SolarLeaf facade

SolarLeaf’s bioreactors have four glass layers. The two inner panes have a 24-litre capacity cavity for circulating the growing medium. Compressed air is introduced to the bottom of each bioreactor at intervals. The gas emerges as large air bubbles and generates an upstream water flow and turbulence to stimulate the algae to take in CO_2 and light. At the same time, a mixture of water, air and small plastic scrubbers washes the inner surfaces of the panels.

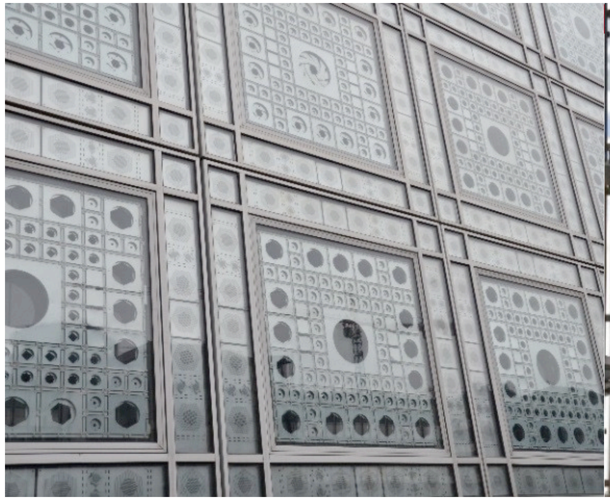
„Living wall systems“

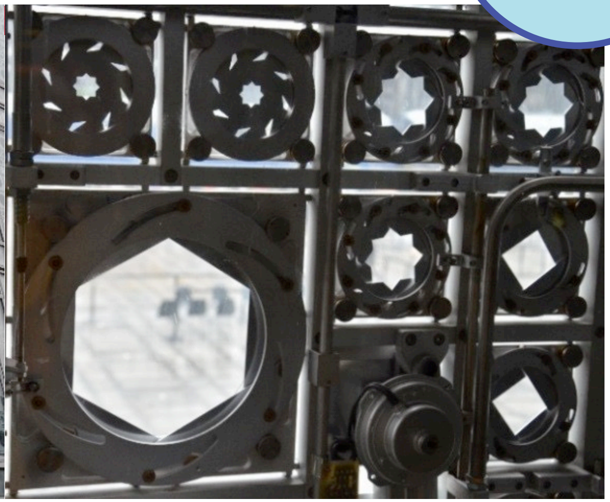
5
Adaptive shading systems

EXAMPLES OF COMPLEX ADAPTIVE SHADING SYSTEMS OF BUILDINGS

Adaptive shading system of Arab World Institute in Paris

- Probably the most known example of adaptive solar shading system is the Arab World Institute designed by architect Jean Nouvel and completed in 1987 in Paris, France.
- The architect drew inspiration from an archetypal element of Arabic architecture (the mashrabiya) and between two glass sheets of southwest facade suggested metal elements like the camera shutters.
- Elements are individually controlled by small motors connected to a central computer control. Users can not overrule the control system.
- The 30,000 light-sensitive mechanical control diaphragms resulted in constant maintenance and serious mechanical problems.

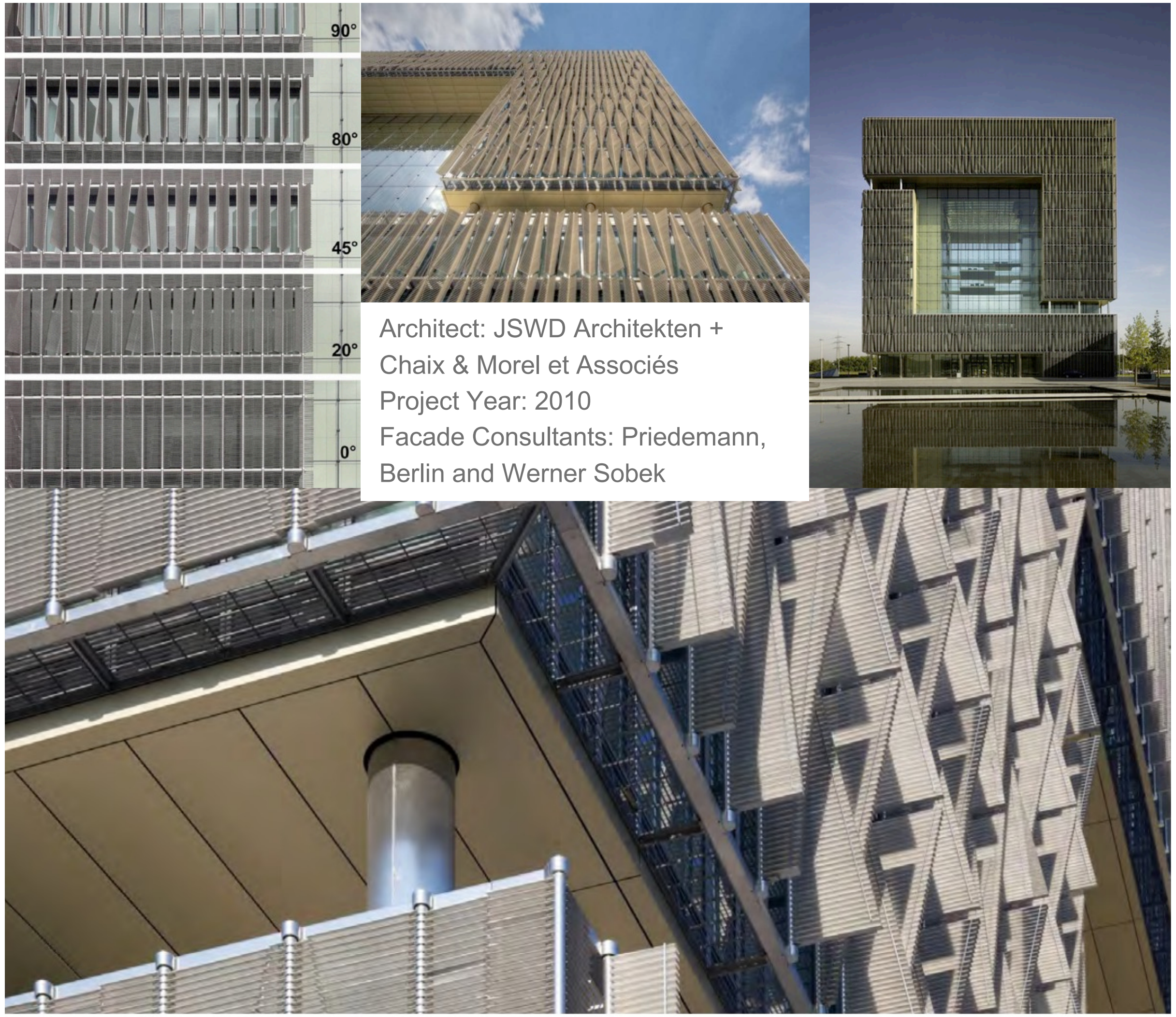




view from the interior

Adaptable shading system of Q1 Building: ThyssenKrupp Quarter

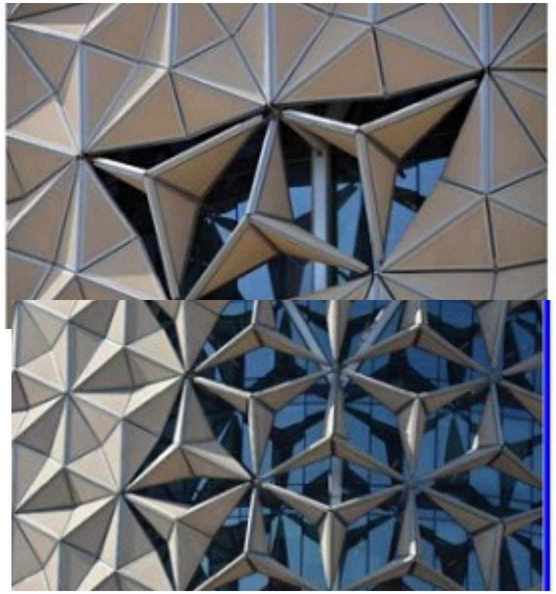
6
Examples of systems



Architect: JSWD Architekten + Chaix & Morel et Associés
Project Year: 2010
Facade Consultants: Priedemann, Berlin and Werner Sobek

- Adaptive solar shading system of ThyssenKrupp Quarter (known as Q1) in Essen in Germany consists from many stainless steel louvers and triangular, square, and trapezoidal fins (totally 400.000 centrally controlled slats), which open and close according to sun position in real-time.
- The movement of the shading elements is ensured by a total of 1600 motors.
- This system also tries to maximize the views for the users, but users have no preference override the control system.
- Daylighting in Q1 is kept at a level that meets standards for artificial lighting.

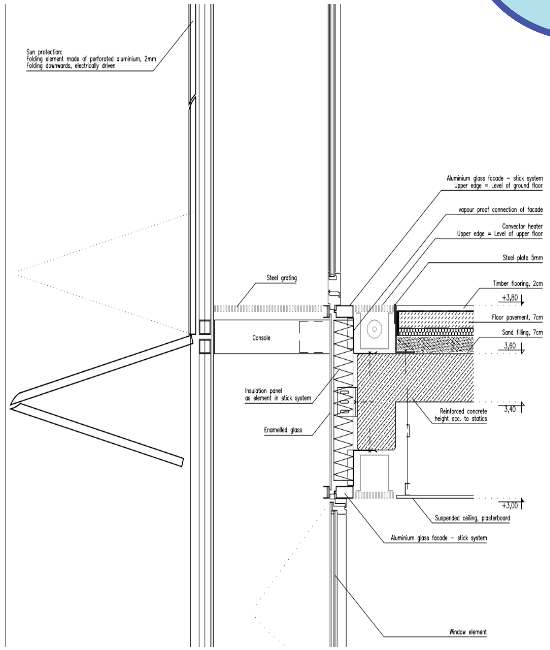
Adaptive shading system of Al Bahr Towers in Abu Dhabi



The sliding and rotating components of adaptive shading system of Al bahr Towers in Abu Dhabi is very complex. Adaptive modules with servomotors and hydraulic pistons must be perfect synchronized. The system is very expensive and difficult to maintain. The system is inspired by traditional Arabic sunscreen called masharabiya. It is made from metal frames and fiberglass panels. When a panel is damaged it is easy replaceable. All components of the sunscreen have been tested in wind tunnel and for fatigue. The shading system should reduce 50% of solar heat gains.

6
Examples of systems

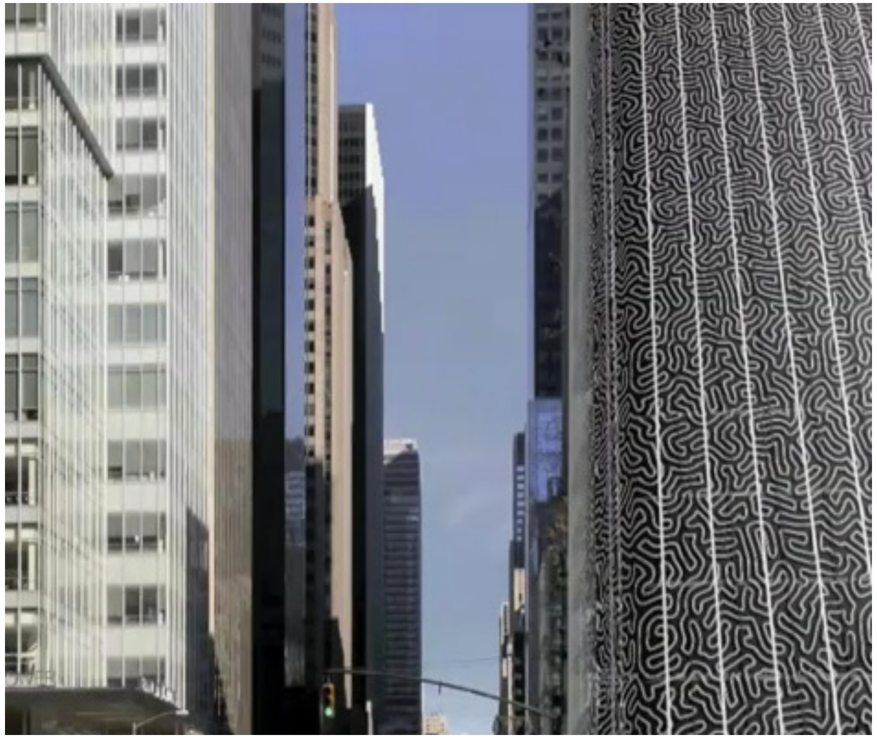
Kiefer Technic Showroom is an exhibition space and office in Bad Gleichenberg in Austria

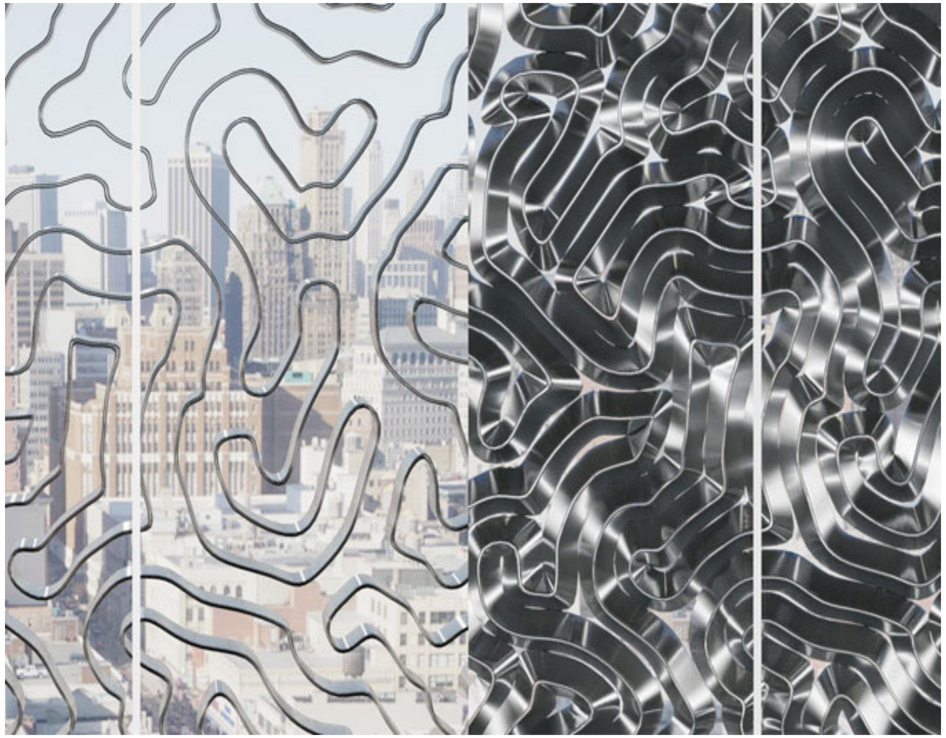


Adaptive shading system consists from 112 folding elements made of perforated aluminium. Elements are electrically driven and can be adapted individually to changing outdoor conditions and users needs. Shading device can also be controlled by optimizing program if users are not present in indoor spaces. So, façade changes continuously and shows a new “face” practically each hour.

The experimental prototype of Homeostatic Facade devised by Decker Yeadon (architectural practice firm based in New York, USA)

6
Examples of systems

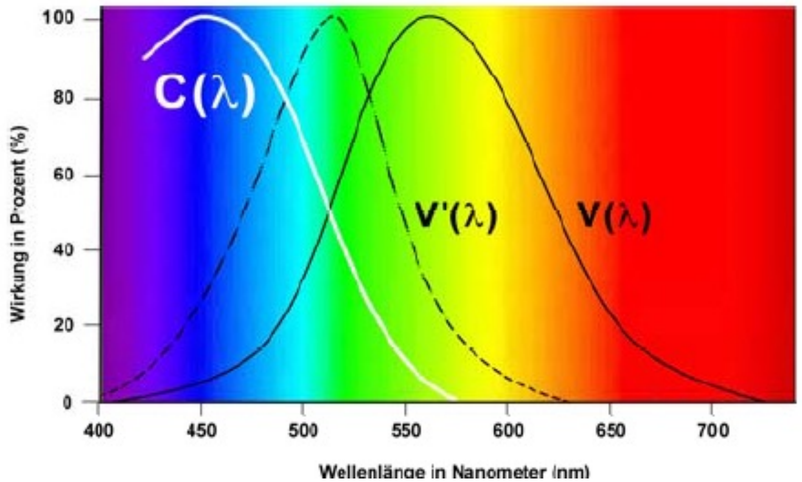




Homeostatic facade system was inspired by homeostasis in biological systems. The shading system is based on principle of dielectric elastomers, which create swirling ribbons. When solar energy warms up indoor environment, the surfaces of the ribbon expand and shade the interior. System works automatically; user has no control on the system.

Hachinger Bach Elementary School, Neubiberg, Germany

6
Examples of systems



- Orange and red colors filter the blue component of daylight, which is unfavorable in terms of chronobiology.
- The photoreceptor melanopsin in the eyes is sensitive to blue light - *C(λ)*. Blue light affects the production of the hormone melatonin that affects a variety of processes: blood circulation, blood pressure, body temperature, metabolism of sugars, fats and proteins, affect immunity etc.

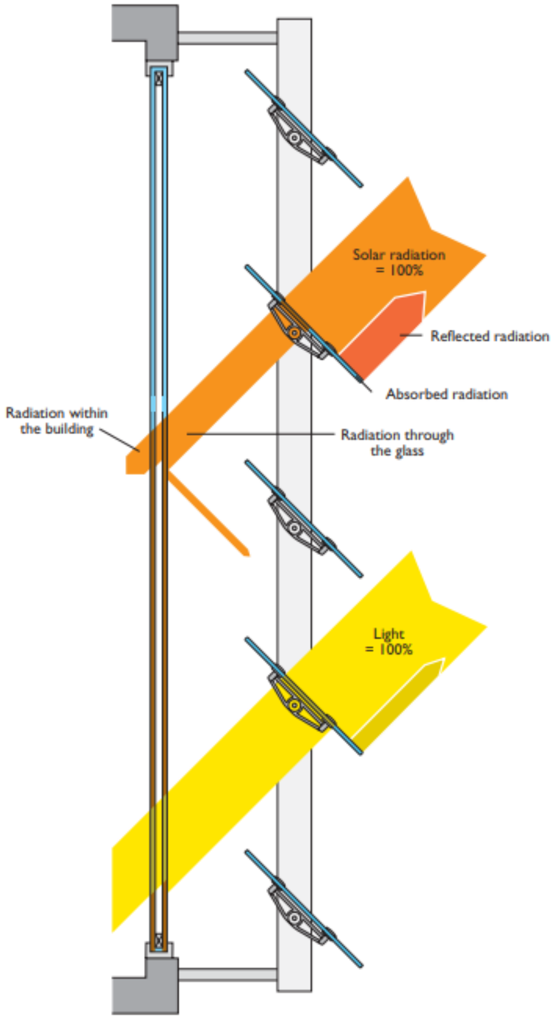
Automatic sun tracking louvres of Berlaymont building of the European Commission in Brussel

- External laminated glass louvres were added to regulate solar gain and glare during large-scale refurbishment in years 1991 - 2004.
- 20,000 m^2 glass used in the motorized louvres.
- This consisted of a pattern of dots which are white on the outside but appear black when viewed from inside. The white helps to reflect solar energy on the outside and provide window privacy. From the inside the black dots absorb rather than reflect light and allow an excellent view outside.
- The one-way glass louvres are controlled by a computer and weather station on the roof of the building, which orients the louvres according to the degree and direction of the sunlight.

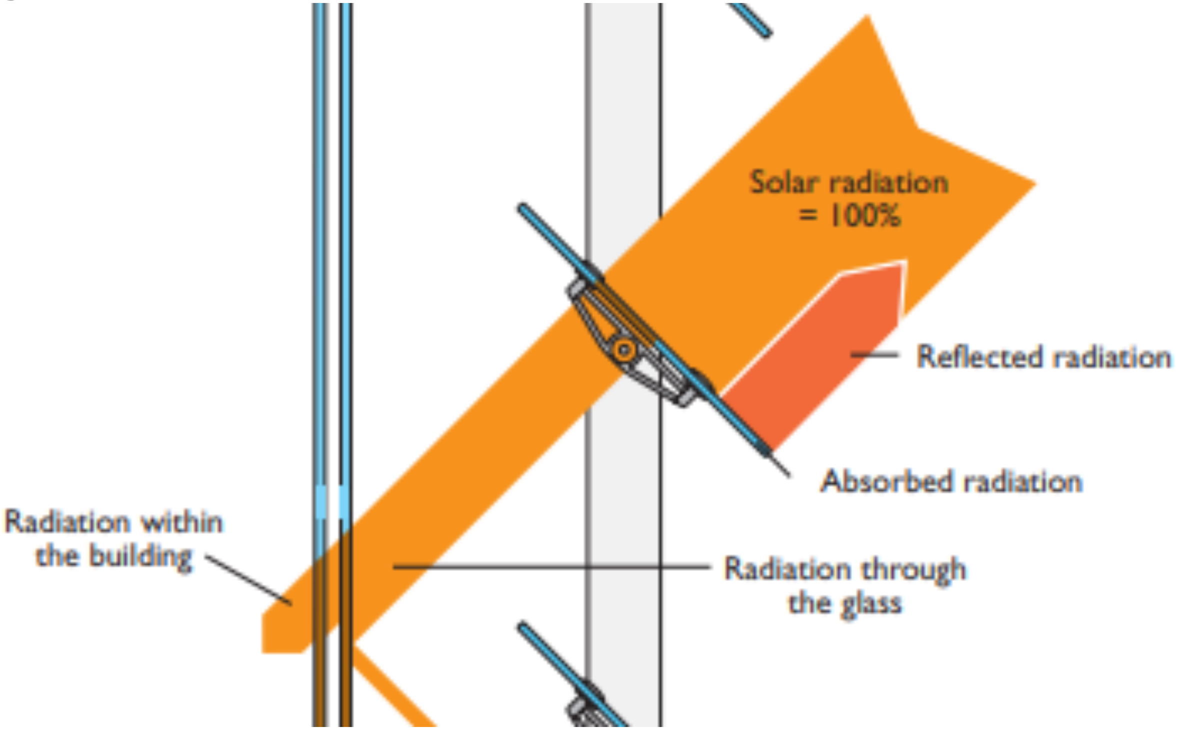
The European Commission's headquarters in the Berlaymont building is not one of the buildings with almost zero energy needs. However, its facade has the features of many nZEBs.

Automatic sun tracking louvres of EC building in Brussel – principle of operation

6
Examples of systems



If a controllable system is installed, adjustable glass louvres track the position of the sun, thereby reducing the numbers of days when the building overheats. Equally, in winter the louvres may be adjusted in such a way that the building benefits from the heat from the sun, and they can be closed at night reducing heat loss.



CONCLUSIONS

Strengths of adaptive shading devices

- ✓ When the adaptive shading devices are controlled in an optimal way, maximum indoor environmental quality and comfort can be ensured and energy performance of buildings can be improved.
- ✓ Adaptive shading devices have the ability to respond to, or benefit from, changes in outside climatic conditions and dynamic occupant requirements.
- ✓ Most of adaptive shading devices enhanced thermal properties of a building facade.
- ✓ Adaptive shading devices considerably reduce glare risk.
- ✓ Most of them improve architectural appearance of a building.

What is the holy grail of adaptive façades in the future? Keep it simple!

Limitations of adaptive shading devices

- Adaptive shading devices require a careful detailed design, installation and HVAC integration for best performance.
- A common problem is that they tend to be designed on the product or component level with less attention to the building level.
- The final overall costs of adaptive shading devices are still higher compared to traditional solutions.
- Many adaptive shading systems require high maintenance. Not yet evidence on long-term durability of adaptive shading devices.
- The adaptive shading systems have the trend to become high-technological and complex because many contemporary buildings are designed too complex and often over-glazed.
- The paradoxical consequence of high-quality adaptive shading devices is that less attention is paid to the physical properties of the facades themselves.
- Post occupancy testing of adaptive façades is urgent and results should be published in order to help improve practice.

Syddansk Universitet, Kolding, Denmark

The Syddansk Universitet in Kolding, Denmark features a climate-responsive kinetic facade that regulates interior temperatures with approximately 1,600 triangular metal shutters that automatically provide the right amount of light to either shade or heat up the interior.

Where and how is the energy included for the production, operation and maintenance of this shading device?

Thank You

For Your Attention!

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