Case Studies – Adaptive Facade Network

Laura Aelenei
Daniel Aelenei
Rosa Romano
Enrico Sergio Mazzucchelli
Marcin Brzezicki
Jose Miguel Rico-Martinez

EUROPEAN COOPERATION
IN SCIENCE AND TECHNOLOGY

Case Studies

Adaptive Facade Network

Case Studies – Adaptive Facade Network

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It allows researchers, engineers and scholars to jointly develop their own ideas and take new initiatives across all fields of science and technology, while promoting multi- and interdisciplinary approaches. COST aims at fostering a better integration of less research intensive countries to the knowledge hubs of the European Research Area. The COST Association, an international not-for-profit association under Belgian Law, integrating all management, governing and administrative functions necessary for the operation of the framework. The COST Association has currently 38 Member Countries.

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Editors
Laura Aelenei, Daniel Aelenei, Rosa Romano, Enrico Sergio Mazzucchelli, Marcin Brzezicki, Jose Miguel Rico-Martinez

Layout and Co-Editing
Ashal Tyurkay, Uta Pottgiesser

Design
Sirene Ontwerpers, Rotterdam

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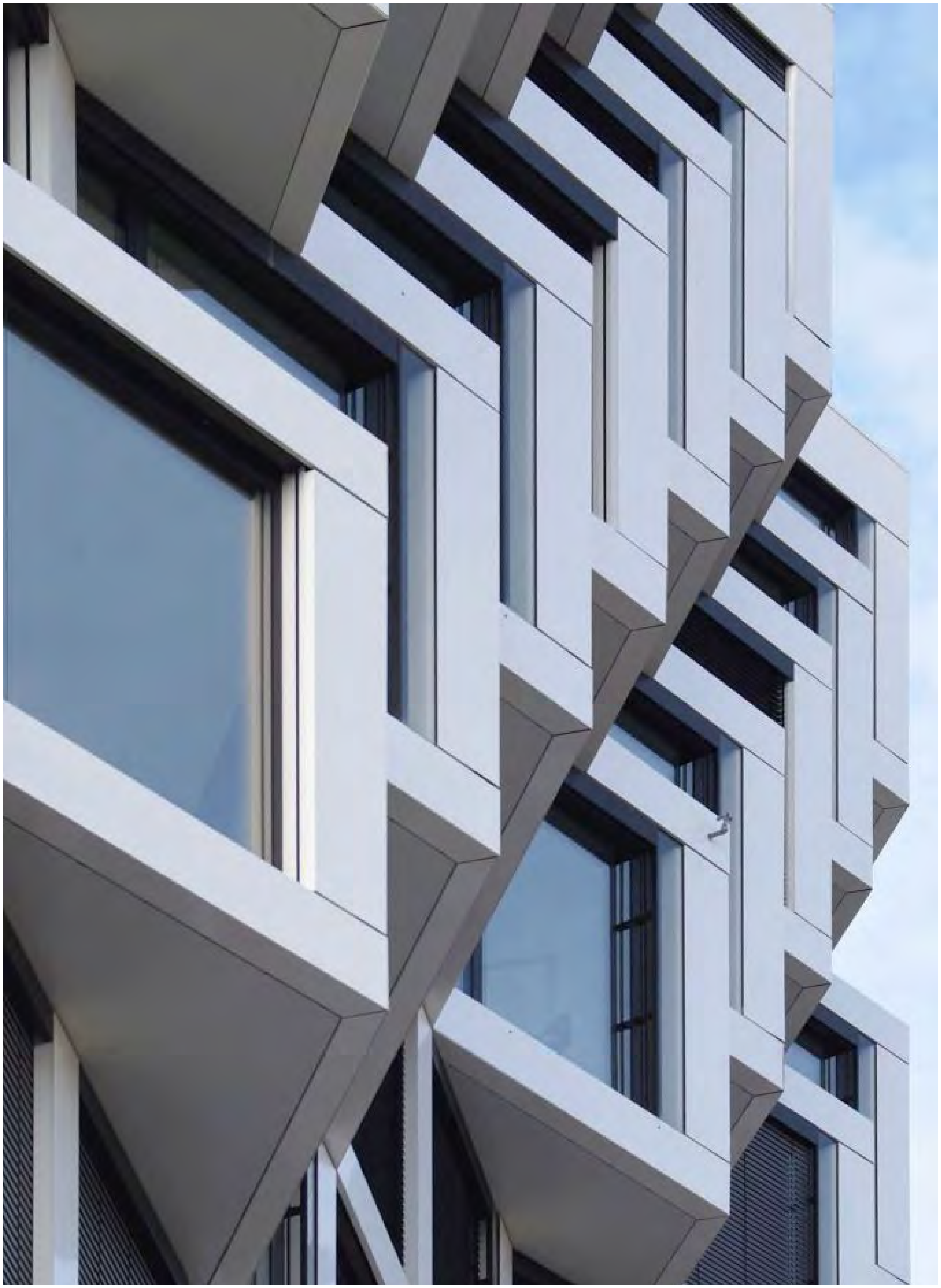
Wohntürme Friends in München / Allmann Sattler Wappner (image: M. Brzezicki)

Preface

Adaptive building envelopes can provide improvements in building energy efficiency and economics, through their capability to change their behaviour in real time according to indoor-outdoor parameters. This may be by means of materials, components or systems. As such, adaptive façades can make a significant and viable contribution to meeting the EU´s 2020 targets. Several different adaptive façade concepts have already been developed, and an increase in emerging, innovative solutions is expected in the near future. In this context the EU initiative COST Action TU 1403 aims to harmonize, share and disseminate technological knowledge on adaptive facades at a European level.

According to the definition given by this COST Action, an adaptive façade is a building envelope consisting of multifunctional and highly adaptive systems that is able to change its functions, features, or behaviour over time in response to transient performance requirements and boundary conditions, with the aim of improving the overall building performance.

In order to explore the available and emerging technologies focusing on adaptive façades, Working Group 1 of the COST Action undertook research to form a database of adaptive façade case studies and projects structured in accordance with a simple classification – materials, components and systems. In addition to this, details of the purpose of the systems/components/materials with adaptive features and the working principle of each technology were also collected together with data regarding design practice, technology readiness, and economical aspects, among others.

The information was collected with the help of a specific online survey (structured in the following main sections: detailed description - metrics- characterization- economic aspects – references). The database includes 165 cases of adaptive façade systems, components, and materials that allowed a variety of analyses to be carried out. According to the classification adopted within WG1 (materials, components, systems), each of the classification terms are introduced together with examples from the case study database in the following sections. This volume ends with a section dedicated to future developments, where different issues are addressed such as embedded functionality and efficiency amd biomimetic inspirations. The importance of adaptive façades through their flexibility, and intelligent design within the context of smart cities is also discussed.

The work within Working Group 1 - Adaptive technologies and products was developed within four distinct sub-groups (SG) in order to provide outputs according to the objectives of this WG and the COST Action: SG1 – Database, SG2 – Educational Pack, SG3 – Publications and Reports and SG4 – Short Term Scientific Missions (STSM).

This work was possible due to the strong commitment and work of all WG1 members: Laura Aelenei, Aleksandra Krstić-Furundžić, Daniel Aelenei, Marcin Brzezicki, Tillmann Klein, Jose Miguel Rico-Martínez, Theoni Karlessi, Christophe Menezo, Susanne Gosztonyi, Nikolaus Nestle, Jerry Eriksson, Mark Alston, Rosa Romano, Maria da Glória Gomes, Enrico Sergio Mazzucchelli, Sandra Persiani, Claudio Aresta, Nitisha Vedula, Miren Juaristi.

Laura Aelenei

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Cubus Office Building / Gigon Guyer Architekten (image: M. Brzezicki)

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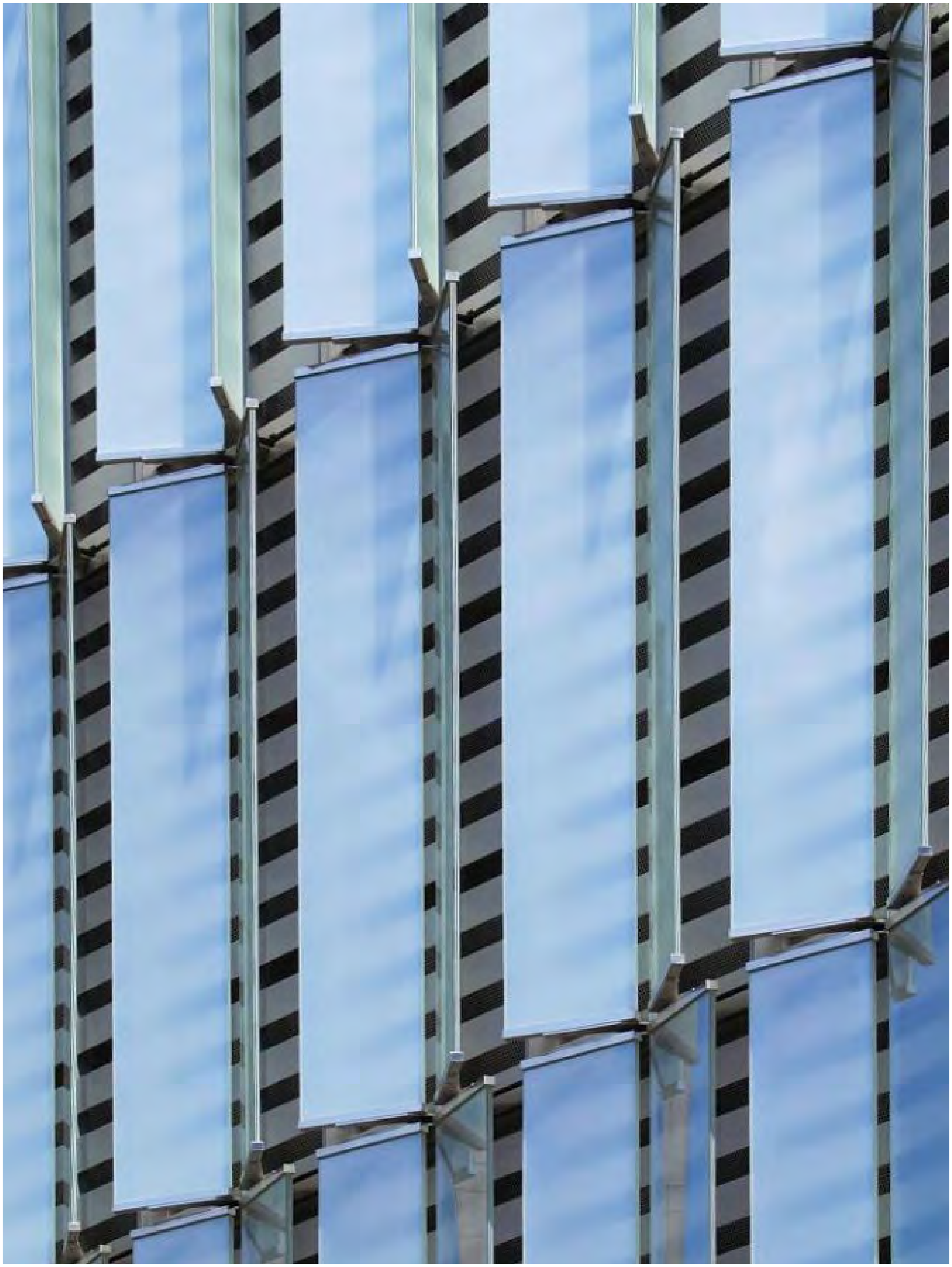
One World Trade Center / David Childs, Skidmore, Owings & Merrill (image: M. Brzezicki)

Introduction

Marcin Brzezicki, Daniel Aelenei, Laura Aelenei, Rosa Romano, Enrico Sergio Mazzucchelli, Jose Miguel Rico-Martinez

Adaptive facades; Definitions and Technological Evolutions

Adaptive façades consist of multifunctional highly adaptive systems, where the physical separator between the interior and exterior environment is able to change its functions, features or behaviour over time in response to transient performance requirements and boundary conditions, with the aim of improving the overall building performance (Loonen et al., 2015). Furthermore, these envelope systems can seize the opportunity to save energy by adapting to prevailing weather conditions, and support comfort levels by immediately responding to occupants' needs and preferences (Loonen et al., 2013). In other words, adaptability can be understood as the ability of a system to deliver intended functionality, considering multiple criteria under variable conditions, through the design variables changing their physical values over time (Ferguson et al., 2007).

But, is it possible to find a single definition for the complex panorama of smart envelope systems that have characterized the contemporary architecture of the last decade? For years, architects and building scientists have envisioned the possibility that future buildings would possess envelopes with a certain type of adaptive response to changing environmental conditions. In 1975 N. Negroponte (Negroponte, 1975) introduced the concept of responsive environment, capable of playing an active role, initiating to a greater or lesser degree changes as a result and function of complex or simple computations. In 1981, Mike Davies proposed the idea of 'The polyvalent wall', an envelope system where several functions can be integrated into one layer (Davies, 1981). However, only in recent years, technological research has been investigating new experimentation frontiers capable of reaffirming the osmotic quality of a process of exchange that concerns energy flows that have passed and exchanged right through the envelope (Altomonte, 2008). These studies are new research to demonstrate if a vertical closure surface can be equipped with systems designed to ensure the dynamics required to the managed energy flows in the same way as a biological organism. From the screening system of the Arab World Institute by Jean Nouvel to the dynamic screenings of Al Bahar Towers by Aedas Architects, the new frontiers of innovation in architecture are oriented towards proposing new models of approach in which the "building organism" is also capable of autonomously ensuring the comfort of its users. In this sense, the evolution and dissemination of Information Technology Control (ITC) systems (from home automation to Building Management Systems (BMS)) to transfer the potential of systems equipped with artificial intelligence to the building scale, has ensured the regulation of space also in the absence of human users and in relation with a whole series of requirements that guarantee optimisation from the functional and physical perspective of the built space.

Therefore, adaptive façades can be considered the last frontier of contemporary architectural and technological research which is more and more related to the wish of designing new dynamic envelope models, which, with the help of sensors, system components for energy production and smart materials, contributes towards reducing the building's energy demand. These are technological solutions that, as previously mentioned, are capable of managing energy flows by altering the properties of fixed devices (smart materials) or by controlling (manually or automatically) moving parts (e.g. sunshades, windows, ventilation outlets, etc.) in relation to the type of user and complexity of the building. This envelope typology is marked by dynamic anisotropy that is the capacity to offer different solutions for the different exposures of the building, where a change in the structure modulates the various environmental flows according to the climatic conditions of the place, including external climatic-environmental conditions.

Given the complexity of the topic and multiple variables affecting the performance of these systems, in the collaborative frame of COST Action TU 1403 (http://tu1403.eu), a characterization was carried out in terms of technologies and purpose, as described in Figure 1, where the first column represents the purpose of façade/components with adaptive capacity, which can be related with thermal comfort, energy performance, indoor air quality (IAQ) and visual and acoustic performance, among other requirements.

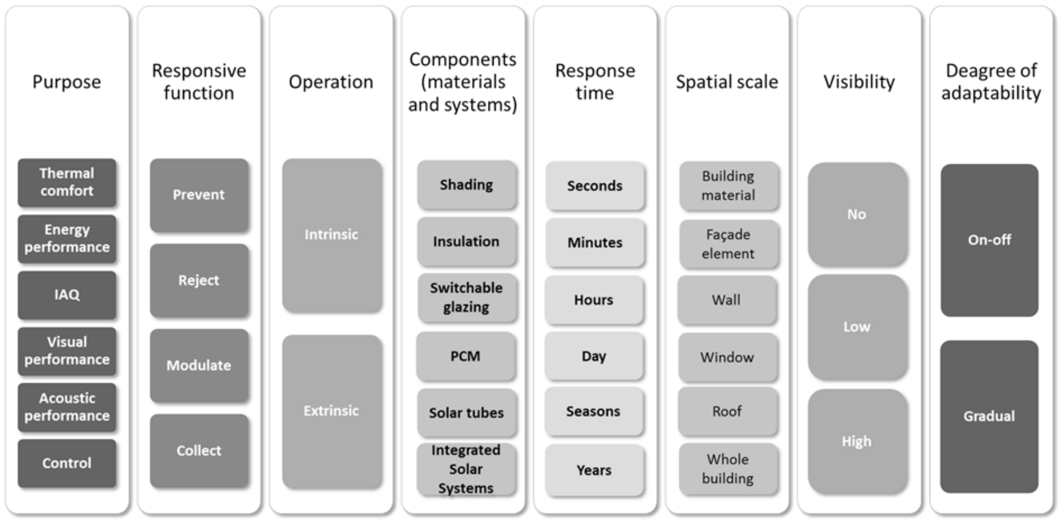

Figure 1 - Overview of characterization concepts for envelope adaptivity (adapted from Loonen et al, 2015)

Adaptive façade classification

The wealth of available adaptive façade technologies called for some systematic approach to recognize and study the façades properly. The attitude presented by the members of WG 1 was towards an analytic approach: the definition of higher rank structures within the façade (façade-systems) and recognition the lower-rank sub-structures: (components and materials) which made up the higher rank structures. This approach also allowed to study the sub-structures separately. In this regard, the database case studies were classified into three main groups, related to the following definitions:

- **Material:** a material can be in different states of refinements such as raw, extruded or coated. Also, materials that are inseparable combined, such as bi-metals, belong to his category. Examples of these types of material are: Polymer, Bi-metal, steel, wood, phase change material.
- **Component**: a component is an assembly of a different set of elements. It forms a complete constructional or functional unit as part of a façade. For example, we can define as component systems an insulated glass unit but also a window frame including glazing or a sun-shading device.
- **Façade-system:** a façade system is composed of different transparent or opaque structural or technical components. It fulfils all basic technical façade functions such as insulation, rain and wind tightness. Example of façade systems are: curtain wall; prefabricated module; double skin façade; ventilated façade, etc.

The conceptual diagram of the case study classification is explained in Figure 2.

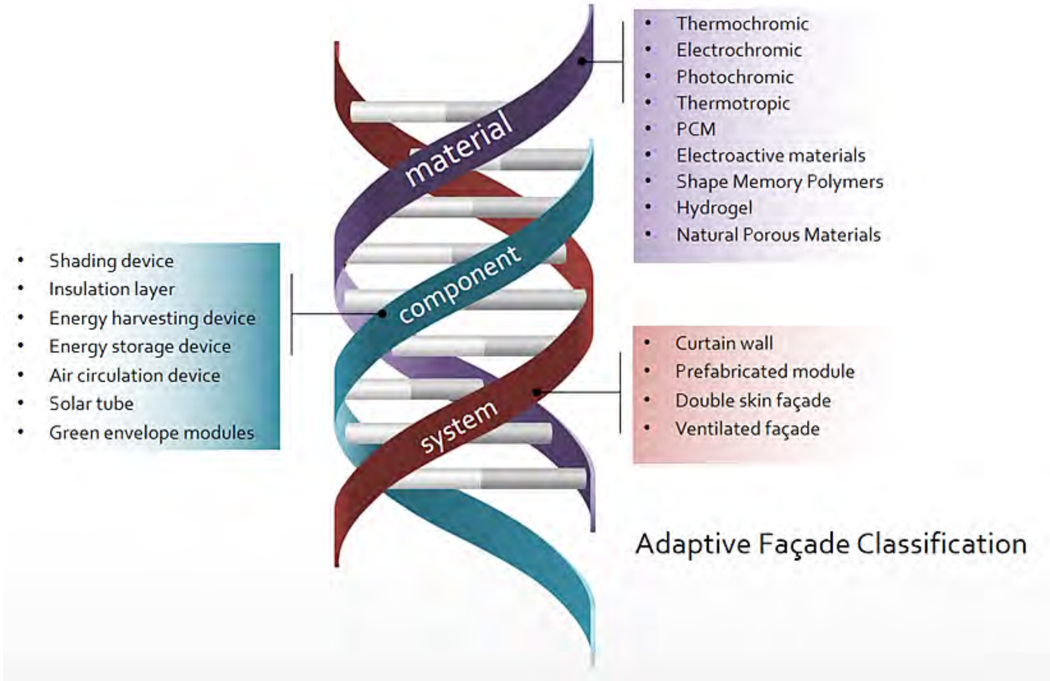

Figure 2 - Conceptual diagram of the case study classification

Case studies database

To study the adaptive façades a case studies database was developed within the frame of COST TU 1403 with the help of a specific online survey (structured in the following main sections: detailed description - metrics- characterization- economic aspects – references). The database includes 165 cases of the adaptive façade systems, components, and materials that allow conducting a variety of analyses. In the following, the results of simple analyses conducted with the objective to find the distribution of the main parameters described in Figure 1 across the case studies are presented. Survey was prepared using the https://www.easygoingsurvey.com/ mechanism, that was made available by School of Architecture of the University of the Basque Country, UPV/EHU.

Basic parameters. The most common entry was the AF System (41%), the AF Component and AF Materials being represented in approximately the same degree with 27% and 32%, respectively (Figure 3). In all the cases, where the area was specified, the majority of buildings are larger than 500 sqm (60%). In this group, the buildings larger than 5.000 sqm represent 34% of database feed (Figure 4).

Regarding type, the most common façade is the double skin façade (DSF) (30%) and prefabricated façade module (32%), while curtain walls constitute the remaining 32% of types (Figure 5). Double façades are popular since the beginning of the 1990s, with the peak in 2014, while e.g. the unitized curtain wall systems initialized in 2012, probably as a result of the CAD/CAM manufacturing systems rapid development.

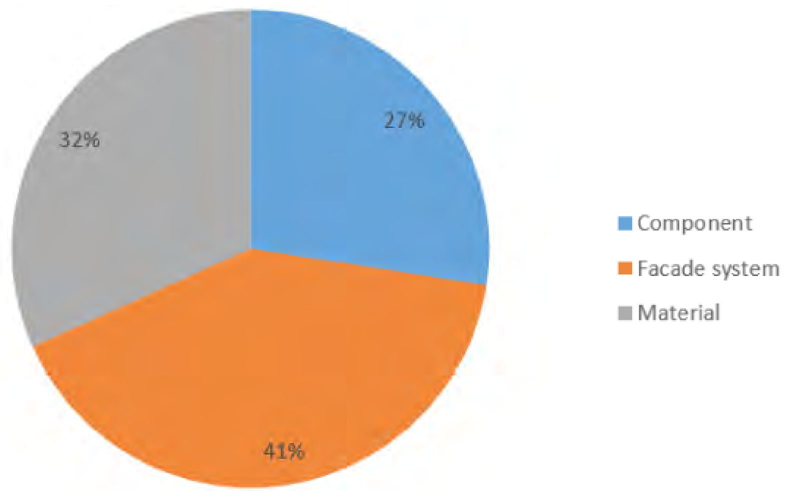

Figure 3 - Adaptive façade type

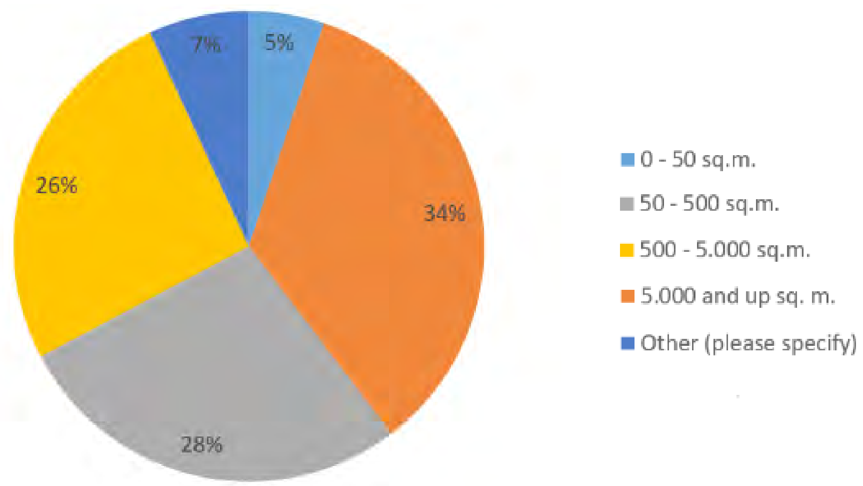

Figure 4 - Building area distribution

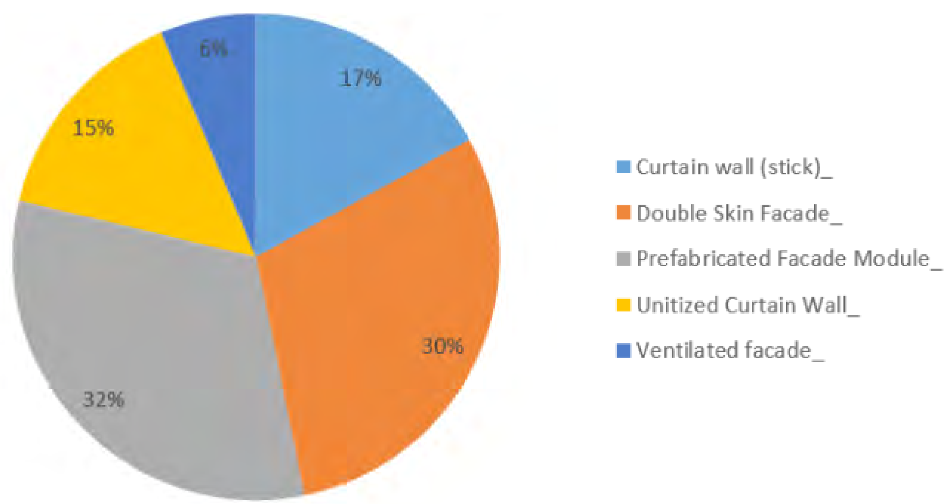

Figure 5 - Façade system type

Function/goal/purpose. With regard of purpose or function, the most frequent features in the façade were thermal (30%) and visual comfort (24%), with a substantial share of the "appearance" answer (16%) (Figure 6). These three inputs constitute over 70% of all entries. This shows that the heat gains and glare are perhaps the major problems in the sustainable design of office buildings because of the environmental cost of HVAC (Heating, ventilation, and air conditioning). The results also emphasize the importance of proper indoor temperature in the building. It could be argued that most entries in the "thermal comfort" category are mostly concerned with the summer performance when there is a significant risk of overheating. The same applies to the entries in the "visual comfort" category which is strongly connected with a glare.

Response time. Regarding response time, the most frequent entries are seconds (49% of cases) and minutes (38% of cases). Diurnal response time is present only in less than 2% of cases. This shows that a relatively fast reaction to the changing outside conditions in the most desirable function of the adaptive façade. This may also indicate that the most important factor that was optimized was insolation.

Another analysis shows that mainly thermal comfort and visual comfort (appearance) are optimized in the scale of seconds and minutes. This strengthens the conclusion that the most common change was the change in terms of centimetres, in order to optimize visual and thermal comfort.

Technology scale. The scale of technology is another important parameter showing development trends and, in this respect, the vast majority of solutions found in the database operate on a scale of "centimeters" (46% of cases). The second largest entry in this category is "nanometers" with 22% which corresponds to technological solutions such as coatings and smart glazing. The comparison of the scale of technology with the year of implementation of the system shows another strong dependence (Figure 7). From the beginning of the development of adaptive façade technologies (approximately in 1998) "centimeter technology" has been developing most dynamically until around 2015, when the share of this scale started to decrease in favour of scale of nanometers and millimeters as a result of coating development.

Technology response time vs. system visibility. Also, the juxtaposition of the "technology response time" and "system visibility" shows important features. 42% of entries shows that technology at the 4th level of visibility (visible change of size and shape like in shutters, flaps, dynamic façade elements) mainly responds in the temporal scale of minutes and seconds. In 12% of cases in total the reaction time was in seconds, but with no visible surface changes (e.g. 2nd level of visibility like in smart glazing) – see Figure 8. A similar relationship is visible between the "response time" and the "degree of adaptivity", where the gradual change concerns 83% of cases in total (the on/off change applies to 15% only). However, the gradual change in the temporal scale of the minutes and seconds applies to as many as 72% of all cases (Figure 9). This clearly shows what type of degree of adaptivity is the most common and in which temporal scale the change takes place.

Control operation type. Extrinsic (requires external control – 53%) and intrinsic (autoreactive – 47%) control operation types are almost equally present. Those two types of control refer in the majority to the technology scale in centimeters (46% of cases), while the intrinsic control is also present in the scale of nanometers (approx. 16% of cases). 53% of cases of both extrinsic and intrinsic control in total refer to the thermal comfort and visual comfort function of the façade. In 16% of cases, the responders also indicated the appearance of the façade – Figure 10.

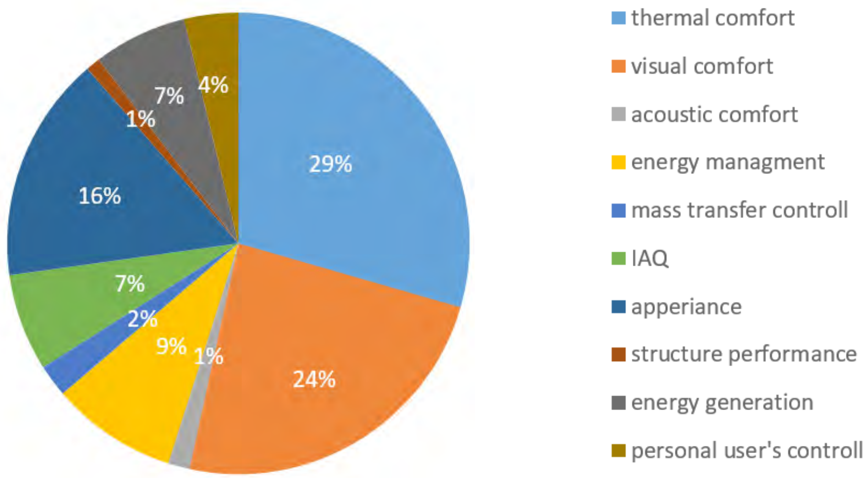

Figure 6 - Function/goal/purpose of the façade

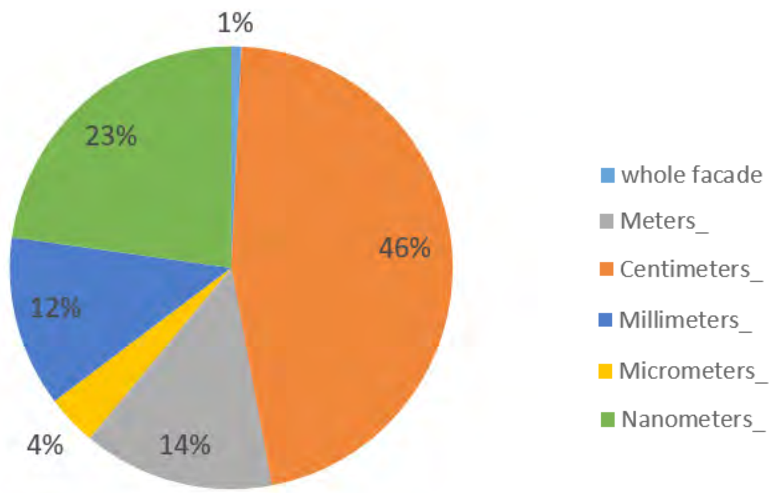

Figure 7 - Technology scale

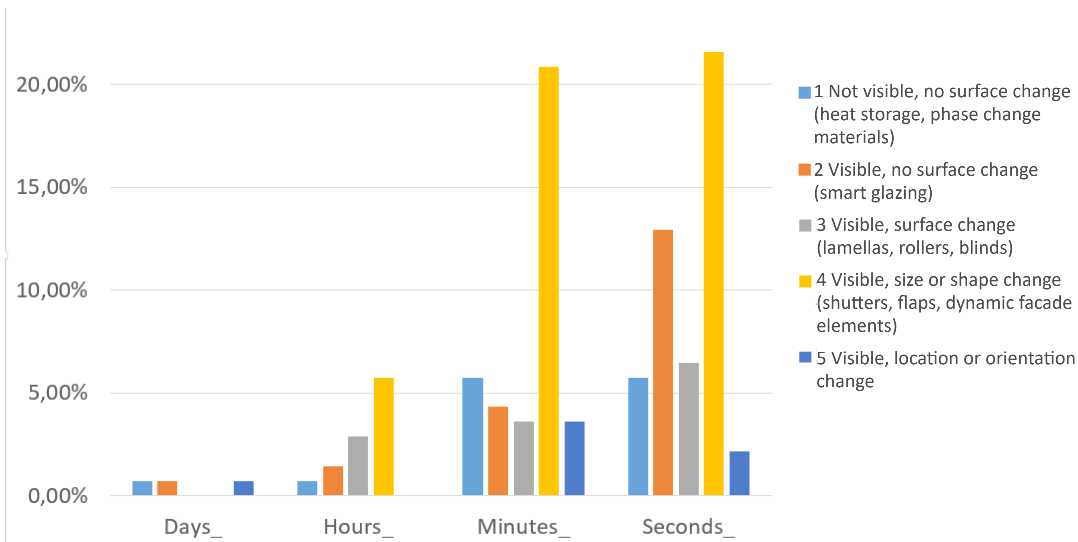

Figure 8 - The juxtaposition of the "technology response time" and "system visibility"

The estimated cost of the façade systems, components and materials. The exact costs of implementing AF technologies were not available to the researchers. Instead, individuals who participated in the survey were asked to assess whether these costs were high, medium or low. In 73% of cases, respondents indicated that the costs of the solutions applied were high, the remaining being divided between medium and low with 19% and 8%, respectively. This means that AF technologies are perceived as expensive, with particular emphasis on the high costs of façade systems, as described in Figure 11.

Map

Throughout the span of the action, WG1 gathered a lot of valuable information including database entries and state of the art on the subject of adaptive systems. Information was available in various databases and formats; the entries were made by different bodies and from different perspectives. The abovementioned information needed verification, master processing, harmonization, and generalization. Existing database was consolidated and reviewed. Missing or improper information was filled.

One of the most important issues in the database created for WG 1 was the establishment of the geographical location of the entries. Climate zone has a profound influence on the adaptive façade solutions that are used in the buildings. It determines the amount of sunlight or e.g. the potential to use sustainable passive technologies like night ventilation and cooling. The map (https://batchgeo.com/map/5487a71fd294c2f8481412c474bcd668) allowed to visualize the location of the entries from the database.

The map is a link between the façade location and the database. Provides the exact geographical location of the building. The map aims to visually determine the location of buildings in space.

Technical map processing. Initially, a modified spreadsheet was created with geographical and web-orientated data. The map was created based on the "batchgeo.com" mechanism that allows for the display of different types of data and for the graphical intuitive data grouping. Case studies were illustrated and linked to the simplified data-sheets that are located on the COST TU 1403 action share point server and are publicly available. The database was prepared, edited and uploaded to batchgeo.com mechanism to prepare professionally working location map of case-studies (encoded with location) or technologies (encoded with inventor's location) with possible grouping options: type; year; climate.

Map Layer Descriptions. Each point in the map has a label featuring the basic data description: the name of the building, the name of the designer, year of construction, link to the designer's web page.

The layer list allows users to select which map layers are visible and active (see Table 1, Fig. 12).

Map scrolling. After scrolling the map the visual representation of all featured case studies will be visible in rows, with the links active. This overview allows seeing all the buildings in a much more accessible form, than on the map.

Map content and conclusions. Some generalization is possible based on the cases gathered in the map. The case studies illustrated on the map are mostly grouped in Central Europe, with some

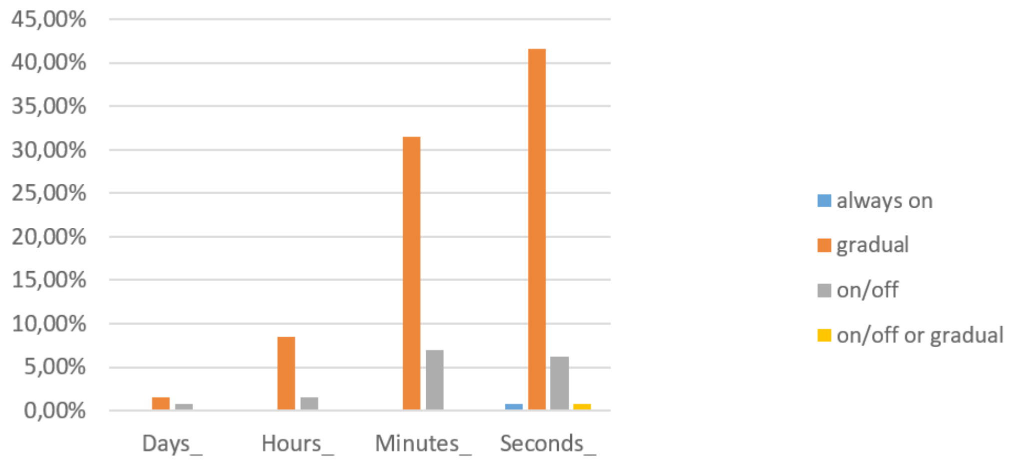

Figure 9 - System degree of adaptivity

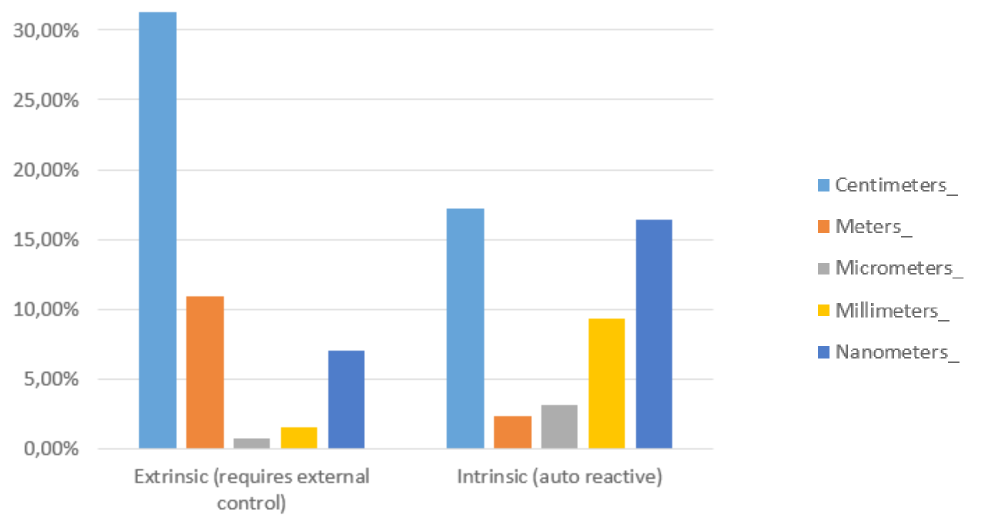

Figure 10 - Control operation time

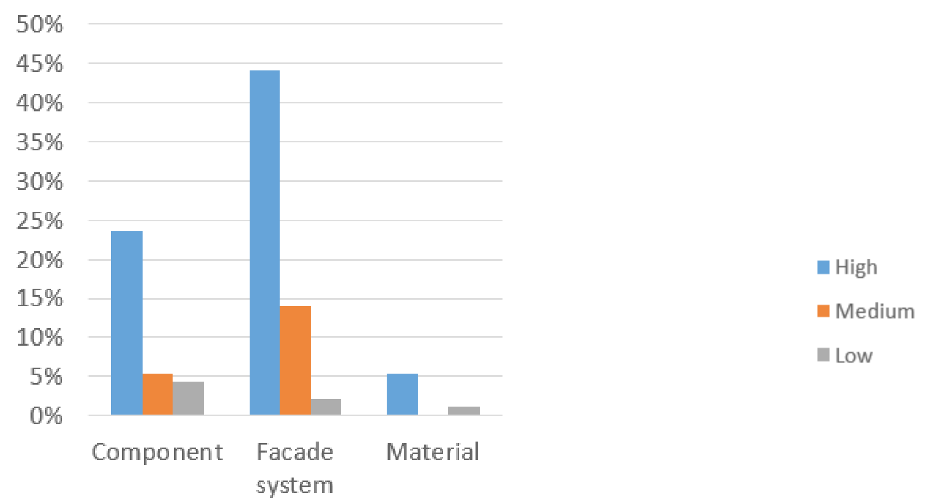

Figure 11 - Estimated cost of the façade systems, components and materials

cases in Scandinavia and the Iberian Peninsula. Some case studies are also located in USA, Middle East, and Asia. The biggest number of case studies is located in Germany (16 case studies). This results in two conclusions:

- The first conclusion is that in wealthy countries with a stable economy and high GDP investors are more likely to implement experimental solutions in buildings, with the emphasis on office buildings. In these countries also, the investment to improve the office rooms user's comfort pays back in a shorter period of time.
- The second conclusion is that adaptive façade solutions work best in the temperate climate zone, where high seasonal temperature variation calls for the use of technologies that adapt to changing climatic conditions – 25% of buildings in Cfb climate (Temperate), and 14% in Dfb climate (Cold continental). Admittedly, in desert climate zones significant seasonal differences in temperature (25-45 °C Jan to Aug) is present, but even in the mildest period of the year temperatures are too high to effectively cool the building through ventilation. In climates where climatic conditions are characterized by low seasonal variability, the use of adaptable façades has less rational justification.

An important conclusion from the map preparation is the ability to precisely locate individual buildings. From the map, it can be clearly seen that most of the buildings are located in city centers with a population of more than 100,000 inhabitants. Especially many buildings are located in the county's capitals, such as 5 buildings in Berlin and 3 in Paris. It is also interesting that the majority of AF Systems in newly built buildings are oriented to the South (75%), which shows that heat gains and glare are the biggest problems in the sustainable design of office buildings because of the environmental cost of HVAC. The database data shows that thermal comfort and visual comfort was the basic main reason for the adaptive façade system in 53% of buildings.

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Table 1 - List of map layers for the basic data description

Name:	Building's name
Location	Exact GPS location of the building. In the case of the material, the location of the institution is given.
Designer or researcher	In the case of the building: name of the designer researcher In the case of the building: name of the designer researcher
Year of construction	Year of construction
Type of entry:	Type of database entry: AF System, AF Component or AF Material
Climate:	Type of climate
Web-link	Provides the link to the designer's webpage

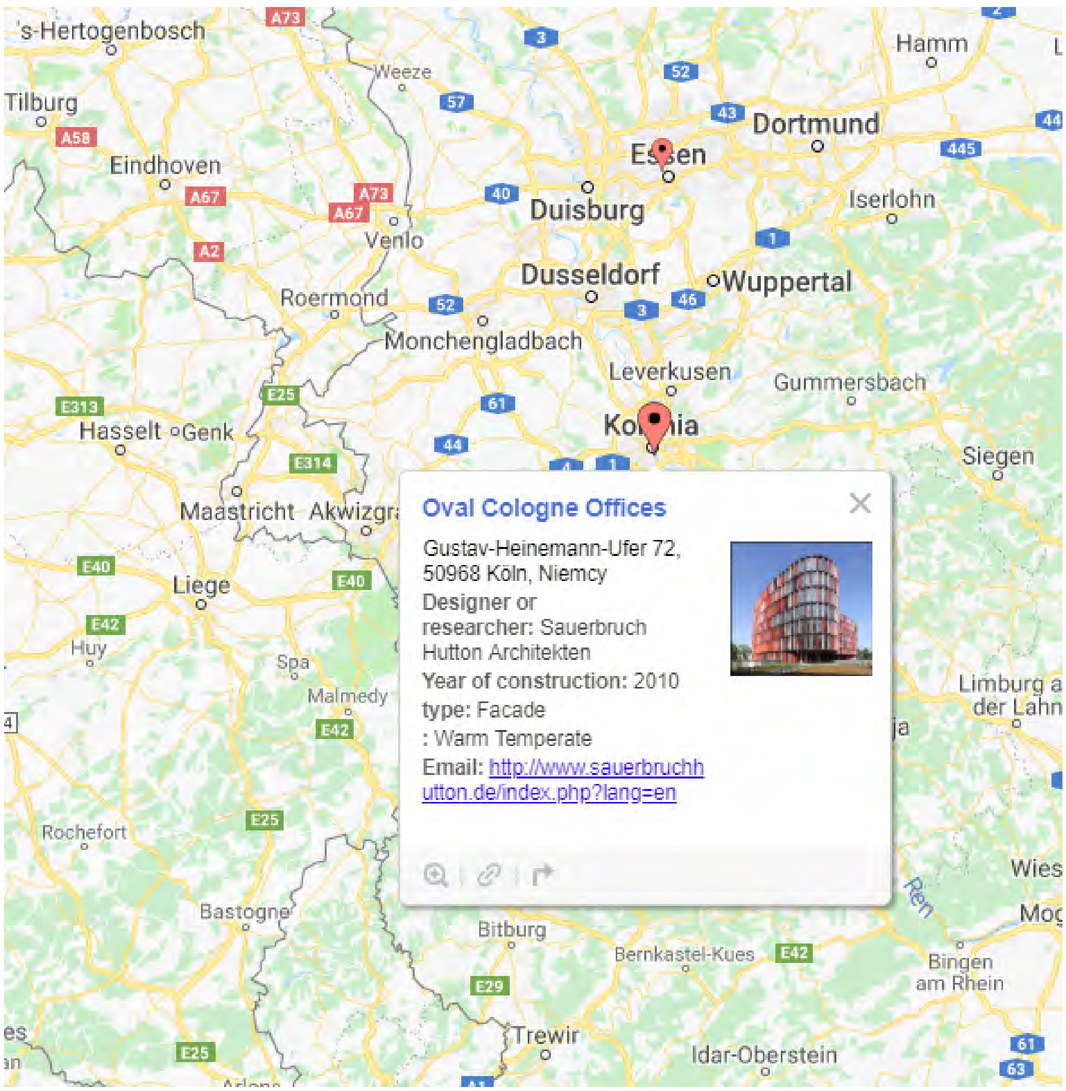


Figure 12 - The tag in the map showing the detailed information about the case-study

Acronyms

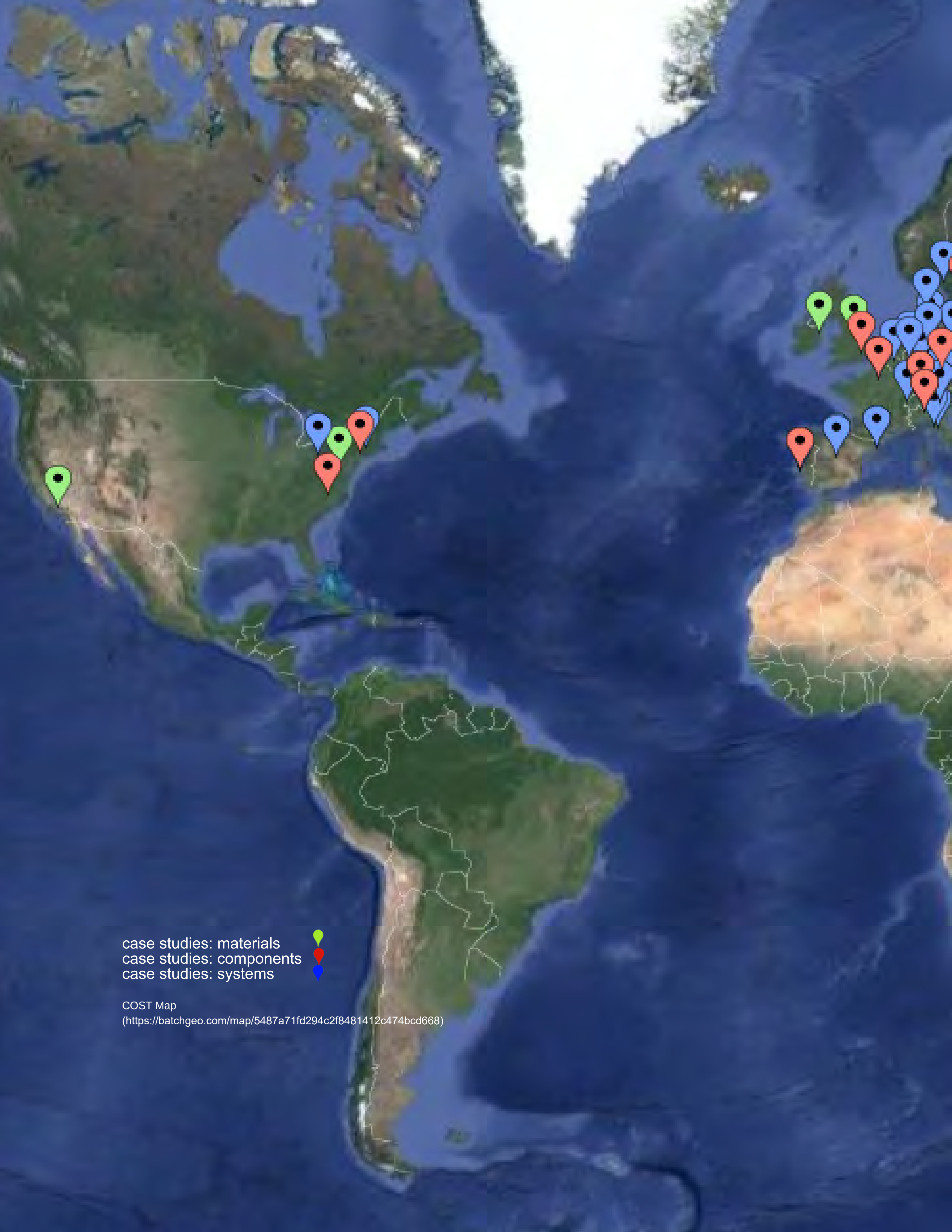
CW	Standard Curtain Wall
ATF	Active Transparent Facades
SG	Switchable Glazing
PCM	Phase Change Materials
MFM	Multifunctional Facade Modules
BF	Biomimetic Facade
AF	Adaptive Facade
CS	Case Study
SMA	Shape Memory Alloys
TIM	Transparent Insulation Material
PTFE	Poly Tetra Fluoro Ethylene
EC	Electro-chromic
SPD	Serial Presence Detect
SDR	Software Defined Radio
CA	Cellular Automata
NN	Neural Networks
EAP	Electro-Active Polymer
CFD	Computational Fluid Dynamics
HVAC	Heating, Ventilation and Air Conditioning systems
TVG	Through Glass Via
SGP®	Sentry Glass Plus
FFG	Fluid Flow Glazing
DSSCs	Dye-Sensitized Solar Cells
NITI	Nickel Titanium
SME	Shape Memory Effect
SE	Super Elasticity Effect
ICCP	Current Cathodic Protection
HEMN	Hydrogel- Embedded Micro-vascular Network
PoDM	Photosensitive organic dye molecules
ETFE	Ethylene Tetra Fluor Ethylene
BIPV	Building Integrated Photovoltaic
ESD	Electro Static Discharge
LED	Light Emitting Diode
UFAD	Under Floor Air Distribution
nZEB	nearly Zero Energy Building
PV	Photovoltaic
EURAC	European Academy
EPFL	École Polytechnique Fédérale De Lausanne
ICTC	Information Communication Technology Centre
IBA	International Building Exhibition
RGB	Red Green Blue
NIR-VIS EC	Spectral Reflectance Measurements Acquired In The Visible (Red) And Near-Infrared Regions
IGU	Insulating Glazing Units
R	Resistance value
°F	Fahrenheit Degree
CO_2	Carbon Dioxide
SELFIE	Smart and Efficient Layer for Innovative Envelope
DE	Germany

IT	Italy
USA	United States America
FR	France
PT	Portugal
DK	Denmark
ROK	South Korea
CH	Switzerland
ES	Spain
AT	Austria
SE	Sweden
FI	Finland
AUS	Australia
CN	China
SE	Sweden
S	South
S-E	South East
S-W	South West
N	North
W	west
N-E	North East
N-W	North West

Climate Type Acronyms from Köppen Climate Classification System (http://www.eoearth.org/view/article/162263/)

Af	tropical rainforest climate
Am	Tropical monsoon climate
Aw/ As	Tropical wet and dry or savanna climate
BWh	desert climate
BWk	Cold desert climates
BWn	Mild desert climates
BSh	Hot semi-arid climates
BSk	Cold semi-arid climates
Csa	Hot-summer Mediterranean climate
Csb	Warm-summer Mediterranean climate
Cwa	Humid subtropical climates
Cwb	Subtropical climates
Cwc	Highland climates
Cfa	Humid subtropical climates
Cfb	oceanic climate
Cfc	oceanic climate
Dsa	Humid continental climates
Dsb	Humid continental climates
Dsc	subarctic climate
Dsd	subarctic climate
Dwa	Humid continental climates
Dwb	Humid continental climates
Dwc	subarctic climate

Dwd	subarctic climate
Dfa	Humid continental climates
Dfb	Humid continental climates
Dfc	Humid continental climates
Dfd	Humid continental climates
ET	Tundra climate
EF	Ice cap climate


case studies: materials
case studies: components
case studies: systems
COST Map
(https://batchgeo.com/map/5487a71fd294c2f8481412c474bcd668)

Case Studies

Toho Cinema in Roppongi Hills / Yu Design (image: M. Brzezicki)

Case Studies - Adaptive Façade Materials

Mark Alston, Nikolaus Nestle, Miren Juaristi, Laura Aelenei, Rosa Romano, Enrico Sergio Mazzucchelli, Jose Miguel Rico-Martinez

Introduction

Materials in the built environment play a major role in operational energy consumption and structural optimization as they are defined by boundary conditions. These materials functions sets the operational performance requirements for building component interfaces as an integrated façade system. Addington and Schodek (2005) identify 'smart materials' as systems possessing 'embedded technological functions' that involve specific environmental responses, operating either through internal physical property changes or through external energy exchanges (Velikov and Thün, 2013). Furthermore, they define the characteristics of smart materials as: 'immediacy' (real-time response), 'transient' (responsive to more than one environmental state), 'self-actuation' (internal intelligence), 'selectivity' (a response is discrete and predictable) and 'directness' (a response is local to the activating events) (Addington and Schodek, 2005).

According with these definitions, the Material chapter (and data base of a selected material grouping) will assess:

- material adaptiveness in response to boundary conditions changes defined by climate, thermal and visual comfort for well-being;
- how materials can be in real time sync with the pattern changes in their environment as an energy, matter connection;
- the dynamic relationship that is achieved through material composite function and material connectivity to building surface geometry. In order to manipulate the climatic environment and obey rules of minimum energy loss and minimized effective power outputs;
- the energy and matter system of material layers, that are nested together to form the overall emergent composition;
- a multi-layering approach at a number of levels of resolution with different spatial and temporal scales;
- the material performative specific tasks that can be classified in the control processing of functional materials, achieved by a bottom up trajectory.

Thermal, visual comfort demands are driven by the prerequisite to moderate climatic regional environments for shelter. To maintain thermal comfort the building envelope acts as a boundary working with mechanical service systems (heating/cooling, lighting) to regulate internal surrounding temperature. In opaque envelopes the technological methods of achieving good thermal insulation is well researched and advanced. However, to achieve visual comfort and contact to the outside environment, at least part of the building skin needs to be transparent. Translucent components can also contribute to visual comfort by allowing ingress of daylight while redirecting it in a way to avoid harsh shadows. By allowing the ingress of solar irradiation into the building comes with heat gain issues that require measures against overheating in warm conditions. Hence, thermal insulation properties of the current state-of-the-art in transparent and translucent building envelopes are rather poor in comparison to those of opaque elements.

Glazed facades in cities offer high value visual and day-lighting provision. Through the optical benefits of view, colour and light intensity cannot be underestimated for human well-being. There are many technical issues to manage this high energy flow between thermal gain and heat loss. Through two types of glazing properties; transparent facades that are optically clear in the visible part of the electromagnetic spectrum and translucent material allowing partial light to pass through for semi-transparent light refraction.

Materials shifting from a transparent to a translucent state is one of the most intensively studied adaptive properties of the façade to regulate transmission of visible light and solar radiation. This is driven by solar radiation impact on a material surface that adsorbs and transports this thermal energy into internal spaces and thus creates a strong need for avoiding unwanted thermal gains and losses. By mainly specifying static quantities such as the U-value and the g-value, present building codes still essentially ignoring the potential of building skin elements for adaptive performance. That directly influences active cooling systems to manage unwanted solar gains fighting internal thermal loads (lighting, equipment, and occupants) for thermal comfort. The challenges in materials with a dominant optic role is optimizing the parameters of visible light transmittance with a lower phase transition temperature for the reduction in air conditioning demand. The ability of current materials to interact with the environment by constant readjustment of functional performance is however still undetermined. In order to meet the demanding Zero Energy Building performance goals a function of adaptability in materials and their integration into component systems is required.

The most controllable form of adaptivity can be reached with materials that can be adapted by an ‘extrinsic’ stimulus such as an electromagnetic field or a pressure change applied to the material. Examples are electrochromic glazing, liquid crystal devices and vacuum insulation that can be switched by a controlled change in the gas partial pressure within the insulation element. To optimally harness the adaptability of such materials, they need to be integrated into special devices that allow the application of the corresponding ‘extrinsic’ stimuli. Another class of adaptive materials reacts to an ‘intrinsic’ stimulus, i.e. a change of a parameter directly relevant for comfort and energy balance of the building such as light intensity, temperature, moisture for example. The characterization of these materials include photochromic glasses, thermo-opaque or shape-memory materials. As an intrinsic environmental stimulus is used to trigger the change in material properties in this case, the integration of the material into a building is usually much simpler than for extrinsically stimulated additivity. However, the adaptively of a facade relying on such a material is autonomous and can’t be extrinsically controlled. That may lead to suboptimal adaptation effects in certain cases (for example, a temperature-induced switching of a facade element to a higher U-value at an external temperature of 12 °C .This is highly useful on a cool summer morning, however, this switching on a warm winter afternoon is unwanted. Alternatively, adaptive facade components responding to intrinsic switching stimuli do not require any connection to active building control systems and thus integration is simpler. Hence, they are extremely attractive to building designers where the aim is aim to increase functionality and performance while at the same time reducing energy use for new or existing buildings.

Further examples are presented in later chapters of the book to illustrate other methods, to realize adaptive facade elements without ‘adaptive’ material (e.g. Yale Sculpture facade; SELFIE facade; BIPV/T Systems). In some of those elements, the material choice nevertheless is crucial for achieving the desired adaptive functionalities in a given facade component. The database illustrates a selective grouping through defining material families and their classification. Materials that depend on a strong deformation cycle of geometry shape change for adaption without fatigue of failure is a prerequisite for this grouping. Nevertheless, it’s not really the material that is adaptive in this case and thus we have decided not to consider such materials in the materials section of this book.

Adaptive Materials Case studies database

Material properties are defined by single values such as thermal conductivity or transmission of solar radiation. Adaptive materials are characterized by a range of values depending on the respective switching parameter or they come with a “memory” for buffered energy flows such as phase change materials. Due to the diversity of these properties, not all materials in the database can be characterized by the same set of properties. Materials with adaptive heat transport properties are scarce with the most notable cases being applied in vacuum panels in which the thermal conductivity is switched by building up a sufficient partial pressure of hydrogen gas to leave the Knudsen regime and phase change materials (PCM) serving as buffer materials for heat.

In the following table, representative adaptive material families are classified according to a dynamic behaviour or performance that they are able to provide as a response to a specific stimulus. As a result, there are four main categories defined by the type of reaction: reversible colour or opacity change, reversible heat flow direction, shape changing materials and materials that absorb water or ambient humidity. Furthermore, this classification becomes more specific when we consider the environmental triggers for reactive self-responses. For instance, thermochromic, electrochromic, photochromic and thermotropic modify their solar reflection, but they do so at different operational scenarios. Thermochromics change their colour when the material reaches a defined temperature, electrochromic materials when an electrical current is applied and photochromics when they are exposed to a specific wave-length of solar radiation. This detailed Material Family Classification, is based on the response input and output, for meaningful scoping in new roles of application in façade systems. By the ability of the material to modify one of their features or properties and to understand under which circumstances that would occur. The following materials have been classified through case study examples as classified by material families and their classification according to their input and output reactions (Table 1).

Table 1 - Material families and classification according to their input and output reactions

Reversible colour / Opacity change	**Reversible heat flow direction**	**Shape Changing Materials**	**Humidity absorption**
Thermochromic [1] Electrochromic [2] Photochromic [3] Thermotropic [4]	Phase Change Materials	Electroactive materials/ piezoelectric materials [5] Shape Memory Polymers [6] Shape Memory Alloys [7] Thermobimetals [8] Bi-layer hygromorph composites [9]	Hydrogel [10] Natural Porous Materials [11]

Material function through Additive Material Manufacturing

The maturing of 3D printing techniques into actual manufacturing technologies will open up further space for the realization of adaptive building components and at the same time further blur the difference between actually adaptive materials and adaptive building elements, whose adaptivity is the result of a combination of several materials into a system. Recently, biomimetic hygroscopic actuators produced by 3D printing of materials with different moisture sorption properties have been demonstrated (Correa and Menges, 2017).

While additive manufacturing definitely will widen the materials toolbox to create adaptive properties in building skins, it also further aggravates the life cycle issues that come with the large-scale use of combinations of different materials at the end of their service life: without viable solutions for separating the different materials again, they will be hard to recycle appropriately. In principle, there are four ways how to deal with this issue:

- monomaterial components that are combined to an adaptive element in a way that can be easily separated again at the end of its service life;
- biodegradable materials (such as suggested in Correa and Menges (2017));
- material combinations that can be separated quantitatively by simple reprocessing techniques such as melting or dissolving a binder component that later is recycled as well;
- material combinations that can be energetically re-used without issues such as dilution of scarce elements or release of hazardous byproducts (for example by using functional carbon materials such as graphene for electrical functionalities instead of metals or inorganic semiconductors).

Conclusions

A selected range of current materials are defined through the data base. In the review to assess the control process methods for an adaptive material function. To reduce solar loads for thermal comfort, through minimizing operational cooling and artificial lighting levels. This material oriented design method will fine tune operational performance to solar gain in real time, for well-being of occupants. The capacity to respond in a dynamic manner to the physical changes of a warming climate is the challenge to advance new and innovative semi/transparent material solutions. To move towards occupant comfort and well-being that is not based on statistical averages but one that is fine-tuned to responsiveness to change. If we assess the information within the database, we realize that more experimental assessments at the façade scale is needed. In order to learn more, what could be new possible application of these materials in Adaptive Facades. However we still need to collect more critical technical data in order to scope their possible innovative applications, through scientific research and product information that are essential for optimized system assembly. We are currently reliant on the origin of the selected materials applied to building envelopes. However a bottom up formulated material approach tailored to their specific task function would advance performative task roles. Hence material composition needs to advance analytically to address the specific challenges of their fields. To enhance visible transmission and solar modulation properties for adaptive facades.

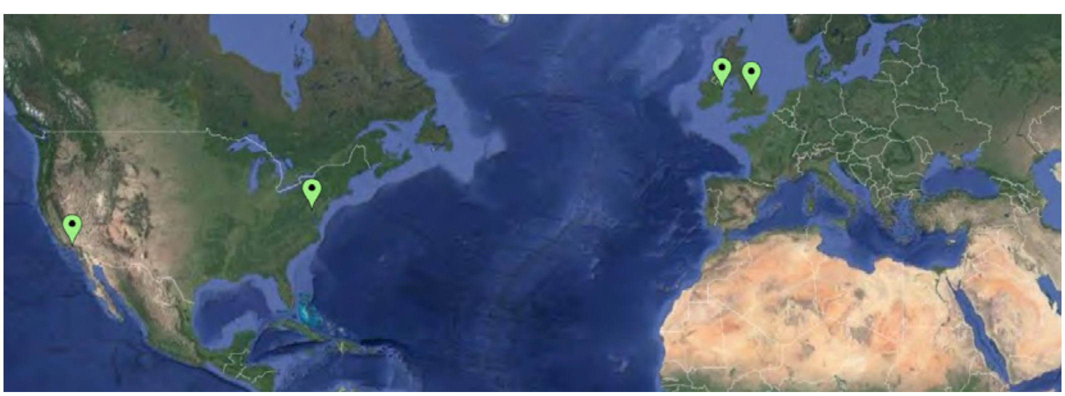


Figure 1 - Locations of case studies “materials”

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DnB NOR Building / MVRDV, Dark Arkitekter and a-lab (image: M. Brzezicki)

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1 Mlyuka, Niklasson and Granqvist (2009); Smart Films International; Ma and Zhu, (2009); Kretzer (2017); LCRHallcrest.

2 Smart Films International; Granqvist (2014); Gavrilyuk, Tritthart and Gey (2007); Llordés et al. (2013); Lampert (2004).

3 LCRHallcrest.

4 Seeboth, Ruhmann and Mühling (2010).

5 Rossi, Augustynowicz et al. ShapeShift (2018); Madden (2008).

6 Fiorito, Sauchelli, et al. (2016); Ge, Sakhaei, et al. (2016); Lendlein, Jiang, et al. (2005); Jiang, Kelchand Lendlein, (2006).

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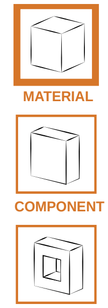
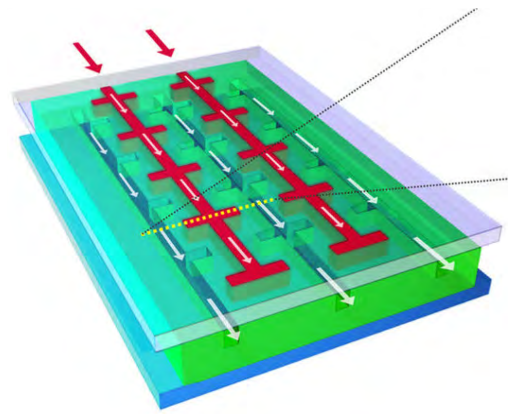
REGENERABLE PV WITH HYDROGEL, North Carolina State University (USA), Hyung-Jun Koo and Orlin D. Velev



Photovoltaic systems based on photosensitive organic dye molecules could be a simple and economical alternative to conventional solar cells, and have been actively developed for decades. The best examples of such devices are the common dye-sensitized solar cells (DSSCs) though other systems based on a dye-embedded hydrogel or naturally derived photoactive molecules have also been reported recently. Since the organic dyes are generally susceptible to light, high temperature or water the degradation of photoactive molecules in the dye-based photovoltaic systems could be a critical problem, which leads to deterioration of the long-term performance of these photovoltaic cells.



PHOTOSYSTEM; REGENERATION; DYE INFUSION; BIOMIMETIC

BUILDING INFORMATION:			
Building floor area	-	Climate Type	All of them
Building use	Energy generation	Orientation of the facade	All orientation
Building status	-	Other	-

DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	■
04. Prototype demonstration	☐
05. Commercial product/Existing building	☐

FUNCTION / GOAL / PURPOSE	
Thermal comfort	☐
Visual comfort	☐
Acoustic comfort	☐
Energy management (harvesting, storing, supply)	■
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	☐
Appearance (aesthetic quality)	☐
Structure performance	☐
Energy generation	■
Personal users' control	☐
Other (durability, accesibility, use of natural resources, etc).	☐

TYPE OF MATERIAL	
Thermochromic	☐
Electrochromic	■
Photochromic	☐
Thermotropic	☐
Phase Change Material	☐
Shape Memory Polymer	☐
Shape Memory Alloy	☐
Thermobimetal	☐
Bi-layer hygromorph composite	☐
Hydrogel	☐
Natural Porous Material	☐

MATERIAL FAMILY	
Reversible colour / Opacity change	■
Reversible heat flow direction	☐
Shape Changing Material	☐
Humidity absorption	☐
Other:	☐

M_01

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): dye-sensitized solar cells	■

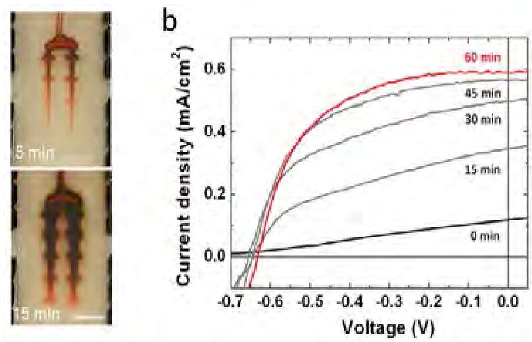
TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify): chemical infusion of organic dye u-FGPV	■

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	☐
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify): energy enhance performance function of PV	■

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	☐
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	■
Other (specify): Manual	☐

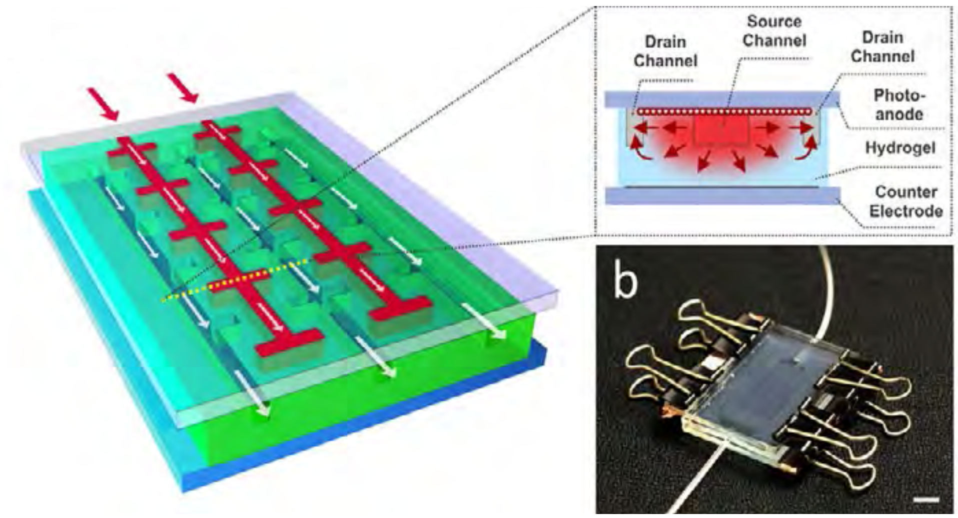
TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify): photoelectrochemical oxidation to reduce accelerated photo degradation for enhanced photovoltaic functionality	■



1

1. (a) Images illustrating the progressive infusion of dye and electrolytes through the gel-vascular network at 5 and 15 min after injection of the solution. Scale bar = 1 cm. The injection rate is 10 μl/min. (b) I–V curves of the μ-FGPVs under illumination after the first injection of the aqueous solution of dye and electrolytes
2. a) A schematic of microfluidic channel network within the hydrogel photovoltaics (μ-FGPVs). The white arrows indicate the convection-dominant transport of dye and electrolyte molecules along the microfluidic channels. The inset displays the cross section view across the dotted yellow line. TiO2 nanoparticles and Pt catalysts are deposited on the photoanode and the counter electrode, respectively. The red arrows indicate the lateral diffusive/convective transport between the source channels and drain channels. (b) A photograph of the prototype μ-FGPVs device. The top electrode is the photoanode. Scale bar = 1 cm. The area and the thickness of TiO2 film are 3 cm² and ~6 μm, correspondingly.
3. (a) Schematics of the three-step regeneration process. (c) I–V curves of the dye-replenished

CONTROL OPERATION DETAILS



2

DETAILED EXPLANATION OF THE CONTROL/OPERATION

Regenerable Photovoltaic Devices with Hydrogel-Embedded Microvascular Network (HEMN) is a material innovation for facades innovation surfaces with biomimetic microvascular network for dye infusion for regenerative photovoltaic performance.
Photosensitive organic Dye Molecules (PoDM) reduce deterioration of long term energy operational outputs and enhance the performance of photovoltaic cells. This biomimetic network of dye infusion gives damage regeneration by chemical compounds of action and reaction have been undertaken by Hyung within self-heal photovoltaic. Vascular networks have been used as regenerative functions for hydrogel photovoltaic devices by photosensitive organic dye infusion.
Organic dyes are generally susceptible to light stress, high temperatures that reduce the long-term performance of photovoltaic cells. Embedded microfluidics within a network enables regenerative functionality by the infusion of chemical regenerative properties by transport of photoactive agents dye and electrolytes to create a microfluidic hydrogel solar cell of optimum performance for electricity generation.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	☐
Extrinsic (requires external control)	☐
Electromagnetic	☐
Other (specify): photovoltaic of u-FGPV in a closed structure	■

SYSTEM RESPONSE TIME	
Seconds	☐
Minutes	☐
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify): depending on dye infusion into network, changes response time of PoDM regeneration	■

SYSTEM DEGREE OF ADAPTIVITY:	
On/off	☐
Gradual	■
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	■
Micrometers	☐
Millimeters	☐
Centimeters	☐
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	■
03 Visible, surface change (lamellas, rollers, blinds)	☐
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	☐
05 Visible, location or orientation change	☐
Other (specify)	☐

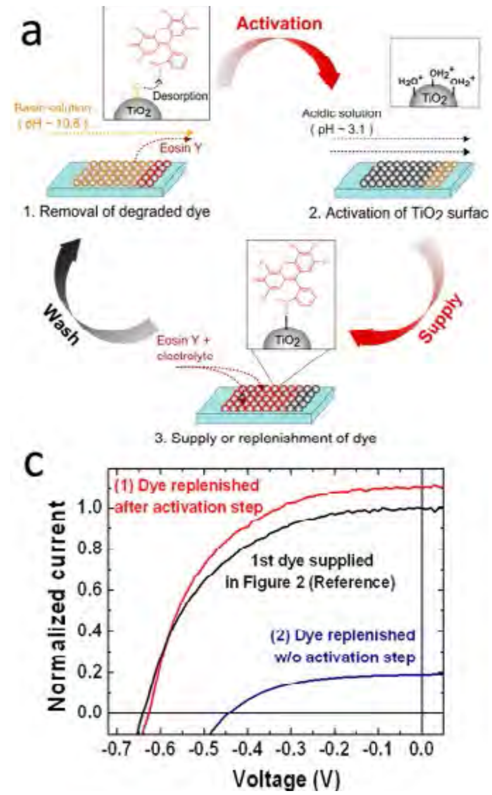
ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	☐
Other (specify): lab testing at this moment - prototype under development	■

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	■

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	☐
Information not available	■

Cost/m2	-
Yearly cost of maintenance	-



3

μ-FGPVs with and without the activation step, showing that the activation process is essential. The device for the curve (1) was washed with aqueous NaOH solution for 3 hrs, followed by treating with HCl solution for 3 hrs before the dye replenishment. The device characterized by curve (2) was washed with aqueous NaOH solution for 6 hrs before dye replenishment. All samples were characterized after the 1 hr dye-supply step.

Reference
Hyung-Jun, K., Orlin, D.V. (2013), *Regenerable photovoltaic devices with a hydrogel-embedded microvascular network,* Nat Sci Rep

Reference to picture
Hyung-Jun, K., Orlin, D.V. (2013), *Regenerable photovoltaic devices with a hydrogel-embedded microvascular network,* Nat Sci Rep

Author of the sheet info
Mark E. Alston
Faculty of Engineering - Architecture and Built Environment, The University of Nottingham

Rosa Romano
Florence University, Department of Architecture

Enrico Sergio Mazzucchelli
Politecnico di Milano

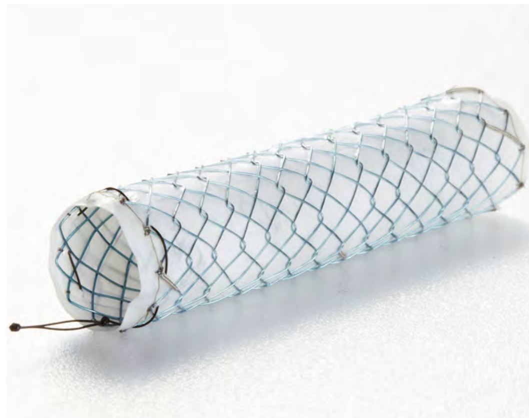
NITINOL (NITI)

MATERIAL

COMPONENT

FACADE

Nichel-titanium (NiTi) alloys are commonly used in shape memory applications, although many other kinds of alloys also exhibit shape-memory effects. These alloys can exist in final product form in two different temperature-dependent crystalline states or phases: the austenite state (higher temperature); the martensite state (lower temperature).
The material in the austenite state is strong and hard, while it is soft and ductile in the martensite phase.The austenite crystal structure is a simple body centred cubic structure, while martensite has a more complex rhombic structure. With respect to the stress–strain curve, the higher temperature austenite behaves similarly to most metals. The stress–strain curve of the lower-temperature martensitic structure, however, resembles an elastomer, since it has 'plateau' stress-deformation characteristics where large deformations can easily occur with little force.



SHAPE MEMORY; ALLOY; KINETIC; TEMPERATURE; REACTIVE

BUILDING INFORMATION:			
Building floor area	-	Climate Type	All of them
Building use	-	Orientation of the facade	All orientation
Building status	-	Other	-

DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	☐
04. Prototype demonstration	☐
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	☐
Visual comfort	■
Acoustic comfort	☐
Energy management (harvesting, storing, supply)	☐
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	☐
Appearance (aesthetic quality)	■
Structure performance	☐
Energy generation	☐
Personal users' control	☐
Other (durability, accesibility, use of natural resources, etc).	☐

TYPE OF MATERIAL	
Thermochromic	☐
Electrochromic	☐
Photochromic	☐
Thermotropic	☐
Phase Change Material	☐
Shape Memory Polymer	■
Shape Memory Alloy	☐
Thermobimetal	☐
Bi-layer hygromorph composites	☐
Hydrogel	☐
Natural Porous Material	☐

MATERIAL FAMILY	
Reversible colour / Opacity change	☐
Reversible heat flow direction	☐
Shape Changing Materials	■
Humidity absorption	☐
Other:	☐

M_02

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): Nichel-titanium (NiTi)	■

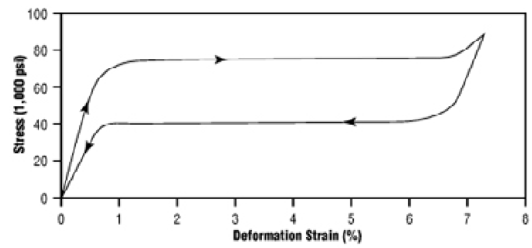
TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	☐
Bi-directional transmission control	■
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify): Shape Memory Material	■

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	■
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	☐
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant’s presence	☐
Other (specify):	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify): Manual	☐

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐



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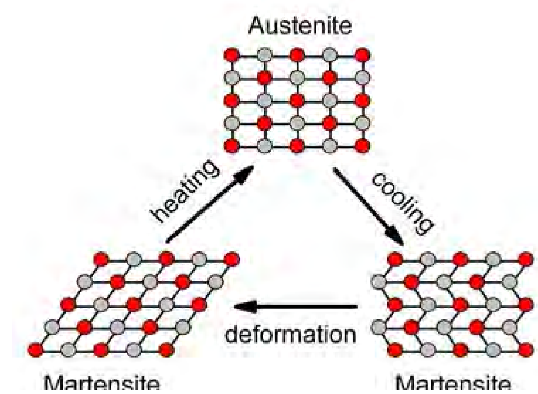

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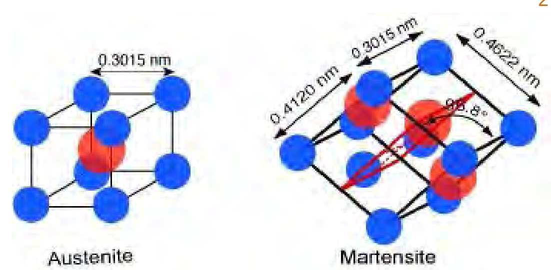

3

1. Typical Loading and Unloading Behavior of Superelastic NiTi
2. 2D view of nitinol’s crystalline structure during cooling/heating cycle
3. 3D view of austenite and martensite structures of the NiTi compound.
4. Reef, New York, NY, 2009. In this sculpture Rob Ley investigates the role emerging material technology can play in the sensitive reprogramming of architectural and public space. Shape Memory Alloys (SMAs), a category of metals that change shape according to temperature, offer the possibility of efficient, fluid movement without the mechanized motion of earlier technologies.

CONTROL OPERATION DETAILS

4

DETAILED EXPLANATION OF THE CONTROL/OPERATION

Nitinol alloys exhibit Shape Memory Effect (SME) and Super Elasticity (SE). Shape memory is the ability to undergo deformation at one temperature, and recover its original undeformed shape upon heating above its “transformation temperature”.
Superelasticity occurs at a narrow temperature range just above its transformation temperature; no heating is necessary to cause the undeformed shape to recover, and the material exhibits enormous elasticity, 10-30 times that of ordinary metal.
Nitinol’s unusual properties are derived from a reversible solid-state phase transformation known as a martensitic transformation, between two different martensite crystal phases. At high temperatures, Nitinol assumes an interpenetrating simple cubic structure referred to as austenite (also known as the parent phase). At low temperatures, Nitinol spontaneously transforms to a more complicated body-centered tetragonal crystal structure known as martensite (daughter phase).

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	■
Extrinsic (requires external control)	□
Electromagnetic	□
Other (specify):	□

SYSTEM RESPONSE TIME	
Seconds	■
Minutes	□
Hours	□
Days	□
Seasons	□
Years	□
Other (specify):	□

SYSTEM DEGREE OF ADAPTIVITY:	
On/off	□
Gradual	■
Other (specify)	□

DEGREE OF SPATIAL ADAPTATION	
Nanometers	■
Micrometers	□
Millimeters	□
Centimeters	□
Meters	□
Other (specify)	□

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	□
02 Visible, no surface change (smart glazing)	□
03 Visible, surface change (lamellas, rollers, blinds)	□
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	■
05 Visible, location or orientation change	□
Other (specify)	□

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	■
No	□
Other (specify):	□

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	□
Medium (curtain walls, ventilated facades, etc)	□
High (double skin facades, high tech, etc)	□
Information not available	■

SYSTEM MAINTENANCE FREQUENCY	
Daily	□
Weekly	□
Monthly	□
Yearly	□
Information not available	■

Reference

Aksamija, A. (2016), *Integrating Innovation in Architecture: Design, Methods and Technology for Progressive Practice and Research*, AD Smart,

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http://www.adaptronik.fraunhofer.de/ (Accessed May 23, 2018)

http://www.rtm-medizintechnik.de/ (Accessed May 23, 2018)

Reference to picture

http://www.g-rau.de/en/products/actuators-made-of-shape-memory-alloys.html (Accessed May 23, 2018)

https://en.wikipedia.org/wiki/Nickel_titanium (Accessed May 23, 2018)

Author of the sheet info

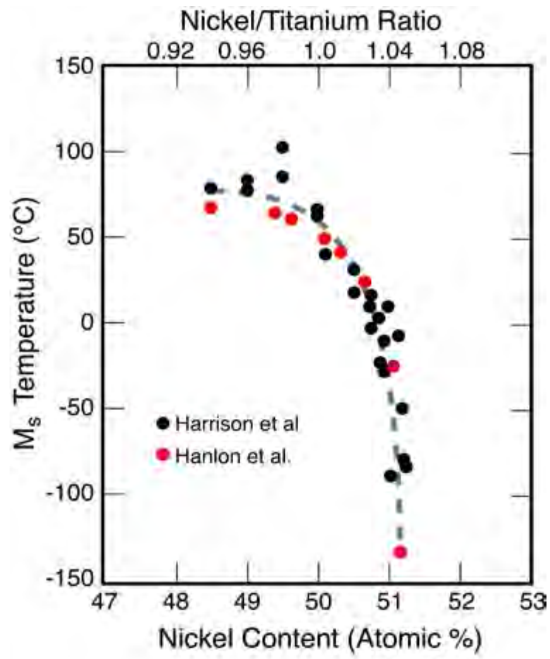
Sandra Persiani
Technical University of Munich

Rosa Romano
Florence University, Department of Architecture

Enrico Sergio Mazzucchelli
Politecnico di Milano

Mark E. Alston
Faculty of Engineering - Architecture and Built Environment, The University of Nottingham

Cost/m2	-
Yearly cost of maintenance	-



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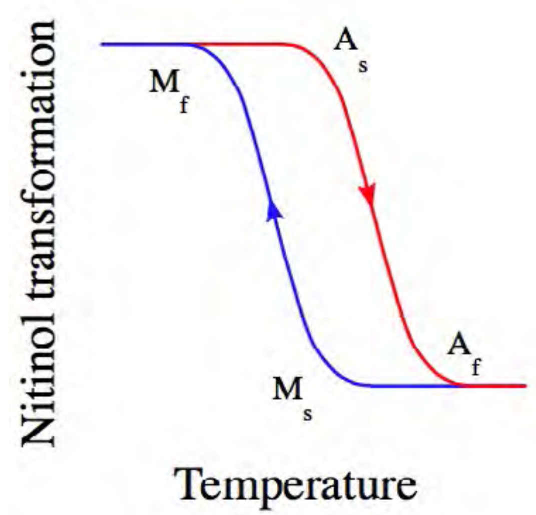


6

5. The effect of nitinol composition on the Ms temperature.
6. Thermal hysteresis of nitinol's phase transformation

Facade panels incorporating cement-based batteries, 2015
DR NIALL HOLMES

MATERIAL

COMPONENT

FACADE

The novel cement based batteries are designed to power low-energy cathodic protection.
One example is Impressed Current Cathodic Protection (ICCP) of reinforcement in concrete structures. ICCP protects reinforcing steel from corrosion by connecting it to an inert, less noble, metal and passing low-level current through it using an external power source.
The preliminary findings demonstrate that cement based batteries can produce sufficient sustainable electrical outputs with the correct materials and arrangement of castin anodes.
Work is on going to determine how these batteries can be recharged using photovoltaic which will further enhance their sustainability properties.

CEMENT-BASED BATTERIES; CATHODIC PROTECTION; REINFORCED CONCRETE; PV

BUILDING INFORMATION:			
Building floor area	-	Climate Type	All of them
Building use	All type of function	Orientation of the facade	All orientation
Building status	Both new and existing	Other	-

DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	■
04. Prototype demonstration	☐
05. Commercial product/Existing building	☐

FUNCTION / GOAL / PURPOSE	
Thermal comfort	☐
Visual comfort	☐
Acoustic comfort	☐
Energy management (harvesting, storing, supply)	■
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	☐
Appearance (aesthetic quality)	☐
Structure performance	■
Energy generation	☐
Personal users' control	☐
Other (durability, accesibility, use of natural resources, etc).	☐

TYPE OF MATERIAL	
Thermochromic	☐
Electrochromic	☐
Photochromic	■
Thermotropic	☐
Phase Change Material	☐
Shape Memory Polymer	☐
Shape Memory Alloy	☐
Thermobimetal	☐
Bi-layer hygromorph composite	☐
Hydrogel	☐
Natural Porous Material	☐

MATERIAL FAMILY	
Reversible colour / Opacity change	☐
Reversible heat flow direction	☐
Shape Changing Material	☐
Humidity absorption	☐
Other: Cement-based batteries	■

M_03

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): Concret	■

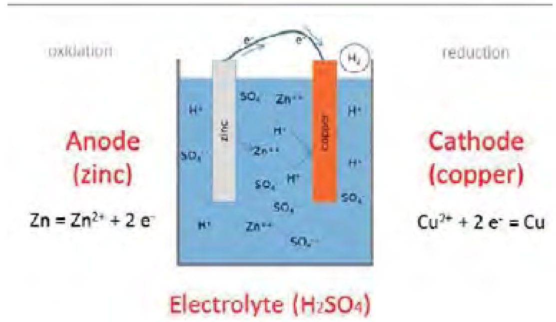
TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify): charging and recharging using photovoltaic elements	■

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	☐
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify): embedded steel corrosion	■

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify): Electrical	■

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐



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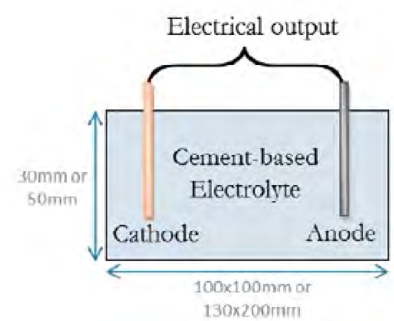

2

1. Conventional battery arrangement.
2. Battery housed in a metal can.
3. Cement

CONTROL OPERATION DETAILS

3

DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

In Cement-based batteries housed in a block both the anode and the cathode are in the form of metal plates. Plastic moulds were used to prevent short circuiting and to allow for a higher volume of sample to be made. These designs were used to compare different additives, anode materials, shapes and sizes.
This type of design is the "best-fit" for cement-based batteries for using with Current Cathodic Protection (ICCP) as they can be incorporated into a cladding panel and fixed onto a structure. For this, particular characteristics are required, namely robustness, long life and a low but consistent current output under resistance load.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	■
Extrinsic (requires external control)	☐
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	☐
Minutes	☐
Hours	☐
Days	■
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/off	■
Gradual	☐
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	☐
Centimeters	☐
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	■
03 Visible, surface change (lamellas, rollers, blinds)	☐
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	☐
05 Visible, location or orientation change	☐
Other (specify)	☐

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	■
No	
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	■

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	☐
Information not available	■

Reference

Holmes, N., Byrne, A. and Norton, B. (2015), *First steps in developing cement-based batteries to power cathodic protection of embedded steel in concrete*, Journal of Sustainable Design and Applied Research (SDAR)

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Reference to picture

Holmes, N., Byrne, A. and Norton, B. (2015), *First steps in developing cement-based batteries to power cathodic protection of embedded steel in concrete*, Journal of Sustainable Design and Applied Research (SDAR)

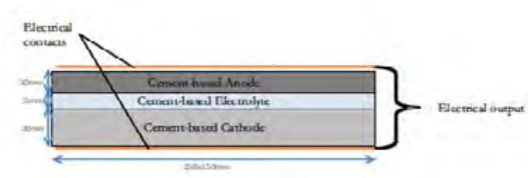
Author of the sheet info

Rosa Romano
Florence University, Department of Architecture

Enrico Sergio Mazzucchelli
Politecnico di Milano

Mark E. Alston
Faculty of Engineering - Architecture and Built Environment, The University of Nottingham

Cost/m2	-
Yearly cost of maintenance	**100,00 €**



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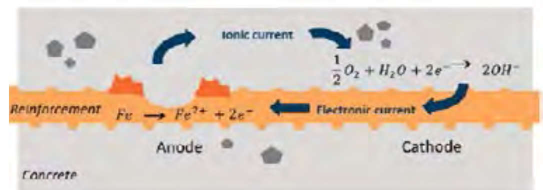


4

6.a

6.b

6.c

4. Layered battery schematic.
5. Corrosion process in embedded steel in concrete
6. Layered batteries cast: 6.a Layered cement-based battery; 6.b Batteries stored in water and Epsom salt; 6.c Electrical contacts (conductive copper)

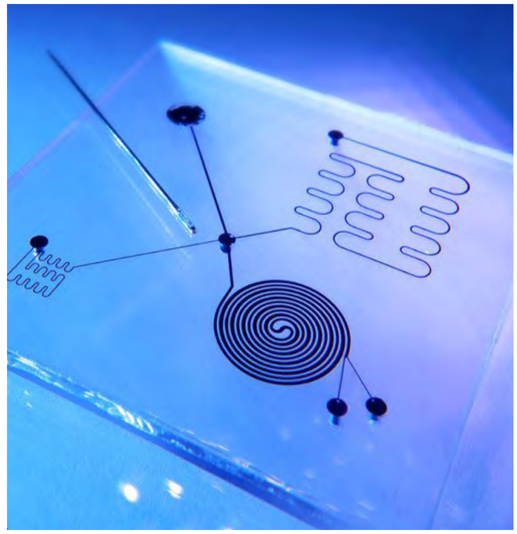
MATERIAL

COMPONENT

FACADE

MICROFLUIDIC GLASS, 2015
M.E.Alston

The research on living glass is focused on the use of a optically transparent, thermal energy adsorbing glass composite. It is in the conceptual prototype type phase. The objective is demonstrate that is possible to evolve glass into a photoactive energy system by evaluation and reactive response for thermal heat flow targeting. A living glass, is in fact, an organism that emulates the chemical reaction cycle of leaves by endothermic principles.
The metabolic cycle of biochemical triggers, can be considered are multifunctional mechanisms to progress glass into an energy, adsorbing composite. The goal of the research is descrive the evolution of glass into a photoactive adsorption layer, at a integrated multiscale level, in response to climatic regionalization, in order to turn glass into a living energy organism that responds to the environment and contributes to the planet's energy needs.



BIOSYSTEM, ENERGY, ADSORPTION, CONDUCTANCE, SOLAR MODULATION

BUILDING INFORMATION:			
Building floor area	device prototype	Climate Type	All climate type
Building use	glazed facades	Orientation of the facade	All orientation
Building status	new built + refurbishment	Other	-

DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	□
02. Technology concept formulated/Design Proposal	■
03. Technology validated in lab	□
04. Prototype demonstration	□
05. Commercial product/Existing building	□

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	■
Acoustic comfort	□
Energy management (harvesting, storing, supply)	■
Mass transfer control (e.g. condensation control)	■
Indoor air quality	□
Appearance (aesthetic quality)	□
Structure performance	□
Energy generation	■
Personal users' control	□
Other (durability, accesibility, use of natural resources, etc).	□

TYPE OF MATERIAL	
Thermochromic	□
Electrochromic	□
Photochromic	■
Thermotropic	□
Phase Change Material	□
Shape Memory Polymer	□
Shape Memory Alloy	□
Thermobimetal	□
Bi-layer hygromorph composite	□
Hydrogel	□
Natural Porous Material	□

MATERIAL FAMILY	
Reversible colour / Opacity change	■
Reversible heat flow direction	□
Shape Changing Material	□
Humidity absorption	□
Other:	□

M_04

TYPE OF MATERIAL	
Liquid crystals	□
Phase Change Materials	□
Polymers	■
Alloys	□
Ceramics	□
Wood	□
Salthydrates	□
Other (specify):	□

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	□
Liquid crystal, SPD	□
Photo-volta-chromic	□
Independently tunable NIR-VIS EC	□
Thermo- tropic / chromic	□
Photo-chromic	□
Fluidglass	■
Other (specify):	□

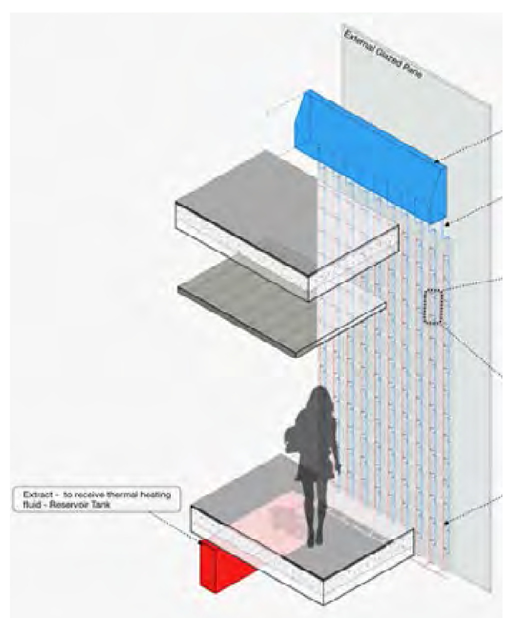
TYPE OF SHADING DEVICE	
Screens / roller shades	□
Blinds with slat angle control	□
Bi-directional transmission control	□
Insulating shutters	□
Shading with dual-axis tracking	□
Other (specify)	□

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	□
Bi-material effect	□
Electroactive material	□
Superabsorbent material	□
Phase Change	□
Other (specify): heat flow transport	■

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	□
Thermal (e.g. outdoor air temperature)	□
Electromagnetic (e.g. solar radiation)	■
Optical (e.g. daylight level, glare)	□
Air quality (humidity, CO2 concentration, etc)	□
Building heating/cooling load	□
Occupant's presence	□
Other (specify)	□

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	□
Pneumatical	□
Electromagnetic	□
Thermal	■
Chemical	□
Other (specify): Manual	□

1



2

1. Building integration
2. Building integration
3. Cellular floor zoning-glass modular facade

CONTROL OPERATION DETAILS

3

DETAILED EXPLANATION OF THE CONTROL/OPERATION

Evaluation of heat flow monitoring and consequent reaction triggers are needed to actively manage nanoscale absorptivity within microvascular networks and thermal conductance effects upon the glass material. The engagement of sensors and actuators controlled by an algorithm management response will enable parameters setting in connection to solar radiation gain. This is achieved by fluidic flow rate control and load shift energy removal from the heat absorber carrier fluid. Hence nanoscale fluidic monitoring by evaluation of heat flow within the network and temperature monitoring decay, heat loss, are strategic functions. This analysis to quantify thermal flow directly relates to datum temperature point setting. This tracking of thermal flow creates a cyclic nanoscale system for conductivity regulation by energy load - unload processes.
This energy load shift tracking of conduction is intrinsic to indoor set-point temperatures.
This active management of thermal heat transport flow will feed into tank reservoirs for energy unload process removal.
Once the energy is removed from the photosynthetic glass, the fluid recirculates back into the network. This feed back loop completes the close loop exothermic cycle. These are learn and apply reaction responses to changing solar radiation and absorptivity. The energy unload process is created at a localized level , serving the microvascular networks in avoidance of extended distribution feeds. This give optimization of pumping energy demands and localized energy load - unload processes. The ability to use tank storage reservoirs enables heat to electricity conversation by semiconducting engineering.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	■
Extrinsic (requires external control)	□
Electromagnetic	□
Other (specify)	□

SYSTEM RESPONSE TIME	
Seconds	■
Minutes	□
Hours	□
Days	□
Seasons	□
Years	□
Other (specify)	□

SYSTEM DEGREE OF ADAPTIVITY:	
On/off	■
Gradual	□
Other (specify)	□

DEGREE OF SPATIAL ADAPTATION	
Nanometers	■
Micrometers	□
Millimeters	□
Centimeters	□
Meters	□
Other (specify)	□

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	■
02 Visible, no surface change (smart glazing)	□
03 Visible, surface change (lamellas, rollers, blinds)	□
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	□
05 Visible, location or orientation change	□
Other (specify)	□

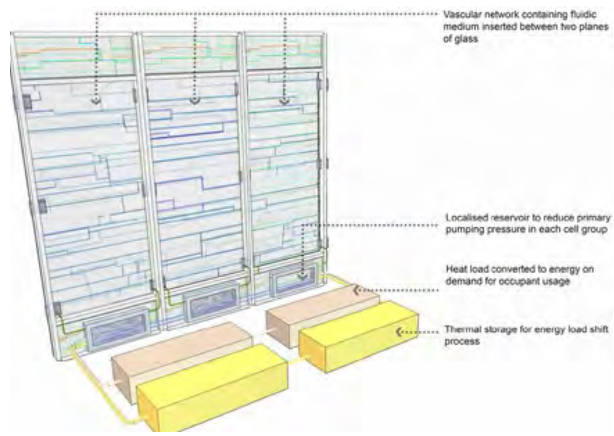
ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	☐
Other (specify): progression of the research	■

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	■

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	☐
Information not available	■

Cost/m2	-
Yearly cost of maintenance	-



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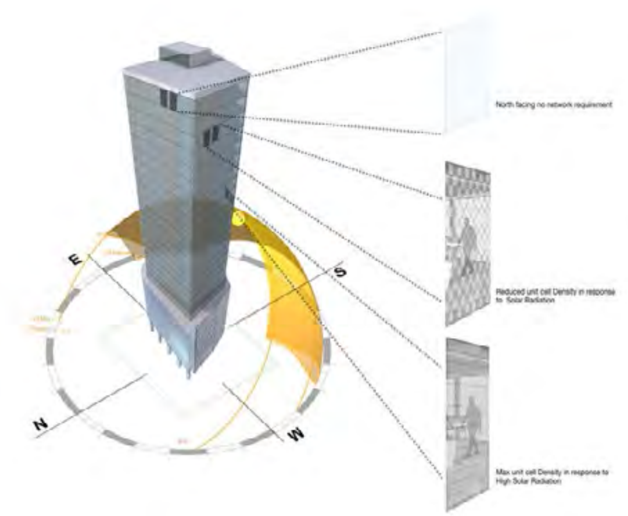

5

4. Modular cellular groups
5. Vascular channel changes in response to solar orientation

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Olugebefola, S.C., Aragon, M.A., Hansen, C.J., Hamilton, A., Wu, W. et al. (2010), *Polymer Microvascular Networks Composites*, J Composite Materials n. 44, pp. 2587- 2603.

Hatton, B.D., Wheeldon, I., Hancock, M.J., Kolle, M. and Ingber, D.E. (2013), *Artificial Vasculature for Adaptive Thermal Control of Windows,* Solar Energy Materials and Solar Cells, 117, pp. 429-436

Reference to picture:

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Author of the sheet info

M.E.Alston
University of Nottingham

Rosa Romano
Florence University, Department of Architecture

THERMAL BIMETAL, “BLOOM”, Los Angeles, California (USA), 2011
DO|SU Studio Architecture, Doris Kim Sung

MATERIAL
COMPONENT
FACADE

Bloom furthers the evolution of projects in the M&A courtyard by utilizing a material that has kinetic potential without the need of a power source or any mechanical parts. The towering shade structure is supported by a self-organizing cellular panel system of laser cut custom fabricated sheet metal. The design of the project, based on research by prof. D.K. Sung and Wahlroos-Ritter, explores the possibilities of a thermally responsive metal surface which reacts to both the change in temperature and direct solar radiation. When the temperature of the metal is cool, the surface will appear as a solid object, but once the afternoon heat penetrates the metal, the panels of custom woven bimetal will adjust and fan out to allow air flow and increase shade potential. The thermo-bimetal alloys used in the project expand the notion of surface and structure in architecture.

Latitude -34.08, Longitude: -118.26

THERMAL BIMETAL, SMART MATERIAL, BIOMIMETICS, SELF VENTILATING

BUILDING INFORMATION:			
Building floor area	device prototype	Climate Type	All climate type
Building use	architectural purpose	Orientation of the facade	All orientation
Building status	new built, refurbishment	Other	-

DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	☐
04. Prototype demonstration	■
05. Commercial product/Existing building	☐

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	■
Acoustic comfort	☐
Energy management (harvesting, storing, supply)	☐
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	☐
Appearance (aesthetic quality)	☐
Structure performance	☐
Energy generation	☐
Personal users’ control	☐
Other: Self ventilating, no additional energy necessary (sustainability)	■

TYPE OF MATERIAL	
Thermochromic	☐
Electrochromic	☐
Photochromic	☐
Thermotropic	☐
Phase Change Material	☐
Shape Memory Polymer	☐
Shape Memory Alloy	■
Thermobimetal	☐
Bi-layer hygromorph composite	☐
Hydrogel	☐
Natural Porous Material	☐

MATERIAL FAMILY	
Reversible colour / Opacity change	☐
Reversible heat flow direction	☐
Shape Changing Material	■
Humidity absorption	☐
Other:	☐

M_05

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): Bimetal	■

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify): Bi-material effect	■

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify): Bi-material effect	■

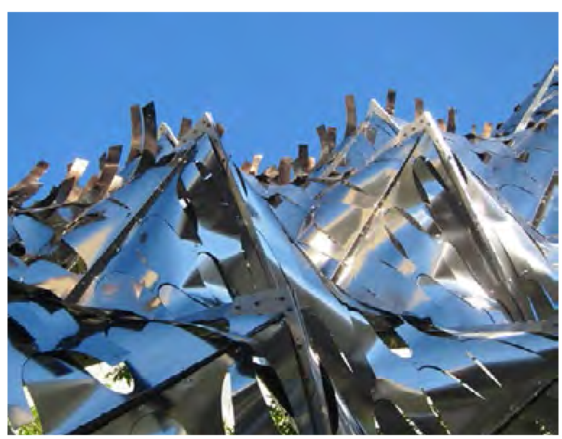
TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	■
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	☐
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	☐
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify): No actuator	■

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	■
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

1

2



3

1. The Bloom in courtyard space image
2. Protype of the Bloom facade
3. The Bloom", Breathing Architecture Installation

CONTROL OPERATION DETAILS

DETAILED EXPLANATION OF THE CONTROL/OPERATION

Made primarily out of a smart thermobimetal, a sheet metal that curls when heated, the form's responsive surface shades and ventilates specific areas of the shell as the sun heats up the Bloom surface. With the aid of complex digital softwares, the surface, made up of approximately 14.000 lasercut pieces, is designed for peak performance on spring equinox, in March 20, 2012.
Composed of 414 hyperbolic paraboloid-shaped stacked panels, the self-supporting structure challenges the capability of the materials to perform as a shell. The panels combine a double-ruled surface of bimetal tiles with an interlocking, folded aluminum frame system. Like the undulation of the surface, the frame, by nature of its folds, is designed to appear on the inner or outer surface at the same cadence of the peaks and valleys. The final monocoque form, lightweight and flexible, is dependent on the overall geometry and combination of materials to provide comprehensive stability. In some areas of "Bloom", the hypar panels are made stiffer by increasing the number of riveted connections, while, in other areas, the panels are deeper to increase structural capability. The severely twisted panel shapes aid in the performance of the surface and challenge the digital and fabrication capabilities of parametric design. Within a single panel, portions of the surface directly face the sun, while the other side is in the shade and requires no reaction or curling. The result is variation in tile shapes and function within each panel.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	■
Extrinsic (requires external control)	☐
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	■
Minutes	☐
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/off	☐
Gradual	■
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	■
Micrometers	☐
Millimeters	☐
Centimeters	☐
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	☐
03 Visible, surface change (lamellas, rollers, blinds)	☐
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	■
05 Visible, location or orientation change	☐
Other (specify)	☐

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	■
No	□
Other (specify): progression of the research	□

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	□
Medium (curtain walls, ventilated facades, etc)	□
High (double skin facades, high tech, etc)	□
Information not available	■

SYSTEM MAINTENANCE FREQUENCY	
Daily	□
Weekly	□
Monthly	□
Yearly	□
Information not available	■

Reference

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Reference to picture

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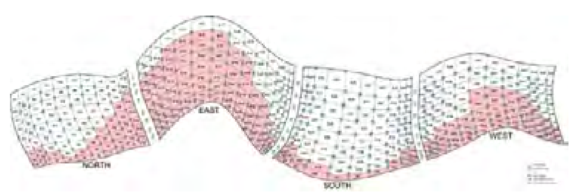
Author of the sheet info

Jonathan Pham
UPV San Sebastian

Rosa Romano
Florence University, Department of Architecture

Cost/m2	-
Yearly cost of maintenance	-

4



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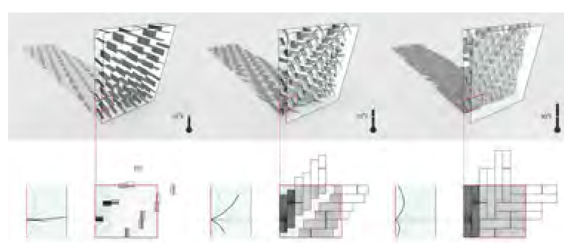
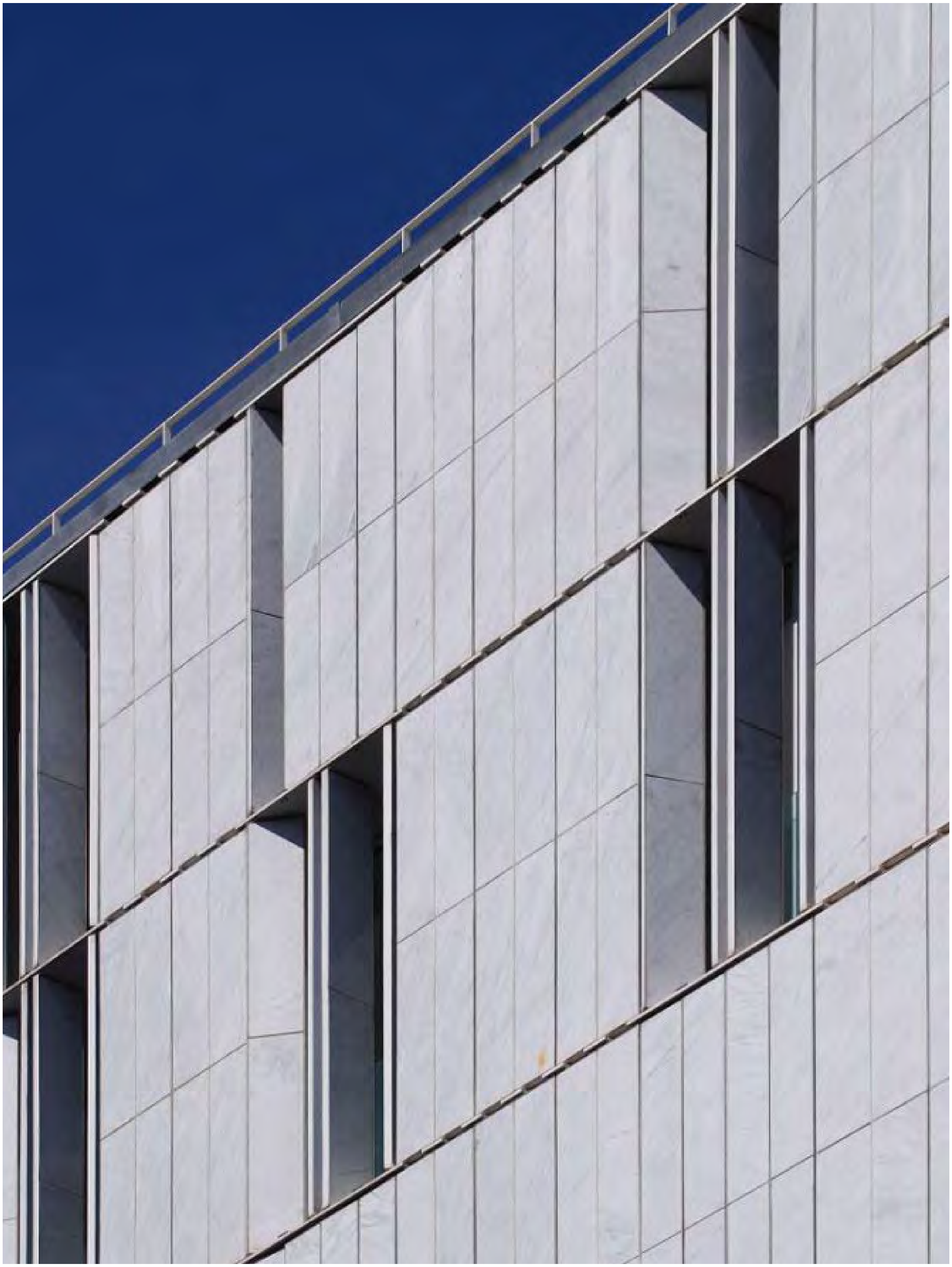


6

4. In courtyard space image
5. 3D model structural analysis image
6. Smart thermobimetal pattern sequence


Lisbon Stone Block / Alberto de Souza Oliveira (image: M. Brzezicki)

Case studies – Adaptive Façade Components

Laura Aelenei, Enrico Sergio Mazzucchelli, Daniel Aeleneil

Introduction

Adaptive façades can provide improvements in the building's energy efficiency and economics, through their capability to change their behaviour in real time according to indoor-outdoor parameters, by means of materials, components and systems. A component can be defined as an assembly of different set of elements. In this regard, it forms a complete constructional or functional unit as part of a façade (for example an insulated glass unit but also a window frame including glazing or a sun shading device).

Unlike the adaptive façades solutions analysed in the WG1 database, most of the component case studies are still in the development, prototype and lab test phases. This demonstrates that the research is constantly aimed at the optimization and development of new and advanced solutions that can be used in this construction sector.

One of the aim of the adaptive components is to react to external stimuli with low-environmental impact and low-cost. In this regard, an understanding of how materials changes with environmental exposure is vital for successful long term architectural application. Moreover, the study of durability and life cycle of these same components becomes crucial to make future applications sustainable.

It's interesting to notice that many adaptive components are directed not only to efficiently contribute to the energy balance of the building and the reduction in energy consumption, but also towards aspects of multimedia communication, where building façades become a means of relating to the city and its inhabitants. Concerning adaptive components, a technological challenge is the implementation in the industry field because the different scale (from prototypes to the industrialized production) is still an unresolved obstacle, related to the industry inertia and economic factors. From the point of view of materials, it is possible to differentiate between entirely new ones and pre-existing ones that find a new use in the building component industry. Using a material for a new purpose is called material transfer, and we can expect several such transfers taking place in the future. Deciding factors for translating a technology's use into a different field are cost of building components or surface coating materials, production capacity or the suitability for industrial manufacturing of potential components (Knaack et al. 2007).

This would also be related to the uncertainty that, today, many components or systems offer in terms of behaviour in the long term, given the short time they have been in place. Moreover, sometimes the results have not always been so successful and, from an economic point of view, often a high initial investment is needed to implement such adaptive components. In this regard exhaustive cost-benefit analysis, largely unrealized, would be needed, because of the experimental or unique character of most existing cases, including the consideration of the entire life cycle cost (Cadenas & Neila Gonzalez, 2015). Closely related to these issues is the maintenance aspect, which must necessarily be considered and developed for future applications. In general, all benefits and criticalities of a specific component need to be considered before making a choice. For example, inserting sunscreen in the spacing between the glass panes of double glazing can save time and eliminates the need for cleaning. But if a glass pane breaks the sun protection element has to be replaced as well. A similar problem can be found using motor-controlled venetian blinds inside double glazing: if a motor fails or the blind jams, the entire double glazing has to be replaced (Knaack, Klein, Bilow & Auer, 2007). Therefore, adaptive solutions could make sense if they consider the maintenance aspect of a façade too: façades are and still will be designed in the next future for a long lifespan, so their functionality has to be ensured throughout.

Finally, it's interesting to notice that many adaptive components are directed not only to efficiently contribute to the energy balance of the building and the reduction in energy consumption, but also towards aspects of multimedia communication, where building façades become a means of relating to the city and its inhabitants.

Adaptive Components Case studies database

Following the classification given previously some representative examples are hereafter described, focusing on the façade component application purpose and the different responsive functions. Regarding the application purpose, the majority of the case studies are used as solutions/applications for energy efficiency, thermal comfort and visual performance. Regarding the responsive functions, for the case of dynamic glazing, optical properties can significantly vary both in terms of quantity of light and solar radiation transmitted. Phase change materials (PCM) can be used in combination with other elements forming a façade component, as for example when used with dynamic glazing, the phase change leads to noticeable variation in the systems performance concerning short and long wave heat transmission, heat storage, indoor surfaces temperatures, but also light transmission, visual perception. PCM can be also used in combination with solar systems – building integrated photovoltaic (BIPV-PCM) contributing to system performance improvement, but also heat storage and indoor temperature.

Some components analysed within the context of the COST Action TU1403 database are characterised by one or more of the following technological features.

- **Screen or solar shading:** Tessellate™ (Hoberman Associates & Buro Happold) and KUMORIgami (Pesenti et. al., 2018) envisions are two examples of adaptive components used as screen or solar kinetic shading. Tessellate, a modular framed glazed screen has a versatile design that can be integrated into existing systems, and is completely self-contained, protected by glass on either side of the moving metal parts. The modules are controlled by a single computer processor, which can be programmed for various purposes with various time steps. The system can respond to changes in temperature, light levels, and different day time.

  In the case of KUMORIgami, a multifaceted Origami family stayed at the base of a component that takes advantage from material combination and responsive actuation to optimise the visual comfort. In order to accommodate a range of situations, the prototype made out of translucent and opaque polymers and is activated with Shape Memory Alloys springs. KUMORIgami is activated with a power supply.

- **Energy harvesting:** Energy-harvesting components can efficiently capture, accumulate, store, manage this energy and supply it in a form that can be used to perform a helpful task. For example the research project InDeWaG (Industrial Development of Fluid Flow Glazing Systems) has been funded for three-and-a-half-years by the EU within the framework of the program HORIZON 2020 with the focus on study a façade component, an insulating glazing unit filled up with a water-glycol fluid circulating within one of the IGU cavities. The glass units are developed for both, the usage within façades and as interior separation walls (Claros-Marfil et al., 2016).

The BIPV Adaptive Flakes (Mazzucchelli & Doniacovo, 2017) is an example of use of photovoltaic cells in orientated in an intrinsic way, in order to optimize the energy production in relation to the outdoor conditions over a year. This component can adapt itself passively to the external climatic conditions without an electrically powered mechanical system.

A different combination resulting in an adaptive façade component is the BIPV-PCM where photovoltaic panel is combined with phase change materials in a single unique prototype. The prototype is composed by a PV panel, a PCM storage module (battery – an insulated box with 10 PCM plates) and a cavity air between the PV and PCM battery. This prototype is also automatized, in order to work alone (capturing and releasing heat) according with the necessity of the indoor air temperature and in order to stabilized the PV module temperature and to assure the optimal performance. The prototypes is installed on the façade of SolarXXI building, in Lisbon (Aelenei et al., 2010).

- **Media and communication:** Interactive window is a window with integrated touch capability for function control. By detecting different inputs this prototype can start/stop music, change tracks, increase/decrease volume, turn lights on/off etc. The interactive window (RISE, Research Institute of Sweden) is equipped with an IR frame as the touch interface. Together with a computing unit and a dedicated software interaction can be customized to specific use cases and different function controls.

  Window antenna (RISE, Research Institute of Sweden) is a modern insulating glazing units combines insulating layers with heat reflective coatings to achieve high energy efficiency. The metal based coatings help keep heat indoor on cold days and outdoor on warm days. However, these coatings also shield radio waves, causing low indoor reception for mobile phones. This prototype demonstrates how the coating instead can be used to amplify radio signals. The heat reflective coating on the glass normally shields radio signals. By making a pattern the electrical conductive coating can be transformed into an antenna that amplifies radio signals for specific frequencies. By connecting the antenna to a router outdoor radio signals can be transferred indoors for improved coverage.

  SolPix LED (Simone Giostra & Partners) is an Energy Generating Solar Shield. Positioned at the convergence of technology, design and the environment, SolPix is a fullscale working prototype demonstrating the ability of the system to interact with its environs while improving the energy performance of the building. Featuring a large scale color LED display and photovoltaic panels integrated to a sun-shading system, SolPix transforms the existing glass structure into an energy-positive skin, harvesting solar energy and using it to power the screen, while protecting the Conservatory from excessive solar radiation. The project is based on GreenPix (Simone Giostra & Partners), a carbon-neutral media wall for the Xicui Entertainment Complex in Beijing, near the site of the 2008 Olympics. Featuring one of the largest color LED display worldwide and the first photovoltaic system integrated into a glass curtain wall in China, GreenPix transforms the building envelop into a self-sufficient organic system.

- **Use of innovative materials:** ShapeShift (Kretzer & Rossi, 2012) is an experiment in future possibilities of architectural materialization and 'organic' kinetics. The project explores the potential application of electro-active polymer (EAP) at an architectural scale. EAP is a polymer actuator that converts electrical power into kinetic force. Due to its extreme flexibility, lightness, transparency,

New Deichman Library / Lund Hagem Arkitekter – Atelier Oslo (image: M. Brzezicki) thin dimensions and its ability to smoothly change shape without the need for external actuators it is a highly attractive component for architectural solutions. The distinctive material properties are not merely used as an actuator replacement but are also orchestrated for their aesthetic qualities. The thin film functions as a possible alternative for conventional building skins and envisions the concept of a futuristic, soft, flexible and sensitive architecture.

Conclusions

— Most of the analysed components are still in the development, prototype and lab test phases. This because the research is constantly moving to the development of new and advanced solutions that can be integrated together in adaptive façade systems. In this regard, the main technological features of the analysed components are related to energy harvesting, communication and media, solar shading. Moreover, many of them are characterized by the use of innovative materials, able to respond in a dynamic manner to climate changes in real time.

References

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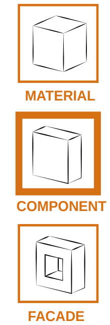
Figure 1 - Locations of case studies “components”

INTERACTIVE WINDOW AND WINDOW ANTENNA, GÖTEBORG (SE), 2013
RISE Research Institutes of Sweden



Interactive window is a window with integrated touch capability for funtion control. By detecting different inputs this prototype can start/stop music, change tracks, increase/decrease volume, turn lights on/off etc.
Window antenna is a modern insulating glazing units combines insulating layers with heat reflective coatings to acheive high energy efficiency. The metal based coatings help keep heat indoor on cold days and outdoor on warm days. However, these coatings also shield radio waves, causing low indoor reception for mobile phones. This prototype demonstrates how the coating instead can be used to amplify radio signals.
Both prototypes were developed by RISE in collaboration with Ericsson and displayed at the Mobile World Congress in Barcelona 2013.

WINDOW ANTENNA; GLASS; SURFACE COATING; INTERACTIVE WINDOW; MOBILE RECEPTION

BUILDING INFORMATION:			
Building floor area	-	Climate Type	All of them
Building use	-	Orientation of the facade	All orientation
Building status	New Built	Other	-

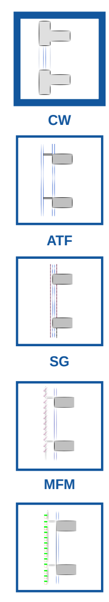
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	☐
04. Prototype demonstration	■
05. Commercial product/Existing building	☐

FUNCTION / GOAL / PURPOSE	
Thermal comfort	☐
Visual comfort	☐
Acoustic comfort	☐
Energy management (harvesting, storing, supply)	■
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	☐
Appearance (aesthetic quality)	☐
Structure performance	☐
Energy generation	☐
Personal users' control	■
Other (durability, accesibility, use of natural resources, etc): Accessibility	■

TYPE OF COMPONENT SYSTEM	
External skin	☐
Curtain wall (stick)	■
Window frame	■
Insulated glass unit	☐
Building services unit	■
Energy harvesting device	☐
Air circulation device	☐
Natural ventilation device	☐
Solar tube	☐
Switchable Glazing	☐
Other:	☐

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	☐
Devices for managing natural ventilation in combination with mechanical ventilation systems	☐
Mobile screens for controlling solar radiation	☐
Technological solutions designed to increase and/or control comfort inside the building	■
Building automation systems for the management of plants and elements of the building skin	☐



CS_01

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): glass	■

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	■
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	■
Superabsorbent material	☐
Phase Change	☐
Other (specify): Shape Memory Material	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	☐
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	■
Other (specify):	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify): Electromagnetic	■


1

2

1. Prototypes developed by RISE Research Institutes of Sweden in collaboration with Ericsson, shown at the Mobile World Congress in Barcelona 2013. Top: interactive window with integrated touch function. Bottom: window with integrated antenna.
2. An example of how printed electronics can be integrated in glass. Here, a printed display has been added to a laminated glass light.
3. Touch-window prototype was exhibited by Ericsson at MWC2013 in Barcelona. Photo: Hans Berggren

CONTROL OPERATION DETAILS

3

DETAILED EXPLANATION OF THE CONTROL/OPERATION

The Interactive Window is eqipped with an IR frame as the touch interface. Togeteher with a computing unit and a dedicated software interaction can be customized to specific use cases and different function controls.
In the Window antenna the heat reflective coating on the glass normally shields radio signals. By making a pattern the electrical conductive coating can be transformed into an antenna that amplifies radio signals for specific frequencies. By connecting the antenna to a router outdoor radio signals can be transfered indoors for improved coverage.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	■
Extrinsic (requires external control)	☐
Electromagnetic	☐
Other (specify):	☐

SYSTEM RESPONSE TIME	
Seconds	■
Minutes	☐
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify):	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/off	■
Gradual	☐
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	■
Micrometers	☐
Millimeters	☐
Centimeters	☐
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	■
03 Visible, surface change (lamellas, rollers, blinds)	☐
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	☐
05 Visible, location or orientation change	☐
Other (specify)	☐

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	■
No	□
Other (specify):	□

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	□
Medium (curtain walls, ventilated facades, etc)	□
High (double skin facades, high tech, etc)	□
Information not available	■

SYSTEM MAINTENANCE FREQUENCY	
Daily	□
Weekly	□
Monthly	□
Yearly	■
Information not available	□

Reference
http://www.glafo.se/projektinformation/13-2/3P00015E2A.htm
(Accessed September 16, 2018)

Reference to picture
http://www.glafo.se/projektinformation/13-2/3P00015E2A.htm
(Accessed September 16, 2018)

Author of the sheet info

Jerry Eriksson
RISE Research Institutes of Sweden

Rosa Romano
Florence University, Department of Architecture

Enrico Sergio Mazzucchelli
Politecnico di Milano

Mark Alston
Faculty of Engineering - Architecture and Built Environment, The University of Nottingham

Cost/m2	-
Yearly cost of maintenance	-

4

5

6

4. Window Prototype
5. Window Prototype
6. Touch-window prototype was exhibited by Ericsson at MWC2013 in Barcelona. Photo: Hans Berggren

MATERIAL
COMPONENT
FACADE

TESSELLATE™, CAMBRIDGE (USA), 2014
Hoberman Associates + Buro Happold

Tessellate™ is a modular framed and glazed screen system whose perforated pattern shifts and evolves kinetically; as the four metal perforated panels glide past one another, they create a dynamic architectural element capable of regulating light and solar gain, airflow, and privacy.
The versatile design can be integrated into existing systems, and is completely self-contained, protected by glass on either side of the moving metal parts. Tessellate™ is named for the patterns designed for the system. These designs are just the beginning of the visual possibilities inherent in the Tessellate System.
Tessellate™ perforations are available in an endless range of patterns. With a library of options ranging from regular grids to free-form and non-repeating patterns. It is possible to develop custom designs for different architecture, or create patterns based on original artwork.

PERFORATED METAL PANEL; KINETIC; SUNSHADING; SLIDING; PANELS

BUILDING INFORMATION:			
Building floor area	-	Climate Type	All of them
Building use	-	Orientation of the facade	All orientation
Building status	New Built	Other	-

DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	☐
04. Prototype demonstration	☐
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	☐
Visual comfort	■
Acoustic comfort	☐
Energy management (harvesting, storing, supply)	☐
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	☐
Appearance (aesthetic quality)	■
Structure performance	☐
Energy generation	☐
Personal users' control	☐
Other (durability, accesibility, use of natural resources, etc):	☐

TYPE OF COMPONENT SYSTEM	
External skin	■
Curtain wall (stick)	☐
Window frame	☐
Insulated glass unit	☐
Building services unit	☐
Energy harvesting device	☐
Air circulation device	☐
Natural ventilation device	☐
Solar tube	☐
Switchable Glazing	☐
Other:	☐

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	☐
Devices for managing natural ventilation in combination with mechanical ventilation systems	☐
Mobile screens for controlling solar radiation	■
Technological solutions designed to increase and/or control comfort inside the building	☐
Building automation systems for the management of plants and elements of the building skin	☐

CW
ATF
SG
MFM
BF

CS_02

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify):metal perforated panels	■

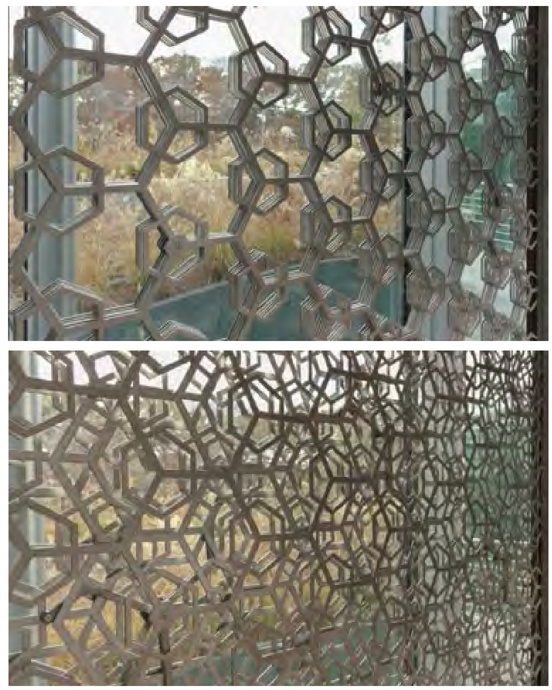
TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify): metal perforated panels shifting kinetically	■

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify): Shape Memory Material	☐

TYPE OF TRIGGER (I-NPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	■
Optical (e.g. daylight level, glare)	☐
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant’s presence	☐
Other (specify):	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify): Manual	☐



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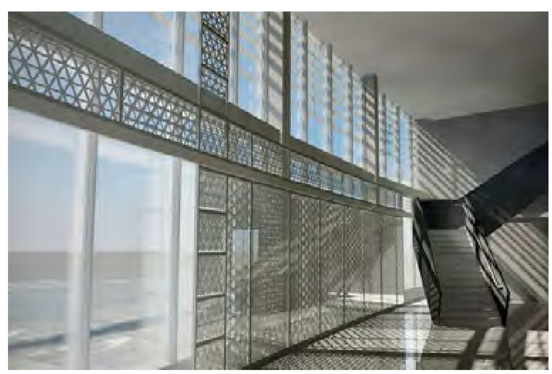


2

1. Photo of the Tessellate™ System with Hexagonal Design in Motion
2. Tessellate™ System used as shading device in a hause project
3. Detail of three stages in a Tesselate screen

CONTROL OPERATION DETAILS

3

DETAILED EXPLANATION OF THE CONTROL/OPERATION

Tessellate is a modular framed and glazed screen system with perforated pattern shifting kinetically, with four metal perforated panels gliding past one another, regulating light and solar gain, airflow, and privacy.
Each Tessellate™ module runs on a single motor. These modules are controlled by a single computer processor, which can be programmed for various purposes. Some clients request that the panels revolve once a minute, some ask for a full revolution every hour. In this case, viewers can hardly witness Tessellate™ moving at all. Still, other clients have requested that the system respond to changes in temperature, light levels, and time of day (these options are available, and encouraged).
When Tessellate™ is set up for this purpose, the result is an exciting moment during the day, the tipping point where the system animates, and the building shifts.
Tessellate™ is suitable for all building geometries; panel shape and size can be tailored to match any building's design and requirements: from non-rectangular profiles, to facets comprising a three-dimensional surface.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	□
Extrinsic (requires external control)	■
Electromagnetic	□
Other (specify):	□

SYSTEM RESPONSE TIME	
Seconds	■
Minutes	■
Hours	■
Days	□
Seasons	□
Years	□
Other (specify):	□

SYSTEM DEGREE OF ADAPTIVITY:	
On/off	□
Gradual	■
Other (specify)	□

DEGREE OF SPATIAL ADAPTATION	
Nanometers	□
Micrometers	□
Millimeters	■
Centimeters	■
Meters	□
Other (specify)	□

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	□
02 Visible, no surface change (smart glazing)	□
03 Visible, surface change (lamellas, rollers, blinds)	■
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	□
05 Visible, location or orientation change	□
Other (specify)	□

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	■
No	□
Other (specify):	□

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	□
Medium (curtain walls, ventilated facades, etc)	□
High (double skin facades, high tech, etc)	□
Information not available	■

SYSTEM MAINTENANCE FREQUENCY	
Daily	□
Weekly	□
Monthly	□
Yearly	■
Information not available	□

Reference
http://www.azahner.com/tessellate.cfm (Accessed September 16, 2018)

http://www.hoberman.com/portfolio/simonscenter.php?projectname=Simons+Center (Accessed September 16, 2018)

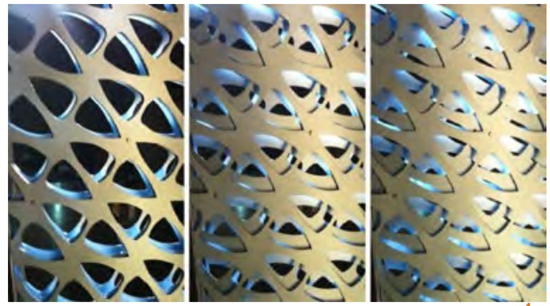
http://www.azahner.com/portfolio/stony-brook (Accessed September 16, 2018)

Reference to picture
http://www.azahner.com/images/tessellate-unveiling.jpg

Author of the sheet info
Rosa Romano
Florence University, Department of Architecture

Enrico Sergio Mazzucchelli
Politecnico di Milano

Cost/m2	-
Yearly cost of maintenance	-



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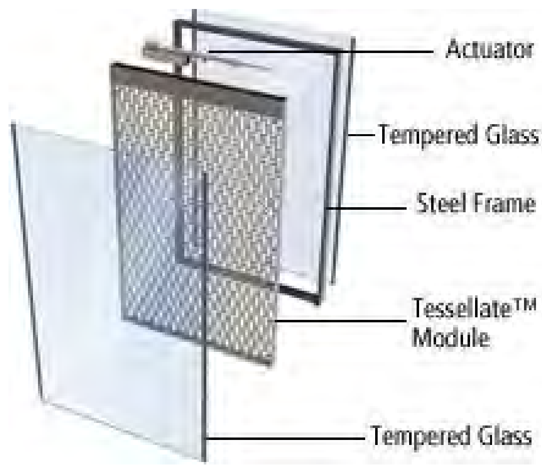
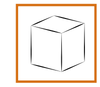


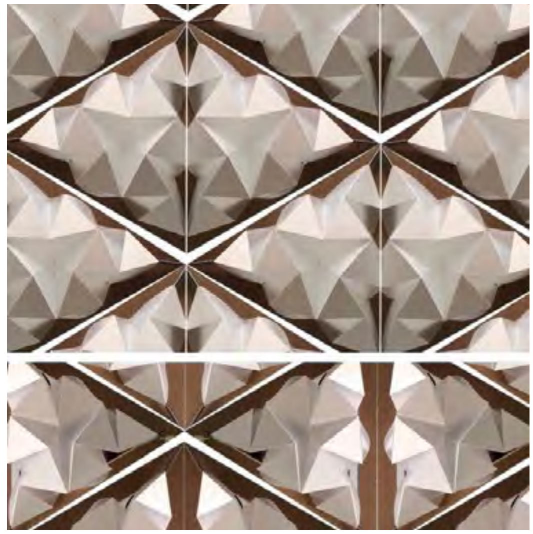
6

4. Dynamic facade with multilayer panel (metal and glass)
5. Dynamic facade with multilayer panel (metal and glass) - TESSELLATE™
6. TEchnological detail of a glass facade with a shading device realized with Tassellate Module

KUMORIgami, MILAN (IT), 2016
Prof. M. PESENTI, Prof. G. MASERA, Prof. F. FIORITO


MATERIAL
COMPONENT
FACADE

KUMORIgami envisions a kinetic shading device that takes advantage from its geometric definition to amplify the deformations carried out by Shape Memory Alloys (SMAs) linear micro actuators.
Based on Ron Resch pattern the kinematics options proper of this multifaceted Origami family stayed at the base of a a component that takes advantage from material combination and responsive actuation to optimise the visual comfort.
In order to accommodate a range of situations, the prototype made out of translucent and opaque polymers and is activated with Shape Memory Alloys springs. KUMORIgami fits to both existing and new buildings thanks to the simplification of its mechanical components and customised solutions that promote the architectural integration.


KUMORIgami Prototype

ORIGAMI, PARAMETRIC, KINETIC, ADAPTIVE, SHAPE MEMORY ALLOY

BUILDING INFORMATION:			
Building floor area	-	Climate Type	All of them
Building use	-	Orientation of the facade	South, East, West
Building status	-	Other	-

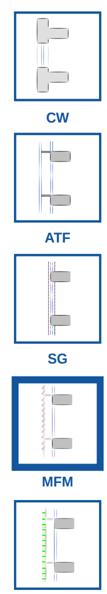
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	■
03. Technology validated in lab	☐
04. Prototype demonstration	☐
05. Commercial product/Existing building	☐

FUNCTION / GOAL / PURPOSE	
Thermal comfort	☐
Visual comfort	■
Acoustic comfort	☐
Energy management (harvesting, storing, supply)	☐
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	☐
Appearance (aesthetic quality)	■
Structure performance	☐
Energy generation	☐
Personal users' control	☐
Other (durability, accesibility, use of natural resources, etc):	☐

TYPE OF COMPONENT SYSTEM	
External skin	■
Curtain wall (stick)	☐
Window frame	☐
Insulated glass unit	☐
Building services unit	☐
Energy harvesting device	☐
Air circulation device	☐
Natural ventilation device	☐
Solar tube	☐
Switchable Glazing	☐
Other:	☐

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	☐
Devices for managing natural ventilation in combination with mechanical ventilation systems	☐
Mobile screens for controlling solar radiation	■
Technological solutions designed to increase and/or control comfort inside the building	☐
Building automation systems for the management of plants and elements of the building skin	☐


CW
ATF
SG
MFM
BF

CS_03

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): translucent polypropylene, opaque methyl methacrylate, NiTinol springs	■

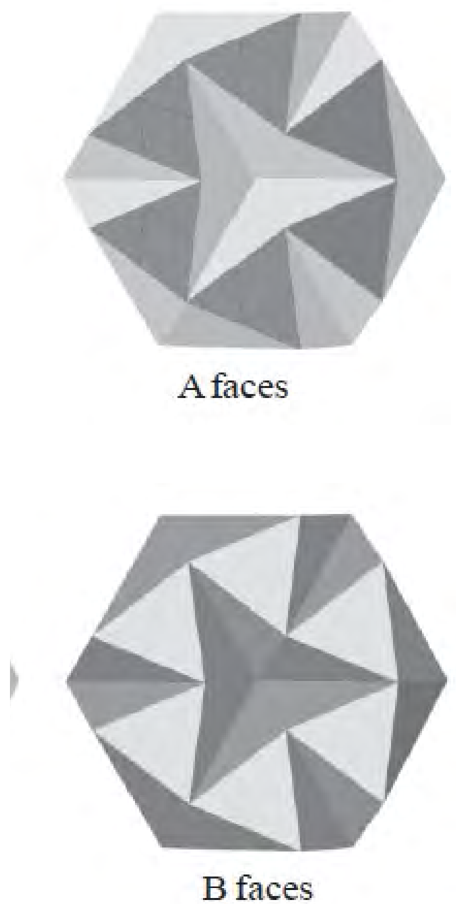
TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify): Deployable screen	■

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify): Heat-joule effect	■

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	■
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant’s presence	☐
Other (specify): Individuall user control	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify): NiTinol springs	■

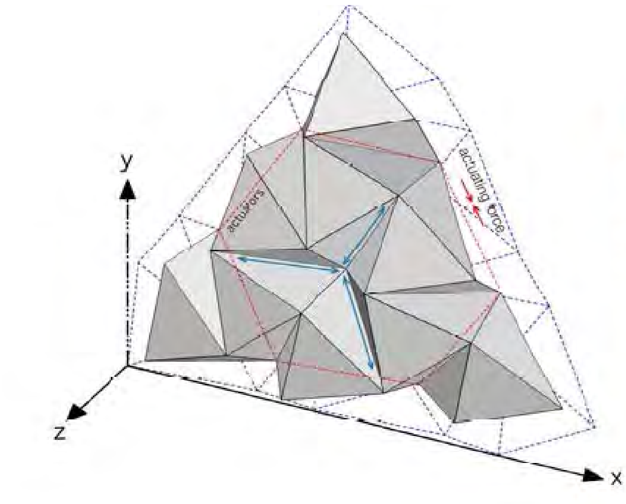
TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

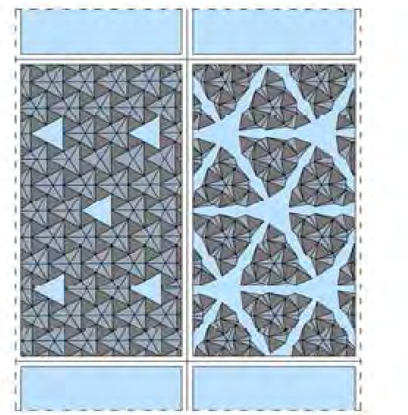


2

1. KUMORIgami Prototype
2. Simplification of the Origami pattern’s geometry
3. Scheme of operation and example of facade’s integration (closed and open configuration).

CONTROL OPERATION DETAILS





3

DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

KUMORIgami is activated with a power supply. If from one side the choice has been made to accommodate users' requirements, to the technological side difficulties have been found due to air temperature and system management when self-actuation is taken into account.
KUMORIgami sees the placement of the actuators along the outer vertexes of the hexagonal module. The linear contraction of the SMA springs produces the radial deployment of the shape, reducing the distances between edges.
The six springs connected in sequence led to values of about 8.4 – 9 V and 1.9 – 2 A to activate the kinematism. To completely close the Origami, 11 V have been required. KUMORIgami shape change is achievable with about 24 W (calculated using the definition of electric power).

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	■
Extrinsic (requires external control)	☐
Electromagnetic	☐
Other (specify): Possibility to switch by using electricity	■

SYSTEM RESPONSE TIME	
Seconds	■
Minutes	■
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/off	■
Gradual	■
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	☐
Centimeters	■
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	☐
03 Visible, surface change (lamellas, rollers, blinds)	☐
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	■
05 Visible, location or orientation change	☐
Other (specify)	☐

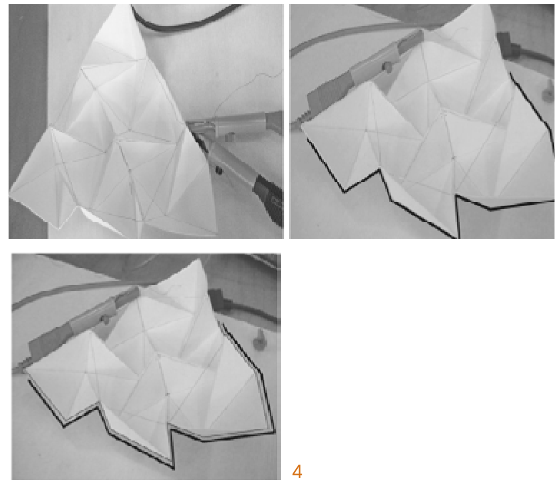
ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	■
No	
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	■

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	☐
Information not available	■

Cost/m2	-
Yearly cost of maintenance	-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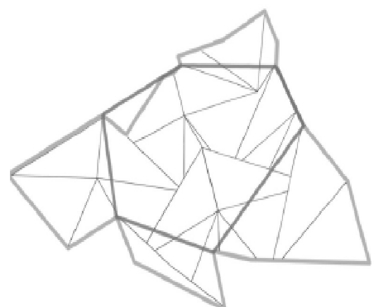
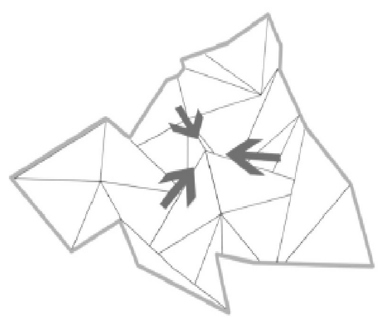

5.a


5.b

4. The actuators placement allows envisioning the deployment direction
5. The embedded SMA wires define the direction of deployment: 5.a, The actuators placement, 5.b. Deployment direction

Reference

Pesenti, M.,Masera, G.,Fiorito, F., Sauchelli, M.(2014), *Kinetic solar skin: a responsive folding technique*,International Conference on Solar Heating and Cooling for Buildings and Industry, SHC

Pesenti, M., Masera, G., Fiorito, F. (2015), *Shaping an Origami shading device through visual and thermal simulations*, 6th International Building Physics Conference, IBPC

Fiorito, F., Sauchelli, M., Arroyo, D., Pesenti, M., Imperadori, M., Masera, G.,Ranzi, G. (2016), *Shape morphing solar shadings: a Review,* Renewable and Sustainable Energy Reviews

Pesenti, M., Masera, G. and Fiorito F. (2018), *Exploration of Adaptive Origami Shading Concepts through Integrated Dynamic Simulations*, Journal of Architectural Engineering. Vol. 24, Issue 4

Reference to picture

Fiorito, F., Sauchelli, M., Arroyo, D., Pesenti, M., Imperadori, M., Masera, G.,Ranzi, G. (2016), *Shape morphing solar shadings: a Review,* Renewable and Sustainable Energy Reviews

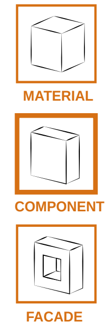
Pesenti, M., Masera, G. and Fiorito F. (2018), *Exploration of Adaptive Origami Shading Concepts through Integrated Dynamic Simulations*, Journal of Architectural Engineering. Vol. 24, Issue 4

Author of the sheet info

Enrico Sergio Mazzucchelli
Politecnico di Milano

Rosa Romano
Florence University, Department of Architecture

SOLPIX, NEW YORK (USA), 2010
Simone Giostra & Partners



Positioned at the convergence of technology, design and environment solution, SolPix is a fulls-cale working prototype demonstrating the ability of the system to interact with its environs while improving the energy performance of the Museum where was presented for the first time.
Giostra collaborated with artists Jeremy Rotsztain and Rory Nugent on the installation.
Featuring a large scale color LED display and photovoltaic panels integrated to a sun-shading system, SolPix transforms the existing glass structure into an energy-positive skin, harvesting solar energy and using it to power its screen, while protecting the buildig envelope from excessive solar radiation.

Latitude 40°69' N Longitude -74°26' W

LED DISPLAY; MEDIA SKIN; PV; GLASS CURTAIN WALL

BUILDING INFORMATION:			
Building floor area	-	Climate Type	All type of climate
Building use	-	Orientation of the facade	South
Building status	New Build	Other	-

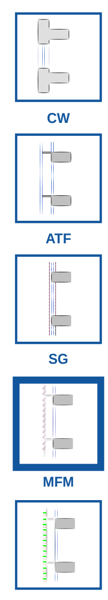
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	☐
04. Prototype demonstration	■
05. Commercial product/Existing building	☐

FUNCTION / GOAL / PURPOSE	
Thermal comfort	☐
Visual comfort	■
Acoustic comfort	☐
Energy management (harvesting, storing, supply)	☐
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	☐
Appearance (aesthetic quality)	■
Structure performance	☐
Energy generation	■
Personal users' control	☐
Other (durability, accesibility, use of natural resources, etc):	☐

TYPE OF COMPONENT SYSTEM	
External skin	■
Curtain wall (stick)	■
Window frame	☐
Insulated glass unit	☐
Building services unit	☐
Energy harvesting device	■
Air circulation device	☐
Natural ventilation device	☐
Solar tube	☐
Switchable Glazing	☐
Other:	☐

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	☐
Devices for managing natural ventilation in combination with mechanical ventilation systems	☐
Mobile screens for controlling solar radiation	■
Technological solutions designed to increase and/or control comfort inside the building	☐
Building automation systems for the management of plants and elements of the building skin	☐



CS_04

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify):PV	■

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

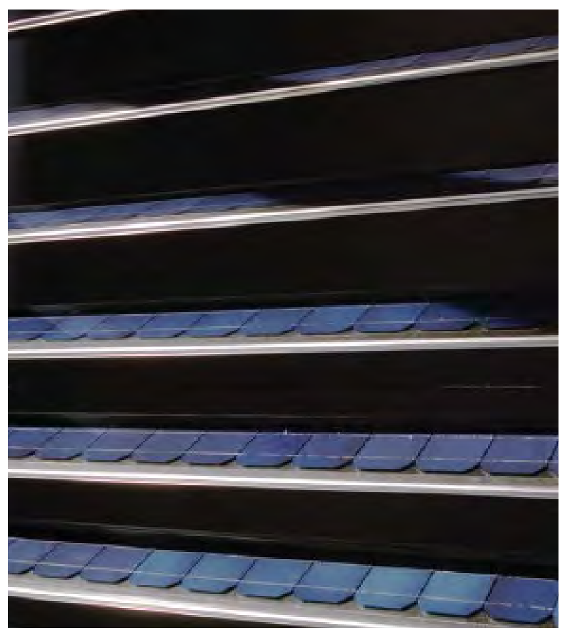
MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	■
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	■
Optical (e.g. daylight level, glare)	☐
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify):	☐

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

1



2

1. View of the LED display showcasing an interactive piece by Jeremy Rotsztain
2. View of the solar cells producing energy for the media wall

CONTROL OPERATION DETAILS

DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

The project is based on GreenPix, a carbon-neutral media wall for the Xicui Entertainment Complex in Beijing. Featuring one of the largest color LED display worldwide and the first photovoltaic system integrated into a glass curtain wall in China, GreenPix transformed the building envelop into a self-sufficient organic system.

New York-based architect Simone Giostra pushes this technology in his site-specific installation, improving the energy efficiency of the previous system, while increasing the resolution of the digital display and effectively achieving a transparent media wall.

SolPix allows daylight into the building while controlling its exposure to direct sunlight, reducing heat gain and transforming excessive solar radiation into energy for the media wall. When applied to building exteriors, the sun-shading elements provide unobstructed outside views from the building interior, while lending a contemporary texture to the building exterior. The horizontal or vertical panels can be mounted at a preferred angle or can be rotated in order to maximize exposure to direct sunlight.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	■
Extrinsic (requires external control)	□
Electromagnetic	□
Other (specify)	□

SYSTEM RESPONSE TIME	
Seconds	□
Minutes	■
Hours	□
Days	□
Seasons	□
Years	□
Other (specify)	□

SYSTEM DEGREE OF ADAPTIVITY:	
On/Off	■
Gradual	□
Other (specify)	□

DEGREE OF SPATIAL ADAPTATION	
Nanometers	□
Micrometers	□
Millimeters	□
Centimeters	□
Meters	□
Other (specify)	□

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	□
02 Visible, no surface change (smart glazing)	■
03 Visible, surface change (lamellas, rollers, blinds)	□
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	□
05 Visible, location or orientation change	□

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	■

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	■
Information not available	☐

Cost/m2	-
Yearly cost of maintenance	-


3


4

3. Interactive Experience
4. System components as applied to a building curtain wall

Reference
Text description provided by the architects: Simone Giostra & Partners

https://inhabitat.com/giant-solpix-led-wall-is-a-photovoltaic-solar-shield/ (Accessed July 22, 2018)

https://www.designboom.com/design/simone-giostra-partners-architects-solpix/ (Accessed July 22, 2018)

https://www.fastcompany.com/1644131/solpix-giant-led-display-doubles-solar-shield (Accessed July 22, 2018)

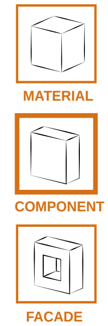
Reference to picture
© Simone Giostra & Partners

Author of the sheet info
Rosa Romano
Florence University, Department of Architecture

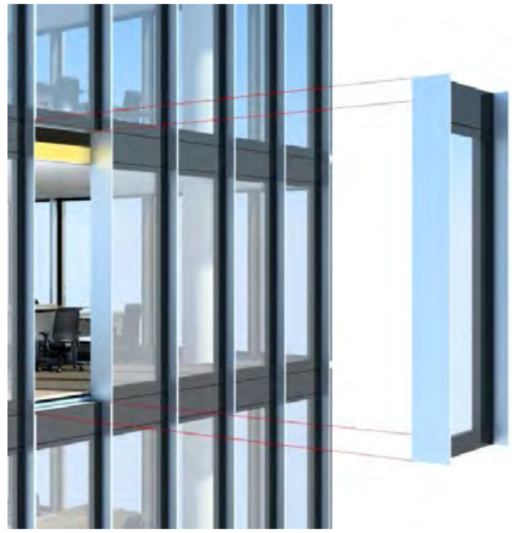
Mark Alston
Faculty of Engineering - Architecture and Built Environment, The University of Nottingham

Enrico Sergio Mazzucchelli
Politecnico di Milano

InDeWaG, BAYREUTH (DE), 2015
Prof. Dr. Dieter Brüggemann



The research project InDeWaG (Industrial Development of Fluid Flow Glazing Systems) has been funded for three and a half years by the European Union within the framework of the program HORIZON 2020.
The project will be ended in March, 2019.
The focus of this project is an insulating glazing unit filled up with a water-glycol fluid circulating within one of the Insulating Glass Units (IGU) cavities. The glass units will be developed for both, the usage within façades and as interior separation walls. They are conceived to serve for both heating and cooling.
The aim is to combine these units with other technologies in HVAC systems, such as photovoltaic and high-efficiency heat exchangers leading to minimized total energy consumptions of buildings without restrictions of daylight autonomy.



FLUID FLOW GLAZING SYSTEMS; INSULATING GLAZING; DAYLIGHT

BUILDING INFORMATION:			
Building floor area	-	Climate Type	All type of climate
Building use	-	Orientation of the facade	All orientation
Building status	-	Other	-

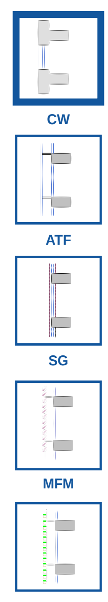
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	☐
04. Prototype demonstration	■
05. Commercial product/Existing building	☐

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	■
Acoustic comfort	☐
Energy management (harvesting, storing, supply)	■
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	■
Appearance (aesthetic quality)	☐
Structure performance	☐
Energy generation	■
Personal users' control	☐
Other (durability, accesibility, use of natural resources, etc):	☐

TYPE OF COMPONENT SYSTEM	
External skin	☐
Curtain wall (stick)	■
Window frame	☐
Insulated glass unit	☐
Building services unit	☐
Energy harvesting device	■
Air circulation device	☐
Natural ventilation device	☐
Solar tube	☐
Switchable Glazing	☐
Other:	☐

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	■
Devices for managing natural ventilation in combination with mechanical ventilation systems	☐
Mobile screens for controlling solar radiation	☐
Technological solutions designed to increase and/or control comfort inside the building	☐
Building automation systems for the management of plants and elements of the building skin	☐



CS_05

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify):Fluidglass	■

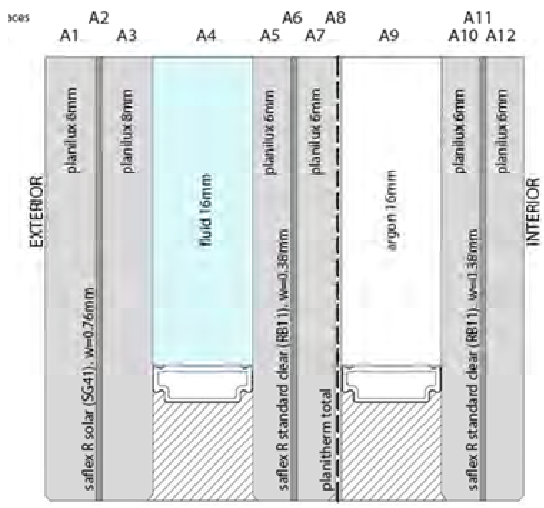
TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	☐
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	☐
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify):	☐

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	■
Other (specify):	☐



1

2

1. An example of WFG (Water Flow Glazing) layers
2. Prototype WFG (Water Flow Glazing) BAU 2017 Münich - ETEM Stand
3. Bulgarian Pavilion with WFG Modules designed by Architektonika (source: http://www.architectonika.com)

CONTROL OPERATION DETAILS

3

DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

InDeWaG facade or radiant thermal management elements do not need sophisticated electrical integration and are designed such as to have “passive” control over heating and cooling by convection and low degree of forced mechanical transport. The core element to achieve this objective is a “Triple Glazing Element”, in which a fluid-mainly a water-glycol mixture - is circulated with a minimum of forced pumping.
The two laminated glass panes each consist of 2,0 x 8,0 mm Through Glass Via (TVG) as well a 1,52 mm thick SentryGlas®Plus (SGP) interlayer.
There is a water chamber between the two TVG panes; in the second Software Defined Radio (SDR) there is an argon-air mixture. Due to the desired floor height, the dimensions of the Glazing element is 1300,0 x 3000,0 mm.
In order to ensure the optimal integration of the Fluid Flow Glazing (FFG) modules in the overall building climate concept, it is essential to understand their exact spectral, thermal, mechanical and fluid dynamic properties.
For this purpose mathematical models for the relevant physical processes (heat exchange, fluid flow dynamics, optical and structural behavior as well as environmental influences) within a software model of the glazing are mapped using highly complex flow simulations Computational Fluid Dynamics (CFD).

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	■
Extrinsic (requires external control)	☐
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	■
Minutes	☐
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/Off	■
Gradual	☐
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	■
Micrometers	☐
Millimeters	☐
Centimeters	☐
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	■
03 Visible, surface change (lamellas, rollers, blinds)	☐
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	☐
05 Visible, location or orientation change	☐
Other (specify)	☐

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	☐
Other (specify): this issue is an ongoing Works within the research project	■

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	■

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	☐
Information not available	■

Reference
Text description provided by: Ümit Esiyok
uesiyok@bollinger-grohmann.de

http://www.indewag.eu/d (Accessed July 22, 2018)

Luis J. Claros-Marfil, J., Padial, F., Lauret, B. (2016), A *New and Inexpensive Open Source Data Acquisition and Controller for Solar Research: Application to a Water-Flow Glazing*, Renewable Energy, v. 92, pp. 450-461

Fernando del Ama, G., Belen, M., Juan, Juan A.Hernandez, R. (2017), *Thermal simulation of a Zero Energy glazed pavilion in Sofia, Bulgaria. New strategies for energy management by means of Water flow Glazing*, IOP Conference Series: Materials Science and Engineering

Reference to picture
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Author of the sheet info

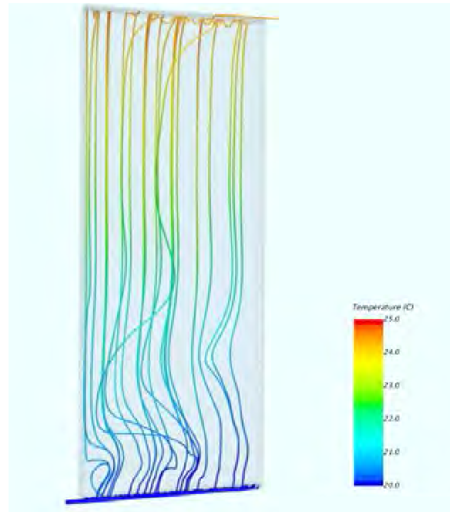
Ümit Esiyok
uesiyok@bollinger-grohmann.de

Rosa Romano
Florence University, Department of Architecture

Enrico Sergio Mazzucchelli
Politecnico di Milano

4. System components as applied to a building curtain wall
5. Principe of Fluid Flow Glazing as actively controllable radiant cooling and heating element (Source: Intelliglass, 2014)
6. FFG façade design. It Is a facade developed with water flow glazing, which is able to actively control the thermal stability in the interior spaces, and, in the same time absorb solar energy, in order to get use of it.

Cost/m2	-
Yearly cost of maintenance	-



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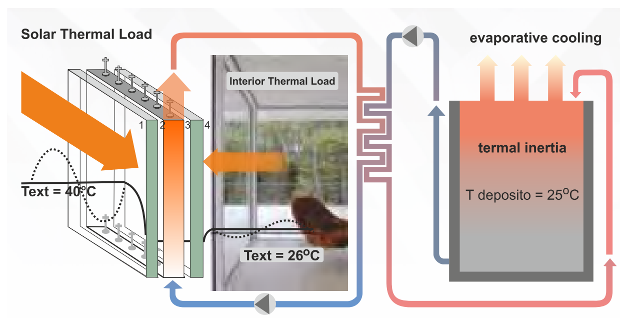

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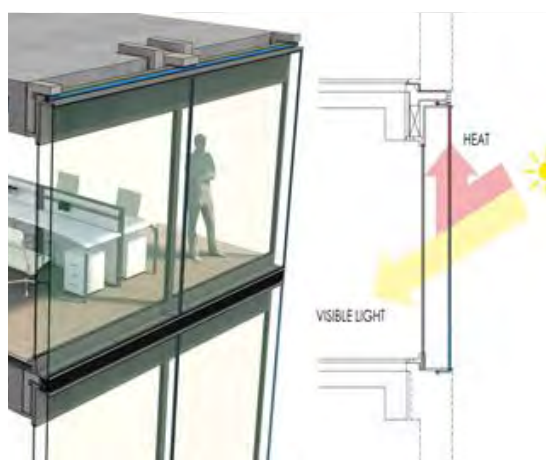
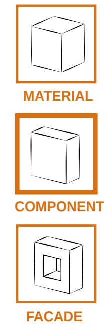


6

BIPV ADAPTIVE FLAKES, MILAN (IT), 2016
Enrico Sergio Mazzucchelli, Luisa Doniacovo



The BIPV façade system, developed from Italian team, is able to orientate the photovoltaic cells in an intrinsic way, in order to optimize the energy production in relation to the outdoor conditions over a year. Because of the passive dynamism, the component can adapt itself to the external climatic conditions without an electrically powered mechanical system. This allows to save the related movement energy consumption, resulting in a more energy-efficient overall system behaviour. The lightness should be maintained to allow the installation on substructures of limited size: this leads to save on cost and use of building materials. At the same time, the component must have a good mechanical behaviour under the action of atmospheric agents such as wind, rain, hail, etc., but also a good behaviour in relation to dust and pollution action. In this regard, the component must be easily cleaned according to the ordinary maintenance frequency and modalities.

BIPV, ADAPTIVE FLAKES, SHADING SYSTEM, HYGROMORPHIC MATERIALS, TIMBER

BUILDING INFORMATION:			
Building floor area	-	Climate Type	All type of climate
Building use	-	Orientation of the facade	South, East, West
Building status	-	Other	-

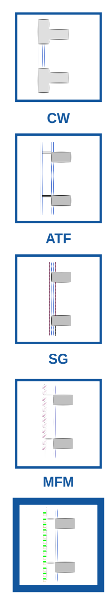
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	■
03. Technology validated in lab	☐
04. Prototype demonstration	☐
05. Commercial product/Existing building	☐

FUNCTION / GOAL / PURPOSE	
Thermal comfort	☐
Visual comfort	■
Acoustic comfort	☐
Energy management (harvesting, storing, supply)	☐
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	☐
Appearance (aesthetic quality)	☐
Structure performance	☐
Energy generation	■
Personal users' control	☐
Other (durability, accesibility, use of natural resources, etc):	☐

TYPE OF COMPONENT SYSTEM	
External skin	☐
Curtain wall (stick)	■
Window frame	☐
Insulated glass unit	☐
Building services unit	☐
Energy harvesting device	■
Air circulation device	☐
Natural ventilation device	☐
Solar tube	☐
Switchable Glazing	☐
Other:	☐

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	■
Devices for managing natural ventilation in combination with mechanical ventilation systems	☐
Mobile screens for controlling solar radiation	■
Technological solutions designed to increase and/or control comfort inside the building	☐
Building automation systems for the management of plants and elements of the building skin	☐



CS_06

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	■
Salthydrates	☐
Other (specify):PV	■

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify): Flake that changes its shape	■

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bio-material effect	■
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	■
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	☐
Air quality (humidity, CO2 concentration, etc)	■
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	☐
Pneumatical	☐
Electromagnetic	☐
Thermal	■
Chemical	☐
Other (specify): outdoor climate	■

1

2

3

1. Flakes adaptive layer (15 x 10 cm) with fixing holes.
2. Detail of the slotted holes and the neoprene gaskets.
3. Flakes with adaptive and photovoltaic layer.

CONTROL OPERATION DETAILS

DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

The BIPV adaptive flakes can be installed on a wood frame to create modular panels that can be used as façade cladding, sun-shading system and street furniture item too. The basic preassembled module consists of a wood perimeter frame, that is the support for transoms, where the flakes are fastened with screws. Concerning the union between the flakes adaptive layer and the photovoltaic one, steel male-female screws are used. The assembly between the adaptive and the photovoltaic layers should allow the adjustment of this last one to the shape taken by the self-adjusting material, depending on the outdoor conditions. For this purpose, slotted holes on the lower part of the flakes have been provided. The male-female screws, inserted into special neoprene gaskets, can move in these holes when the flake changes its shape. The holes provided for the connection at the upper part are instead circular and they constitute the fixed connection point between the two layers. These joints, protruding from the flake surface, allow a 0.5 cm back-PV cell ventilation, designed to avoid the overheating of the cells themselves. The 15x10 cm flake has four fixing point. BIPV flakes can also be used as fixed or mobile sun-shading system, modifying the panel's wooden frame. In this case, the panels consist of a timber framework (40x100 mm in section) and intermediate transoms, where the flakes are fastened. In addition, transoms of 20x100 mm (at the base and at the top of the mullions, as well as every 60 cm) are inserted to tighten the substructure. In case of mobile sun-shading, the handling system is made up of steel guides anchored to the upper floor, where sliding carriages, connected to the panels, are inserted.
About the electrical wires that connect the PV cells, they are inserted into special grooves of the wooden frame profiles.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	■
Extrinsic (requires external control)	□
Electromagnetic	□
Other (specify)	□

SYSTEM RESPONSE TIME	
Seconds	□
Minutes	■
Hours	■
Days	□
Seasons	□
Years	□
Other (specify)	□

SYSTEM DEGREE OF ADAPTIVITY:	
On/Off	□
Gradual	■
Other (specify)	□

DEGREE OF SPATIAL ADAPTATION	
Nanometers	□
Micrometers	□
Millimeters	■
Centimeters	□
Meters	□
Other (specify)	□

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	□
02 Visible, no surface change (smart glazing)	□
03 Visible, surface change (lamellas, rollers, blinds)	□
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	■
05 Visible, location or orientation change	□

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	■

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	■
Information not available	☐

Reference
Text description provided by the:
Enrico Sergio Mazzucchelli

Mazzucchelli, E. S., Doniacovo, L. (2017), *The integration of BIPV adaptive lakes in the building envelope*, 12th Conference on Advanced Building Skins

Mazzucchelli, E. S., Alston, M., Doniacovo, L. (2017), *Combining timber and photovoltaic technologies: study of a BIPV wooden adaptive system*, Ne-xt facades Conference, Lucerne

Mazzucchelli, E. S., Alston, M., Brzezicki, M. and Pottgiesser, U. (2017), *Desired morphology in energy capture and storage advanced façades*, Ne-xt facades Conference, Lucerne

Reference to picture
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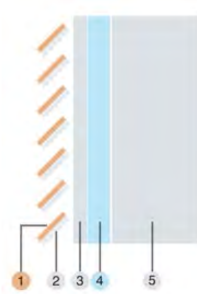
Author of the sheet info
Enrico Sergio Mazzucchelli
Politecnico di Milano, Italy

Rosa Romano
Florence University, Department of Architecture

Cost/m2	-
Yearly cost of maintenance	-



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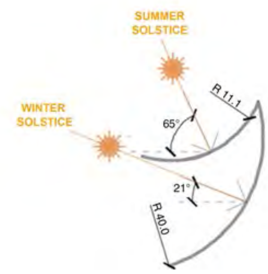

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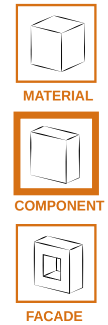
4. Façade functional layers: 1 – Energy capture layer, 2 – Self-adjusting layer, 3 – Substructure layer, 4 – Ventilation gap, 5 – Other wall layers (support layer, thermal insulation, etc.).
5. Example of flakes curvature
6. Example of BIPV adaptive flakes integration in an envelope system

SHAPESHIFT, Zürich (CH), 2010
M. Kretzer, D. Rossi, E. Augustynowicz, S. Georgakopulou, S. Sixt



‘ShapeShift’ is an experiment in future possibilities of architectural materialization and ‘organic’ kinetics. The project explores the potential application of Electro Active Polymer (EAP) at an architectural scale. EAP is a polymer actuator that converts electrical power into kinetic force. Due to its extreme flexibility, lightness, transparency, thin dimensions and its ability to smoothly change shape without the need for external actuators it is a highly attractive component for architectural solutions. In this proposal, the distinctive material
properties are not merely used as an actuator replacement but are also orchestrated for their aesthetic qualities. The thin film functions as a possible alternative for conventional building skins and
envisions the concept of a futuristic, soft, flexible and sensitive architecture.

EAP, ORGANIC’ KINETICS, SENSITIVE ARCHITECTURE, ACRYLIC TAPE

BUILDING INFORMATION:			
Building floor area	-	Climate Type	-
Building use	-	Orientation of the facade	-
Building status	-	Other	-

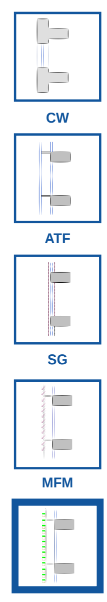
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	■
04. Prototype demonstration	☐
05. Commercial product/Existing building	☐

FUNCTION / GOAL / PURPOSE	
Thermal comfort	☐
Visual comfort	■
Acoustic comfort	☐
Energy management (harvesting, storing, supply)	☐
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	☐
Appearance (aesthetic quality)	■
Structure performance	☐
Energy generation	☐
Personal users’ control	☐
Other (durability, accesibility, use of natural resources, etc):	☐

TYPE OF COMPONENT SYSTEM	
External skin	■
Curtain wall (stick)	☐
Window frame	☐
Insulated glass unit	☐
Building services unit	☐
Energy harvesting device	☐
Air circulation device	☐
Natural ventilation device	☐
Solar tube	☐
Switchable Glazing	☐
Other:	☐

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	☐
Devices for managing natural ventilation in combination with mechanical ventilation systems	☐
Mobile screens for controlling solar radiation	■
Technological solutions designed to increase and/or control comfort inside the building	☐
Building automation systems for the management of plants and elements of the building skin	☐



CS_07

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	■
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify):	☐

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify): Not present	■

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify): Adaptive material	■

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	■
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	☐
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify): Electric	■

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	☐
Pneumatical	☐
Electromagnetic	☐
Thermal	■
Chemical	☐
Other (specify):	☐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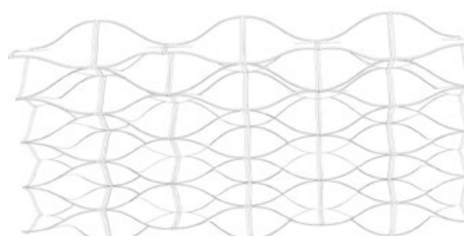
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6

1. SHAPESHIFT prototype
2. Side View
3. Front View
4. Component
5. Perspective View
6. Concept of the facade system

CONTROL OPERATION DETAILS

3

DETAILED EXPLANATION OF THE CONTROL/OPERATION

The component based form results from the material's desire to return into its original shape combined with specially designed structural frames developed to allow an appropriate degree of flexibility.
This minimum energy structure retains a variable stiffness, which allows for a variety of deformations within a given range. Each element consists of a thin layer of highly elastic, stretched acrylic tape that is attached to a supportive frame and sandwiched between two electrodes. This is achieved through coating both sides of the film equally with conductive carbon powder and insulating them with a thin layer of liquid silicon. Once a voltage in the range of several kilovolts is applied, the polymer changes its shape in two ways. First, due to the attraction of the opposing charges, the film is squeezed in its thickness direction. Second, the repelling forces between equal charges on both electrodes result in a linear expansion of the film. After actuation the film becomes thinner and its surface area increases. As the membrane is attached to 1,5 mm flexible acrylic frames, due to the initial prestretching of the polymer film, the rhombic frame bends when the material is in its relaxed condition. After the high voltage is applied, the material expands, and the component flattens out. Parallel to the design of a single element, efforts in structural arrangements and tessellations were performed.
As with the single units, the dynamic structures achieve their shape from the relationship of the pre-stretched EAP to the flexible frame. Through direct component-to-component linkages an added layer of complexity is achieved. Each entity has an influence on the form and movement of its neighbours, and therefore, on the structure as a whole.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	■
Extrinsic (requires external control)	☐
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	■
Minutes	☐
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/off	☐
Gradual	■
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	■
Centimeters	☐
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	☐
03 Visible, surface change (lamellas, rollers, blinds)	■
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	☐
05 Visible, location or orientation change	☐
Other (specify)	☐

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	■
Information not available	☐

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	■
Information not available	☐

Cost/m2	-
Yearly cost of maintenance	-

Reference
Text description provided by: Manuel Kretzer

http://caad-eap.blogspot.it/ (Accessed May 15, 2018)

http://materiability.com/about/ (Accessed May 15, 2018)

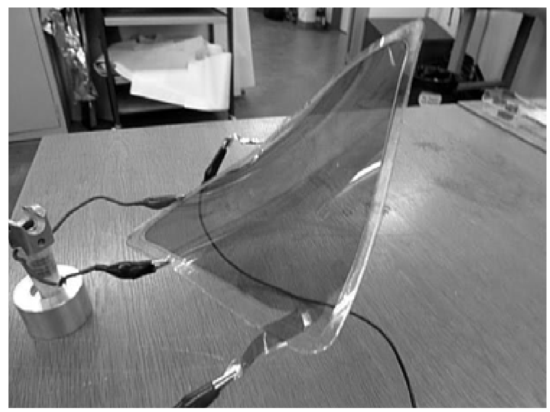
Kretzer, M., Rossi, D. (2012), *SHAPESHIFT*, Leonardo, Vol. 45, N. 5, pp. 480–481

Lochmatter, P. (2007), *Development of a Shell-like Electroactive Polymer (EAP) Actuator*, (PhD thesis) Swiss Federal Institute of Technology (ETH), Zurich

Reference to picture

Author of the sheet info
Rosa Romano
Florence University, Department of Architecture

7



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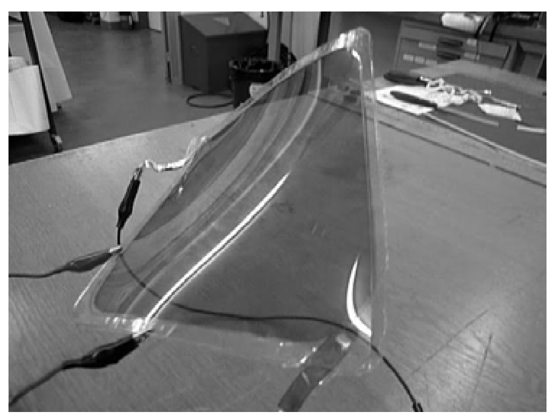


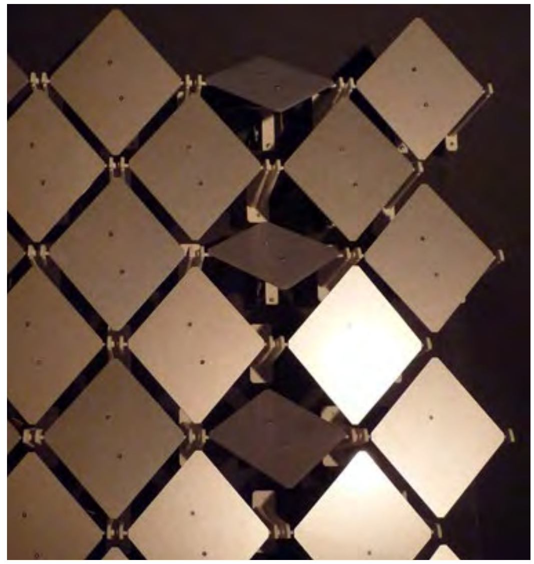
9

7. Electrical connection
8. Thin layer Prototype
9. Thin layer Prototype

ADAPTIVE FA[CA]DE, London (UK), 2009
Marilena Skavara

MATERIAL
COMPONENT
FACADE

Driven by the need to effectively mediate the light levels of buildings and following the paradigm of natural systems, Adaptive Fa[CA]de explores the possibilities of learning the emergent complexity of Cellular Automata (CA) with artificial Neural Networks (NN) to control an adaptive skin. While is often assumed that adaptation to a complex set of phenomena requires equally (or even more) complex control mechanisms, Adaptive Fa[CA]de suggests a simpler control system in terms of independent units, yet more contextual to its environment.



ADAPTIVE, MACHINE LEARNING, NEURAL NETWORKS, CELLULAR AUTOMATA

BUILDING INFORMATION:			
Building floor area	-	Climate Type	-
Building use	-	Orientation of the facade	-
Building status	-	Other informations	-

DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	■
04. Prototype demonstration	☐
05. Commercial product/Existing building	☐

FUNCTION / GOAL / PURPOSE	
Thermal comfort	☐
Visual comfort	■
Acoustic comfort	☐
Energy management (harvesting, storing, supply)	☐
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	☐
Appearance (aesthetic quality)	■
Structure performance	☐
Energy generation	☐
Personal users' control	☐
Other (durability, accesibility, use of natural resources, etc):	☐

TYPE OF COMPONENT SYSTEM	
External skin	■
Curtain wall (stick)	☐
Window frame	☐
Insulated glass unit	☐
Building services unit	☐
Energy harvesting device	☐
Air circulation device	☐
Natural ventilation device	☐
Solar tube	☐
Switchable Glazing	☐
Other:	☐

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	☐
Devices for managing natural ventilation in combination with mechanical ventilation systems	☐
Mobile screens for controlling solar radiation	■
Technological solutions designed to increase and/or control comfort inside the building	☐
Building automation systems for the management of plants and elements of the building skin	☐

CW
ATF
SG
MFM
BF

CS_08

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	■
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify):	☐

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify): Not present	■

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	☐
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant’s presence	☐
Other (specify): Electric	■

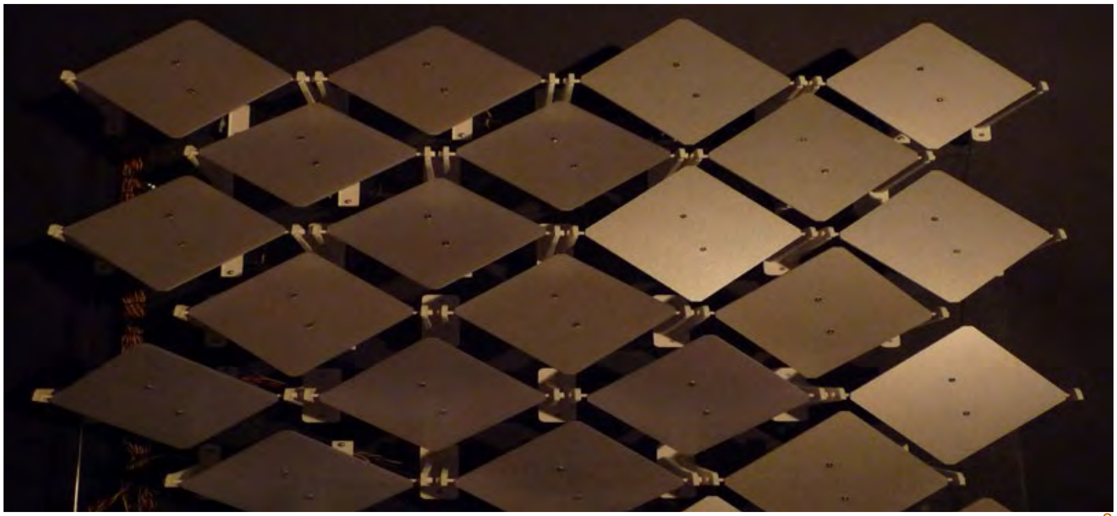
TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify):	☐

1

2

1. Side view of the kinetic prototype showing the 3D-printed armature that supports the kinetic panels. a-g. Various Cellular Automata patterns as manifested on the working prototype
2. Adaptive Fa[CA]de render

CONTROL OPERATION DETAILS



3

DETAILED EXPLANATION OF THE CONTROL/OPERATION

Adaptive Fa[CA]de utilises the inherent complexity found in several CA to effectively minimise the input from the environment and achieve maximum adaptability, significantly reducing energy and cost and leveraging the building's performance.
A finite grid of panels, each capable of tilting to various angles but obeying to a CA rule, allows different amounts of light to penetrate the building. Using CA patterns as an interface between external conditions and desired overall and local optima throughout a building, the signal is efficiently communicated down the façade. However intricate, or chaotic, the generated patterns are, no compromise between aesthetic merit and pragmatic goals needs to be made.
This project suggests that complex adaptations can be achieved and that complexity itself can be the tool for a deeper understanding of our natural and constructed world. The fact that the system is able to accommodate complexity both in the environmental data and in the CA structure itself suggests that a control system can be made to adapt to such conditions even when the mechanism for doing so is initially unknown or unperceived. Shifting from responsiveness to intelligence and adaptability can lead to dynamic, sustainable configurations of high aesthetic value.
The kinetic prototype shown here was manufactured with laser-cut acrylic panels connected to a system of 3d-printed joints. Each panel was operated by a simple servo motor and the whole grid was controlled by a centralised script running real-time in Processing language. The script included a fixed virtual model, a given 7-state CA rule and an artificial NN employed to train the system.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	☐
Extrinsic (requires external control)	■
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	☐
Minutes	■
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/off	☐
Gradual	■
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	■
Millimeters	☐
Centimeters	☐
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	☐
03 Visible, surface change (lamellas, rollers, blinds)	☐
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	■
05 Visible, location or orientation change	☐
Other (specify)	☐

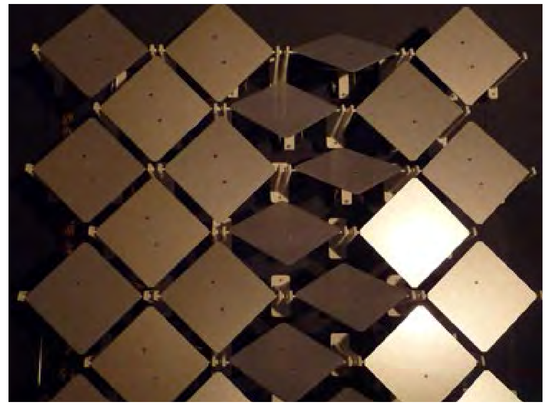
ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	■
Information not available	☐

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	☐
Information not available:	■

Cost/m2	-
Yearly cost of maintenance	-



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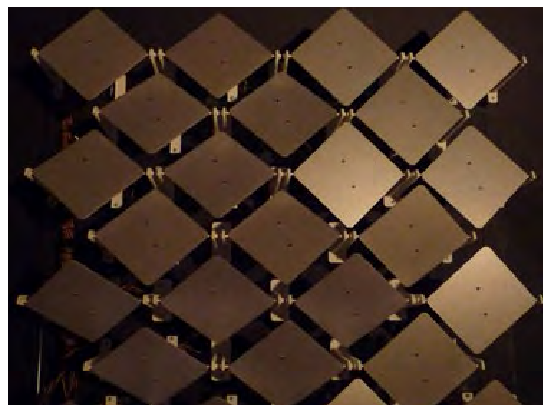

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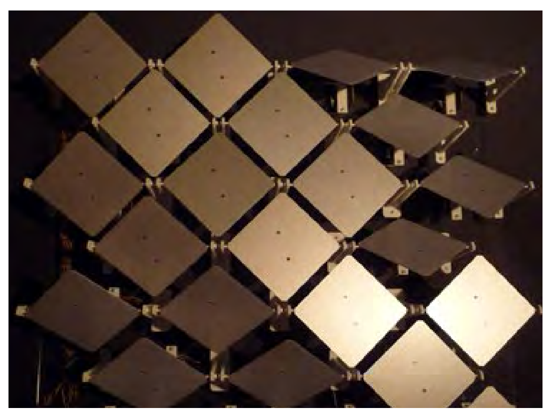

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Reference
Text description provided by: Marilena Skavara

http://discovery.ucl.ac.uk/19042/ (Accessed May 15, 2018)

Reference to picture:
© Marilena Skavara

Author of the sheet info
Marilena Skavara
The Bartlett School of Architecture, UCL

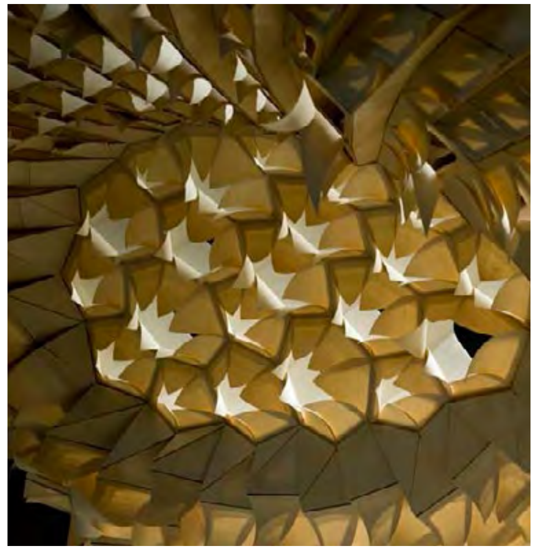
Rosa Romano
Florence University, Department of Architecture

3. Perspective view of the model in action.
4. Perspective view of the model in action.
5. Perspective view of the model in action.

HYGROSCOPE, Centre Pompidou, Paris (FR), 2012
Achim Menges Architect

MATERIAL
COMPONENT
FACADE

The project explores a novel mode of responsive architecture based on the combination of material inherent behaviour and computational morphogenesis. The dimensional instability of wood in relation to moisture content is employed to construct a climate responsive architectural morphology. Suspended within a humidity controlled glass case the model opens and closes in response to climate changes with no need for any technical equipment or energy. Mere fluctuations in relative humidity trigger the silent changes of material-innate movement. The material structure itself is the machine.
The project was commissioned by the Centre Pompidou Paris for its permanent collection and it was first shown in the exhibition “Multiversités Créatives“ on 2nd of May 2012.



MOISTURE SENSITIVE; PARAMETRIC; WOOD; KINETIC; AUTOREACTIVE

BUILDING INFORMATION:			
Building floor area	-	Climate Type	All with significant RH variations
Building use	-	Orientation of the facade	All orientation
Building status	New Built	Other	-

DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	☐
04. Prototype demonstration	■
05. Commercial product/Existing building	☐

FUNCTION / GOAL / PURPOSE	
Thermal comfort	☐
Visual comfort	■
Acoustic comfort	☐
Energy management (harvesting, storing, supply)	☐
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	☐
Appearance (aesthetic quality)	☐
Structure performance	☐
Energy generation	☐
Personal users' control	☐
Other (durability, accesibility, use of natural resources, etc):	☐

TYPE OF COMPONENT SYSTEM	
External skin	■
Curtain wall (stick)	☐
Window frame	☐
Insulated glass unit	☐
Building services unit	☐
Energy harvesting device	☐
Air circulation device	☐
Natural ventilation device	☐
Solar tube	☐
Switchable Glazing	☐
Other:	☐

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	☐
Devices for managing natural ventilation in combination with mechanical ventilation systems	☐
Mobile screens for controlling solar radiation	■
Technological solutions designed to increase and/or control comfort inside the building	☐
Building automation systems for the management of plants and elements of the building skin	☐

CW
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CS_09

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	■
Salthydrates	☐
Other (specify):	☐

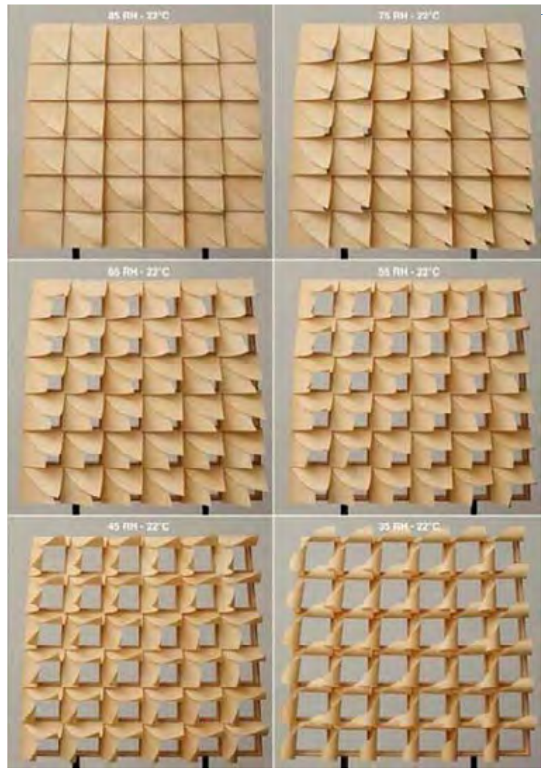
TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	☐
Bi-directional transmission control	■
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	■
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (IMPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	☐
Air quality (humidity, CO2 concentration, etc)	■
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify):	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify):	☐



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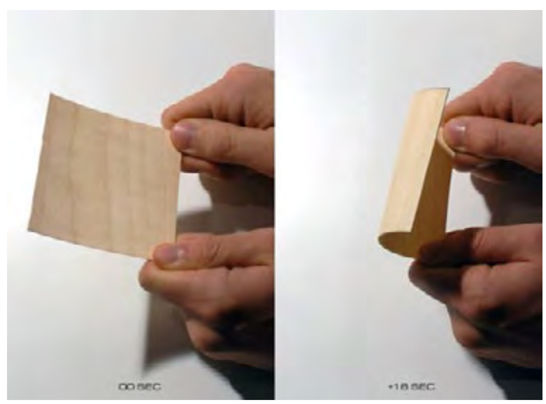


2

1. Hygroscope – Achim Mengis/ICD Stuttgart 2012: Understanding material properties of wood – folding with humidity (www.achimmenges.net)
2. Hygroscope – Achim Mengis/ICD Stuttgart 2012: Understanding material properties of wood – folding with humidity (www.achimmenges.net)

CONTROL OPERATION DETAILS

3

DETAILED EXPLANATION OF THE CONTROL/OPERATION

The project is based on more than five years of design research on climate responsive architectural systems that do not require any sensory equipment, motor functions or even energy. Here, the responsive capacity is ingrained in the material's hygroscopic behaviour and anisotropic characteristics. Anisotropy denotes the directional dependence of a material's characteristics, in this case the different physical properties of wood in relation to grain directionality. Hygroscopicity refers to a substance's ability to take in moisture from the atmosphere when dry and yield moisture to the atmosphere when wet, thereby maintaining a moisture content in equilibrium with the surrounding relative humidity. In the process of adsorption and desorption of moisture the material changes physically, as water molecules become bonded to the material molecules.

The increase or decrease of bound water changes the distance between the microfibrils in the wood cell tissue, resulting in both a change in strength due to interfibrillar bonding and a significant decrease in overall dimension. Given the right morphological articulation, this dimensional change can be employed to trigger the shape change of a responsive element. This enables to employ simple wood, one of the oldest and most common construction materials, as a climate-responsive, natural composite that can be physically programmed to compute different shapes in response to changes in relative humidity.

The thin wooden sheets curve (opening) and extend (closing) through a hygroscopic behaviour (ability to take in moisture from the atmosphere when dry and yield moisture to the atmosphere when wet) in response to R.H. fluctuations which trigger the anisotropic characteristics of the materials.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	■
Extrinsic (requires external control)	□
Electromagnetic	□
Other (specify):	□

SYSTEM RESPONSE TIME	
Seconds	■
Minutes	■
Hours	□
Days	□
Seasons	□
Years	□
Other (specify):	□

SYSTEM DEGREE OF ADAPTIVITY:	
On/off	□
Gradual	■
Other (specify)	□

DEGREE OF SPATIAL ADAPTATION	
Nanometers	□
Micrometers	■
Millimeters	□
Centimeters	□
Meters	□
Other (specify)	□

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	□
02 Visible, no surface change (smart glazing)	□
03 Visible, surface change (lamellas, rollers, blinds)	□
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	■
05 Visible, location or orientation change	□
Other (specify)	□

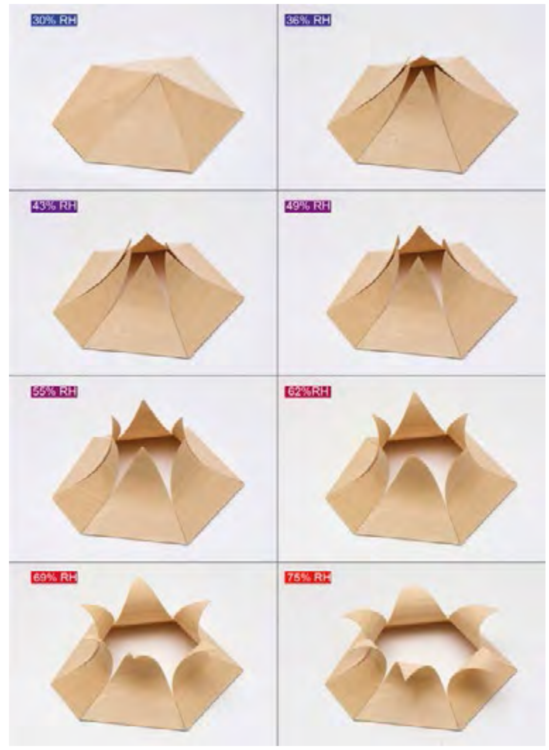
ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	■
No	☐
Other (specify):	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	■

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	☐
Information not available	■

Cost/m2	-
Yearly cost of maintenance	-



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5

Reference
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http://icd.uni-stuttgart.de/?p=7291 (Accessed September 16, 2018)

https://www.centrepompidou.fr/cpv/resource/c7GpBeA/rb964z (Accessed September 16, 2018)

http://www.biomimetic-architecture.com/2012/hygroscope-centre-pompidou-paris/ (Accessed September 16, 2018)

Reference to picture
http://www.achimmenges.net/?p=5083 (Accessed September 16, 2018)

Author of the sheet info
Sandra Persiani
Technical University of Munich

Rosa Romano
Florence University, Department of Architecture

Enrico Sergio Mazzucchelli
Politecnico di Milano

3. Hygroscope – Achim Mengis/ICD Stuttgart 2012: Prototype (www.achimmenges.net)
4. Scientific Development: Humidity Responsive Wood Composites
5. HygroScope: Meteorosensitive Morphology, Achim Menges in collaboration with Steffen Reichert, 2012

SOLAR XXI – BIPV - PCM, LISBON (PT), 2015
Laura Aelenei

MATERIAL
COMPONENT
FACADE

Solar XXI building was built in Lisbon in 2006 as a nearly Zero Energy Building demonstration project. One of the main objective of the project was from the beginning the integration of the solar system in order to offset the low energy consumption of the building. A BIPV-T system was integrated into the south building façade also for the improvement of the indoor climate during heating season in the day time hours, when the heat released in the process of converting solar radiation into power is successfully recovered. In order to test other strategies for using a BIPV for the improuvment of the indoor climate and regulating PV cells, a different combination was designed, using a storage module. The storage module is an insulated box with 10 PCM (DuPont Energain Datasheet) plates. Between the PV and the storage box, there is a cavity air, mechanically ventilated. In this manner, the BIPV-PCM can function also as heat recover through ventilation of the cavity air.

BIPV-T; THERMAL STORAGE; PCM; ENERGY STORAGE

BUILDING INFORMATION:			
Building floor area	-	Climate Type	-
Building use	-	Orientation of the facade	South
Building status	-	Other informations	-

DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	□
02. Technology concept formulated/Design Proposal	□
03. Technology validated in lab	□
04. Prototype demonstration	■
05. Commercial product/Existing building	□

FUNCTION / GOAL / PURPOSE	
Thermal comfort	□
Visual comfort	□
Acoustic comfort	□
Energy management (harvesting, storing, supply)	■
Mass transfer control (e.g. condensation control)	■
Indoor air quality	■
Appearance (aesthetic quality)	□
Structure performance	□
Energy generation	■
Personal users' control	□
Other (durability, accesibility, use of natural resources, etc):	□

TYPE OF COMPONENT SYSTEM	
External skin	□
Curtain wall (stick)	■
Window frame	□
Insulated glass unit	□
Building services unit	□
Energy harvesting device	■
Air circulation device	□
Natural ventilation device	□
Solar tube	□
Switchable Glazing	□
Other: PV panel	■

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	■
Devices for managing natural ventilation in combination with mechanical ventilation systems	□
Mobile screens for controlling solar radiation	□
Technological solutions designed to increase and/or control comfort inside the building	□
Building automation systems for the management of plants and elements of the building skin	□

CW
ATF
SG
MFM
BF

CS_10

TYPE OF MATERIAL	
Liquid crystals	[ ]
Phase Change Materials	[x]
Polymers	[ ]
Alloys	[ ]
Ceramics	[ ]
Wood	[ ]
Salthydrates	[ ]
Other (specify): PV	[x]

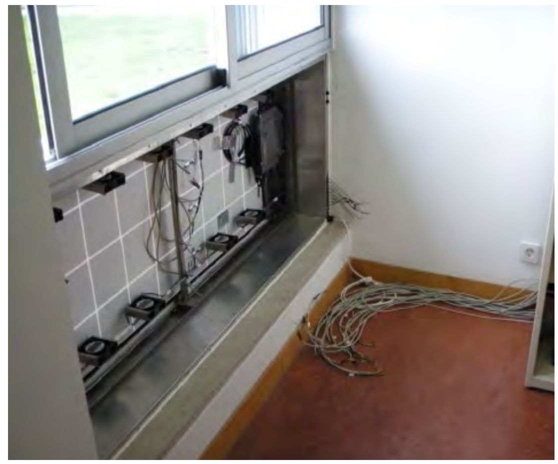
TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	[ ]
Liquid crystal, SPD	[ ]
Photo-volta-chromic	[ ]
Independently tunable NIR-VIS EC	[ ]
Thermo- tropic / chromic	[ ]
Photo-chromic	[ ]
Fluidglass	[ ]
Other (specify): Not present	[x]

TYPE OF SHADING DEVICE	
Screens / roller shades	[ ]
Blinds with slat angle control	[ ]
Bi-directional transmission control	[ ]
Insulating shutters	[ ]
Shading with dual-axis tracking	[ ]
Other (specify):	[ ]

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	[ ]
Bi-material effect	[ ]
Electroactive material	[ ]
Superabsorbent material	[ ]
Phase Change	[x]
Other (specify):	[ ]

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	[ ]
Thermal (e.g. outdoor air temperature)	[x]
Electromagnetic (e.g. solar radiation)	[x]
Optical (e.g. daylight level, glare)	[ ]
Air quality (humidity, CO2 concentration, etc)	[ ]
Building heating/cooling load	[ ]
Occupant's presence	[ ]
Other (specify):	[ ]

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	[ ]
Pneumatical	[ ]
Electromagnetic	[ ]
Thermal	[x]
Chemical	[ ]
Other (specify):	[ ]



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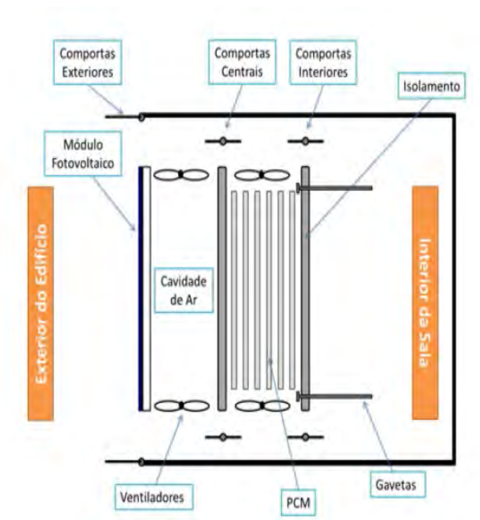


2

1. Inside view of the prototype
2. System configuration
3. Views of the prototype installed on the SolarXXI main façade.

CONTROL OPERATION DETAILS

3

DETAILED EXPLANATION OF THE CONTROL/OPERATION

The prototype BIPV-PCM has been designed, installed and tested in real condition on the main façade of SolarXXI office building in Lisbon. The building was designed and prepared to work as a test facility, allowing the installation of the prototype on the façade.
The prototype under study consists of an outer layer (PV module) and an inner layer (gypsum wallboard incorporating PCM - Alba®balance with operating temperature of 23ºC). The properties of the system defined by the three layers are:

- PV. The PV polycrystalline modules has a peak power, Pmax, of about 120 (Wp), a Short Circuit Current (ISC) of 7,7 (A) and an Open Circuit Voltage (VOC) of 21,8 (V).
- Air Cavity. The air cavity cross section has a rectangular shape with 1,75 m width and 0,1 m depth, and the cavity has a height of 66 cm.
- PCM. The PCM used is incorporated in the gypsum board Alba®balance plasterboards type. The PCM gypsum board is integrated in the BIPV-PCM system adjacent to the interior room with 2,5 cm thick. According to the manufacturing company, the PCM has a conductivity of 0.33 (W/m.K) , and is considered a general specific heat of 1132 (J/Kg.K). The material has a density of 1000 (Kg/m3), a latent heat of 12000 (J/kg) and a freezing starts and end temperatures of 18ºC and 23ºC respectively.

In the case of BIPV-PCM (that is the case of the module integrating PCM in the gypsum board), during the daytime, due to sun exposure, the PV panels absorb the solar radiation, generating heat during conversion process, heat that is used for phase change material melting. During the nighttime, the melted PCM solidifies and delivers heat that keeps the panel warm for a prolonged period of time.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	■
Extrinsic (requires external control)	□
Electromagnetic	□
Other (specify)	□

SYSTEM RESPONSE TIME	
Seconds	■
Minutes	□
Hours	□
Days	□
Seasons	□
Years	□
Other (specify)	□

SYSTEM DEGREE OF ADAPTIVITY:	
On/off	□
Gradual	■
Other (specify)	□

DEGREE OF SPATIAL ADAPTATION	
Nanometers	□
Micrometers	■
Millimeters	□
Centimeters	□
Meters	□
Other (specify)	□

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	■
02 Visible, no surface change (smart glazing)	□
03 Visible, surface change (lamellas, rollers, blinds)	□
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	□
05 Visible, location or orientation change	□
Other (specify)	□

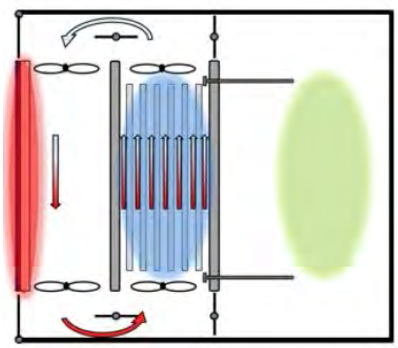
ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	■
Information not available	☐

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	☐
Information not available:	■

Cost/m2	-
Yearly cost of maintenance	-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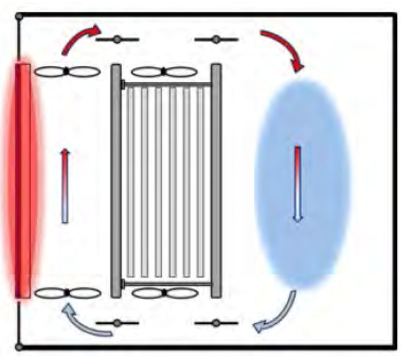
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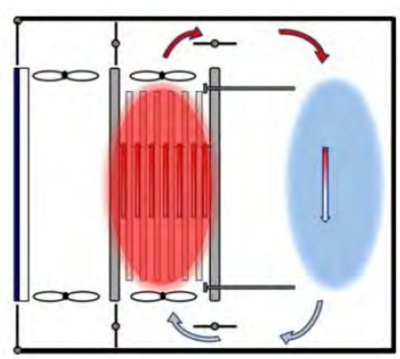
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4. Operating mode 1. Winter configuration. Heat transfer from PV to PCM
5. Operating mode 2. Winter configuration. Heat transfer from PV to the indoor space
6. Operating mode 3. Winter configuration. Heat transfer from PCM to indoor space

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Reference to picture:

Author of the sheet info

Laura Aelenei
LNEG

Rosa Romano
Florence University, Department of Architecture

ESO European Southern Observatory / Auer Weber (image: M. Brzezicki)

Case studies – Adaptive Façade Systems

Rosa Romano, Daniel Aelenei, Laura Aelenei, Enrico Sergio Mazzucchelli, Maria da Glória Gomes, Aleksandra Krstić-Furundžić, Theoni Karlessi, Christophe Menezo

Introduction

The need to comply with European regulations on the energy efficiency of new and existing buildings has led the construction and scientific research sectors in recent decades to experiment in the smart and adaptive envelopes sector: a new generation of vertical closure systems capable of reducing to zero the net energy consumption of the building in which they are integrated, with the aim of improving the comfort and sustainability of our cities.

At the same time, envelope systems have been transformed from passive technological solutions to active systems capable of producing renewable energy and, above all, able of changing the building in a dynamic and adaptive system, in terms of the spatial configurations and behaviour of its external skin, to improve indoor comfort conditions. Thanks to the presence of smart materials and/or automated systems with varying degrees of complexity the building thereby becomes a dynamic system, which can be likened to a living organism, in which each part reacts to external and internal input, adapting to the surrounding space with the aim of regulating the energy balance necessary for it to function.

Case Studies and Adaptivity Readiness Level

The adaptive façade system that have been analysed in the frame of the COST Action TU1403 are technological systems that efficiently contribute to the energy balance of the building, limiting the need to use air conditioning devices, with the consequent reduction in energy consumption.

In many cases, intrinsic dynamic façade systems are used which delegate the adaptive capacity to the smart materials (e.g. Phase Change Material (PCM), Transparent Insulation Material (TIM), Ethylene TetrafluoroEthylene (ETFE), Building Integrated Photovoltaic (BIPV), etc.) they are composed of. In these façades, the system's adaptivity does not necessarily involve a change in the spatial configuration but concerns regulation of the thermophysical properties based on the external climatic conditions. This is the case of:

- **Palazzo Lombardia (Italy).** The façade consists of an external "skin" (curtain wall) and an internal "skin" (inter-storey height) in stratified glass. The double skin gap is 95,00 cm. This space, accessible for the maintenance activities, is equipped with a floating micro-perforated aluminium floor that regulates the air intake and distribution in the double skin buffer. The building has an integrated photovoltaic façade that partly provides its energy needs. The sunshields layout, as well as the airflow, are controlled through a supervision system that operates as a response to temperature and natural light sensors.
- **nZEB office building Ympäristötalo (Finland)**, that is characterized by a double skin south facades with integrated PV cells with an effective solar protection. The total installed PV power is 60 kW (570 m²) that provides about 17% of electricity use of the building. The double skin facade cavity is open on the bottom and has motorized ventilation openings on the top.

- **BIPV/T Systems integrated into the south facade of Solar XXI building in Lisbon (Portugal)** also for the improvement of the indoor climate during heating season in the day time hours, when the heat released in the process of converting solar radiation into power is successfully recovered.

  The storage module has an insulated box with 10 PCM plates. Between the PV and the storage box, there is a cavity air, mechanically ventilated. In this manner, the BIPV-PCM can function also as heat recover. As a heating strategy, in winter time during the days with high solar radiation, the temperature of the air heated by BIPV-T and insufflated into the offices can rich 30°C (Aelenei 2010).

Other examples, in which adaptivity can be interpreted as the capacity to produce energy in a dynamic way according to the energy requirement of the building, are the façades of:

- **The Zero Energy Media Wall**; where the GreenPix curtain wall transforms the building envelop into a self-sufficient organic system, harvesting solar energy by day and using it to illuminate the screen after dark, mirroring a day's climatic cycle. With the support of leading German manufacturers Schueco and SunWays, Giostra and Arup developed for this building a new technology for laminating photovoltaic cells in a glass curtain wall and oversaw the production of the first glass solar panels by Chinese manufacturer Sun-Tech. The polycrystalline photovoltaic cells are laminated within the glass of the curtain wall and placed with changing density on the entire building's skin. The density pattern increases building performance, allowing natural light when required by interior program, while reducing heat gain and transforming excessive solar radiation into energy for the media wall. With customised software, the skin interacts with the building interiors and outside public space, transforming the façade into a responsive environment for entertainment and public engagement.
- **The ENERGYbase** that with its special form carries PV elements mounted with an air space behind (12,00 cm gap). Furthermore, thermal collectors are integrated in the top segment of the façade as shell of the building and they are used for solar cooling (evaporative cooling cycle) in summer and contribute to heating in winter. As the windows are set high, daylight can penetrate right into the rooms in winter, so even the core of the building is very well lit, thanks to ample interior glazing (Goschenhofer 2011).
- **The Swisstech Convention Center.** On the western façade of this building, a transparent and coloured glazing performs the double function of solar protection of the façade and electricity producer. It is the first large-scale implementation of the dyed cells invented by Michael Grätzel, professor at EPFL and manufactured by Solaronix, an EPFL spin off. In the Swisstech application the 1400 solar modules, each one 35,00 by 50,00 cm in size, combine for a total surface area of 300,00 m2 (Coccolo, Kaempf, Scartezzini 2015). The translucent panels are integrated as vertical shading devices, and create an interesting pattern through five different colours, giving the ensemble a warm, dynamic aspect. Each panel features a dedicated micro-converter that continually adapts to the changing light conditions, maximizing the power output of the whole installation. This innovative type of solar panels have the unmistakable advantage of maintaining equal or better efficiency when light intensity decreases. As a result, they work perfectly well with the diffuse hazy and cloudy days often seen at our latitude.

In other cases studies the adaptivity is instead explicit in the façade system's capacity to move all or some of its parts. These are known as kinetic façade systems (Fox and Yeh 1991 and Wang et al. 2012) capable of changing by moving in space and taking on different structures and configurations over time. The long-term changes are achieved through reversible and unique conversions in the context of a flexible structure, while short-term reversible adaptations can be brought about through mechanical solutions. Example of these type of dynamic envelopes are:

- **The west façade of GSW Office Tower** in Berlin with its automated coloured panels that can pivot vertically and sliding horizontally. These shading devices are located in the buffer zone of double skin and help to manage solar heat gain and natural lighting. Furthermore, this façade system serves as a second buffer for thermal and acoustic variations and its second glass ventilates and cools the building, dispelling hot and stale air. Thanks to control fins located on the top and bottom of the facade cavity, the airflow is more or less independent from the external conditions and allows the air change inside the building to be comparable with that obtainable with a mechanical system.
- **The dynamic full-façade shading system of Kiefer Technic Showroom.** The 112 white metal panels of the façade are electrically moveable, individually and continuously with the help of 56 integrated motors and a smart control system. Thus, the panels create a dynamic three-dimensional folding surface. With various choreographed scenarios, the goal of either shade parts of the façade according to the weather conditions or process a media façade scenario are achieved.
- **ThyssenKrupp Quarter façade systems** that show metallic sunshades comparable to vertical moveable feathers. These feathers consist of an axis with two series of horizontal slats on either side; the «barbs» enable the amount of sunlight entering the building to be regulated. The hollow axes of these feathers are installed every 67,5 cm to fit in with the design of the offices. To maximize sun protection an automatic adjustment of the system tracks the movement of the sun throughout the day without blocking the view. The tracking, shape and angle of the horizontal slats enable light to be reflected indirectly providing constant natural lighting to the offices (and avoiding the need for additional electric lighting). Thanks to this system, the view from the Headquarters is always pleasing: total transparency when the slats are open – partial transparency when the slats are unfolded (Sauerborn, Fastabend, Constantin, Schücker 2010).

Furthermore, the adaptive façades analysed within the context of the COST database are characterised by the complementary nature of the system and building technologies and by the presence of regulation and control systems that make them a key element in the complex building-plant system.

In general, the façade systems presented in this book stand out for the presence of one or more of the following technological features:

- High-performance innovative materials and systems for absorbing and storing solar energy, e.g.:

The SolarLeaf's façade system integrated into Algaehouse in Hamburg. These bioreactors aim to cultivate micro-algae to generate heat and biomass as renewable energy sources. The maximum temperature that can be extracted from the bioreactors is around 40 degrees Celsius, as higher levels would affect the microalgae. The system can be operated all year round. The efficiency of the conversion of light to biomass is currently 10% and light to heat is 38%. The biomass and heat generated by the façade are transported by a closed loop system to the building's energy management centre, where the biomass is harvested through floatation and the heat by a heat exchanger. Because the system is fully integrated with the building services, the excess heat from the photo-bioreactors (PBRs) can be used to help supply hot water or heat the building, or stored for later use.

The outer skin of the RMIT Design Hub that comprises a specifically detailed double glazed inner skin on each face of the building and an automated operable second skin-shading device. It is made up of nominally 600 mm diameter sandblasted glass disks, which are fixed to either a horizontal or vertical aluminium axle. The glass cells track the sun via the building computer automation system to help shade and power the building. In a sections of the façade is incorporated Building Integrated Photovoltaics (BIPV), manufactured using the same high performing interlayer.

Perimeter air intakes and fine mist sprinklers incorporated into the double glazed inner skin provide passive cooling to the under floor air distribution system.

- Devices for managing natural ventilation in combination with mechanical ventilation systems, e.g.:

  The envelope solution for the KfW Westarkade office building, where a not conventional double skin facade has been integrated. In this envelope the cavity is not ventilated by means of the “stack effect” and its façade’s outer layer contains sensor-controlled flap openings that maintain a constant and even air pressure within the ring. The flaps are designed to adjust to five wind directions as well as outside temperature, solar radiation and pressure differences on the windward and leeward sides of the building. During warmer months, these motorised flaps on the south-west and north-east elevations open to allow air to flow through the cavity, while during cooler times of year the flaps are closed, allowing air to be preheated before entering the offices. As a result, the offices can be ventilated naturally for eight months of the year without creating drafts or undesired heat loss.

  The north and south facades of Museion in Bozen, designed as “transparent membranes” that divide and at the same time link the urban setting and the museum. These two multi-layered glass façades are suspended from a cable construction and fixed only at the corner. The space in between the two glass surfaces of the façade systems is developed as an active air-conditioning zone. On its way between the roof and the plant room in the basement, the incoming or exhaust air flows through the space between the glass walls. Depending on the time of year and the position of the sun, the outside air is used to create an energy efficient buffer. Furthermore, during the day the light can be directed and shaped room by room in all the exhibition areas. This effect is obtained by using the movable, translucent louvres between the two layers of glass that make up the wall and a screen in the inner side. When outside is dark, instead, the plates become a surface on which to project and the light travels the opposite way.

  The box-window façade of the DB Tower that is developed on the principle of the box window but consists of storey-high façade elements. The interior windows can be opened for ventilation into the gap between the two façade layers. The exterior façade comprises openings for supply and exhaust air. Horizontal as well as vertical separation from adjacent elements ensures optimum sound insulation not only from the outside but from neighbouring offices as well. Ventilation is provided for by gaps at the top and the bottom, whereby the upper gap can be closed by vertically shifting the position of the exterior window. This could better utilise the air collection effect in the façade gap during heating periods.

- Mobile screens for controlling solar radiation, e.g.:

  The façade of Kolding Campus that consists of 1600 perforated steel solar shading panels controlled by sensors that monitor light and heat levels around the building, adjusting themselves by either opening or closing automatically. This system allows for optimal user comfort in terms of lighting and heating.

  The glass façade of Cologne Oval Office Buildings that is made out of colored glass folding shutters that are automatically and individually controllable. This innovative dynamic envelope is able (thanks to the presence of light sensors) following the position of the sun, offering a spectacular sight over the Rhine and Dome of Cologne and guarantying good day lighting inside the office buildings.

The new type of closed-cavity facades of the building envelope of Allianz Suisse Headquarters. It is characterized from an air cavity (hermetically sealed and mechanically ventilated, which avoids condensation problems) where a curtain hangs of aluminium-coated silver is located. The curtain fabric of highly reflective aluminium vapour coating is able responding to external environmental factors processed by computer-controlled algorithm. This innovative shading device is employed for the first time as a glare control in an office building.

- Technological solutions designed to increase daylighting inside the building, e.g.:

In the Yale Sculpture Building, the curtain wall of triple glazing and insulating translucent spandrel panels was combined with an exterior sun shading system to control glare and prevent solar heat gain in the summer. In detail, the transparent panel consisted of a low-E Insulating Glazing Units (IGU) at the exterior, an air cavity, and a Kalwall panel filled with aerogel insulation. Both the IGU and the Kalwall were glazed directly into the thermally broken curtain wall mullion. In this case, the aerogel panel not only fulfils current energy-saving standards for the transparent envelope, but with Uf values of up to 0,7 W/m2K, already exceeds some of these requirements today.

The adaptive façade of the Cyclebowl that was constructed with ETFE cushions realized as three-layer Texlon Foil Systems with two pressure chambers. The external and middle layer had a positive/negative leaf pattern printed. By pneumatically changing the pressure in the chambers, the middle layer adhered either to the inside or to the outer layer, changing the parameters of the envelope (Brueckner 2000). This adaptive envelope can be considered one of first applications of sun protection provided by pneumatically controlled shading system.

The innovative translucent ETFE facade cladding of the Media Tic Building that performs simultaneously as an external protection and a mobile solar screen to regulate both light and temperature and, hence, contributing to decrease the building energy demand. The cladding has three layers of material on the façade that receives the most sunshine. These layers can be automatically inflated using sensors to form two air chambers. The first layer of ETFE is transparent; the second and third layers have a reverse pattern design which, when inflated or deflated, makes the façade transparent or opaque. This avoids the entry of light and heat at times of maximum sunlight.

- Building automation systems for the management of plants and elements of the building skin, e.g.:

The AGC external façade that is fully covered with double glazing system in combination with thermally insulated glass sunshades printed with white silk screen. These louvers respond dynamically and automatically to the angle of the sun in order to improve the control over energy consumption, solar radiation and glare with the ability to admit natural light into the building while affording a view over the surrounding countryside. When in the east and west, the sun is relatively low and the vertical louvres are better able to track it. Louvers are fixed in their open position in the case of rain and when the outside temperature is below 3°C (risk of icing). COLT, widely known in the manufacture of solar shading and climate control systems, designed the standard louvres control software: the system is based on light levels measured by a roof mounted sensor. 256 actuators thus control the louvres of the four facades: 72 for each north/south facade and 56 for each east/west façade (Attia, Bashandy 2016).

The dynamic façade of Al Bahar Towers, conceived as a contemporary interpretation of the traditional Islamic “mashrabiya”: a popular form of wooden lattice screen found in vernacular Islamic architecture and used as a device for achieving privacy while reducing glare and solar gain. Each of the two towers comprises over 1.000 transparent umbrella-like components that open and close in response to the sun's path. These shading device are controlled via the Building Management System, creating an intelligent façade (Attia 2017).

Finally, it is interesting to note how the selected case studies feature, with respect to traditional envelope systems, construction costs and higher maintenance costs due to the materials used, the number of special pieces, the complexity of managing the components and their reciprocal placement.

Conclusions

The analysed adaptive façades demonstrate that architectural research is moving towards innovative solutions that (by exploiting the possibility of integrating IT systems, mechanical actuators and innovative materials) are able of transforming it from a static element into a dynamic element capable of rapidly and efficiently changing shape in relation to specific functional, static, and physical requirements. This is the era of media, dynamic, multimedia, and smart architecture able of changing structure with respect to external environmental stimuli and user requirements. The advanced screen, eco-efficient and sustainable envelope interacts and regulates energy flows and, in some cases, becomes a plant system, by itself, able of producing energy, heat or electricity, and of distributing it at a building or even an urban scale.

Figure 1 - Locations of case studies "systems"

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YALE SCULPTURE BUILDING, New Haven Connecticut (USA), 2007
KIERANTIMBERLAKE ASSOCIATES LLP

MATERIAL

COMPONENT

FACADE

The 51,000 square-foot studio building contains three floors of individual and group studios above ground and basement floors of classrooms, machine shops, and administrative spaces. Conceived as a loft to accommodate a range of artistic activities, the structure is an exposed steel frame. The columns and beams are all narrow eight inch wide flange sections, with beams lapping over girders in a simple yet eloquent woven pattern.
KieranTimberlake worked with Schuco and Kalwall Corporation to develop the facade system. This wall system incorporates solar shading, a triple glazed low-e vision panel, 8 foot-high operable windows, and a translucent double cavity spandrel panel. As a result, the entire skin of the building admits natural light and actively works to control the temperature in the interior.

Latitude 41°30', Longitude 72°94'

DOUBLE SKIN FACADE, SMART ENVELOPE, PV SYSTEM, ENERGY SAVING

BUILDING INFORMATION:			
Building floor area	5000 sq.m	Climate Type	Dfd
Building use	Office	Orientation of the facade	All orientation
Building status	New Built	Other	-

DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	□
02. Technology concept formulated/Design Proposal	□
03. Technology validated in lab	□
04. Prototype demonstration	□
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	■
Acoustic comfort	■
Energy management (harvesting, storing, supply)	□
Mass transfer control (e.g. condensation control)	□
Indoor air quality	□
Appearance (aesthetic quality)	■
Structure performance	□
Energy generation	□
Personal users' control	□
Other (durability, accessibility, use of natural resources, etc.):	□

TYPE OF FACADE SYSTEM	
Active façade	□
Advanced façade	□
Biomimetic façade	□
Kinetic façade	□
Intelligent façade	□
Interactive façade	□
Movable façade	□
Responsive façade	□
Smart façade	■
Transformable façade	□
Switchable façade	□

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	■
Devices for managing natural ventilation in combination with mechanical ventilation systems	□
Mobile screens for controlling solar radiation	□
Technological solutions designed to increase and/or control comfort inside the building	□
Building automation systems for the management of plants and elements of the building skin	□

CW

ATF

SG

MFM

BF

FS_01

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): TIM (Nanogel, Kalwall)	■

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify): Not present	■

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	■
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify)	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	■
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	■
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	☐
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	■
Chemical	☐
Other (specify): Manual	☐

1

2

1. South facade ©EnzoFigueres
2. Façade, external view, © EnzoFigueres
3. Building view, © EnzoFigueres

CONTROL OPERATION DETAILS

3

DETAILED EXPLANATION OF THE CONTROL/OPERATION

The spandrel of KieranTimberlake facade consists of a low-E IGU at the exterior, a three-inch cavity, and a two and a half-inch Kalwall panel filled with aerogel insulation. Both the IGU and the Kalwall are glazed directly into the thermally broken curtainwall mullion. Testing has suggested that the overall R value of the spandrel assembly is in excess of R 20, while maintaining 20% visible light transmittance. The cavity traps solar radiation, forming a warm air layer that further increases thermal performance when the sun is shining. Operable windows allow the building to ventilate naturally in spring and fall, reducing fan loads and providing surplus ventilation capacity for high occupancies, while connecting the building to its external environment.To enhance occupant control over the interior environment, every space is provided with interior shades.There has been significant post-occupancy testing of the façade for thermal performance. Temperature, humidity, and solar radiation monitors were installed within the rooms and on the roof. Within the wall structure, the temperature of the cavity between the translucent insulation panel and the one-inch insulated glazing unit was analyzed. Two panels with ventilation gaps were also monitored for temperature and air movement. Findings indicate that temperatures in the chambers are nearly 140°F but will not damage the translucent insulation panel.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	■
Extrinsic (requires external control)	■
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	☐
Minutes	☐
Hours	☐
Days	■
Seasons	■
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/off	☐
Gradual	■
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	☐
Centimeters	■
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	■
02 Visible, no surface change (smart glazing)	☐
03 Visible, surface change (lamellas, rollers, blinds)	☐
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	☐
05 Visible, location or orientation change	☐
Other (specify)	☐

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	■
Information not available	☐

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	■
Information not available	☐

Cost/m2	-
Yearly cost of maintenance	-

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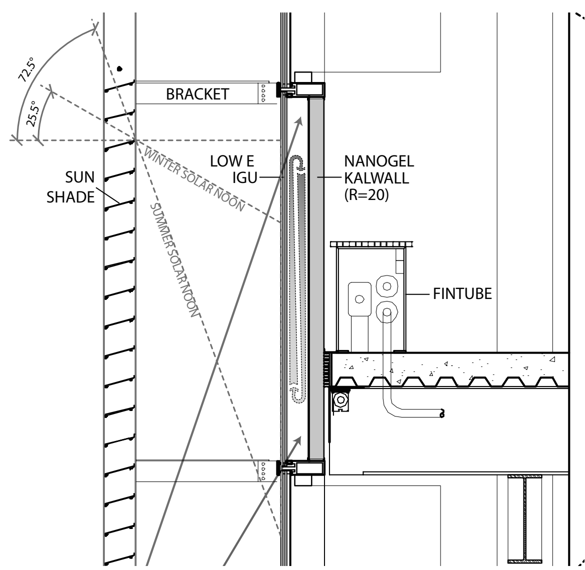
Author of the sheet info
Rosa Romano
Florence University, Department of Architecture

Enrico Sergio Mazzucchelli
Politecnico di Milano

4



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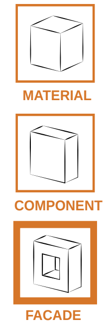
4. Façade detail © EnzoFigueres
5. Façade Technological detail by KIERANTIMBERLAKE ASSOCIATES LLP

OVAL COLOGNE OFFICES, Cologne (DE), 2010
Sauerbruch Hutton Architekten



Despite the increasing building density on the Rhine riverfront south of the city centre, the Cologne Oval Offices were designed to maintain the landscape qualities of this area. The two offset volumes also help to integrate an existing 12-storey block into the lower-height urban fabric. Each volume contains three cores, around which the functional areas are laid out in a curving strip. Internal finger-like soffit “sails”, which play an acoustic role, also serve to define working zones and to mask various technical systems. The extensively glazed facade allows good daylighting, while nearly 5000 external folding shutters reduce solar heat gains. Printed externally in various shades, the shutters lend the outer skin an iridescent coloration.

Latitude 50°56’, Longitude 07°57’

AUTOMATIC VERTICAL SHUTTER; DAYLIGHT REGULATION; OVAL; COLOR IN ARCHITECTURE

BUILDING INFORMATION:			
Building floor area	43.000 sq.m	Climate Type	Cfb
Building use	Office	Orientation of the facade	All orientation
Building status	New Built	Other	-

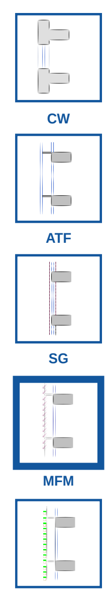
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	☐
04. Prototype demonstration	☐
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	■
Acoustic comfort	☐
Energy management (harvesting, storing, supply)	☐
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	☐
Appearance (aesthetic quality)	■
Structure performance	☐
Energy generation	☐
Personal users’ control	☐
Other (durability, accessibility, use of natural resources, etc.):	☐

TYPE OF FACADE SYSTEM	
Active façade	☐
Advanced façade	☐
Biomimetic façade	☐
Kinetic façade	☐
Intelligent façade	☐
Interactive façade	☐
Movable façade	■
Responsive façade	☐
Smart façade	☐
Transformable façade	☐
Switchable façade	☐

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	☐
Devices for managing natural ventilation in combination with mechanical ventilation systems	☐
Mobile screens for controlling solar radiation	■
Technological solutions designed to increase and/or control comfort inside the building	☐
Building automation systems for the management of plants and elements of the building skin	☐



FS_02

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify):	☐

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

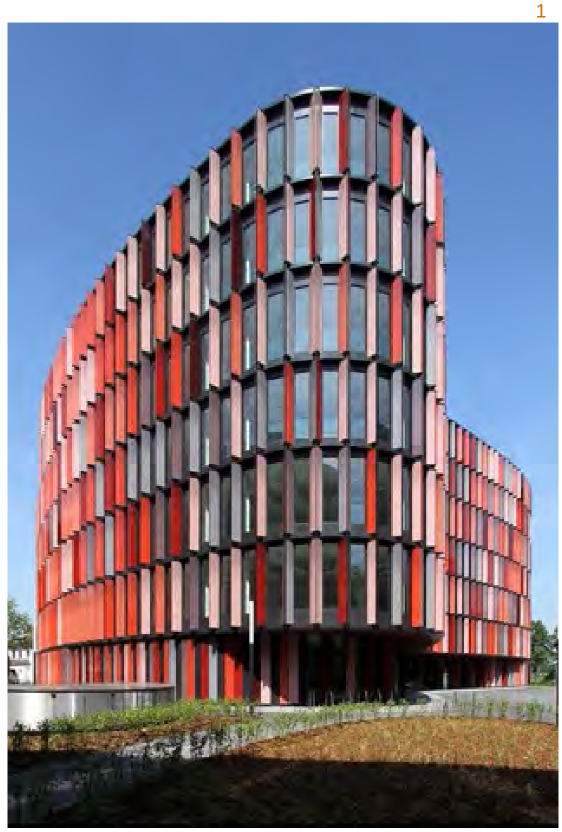
TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	■
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify)	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	■
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	☐
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify): Manual	☐

1



2

1. Shading device
2. Façade, external view
3. Building view

CONTROL OPERATION DETAILS

3

DETAILED EXPLANATION OF THE CONTROL/OPERATION

The architects at Sauerbruch Hutton always aim to invent something new in their architecture and they stay true to this. Together with Dobler's realisation of the facades the architects vision was proved again, through groundbreaking energy concepts, flexible interior design and highly creative requirements in the best shapes and colours available.
At the Cologne Oval Office, the glass facade lets the day light deep into the rooms of the free formed main body of the building with its inner courtyard.
The glass of the building envelope, sitting in front of the facade and following the position of the sun, offers a spectacular sight over the Rhine and Dome of Cologne.
The folding shutters are the sunscreens. They are made out of colored glass and they are automatically and individually controllable. In particular there are shutters controlled only manually on the ground floor (with view of sun protection fixtures).
In the other floors the shutters are controlled externally by the system measuring the insolation.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	■
Extrinsic (requires external control)	□
Electromagnetic	□
Other (specify)	□

SYSTEM RESPONSE TIME	
Seconds	■
Minutes	■
Hours	□
Days	□
Seasons	□
Years	□
Other (specify)	□

SYSTEM DEGREE OF ADAPTIVITY:	
On/off	□
Gradual	■
Other (specify)	□

DEGREE OF SPATIAL ADAPTATION	
Nanometers	□
Micrometers	□
Millimeters	□
Centimeters	■
Meters	□
Other (specify)	□

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	□
02 Visible, no surface change (smart glazing)	□
03 Visible, surface change (lamellas, rollers, blinds)	□
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	■
05 Visible, location or orientation change	□
Other (specify)	□

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	■
Information not available	☐

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	■
Yearly	☐
Information not available	☐

Cost/m2	-
Yearly cost of maintenance	-

Reference

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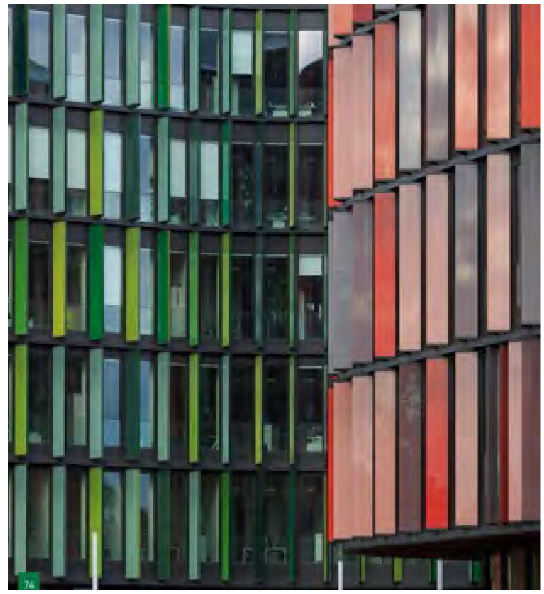
Reference to picture:

http://www.studiomaven.org/images/6/66/Sauerbruch-hutton_Cologne_Oval_Offices.jpg (Accessed October 15, 2018)

Author of the sheet info

Marcin Brzezicki
Wroclaw University of Technology

Rosa Romano
Florence University, Department of Architecture

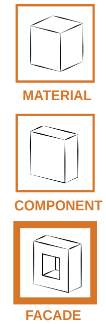


4

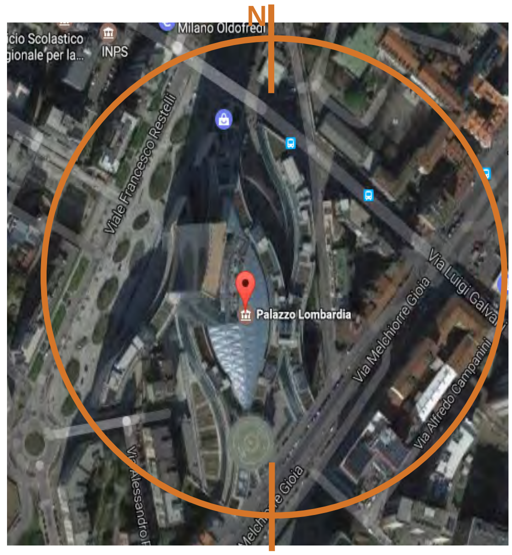
5

4. Façade detail. The vertical axis glazed sun louvers serve the purpose of light regulation and, simultaneously, perform as outstanding architectural façade element.
5. Façade detail

PALAZZO LOMBARDIA, Milan (IT), 2010
Pei Cobb Freed & Partners, Caputo Partnership



Palazzo Lombardia consists of curvilinear eight-floor buildings and a 39 floor, 161,30 m high central tower. The façade consists of an external "skin" (curtain wall) and an internal "skin" (inter-storey height) in stratified glass. The double skin gap is 95,00 cm. This space, accessible for the maintenance activities, is equipped with a floating micro-perforated aluminium floor that regulates the air intake and distribution in the double skin buffer. The building has an integrated photovoltaic façade that partly provides its energy needs. The sunshields layout, as well as the air flow, are controlled through a supervision system that operates as a response to temperature and natural light sensors.



Latitude 45° 29' Longitude 09° 11'

BUILDING INTEGRATED PHOTOVOLTAIC; SKYSCRAPER; RENEWABLE ENERGY

BUILDING INFORMATION:			
Building floor area	72.000 sq.m	Climate Type	Cfa
Building use	Office	Orientation of the facade	All orientation
Building status	New Built	Other	-

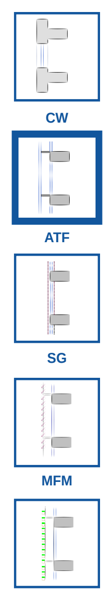
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	☐
04. Prototype demonstration	☐
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	☐
Acoustic comfort	☐
Energy management (harvesting, storing, supply)	☐
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	☐
Appearance (aesthetic quality)	☐
Structure performance	☐
Energy generation	■
Personal users' control	☐
Other (durability, accessibility, use of natural resources, etc.):	☐

TYPE OF FACADE SYSTEM	
Active façade	☐
Advanced façade	☐
Biomimetic façade	☐
Kinetic façade	☐
Intelligent façade	☐
Interactive façade	☐
Movable façade	☐
Responsive façade	☐
Smart façade	■
Transformable façade	☐
Switchable façade	☐

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	■
Devices for managing natural ventilation in combination with mechanical ventilation systems	☐
Mobile screens for controlling solar radiation	☐
Technological solutions designed to increase and/or control comfort inside the building	☐
Building automation systems for the management of plants and elements of the building skin	☐



FS_03

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): Aluminium and PV Panels	☐

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

TYPE OF SHADING DEVICE	
Screens / roller shades	■
Blinds with slat angle control	■
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify)	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	■
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	■
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant’s presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify): Manual	☐

1

2

1. Facade
2. Building view

CONTROL OPERATION DETAILS

DETAILED EXPLANATION OF THE CONTROL/OPERATION

A “climate wall” houses vertical brise soleil in order to exploit exploit sun energy and shield direct light to optimize indoor lighting and temperatures. A Building Management System controls the system and ensures maximum efficiency. The sunshields layout, supervision system that operates as a response to temperature and natural light sensors. This system operates separately on each section of the buffer space to take into account the variability of the façade structure and therefore of the different solar load. In this way it is possible to balance the solar energy contribution by enhancing it in winter and controlling it in summer, in accordance with the natural lighting objectives.
The building has an integrated photovoltaic façade that partly provides its energy needs. On the smaller fronts of the tower, the windows have been integrated with photovoltaic cells with a total power of about 160 KWp for an estimated energy production of around 104000 kWh/year and a CO^2 saving of around 73 tons/year. The photovoltaic generator is integrated in the two facades of the central tower facing south and southwest and it occupies over 100,00 m in height. Each of the 450 modules is made up of 120 high efficiency monocrystalline cells for a power of 350 Wp per module. Furthermore, the photovoltaic layout has been designed to give the degree of shading glass required by designers and to reduce the solar radiation inside the building.
This system operates separately on each section of the buffer space to take into account the variability of the façade structure and therefore of the different solar load. In this way it is possible to balance the solar energy contribution by enhancing it in winter and controlling it in summer, in accordance with the natural lighting objectives.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	■
Extrinsic (requires external control)	■
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	☐
Minutes	■
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/off	■
Gradual	☐
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	☐
Centimeters	■
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	■
03 Visible, surface change (lamellas, rollers, blinds)	☐
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	☐
05 Visible, location or orientation change	☐
Other (specify)	☐

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?

Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY

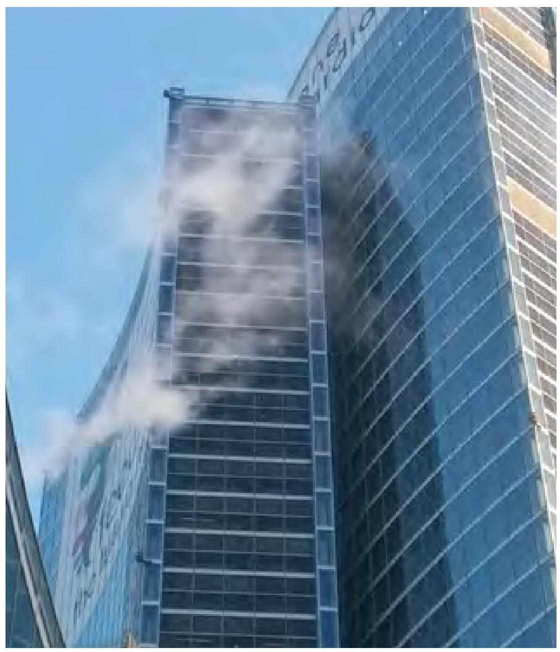
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	■
Information not available	☐

SYSTEM MAINTENANCE FREQUENCY

Daily	☐
Weekly	☐
Monthly	■
Yearly	☐
Information not available	☐

Cost/m2	-
Yearly cost of maintenance	-

3



5

3. Façade detail.
4. Façade detail.

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Reference to picture:
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Politecnico di Milano

Author of the sheet info
Enrico Sergio Mazzucchelli
Politecnico di Milano

Rosa Romano
Florence University, Department of Architecture

CYCLEBOWL, Hannover Expo (DE), 2000
ATELIER BRÜCKNER GmbH

MATERIAL

COMPONENT

FACADE

"Duales System" (a German recycling company) built a pavilion For the World Exposition 2000 in Hanover. The façade of the building utilized Texlon Foil Systems. The adaptive façade was constructed to control the light incoming into the pavilion, and was constructed as a three-layer system with two pressure chambers. The external and middle layer had a positive/negative leaf pattern printed. By pneumatically changing the pressure in the chambers, the middle layer adhered either to the inside or to the outer layer, changing the parameters of the envelope. It had 45% of transparency in open state, and was fully opaque closed state.

Latitude 52° 32' Longitude 09° 81'

PNEUMATIC; SUN SHADING; ETFE; CUSHION; PATTERN

BUILDING INFORMATION:			
Building floor area	1600 sq.m	Climate Type	Cfb
Building use	Exhibition pavillion	Orientation of the facade	South East, East, South West
Building status	New Built	Other	-

DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL

- ☐ 01. Basic principles observed and reported/ Idea
- ☐ 02. Technology concept formulated/Design Proposal
- ☐ 03. Technology validated in lab
- ☐ 04. Prototype demonstration
- ■ **05. Commercial product/Existing building**

FUNCTION / GOAL / PURPOSE

- ■ **Thermal comfort**
- ■ **Visual comfort**
- ☐ Acoustic comfort
- ■ **Energy management (harvesting, storing, supply)**
- ■ **Mass transfer control (e.g. condensation control)**
- ☐ Indoor air quality
- ☐ Appearance (aesthetic quality)
- ☐ Structure performance
- ☐ Energy generation
- ☐ Personal users' control
- ☐ Other (durability, accessibility, use of natural resources, etc.):

TYPE OF FACADE SYSTEM

- ☐ Active façade
- ☐ Advanced façade
- ☐ Biomimetic façade
- ☐ Kinetic façade
- ☐ Intelligent façade
- ■ **Interactive façade**
- ☐ Movable façade
- ☐ Responsive façade
- ☐ Smart façade
- ☐ Transformable façade
- ☐ Switchable façade

TECHNOLOGICAL FEATURES

- ☐ High-performance innovative materials and systems for absorbing and storing solar energy
- ☐ Devices for managing natural ventilation in combination with mechanical ventilation systems
- ☐ Mobile screens for controlling solar radiation
- ■ **Technological solutions designed to increase and/or control comfort inside the building**
- ☐ Building automation systems for the management of plants and elements of the building skin

CW

ATF

SG

MFM

BF

FS_04

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	■
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify):	☐

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify): pneumatic blinds	■

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	■
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	☐
Pneumatical	■
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify): Manual	☐


1


2


3

1. Detail of positive/ negative leaf pattern printed on the outer two of the three-layer system
2. Building view
3. Facade built with Folitec

CONTROL OPERATION DETAILS

4

DETAILED EXPLANATION OF THE CONTROL/OPERATION

Interior sun protection is provided by pneumatically controlled shading systems realized with ETFE cushions (width of element approx. 1,70 m, height of middle element approx. 1,80 m, three layers).
These nylon+ polyurethane cushions has a flexible transparent layer inside.
A positive/negative pattern is printed on the middle and on the outer layer of the cushions. When the middle layer overlaps with the outer layer, the printed patterns superimpose and shading is provided. When it moves away from the outer layer, light filters through the patterns printed on the surfaces. Intermediate ranges of shading are possible depending on the position of the middle layer.
Cushions are mechanically activated by an exterior (powered) system.
Foiltec was selected for the design and manufacture of the pavilion's envelope not only for its variable transparency technologies but also for its ecological characteristics.
The foil products have an extremely low energy consumption during their manufacturing process; and the complete system weighs between 50 and 90 percent less than systems made from other materials with comparable properties further conserving on the structural system needed to support the cladding.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	☐
Extrinsic (requires external control)	■
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	☐
Minutes	■
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/off	☐
Gradual	■
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	☐
Centimeters	■
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	☐
03 Visible, surface change (lamellas, rollers, blinds)	■
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	☐
05 Visible, location or orientation change	☐
Other (specify)	☐

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	■
No	☐
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	■
Information not available	☐

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	☐
Information not available	■

Cost/m2	-
Yearly cost of maintenance	-

5

6

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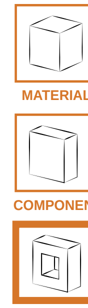
Author of the sheet info
Sandra Persiani
Technical University of Munich

Rosa Romano
Florence University, Department of Architecture

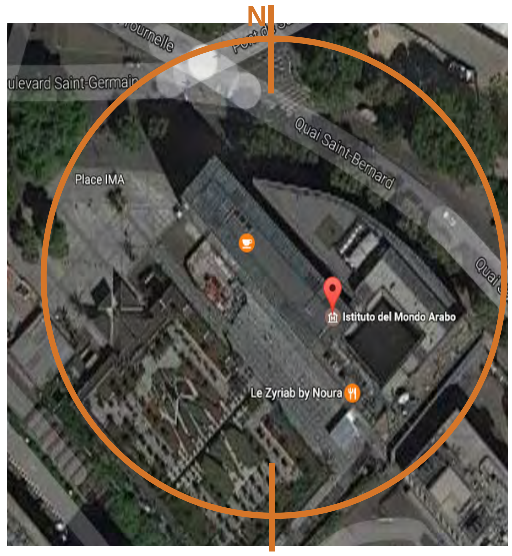
Marcin Brzezicki
Wroclaw University of Technology

4. Facade system
5. Building otuside view.
6. Building inside view.

ARAB WORLD INSTITUTE, Paris (FR), 1987
Atelier Jean Nouvel


MATERIAL
COMPONENT
FACADE

The building itself is a sharing of culture with the north façade reflecting the Parisian blocks across the River, and the south façade covered in the motorized hexagonal lenses. Their pattern and light properties are a reference to mashrabiya, a lattice-work motif found in Arabian architecture that provides shaded light and privacy with a view.
Consisting of 30000 diaphragms on 1600 elements resting on a stainless-steel, aluminum and glass framework, the geometric array is a compilation of high-tech photosensitive mechanical devices. Using photovoltaic cells, the light levels and transparency can be adjusted in a fashion similar to a camera lens by a central computer system to allow 10-30% of light in. Although designed in an exploration of light, reflections, contours and shadows, this concept can be applied to solar shading in efforts to reduce cooling loads.



Latitude 48°84' Longitude 02°85'

MECHANIC; LIGHT REGULATING; DIAPHRAGM; MOUCHARABIEH; POLYGON

BUILDING INFORMATION:			
Building floor area	5000 sq.m	Climate Type	Cfb
Building use	Education Museum	Orientation of the facade	South
Building status	New Built	Other	-

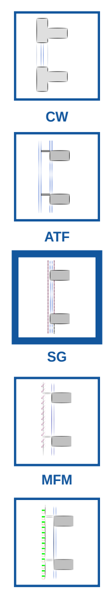
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	☐
04. Prototype demonstration	☐
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	☐
Visual comfort	■
Acoustic comfort	☐
Energy management (harvesting, storing, supply)	☐
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	☐
Appearance (aesthetic quality)	■
Structure performance	☐
Energy generation	☐
Personal users' control	☐
Other (durability, accessibility, use of natural resources, etc.):	☐

TYPE OF FACADE SYSTEM	
Active façade	☐
Advanced façade	☐
Biomimetic façade	☐
Kinetic façade	☐
Intelligent façade	☐
Interactive façade	☐
Movable façade	☐
Responsive façade	■
Smart façade	☐
Transformable façade	☐
Switchable façade	☐

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	☐
Devices for managing natural ventilation in combination with mechanical ventilation systems	☐
Mobile screens for controlling solar radiation	■
Technological solutions designed to increase and/or control comfort inside the building	☐
Building automation systems for the management of plants and elements of the building skin	☐


CW
ATF
SG
MFM
BF

FS_05

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): Aluminium	■

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	

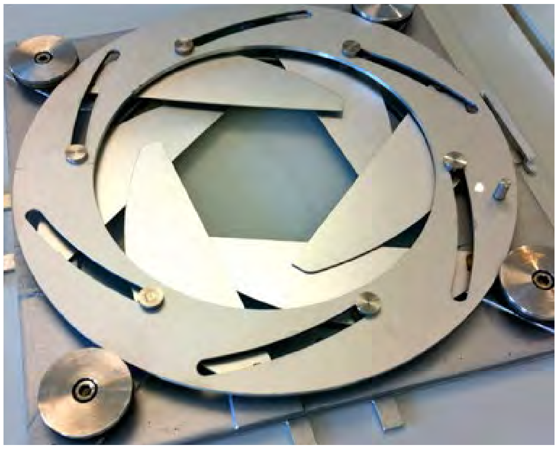
TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify): shutter diaphragms	■

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	■
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify): Manual	☐

1



2

1. Detail of shading device system
2. Detail of elements resting on a stainless-steel, aluminum and glass framework
3. South facade

CONTROL OPERATION DETAILS

4

DETAILED EXPLANATION OF THE CONTROL/OPERATION

This southern facade is entirely composed of 240 motor-controlled camera-like diaphragms in metal screened by a glass facade.
The devices automatically adjust their openness / closeness every hour to match the outdoor changing light levels with the desired interior light level, filtering light in and out of the building throughout the day.
The “Institute du Monde Arabe” is an example for a kinetic architecture that depends on mechanicals movements. A complex system of sensor-brain devices analyze the indoor light conditions and adjust the hexagonal screens by a more or less centralized control system.
During the various phases of the lens, a shifting geometric pattern is formed and showcased as both light and void. Squares, circles, and octagonal shapes are produced in a fluid motion as light is modulated in parallel. Interior spaces are dramatically modified, along with the exterior appearance.
While these ocular devices create an incredible aesthetic, they are functional from an environmental controls standpoint as well. Solar gain is easily mitigated by closing or reducing the aperture sizes.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	□
Extrinsic (requires external control)	■
Electromagnetic	□
Other (specify)	□

SYSTEM RESPONSE TIME	
Seconds	■
Minutes	■
Hours	□
Days	□
Seasons	□
Years	□
Other (specify)	□

SYSTEM DEGREE OF ADAPTIVITY:	
On/off	□
Gradual	□
Other (specify)	□

DEGREE OF SPATIAL ADAPTATION	
Nanometers	□
Micrometers	□
Millimeters	■
Centimeters	■
Meters	□
Other (specify)	□

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	□
02 Visible, no surface change (smart glazing)	□
03 Visible, surface change (lamellas, rollers, blinds)	■
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	
05 Visible, location or orientation change	□
Other (specify)	□

ECONOMICAL ASPECTS

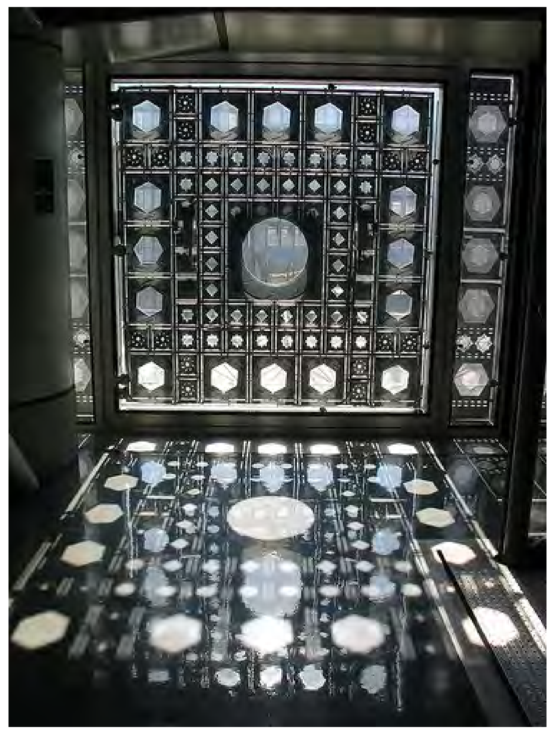
IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	■
Information not available	☐

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	☐
Information not available	■

Cost/m2	-
Yearly cost of maintenance	-

4



5

4. The kinetic facade from the library
5. Detail of shading device system from inside of the building

Reference

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Moloney, J. (2011), *Designing Kinetics for Architectural Facades, State Change,* Routledge, New York

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Reference to picture

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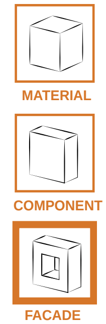
https://aehistory.wordpress.com/1987/10/04/164/ (Accessed October 15, 2018)

Author of the sheet info

Rosa Romano
Florence University, Department of Architecture

Enrico Sergio Mazzucchelli
Politecnico di Milano

ARTICULATED CLOUD, Pittsburgh (USA), 2004
Ned Kahn and Koning Eizenberg Architecture



Ned Kahn collaborated with Hank Koning and Julie Eizenberg to create the museum's facade.
The building façades become a wind sculpture thanks to 43.000 individual light and shadows hinged to a steel screen.
At night it's lit from within, turning the entrance into a shimmering lantern.
Composed of thousands of translucent, white plastic squares that move in the wind, the artwork is intended to suggest that the building has been enveloped by a digitized cloud. The optical qualities of the skin change with the weather and the time of day.

Latitude 40°76' Longitude -80°44'

KINETIC; SCREEN; PLASTIC; TILES; ART

BUILDING INFORMATION:			
Building floor area	5.000 and up sq. m.	Climate Type	Dfb
Building use	Museum	Orientation of the facade	All orientation
Building status	New Built	Other	-

DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL

- [ ] 01. Basic principles observed and reported/ Idea
- [ ] 02. Technology concept formulated/Design Proposal
- [ ] 03. Technology validated in lab
- [ ] 04. Prototype demonstration
- [x] **05. Commercial product/Existing building**

FUNCTION / GOAL / PURPOSE

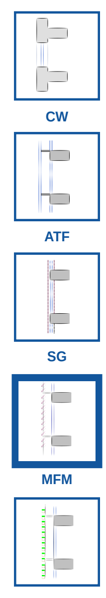
- [ ] Thermal comfort
- [x] **Visual comfort**
- [ ] Acoustic comfort
- [ ] Energy management (harvesting, storing, supply)
- [ ] Mass transfer control (e.g. condensation control)
- [ ] Indoor air quality
- [x] **Appearance (aesthetic quality)**
- [ ] Structure performance
- [ ] Energy generation
- [ ] Personal users' control
- [ ] Other (durability, accessibility, use of natural resources, etc.):

TYPE OF FACADE SYSTEM

- [ ] Active façade
- [ ] Advanced façade
- [ ] Biomimetic façade
- [ ] Kinetic façade
- [ ] Intelligent façade
- [ ] Interactive façade
- [ ] Movable façade
- [x] **Responsive façade**
- [ ] Smart façade
- [ ] Transformable façade
- [ ] Switchable façade

TECHNOLOGICAL FEATURES

- [ ] High-performance innovative materials and systems for absorbing and storing solar energy
- [ ] Devices for managing natural ventilation in combination with mechanical ventilation systems
- [x] **Mobile screens for controlling solar radiation**
- [ ] Technological solutions designed to increase and/or control comfort inside the building
- [ ] Building automation systems for the management of plants and elements of the building skin



FS_06

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	■
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify):	☐

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	

TYPE OF SHADING DEVICE	
Screens / roller shades	■
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	■
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	☐
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify)	☐

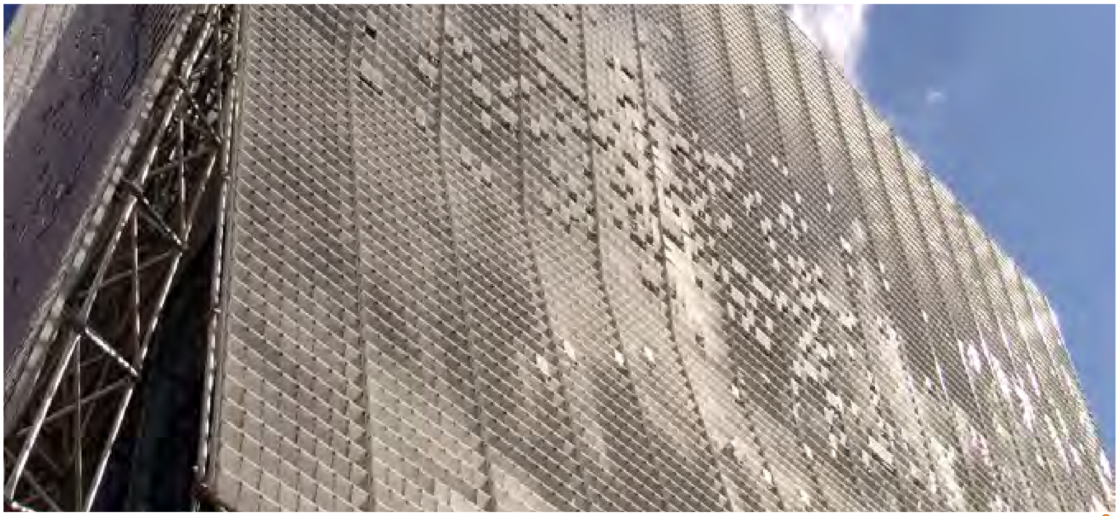
TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify):	☐


1


2

1. Detail of facade system with articulated cloud
2. Articulated Cloud, by Ned Kahn. Reacts to wind and other stresses, much like a cloud would.
3. Facade of the museum, (c) Ned Kahn Studios

CONTROL OPERATION DETAILS



3

DETAILED EXPLANATION OF THE CONTROL/OPERATION

The facade system is an aluminium frame with thousands of translucent, white plastic squares that move with the wind. According to the artist's website, "the artwork is intended to suggest that the building has been enveloped by a digitized cloud", making the wind visible. The optical qualities of the material make the appearance change in different lighting and weather conditions.
The facade consists of a grid of 43.000 small polycarbonate panels, hinged to a steel frame, that can be moved individually by the wind action.
The internal lighting and transparent/translucent skin allows the building to emit a bright but gentle lantern-like glow, brightening Allegheny Square at night, and is intended to serve as an actual and metaphorical beacon in the Northside neighborhood.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	■
Extrinsic (requires external control)	☐
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	■
Minutes	☐
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/off	☐
Gradual	■
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	■
Centimeters	■
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	☐
03 Visible, surface change (lamellas, rollers, blinds)	☐
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	
05 Visible, location or orientation change	■
Other (specify)	☐

ECONOMICAL ASPECTS

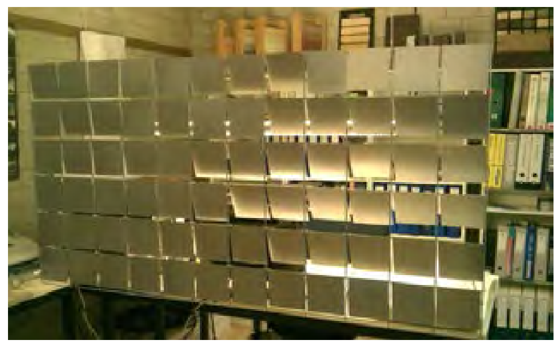
IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	■
Information not available	☐

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	☐
Information not available	■

Cost/m2	-
Yearly cost of maintenance	-

4



5

6

Reference

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https://www.youtube.com/watch?v=nvkNdlKVP2Y (Accessed October 15, 2018)

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https://www.rudybruneraward.org/wp-content/uploads/2007/01/03-Childrens-Museum-of-Pittsburgh-1.pdf (Accessed October 15, 2018)

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Reference to picture

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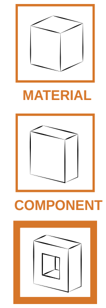
Author of the sheet info

Rosa Romano
Florence University, Department of Architecture

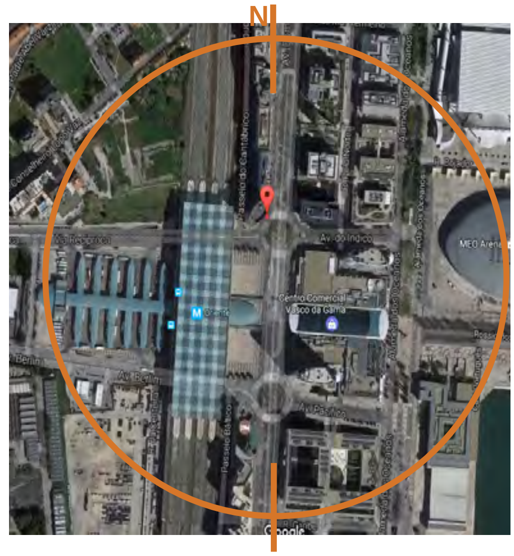
Enrico Sergio Mazzucchelli
Politecnico di Milano

4. Facade of the museum, (c) Ned Kahn Studios
5. Prototype of Articulated Cloud
6. Detail of Facade of the museum

ES VIAGENS BUILDING/ PT BUILDING, Lisbon (PT), 1998
Sua Kay Arquitectos


MATERIAL
COMPONENT
FACADE

ESViagens/PT building was designed by Sua Kay Architects and built in 1998 in a completely revitalised district of Lisbon, Portugal, to host Expo98, alongside the Tagus River.
It has a 2500,00 sq.m double skin façade envelope which provides a great transparency and connection to the outside.
The shading device is a horizontal slat venetian blind which is located in the airgap and is automatically controlled.
The double skin facade has an outdoor air curtain corridor typology and hybrid air gap ventilation.



Latitude 38°46' Longitude 9°05'

DOUBLE SKIN FACADE; AUTOMATIC VENETIAN BLIND AND EXHAUST AIR-GAP VENTILATION; DAYLIGHT REGULATION

BUILDING INFORMATION:			
Building floor area	13.250,00 sq.m	Climate Type	Csa
Building use	Office	Orientation of the facade	South-East North-West
Building status	New Built	Other	-

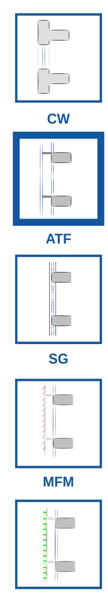
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	☐
04. Prototype demonstration	☐
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	■
Acoustic comfort	■
Energy management (harvesting, storing, supply)	☐
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	☐
Appearance (aesthetic quality)	■
Structure performance	☐
Energy generation	☐
Personal users' control	☐
Other (durability, accessibility, use of natural resources, etc.):	☐

TYPE OF FACADE SYSTEM	
Active façade	☐
Advanced façade	☐
Biomimetic façade	☐
Kinetic façade	☐
Intelligent façade	■
Interactive façade	☐
Movable façade	☐
Responsive façade	☐
Smart façade	☐
Transformable façade	☐
Switchable façade	☐

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	☐
Devices for managing natural ventilation in combination with mechanical ventilation systems	■
Mobile screens for controlling solar radiation	☐
Technological solutions designed to increase and/or control comfort inside the building	☐
Building automation systems for the management of plants and elements of the building skin	☐


CW
ATF
SG
MFM
BF

FS_07

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): Aluminium and PV Panels	☐

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	■
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	■
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	☐
Air quality (humidity, CO2 concentration, etc)	■
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify): Manual	☐

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	

1

2

1. Detail of facade system near the roof of the tower
2. View of the building.
3. Facade system

CONTROL OPERATION DETAILS

3

DETAILED EXPLANATION OF THE CONTROL/OPERATION

ESViagens/PT building has both double skin facade airgap ventilation and shading device systems adaptive. The air gap has a hybrid ventilation. The air gap exhaust ventilator switches on as soon as:
i) outdoor temperature higher than 24ºC and air gap temperature higher than 40ºC;
ii) outdoor temperature lower than 24ºC and air gap temperature higher than 30ºC. It switches off when air gat temperature is lower than 30ºC.
The venetian blind shading device is automatically pulled down depending on the illuminance level on lux meters located on building roof. However, this shading control system is frequently overridden by the users.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	☐
Extrinsic (requires external control)	■
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	■
Minutes	☐
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/off	■
Gradual	☐
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	☐
Centimeters	■
Metres	■
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	☐
03 Visible, surface change (lamellas, rollers, blinds)	■
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	☐
05 Visible, location or orientation change	☐
Other (specify)	☐

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	■
No	■
Other (specify)	□

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	□
Medium (curtain walls, ventilated facades, etc)	□
High (double skin facades, high tech, etc)	■
Information not available	□

SYSTEM MAINTENANCE FREQUENCY	
Daily	□
Weekly	□
Monthly	□
Yearly	■
Information not available	□

Cost/m2	-
Yearly cost of maintenance	-

4

4. ES Viagens/PT Building

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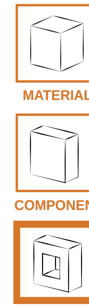
Reference to picture
http://www.suakay.com/projecto.php?pid=142&sid=41&ssid=109 (Accessed October 15, 2018)

Author of the sheet info
Maria da Glória Gomes
Department of Civil Engineering, Architecture and Georesources
Instituto Superior Técnico, Universidade de Lisboa

Rosa Romano,
Florence University, Department of Architecture

CAMPUS KOLDING, Kolding (DK), 2014
Henning Larsen Architects



MATERIAL

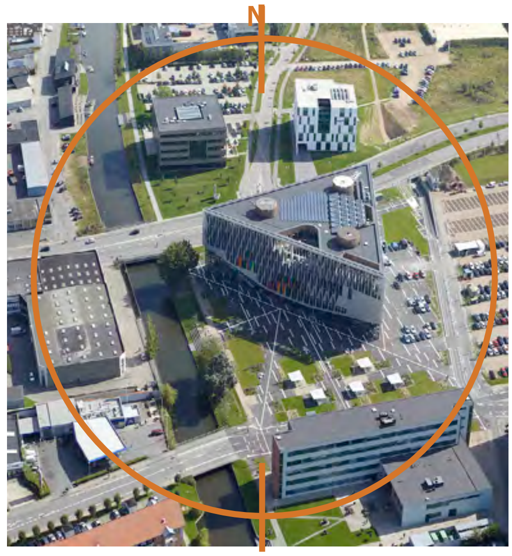
COMPONENT

FACADE

As the new learning centre of excellence, Kolding Campus will house the courses in communications, design, culture and languages of the University of Southern Denmark.

The main feature of the building is the façade. It consists of 1600 perforated steel solar shading panels. These triangular shaped solar shading devices are controlled by sensors that monitor light and heat levels around the building, adjusting themselves by either opening or closing automatically. This system allows for optimal user comfort in terms of lighting and heating.

The building features a number of sustainable features, for instance cooling by means of water from Kolding River, mechanical low-energy ventilation and solar cells.



Latitude 55°48', Longitude 9°48'

SHADING DEVICE, DYNAMIC AND ADAPTIVE ENVELOPE, ENERGY SAVING

BUILDING INFORMATION:			
Building floor area	5000 sq.m	Climate Type	Cfb
Building use	Office, Education	Orientation of the facade	South, East, West
Building status	New Built	Other	-

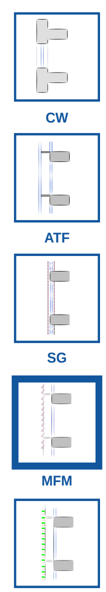
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	□
02. Technology concept formulated/Design Proposal	□
03. Technology validated in lab	□
04. Prototype demonstration	□
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	■
Acoustic comfort	□
Energy management (harvesting, storing, supply)	□
Mass transfer control (e.g. condensation control)	□
Indoor air quality	□
Appearance (aesthetic quality)	■
Structure performance	□
Energy generation	□
Personal users' control	■
Other (durability, accessibility, use of natural resources, etc.):	□

TYPE OF FACADE SYSTEM	
Active façade	□
Advanced façade	□
Biomimetic façade	□
Kinetic façade	■
Intelligent façade	□
Interactive façade	■
Movable façade	□
Responsive façade	■
Smart façade	□
Transformable façade	□
Switchable façade	□

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	□
Devices for managing natural ventilation in combination with mechanical ventilation systems	□
Mobile screens for controlling solar radiation	■
Technological solutions designed to increase and/or control comfort inside the building	□
Building automation systems for the management of plants and elements of the building skin	■



CW

ATF

SG

MFM

BF

FS_08

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): Aluminium	■

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	■
Other (specify)	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	■
Optical (e.g. daylight level, glare)	☐
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify): Manual	☐


1


2

1. South facade ©Hufton+Crow
2. Façade, detail of shading device, ©Hufton+Crow
3. Façade, detail of shading device, ©Hufton+Crow

CONTROL OPERATION DETAILS

3

DETAILED EXPLANATION OF THE CONTROL/OPERATION

The solar shading system consists of 1600 triangular shutters of perforated steel. They are mounted on the facade in a way which allows them to adjust to the changing intensity of daylight and desired inflow of light. When the shutters are closed, they lie flat along the facade. They protrude from the facade when open as desired and when entirely open they provide the building with a very expressive appearance. The solar shading system is fitted with sensors that continuously measure light and heat levels and regulate the shutters mechanically by means of a small motor.
The perforation of the huge shutters is a light, organic pattern of round holes, which provides a distinctive play in the facade on the outside as well as a dynamic play of light on the inside. The holes in the facade are designed and adapted to an opening angle of approx. 30 %. Engineers and architects have conducted analyses and calculations to establish this as the optimal opening angle in relation to the amount of light and energy let in and out of the building - while at the same time providing users with optimal views to the outside urban space.
Sensors monitor heat and light levels around the building, allowing the facade panels to shift from open to half-open to fully open. Even when fully closed, a controlled amount of natural light is able to shine through a custom pattern of round holes, some of which are linked to create amoeba-like openings.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	■
Extrinsic (requires external control)	■
Electromagnetic	□
Other (specify)	□

SYSTEM RESPONSE TIME	
Seconds	■
Minutes	■
Hours	■
Days	□
Seasons	□
Years	□
Other (specify)	□

SYSTEM DEGREE OF ADAPTIVITY:	
On/off	□
Gradual	■
Other (specify)	□

DEGREE OF SPATIAL ADAPTATION	
Nanometers	□
Micrometers	□
Millimeters	□
Centimeters	■
Meters	□
Other (specify)	□

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	□
02 Visible, no surface change (smart glazing)	□
03 Visible, surface change (lamellas, rollers, blinds)	□
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	■
05 Visible, location or orientation change	□
Other (specify)	□

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?

Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY

Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	■
Information not available	☐

SYSTEM MAINTENANCE FREQUENCY

Daily	☐
Weekly	☐
Monthly	☐
Yearly	■
Information not available	☐

Cost/m2	-
Yearly cost of maintenance	-

4

5

4. Detail of triangular shutters
5. Detail of perforated steel

Reference

http://www.henninglarsen.com/projects/0900-0999/0942-sdu-kolding-campus.aspx (Accessed October 15, 2018)

http://www.dezeen.com/2015/07/14/henning-larsen-syddansk-universitet-sdu-kolding-campus-buildingdenmark-green-standards-university/ (Accessed October 15, 2018)

http://www.archdaily.com/590576/sdu-campus-kolding-henning-larsen-architects (Accessed October 15, 2018)

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https://www.ribaj.com/products/campus-kolding-university-of-southern-denmark (Accessed October 15, 2018)

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http://bustler.net/news/3096/construction-update-dynamic-facade-on-henning-larsen-architects-kolding-campus (Accessed October 15, 2018)

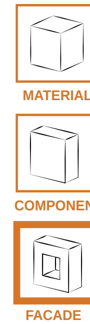
Reference to picture

Author of the sheet info

Rosa Romano
Florence University, Department of Architecture

Enrico Sergio Mazzucchelli
Politecnico di Milano

ALLIANZ HEADQUARTERS, Wallisellen (CH), 2014
Wiel Arets, Felix Thies, Maik Ilmer



The Allianz Suisse Headquarters consists of two buildings: a 17 storeys tower plus roof terrace and a five-storey block perimeter building with an inner courtyard. Glazed bridges connect the buildings. Characteristic of the buildings is its fully glazed building envelope applying a suspended unitized façade with closed cavity. To meet the local urban planning requirements of the district Richti, a façade style with clearly defined window structures is chosen: two glass elements are framed with foils that depict the abstract picture of an onyx marble.
Thanks to the highly insulating multiple glazing, the building still meets the Swiss Minergie standard and 2000W label. The air cavity in the façade elements is hermetically sealed and mechanically ventilated, which prevents moisture. Furthermore, contribute computer-controlled sun protections in the façade cavity, made of aluminium coated silver curtains, to the indoor climate regulation.

Latitude: 47°41′ N Longitude: 8°59′ E

CURTAIN WALL; SHADING; DAYLIGHT CONTROL; THERMAL COMFORT; AESTETHIC QUALITY

BUILDING INFORMATION:			
Building floor area	40.300 sq.m	Climate Type	Dfb
Building use	Office	Orientation of the facade	All orientation
Building status	New Built	Other	-

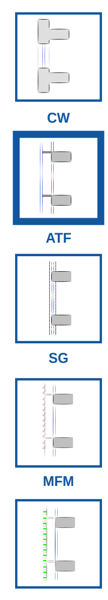
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	☐
04. Prototype demonstration	☐
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	■
Acoustic comfort	☐
Energy management (harvesting, storing, supply)	☐
Mass transfer control (e.g. condensation control)	■
Indoor air quality	☐
Appearance (aesthetic quality)	■
Structure performance	☐
Energy generation	☐
Personal users' control	■
Other (durability, accessibility, use of natural resources, etc.):	☐

TYPE OF FACADE SYSTEM	
Active façade	■
Advanced façade	☐
Biomimetic façade	☐
Kinetic façade	☐
Intelligent façade	☐
Interactive façade	☐
Movable façade	☐
Responsive façade	☐
Smart façade	☐
Transformable façade	☐
Switchable façade	☐

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	☐
Devices for managing natural ventilation in combination with mechanical ventilation systems	☐
Mobile screens for controlling solar radiation	■
Technological solutions designed to increase and/or control comfort inside the building	☐
Building automation systems for the management of plants and elements of the building skin	■



FS_09

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): -	☐

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify): Aluminium coated silver curtain	■

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	■
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	■
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant’s presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify): Manual	☐

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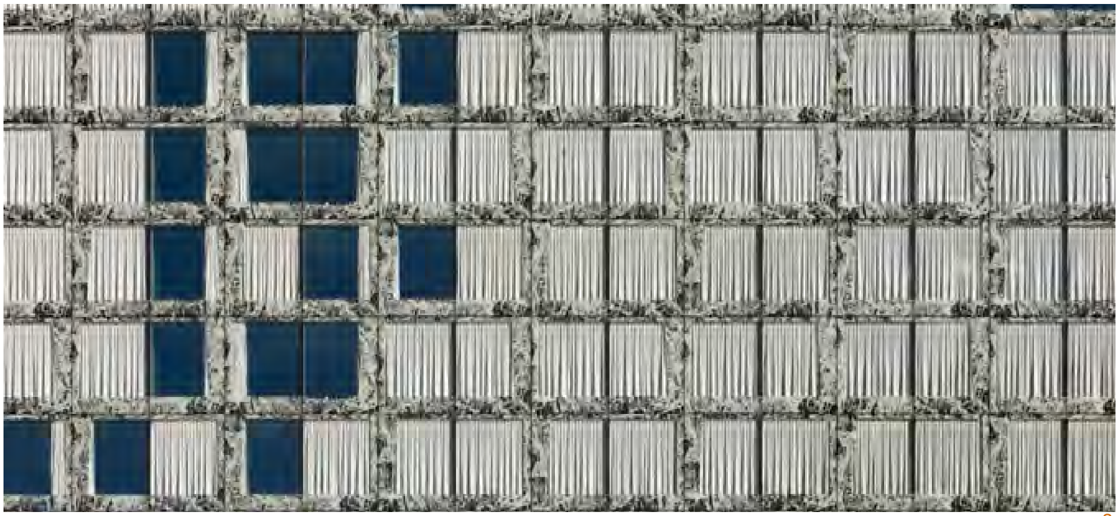
1. Buildind view ©*Welaretsarchitects*
2. Building view, ©*Welaretsarchitects*
3. Façade, detail of shading device, ©*Welaretsarchitects*

CONTROL OPERATION DETAILS



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DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

A new type of closed-cavity facades composes the building envelope. The single elements are comprised of hermetically sealed, multiple glazing with high insulation efficiency. The air cavity is mechanically ventilated, which avoids condensation problems. The result of a series of tests demonstrated that moisture is constantly extracted from the air that is pumped through the cavity. Additionally, the cavity also hosts the shading curtains. Suspended from the construction, the unitized facade is providing a visually flowing surface by a flush-mounted construction. Two facade elements each are framed by a pixel pattern of natural stone onyx, as an interpretation of the district's requirement to provide natural stone facades.
Wiel Arets Architects decided to photograph and abstract the onyx window pattern of Mies van der Rohe's pavilion in Barcelona as a tribute to the famous architect who was a son of a stone mason. The way the patterns are placed on the façade appears as if offset struts flow all way from the top to the ground floor of the buildings surface. The pattern gives the fully glazed façade the impression of a marble cladding, and the placement of curtain hangs instead of conventional blinds gives it a special visual impression. The curtain hangs of aluminum coated silver respond to external environmental factors processed by computer-controlled algorithm. The curtain fabric of highly reflective aluminium vapour coating are employed for the first time as an integrated shading and glare control. When the curtains are open, the façade looks like a thin membrane from the inside despite the element thickness of 300,00 mm. It seems to close with direct sunlight irradiation.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	☐
Extrinsic (requires external control)	■
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	■
Minutes	■
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/off	☐
Gradual	■
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	☐
Centimeters	■
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	☐
03 Visible, surface change (lamellas, rollers, blinds)	■
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	☐
05 Visible, location or orientation change	☐
Other (specify)	☐

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	■
No	☐
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	■
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	■
Information not available	☐

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	■
Information not available	☐

Cost/m2	-
Yearly cost of maintenance	-

Reference
https://www.detail.de/artikel/vorhang-auf-fuer-ein-neues-stadtquartier-das-richti-areal-in-zuerich-wallisellen-12391/ (Accessed October 15, 2018)

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curtain wall fabric: https://www.creationbaumann.com/de/Richti-Areal-Buerogebaeude-und-Hochhaus-Wallisellen-Schweiz-5266.html (Accessed October 15, 2018)

Reference to picture
© Welarets Architects

Author of the sheet info
Susanne Gosztonyi
Lucerne University, Institute of Civil Engineering IBI

Rosa Romano
Florence University, Department of Architecture

Enrico Sergio Mazzucchelli
Politecnico di Milano

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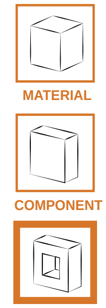
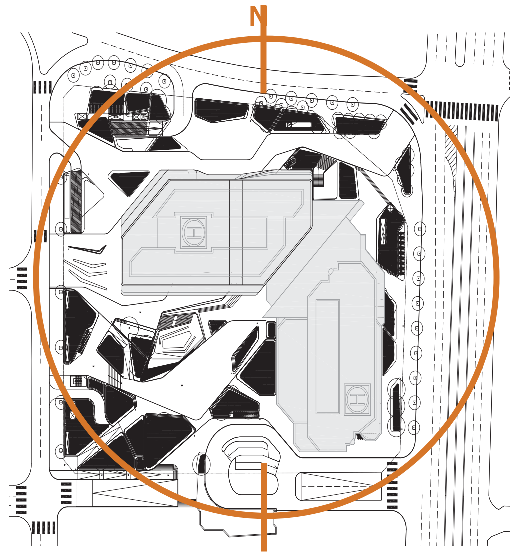
4. Facade system, external view. ©*Welaretsarchitects*
5. Detail of facade. ©*Welaretsarchitects*

HANWHA HEADQUARTERS REMODELLING, SEOUL (ROK), 2013
UNStudio and Arup Hong Kong



UNStudio's design has been selected as the winning entry in the competition for the remodeling of the Hanwha headquarters building in Seoul.
The renovation of the office tower incorporates the remodelling of the facade, the interior of the common spaces, lobbies, meeting levels, auditorium and executive areas, along with the redesign of the landscaping.
Located on the Cheonggyecheon in Seoul, the 57,696 m^2 headquarter building was seen to no longer reflect Hanwha as one of the leading environmental technology providers in the world.
For the competition to remodel the tower UNStudio teamed with Arup (sustainability and facade consultant) and Loos van Vliet (landscape designer). Following the selection of the competition design, AG Licht joined as lighting consultant for the interior, landscape and facade lighting.



Latitude 37°33', Longitude 126°58'

FAÇADE RETROFIT; FAÇADE RENOVATION; SUN SHADING; BIPV; DYNAMIC LED LIGHTING

BUILDING INFORMATION:			
Building floor area	57.969 sq.m	Climate Type	Cwa
Building use	Office	Orientation of the facade	All orientation
Building status	Refurbished	Other	-

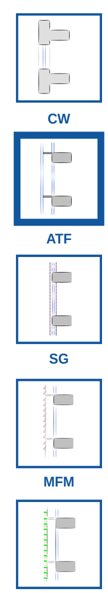
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	□
02. Technology concept formulated/Design Proposal	□
03. Technology validated in lab	□
04. Prototype demonstration	□
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	■
Acoustic comfort	■
Energy management (harvesting, storing, supply)	■
Mass transfer control (e.g. condensation control)	□
Indoor air quality	□
Appearance (aesthetic quality)	■
Structure performance	□
Energy generation	■
Personal users' control	□
Other (durability, accessibility, use of natural resources, etc.):	□

TYPE OF FACADE SYSTEM	
Active façade	■
Advanced façade	□
Biomimetic façade	□
Kinetic façade	□
Intelligent façade	□
Interactive façade	□
Movable façade	□
Responsive façade	□
Smart façade	□
Transformable façade	□
Switchable façade	□

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	■
Devices for managing natural ventilation in combination with mechanical ventilation systems	□
Mobile screens for controlling solar radiation	□
Technological solutions designed to increase and/or control comfort inside the building	□
Building automation systems for the management of plants and elements of the building skin	□



FS_10

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): PV	■

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify): Geometry of the window frame	■

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	■
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	■
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify)	☐

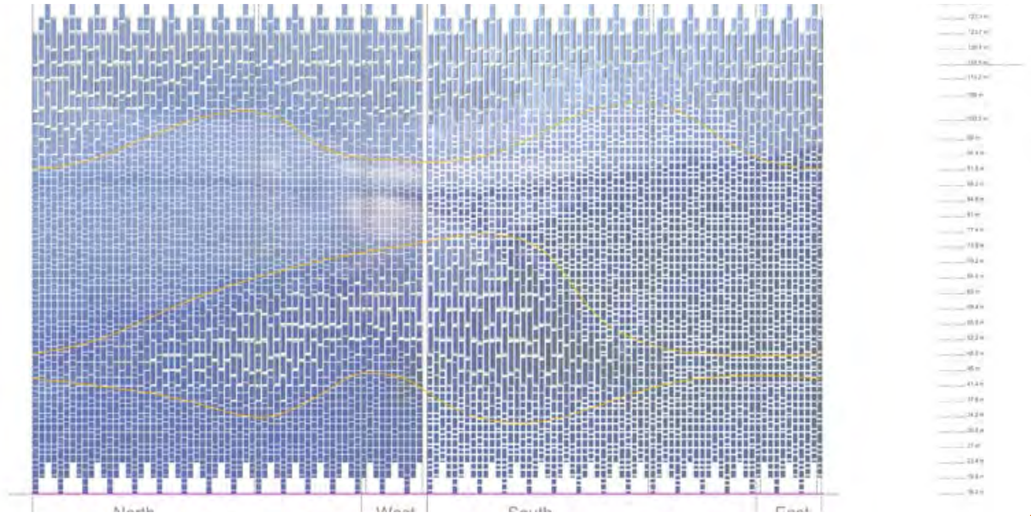
TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify):	☐

1

2

1. Hanwha_PV Diagram ©*UNStudio*
2. Building view, ©*UNStudio*
3. Façade, detail of PV windows, ©*UNStudio*

CONTROL OPERATION DETAILS



3

DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

UNStudio developed an integrated responsive facade concept which improves the indoor climate of the existing building and reacts to both the programmed distribution and the location. Through fully integrated design strategies the UN facades can provide responsive and performative envelopes that both contextually and conceptually react to their local surroundings, whilst simultaneously determining interior conditions.
The geometry (pattern, size and reveal) of the framing is further defined by the sun and orientation factors to ensure user comfort inside and reduced energy consumption. In the design for the Hanwha headquarter building the North facade opens to enable day lighting within the building but becomes more opaque on the South façade, where the sun would otherwise have too much impact on the heat load of the building.
Openings within the facade are further related to the views: opening up where views are possible but becoming more compact on the side adjacent to the nearby buildings.
Direct solar impact on the building is reduced by shading which is provided by angling the glazing away from direct sunlight, while the upper portion of the South facade is angled to receive direct sunlight. PV cells are placed on the opaque panels on the South / Southeast facade. Furthermore, PV panels are angled in the areas of the facade where energy from the sun can best be harvested.
The facade will boast a distinctive nighttime glow, with thousands of LED pixels to be controlled by a sophisticated computerized lighting system that will allow for a virtually limitless array of possibilities in terms the tower's outward appearance.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	☐
Extrinsic (requires external control)	■
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	■
Minutes	■
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/off	☐
Gradual	■
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	☐
Centimeters	☐
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	■
02 Visible, no surface change (smart glazing)	■
03 Visible, surface change (lamellas, rollers, blinds)	☐
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	☐
05 Visible, location or orientation change	☐
Other (specify)	☐

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	■
No	☐
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	■
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	☐

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	■
Information not available	☐

Cost/m2	-
Yearly cost of maintenance	-

Reference

http://www.unstudio.com/projects/hanwha-headquarter-remodeling (Accessed October 15, 2018)

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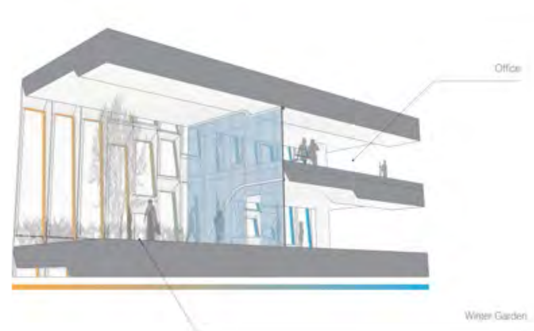
Reference to picture

Author of the sheet info

Rosa Romano
Florence University, Department of Architecture

Enrico Sergio Mazzucchelli
Politecnico di Milano



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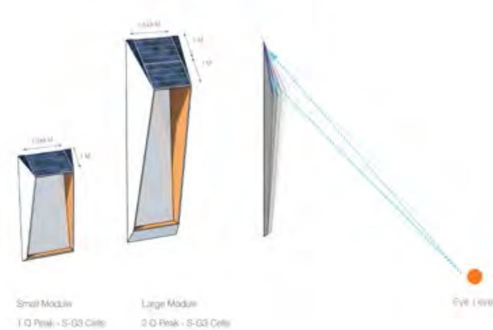

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6

4. Outside view with PV window. ©*UNStudio*
5. Configuration detail. ©*UNStudio*
6. Section of building with integration of PV window. ©*UNStudio*

NORDIC EMBASSIES IN BERLIN, Berlin (DE), 1999
Alfred Berger, Tina Parkkinen

MATERIAL

COMPONENT

FACADE

Berger and Parkkinen developed a master plan for the Nordic embassy in Berlin and initiated the development of building in 1999.
The shape of the building (with acute angle corners) is derived from pedestrian paths passing through the urban landscape.
The main façade is covered with copper with horizontal lamellas that are supposed to give the unique impression of what is a five separate buildings.
The lamellas in the façade could be controlled in groups, revealing the proper façade, that is hidden below.

Latitude 52°30', Longitude 13°21'

PRE-PATINATED LAMELLAS; COPPER LAMELLAS; SUN SHADE; EMBASSY; UNIFIED APPEARANCE

BUILDING INFORMATION:			
Building floor area	17.900 sq.m	Climate Type	Dfb
Building use	Office	Orientation of the facade	All orientation
Building status	New built	Other informations	-

DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	□
02. Technology concept formulated/Design Proposal	□
03. Technology validated in lab	□
04. Prototype demonstration	□
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	■
Acoustic comfort	□
Energy management (harvesting, storing, supply)	□
Mass transfer control (e.g. condensation control)	□
Indoor air quality	□
Appearance (aesthetic quality)	■
Structure performance	□
Energy generation	□
Personal users' control	□
Other (durability, accessibility, use of natural resources, etc.):	□

TYPE OF FACADE SYSTEM	
Active façade	■
Advanced façade	□
Biomimetic façade	□
Kinetic façade	□
Intelligent façade	□
Interactive façade	□
Movable façade	□
Responsive façade	□
Smart façade	□
Transformable façade	□
Switchable façade	□

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	□
Devices for managing natural ventilation in combination with mechanical ventilation systems	□
Mobile screens for controlling solar radiation	■
Technological solutions designed to increase and/or control comfort inside the building	□
Building automation systems for the management of plants and elements of the building skin	□

CW

ATF

SG

MFM

BF

FS_11

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): Copper	■

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	■
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify): Geometry of the window frame	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	■
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify): Manual	☐

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

1

2

1. The copper wall with louvres
2. Main Entrance
3. The copper wall with louvres

CONTROL OPERATION DETAILS

3

DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

Common external façade of the six embassy buildings is 230 meters long and 15 meters high.
The wavy wall is a Berger and Parkkinen project. The envelope is a sum of copper lamellas mounted on a stainless steel construction, encloses the six buildings as a continuous and autonomous element.
The angles at which the copper lamellas are inclined allow controlling the amount of light, view and air that moving from outside to inside the buildinga and vice-versa.
Some of the blinds are equipped with hydraulic pumps with which they are electrically maneuvered from the interior.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	☐
Extrinsic (requires external control)	■
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	☐
Minutes	■
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/off	☐
Gradual	■
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	☐
Centimeters	■
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	☐
03 Visible, surface change (lamellas, rollers, blinds)	☐
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	■
05 Visible, location or orientation change	☐
Other (specify)	☐

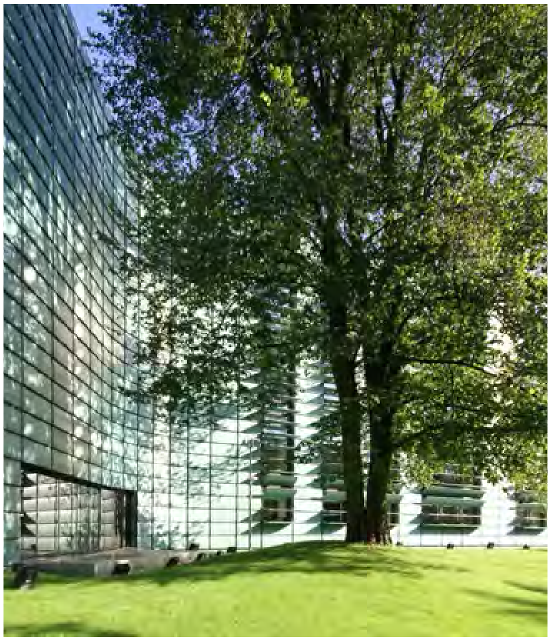
ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	■
No	☐
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	■
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	☐

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	■
Information not available	☐

Cost/m2	-
Yearly cost of maintenance	-



4

5

4. Perforated stainless steel panels on the facade of the Danish Embassy
5. Detail of the copper band that encircles the five embassies

Reference

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Reference to picture

Author of the sheet info

Rosa Romano
Florence University, Department of Architecture

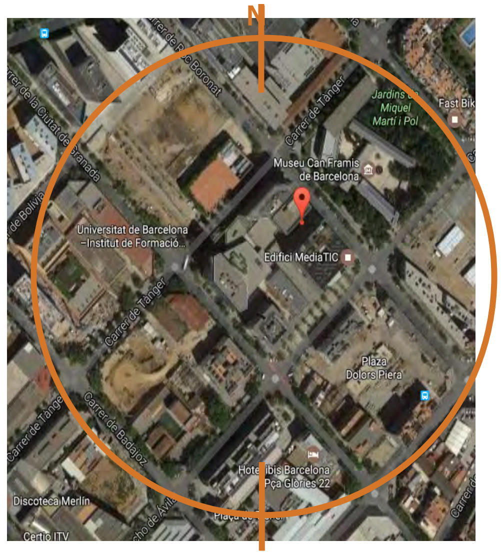
Enrico Sergio Mazzucchelli
Politecnico di Milano

Marcin Brzezicki
Wroclaw University of Technology

MEDIA-TIC, Barcelona (ES), 2007
Enric Ruiz-Geli

MATERIAL · COMPONENT · **FACADE**

Media Tic building was designed by Enric Ruiz-Geli (Cloud-9) and intend to be a vehicle for spreading new technologies to all citizens. It is a building of great transparency, open to the public, gathering a creative and environmental awareness. It features a large auditorium with a seating capacity of about 300.
It has an innovative and attractive translucent Ethylene Tetra Fluoro Ethylene (ETFE) facade cladding, with 2500 m^2, which performs simultaneously as an external protection and a mobile solar screen to regulate both light and temperature and, hence, contributing to decrease the building energy demand.



Latitude 41°40'; Longitude 2°19'

PNEUMATIC FACADE AND BLIND; DAYLIGHT REGULATION; OFFICE BUILDING; ETFE

BUILDING INFORMATION:			
Building floor area	23.104,00 sq.m	Climate Type	BSk
Building use	Office	Orientation of the facade	South-east, South-west
Building status	New built	Other	-

DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	□
02. Technology concept formulated/Design Proposal	□
03. Technology validated in lab	□
04. Prototype demonstration	□
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	■
Acoustic comfort	□
Energy management (harvesting, storing, supply)	□
Mass transfer control (e.g. condensation control)	□
Indoor air quality	□
Appearance (aesthetic quality)	■
Structure performance	□
Energy generation	□
Personal users' control	□
Other (durability, accessibility, use of natural resources, etc.):	□

TYPE OF FACADE SYSTEM	
Active façade	■
Advanced façade	□
Biomimetic façade	□
Kinetic façade	□
Intelligent façade	□
Interactive façade	□
Movable façade	□
Responsive façade	□
Smart façade	□
Transformable façade	□
Switchable façade	□

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	□
Devices for managing natural ventilation in combination with mechanical ventilation systems	□
Mobile screens for controlling solar radiation	□
Technological solutions designed to increase and/or control comfort inside the building	□
Building automation systems for the management of plants and elements of the building skin	■

CW · **ATF** · SG · MFM · BF

FS_12

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): ETFE (ethylene tetrafluorethylene) cladding	■

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify): ETFE with serigrafy	■

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify): Pneumatic mechanisms	■

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	■
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant’s presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	☐
Pneumatical	■
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify): Manual	☐

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

1

2

1. Detail of one of the mobile bags that function as a solar screen
2. Facade system
3. Detail of one of the mobile bags that function as a solar screen

CONTROL OPERATION DETAILS

3

DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

The Sancho de Ávila Façade (south-east façade) takes an average of 6 hours of sunshine in one day, need an external solar system based on a double layer of cladding that is regulated, domotic, structurally light, with low energy consumption and great illumination efficiency. The solution is an exterior "film" of material with a variable ETFE solar filter in Diaphragm configuration, constructed with three layers of ETFE, with constant pressure and variable circulation of air between the chambers. The first layer is transparent, the second (middle) and third layers have a reverse pattern design which, when inflated and joined together, create shade, or in other words a single opaque layer. When the second and third layers are joined, creating shade, the inflatable section only has one air chamber. The system activates itself automatically with a temperature sensor network. Each of the "pillows" have their own sensors and are controlled separately. They measure the temperature, heat, and the sun's angle to control the climate of the building's interior.It performs and regulates the solar energy with a filter in the façade, which combines a nitrogen particle system with air from the ETFEs and creates a cloud that protects the building´s interior. The sensors work in real-time with air chambers to make it inflate or deflate.
Another façade with a singular configuration is that which looks onto the interior street: this façade also receives a fair amount of sunshine and in this case the "EFTE Lenticular" configuration is used, which injects a spray of nitrogen into a number of ETFE longitudinal bags arranged along the SW façade. This brings the solar factor down from 0,45, as required by the Building Code, to 0,10, four times less.
The other two façades of the cube are glassed-in and have little exposure to the sun.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	☐
Extrinsic (requires external control)	■
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	☐
Minutes	■
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/off	☐
Gradual	■
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	☐
Centimeters	☐
Meters	■
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	☐
03 Visible, surface change (lamellas, rollers, blinds)	☐
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	■
05 Visible, location or orientation change	☐
Other (specify)	☐

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	☐
Other (specify): 20.791.486,00 €	■

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	■
Information not available	☐

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	☐
Information not available	■

Reference

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Author of the sheet info

Marcin Brzezicki
Wroclaw University of Technology

Rosa Romano
Florence University, Department of Architecture

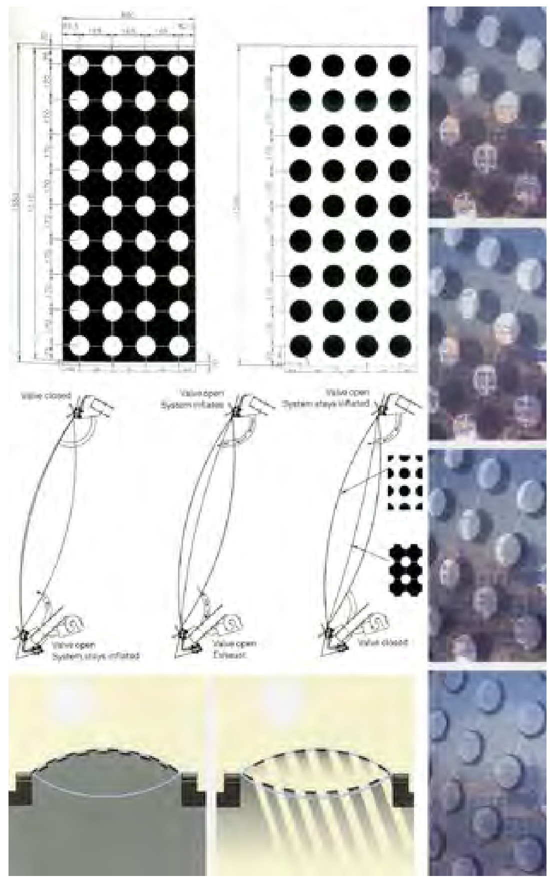
Enrico Sergio Mazzucchelli
Politecnico di Milano

Maria da Glória Gomes
Department of Civil Engineering, Architecture and Georesources
Instituto Superior Técnico, Universidade de Lisboa

Dilara Güler
Universidad Del Pais Vasco

Cost/m2	-
Yearly cost of maintenance	-

4



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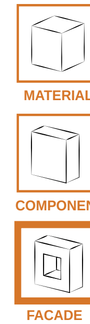
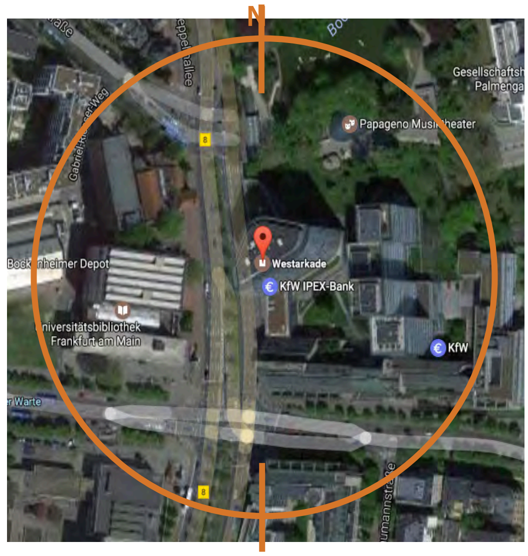
4. Media-TIC at the intersection of Sancho de Ávila and Roc Boronat
5. Diagrams of the way the ETFE Diaphragm works

KFW WESTARKADE, Frankfurt (DE), 2010
Sauerbruch Hutton, Architekten Theiss Planungsgesellschaft mbH, Transsolar



In 2002, the Kreditanstalt für Wiederaufbau began to renovate and extend its head office northwest of Frankfurt's city centre. With primary energy usage remaining below 100 kWh/m^2/year, the Westarkade sets new energy standards for high-rise office buildings. In contrast to conventional double skin facade construction, the facade cavity is not ventilated by means of the "stack effect", in which air is ventilated upwards through the building but, instead wind pressure and suction at the lee side of the tower are utilised. To enable this, the facade is clad with zigzagged transparent colourised glass panes and narrow ventilation flaps. Furthermore, the double-layered wind-pressurized facade has high insulation values and offers natural ventilation independent of the weather, as well as efficient solar protection.



Latitude 50°07'; Longitude 8°30'

DOUBLE FACADE; OFFICE BUILDING; LOW-ENERGY BUILDING; VENTILATION FLAPS

BUILDING INFORMATION:			
Building floor area	5000 sq.m	Climate Type	Cfb
Building use	Office	Orientation of the facade	All orientation
Building status	New built	Other	-

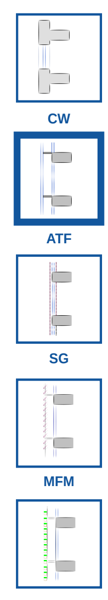
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	☐
04. Prototype demonstration	☐
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	■
Acoustic comfort	☐
Energy management (harvesting, storing, supply)	☐
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	■
Appearance (aesthetic quality)	■
Structure performance	☐
Energy generation	☐
Personal users' control	☐
Other (durability, accessibility, use of natural resources, etc.):	☐

TYPE OF FACADE SYSTEM	
Active façade	☐
Advanced façade	■
Biomimetic façade	☐
Kinetic façade	☐
Intelligent façade	☐
Interactive façade	☐
Movable façade	☐
Responsive façade	☐
Smart façade	☐
Transformable façade	☐
Switchable façade	☐

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	☐
Devices for managing natural ventilation in combination with mechanical ventilation systems	☐
Mobile screens for controlling solar radiation	☐
Technological solutions designed to increase and/or control comfort inside the building	■
Building automation systems for the management of plants and elements of the building skin	☐



FS_13

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): Glass	■

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	☐
Air quality (humidity, CO2 concentration, etc)	■
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify): Manual	☐

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

1

2

1. Facade view
2. Building view
3. Detail of facade system

CONTROL OPERATION DETAILS

3

DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

The façade's outer layer contains sensor-controlled flap openings that maintain a constant and even air pressure within the ring.

The inner layer has operable windows that allow the offices within to be ventilated. The air flow within the pressure ring is regulated to never exceed 6 m/s.

The flaps are designed to adjust to five wind directions as well as outside temperature, solar radiation and pressure differences on the windward and leeward sides of the building. As a result, the offices can be ventilated naturally for eight months of the year without creating drafts or undesired heat loss. Mechanical ventilation is required for less than 50% of all working hours.

The double façade also functions as a passive thermal solar collector, as the flow of fresh air is pre-tempered by solar radiation within the double façade. In this way heat loss is minimized and heat energy is conserved. The outer skin of the double façade can be opened completely in order to avoid overheating of the building in summer. During warmer months, the motorised flaps on the south-west and north-east elevations open to allow air to flow through the cavity, while during cooler times of year the flaps are closed, allowing air to be preheated before entering the offices.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	□
Extrinsic (requires external control)	■
Electromagnetic	□
Other (specify)	□

SYSTEM RESPONSE TIME	
Seconds	□
Minutes	■
Hours	□
Days	□
Seasons	□
Years	□
Other (specify)	□

SYSTEM DEGREE OF ADAPTIVITY:	
On/off	■
Gradual	□
Other (specify)	□

DEGREE OF SPATIAL ADAPTATION	
Nanometers	□
Micrometers	□
Millimeters	□
Centimeters	■
Meters	□
Other (specify)	□

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	□
02 Visible, no surface change (smart glazing)	□
03 Visible, surface change (lamellas, rollers, blinds)	□
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	■
05 Visible, location or orientation change	□
Other (specify)	□

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	■

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	☐
Information not available	■

Cost/m2	-
Yearly cost of maintenance	-

4

5

4. View of the Office
5. Facade construction phase

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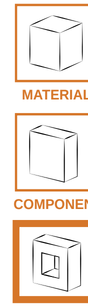
Author of the sheet info

Marcin Brzezicki
Wroclaw University of Technology

Rosa Romano
Florence University, Department of Architecture

Enrico Sergio Mazzucchelli
Politecnico di Milano

HEAD OFFICE OF AGC GLASS EUROPE, Ottignies-Louvain-la-Neuve (DE), 2014
SAMYN and PARTNERS, Daidalos Peutz, AGC Glass

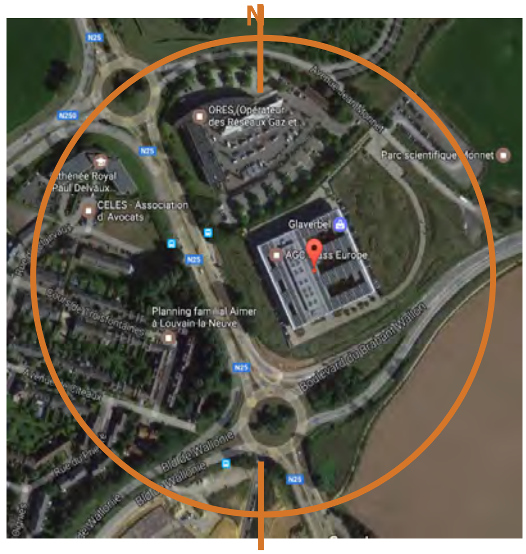


MATERIAL

COMPONENT

FACADE

Glass facades of AGC Head Office were equipped with glass sun shades, that turn towards the sun automatically. The light allowed into the interior is diffused, as their surfaces have been treated and printed with alternate bands of white screen-printed stripes. Removable blinds made of bamboo wood were also installed on all the other openings in the building.
In terms of energy performance, the aim for the building is to achieve zero energy.
Energy saving, throughout (natural light, insulation etc.) the use of efficient materials (energy-saving circulation, regulation etc.) and reliance on renewable energy (photovoltaic panels, ground probes, heat pumps etc.) made it possible to do so.



Latitude 50°40'; Longitude 4°37'

GLASS BUILDING; MOVABLE LOUVRES; AUTOMATED CONTROL; NATURAL LIGHT

BUILDING INFORMATION:			
Building floor area	10.923 sq.m	Climate Type	Cfb
Building use	Office	Orientation of the facade	All orientation
Building status	New built	Other	-

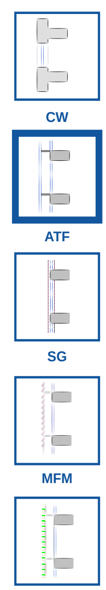
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	□
02. Technology concept formulated/Design Proposal	□
03. Technology validated in lab	□
04. Prototype demonstration	□
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	■
Acoustic comfort	□
Energy management (harvesting, storing, supply)	□
Mass transfer control (e.g. condensation control)	□
Indoor air quality	□
Appearance (aesthetic quality)	■
Structure performance	□
Energy generation	□
Personal users' control	■
Other (durability, accessibility, use of natural resources, etc.):	□

TYPE OF FACADE SYSTEM	
Active façade	□
Advanced façade	■
Biomimetic façade	□
Kinetic façade	□
Intelligent façade	□
Interactive façade	□
Movable façade	□
Responsive façade	■
Smart façade	□
Transformable façade	□
Switchable façade	□

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	□
Devices for managing natural ventilation in combination with mechanical ventilation systems	□
Mobile screens for controlling solar radiation	■
Technological solutions designed to increase and/or control comfort inside the building	□
Building automation systems for the management of plants and elements of the building skin	■



CW

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FS_14

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): Glass	■

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify): Shading with dual-axis tracking	■

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	■
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant’s presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify): Manual	☐

1

2

1. Building view
2. Facade detail
3. Glass shading device detail

CONTROL OPERATION DETAILS

3

DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

The external façade is fully covered with double glazing system in combination with thermally insulated glass sunshades printed with white silk screen. These louvers respond dynamically and automatically to the angle of the sun which improves the control over energy consumption, solar radiation and glare with the ability to admit natural light into the building while affording a view over the surrounding countryside.
The louvres on the north and south facades are installed horizontally, while those on the east and west facades are vertical. When in the east and west, the sun is relatively low and the vertical louvres are better able to track it. In special case, louvers are fixed in their open position in the case of rain and when the outside temperature is below 3C: risk of icing. 'TOP on Clearvision', the AGC glass's product was selected after doing several tests and modifications to choose the type of glazing for the adaptive façade.
The standard louvres control software was designed by COLT, widely known in the manufacture of solar shading and climate control systems. The system is based on light levels measured by a roof mounted sensor. The louvres of the four facades are thus controlled by 256 actuators: 72 for each north/south facade and 56 for each east/west façade.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	■
Extrinsic (requires external control)	☐
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	■
Minutes	☐
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/Off	■
Gradual	☐
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	☐
Centimeters	■
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	☐
03 Visible, surface change (lamellas, rollers, blinds)	☐
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	☐
05 Visible, location or orientation change	■
Other (specify)	☐

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?

Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY

Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	■
Information not available	☐

SYSTEM MAINTENANCE FREQUENCY

Daily	☐
Weekly	☐
Monthly	■
Yearly	☐
Information not available	☐

Reference

Attia, S. and Bashandy, H. (2016), *Evaluation of Adaptive Facades: The Case Study of AGC Headquarter in Belgium*, Challenging Glass 5 – Conference on Architectural and Structural Applications of Glass, Belis, Bos & Louter (Eds.), Ghent University

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Author of the sheet info

Shady Attia
Liege University

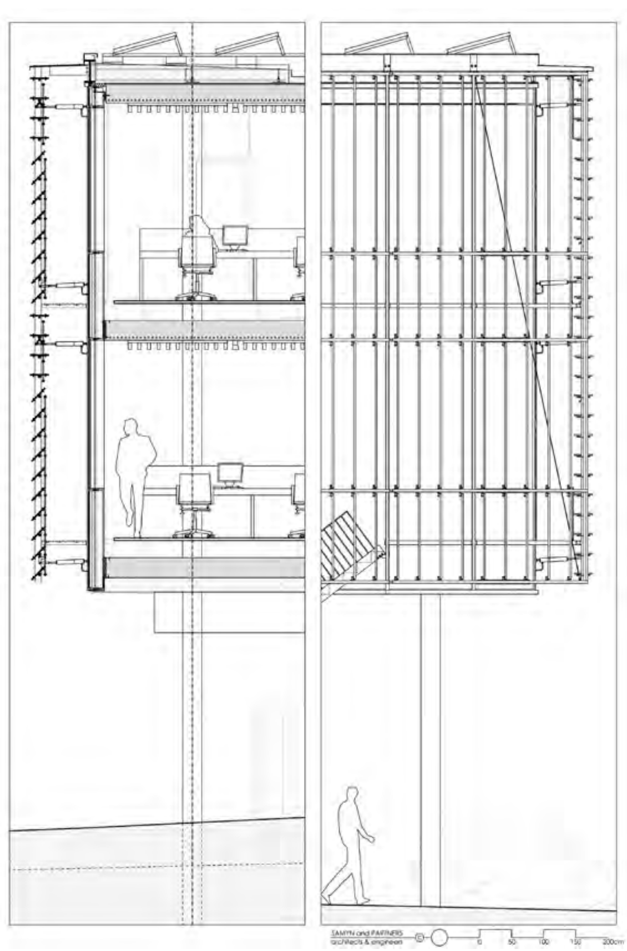
Marcin Brzezicki
Wroclaw University of Technology

Rosa Romano
Florence University, Department of Architecture

Enrico Sergio Mazzucchelli
Politecnico di Milano

Cost/m2	-
Yearly cost of maintenance	-

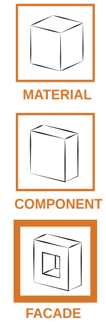
4



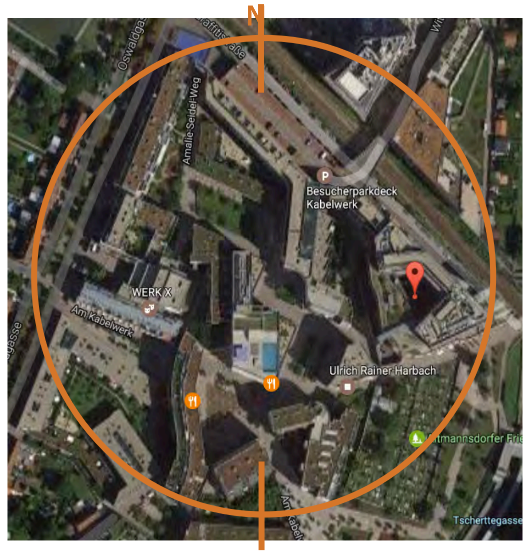
5

4. Facade detail
5. Technological section

NURSING HOME MEIDLING, Vienna (AT), 2011
HERMANN & VALENTINY UND PARTNER, COLT



Spread over five floors, the home houses 256 beds for those in need of round-the-clock care. All of the rooms boast spacious, barrier-free loggias, which have been built so as to form a walkway around the entire building on each floor. To protect the residents from direct sunlight and ensure their privacy, these loggias are enveloped in salmon-pink sliding and rotating shutters made of perforated aluminum. The fixed and movable elements used here ensure that light and shadow interplay, bringing this concrete building to life. Each loggia is fitted with three four-wing sliding-folding shutters, two of which are fixed and one moveable, although some of the loggias boast six-wing shutters. All of these elements are uniform in size, measuring 68,00 cm in width and 230 cm in height.



Latitude 48°09’, Longitude 16°19’

SLIDING-FOLDING SHUTTERS; HEALTHCARE; ELDERLY ACCOMMODATION

BUILDING INFORMATION:			
Building floor area	16.930 sq.m	Climate Type	Dfb
Building use	Healthcare	Orientation of the facade	South, West
Building status	New built	Other	-

DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL

- [ ] 01. Basic principles observed and reported/ Idea
- [ ] 02. Technology concept formulated/Design Proposal
- [ ] 03. Technology validated in lab
- [ ] 04. Prototype demonstration
- [x] **05. Commercial product/Existing building**

FUNCTION / GOAL / PURPOSE

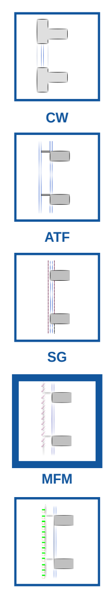
- [ ] Thermal comfort
- [x] **Visual comfort**
- [ ] Acoustic comfort
- [ ] Energy management (harvesting, storing, supply)
- [ ] Mass transfer control (e.g. condensation control)
- [ ] Indoor air quality
- [x] **Appearance (aesthetic quality)**
- [ ] Structure performance
- [ ] Energy generation
- [x] **Personal users’ control**
- [ ] Other (durability, accessibility, use of natural resources, etc.):

TYPE OF FACADE SYSTEM

- [ ] Active façade
- [ ] Advanced façade
- [ ] Biomimetic façade
- [x] **Kinetic façade**
- [ ] Intelligent façade
- [ ] Interactive façade
- [ ] Movable façade
- [ ] Responsive façade
- [ ] Smart façade
- [ ] Transformable façade
- [ ] Switchable façade

TECHNOLOGICAL FEATURES

- [ ] High-performance innovative materials and systems for absorbing and storing solar energy
- [ ] Devices for managing natural ventilation in combination with mechanical ventilation systems
- [x] **Mobile screens for controlling solar radiation**
- [ ] Technological solutions designed to increase and/or control comfort inside the building
- [ ] Building automation systems for the management of plants and elements of the building skin



FS_15

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify):	☐

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify): Sliding-folding shutters	■

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

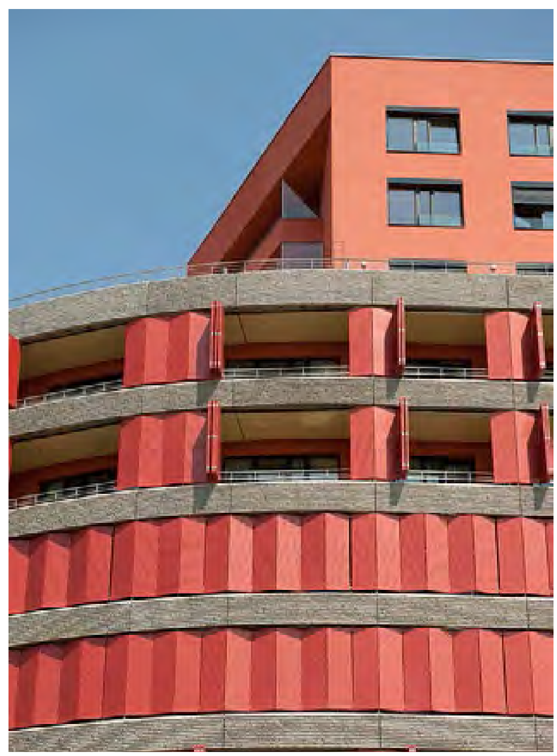
TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	☐
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify): Individuall user control	■

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	☐
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify): Manual	■

1. The loggias provide the residents with more space as well as a private, accessible outdoor area, photo © Colt International GmbH | David Auner Photography, Vienna

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

1



2

2. The fixed and moveable façade elements define the building's external appearance, photo © Colt International GmbH | David Auner Photography, Vienna
3. The moveable sliding and folding shutters can be controlled from each of the nursing home's rooms, photo © Colt International GmbH | David Auner Photography, Vienna

CONTROL OPERATION DETAILS

3

DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

The fixed and movable elements used here ensure that light and shadow interplay, bringing this concrete building to life. Each loggia is fitted with three four-wing sliding-folding shutters, two of which are fixed and one moveable, although some of the loggias boast six-wing shutters. All of these elements are made of perforated aluminum panels, whose edges are folded over thrice all the way round, increasing their stability.
The upper edge of each shutter is attached to the concrete façade, where a timing belt is used to open and close them. The bottom edge is set in a track, which is in turn integrated into a rail, also designed by Colt International. A 230-volt motor allows each user to control their individual shutters as they wish, while the soft-start/soft-stop mechanism ensures that the shutters don't make too much noise as possible when opening and closing.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	☐
Extrinsic (requires external control)	■
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	☐
Minutes	■
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/off	☐
Gradual	■
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	☐
Centimeters	■
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	☐
03 Visible, surface change (lamellas, rollers, blinds)	☐
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	■
05 Visible, location or orientation change	☐
Other (specify)	☐

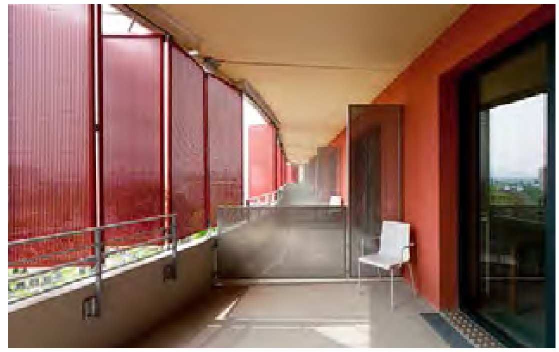
ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	■

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	☐
Information not available	■

Cost/m2	-
Yearly cost of maintenance	-



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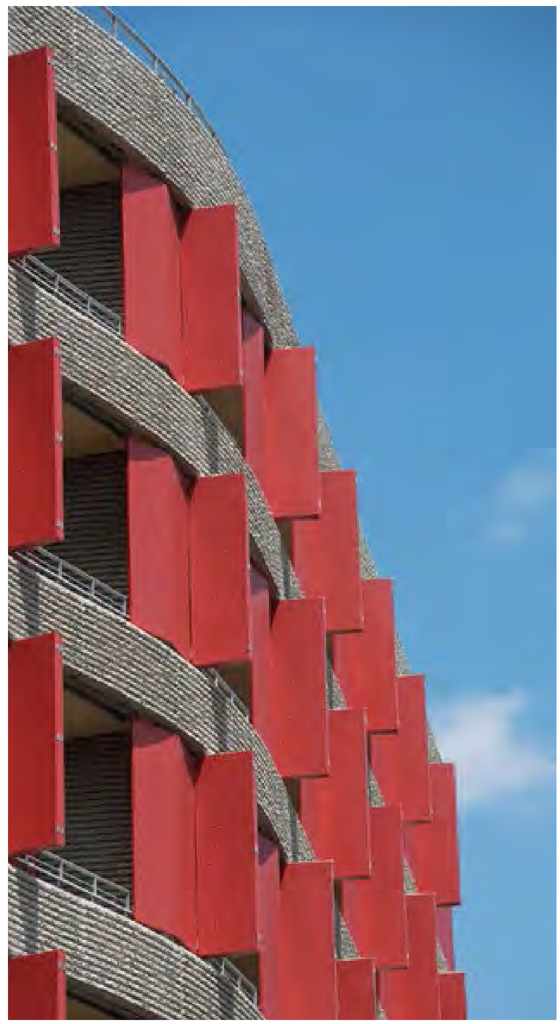

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Reference to picture
https://www.stylepark.com/en/news/moving-facades (Accessed October 15, 2018)

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Author of the sheet info
Marcin Brzezicki
Wroclaw University of Technology

Rosa Romano
Florence University, Department of Architecture

Enrico Sergio Mazzucchelli
Politecnico di Milano

4. The loggias form a walkway around the entire building, photo © Colt International GmbH | David Auner Photography, Vienna
5. The salmon-pink sliding and folding shutters by Colt International define the façades of Vienna's latest nursing home, photo © Colt International GmbH | David Auner Photography, Vienna

OFFICE BUILDING FRIEDRICHSTRASSE 40, Berlin (DE), 2011
HERMANN & VALENTINY UND PARTNER, COLT

MATERIAL

COMPONENT

FACADE

The front facade to Friedrichstrasse is perfectly transparent with vertical glass lamellas to protect against heating and which link the house to the environment. The garden front is different: with sliding doors and a shading device made from textile material. The interior sees a mix of glass, wood and textile.
The artistic interpretation of the place by Antje Schiffers escorts the public within the public accommodations of the house. Sustainability in construction and technology has been pre-certified with the GOLD award of the Deutsche Gesellschaft für Nachhaltiges Bauen.

Latitude 52°30', Longitude 15°35'

ROLLERS; HIGH-PERFORMANCE FACADE; OPERABLE TEXTILE SCREENS; DOUBLE FACADE

BUILDING INFORMATION:			
Building floor area	500 - 5000 sq.m	Climate Type	Dfb
Building use	Office	Orientation of the facade	East
Building status	New built	Other	-

DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	□
02. Technology concept formulated/Design Proposal	□
03. Technology validated in lab	□
04. Prototype demonstration	□
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	■
Acoustic comfort	□
Energy management (harvesting, storing, supply)	□
Mass transfer control (e.g. condensation control)	□
Indoor air quality	□
Appearance (aesthetic quality)	■
Structure performance	□
Energy generation	□
Personal users' control	□
Other (durability, accessibility, use of natural resources, etc.):	□

TYPE OF FACADE SYSTEM	
Active façade	■
Advanced façade	□
Biomimetic façade	□
Kinetic façade	□
Intelligent façade	□
Interactive façade	□
Movable façade	□
Responsive façade	□
Smart façade	□
Transformable façade	□
Switchable façade	□

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	□
Devices for managing natural ventilation in combination with mechanical ventilation systems	□
Mobile screens for controlling solar radiation	■
Technological solutions designed to increase and/or control comfort inside the building	□
Building automation systems for the management of plants and elements of the building skin	□

CW

ATF

SG

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BF

FS_16

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): Glass	■

TYPE OF SHADING DEVICE	
Screens / roller shades	■
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify): Sliding-folding shutters	■

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	■
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify): Individuall user control	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify): Manual	■

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

1

2

1. View of the facade from an apartment ©Jan Bitter
2. The front facade ©Jan Bitter
3. Detail of the double skin facade on the front ©Jan Bitter

CONTROL OPERATION DETAILS

3

DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

The garden side is outfitted with operable shade screens that extend down over each window to protect the interior from the morning glare. Roll-out textile shades can be extended when needed, or retracted for more light once the sun has moved past its zenith.
On the street side, the building features three two-story high bay windows, with a specially designed double-glazed facade.
A series of vertical fins are integrated to the outside of the windows that can be rotated to protect against the heat.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	☐
Extrinsic (requires external control)	■
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	☐
Minutes	■
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/off	☐
Gradual	■
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	☐
Centimeters	■
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	☐
03 Visible, surface change (lamellas, rollers, blinds)	☐
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	■
05 Visible, location or orientation change	☐
Other (specify)	☐

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	■

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	☐
Information not available	■

Cost/m2	-
Yearly cost of maintenance	-

4

5

Reference
https://www.german-architects.com/en/petersenarchitekten-berlin/project/f40-geschaftshaus (Accessed October 15, 2018)

http://inhabitat.com/berlin-office-building-features-two-different-high-performance-facades/ (Accessed October 15, 2018)

https://divisare.com/projects/169096-petersen-architekten-jan-bitter-f40-office-building (Accessed October 15, 2018)

Reference to picture
©Jan Bitter by: https://divisare.com/projects/169096-petersen-architekten-jan-bitter-f40-office-building (Accessed October 15, 2018)

Author of the sheet info
Marcin Brzezicki
Wroclaw University of Technology

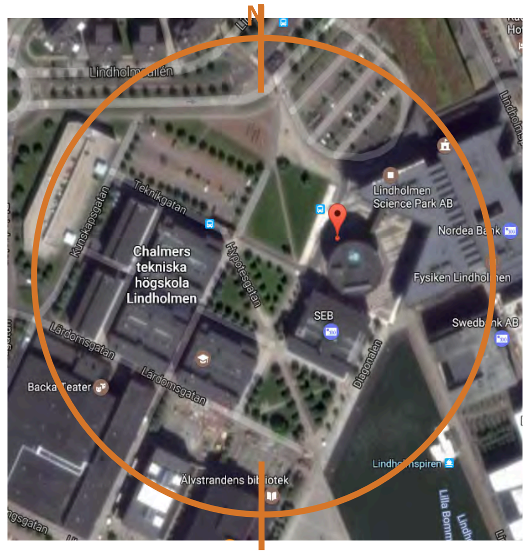
Rosa Romano
Florence University, Department of Architecture

Enrico Sergio Mazzucchelli
Politecnico di Milano

4. Front facade and the garden front views. ©Jan Bitter
5. Detail of the shading device on the garden front. ©Jan Bitter

KUGGEN, Göteborg (SE), 2011
WINGÅRDH ARKITEKTKONTOR

The building in the middle of the town square serves local Chalmers University. The upper floors project out over the lower ones. In a result the building partially shades itself when the sun is high in the sky, what happens is a summer months in Scandinavia. This is also the reason why the floor at the top of the building needs additional shade (no floor to shade this one). A solution was provided by a rotating shading screen, that follows a circular guides around the building. The screen is adjusted according to the sun's path.



Latitude 57°42', Longitude 11°56'

ROTATING SCREEN; TRIANGULAR FACADE MODULE; MULTICOLOUR FACADE CLADDING

BUILDING INFORMATION:			
Building floor area	5350.0 sq.m	Climate Type	Dfb
Building use	Office	Orientation of the facade	East
Building status	New built	Other	-

DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	☐
04. Prototype demonstration	☐
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	☐
Visual comfort	■
Acoustic comfort	☐
Energy management (harvesting, storing, supply)	☐
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	☐
Appearance (aesthetic quality)	■
Structure performance	☐
Energy generation	☐
Personal users' control	☐
Other (durability, accessibility, use of natural resources, etc.):	☐

TYPE OF FACADE SYSTEM	
Active façade	■
Advanced façade	☐
Biomimetic façade	☐
Kinetic façade	☐
Intelligent façade	☐
Interactive façade	☐
Movable façade	☐
Responsive façade	☐
Smart façade	☐
Transformable façade	☐
Switchable façade	☐

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	☐
Devices for managing natural ventilation in combination with mechanical ventilation systems	☐
Mobile screens for controlling solar radiation	■
Technological solutions designed to increase and/or control comfort inside the building	☐
Building automation systems for the management of plants and elements of the building skin	☐

MATERIAL
COMPONENT
FACADE

CW
ATF
SG
MFM
BF

FS_17

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify):	☐

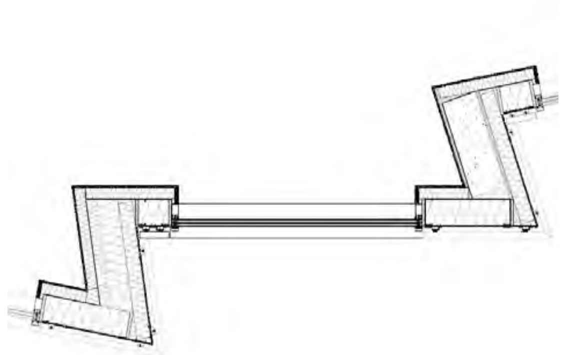
TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify): Rotating screen on circular railing	■

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (IMPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	■
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant’s presence	☐
Other (specify): Individuall user control	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify): Manual	☐



1

2

1. Technological Detail of Facade System
2. Facade System
3. Detail of Facade

CONTROL OPERATION DETAILS

3

DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

The building is characterized from the integration of a rotating screen that is able shaded the top floors, following the sun's path around it.
The upper floors project out over the lower—more on the south side than on the north, so that the building partially shades itself when the sun is high in the sky.
The form of the facade components offers lots of floor space in relation to the amount of exposed exterior wall surface.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	☐
Extrinsic (requires external control)	■
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	☐
Minutes	■
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/off	☐
Gradual	■
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	☐
Centimeters	■
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	☐
03 Visible, surface change (lamellas, rollers, blinds)	☐
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	☐
05 Visible, location or orientation change	■
Other (specify)	☐

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	■
Other (specify)	☐

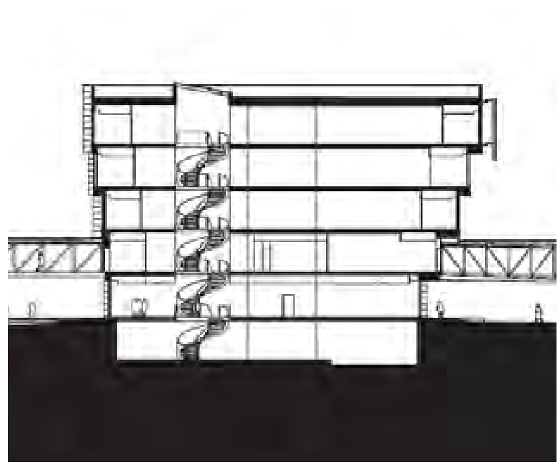
ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	■

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	☐
Information not available	■

Cost/m2	-
Yearly cost of maintenance	-

4

5



6

Reference

http://www.archdaily.com/289856/kuggen-wingardh-arkitektkontor (Accessed October 15, 2018)

http://www.e-architect.co.uk/sweden/kuggen-gothenburg (Accessed October 15, 2018)

https://www.behance.net/gallery/21776507/The-Kuggen-Lindholmen-Goeteborg-Sweden (Accessed October 15, 2018)

http://cudaarchitektury.pl/kuggen/ (Accessed October 15, 2018)

Reference to picture

https://mir-s3-cdn-cf.behance.net/project_modules/disp/018b2b21776507.5630751a2eae9.jpg, Mabry Campbell (Accessed October 15, 2018)

http://images.adsttc.com/media/images/5097/f0f9/28ba/0d49/de00/03e3/large_jpg/section.jpg?1414171450, Courtesy of Wingårdh Arkitektkontor (Accessed October 15, 2018)

http://www.designboom.com/cms/images/erica/-----kuggen/kuggen02.jpg (Accessed October 15, 2018)

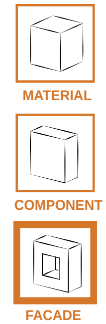
Author of the sheet info

Marcin Brzezicki
Wroclaw University of Technology

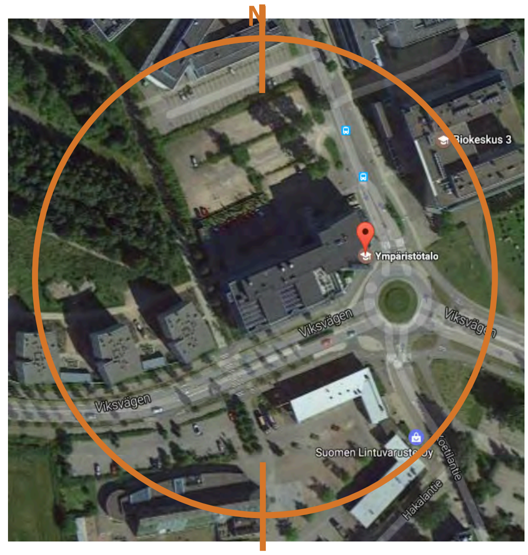
Rosa Romano
Florence University, Department of Architecture

4. Building in the urban contest
5. Facade view
6. Technological section of the building

nZEB OFFICE BUILDING YMPÄRISTÖTALO, Ympäristötalo, Helsinki, (FI), 2011
AB CASE CONSULT LTD, KIMMO KUISMANEN



The nZEB office building is characterized by a double skin south facades with integrated PV cells with an effective solar protection. Apart from the atrium space, all the building is air-conditioned with effective integrated balanced ventilation and free cooling system with both passive and active chilled beams.
Although window area in only 23% of the external wall area, the building stills has an outlook of a glass building. The double skin facade cavity is open on the bottom and has motorized ventilation openings on the top.



Latitude 60°10', Longitude 24°56'

nZEB; BUILDING INTEGRATED PV; DOUBLE SKIN FAÇADE; SOLAR SHADING

BUILDING INFORMATION:			
Building floor area	6.791 and up sq. m.	Climate Type	Dfb
Building use	Office	Orientation of the facade	South
Building status	New built	Other	-

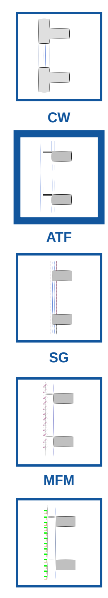
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	☐
04. Prototype demonstration	☐
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	☐
Acoustic comfort	☐
Energy management (harvesting, storing, supply)	☐
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	☐
Appearance (aesthetic quality)	☐
Structure performance	☐
Energy generation	■
Personal users' control	☐
Other (durability, accessibility, use of natural resources, etc.):	☐

TYPE OF FACADE SYSTEM	
Active façade	■
Advanced façade	☐
Biomimetic façade	☐
Kinetic façade	☐
Intelligent façade	☐
Interactive façade	☐
Movable façade	☐
Responsive façade	☐
Smart façade	☐
Transformable façade	☐
Switchable façade	☐

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	☐
Devices for managing natural ventilation in combination with mechanical ventilation systems	☐
Mobile screens for controlling solar radiation	☐
Technological solutions designed to increase and/or control comfort inside the building	■
Building automation systems for the management of plants and elements of the building skin	☐



FS_18

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): Glass and PV	■

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify): PV panels have a shading function	■

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	■
Thermal (e.g. outdoor air temperature)	■
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	☐
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify): Individuall user control	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify): Manual	■

1

2

1. Atrium space.
2. View of the building
3. PV installation on the south double facade

CONTROL OPERATION DETAILS

3

DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

South facade of the building has a double facade with vertical PV panels and some panels are also installed on the roof. The total installed PV power is 60 kW (570 m²) that provides about 17% of electricity use of the building.
Atrium space of the building has no installed cooling and overheating is avoided by opening bottom and top windows.
Motorized operable windows can to be open manually when needed and will be closed by weather station control (wind, rain and temperature control) automatically.
In total there are about 30 motorized openings/windows used for the double facade and atrium excess heat removal and some of them are also used for smoke removal.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	■
Extrinsic (requires external control)	■
Electromagnetic	□
Other (specify)	□

SYSTEM RESPONSE TIME	
Seconds	□
Minutes	■
Hours	□
Days	□
Seasons	□
Years	□
Other (specify)	□

SYSTEM DEGREE OF ADAPTIVITY:	
On/off	□
Gradual	■
Other (specify)	□

DEGREE OF SPATIAL ADAPTATION	
Nanometers	□
Micrometers	□
Millimeters	□
Centimeters	■
Meters	□
Other (specify)	□

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	□
02 Visible, no surface change (smart glazing)	■
03 Visible, surface change (lamellas, rollers, blinds)	□
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	□
05 Visible, location or orientation change	□
Other (specify)	□

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	■
No	
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	■

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	☐
Information not available	■

Cost/m2	-
Yearly cost of maintenance	-

4

4. PV installation on the south double facade

Reference
http://www.rehva.eu/publications-and-resources/hvac-journal/2012/022012/nzeb-office-buildingympaeristoetalo-in-helsinki-finland/ (Accessed October 15, 2018)

Kurnitski, J. (2012), *nZEB Office Building - Ympäristötalo in Helsinki, Finland*, Rheva Journal, n. 2, pp. 44-49

http://www.energy-cities.eu/db/Helsinki_nzeb-office-building_2012_en.pdf (Accessed October 15, 2018)

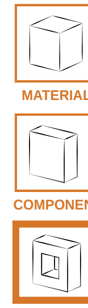
Reference to picture
http://www.rehva.eu/publications-and-resources/hvac-journal/2012/022012/nzeb-office-building-ympaeristoetaloin-helsinki-finland/ (Accessed October 15, 2018)

Author of the sheet info
Enrico Sergio Mazzucchelli
Politecnico di Milano

Rosa Romano
Florence University, Department of Architecture

Maria da Glória Gomes
Department of Civil Engineering, Architecture and Georesources

MUSEION, Bolzen (IT), 2008
Krueger, Schuberth, Vandreike, KSV


MATERIAL
COMPONENT
FACADE

Museion building measures 54 metres in length, 25 metres in height and 23 metres in width. It's characterized by transparent front and rear façades that connect the historic centre and the new city, as well as the grassy banks of the Talvera river. In this way the building is a physical and symbolic link between the two parts of the city.
The sculptural effect that characterises the building is given by the contrast between the closed metal shell of the side walls and the funnel-shaped, transparent glass façades.
The façade is a "transparent membrane" that divides and at the same time links the urban setting and the museum. It hosts screenings of videos, photos and animations that the artists select to have a dialogue with Museion's architectural structure and the urban landscape.

Latitude 49°49', Longitude 11°34'

GLAZED FACADE; MEDIA FACADE; NATURAL LIGHT; ACTIVE AIR-CONDITIONING WALL

BUILDING INFORMATION:			
Building floor area	8.370 sq.m	Climate Type	Dfa
Building use	Museum	Orientation of the facade	East- West
Building status	New built	Other informations	-

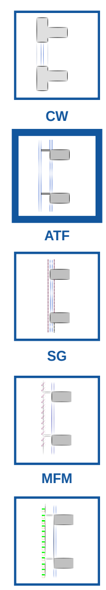
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	☐
04. Prototype demonstration	☐
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	■
Acoustic comfort	☐
Energy management (harvesting, storing, supply)	☐
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	■
Appearance (aesthetic quality)	■
Structure performance	☐
Energy generation	☐
Personal users' control	☐
Other (durability, accessibility, use of natural resources, etc.):	☐

TYPE OF FACADE SYSTEM	
Active façade	☐
Advanced façade	☐
Biomimetic façade	☐
Kinetic façade	☐
Intelligent façade	■
Interactive façade	☐
Movable façade	☐
Responsive façade	☐
Smart façade	☐
Transformable façade	☐
Switchable façade	☐

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	☐
Devices for managing natural ventilation in combination with mechanical ventilation systems	☐
Mobile screens for controlling solar radiation	☐
Technological solutions designed to increase and/or control comfort inside the building	■
Building automation systems for the management of plants and elements of the building skin	☐


CW
ATF
SG
MFM
BF

FS_19

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): Glass	■

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	■
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	■
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	■
Occupant’s presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify): Manual	☐

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

1

2

1. East Facade
2. West multimedia facade

CONTROL OPERATION DETAILS

DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

In contrast to the thick metal skin, the exterior glass façade provides the maximum transparency. It is suspended from a cable construction and fixed only at the corner. In the evening, the interaction between the interior glazing and the moveable, translucent louvres causes the museum to start emitting a light and radiance of its own.
Moreover, the multi-layered glass façade also acts as a filter. The glass walls of each exhibition floor act as "side" skylights and give these spaces a distinctive atmosphere. On the other way, during the day, the light can be directed and shaped room by room in all the exhibition areas. This effect is obtained by using the movable, translucent louvres between the two layers of glass that make up the wall and a screen in the inner side. When outside is dark, instead, the plates become a surface on which to project and the light travels the opposite way. In this way, a large number of networked projectors transform the entire glass wall into a giant screen.
The two Media Façades can operate simultaneously or alternately, depending on the proposed artistic projects, choosing the façade that faces the centre of the city or the one towards the meadows of the Talvera river.
To enable the museum to be open to the outside world via the large glass walls and at the same time have a wall with high energy properties, the space in between the two glass surfaces of the façade systems is used as an active air-conditioning zone. On its way between the roof and the plant room in the basement, the incoming or exhaust air flows through the space between the glass walls. Depending on the time of year and the position of the sun, the outside air is used to create an energy-efficient buffer.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	☐
Extrinsic (requires external control)	■
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	☐
Minutes	■
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/Off	☐
Gradual	■
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	☐
Centimeters	■
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	☐
03 Visible, surface change (lamellas, rollers, blinds)	☐
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	■
05 Visible, location or orientation change	☐
Other (specify)	☐

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	■

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	☐
Information not available	■

Cost/m2	-
Yearly cost of maintenance	-

3

4

3. Facade structural detail
4. Indoor view of the facade system

Reference
http://www.ksv-network.de/en/project/museion-museum-fur-moderne-und-zeitgenossische-kunst/ (Accessed October 15, 2018)

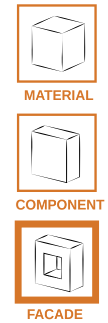
http://www.museion.it/the-building/?lang=en#1463749601228-39d6e8d9-b287 (Accessed October 15, 2018)

Reference to picture

Author of the sheet info
Rosa Romano
Florence University, Department of Architecture

Enrico Sergio Mazzucchelli
Politecnico di Milano

GSW HEADQUARTERS, Berlin (DE), 1999
SAUERBRUCH & HUTTON ARCHITEKTEN



The GSW Headquarters building, a real estate company of private property, was the first skyscraper to be built in Berlin after the fall of the Wall in 1989.
The red and pink hues of the west façade provide a distinct identity to the new office tower, helping to differentiate the elements of the new set: a pair of low-rise buildings along the street ceramic coated anthracite, the existing tower with grey and ochre, called “pillbox”. The design of high-rise slab is generated to create an exemplary working environment by the passive control of energy consumption and by the commitment to an architecture that is economical towards both natural and built environmental resources.

Latitude 52°50’, Longitude 13°39’

DOUBLE SKIN; SOLAR CHIMNEY; NATURAL LIGHTING; LOUVER SYSTEM

BUILDING INFORMATION:			
Building floor area	50.000 sq.m	Climate Type	Dfa
Building use	Office	Orientation of the facade	East- West
Building status	New built	Other	-

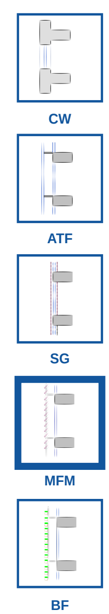
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	☐
04. Prototype demonstration	☐
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	■
Acoustic comfort	☐
Energy management (harvesting, storing, supply)	☐
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	■
Appearance (aesthetic quality)	■
Structure performance	☐
Energy generation	☐
Personal users’ control	☐
Other (durability, accessibility, use of natural resources, etc.):	☐

TYPE OF FACADE SYSTEM	
Active façade	☐
Advanced façade	☐
Biomimetic façade	☐
Kinetic façade	☐
Intelligent façade	■
Interactive façade	☐
Movable façade	☐
Responsive façade	☐
Smart façade	☐
Transformable façade	☐
Switchable façade	☐

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	☐
Devices for managing natural ventilation in combination with mechanical ventilation systems	☐
Mobile screens for controlling solar radiation	☐
Technological solutions designed to increase and/or control comfort inside the building	■
Building automation systems for the management of plants and elements of the building skin	☐



FS_20

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): Glass	■

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	■
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	■
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	■
Occupant's presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify):	☐

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐


1


2

1. Facade detail
2. Shading device

CONTROL OPERATION DETAILS

DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

The double skin automated colored panels on the west facade, creates a cavity that help to manage solar heat gain and natural lighting. An integrated system of closures, construction technique of low energy consumption inside the wall allows natural cross ventilation, facilitating the airflow from the front east to west through the interior spaces and specially designed openings in the corridors.
The louver system on the west facade has an important role in reducing the use of artificial heating and cooling. The choice of the parasols color was a key feature too. The shading of the west facade is achieved with a series of panels that pivot vertically and sliding panels suspended in the thermal chimney with 18% perforated area.
The western facade has a second glass skin that ventilates and cools the building, dispelling hot and stale air. In addition, the double façade serves as a second buffer for thermal and acoustic variations.
Convection in the double west façade of the building creates a negative pressure that can pull cool air through the building. When the two facades windows open, fresh air flows from east to west side. Thanks to control fins on the top and bottom of the solar chimney, the air flow is more or less independent from the external conditions and allows the air change to be comparable with that obtainable with a mechanical system.
One result of these interventions design is energy saving up to 40% compared to traditional ones.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	□
Extrinsic (requires external control)	■
Electromagnetic	□
Other (specify)	□

SYSTEM RESPONSE TIME	
Seconds	□
Minutes	■
Hours	□
Days	□
Seasons	□
Years	□
Other (specify)	□

SYSTEM DEGREE OF ADAPTIVITY:	
On/Off	□
Gradual	■
Other (specify)	□

DEGREE OF SPATIAL ADAPTATION	
Nanometers	□
Micrometers	□
Millimeters	□
Centimeters	■
Meters	□
Other (specify)	□

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	□
02 Visible, no surface change (smart glazing)	□
03 Visible, surface change (lamellas, rollers, blinds)	□
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	■
05 Visible, location or orientation change	□
Other (specify)	□

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?

Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY

Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	■

SYSTEM MAINTENANCE FREQUENCY

Daily	☐
Weekly	☐
Monthly	☐
Yearly	☐
Information not available	■

Cost/m2	-
Yearly cost of maintenance	-

3


4

3. Building in the skyline of the Berlin
4. East facade

Reference
http://www.sauerbruchhutton.de/images/GSW_headquarters_en.pdf (Accessed October 15, 2018)

http://www.architecturerevived.com/gsw-headquarters-berlin-germany/ (Accessed October 15, 2018)

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Reference to picture
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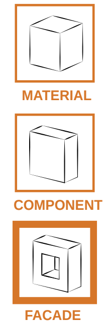
Author of the sheet info
Rosa Romano
Florence University, Department of Architecture

Enrico Sergio Mazzucchelli
Politecnico di Milano

ALTIS BELÉM HOTEL, Lisoba (PT), 2008
RISCO Architects



Altis Belém Hotel Building is a narrow structure perpendicular to the Tagus River in Lisbon, in order minimize the visual obstacle along the waterfront axis between the Belém Tower and the Monument to the Discoveries.
It is mainly composed of a rectangular platform and "pockets" that provide privacy to different uses, such as a restaurant. Above this rectangular platform, there is an accessible large green space.
The exterior vertical building envelope is an intricate surface which is actually a solar protection system of aluminum perforated shutters that guests can operate to expose their balconies. This "waves of lace" moveable shutters, as referred to by Architect João Almeida, of Gabinet Risco, helps sheltering the rooms from the sun while highlighting the views from the city to the Tagus River.

Latitude 38°69' Longitude -9°21'

HOTEL; SHADING DEVICE; ALUMINIUM; CURTAIN WALL; BALCONIES

BUILDING INFORMATION:			
Building floor area	9.086 sq.m	Climate Type	Csa
Building use	Hotel	Orientation of the facade	All orientation
Building status	New Construction	Other informations	-

DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL

01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	☐
04. Prototype demonstration	☐
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE

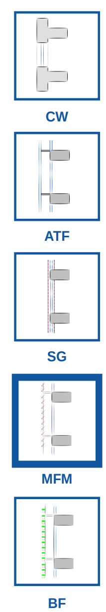
Thermal comfort	■
Visual comfort	■
Acoustic comfort	☐
Energy management (harvesting, storing, supply)	☐
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	☐
Appearance (aesthetic quality)	■
Structure performance	☐
Energy generation	☐
Personal users' control	☐
Other (durability, accessibility, use of natural resources, etc.):	☐

TYPE OF FACADE SYSTEM

Active façade	☐
Advanced façade	☐
Biomimetic façade	☐
Kinetic façade	■
Intelligent façade	☐
Interactive façade	☐
Movable façade	☐
Responsive façade	☐
Smart façade	☐
Transformable façade	☐
Switchable façade	☐

TECHNOLOGICAL FEATURES

High-performance innovative materials and systems for absorbing and storing solar energy	☐
Devices for managing natural ventilation in combination with mechanical ventilation systems	☐
Mobile screens for controlling solar radiation	■
Technological solutions designed to increase and/or control comfort inside the building	☐
Building automation systems for the management of plants and elements of the building skin	☐



FS_21

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): Aluminium	■

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	■
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	☐
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant’s presence	☐
Other (specify): Manual	■

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify):	☐

2

1. South facade
2. Detail of West Facade

CONTROL OPERATION DETAILS

DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

The facade of Altis Belem Hotel is fronted with floor-to-ceiling vertical adjustable sunshading elements. Hunter Douglas provided motor driven folding shutters that open up to reveal deep balconies.
The pattern chosen by the architect for the glass façade needed to continue in the folding shutters. Hunter Douglas met this challenge by cutting out the pattern from aluminum plates. These plates were then mounted onto a frame.
To close the shutters completely, each section starts with a shutter of a half width. All panels are driven individually for ease of operation.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	☐
Extrinsic (requires external control)	■
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	☐
Minutes	■
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/Off	☐
Gradual	■
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	☐
Centimeters	■
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	☐
03 Visible, surface change (lamellas, rollers, blinds)	☐
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	■
05 Visible, location or orientation change	☐
Other (specify)	☐

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	■

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	☐
Information not available	■

Cost/m2	-
Yearly cost of maintenance	-

Reference

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https://www.dezeen.com/2010/03/20/altis-belém-hotel-by-risco/ (Accessed October 15, 2018)

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Reference to picture

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Author of the sheet info

Rosa Romano
Florence University, Department of Architecture

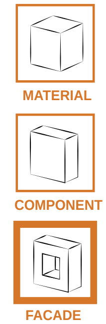
Maria da Glória Gomes
Department of Civil Engineering, Architecture and Georesources

3

4

3. West facade
4. West facade

BAHN TOWER, Berlin (DE), 1998-2000
Murphy/Jahn Architects



The Sony Center - Potsdamer Platz created a pulsating urban development in the heart of Berlin.
The Center, with a floor space of approximately 132500 m^2, houses the European Headquarters of Sony, the Filmhaus and German Mediateque, 134 apartments and an Imax 3D-cinema theatre.
The transparent office tower with a semicircular glass facade is towering towards Potsdamer Platz.

Latitude 52°50', Longitude 13°17'

GLASS FACADES; DOUBLE SKIN FACADE; TOWER; BOX-WINDOW FAÇADE

BUILDING INFORMATION:			
Building floor area	22.000 sq.m	Climate Type	Dfb
Building use	Office Building	Orientation of the facade	All orientation
Building status	New Construction	Other	-

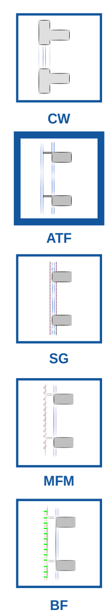
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	☐
04. Prototype demonstration	☐
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	■
Acoustic comfort	■
Energy management (harvesting, storing, supply)	☐
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	☐
Appearance (aesthetic quality)	■
Structure performance	☐
Energy generation	☐
Personal users' control	☐
Other (durability, accessibility, use of natural resources, etc.):	☐

TYPE OF FACADE SYSTEM	
Active façade	☐
Advanced façade	☐
Biomimetic façade	☐
Kinetic façade	☐
Intelligent façade	■
Interactive façade	☐
Movable façade	☐
Responsive façade	☐
Smart façade	☐
Transformable façade	☐
Switchable façade	☐

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	☐
Devices for managing natural ventilation in combination with mechanical ventilation systems	☐
Mobile screens for controlling solar radiation	☐
Technological solutions designed to increase and/or control comfort inside the building	■
Building automation systems for the management of plants and elements of the building skin	☐



FS_22

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): Glass	■

TYPE OF SHADING DEVICE	
Screens / roller shades	■
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	■
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	☐
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify):	☐

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

1

2

1. Detail of facade system
2. The Bahn Tower from Postdamer Platz

CONTROL OPERATION DETAILS

DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

The box-window façade of the DB Tower is based on the principle of the box window but consists of storey-high façade elements.
The interior windows can be opened for ventilation into the gap between the two façade layers.
The exterior façade comprises openings for supply and exhaust air. Horizontal as well as vertical separation from adjacent elements ensures optimum sound insulation not only from the outside but from neighbouring offices as well.
Unpleasant odour and flashover can be prevented rather easily if the compartmentalisation is designed correctly. Thermal shorts, meaning exhaust air from a lower element flowing into an element above, can be avoided by offsetting the supply and exhaust openings from storey to storey.
Ventilation is provided for by gaps at the top and the bottom, whereby the upper gap can be closed by vertically shifting the position of the exterior window. This could better utilise the air collection effect in the façade gap during heating periods.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	☐
Extrinsic (requires external control)	■
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	☐
Minutes	■
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/Off	☐
Gradual	■
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	☐
Centimeters	■
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	☐
03 Visible, surface change (lamellas, rollers, blinds)	☐
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	■
05 Visible, location or orientation change	☐
Other (specify)	☐

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	■

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	☐
Information not available	■

Cost/m2	-
Yearly cost of maintenance	-

3

4

3. Detail of double facade system
4. View of the tower from

Reference
http://www.architecturerevived.com/bahn-tower-potsdamer-platz-berlin/ (Accessed October 15, 2018)

http://www.jahn-us.com (Accessed October 15, 2018)

Reference to picture
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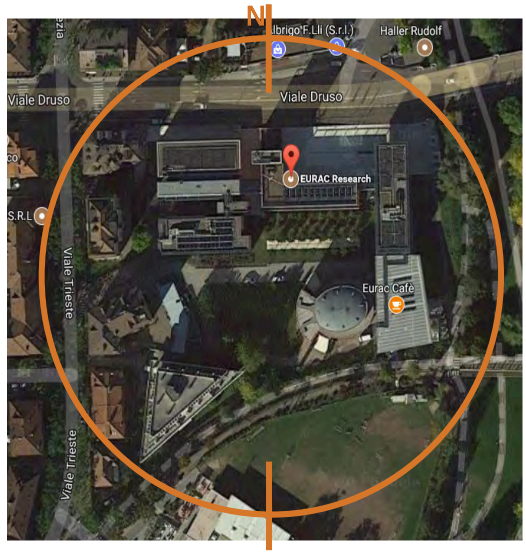
Author of the sheet info
Rosa Romano
Florence University, Department of Architecture

Enrico Sergio Mazzucchelli
Politecnico di Milano

EUROPEAN ACADEMY (EURAC), BOLZANO (IT), 2003
Architekturbüro

MATERIAL
COMPONENT
FACADE

The new EURAC buildings were realized using cast in-situ and composite constructions with point-supported slabs in exposed concrete. Most of the supports function as composite columns with steel cores. The designer used a joint-free building method and kept crack widths in the reinforced concrete to a minimum. The wingshaped steel foyer roof with its large overhang presented a structural challenge, as did the all-glass structural glazing facades. These facades are partially realised without mullions, with vertical loads being transmitted by round steel rods suspended inside the glass joints.



Latitude 46°49', Longitude 11°34'

STRUCTURAL GLASS; DOUBLE SKIN FACADE; VENETIAN BLINDS; MULTI-STOREY FAÇADES

BUILDING INFORMATION:			
Building floor area	5.500 sq.m	Climate Type	Dfa
Building use	Research Center	Orientation of the facade	North, East, West
Building status	New Construction	Other	-

DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	☐
04. Prototype demonstration	☐
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	■
Acoustic comfort	■
Energy management (harvesting, storing, supply)	☐
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	☐
Appearance (aesthetic quality)	■
Structure performance	☐
Energy generation	☐
Personal users' control	☐
Other (durability, accessibility, use of natural resources, etc.):	☐

TYPE OF FACADE SYSTEM	
Active façade	☐
Advanced façade	☐
Biomimetic façade	☐
Kinetic façade	☐
Intelligent façade	■
Interactive façade	☐
Movable façade	☐
Responsive façade	☐
Smart façade	☐
Transformable façade	☐
Switchable façade	☐

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	☐
Devices for managing natural ventilation in combination with mechanical ventilation systems	☐
Mobile screens for controlling solar radiation	☐
Technological solutions designed to increase and/or control comfort inside the building	■
Building automation systems for the management of plants and elements of the building skin	☐

CW
ATF
SG
MFM
BF

FS_23

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): Glass	■

TYPE OF SHADING DEVICE	
Screens / roller shades	■
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	■
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify):	☐

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

1

2

1. Detail of the openings at the floor level
2. East facade

CONTROL OPERATION DETAILS

DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

The Eurac facade is designed as a second-skin or multi-storey façades. Instead, the exterior façade contains a layer of air that envelops the entire building as a buffer in front of the interior façade.
The exterior façade is ventilated through openings at floor and ceiling level. The vents can be closed during winter to make use of the greenhouse effect and to increase the thermal protection.
In summer, the façade flaps can be opened to prevent overheating.
The venetian blinds, that are between the two glass layers, control the daylighting inside the building and reduce the overheating in the summer months.
The limited number of ventilation openings ensures good sound insulation from the outside but, within the façade, entails the risk of sound propagation from room to room.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	☐
Extrinsic (requires external control)	■
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	☐
Minutes	■
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/Off	☐
Gradual	■
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	☐
Centimeters	■
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	■
02 Visible, no surface change (smart glazing)	☐
03 Visible, surface change (lamellas, rollers, blinds)	☐
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	☐
05 Visible, location or orientation change	☐
Other (specify)	☐

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?

Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY

Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	■

SYSTEM MAINTENANCE FREQUENCY

Daily	☐
Weekly	☐
Monthly	☐
Yearly	☐
Information not available	■

Reference
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Reference to picture

Author of the sheet info
Rosa Romano
Florence University, Department of Architecture

Cost/m2	-
Yearly cost of maintenance	-

3

4

3. West facade
4. Detail of the venetian blinds inside the double skin

FÜNF HÖFE, FIVE COURTYARDS, Munich (DE), 2003
Herzog & de Meuron, Ivano Gianola and Hilmer & Sattler

MATERIAL

COMPONENT

FACADE

Close to Marienplatz, in the heart of Munich, a historical and traditional street block was transformed into a new city space. Retaining largely the overall structure and the street façades, the intervention designed by Herzog & de Meuron took advantage of the existing buildings to create unexpectedly singular spaces. The city block was carefully opened up for pedestrian access, creating a network of arcades and courtyards varying in size and shape, every section with its own character. The only new building constructed, on Theatinerstrasse, highlights the main entrance of the complex as it innovates on material use and at the same time respects its urban context. The glass façade is covered by a multi-layered skin of bronze perforated elements that guarantee a dynamic effect in an contrasting open/ closed, heavy/light, dark/bright face.

Latitude 48°14', Longitude 11°57'

MULTI-LAYERED SKIN; BRONZE PERFORATED ELEMENTS; SHADING DEVICES

BUILDING INFORMATION:			
Building floor area	48.000 sq.m	Climate Type	Dfa
Building use	Commercial Building	Orientation of the facade	East
Building status	New Building	Other	-

DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL

- ☐ 01. Basic principles observed and reported/ Idea
- ☐ 02. Technology concept formulated/Design Proposal
- ☐ 03. Technology validated in lab
- ☐ 04. Prototype demonstration
- ■ **05. Commercial product/Existing building**

FUNCTION / GOAL / PURPOSE

- ☐ Thermal comfort
- ■ **Visual comfort**
- ☐ Acoustic comfort
- ☐ Energy management (harvesting, storing, supply)
- ☐ Mass transfer control (e.g. condensation control)
- ☐ Indoor air quality
- ■ **Appearance (aesthetic quality)**
- ☐ Structure performance
- ☐ Energy generation
- ☐ Personal users' control
- ☐ Other (durability, accessibility, use of natural resources, etc.):

TYPE OF FACADE SYSTEM

- ☐ Active façade
- ☐ Advanced façade
- ☐ Biomimetic façade
- ■ **Kinetic façade**
- ☐ Intelligent façade
- ☐ Interactive façade
- ☐ Movable façade
- ☐ Responsive façade
- ☐ Smart façade
- ☐ Transformable façade
- ☐ Switchable façade

TECHNOLOGICAL FEATURES

- ☐ High-performance innovative materials and systems for absorbing and storing solar energy
- ☐ Devices for managing natural ventilation in combination with mechanical ventilation systems
- ■ **Mobile screens for controlling solar radiation**
- ☐ Technological solutions designed to increase and/or control comfort inside the building
- ☐ Building automation systems for the management of plants and elements of the building skin

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TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): Bronze perforated elements	■

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	■
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	■
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant’s presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify):	☐

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

1

2

1. Detail of the mechanism to move the bronze shading devices
2. View of the facade from Theatinerstrasse

CONTROL OPERATION DETAILS

DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

Haus Theatinerstrasse 8, the only new building, extends from the interior of the block to the street front, is characterized from a multi-layered façade that produces varying effects both inside and outside.
Herzog & de Meuron studio is carefully exploring in this project the possibilities of perforated sheet filters.
The whole façade of this building in Munich is covered with a layer of horizontal folding sliding metal panels. The manipulation of these leaves can be done from the inside through a sophisticated mechanism.
Each leaf is formed from a drilled metal sheet, with circular perforations about a couple of centimetres diameter. The perforated sheet is then corrugated, giving the panel more rigidity and a more complex transparency.
From the inside, the visual texture of the metal sheet seems a textile curtain, and allows the view to the outside and an adequate lighting. The solar protection is not very high, but perhaps appropriate to these latitudes.
This external skin of bronze elements guides the perception of the environs and the buildings, moving its parts in relaction of the time of day and the lighting requirment of indoor spaces. In this way ,the building oscillates between open and closed, light and heavy, bright and dark, metallic and textile.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	☐
Extrinsic (requires external control)	■
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	☐
Minutes	■
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/Off	☐
Gradual	■
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	☐
Centimeters	☐
Meters	■
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	☐
03 Visible, surface change (lamellas, rollers, blinds)	■
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	☐
05 Visible, location or orientation change	☐
Other (specify)	☐

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	■

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	☐
Information not available	■

Cost/m2	-
Yearly cost of maintenance	-

3

4

3. Detail of perforated sheet
4. View of the facade from Theatinerstrasse

Reference

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Reference to picture

© Rosa Romano

Author of the sheet info

Rosa Romano
Florence University, Department of Architecture

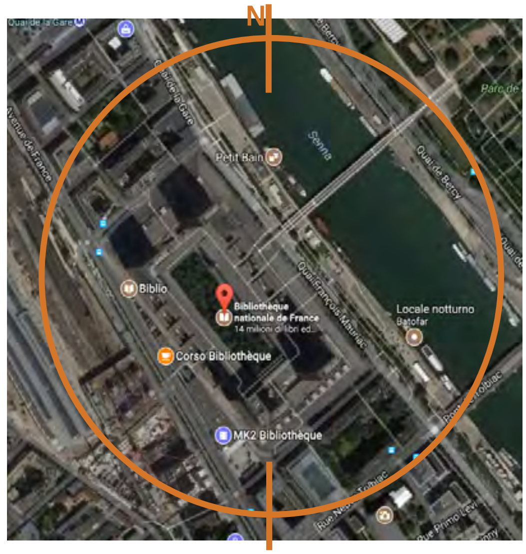
THE NATIONAL LIBRARY OF FRANCE, Paris (FR), 1996
Dominique Perrault Architecture

MATERIAL

COMPONENT

FACADE

Design by architect Dominique Perrault, the French National Library is considered the first example of minimalist modern architecture on a large scale.
The library is composed by four 25-story glass towers defining the borders of a large excavated esplanade to create a large forest-garden.
Walls and ceilings are wrapped with metal knitting originally developed for the aerospace industry and filters production.
Perrault intentionally exploited the expressive force of this material that affects the chromatic shades of the different areas of the building. The materials used for the construction of the Library (exposed concrete, stainless steel and doussié wood) are the heart of the design concept of the building.



Latitude 48°83', Longitude 2°37'

STRUCTURALLY GLAZED; WOOD SHADING DEVICE; TOWER

BUILDING INFORMATION:			
Building floor area	365.178 sq.m	Climate Type	Cfb
Building use	Cultural Building	Orientation of the facade	All orientation
Building status	New Construction	Other	-

DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	☐
04. Prototype demonstration	☐
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	■
Acoustic comfort	■
Energy management (harvesting, storing, supply)	☐
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	☐
Appearance (aesthetic quality)	■
Structure performance	☐
Energy generation	☐
Personal users' control	☐
Other (durability, accessibility, use of natural resources, etc.):	☐

TYPE OF FACADE SYSTEM	
Active façade	■
Advanced façade	☐
Biomimetic façade	☐
Kinetic façade	☐
Intelligent façade	☐
Interactive façade	☐
Movable façade	☐
Responsive façade	☐
Smart façade	☐
Transformable façade	☐
Switchable façade	☐

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	☐
Devices for managing natural ventilation in combination with mechanical ventilation systems	☐
Mobile screens for controlling solar radiation	☐
Technological solutions designed to increase and/or control comfort inside the building	■
Building automation systems for the management of plants and elements of the building skin	☐

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TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): Glass, Wood	■

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	■
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	■
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify):	☐

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

1

2

1. Detail of wood shading devices
2. View of the facade system

CONTROL OPERATION DETAILS

DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

The Bibliothèque Nationale de France was designed to resemble four open books, each facing one another. The four corner towers are made up of more than 60.000 m² of structurally glazed monolithic panels.
The buildings, characterised by a double façade, are visually complex and layered, refracting a prismatic display of natural and artificial light that is both artistic expression and purposeful signage.
The thermal performance of the buildings is essential for books preservation: it is maintained by an air flow system whereby pumped air is continuously circulated between the two glass façades, that are the two main skins of the buildings.
On the glass panels (1,8 m x 3,6 m) structural silicone joints were designed without the use of supporting setting blocks. This allows a perfectly isotropic and uniform dilatation of the glass and aluminium and decreases the shear movement on the silicone joint by a factor of two.
Movable wood panels are located in the indoor spaces of the double skin facade in order to control the daylighting in the reading rooms and decreasing the overheating phenomena.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	☐
Extrinsic (requires external control)	■
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	☐
Minutes	■
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/Off	☐
Gradual	■
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	☐
Centimeters	■
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	☐
03 Visible, surface change (lamellas, rollers, blinds)	■
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	☐
05 Visible, location or orientation change	☐
Other (specify)	☐

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?

Yes	☐
No	■
Other (specify)	☐

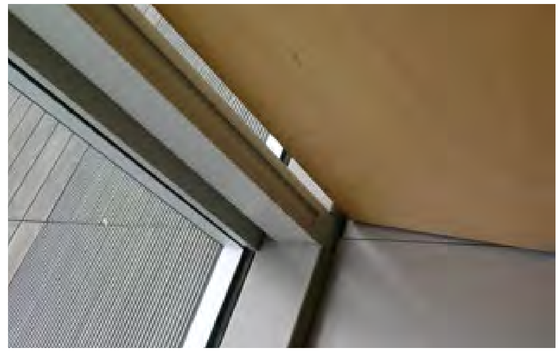
ESTIMATE THE COST OF THE CASE-STUDY

Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	■

SYSTEM MAINTENANCE FREQUENCY

Daily	☐
Weekly	☐
Monthly	☐
Yearly	☐
Information not available	■

Cost/m2	-
Yearly cost of maintenance	-



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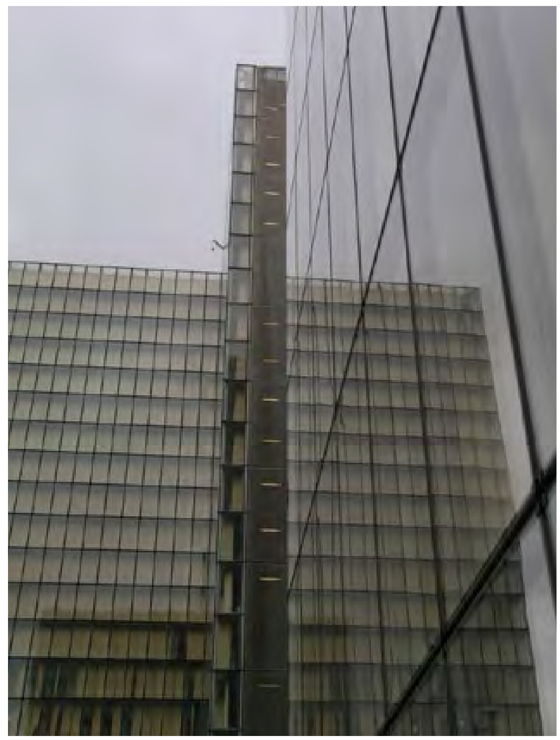

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3. Detail of the aluminium frame
4. View from central place

Reference

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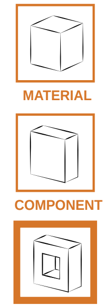
Reference to picture

Author of the sheet info

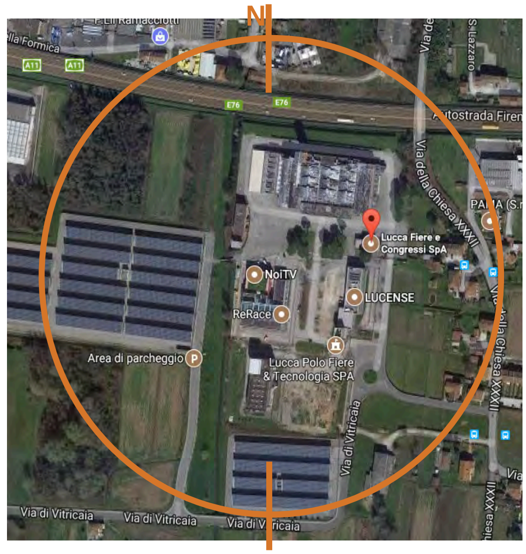
Rosa Romano
Florence University, Department of Architecture

Enrico Sergio Mazzucchelli
Politecnico di Milano

INFORMATION COMMUNICATION TECHNOLOGY CENTRE, Lucca (IT), 2003
Centro ABITA Florence, Arch. R. Romano, Arch. M. Sala



The ICT Center has been committed by Chamber of Commerce of Lucca. ABITA Center was in charge of green design to test new technologies related to energy efficiency for office buildings located in the Med Area. The project has been focused on: development of components and advanced energy saving systems, integration of dynamic facades in order to reduce the heat loss through building envelope and energy production by renewable energy sources. All windows have movable aluminum shading device, allowing sun protection. The south glass roof of greenhouse is made by semi-transparent photovoltaic panel, which are integrated also on the south façade. The selective low-E glass skylight and transparent surfaces has been designed to ensure excellent natural lighting inside the building. Air exchange is provided by natural ventilation system.



Latitude 43°82', Longitude 10°50'

SMART FACADE; PV; DOUBLE SKIN FACADE

BUILDING INFORMATION:			
Building floor area	5.000 sq.m	Climate Type	Csa
Building use	Office Building	Orientation of the facade	South, East
Building status	New Construction	Other	-

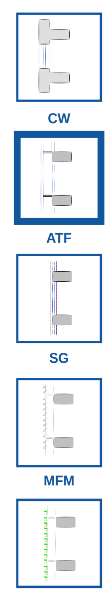
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	☐
04. Prototype demonstration	☐
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	■
Acoustic comfort	■
Energy management (harvesting, storing, supply)	☐
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	☐
Appearance (aesthetic quality)	■
Structure performance	☐
Energy generation	■
Personal users' control	☐
Other (durability, accessibility, use of natural resources, etc.):	☐

TYPE OF FACADE SYSTEM	
Active façade	☐
Advanced façade	☐
Biomimetic façade	☐
Kinetic façade	☐
Intelligent façade	☐
Interactive façade	☐
Movable façade	☐
Responsive façade	☐
Smart façade	■
Transformable façade	☐
Switchable façade	☐

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	☐
Devices for managing natural ventilation in combination with mechanical ventilation systems	☐
Mobile screens for controlling solar radiation	☐
Technological solutions designed to increase and/or control comfort inside the building	■
Building automation systems for the management of plants and elements of the building skin	☐



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TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): Glass, PV	■

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

TYPE OF SHADING DEVICE	
Screens / roller shades	■
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	■
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify):	☐


1


2


3

1. View of Building
2. Domino facade's Prototype
3. Domino facade's Prototype

CONTROL OPERATION DETAILS

DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

The smart skin developed for this building is a mobile double skin with a 50% opaque module (where a PV or solar thermal panel can be integrated) and a 50% transparent module. It consists of several parts "dry" assembled with a window frame whit an aluminum metal coating.
Furthermore, it uses a technological solution with the recessed panels that allows to hide in the aluminum box mobile elements: a glass panel and a shading device. The recessed panel can bear a weight of 180 Kg. In the opaque outdoor module can be installed three PV panels that have a electrical energy production between 0,50 and 0,30 kWP. The energy production depends on orientation and localization of the façade system.
The modules are dynamic and can change configuration. In front of the transparent module a metallic mosquito net is installed; it allowos opening the window of the transparent module at night so to improve night cooling in the building during summer months.
The fixed and mobile parts of the two module can be operated by automatic or manual controls.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	☐
Extrinsic (requires external control)	■
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	☐
Minutes	■
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/Off	☐
Gradual	■
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	☐
Centimeters	■
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	☐
03 Visible, surface change (lamellas, rollers, blinds)	■
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	☐
05 Visible, location or orientation change	☐
Other (specify)	☐

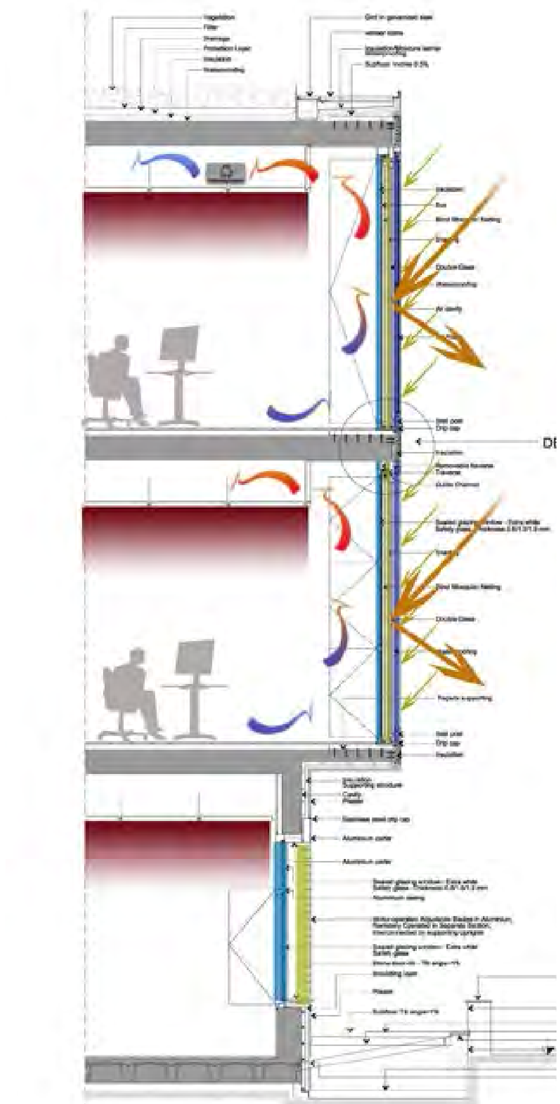
ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	■
No	□
Other (specify)	□

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	□
Medium (curtain walls, ventilated facades, etc)	■
High (double skin facades, high tech, etc)	□
Information not available	□

SYSTEM MAINTENANCE FREQUENCY	
Daily	□
Weekly	□
Monthly	□
Yearly	■
Information not available	□

Cost/m2	750,00
Yearly cost of maintenance	0,00



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4. Bioclimatic section of the office building "Ex Bertolli" in Lucca.

Reference

Sala, M., Romano, R. (2007), *Sistema di facciata Intelligente. Integrazione architettonica ai tecnologie per il risparmio energetico,* Convegno Abitare Verde 2007, NAPOLI, 2007, Luciano Editore, pp. 450-454

Sala, M., Romano, R. (2011), *(2011). The new information communication Technology Centre of Lucca,* Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland, 14-16 September 2011, Ecole Polytechnique Fédérale de Lausanne, pp. 255-260

Sala, M., Romano, R. (2011), *Innovazione per l'involucro architettonico:Smart Facade per edifici non residenziali,* TECHNE, vol. 02, pp. 158-169

Reference to picture

Author of the sheet info

Rosa Romano

Florence University, Department of Architecture

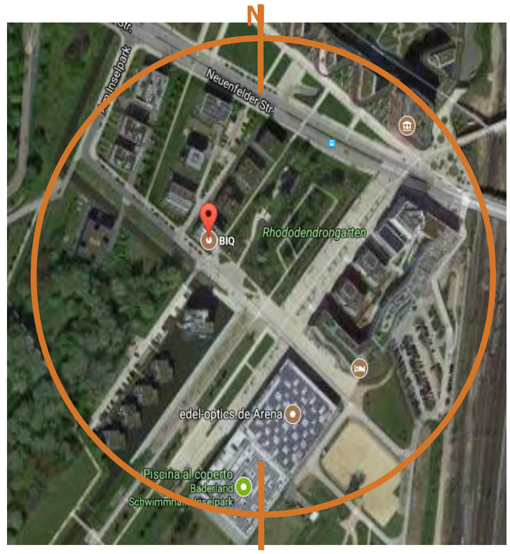
BIQ – THE ALGAEHOUSE – THE CLEVER TREEFROG, Hamburg (DE), 2013
SolarLeaf, Arup, Colt, SCC, Splitterwerk Architects

MATERIAL

COMPONENT

FACADE

The world´s first bio-reactive façade generates renewable energy from algal biomass and solar thermal heat. The integrated system, which is suitable for both new and existing buildings, was developed collaboratively by Strategic Science Consult of Germany (SSC), Colt International and Arup. This system has been tested in a pilot project at the International Building Exhibition (IBA) in Hamburg in 2013.
The biomass and heat generated by the façade are transported by a closed loop system to the building's energy management centre, where the biomass is harvested through floatation and the heat by a heat exchanger. Because the system is fully integrated with the building services, the excess heat from the photobioreactors (PBRs) can be used to help supply hot water or heat the building, or stored for later use.



Latitude 53°49', Longitude 10°00'

SMART HOUSE; ALGAE BIOREACTOR FAÇADES; BIOMASS PRODUCTION

BUILDING INFORMATION:			
Building floor area	1.600 sq.m	Climate Type	Cfb
Building use	Residential	Orientation of the facade	South-west, South-east
Building status	New Built	Other informations	-

DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	☐
04. Prototype demonstration	☐
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	☐
Visual comfort	☐
Acoustic comfort	☐
Energy management (harvesting, storing, supply)	■
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	☐
Appearance (aesthetic quality)	■
Structure performance	☐
Energy generation	■
Personal users' control	☐
Other (durability, accessibility, use of natural resources, etc.): Biomass production	■

TYPE OF FACADE SYSTEM	
Active façade	☐
Advanced façade	☐
Biomimetic façade	■
Kinetic façade	☐
Intelligent façade	☐
Interactive façade	☐
Movable façade	☐
Responsive façade	☐
Smart façade	☐
Transformable façade	☐
Switchable façade	☐

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	■
Devices for managing natural ventilation in combination with mechanical ventilation systems	☐
Mobile screens for controlling solar radiation	☐
Technological solutions designed to increase and/or control comfort inside the building	☐
Building automation systems for the management of plants and elements of the building skin	☐

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TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): Glass	■

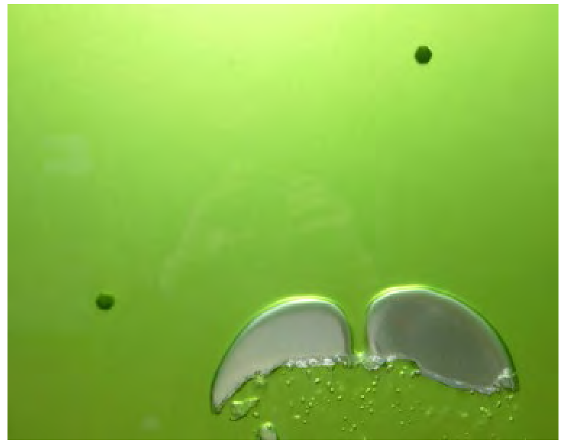
TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	■
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify): Bioreactors used as dynamic shading devices	■

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify): bio-reactive	■

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	■
Optical (e.g. daylight level, glare)	☐
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	☐
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify): Energy	■

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify): Not present	■



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1. The biomass inside of the facade components, Photo © Arup
2. Detail bioreactor facade, Photo © Paul Ott
3. South elevation with bioreactor facade, Photo © Paul Ott

CONTROL OPERATION DETAILS

3

DETAILED EXPLANATION OF THE CONTROL/OPERATION

SolarLeaf façade was installed for the first time on the BIQ house at the IBA in Hamburg in 2013. In total, 129 bioreactors measuring 2.5m x 0.7m have been installed on the south-west and south-east faces of the four-storey residential building to form a secondary façade. It provides around one third of the total heat demand of the 15 residential units in the BIQ house.

The flat photobioreactors are highly efficient for algal growth and need minimal maintenance. SolarLeaf's bioreactors have four glass layers. The two inner panes have a 24-litre capacity cavity for circulating the growing medium. Either side of these panels, insulating argon-filled cavities help to minimise heat loss. The front glass panel consists of white antireflective glass, while the glass on the back can integrate decorative glass treatments. 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. SolarLeaf integrates all servicing pipes for the inflow and outflow of the culture medium and the air into the frames of its elements. The maximum temperature that can be extracted from the bioreactors is around 40 degrees Celsius, as higher levels would affect the microalgae.

The system can be operated all year round. The efficiency of the conversion of light to biomass is currently 10% and light to heat is 38%. For comparison, photovoltaic systems have an efficiency of 12-15% and solar thermal systems 60-65%. The heat generated by the façade are transported by a closed loop system to the building's energy management centre.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	☐
Extrinsic (requires external control)	■
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	☐
Minutes	☐
Hours	■
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/off	☐
Gradual	■
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	☐
Centimeters	☐
Meters	☐
Other (specify): Not applicable	■

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	■
03 Visible, surface change (lamellas, rollers, blinds)	☐
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	☐
05 Visible, location or orientation change	☐
Other (specify)	☐

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	■
Information not available	☐

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	■
Information not available	☐

Cost/m2	-
Yearly cost of maintenance	-

4

5

4. South elevation with bioreactor facade, Photo © Paul Ott
5. North elevation with bioreactor facade, Photo © Paul Ott

Reference
http://www.iba-hamburg.de/en/themes-projects/the-building-exhibition-within-the-buildingexhibition/smart-material-houses/biq/projekt/biq.html (Accessed September 18, 2017)

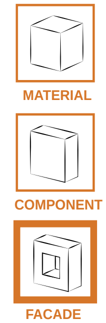
http://www.arup.com/projects/solarleaf/details (Accessed September 18, 2017)

Reference to picture
© SPLITTERWERK
© Colt/Arup/SCC

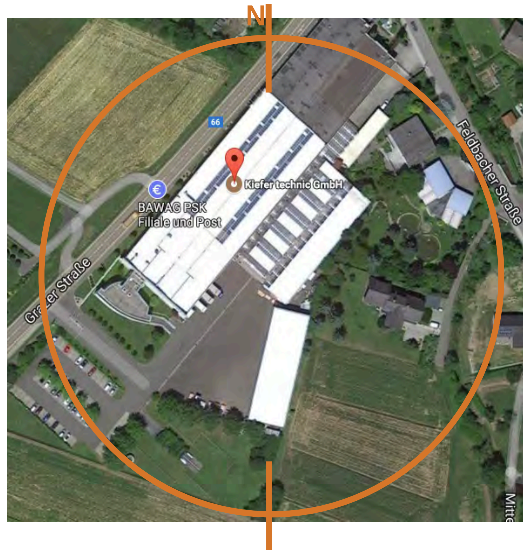
Author of the sheet info
Rosa Romano
Florence University, Department of Architecture

Enrico Sergio Mazzucchelli
Politecnico di Milano

KIEFER TECHNIC SHOWROOM, BAD GLEICHENBERG (A), 2007
Ernst Giselbrecht + Partner



The Kiefer Technic Showroom is an office building with an exhibition space for the clean room specialist company Kiefer Technik GmbH.
The showroom is added to the South-West side of the existing production halls; its façade is intended to demonstrate the creative handling and innovative precise processing of stainless steel by employing a dynamic full-façade shading system.
The 112 white metal panels of the façade are electrically moveable, individually and continuously with the help of 56 integrated motors and a smart control system. Thus, the panels create a dynamic three-dimensional folding surface. With various choreographed scenarios, the goal of either shade parts of the façade according to the weather conditions or process a media façade scenario are achieved.



Latitude 46°88', Longitude 15°89'

KINETIC FACADE; DOUBLE SKIN FACADE; SHADING DEVICE

BUILDING INFORMATION:			
Building floor area	298 sq.m	Climate Type	Dfb
Building use	Office Building	Orientation of the facade	South
Building status	New Construction	Other	-

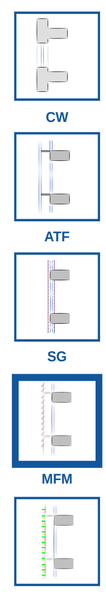
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	□
02. Technology concept formulated/Design Proposal	□
03. Technology validated in lab	□
04. Prototype demonstration	□
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	■
Acoustic comfort	□
Energy management (harvesting, storing, supply)	□
Mass transfer control (e.g. condensation control)	□
Indoor air quality	□
Appearance (aesthetic quality)	■
Structure performance	□
Energy generation	□
Personal users' control	■
Other (durability, accessibility, use of natural resources, etc.):	□

TYPE OF FACADE SYSTEM	
Active façade	□
Advanced façade	□
Biomimetic façade	□
Kinetic façade	■
Intelligent façade	□
Interactive façade	□
Movable façade	□
Responsive façade	□
Smart façade	□
Transformable façade	□
Switchable façade	□

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	□
Devices for managing natural ventilation in combination with mechanical ventilation systems	□
Mobile screens for controlling solar radiation	■
Technological solutions designed to increase and/or control comfort inside the building	□
Building automation systems for the management of plants and elements of the building skin	□



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TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): Aluminium	■

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	■
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	■
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify):	☐


1


2


3

1. View of the facade with panels closed
2. View of the facade with partially panels closed
3. View of the facade with panels open

CONTROL OPERATION DETAILS

DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

The kinetic façade of the Kiefer showroom has several functions:
- First, it should provide shade in accordance with changing weather conditions. This causes the panels to expand or to contract vertically, thereby regulating the irradiance of sunlight.
- Secondly, it serves as a media façade, in that it can play choreographed scenarios of moving elements, each of which can be individually controlled.
The construction of the façade looks like this:
- The transparent façade construction itself is an aluminium mullion-transom facade with the opaque parts of the building having an EISF-façade system.
- The air cavity with the maintenance walkways between the two façade layers functions as a climate buffer according to the box window principle.
- The supporting elements of the kinetic façade layer are stainless steel swords attached to the polygonal glass façade of the building. On these swords are vertical stainless steel guide rails mounted, who contain the rolling apparatuses and the electric geared motors, which move the 112 cassette panels.
- The panel consist of perforated, powder-coated light metal cassettes, which can be steplessly moved in all three dimensions by the 56 motors and by a BUS/SPS intelligent control system. Each panel is also individually controllable by a touch screen through the users to allow maximum freedom.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	☐
Extrinsic (requires external control)	■
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	■
Minutes	☐
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/Off	☐
Gradual	■
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	☐
Centimeters	■
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	☐
03 Visible, surface change (lamellas, rollers, blinds)	■
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	☐
05 Visible, location or orientation change	☐
Other (specify)	☐

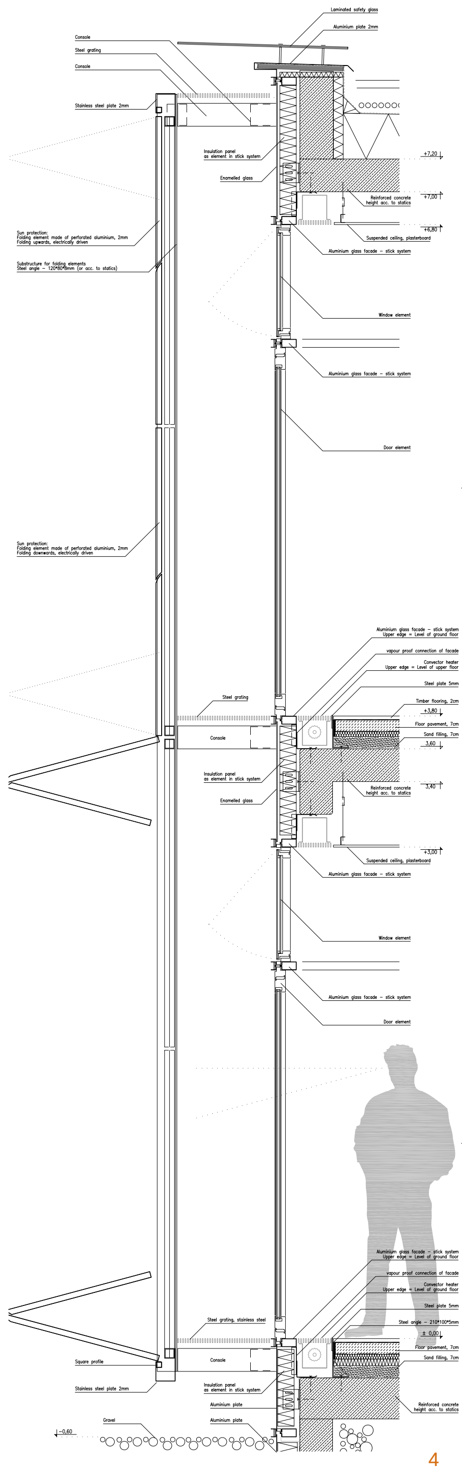
ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	■
High (double skin facades, high tech, etc)	☐
Information not available	☐

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	■
Information not available	☐

Cost/m2	-
Yearly cost of maintenance	-



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4. Technological Section

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http://giselbrecht.at/projekte/gewerbe_industriebauten/kiefer/index.html# (Accessed September 18, 2017)

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https://www.wiconafinder.com/de/references/osterreich/kiefer-technic-showroom/ (Accessed September 18, 2017)

https://www.archdaily.com/89270/kiefer-technic-showroom-ernst-giselbrecht-partner (Accessed September 18, 2017)

Reference to picture

Author of the sheet info

Susanne Gosztonyi

Lucerne University, Institute of Civil Engineering IBI

Rosa Romano

Florence University, Department of Architecture

AALEN UNIVERSITY EXTENSION, AALEN (DE), 2006
MGF Architekten

MATERIAL

COMPONENT

FACADE

These three buildings are an extension to the Faculty of Applied Sciences and Business at the University of Aalen. The buildings have a striking slatted wooden façade combined with extensive use of galvanized steel in the structure. These materials, with their natural appearance, dominate the design of the buildings. The gentle shimmer of galvanized steel combined with the smoothness of the wooden slats provides a welcoming tone to the building. The durability and reliability of the galvanized steel structure are said to be consistent with the aims of the university that it serves.

Latitude 48°82', Longitude 10°12'

WOODEN FACADE; DOUBLE SKIN FACADE; SHADING DEVICE

BUILDING INFORMATION:			
Building floor area	4500 sq.m	Climate Type	Cfb
Building use	School Building	Orientation of the facade	All orientation
Building status	New Construction	Other informations	-

DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	□
02. Technology concept formulated/Design Proposal	□
03. Technology validated in lab	□
04. Prototype demonstration	□
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	■
Acoustic comfort	□
Energy management (harvesting, storing, supply)	□
Mass transfer control (e.g. condensation control)	□
Indoor air quality	□
Appearance (aesthetic quality)	■
Structure performance	□
Energy generation	□
Personal users' control	■
Other (durability, accessibility, use of natural resources, etc.):	□

TYPE OF FACADE SYSTEM	
Active façade	□
Advanced façade	□
Biomimetic façade	□
Kinetic façade	■
Intelligent façade	□
Interactive façade	□
Movable façade	□
Responsive façade	□
Smart façade	□
Transformable façade	□
Switchable façade	□

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	□
Devices for managing natural ventilation in combination with mechanical ventilation systems	□
Mobile screens for controlling solar radiation	■
Technological solutions designed to increase and/or control comfort inside the building	□
Building automation systems for the management of plants and elements of the building skin	□

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TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): Wood	■

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	■
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	■
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify):	☐


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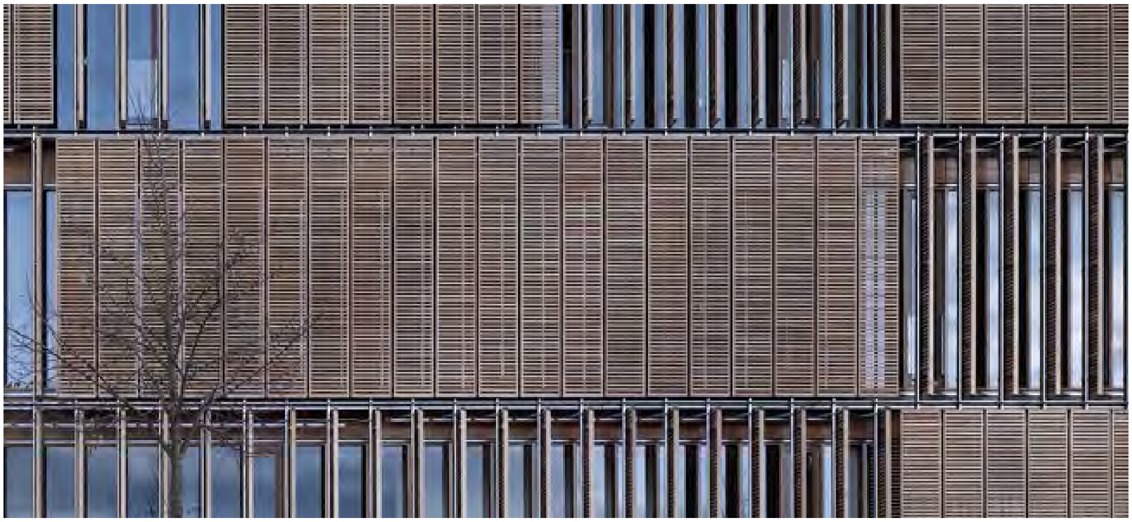
1. View of the facade
2. View of the facade
3. View of the facade with panels open

CONTROL OPERATION DETAILS



DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

The facade elements, constructed in larch, establish a link with the nearby forest. The appearance of the facade changes with the position of the sun. In a closed state, the untreated louvred elements have a bright, reddish, shimmering surface. When the pivoting shutters are mechanically opened room by room, the darker areas of the glass to the rear are revealed, and the projecting edges of the shutters establish a pronounced sense of relief. The timber-clad narrower end faces of the buildings are completely closed. Here, a vertical recess indicates the internal structure.

The facades are textured with numerous vertical lines. Made in larch, the wooden shutters create a deep, changing surface; a game between visual transparency und closeness. It takes 90 seconds to open the shutters and the transparent facade appears. Depending on the position of the louvers the building look like a box of wood or a glass object. 2420 revolving shutters cover about 4500 m^2 of the main facades. Due to the modular grid of 60 cm the design enables a flexible partitioning of rooms.

Basically the main facade is split into three levels of function. The room-high glass facade covers the long sides of the buildings. The prefabricated wooden construction includes double glazing which provides the thermal insulation. The ventilated cavity between the glass facade and the wooden sunscreen is used as service space. On the galvanised steel substructure the wooden shutters are fixated. Because of its self-supporting system only the horizontal forces are lead to the concrete construction. The rotating shutters are individually mechanical operated.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	☐
Extrinsic (requires external control)	■
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	■
Minutes	☐
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/Off	☐
Gradual	■
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	☐
Centimeters	■
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	☐
03 Visible, surface change (lamellas, rollers, blinds)	■
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	☐
05 Visible, location or orientation change	☐
Other (specify)	☐

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	■

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	■
Information not available	☐

Cost/m2	-
Yearly cost of maintenance	-

4

5

4. View of the facade
5. View of the facade with the shading devices closed

Reference

https://www.archdaily.com/948/aalen-university-extension-mgf-architekten (Accessed September 18, 2017)

https://www.intergalva.com/awards/2009/aalen-university/ (Accessed September 18, 2017)

http://www.mgf-architekten.de/index.php?option=com_content&view=article&id=4&Itemid=7&lang=en (Accessed September 18, 2017)

https://divisare.com/projects/17911-mgf-architekten-christian-richters-university-for-technical-studies-and-economics (Accessed September 18, 2017)

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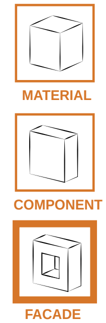
https://www.intergalva.com/awards/2009/aalen-university/ (Accessed September 18, 2017)

Author of the sheet info

Rosa Romano
Florence University, Department of Architecture

CARABANCHEL SOCIAL HOUSING, MADRID (ES), 2007
FOA (Foreign Office Architects)



Bamboo louvres mounted on folding frames cover the façades of the building in Madrid's Carabanchel public housing development in the city's southern suburbs. The basic parallelogram block contains units of different shapes and sizes which, thanks to their tube-like interior, all have a dual east-west orientation as well as access to a private garden on the eastern side. The louvres not only provide the necessary protection from the blazing summer sun, but also enhance security and, because they are completely under the control of each unit's occupants, they also highlight the latter's spatial independence.

Latitude 40°22', Longitude 03°45'

BAMBOO FACADE; DOUBLE SKIN FACADE; SHADING DEVICE

BUILDING INFORMATION:			
Building floor area	11384 sq.m	Climate Type	Csb
Building use	Social Housing	Orientation of the facade	All orientation
Building status	New Construction	Other	-

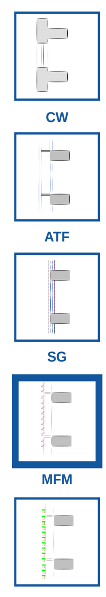
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	☐
04. Prototype demonstration	☐
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	■
Acoustic comfort	☐
Energy management (harvesting, storing, supply)	☐
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	☐
Appearance (aesthetic quality)	■
Structure performance	☐
Energy generation	☐
Personal users' control	■
Other (durability, accessibility, use of natural resources, etc.):	☐

TYPE OF FACADE SYSTEM	
Active façade	☐
Advanced façade	☐
Biomimetic façade	☐
Kinetic façade	■
Intelligent façade	☐
Interactive façade	☐
Movable façade	☐
Responsive façade	☐
Smart façade	☐
Transformable façade	☐
Switchable façade	☐

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	☐
Devices for managing natural ventilation in combination with mechanical ventilation systems	☐
Mobile screens for controlling solar radiation	■
Technological solutions designed to increase and/or control comfort inside the building	☐
Building automation systems for the management of plants and elements of the building skin	☐



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TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): Bamboo	■

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	■
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

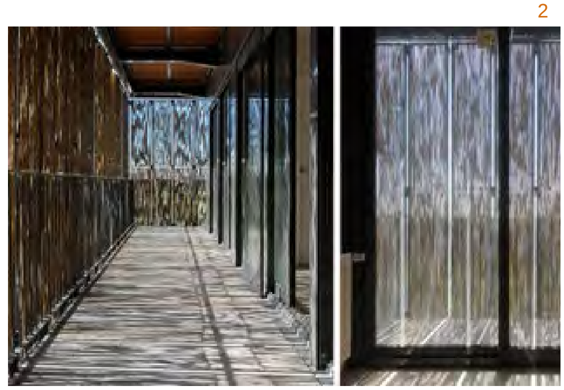
MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	■
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	☐
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify): Manual	■

1

2



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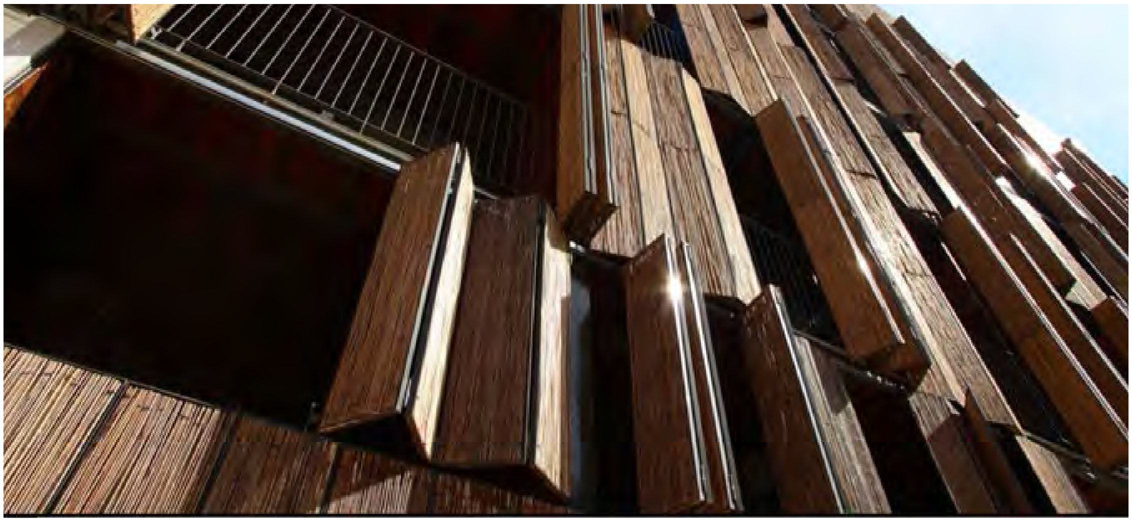
1. View of the building
2. View of the facade system
3. View of the balcony

CONTROL OPERATION DETAILS



DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

Each side of the building is provided with a 1,50 m wide terrace along the full façade that will make possible a semi-exterior type of use during certain seasons. These terraces are enclosed with bamboo louvers mounted on folding frames that provide with the necessary protection from the strong East-West sun exposure, provide security to the units.
Each opening part of the envelope is made up of a variable number, between 4 and 7, of hinged panels (40 cm width).
These panels are composed of a micro-perforated zinc grid, framed in a steel structure, connected, through the sliding device, to the edge beams of the floors.
The bamboo mats are attached to the wire mesh and arranged vertically, on a double order.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	☐
Extrinsic (requires external control)	■
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	■
Minutes	☐
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/Off	☐
Gradual	■
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	☐
Centimeters	■
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	☐
03 Visible, surface change (lamellas, rollers, blinds)	■
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	☐
05 Visible, location or orientation change	☐
Other (specify)	☐

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	■
Other (specify)	☐

Cost/m2	-
Yearly cost of maintenance	-

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	■

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	■
Information not available	☐

Reference

https://www.archdaily.com/1580/caranbachel-housing-foreign-office-architects (Accessed September 18, 2017)

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Reference to picture

https://www.archdaily.com/1580/caranbachel-housing-foreign-office-architects (Accessed September 18, 2017)

Author of the sheet info

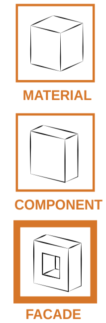
Rosa Romano
Florence University, Department of Architecture

4

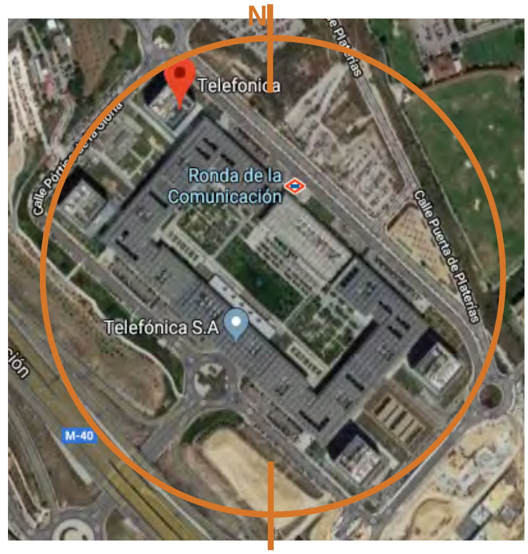
5

4. View of the facade system
5. View of the facade from the balcony with the shading devices closed

TELEFONICA HEADQUARTERS, MADRID (ES), 2008
Rafael de La-Hoz



Telefonica, as the larger Spanish company, creates the strategic challenge of regroup its fourteen thousand employees in one and unique headquarters in Madrid. With a unique special glass system-created only for this project- and a extensive protective and sun accumulator overhang top, prevents a scattered perception of the complex.
The buildings resemble a group of ice blocks, due to the inside glass sections being printed with white dots and the shiny reflective quality of the outer skin. The total surface of the façade is more than 60.000 m², but the total surface area of the glass is almost twice this size. The façade of the office blocks is a double skin, with the external glass hung out from staggered glass fins.



Latitude 40°51', Longitude 03°45'

GLASS FACADE; DOUBLE SKIN FACADE; SHADING DEVICE

BUILDING INFORMATION:			
Building floor area	5000 sq.m	Climate Type	Csb
Building use	Office	Orientation of the facade	All orientation
Building status	New Construction	Other	-

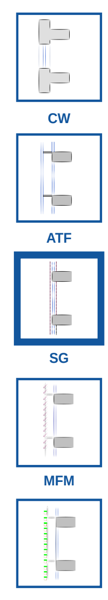
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	☐
04. Prototype demonstration	☐
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	■
Acoustic comfort	■
Energy management (harvesting, storing, supply)	☐
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	☐
Appearance (aesthetic quality)	■
Structure performance	☐
Energy generation	☐
Personal users' control	☐
Other (durability, accessibility, use of natural resources, etc.):	☐

TYPE OF FACADE SYSTEM	
Active façade	☐
Advanced façade	☐
Biomimetic façade	☐
Kinetic façade	☐
Intelligent façade	☐
Interactive façade	☐
Movable façade	☐
Responsive façade	☐
Smart façade	■
Transformable façade	☐
Switchable façade	☐

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	☐
Devices for managing natural ventilation in combination with mechanical ventilation systems	☐
Mobile screens for controlling solar radiation	☐
Technological solutions designed to increase and/or control comfort inside the building	■
Building automation systems for the management of plants and elements of the building skin	☐



FS_31

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): Glass	■

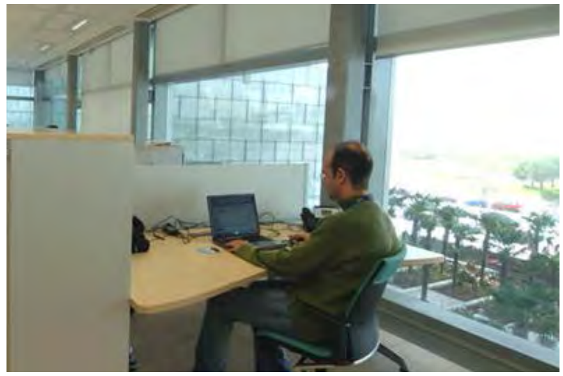
TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	■
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant’s presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	☐
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify): Manual	☐



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3

1. View of the facade from the office inside the building
2. View of the facade system

CONTROL OPERATION DETAILS

DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

Due to the large scale of the project, Rafael de La-Hoz architects have to use one single finishing material: glass.
Furthermore the designers use the whole range: from total transparency as the intrinsic quality of glass, to the artificial and absolute opacity of coloured serigraph glass.
In particular in this project a large-scale (4 x 2 m) extra clear glass was developed. This new type of glass, thanks to the advanced technology with which it was designed, makes seeing inside compatible with the opacity on the exterior surface.
The façade is the result of the interaction of two systems, mutant glass and serialised shadow, in accordance with the modular requirements and the construction logic of the façade.
Technically, the façade is built using a modular double curtain wall system. The combination of filtering qualities and distances between layers reduces the resulting solar factor (ratio of visible transmitted light and rejected heat) to 19%.
This favourable ratio is essential for the installation of the chilled beam air-conditioning system, which is cheaper to maintain.
The inside skin is a unit system, totally prefabricated in-shop before construction. The glass fins must support dead load, wind and lateral load of the external skin, and transmit all these loads to the structure. The interior glass skin is ceramic fritted in white dots, giving the appearance of a group of ice blocks.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	■
Extrinsic (requires external control)	☐
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	☐
Minutes	☐
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/Off	☐
Gradual	☐
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	☐
Centimeters	☐
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	■
02 Visible, no surface change (smart glazing)	☐
03 Visible, surface change (lamellas, rollers, blinds)	☐
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	☐
05 Visible, location or orientation change	☐
Other (specify)	☐

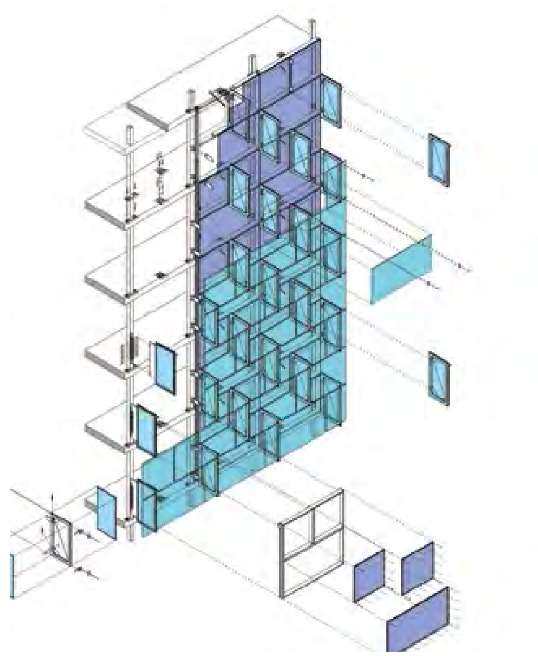
ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	■

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	■
Information not available	☐

Cost/m2	-
Yearly cost of maintenance	-



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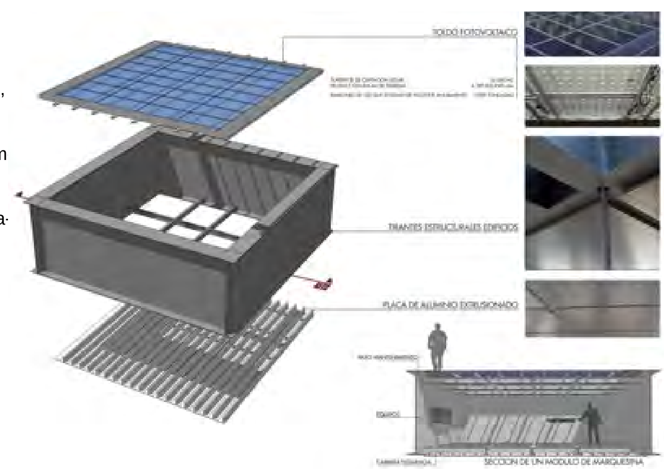

5

3. Technological detail of the construction scheme
4. PV roof

Reference

Rafael de La-Hoz Castanys,
www.rafaeldelahoz.com

https://www.archdaily.com/20158/the-new-headquarters-of-telefonica-in-madrid-rafael-de-la-hoz (Accessed September 18, 2017)

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Reference to picture

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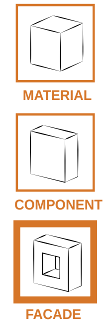
Author of the sheet info

Rosa Romano
Florence University, Department of Architecture

ENERGYbase, VIENNA (AT), 2008
pos Architekten ZT KG



The ENERGYbase office building, built in 2008 as part of “Building of Tomorrow”. It can be considered a demonstration building that intended to provide design stimuli for cutting-edge offices and industrial constructions.
Passive-house standard, a stepped façade as solar generator and sunshield, solar cooling and plants filtering the air indoors for top quality are only a few of the elements that go to make up the integrated building design. ENERGYbase uses the sun’s power four times: twice passively and twice actively.
The passive thermal gain goes to the south-facing rooms directly and to the north-facing rooms indirectly, via the ventilation system. With its special form, the stepped façade delivers these gains only in winter; in summer sunlight cannot enter the rooms directly, as each step in the façade in overshadowed by the step above.

Latitude 48°26’, Longitude 16°42’

PASSIVE HOUSE STANDARD; DOUBLE SKIN FACADE; SHADING DEVICE; STEPPED FACADE

BUILDING INFORMATION:			
Building floor area	9200 sq.m	Climate Type	Dvb
Building use	Office	Orientation of the facade	South
Building status	New Construction	Other	-

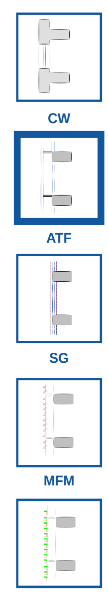
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	□
02. Technology concept formulated/Design Proposal	□
03. Technology validated in lab	□
04. Prototype demonstration	□
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	■
Acoustic comfort	■
Energy management (harvesting, storing, supply)	□
Mass transfer control (e.g. condensation control)	□
Indoor air quality	■
Appearance (aesthetic quality)	■
Structure performance	□
Energy generation	■
Personal users’ control	□
Other (durability, accessibility, use of natural resources, etc.):	□

TYPE OF FACADE SYSTEM	
Active façade	■
Advanced façade	□
Biomimetic façade	□
Kinetic façade	□
Intelligent façade	□
Interactive façade	□
Movable façade	□
Responsive façade	□
Smart façade	□
Transformable façade	□
Switchable façade	□

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	□
Devices for managing natural ventilation in combination with mechanical ventilation systems	□
Mobile screens for controlling solar radiation	□
Technological solutions designed to increase and/or control comfort inside the building	■
Building automation systems for the management of plants and elements of the building skin	□



FS_32

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): Glass and PV	■

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

TYPE OF SHADING DEVICE	
Screens / roller shades	■
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	■
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	■
Occupant's presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	☐
Pneumatical	☐
Electromagnetic	☐
Thermal	■
Chemical	■
Other (specify): Manual	☐


1


2

1. View of the South facade
2. Folded Facade

CONTROL OPERATION DETAILS

DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

Behind the stepped façade perforated anti-dazzle slats are located, with the air exhaust for the entire storey above them. This arrangement allows that warmed air behind the façade is exhausted directly, not into the room. On sunny winter days the air passes through a heat exchanger, so its heat content is transferred to fresh air and thus reaches the north-facing rooms, too. The active photovoltaic and solar heat components are arranged specially to achieve maximum energy yields. The façade carries PV elements mounted with an air space behind (12 cm gap).
The 400,00 m^2 of photovoltaic modules supply around 37.000 kWh of solar power per year. Inclined at an angle of 31,5°, the modules are much more effective – particularly in the summer months – than vertical modules integrated in the façade would be.
Thermal collectors are integrated in the top segment of the façade as shell of the building; these are used for solar cooling (evaporative cooling cycle) in summer and contribute to heating in winter. As the windows are set high, daylight can penetrate right into the rooms in winter, so even the core of the building is very well lit, thanks to ample interior glazing.
Lighting intensity is regulated as a function of daylight, measures typical of cold-storage facilities are taken to increase lighting efficiency, and customized solar shading also helps to make the lighting system more efficient: all in all the energy savings can add up to 65 %.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	■
Extrinsic (requires external control)	☐
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	☐
Minutes	■
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/Off	■
Gradual	☐
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	☐
Centimeters	■
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	■
02 Visible, no surface change (smart glazing)	☐
03 Visible, surface change (lamellas, rollers, blinds)	☐
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	☐
05 Visible, location or orientation change	☐
Other (specify)	☐

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?

Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY

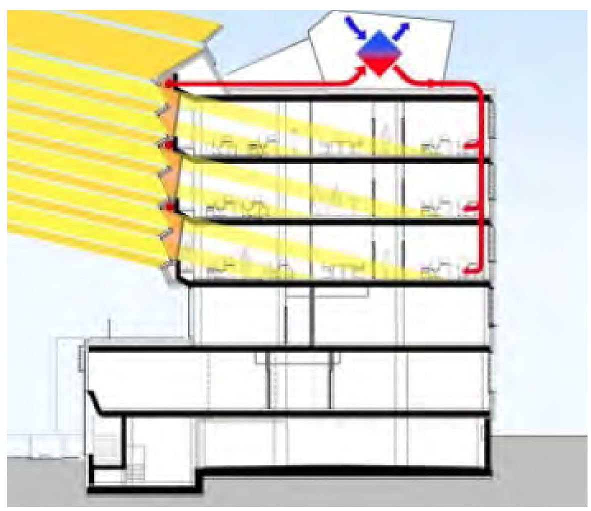
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	■

SYSTEM MAINTENANCE FREQUENCY

Daily	☐
Weekly	☐
Monthly	☐
Yearly	■
Information not available	☐

Cost/m2	-
Yearly cost of maintenance	-

3



4

3. South Facade Detail
4. Envelope operating scheme

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Reference to picture
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Author of the sheet info
Rosa Romano
Florence University, Department of Architecture

FIRE AND POLICE STATION, BERLIN (DE), 2004
Sauerbruch Hutton

MATERIAL

COMPONENT

FACADE

The building is set back considerably from the main road. The facade of the extension is made of large glass shingles that celebrate the formal and material contrast between an existing Berlin building fragment and its new extension. The reds and greens used in the facade are inspired by the heraldic colors of Germany's fire brigades and police, as well as the color contrast between the existing brick structure and the surrounding groups of mature trees. The slight tilt of the glass shingles when closed lets the building volume reflect the sky. Shingles located directly in front of windows can be opened as required for protection from sun and glare.

Latitude 52°58', Longitude 13°25'

FIRE STATION; DOUBLE SKIN FACADE; SHADING DEVICE; GLASS SHINGLES

BUILDING INFORMATION:			
Building floor area	6900 sq.m	Climate Type	Dfb
Building use	Office	Orientation of the facade	West
Building status	New Construction	Other	-

DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	☐
04. Prototype demonstration	☐
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	■
Acoustic comfort	■
Energy management (harvesting, storing, supply)	☐
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	☐
Appearance (aesthetic quality)	■
Structure performance	☐
Energy generation	☐
Personal users' control	☐
Other (durability, accessibility, use of natural resources, etc.):	☐

TYPE OF FACADE SYSTEM	
Active façade	☐
Advanced façade	☐
Biomimetic façade	☐
Kinetic façade	■
Intelligent façade	☐
Interactive façade	☐
Movable façade	☐
Responsive façade	☐
Smart façade	☐
Transformable façade	☐
Switchable façade	☐

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	☐
Devices for managing natural ventilation in combination with mechanical ventilation systems	☐
Mobile screens for controlling solar radiation	■
Technological solutions designed to increase and/or control comfort inside the building	☐
Building automation systems for the management of plants and elements of the building skin	☐

CW

ATF

SG

MFM

BF

FS_33

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): Glass	■

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	■
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	■
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify):	☐

1

2

1. Detail of glass lamellas
2. West Facade

CONTROL OPERATION DETAILS

DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

The façade comprises large-scale horizontal glass shingles of varying length, which carry two colour-families of red and green, relating to the brick of the old building and to the tones of surrounding trees.
The hues are combined to present a unified appearance when seen from a distance, with an articulated flow along the length of the building from north to south, from green to red.
Closer to the building the chromatic treatment becomes differentiated and individual hues emerge.
The glass shingles of the façade are tilted a few degrees to bring the sky down onto the building in multiple reflections, celebrating the contrast between their own smooth surface and the mattness of the existing brick and stone. They provide wind protection, holding a buffer of air against the building for extra insulation.
The colour was screen—printed onto the weather—protected back of the glass, such that most of the shingles are opaque. Only those lying in front of windows have a calibrated transparency and function as sun-shades for the occupants, opening and shutting by means of a central management system that can be overridden individually. Light entering the building is 'informed' but not 'coloured' as it passes through the glass, subtly bringing the hues of the façade into the white-painted rooms behind.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	☐
Extrinsic (requires external control)	■
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	☐
Minutes	■
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/Off	■
Gradual	☐
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	☐
Centimeters	■
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	☐
03 Visible, surface change (lamellas, rollers, blinds)	■
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	☐
05 Visible, location or orientation change	☐
Other (specify)	☐

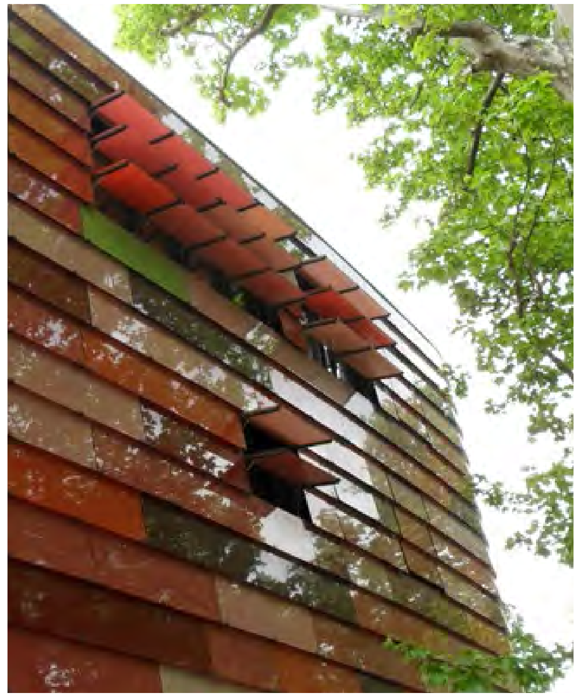
ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	■

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	■
Information not available	☐

Cost/m2	-
Yearly cost of maintenance	-



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4

3. Facade Detail
4. West facade

Reference

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Reference to picture

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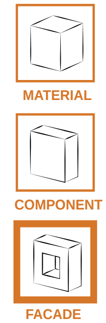
Author of the sheet info

Rosa Romano

Florence University, Department of Architecture

SOLAR XXI – BIPV/T SYSTEMS, LISBON (PT), 2006
P. Cabrita, I. Diniz, L. Aelenei



Solar XXI building was built in Lisbon in 2006 as a demonstration project. The building is considered a very high efficient building, from the national regulation point of view, with a difference in energy performance 1/10 regarding a standard Portuguese office building. From the nZEB goal perspective, the building, which design is based on a combination of passive design techniques with renewable energy technologies (PV, solar collectors).
One of the strategies adopted in the design of SOLAR XXI building in order to reduce the thermal loads and provide a good thermal comfort conditions consisted in optimization of building envelope. The main façade has a PV system with heat recovery which assists the heating in winter time. In summer a ground cooling system (earth tubes) is used to cool the building, together with night cooling strategies.

Latitude 36°46' Longitude 9°10'

ENERGY EFFICIENCY; PHOTOVOLTAIC; HEATING AND COOLING; DOUBLE SKIN FACADE

BUILDING INFORMATION:			
Building floor area	1500 sq.m	Climate Type	Csa
Building use	Office	Orientation of the facade	South
Building status	New Build	Other	-

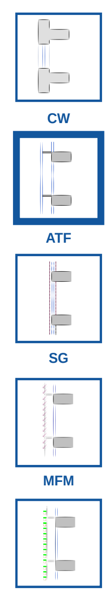
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	☐
04. Prototype demonstration	☐
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	■
Acoustic comfort	■
Energy management (harvesting, storing, supply)	■
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	■
Appearance (aesthetic quality)	■
Structure performance	☐
Energy generation	■
Personal users' control	☐
Other (durability, accessibility, use of natural resources, etc.):	☐

TYPE OF FACADE SYSTEM	
Active façade	☐
Advanced façade	☐
Biomimetic façade	☐
Kinetic façade	☐
Intelligent façade	☐
Interactive façade	☐
Movable façade	☐
Responsive façade	☐
Smart façade	■
Transformable façade	☐
Switchable façade	☐

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	☐
Devices for managing natural ventilation in combination with mechanical ventilation systems	☐
Mobile screens for controlling solar radiation	☐
Technological solutions designed to increase and/or control comfort inside the building	■
Building automation systems for the management of plants and elements of the building skin	☐



FS_34

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): PV, PCM	■

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

TYPE OF SHADING DEVICE	
Screens / roller shades	■
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	☐
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	■
Occupant's presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	☐
Pneumatical	☐
Electromagnetic	☐
Thermal	■
Chemical	☐
Other (specify):	☐

1

2

1. South facade
2. South facade

CONTROL OPERATION DETAILS

DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

The Solar XXI building south façede is covered by windows and PV modules by equivalent proportions. This large glazing area (about 46% of the south façade and 12% of building conditioned floor area) interact directly with the office rooms permanently occupied, collecting direct solar energy, providing heat and natural light to these spaces. Increasing the solar heat gains in winter time consisted one of the dominant strategies in the building design, by adopting essential features such as location, size and orientation (south) of the main glazing area. Natural ventilation is provided due to cross wind and stack effect via openings in the façade and roof level.

The façade openings together with adjustable vents on all office room doors provide the cross ventilation, allowing the air to flow from inside to outside and vice versa.

In the building central hall there is a skylight, which allows for natural ventilation by stack effect. The set of ventilation strategies (day and night) provide a high comfort level in the summer, especially when applicable during night period minimizing the thermal loads accumulated during daytime within the building and its temperature.

In addition to the use of direct solar gains through the windows, the BIPV-T system integrating south building façade is also contributing for the improvement of the indoor climate during heating season in the day time hours, when the heat released in the process of converting solar radiation into power is successfully recoverer. As a heating strategy, in winter time during the days with high solar radiation, the temperature of the air heated by BIPV-T and insufflated into the offices can rich 30°C.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	☐
Extrinsic (requires external control)	■
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	☐
Minutes	☐
Hours	■
Days	☐
Seasons	■
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/Off	■
Gradual	☐
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	☐
Centimeters	■
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	■
02 Visible, no surface change (smart glazing)	☐
03 Visible, surface change (lamellas, rollers, blinds)	☐
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	☐
05 Visible, location or orientation change	☐
Other (specify)	☐

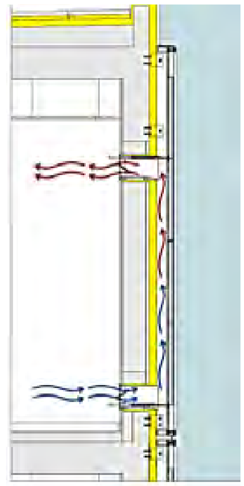
ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	■
Information not available	☐

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	■
Information not available	☐

Cost/m2	800 €/m2
Yearly cost of maintenance	-



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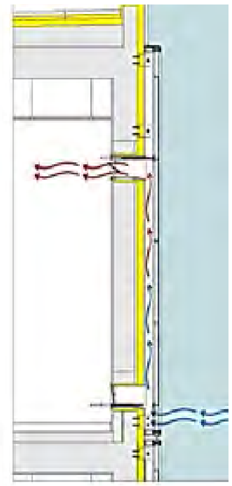

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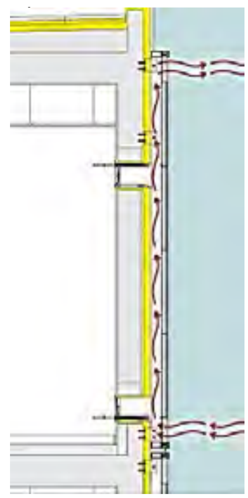

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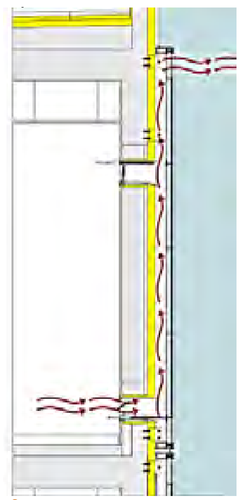

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3. The heat released in the process of converting solar radiation into power is successfully recovered (natural convection) and insufflated into adjacent room, as a heating strategy for the improvement of the indoor climate during heating season in the day time hours.
4. In the mid-season months, the system can function as a fresh air pre-heating system in which air is admitted from outside through the lower vents, which heats thereafter in the air gap of BIPV-T before insuflatted directly into the room by natural convection through the upper internal vents.
5. During cooling season is important to extract the heat from the modules to the environment. Therefore, the most used functional situation is the extraction of the heat to outside through the two external vents , in this situation the internal vents are closed.
6. Another possible situation in terms of functional use, is the evacuation of the hot air from the room through the lower internal vents, and use the “chimney effect” released to the outside

Reference

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Reference to picture:

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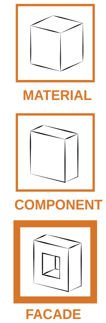
Author of the sheet info

Laura Alenei
LNEG, Lisbon

Rosa Romano
Florence University, Department of Architecture

Betil Dilekci
Upv/Ehu

RMIT DESIGN HUB, MELBOURNE (AUS), 2012
Sean Godsell, Hayley Franklin



The Hub has a large number of Environmentally Sustainable Design features and incorporates strategies of water, waste and recycling management. In particular, the outer skin of the Hub incorporates automated sun-shading that includes photovoltaic cells, evaporative cooling and fresh air intakes that improve the internal air quality and reduce running costs.
The cells have been designed so that they can be easily replaced as research into solar energy results in improved technology and part of the northern façade is actually dedicated to ongoing research into solar cells to be conducted jointly by industry and Royal Melbourne Institute of Technology (RMIT) . The entire building façade has the capacity to be upgraded as solar technology evolves and may one day generate enough electricity to run the whole building.

Latitude - 37°80', Longitude 144°96'

OFFICE BUILDING; SUNSCREEN; BIPV; EVAPORATIVE COOLING

BUILDING INFORMATION:			
Building floor area	13000 sq.m	Climate Type	Cfc
Building use	Office	Orientation of the facade	All orientation
Building status	New Build	Other	-

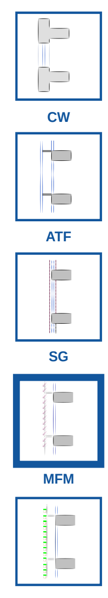
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	☐
04. Prototype demonstration	☐
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	■
Acoustic comfort	☐
Energy management (harvesting, storing, supply)	☐
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	■
Appearance (aesthetic quality)	■
Structure performance	☐
Energy generation	■
Personal users' control	☐
Other (durability, accessibility, use of natural resources, etc.):	☐

TYPE OF FACADE SYSTEM	
Active façade	☐
Advanced façade	☐
Biomimetic façade	☐
Kinetic façade	☐
Intelligent façade	☐
Interactive façade	☐
Movable façade	☐
Responsive façade	■
Smart façade	☐
Transformable façade	☐
Switchable façade	☐

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	☐
Devices for managing natural ventilation in combination with mechanical ventilation systems	☐
Mobile screens for controlling solar radiation	☐
Technological solutions designed to increase and/or control comfort inside the building	☐
Building automation systems for the management of plants and elements of the building skin	■



FS_35

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): BIPV, glass disks	■

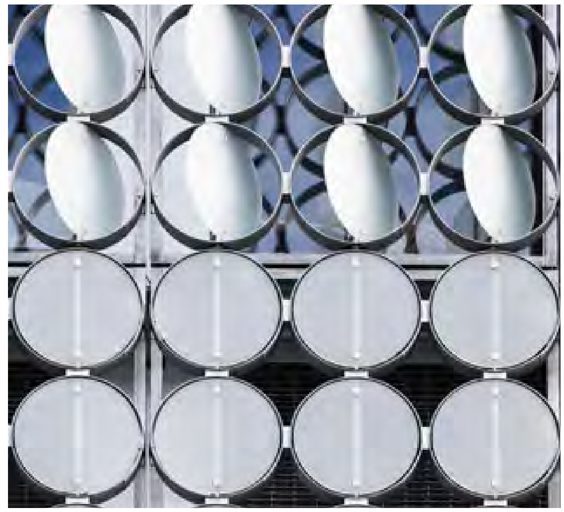
TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	■
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	■
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify):	☐

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐



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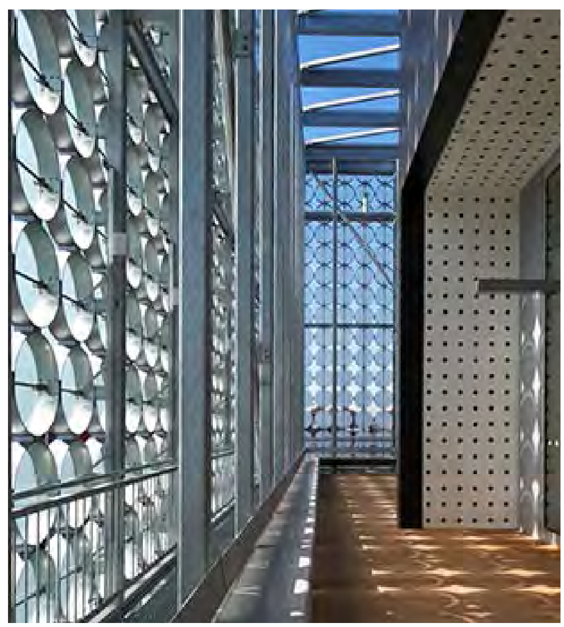

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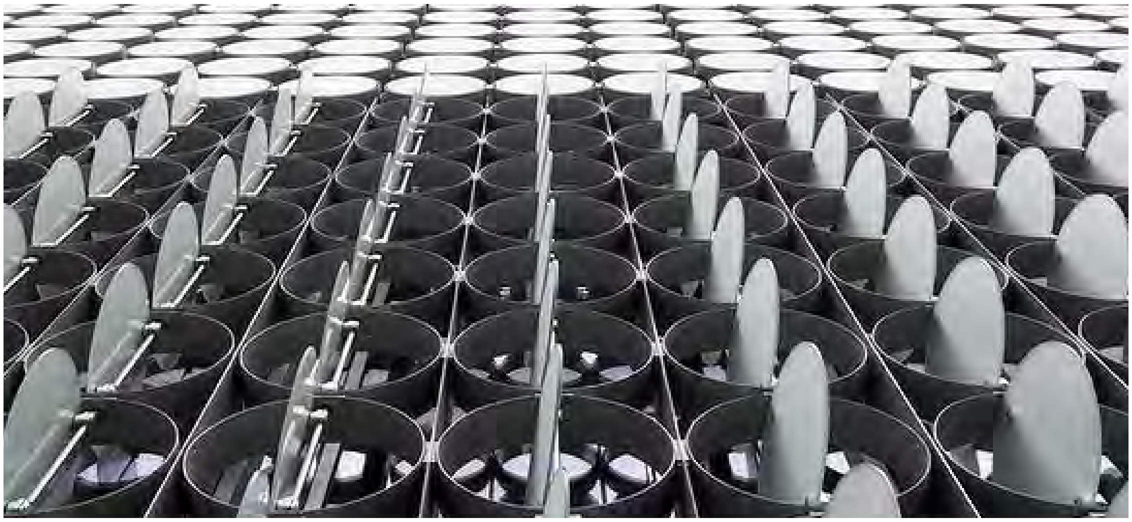
1. View of operable glass discs
2. Buffer zone between the external and inner skin

CONTROL OPERATION DETAILS



DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

The façade comprises a specifically detailed double glazed inner skin on each face of the building and an automated operable second skin shading device.
The second skin shading device surrounds the entire building, from the ground floor to the roof plant level. It is made up of nominally 600 mm diameter sandblasted glass disks, which are fixed to either a horizontal or vertical aluminium axel. Each axel is fixed to the outer face of a galvanised steel cylinder of a slightly greater diameter and nominally 130 mm in depth.
21 glass discs and steel cylinders are fixed together in panels of nominally 1,8 m by 4,2 m, which are supported on a secondary galvanised steel frame set out about 700 mm from the curtain wall face of the building. These are accessed by an external service walkway on each level. Each typical panel is made up of 12 operable glass discs and 9 discs which are fixed. At the ground and plant room levels all glass disks will be fixed. There are 86 panels on each level and therefore 774 panels for the nine levels of the building.
The glass cells track the sun via the building computer automation system to help shade and power the building. In a sections of the façade will be incorporated Building Integrated Photovoltaics (BIPV), manufactured using the same high performing interlayer and act as an applied learning and teaching showcase and a research test bed, advancing practical solar research.
Perimeter air intakes and fine mist sprinklers incorporated into the double glazed inner skin provide passive cooling to the Underfloor air distribution (UFAD) system. The water used in this ‘Coolgardie safe’ system is harvested from the roof. Fresh naturally cooled air provides a less expensive, lower energy consumption and more desirable thermal comfort alternative to a wholly conditioned work environment.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	☐
Extrinsic (requires external control)	■
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	☐
Minutes	■
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/Off	☐
Gradual	■
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	☐
Centimeters	■
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	☐
03 Visible, surface change (lamellas, rollers, blinds)	■
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	☐
05 Visible, location or orientation change	☐
Other (specify)	☐

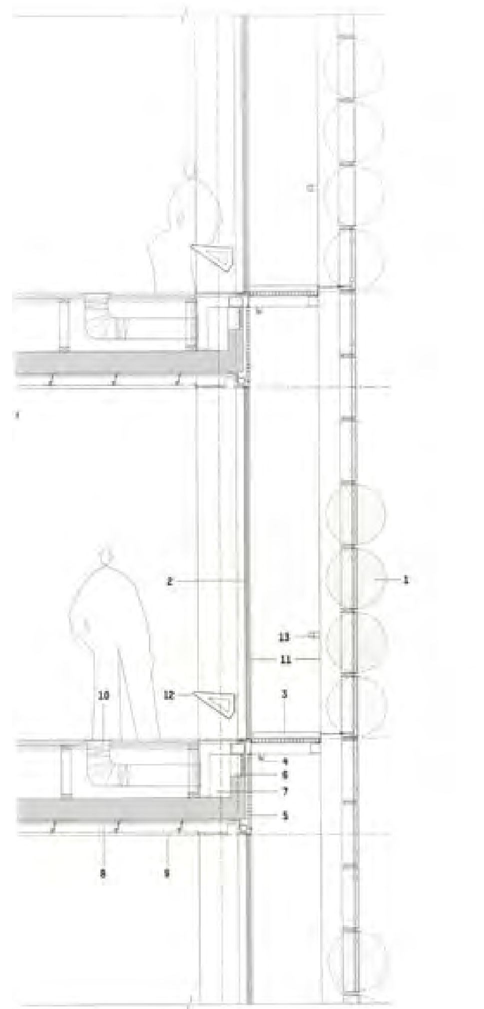
ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	■

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	■
Information not available	☐

Cost/m2	-
Yearly cost of maintenance	-



3

3. Facade system detail

Reference

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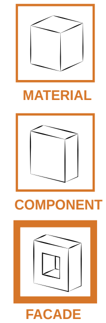
https://architectureau.com/articles/rmit-design-hub/ (Accessed September 18, 2017)

Author of the sheet info
Rosa Romano
Florence University, Department of Architecture

SELFIE FACADE, FLORENCE (IT), 2017
ABITA Interuniversity Research Centre (R. Romano, P. Gallo, M. Sala)



The innovative “SELFIE system” has been developed with smart materials and novel technologies to produce clean energy and decrease total consumptions in the new and/or existing buildings.
The components of the “SELFIE system”, in fact, has been designed as preassembled elements that is possible to compose in a modular façade for new buildings envelope or replace the existing ones. The three prototype of facades components SELFIE has been realized how modular elements with a size of 90,0 cm x 140,0 cm, that can be assembled, with different geometric configurations in the SELFIE facade system (280.0 cm x 280.0 cm). They provide the following performances: Reduction of energy consumptions and CO2 gas emission; Wellness and health; Energy production; Reduction urban pollution; Management of buildings consumptions.

Latitude 43°77’, Longitude 11°24’

ENERGY SAVING; RENEWABLE ENERGY; BIPV; PCM; NANOMATERIALS

BUILDING INFORMATION:			
Building floor area	-	Climate Type	Csa
Building use	Office	Orientation of the facade	South
Building status	New Build	Other	-

DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL

- [ ] 01. Basic principles observed and reported/ Idea
- [ ] 02. Technology concept formulated/Design Proposal
- [ ] 03. Technology validated in lab
- [ ] 04. Prototype demonstration
- [x] **05. Commercial product/Existing building**

FUNCTION / GOAL / PURPOSE

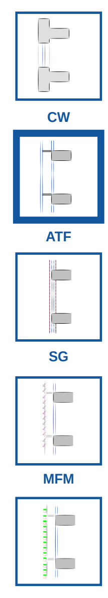
- [x] **Thermal comfort**
- [x] **Visual comfort**
- [x] **Acoustic comfort**
- [x] **Energy management (harvesting, storing, supply)**
- [x] **Mass transfer control (e.g. condensation control)**
- [x] **Indoor air quality**
- [x] **Appearance (aesthetic quality)**
- [ ] Structure performance
- [x] **Energy generation**
- [ ] Personal users’ control
- [ ] Other (durability, accessibility, use of natural resources, etc.):

TYPE OF FACADE SYSTEM

- [ ] Active façade
- [ ] Advanced façade
- [ ] Biomimetic façade
- [ ] Kinetic façade
- [ ] Intelligent façade
- [ ] Interactive façade
- [ ] Movable façade
- [ ] Responsive façade
- [x] **Smart façade**
- [ ] Transformable façade
- [ ] Switchable façade

TECHNOLOGICAL FEATURES

- [x] **High-performance innovative materials and systems for absorbing and storing solar energy**
- [ ] Devices for managing natural ventilation in combination with mechanical ventilation systems
- [ ] Mobile screens for controlling solar radiation
- [ ] Technological solutions designed to increase and/or control comfort inside the building
- [ ] Building automation systems for the management of plants and elements of the building skin



FS_36

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	■
Polymers	☐
Alloys	☐
Ceramics	■
Wood	☐
Salthydrates	☐
Other (specify): BIPV	■

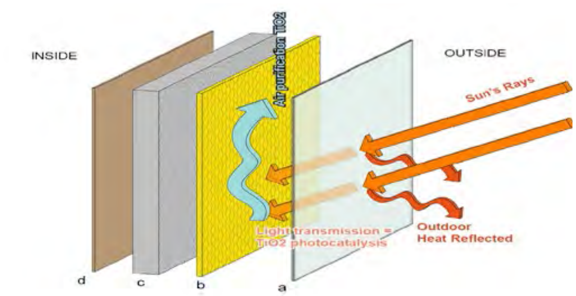
TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

TYPE OF SHADING DEVICE	
Screens / roller shades	■
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	■
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	■
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	■
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	■
Chemical	■
Other (specify):	☐



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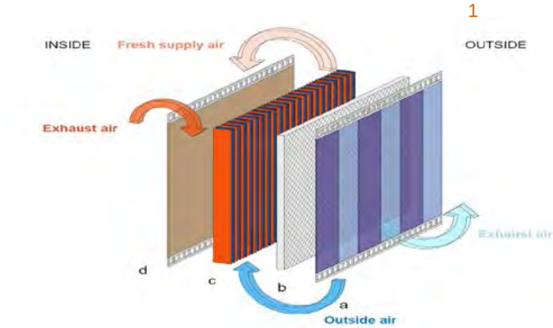

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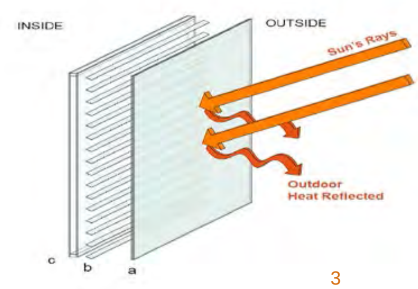
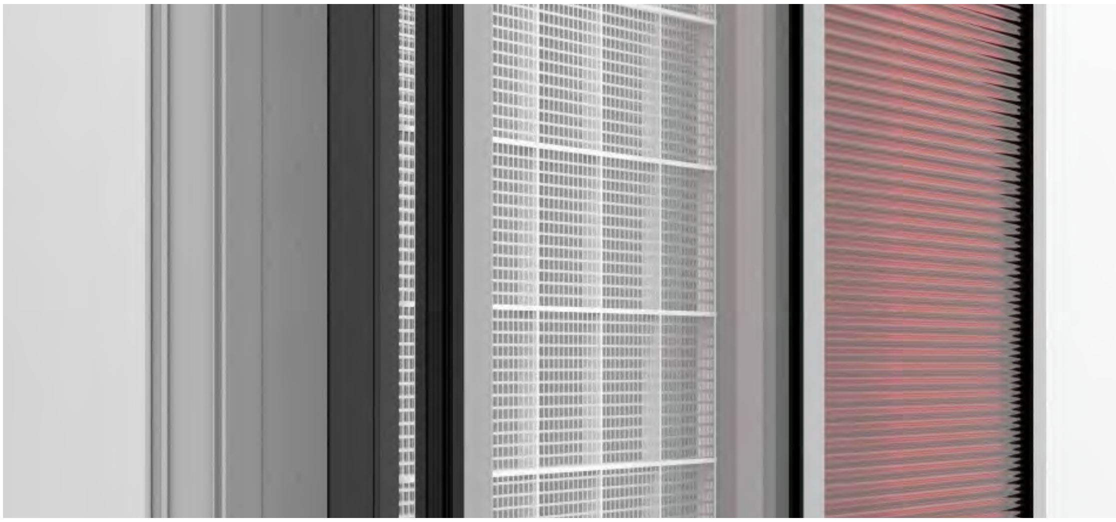


3

1. Selfie_1: a. Glass layer with PVB and IR reflecting coatings; b.Honeycomb with TiO2. C. Foam glass with PCM; d. closure panel
2. Selfie_2: a. Pv panels with air grids; b. Insulating panel; c. Heat exchanger; d. Closure panel
3. Selfie_3: a. Glass layer with PVB and IR reflecting coatings; b. Air gap and shading device; c. Double glazing

CONTROL OPERATION DETAILS



DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

The adaptive SELFIE facade has been realized as a unitized curtainwall system that allows an easy installation on building site. The SELFIE modular components can be placed in this technological frame with different geometric configurations, different types of materials and different colors in order to guarantee the customization of all façade system. The facade consists of fixed and mobile parts (opaque and transparent), that can be operated through automatic or manual controls to regulate the air temperature and air quality inside the building during all year. Furthermore, the dynamic façade has been designed to achieve good performance in the terms of:

1) Structural safety, ensuring: Mechanical Resistance to static, suspended and dynamic loads; Shock, Fire and deformation resistance; Contact safety.

2) Indoor comfort, thought the control of the following parameters: Air permeability; Water tightness; Thermal transmittance (In the transparent modules will have a U value at list of 1,2 W/m^{2}K and the opaque modules will have at list a U value of 0,20 W/m^{2}K); Hygrothermal insulation; Thermal inertia; Daylighting and solar protection; Acoustic insulation (at list 50dB)

3) Maintainability: the choose to use modular elements will be enable to repair (with isolated action of maintainability) the facade system without changing the global performance of the façade

4) Functioning, guarantying to the users to manage the façade also in absence of an automated system of control.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	■
Extrinsic (requires external control)	■
Electromagnetic	□
Other (specify)	□

SYSTEM RESPONSE TIME	
Seconds	□
Minutes	■
Hours	□
Days	□
Seasons	□
Years	□
Other (specify)	□

SYSTEM DEGREE OF ADAPTIVITY:	
On/Off	□
Gradual	■
Other (specify)	□

DEGREE OF SPATIAL ADAPTATION	
Nanometers	■
Micrometers	□
Millimeters	□
Centimeters	□
Meters	□
Other (specify)	□

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	■
02 Visible, no surface change (smart glazing)	□
03 Visible, surface change (lamellas, rollers, blinds)	□
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	□
05 Visible, location or orientation change	□
Other (specify)	□

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	■
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	☐

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	■
Information not available	☐

Cost/m2	-
Yearly cost of maintenance	-

Reference

Romano, R., Gallo, P. (2017), *Adaptive facades, developed with innovative nanomaterials, for a sustainable architecture in the Mediterranean area,* Procedia Engineering, pp.1-10

Romano, R., Gallo, P. (2016), *The SELFIE Project Smart and efficient envelope' system for nearly zero energy buildings in the Mediterranean Area,* Advances In Architecture and Civil Engineering Conference, Singapore, pp. 562-569

Reference to picture

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Author of the sheet info

Rosa Romano
Florence University, Department of Architecture

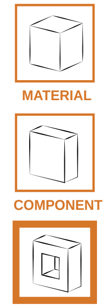
4

5

6

4. The SELFIE prototype in the test-cell of the University of Florence
5. PCM panel prototype
6. Honeycomb with TiO2 in SELFIE 1

GREENPIX – ZERO ENERGY MEDIA WALL, BEIJING (CN), 2008
Simone Giostra & Partners

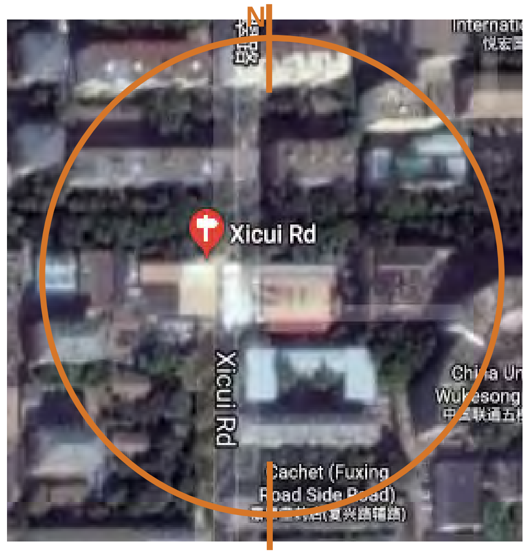


MATERIAL

COMPONENT

FACADE

Simone Giostra & Partners Architects designed the GreenPix - Zero Energy Media Wall - a ground-breaking project applying sustainable and digital media technology to the curtain wall of Xicui Entertainment Complex in Beijing, near the site of the 2008 Olympics. Featuring one of the largest color LED display worldwide and the first photovoltaic system integrated into a glass curtain
wall in China, GreenPix transformed the building envelop into a self-sufficient organic system, harvesting solar energy by day and using it to illuminate the screen after dark, mirroring a day's climatic cycle.
The Media Wall provided the city of Beijing with its first venue dedicated to digital media art, while offering the most radical example of photovoltaic technology applied to an entire building's envelope to date.



Latitude 39°90', Longitude 116°28'

OFFICE BUILDING; MEDIA WALL; PV; GLASS CURTAIN WALL

BUILDING INFORMATION:			
Building floor area	2200 sq.m	Climate Type	Dwc
Building use	Office/Commercial	Orientation of the facade	South
Building status	New Build	Other	-

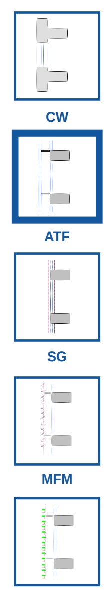
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	☐
04. Prototype demonstration	☐
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	☐
Visual comfort	■
Acoustic comfort	☐
Energy management (harvesting, storing, supply)	☐
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	☐
Appearance (aesthetic quality)	■
Structure performance	☐
Energy generation	■
Personal users' control	☐
Other (durability, accessibility, use of natural resources, etc.):	☐

TYPE OF FACADE SYSTEM	
Active façade	☐
Advanced façade	☐
Biomimetic façade	☐
Kinetic façade	☐
Intelligent façade	☐
Interactive façade	■
Movable façade	☐
Responsive façade	☐
Smart façade	☐
Transformable façade	☐
Switchable façade	☐

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	■
Devices for managing natural ventilation in combination with mechanical ventilation systems	☐
Mobile screens for controlling solar radiation	☐
Technological solutions designed to increase and/or control comfort inside the building	☐
Building automation systems for the management of plants and elements of the building skin	☐



CW

ATF

SG

MFM

BF

FS_37

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify):PV	■

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	■
Optical (e.g. daylight level, glare)	☐
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	☐
Pneumatical	☐
Electromagnetic	■
Thermal	☐
Chemical	☐
Other (specify):	☐

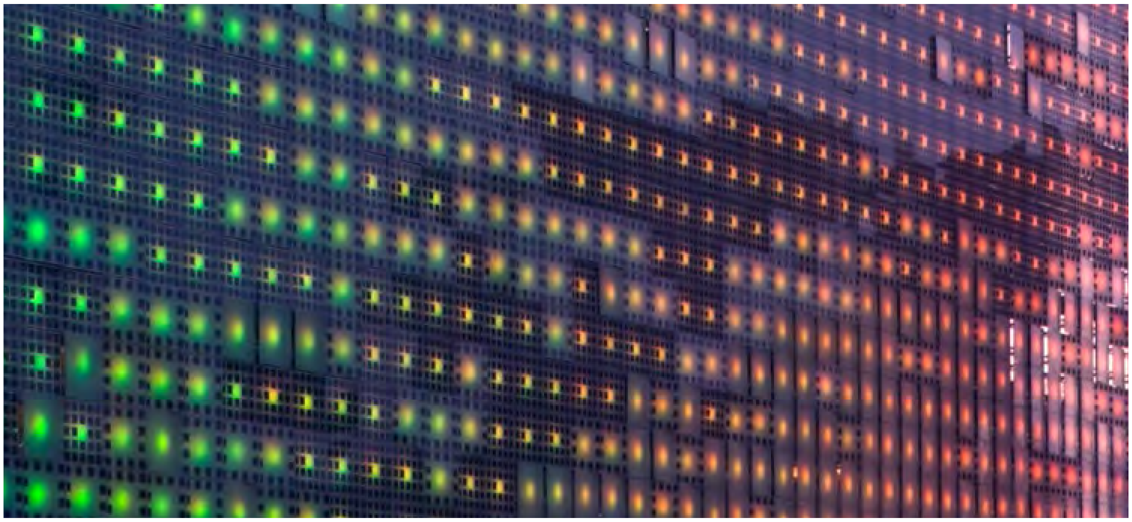
TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

1

2

1. View of PV cells
2. View if the PV facade

CONTROL OPERATION DETAILS



DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

GreenPix is a large-scale display comprising of 2292 color (RGB) LED's light points comparable to a 2200 m^2 monitor screen for dynamic content display. The very large scale and the characteristic low resolution of the screen enhances the abstract visual qualities of the medium, providing an art-specific communication form in contrast to commercial applications of high resolution screens in conventional media façades.
With the support of leading German manufacturers Schueco and SunWays, Giostra and Arup developed a new technology for laminating photovoltaic cells in a glass curtain wall and oversaw the production of the first glass solar panels by Chinese manufacturer Sun-Tech. The polycrystalline photovoltaic cells are laminated within the glass of the curtain wall and placed with changing density on the entire building's skin. The density pattern increases building's performance, allowing natural light when required by interior program, while reducing heat gain and transforming excessive solar radiation into energy for the media wall.
With customised software, the skin interacts with the building interiors and outside public space, transforming the façade into a responsive environment for entertainment and public engagement.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	■
Extrinsic (requires external control)	☐
Electromagnetic	☐
Other (specify)	☐

SYSTEM RESPONSE TIME	
Seconds	☐
Minutes	■
Hours	☐
Days	☐
Seasons	☐
Years	☐
Other (specify)	☐

SYSTEM DEGREE OF ADAPTIVITY:	
On/Off	■
Gradual	☐
Other (specify)	☐

DEGREE OF SPATIAL ADAPTATION	
Nanometers	☐
Micrometers	☐
Millimeters	☐
Centimeters	☐
Meters	☐
Other (specify)	☐

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	☐
02 Visible, no surface change (smart glazing)	■
03 Visible, surface change (lamellas, rollers, blinds)	☐
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	☐
05 Visible, location or orientation change	☐
Other (specify)	☐

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	■

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	■
Information not available	☐

Cost/m2	-
Yearly cost of maintenance	-

3

4

3. View of the Media Building
4. Facade system detail

Reference

Text description provided by the architects Simone Giostra & Partners, http://sgp-a.com

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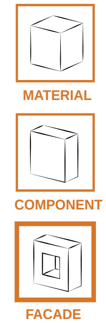
Reference to picture

Author of the sheet info

Rosa Romano
Florence University, Department of Architecture

Enrico Sergio Mazzucchelli
Politecnco di Milano

SWISSTECH CONVENTION CENTER WESTERN FACADE, Lausanne (CH), 2014
Michael Grätzel



On the western façade of Swisstech Cener, a transparent and colored glazing performs the double function of solar protection of the façade and electricity producer. It is the first large-scale implementation of the dyed cells invented by Michael Grätzel, professor at École polytechnique fédérale de Lausanne (EPFL) and manufactured by Solaronix, an EPFL spin off. The Dye-sensitized solar cells are able reproduce the principles of photosynthesis in plants.
In the Swisstech application the 1400 solar modules, each one 35,00 by 50,00 cm in size, combine for a total surface area of 300 m^2. The translucent panels are integrated as vertical shading devices, and create an interesting pattern through five different colors, giving the ensemble a warm, dynamic aspect.

Latitude 46°30', Longitude 6°37'

DYE-SENSITIZED SOLAR CELLS; VERTICAL SHADING DEVICES; CONVENTION CENTER

BUILDING INFORMATION:			
Building floor area	41.822,0 sqm	Climate Type	Dfb
Building use	Convention Center	Orientation of the facade	West
Building status	New Build	Other	-

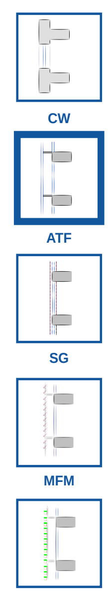
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	□
02. Technology concept formulated/Design Proposal	□
03. Technology validated in lab	□
04. Prototype demonstration	□
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	□
Visual comfort	■
Acoustic comfort	□
Energy management (harvesting, storing, supply)	□
Mass transfer control (e.g. condensation control)	□
Indoor air quality	□
Appearance (aesthetic quality)	■
Structure performance	□
Energy generation	■
Personal users' control	□
Other (durability, accessibility, use of natural resources, etc.):	□

TYPE OF FACADE SYSTEM	
Active façade	■
Advanced façade	□
Biomimetic façade	□
Kinetic façade	□
Intelligent façade	□
Interactive façade	□
Movable façade	□
Responsive façade	□
Smart façade	□
Transformable façade	□
Switchable façade	□

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	■
Devices for managing natural ventilation in combination with mechanical ventilation systems	□
Mobile screens for controlling solar radiation	□
Technological solutions designed to increase and/or control comfort inside the building	□
Building automation systems for the management of plants and elements of the building skin	□



FS_38

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): Photovoltaic (Dye-sensitized solar cells)	■

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	■
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

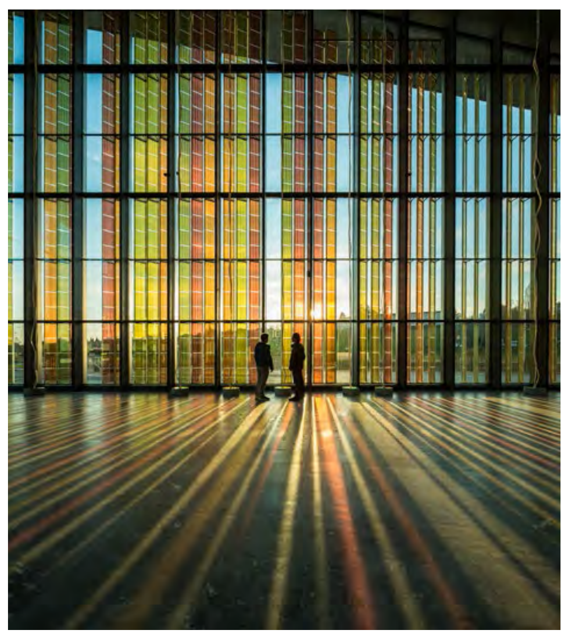
MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	■
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	■
Optical (e.g. daylight level, glare)	☐
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant’s presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	☐
Pneumatical	☐
Electromagnetic	■
Thermal	☐
Chemical	☐
Other (specify):	☐

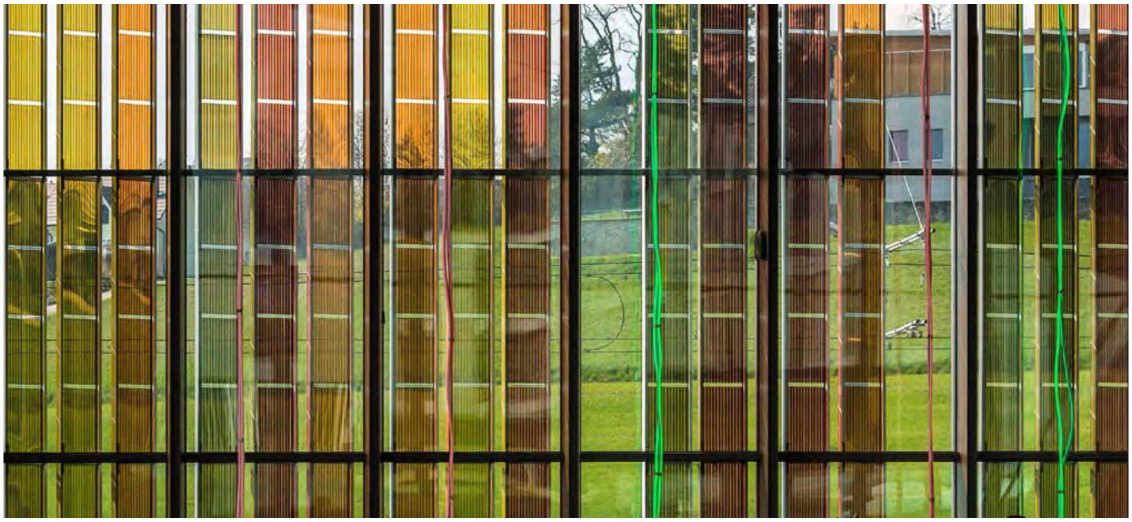
TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐


1


2

1. View of westrn facade from outside
2. View of westrn facade from Main foyer

CONTROL OPERATION DETAILS



DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

The 300,0 m^2 installation encompasses a length of 36 meters and a maximum height of 15 meters. No less than 355 panels were installed for 200,0 m^2 of active photovoltaic area. In order to fit with the inclination of the roof, panels from 1,0 m to 2,5 m were produced by grouping together two to five 50 cm modules. The panels are arranged in 65 colored columns that perfectly complement the architecture of the edifice, fulfilling both the aesthetic ambition and energy awareness of the designers. The transparency of red, green, and orange panels were tuned to meet the overall light transmission target of the architects. The solar façade completes both functions: passively preventing incoming sunlight from overheating the majestic entrance hall while actively producing renewable electricity from sunlight. Mixed and matched, the arrangement of colors ingeniously designed by artist Catherine Bolle gives a unique dynamic to the façade while providing a smooth color tone to the light transmitted into the hall.
Furthermore, the photovoltaic grid can accommodate the demanding possibility of mixing panel sizes, tints, and exposure angles. The electricity produced by the panels is harvested with a safe, low-voltage electrical backbone running through the installation. This system allows for maintenance or upgrades of any part of the installation without interruption.
Each panel features a dedicated micro-converter that continually adapts to the changing light conditions, maximizing the power output of the whole installation.
This innovative type of solar panels have the unmistakable advantage of maintaining equal or better efficiency when light intensity decreases. As a result, they work perfectly well with the diffuse hazy and cloudy days often seen at our latitude.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	■
Extrinsic (requires external control)	□
Electromagnetic	□
Other (specify)	□

SYSTEM RESPONSE TIME	
Seconds	■
Minutes	□
Hours	□
Days	□
Seasons	□
Years	□
Other (specify)	□

SYSTEM DEGREE OF ADAPTIVITY:	
On/Off	■
Gradual	□
Other (specify)	□

DEGREE OF SPATIAL ADAPTATION	
Nanometers	■
Micrometers	□
Millimeters	□
Centimeters	□
Meters	□
Other (specify)	□

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	■
02 Visible, no surface change (smart glazing)	□
03 Visible, surface change (lamellas, rollers, blinds)	□
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	□
05 Visible, location or orientation change	□
Other (specify)	□

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	■

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	■
Information not available	☐

Cost/m2	-
Yearly cost of maintenance	-

Reference

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Reference to picture

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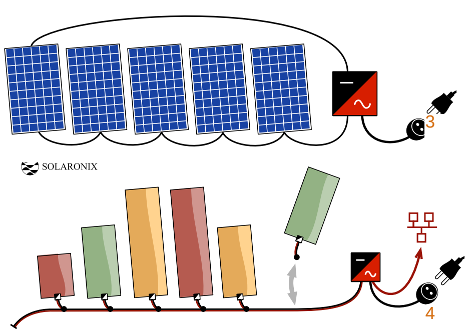
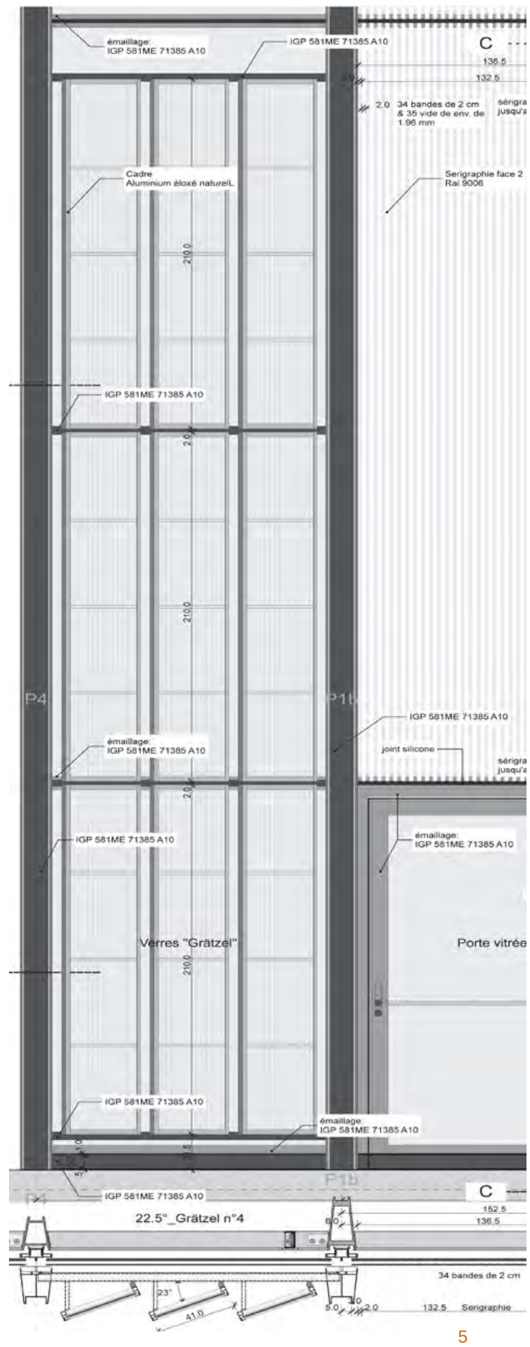
Author of the sheet info

Rosa Romano
Florence University, Department of Architecture

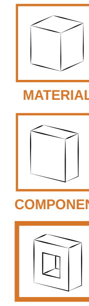
Enrico Sergio Mazzucchelli
Politecnico di Milano



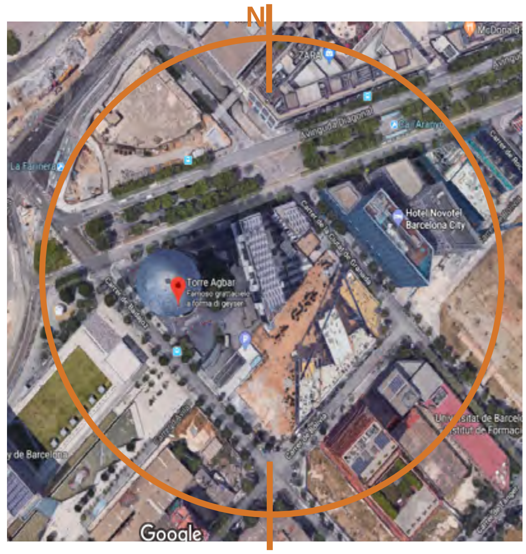


3. Conventional photovoltaic chain installation
4. Solaronix' smart photovoltaic installation
5. Facade detail

AGBAR TOWER BARCELONA, BARCELONA (ES), 2004
Jean Nouvel and Fermín Vázquez



The Agbar Tower in Barcelona was designed by the French architect Jean Nouvel, in association with the Spanish firm Fermín Arquitectos, for the Agbar Group, a holding company. The unusual form of the tower is inspired by the shape of a geyser that is rising into the air and by the towers of the Sagrada Familia. The height of the tower is 144,0 m.
The tower itself is based on two concentric concrete oval cylinders of which the outer cylinder encases the inner cylinder.
The structure is built with reinforced concrete and the cladding of the façade is done with aluminium and mobile glass louvres.
A special aesthetical effect is created at night by the 4500 LED devices, that can create millions of colours.



Latitude 41°24', Longitude 2°11'

DOUBLE-SKIN FAÇADE; GLASS LOUVRES; TOWER

BUILDING INFORMATION:			
Building floor area	30.000,0 sqm	Climate Type	Cfc
Building use	Office and conference centre	Orientation of the facade	All orientation
Building status	New Build	Other	-

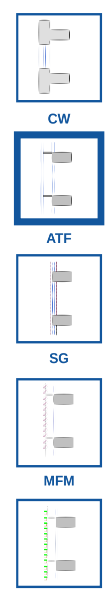
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	□
02. Technology concept formulated/Design Proposal	□
03. Technology validated in lab	□
04. Prototype demonstration	□
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	■
Acoustic comfort	□
Energy management (harvesting, storing, supply)	□
Mass transfer control (e.g. condensation control)	□
Indoor air quality	□
Appearance (aesthetic quality)	■
Structure performance	□
Energy generation	■
Personal users' control	□
Other (durability, accessibility, use of natural resources, etc.):	□

TYPE OF FACADE SYSTEM	
Active façade	■
Advanced façade	□
Biomimetic façade	□
Kinetic façade	□
Intelligent façade	□
Interactive façade	□
Movable façade	□
Responsive façade	□
Smart façade	□
Transformable façade	□
Switchable façade	□

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	□
Devices for managing natural ventilation in combination with mechanical ventilation systems	□
Mobile screens for controlling solar radiation	■
Technological solutions designed to increase and/or control comfort inside the building	□
Building automation systems for the management of plants and elements of the building skin	■



FS_39

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify):Glass	■

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

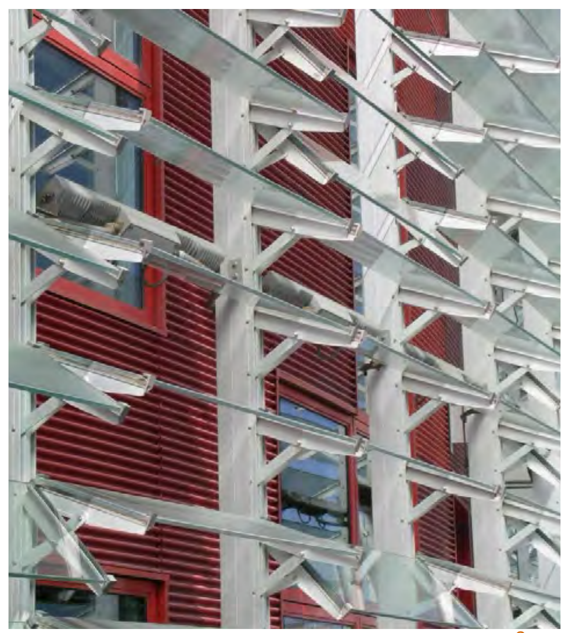
TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	■
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	■
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	■
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant’s presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify):	☐


1


2

1. Detail of pivoting blinds from indor space
2. Detail of pivoting blinds from outside

CONTROL OPERATION DETAILS

DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

All sides of the Agbar Tower have a double-skin façade. It is made up of 4.400 windows and 56.619 transparent glass plates and translucent ones.
The cladding consists of aluminium panels in twentyfive colours behind glass louvres. The louvres are titled at fourteen different angles calculated to deflect direct sun light.
In addition, temperature sensors regulate the opening and closes of the glass blinds of the facade, optimizing the consumption of necessary energy to the air conditioning.
The louvers are moving according to a horizontal pivoting motion with a fixed pivoting axis.The inner layer of the double-skin façade is composed out of concrete (30,0 - 50,0 cm thick) and is thermally insulated on the inside. The space between the facade layers forms a thermal buffer and allows a natural circulation of air and ventilation.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	■
Extrinsic (requires external control)	□
Electromagnetic	□
Other (specify)	□

SYSTEM RESPONSE TIME	
Seconds	□
Minutes	■
Hours	□
Days	□
Seasons	□
Years	□
Other (specify)	□

SYSTEM DEGREE OF ADAPTIVITY:	
On/Off	□
Gradual	■
Other (specify)	□

DEGREE OF SPATIAL ADAPTATION	
Nanometers	□
Micrometers	□
Millimeters	□
Centimeters	■
Meters	□
Other (specify)	□

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	□
02 Visible, no surface change (smart glazing)	□
03 Visible, surface change (lamellas, rollers, blinds)	■
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	□
05 Visible, location or orientation change	□
Other (specify)	□

ECONOMICAL ASPECTS

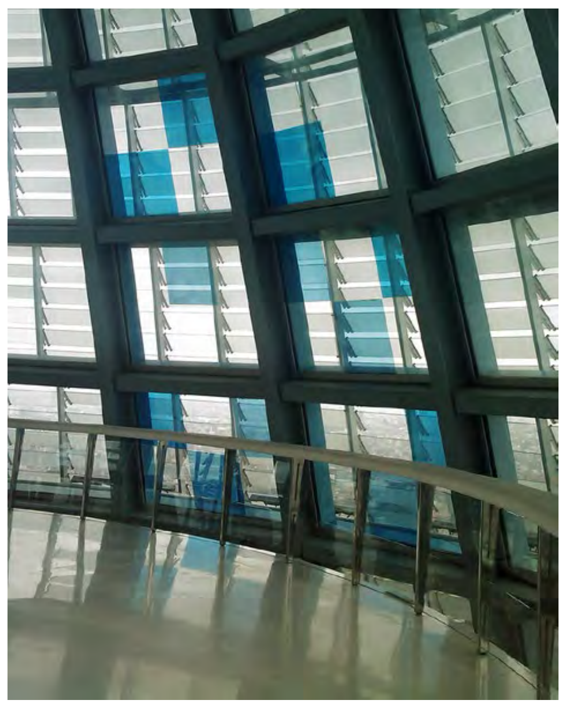
IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	■

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	■
Information not available	☐

Cost/m2	-
Yearly cost of maintenance	-

3



4

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Marysse, C. (2016), *Structural Adaptive Façades*, (Master's dissertation) Department of Structural Engineering, Faculty of Engineering and Architecture, Gent University

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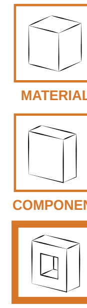
Author of the sheet info

Rosa Romano
Florence University, Department of Architecture

Enrico Sergio Mazzucchelli
Politecnico di Milano

3. Detail of the double-skin façade
4. Detail of the double-skin façade

AL BAHAR TOWERS, ABU DHABI (AE), 2012
Aedas Architects, Ltd.

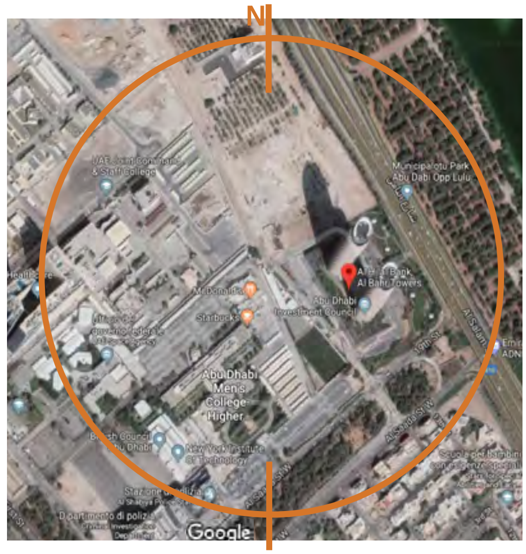


MATERIAL

COMPONENT

FACADE

The Al Bahar Towers took inspiration from a traditional Islamic motif to design an innovative and visually interesting external automated shading system for the building.
The dynamic façade has been conceived as a contemporary interpretation of the traditional Islamic “mashrabiya”; a popular form of wooden lattice screen found in vernacular Islamic architecture and used as a device for achieving privacy while reducing glare and solar gain.
The “mashrabiya” at Al Bahar Towers comprises a series of transparent umbrella-like components that open and close in response to the sun’s path. Each of the two towers comprises over 1.000 individual shading devices that are controlled via the Building Management System, creating an intelligent façade.



Latitude 24°27’ Longitude 54°39’

MASHRABIYA; DOUBLE SKIN FACADE; SHADING DEVICE; PTFE

BUILDING INFORMATION:			
Building floor area	5600 sq.m	Climate Type	Bhv
Building use	Office	Orientation of the facade	South, East; West
Building status	New Construction	Other	-

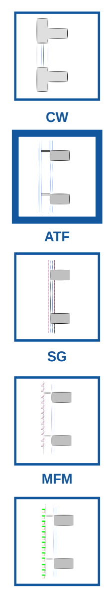
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL	
01. Basic principles observed and reported/ Idea	☐
02. Technology concept formulated/Design Proposal	☐
03. Technology validated in lab	☐
04. Prototype demonstration	☐
05. Commercial product/Existing building	■

FUNCTION / GOAL / PURPOSE	
Thermal comfort	■
Visual comfort	■
Acoustic comfort	■
Energy management (harvesting, storing, supply)	☐
Mass transfer control (e.g. condensation control)	☐
Indoor air quality	☐
Appearance (aesthetic quality)	■
Structure performance	☐
Energy generation	☐
Personal users’ control	☐
Other (durability, accessibility, use of natural resources, etc.):	☐

TYPE OF FACADE SYSTEM	
Active façade	☐
Advanced façade	☐
Biomimetic façade	☐
Kinetic façade	☐
Intelligent façade	☐
Interactive façade	☐
Movable façade	☐
Responsive façade	■
Smart façade	☐
Transformable façade	☐
Switchable façade	☐

TECHNOLOGICAL FEATURES	
High-performance innovative materials and systems for absorbing and storing solar energy	☐
Devices for managing natural ventilation in combination with mechanical ventilation systems	☐
Mobile screens for controlling solar radiation	■
Technological solutions designed to increase and/or control comfort inside the building	☐
Building automation systems for the management of plants and elements of the building skin	■



CW

ATF

SG

MFM

BF

FS_40

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): PTFE	■

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

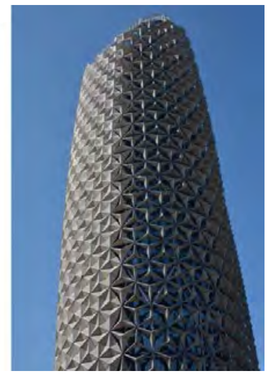
TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify): triangulate units	■

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	☐
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	■
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify):	☐

1



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3

4

1. Northern facade (photo courtesy: Terry Boake)
2. South facade (photo courtesy: Terry Boake)
3. Detailed 3D model of an individual shading device (photo courtesy: Wood)
4. Detail façade view

CONTROL OPERATION DETAILS

DETAILED EXPLANATION OF THE FACADE AND OF THE CONTROL/OPERATION SYSTEM

The tower curtain wall is comprised of unitized panels (with a floor-to-floor height of 4200,0 mm and a variable width of 900,0 –120,0 mm) separated from the kinetic shading system through a substructure by means of movement joints. The fixation of the substructure movement joints (cantilever struts) is at the first basement, ground floor, and podium levels, thereby allowing them to respond independently from the substructure.
The dynamic shading system is a screen comprised of triangulate units such as origami umbrellas. The triangular units act as individual shading devices that unfold to various angles in response to the sun's movement in order to obstruct the direct solar radiation.
Each mashrabiya was conceived as a unitized system, cantilevering 2,8 m from the primary structure.
The shading device system contains stainless steel supporting frames, aluminum dynamic frames, and fiberglass mesh infill. The folding system transforms the shading screen from a seamless veil into a lattice-like pattern to provide shade or light. Each shading device comprises a series of stretched polytetrafluoroethylene (PTFE) panels.
When the shading device is closed, occupants can still see through from inside to the outside.
In total, each tower has 1049 mashrabiya shading devices, each weighing about 1,5 tonnes. The shape of the building in plan and elevation led to 22 different variations in the mashrabiya geometries, which in itself created a challenge for managing their manufacture and assembly. The shading screen is computer-controlled to respond to optimal solar and light conditions.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	■
Extrinsic (requires external control)	□
Electromagnetic	□
Other (specify)	□

SYSTEM RESPONSE TIME	
Seconds	□
Minutes	■
Hours	□
Days	□
Seasons	□
Years	□
Other (specify)	□

SYSTEM DEGREE OF ADAPTIVITY:	
On/Off	□
Gradual	■
Other (specify)	□

DEGREE OF SPATIAL ADAPTATION	
Nanometers	□
Micrometers	□
Millimeters	□
Centimeters	■
Meters	□
Other (specify)	□

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	□
02 Visible, no surface change (smart glazing)	□
03 Visible, surface change (lamellas, rollers, blinds)	□
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	■
05 Visible, location or orientation change	□
Other (specify)	□

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	☐
Information not available	■

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	■
Information not available	☐

Cost/m2	-
Yearly cost of maintenance	-

5

6

7

5. Three fully opened shading devices allowing an open view during non-solar periods (photo courtesy: Terry Boake).
6. A group of fully opened shading devices (photo courtesy: Terry Boake).
7. View of the Al Bahr Towers from south

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Reference to picture

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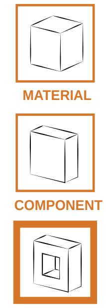
Author of the sheet info

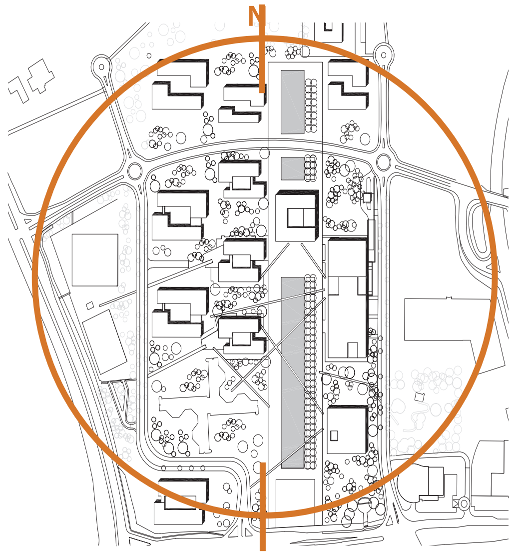
Shady Attia
Liege Universitè, Techniques de construction des bâtiments Urban and Environmental Engineering

Rosa Romano
Florence University, Department of Architecture



THYSSENKRUPP QUARTER, Essen (DE), 2010
JSWD Architekten + Chaix & Morel et Associés

The campus buildings were designed using the “core shell” principle to highlight the contrast between the exterior and the interior.
Two types of façades were used: one facing the central space and one facing the exterior to create maximum visitor impact.
The outside of the buildings are clad in steel sheets with an unfinished texture.
The façades have a vertical cadence; this is present in different form depending on the buildings and the chosen sunshade systems.
Unlike the sculpted, metallic external shells, those used within the buildings are smooth and golden resembling the colours of fruit pulp. These smooth sheets used internally or externally depending on the building are made of lacquer coated steel sheets.



Latitude 51°27’, Longitude 7°04’

DOUBLE SKIN FACADE, SMART ENVELOPE, STEEL SHEETS, ENERGY SAVING

BUILDING INFORMATION:			
Building floor area	25.200 sq.m	Climate Type	Cfb
Building use	Office	Orientation of the facade	South, East, West
Building status	New Built	Other	-

DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

TECHNOLOGY READINESS LEVEL

- [ ] 01. Basic principles observed and reported/ Idea
- [ ] 02. Technology concept formulated/Design Proposal
- [ ] 03. Technology validated in lab
- [ ] 04. Prototype demonstration
- [x] **05. Commercial product/Existing building**

FUNCTION / GOAL / PURPOSE

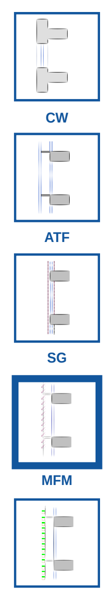
- [x] **Thermal comfort**
- [x] **Visual comfort**
- [x] **Acoustic comfort**
- [ ] Energy management (harvesting, storing, supply)
- [ ] Mass transfer control (e.g. condensation control)
- [ ] Indoor air quality
- [x] **Appearance (aesthetic quality)**
- [ ] Structure performance
- [ ] Energy generation
- [ ] Personal users’ control
- [ ] Other (durability, accessibility, use of natural resources, etc.):

TYPE OF FACADE SYSTEM

- [ ] Active façade
- [ ] Advanced façade
- [ ] Biomimetic façade
- [x] **Kinetic façade**
- [ ] Intelligent façade
- [ ] Interactive façade
- [ ] Movable façade
- [ ] Responsive façade
- [ ] Smart façade
- [ ] Transformable façade
- [ ] Switchable façade

TECHNOLOGICAL FEATURES

- [ ] High-performance innovative materials and systems for absorbing and storing solar energy
- [ ] Devices for managing natural ventilation in combination with mechanical ventilation systems
- [x] **Mobile screens for controlling solar radiation**
- [ ] Technological solutions designed to increase and/or control comfort inside the building
- [x] **Building automation systems for the management of plants and elements of the building skin**



FS_41

TYPE OF MATERIAL	
Liquid crystals	☐
Phase Change Materials	☐
Polymers	☐
Alloys	☐
Ceramics	☐
Wood	☐
Salthydrates	☐
Other (specify): Steel	■

TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify): Not present	■

TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	■
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify)	☐

MATERIAL EFFECT HOW DOES THE MATERIAL ADAPT?	
Shape Memory Material	☐
Bi-material effect	☐
Electroactive material	☐
Superabsorbent material	☐
Phase Change	☐
Other (specify):	☐

TYPE OF TRIGGER (INPUT)	
Mechanical (e.g. wind load)	☐
Thermal (e.g. outdoor air temperature)	■
Electromagnetic (e.g. solar radiation)	☐
Optical (e.g. daylight level, glare)	☐
Air quality (humidity, CO2 concentration, etc)	☐
Building heating/cooling load	☐
Occupant's presence	☐
Other (specify)	☐

TYPE OF ACTUATOR (OUTPUT)	
Mechanical	■
Pneumatical	☐
Electromagnetic	☐
Thermal	☐
Chemical	☐
Other (specify): Manual	☐

1

2

1. Photo of the south facade - central atrium window and shading system surrounding it, ©CA
2. Façade, external view, ©CMA

CONTROL OPERATION DETAILS

3

DETAILED EXPLANATION OF THE CONTROL/OPERATION

The Headquarter façades have metallic sun shades which are comparable to vertical moveable feathers. These feathers consist of an axis with two series of horizontal slats on either side; the «barbs» enable the amount of sunlight entering the building to be regulated.
The hollow axes of these feathers are installed every 67,5 cm to fit in with the design of the offices. The illusion of a wheat field waving in the wind is created by the three shapes of the slats that cover the building: a triangle, a trapezium and a rectangle. It is the way in which they are assembled that gives the impression of movement.
When the barbs of the two neighbouring feathers are open they can crisscross each other and superimpose themselves to allow a maximum amount of sunlight to enter the building. The triangular and trapezoidal panels measure from 0 to 67,5 cm in width and the rectangular panels measure 33,75 cm. The panels are the height of a floor to be adapted to the users.
To maximize sun protection an automatic adjustment of the system tracks the movement of the sun throughout the day without blocking the view. The tracking, shape and angle of the horizontal slats enable light to be reflected indirectly providing constant natural lighting to the offices (and avoiding the need for additional electric lighting).
Around 400.000 centrally controlled slats provide protection from the sun; this is comparable to traditional external sun protection systems. However, these slats have the advantage of not blocking the view and are entirely functional even in the event of very high winds. Thanks to this system, the view from the Headquarters is always pleasing: total transparency when the slats are open – partial transparency when the slats are unfolded.

CONTROL/OPERATION TYPE	
Intrinsic (auto reactive)	■
Extrinsic (requires external control)	□
Electromagnetic	□
Other (specify)	□

SYSTEM RESPONSE TIME	
Seconds	□
Minutes	■
Hours	□
Days	□
Seasons	□
Years	□
Other (specify)	□

SYSTEM DEGREE OF ADAPTIVITY:	
On/off	□
Gradual	■
Other (specify)	□

DEGREE OF SPATIAL ADAPTATION	
Nanometers	□
Micrometers	□
Millimeters	□
Centimeters	■
Meters	□
Other (specify)	□

LEVEL OF AF VISIBILITY	
01 Not visible (heat storage, phase change materials)	□
02 Visible, no surface change (smart glazing)	□
03 Visible, surface change (lamellas, rollers, blinds)	■
04 Visible, size or shape change (shutters, flaps, dynamic facade elements)	□
05 Visible, location or orientation change	□
Other (specify)	□

ECONOMICAL ASPECTS

IS THE SYSTEM ECONOMICALLY VIABLE?	
Yes	☐
No	■
Other (specify)	☐

ESTIMATE THE COST OF THE CASE-STUDY	
Low (traditional, residential, simple prefabricated, etc)	☐
Medium (curtain walls, ventilated facades, etc)	☐
High (double skin facades, high tech, etc)	■
Information not available	☐

SYSTEM MAINTENANCE FREQUENCY	
Daily	☐
Weekly	☐
Monthly	☐
Yearly	■
Information not available	☐

Cost/m2	-
Yearly cost of maintenance	-

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Reference to picture

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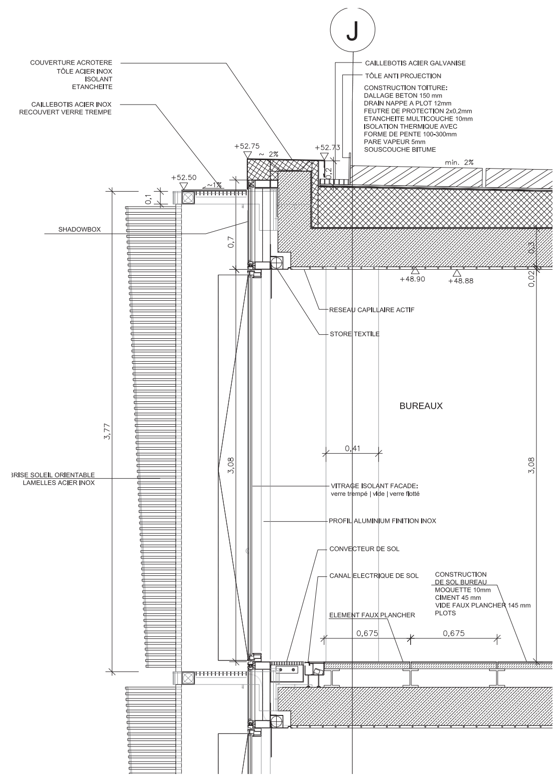
Author of the sheet info

Rosa Romano

Florence University, Department of Architecture



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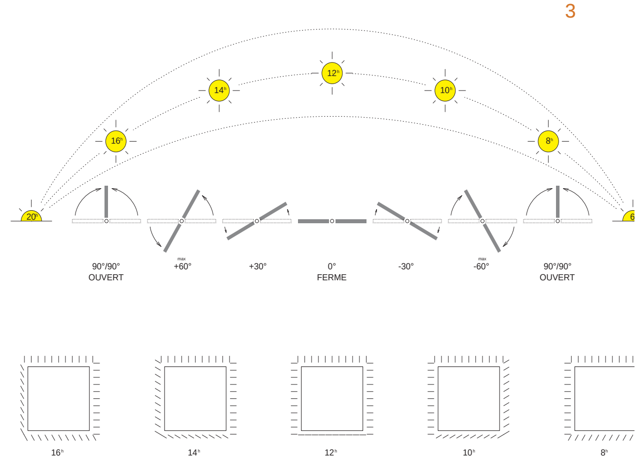

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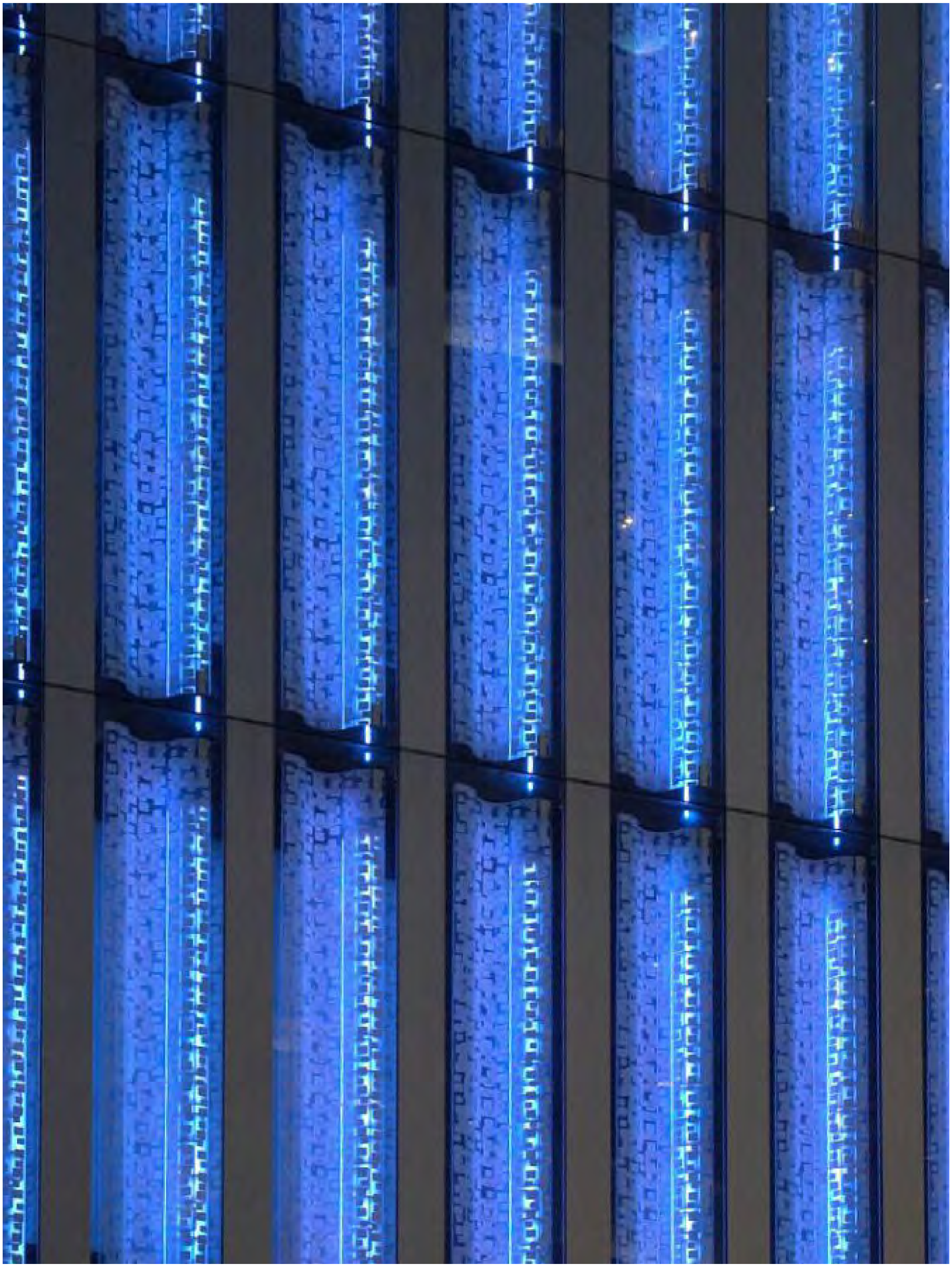
3. Vertical section in detail, by Chaix & Morel et associés
4. Scheme of the automated movement of the facade during the day, on different sides of the building by Chaix & Morel et associés

Messe Basel – New Hall / Herzog & De Meuron (image: M. Brzezicki)

Future Developments


Pola Ginza / Nikken Sekkei, Yasuda Atelier (image: M. Brzezicki)

Future Developments

Innovations for the next generation of adaptive building envelopes

Susanne Gosztonyi, Enrico Sergio Mazzucchelli, Rosa Romano, Nikolaus Nestle, Marcin Brzezicki, Christophe Menezo

Introduction

The adaptability of façades is actually nothing new. The façade has always had a variety of static and dynamic tasks. For example, manually controllable openings or sun protection devices are traditional “adaptive” components - and yet these components in particular have experienced a considerable leap in innovation in recent years. Under the collective term “Future Developments”, this chapter would like to provide a glance into ongoing research and development topics for new technical solutions of adaptive façades. The focus is on innovations that are not yet established on the market and are being touched by the COST TU1403 Adaptive Façades Network at the time of writing. It can certainly be assumed that there are many more innovations in the field of adaptive façades. The COST TU1403 publications refer in this sense to further topics, which are not illustrated here.

Goals for adaptive facades: Future technical developments for façades will focus on the material design criteria for outdoor applications, concerning increased durability and mechanical resistance, as well as on the responsiveness of the components. Among all features that are expected, reliability is one of the key issues that asks for caution due to the intensive use of e.g. mechanical or embedded controls. With active devices, as it was the case in earlier years, there is often a loss of adaptability in the event of a breakdown, or when these have to be ‘restarted’ several times before being abandoned. According to Bridgens, Holstov and Farmer (2017), the main typologies of future applications within architectural design focus on: functional devices/ components (actuators, micro-generators, sensors, locomotion engines etc.), performance-oriented adaptive systems (enhanced occupant comfort, energy efficiency, etc.), formal/ aesthetic/ spatial experience values (e.g. enhanced visual appearance of a dynamic façades) and contextual/location-specific values (buildings as a physical representation of local environment and climate). Inspirations from other domains, such as from nature, are a huge potential to support the development of such typologies in an innovative way.

From adaptive façades to intelligent buildings in the framework of smart cities: Following the outlines of the Smart Cities and Communities Initiative of the European SET Plan, the concept of *Smart City* is clearly focused on the promotion and dissemination of a new generation of innovative, intelligent and energy-efficient building envelopes. In particular, the Smart City represents a new generation of built environments, where energy efficiency is not exclusively achieved by a single building but rather involves the entire energy infrastructure network of the city, and where building envelopes represent essential and strategic nodes for reducing the energy consumption and increasing the production of renewable energy (Arbizzani et al., 2015). For decades, architects and building scientists have envisioned the possibility of the envelopes of future buildings replicating human skin's adaptive response to changing environmental conditions (Davis, 1981; Wigginton and Harris, 2002). Advances in material technology and building automation are drawing these parallels between adaptive envelopes and the intelligent response of human behaviour and skin to environmental stimuli. It is seen as an increasingly feasible way of regulating energy flows through a building's thermal barrier in a controlled way that promotes energy reduction and users comfort. Over time, this concept has been defined as an envelope able of changing shape in relation to external thermo-physical stresses, shifting from transparent to opaque, altering its colour, and varying its optical properties. These characteristics can be determined by choosing materials that offer advanced solutions in relation to their chemical composition or the ongoing application on the envelope of dynamic elements. Michael Wigginton and Jude Harris (2002) in their text on Intelligent Skin define this concept as an adaptive and dynamic control system able of regulating the interchange of energy between an internal and external environment, ensuring an excellent level of comfort through the possibility of automatically varying the building's structure. A large number of sensors should regulate the system with precision, turning the building into a smart building. The variability of the façade system makes it possible to regulate heat and light energy flows through its conformational layers, and has led to an evolution in research related to phase change materials, advanced glass surfaces (such as electrochromic and/or photochromic glass) and mobile (horizontal and vertical) external screening systems. Therefore, in the next years, the concept of smart building will be closely linked to that of adaptive envelope, as the façade itself is the main element able of changing its structure to ensure the required performance, emphasizing its resemblance to human skin. Finally, the future envelope will become a real organism connected to the building's central control system, where the air conditioning system can be compared with the human circulatory system. In this context, the novel concepts of adaptive envelopes developed in the last years by Doris Sung and Ingalill Wahlroos-Ritter (Bloom installation), Achim Menges (HygroSkin), Hoberman Associates (Tessellate™), Ned Kahn and Koning Eizenberg Architecture (Articulated Cloud), Simone Giostra (Sol Pix), etc. are interesting. These are innovative approaches able to not only to increase the building energy performance and to produce renewable energy at the same time, but also to improve the environment of our cities.

This chapter touches some developments for these objectives, such as innovations for e.g. components that are independently adaptable due to smart material or construction properties.

The digitalization potential: Another topic is the digitalization of design, planning, production and operation, which seems to be particularly advantageous for the performance-oriented combination of complex systems with flexible designs. The virtual planning environment enables also a holistic consideration of the life cycle of a façade and its components. Even passive systems can become then somewhat adaptive. Using parametric, multi-criteria planning methods, a façade construction can be designed in such way that it is adapting to changing local climatic conditions by its specific design. The performance potential of this approach might be higher than currently used. The economic effort for such is then shifting from high costs in the production and implementation of a multifunctional system towards more complex design and planning efforts. Ultimately, it seems beneficial to bring active and passive components together in a complementary way: The more intelligently the passive and active properties of a façade interact, the more robust the desired output is in terms of maintenance and performance.

Smart devices: The development of smart control systems for adaptive façades will be another technological challenge. In this regard, the transition from centralized to decentral distributed models, often more coherent with properties and behaviour of smart materials, shows huge potential. One of the advantages of active systems is their intelligent interaction ability with the building energy management. Combined with renewable systems, the required operating energy may not only be generated by the façade, but also support the total building operation. Intelligent façade management, coupled with building energy management, may then enable economic optimisation and contribute to the smart living features.

Only few of these challenges can be addressed in the following pages. The chapter draws a picture from the role of adaptive façades in the future smart city, to development approaches of its intelligent components by applying new materials and methods, up to the need for new production processes and new integration requirements for the adaptive functionality in the building context. Many more topics are elaborated and addressed throughout the COST TU1403 activities, which are provided in the booklets and proceedings.

Material systems – embedded functionality and efficiency

The integration of building services functions and renewable energy systems into façades shall increase the total performance efficiency of a building while providing individual comfort in zones (adjacent to the respective façade). This idea undergoes currently a fundamental change, starting from the first multifunctional façades to new adaptive systems. The vision is to merge the various functions of an element, such as e.g. structural or building services requirements, into an intelligently designed façade system without applying the additive approach. So-called '*material-systems*' (Hensel, Kamvari and Menges, 2008) and corresponding structures contribute to this vision: Material-systems are materials that are designed on the basis of performance-orientated, formal and structural criteria in combination, with the aim of reacting dynamically and autonomously to varying conditions and at the same time being able to take on other functions, such as serving as structural elements. The difference is that only one or a few raw materials are used for this. The various functionalities are embedded in the geometry of the designed material-system. Instead of the additive assembly of mono-functional subsystems to a complete system, as we build multifunctional façades today, material-systems reduce the application of various materials and components and the associated problems coming with composites. Using parametric computational design methods, the morphogenetic potential of materials can thus be utilized in such way that they provide e.g. shape-varying, thermo-adaptive, light-emitting, energy-generating or -storing properties.

An interesting approach herein is the utilization of physical properties embedded in material properties by nanotechnologies or micro-structuring: For example, colour change mechanisms in squid skins (achieved through active and fast shape changes of colour-containing vesicles in the skin) could provide technical inspiration to control glare and solar gain. Structural colours and photonic crystals are used in nature to change colour appearance without any change of the material structure or properties at all (cp. Gosztonyi, 2015). Ferrofluids or electro-wetting mechanisms might be another, low energy-consuming approach in this context. For example, ferrofluids could be arranged by using transparent micro-coils to shade areas, which would then have electrostatic, constant power consumption in contrast to electromagnets.

However, these developments ask for a further obligatory criterion, which should be applied in the future investigations to allow a real innovation step: The sustainable use of raw materials and the reduction of (non-recyclable) composite materials. Material-systems ideally use only one or a few raw materials to fulfil several functions, but the type of raw material is not refined towards sustainability. In order to follow sustainable goals, this would also have to be considered, since not all current material-structure solutions are recyclable and therefore sustainable.

Biomimetic inspirations

A possible source of inspiration for the development of sustainable, performance-oriented material-structures is the systematic analysis of biological principles in nature. By analysing functional phenomena in nature, as nature is using the logic of material-systems, the functions, dependencies and properties can be probed and processed for applications in technology. The transfer potential of biological solutions is huge, as many recent research projects demonstrate (Shimomura, 2010) (Gosztonyi, 2013). Whether for plants or animals, the interfaces between the outside and the inside of living organisms, such as the epidermis or cuticle, play a major role in overcoming physical and physiological problems related to an ambient environment (by radiation, temperature, humidity, wind, etc.). Even if these interface properties are complex and based on physicochemical principles that are currently largely non-duplicable, certain structures, materials and processes can still serve as inspiration for technical innovations. In order to highlight the main functional evolutions related to the climate, it is therefore essential to study living organisms in their climatic environments.

Bio-inspired solutions – air conditioning and wood-related construction components

A possible bio-inspired topic concerns the implementation of organic gaseous exchange systems in buildings, such as decentralized air-conditioning systems already applied in selected buildings. Decentralized air-conditioning systems can be compared with gaseous exchange systems in insects, where the air is sucked directly into the tissue through a system of tracheal tubes and spiracles. The air exchange system of Capricorn house in Düsseldorf (designed by the architects Gatermann and Schossig in 2008) was modelled on this principle. The façade modules are independent ventilation/cooling and heating elements that suck the air directly from the surrounding into the rooms. A central air-conditioning system does not exist in the building. The advantage of this system is the unique possibility to maintain very different climatic conditions in adjacent rooms and to switch off the system when rooms are not occupied. The disadvantage is a high level of complexity and maintenance of each façade module that practically are single air-conditioning units.

Some bio-inspired material-structures targeting wood have already been tested for practical applications, as e.g. the elastic bending behaviour of wood fibre materials in relation to the relative moisture content of the environment in the research project HygroSkin of the ICD, University of Stuttgart (Krieg et al., 2014). In doing so, the morphogenetic functional potential of the wood was exploit, by means of which the proven material is once again elevated to a new dimension of intelligent adaptive materials. And incidentally, wood itself would fulfil the criteria of sustainability and resource efficiency. The development of such therefore offers the opportunity to innovatively combine high-tech functions and sustainability. Similar applications on wood-based, responsive building skins have been recently deepened by Bridgens, Holstov and Farmer (2017) and Mazzucchelli and Doniacovo (2017). Because these components can be used as cladding panels, sunscreen, passive layer for photovoltaic systems and others, the maintenance and durability aspects that usually depend on wood species must be taken into account. In this regard, it is important to note that the vapour phase transport is not disturbed by non-sealing, hydrophobic treatments (oil- and wax-based).

Cellulose is another material within this category: It is used, for example, by insects, like e.g. hornets, for the manufacture of the combs and the entire nest shell, which is designed to dissipate heat in hot periods or to limit heat loss in cold periods. These flexible and lightweight envelopes also provide the UV and water protection function by cellulose fibres taken from tree barks or dead wood. These fibres are processed into a cellulose mass, which the hornets use as cement to build larger scales, each layer of which is interspersed with beige and brown. This composition is comparable to 3D printing (Merlin and Ménézo, 2018).

Digital design and production potential

Digital design and production process chains, such as the coupling of parametric design and additive manufacturing (AM), enable a flexible, material and time-saving design process of complex shapes and functional components. In addition, it allows nearly any type of embedded functionality that enables the product to become smart and responsive.

The starting point is to create a computer-based, three-dimensional model: this model is created by the combination of static and dynamic parameters, and input/output conditions and target variables, in a parametric design environment. Thus, the design development is no longer created 100% manually, but developed based on dynamic data and generic algorithms. As the environment is dynamic and allows variation studies and optimization loops, the results can be manifold (Wang, Zmeureanu and Rivard, 2005). With digital production methods, it is then possible to realize some of the chosen results while maintaining the quality and - in the near future - producing any quantity in cost- and material-efficient manner.

AM products can be designed of single raw materials, such as polymers, fibres, metal or minerals, which also promise simplification in terms of re-use and recycling. Their quality in function and production is already at a very high and mature level on the prototyping scale (Lim et al., 2012). It is expected to reach economic feasibility for prefabricated modular components of a façade in sooner future. Today, AM techniques or rapid prototyping are particularly suitable for the production of complex connections or for the rapid realisation of prototypes on small scales (testing and design phase).

Smart controlled

A major challenge in making optimal use of adaptive façade elements is their appropriate consideration in the building control system. This is not only true for elements responding to extrinsic stimuli (and thus can be actively controlled) but also for elements responding to intrinsic stimuli (which cannot be controlled but nevertheless need to be considered by anticipating their adaptation effect for an optimal control of other building components by the building control system). This requires sufficiently simple, fast and robust models for energy and material flows through the adaptive façade components. The models can be run as a routine in an optimization kernel, which continuously calculates the energetically optimal operation of all building components based on sensor data and anticipative information, such as the weather forecast and energy quantities available in smart grids for electricity and heat. If run together with a simulation of a non-adaptive benchmark model building, such a building control system can also be used to validate and quantify economic and energetic gains from the use of the adaptive façade.

The lack of plug-in solutions for both aspects of the building control system is probably a major factor in the slow market penetration of adaptive façades up to now. The development of appropriate building control systems capable of dealing with adaptive building skins will therefore be a key challenge in developing adaptive façade solutions to their full potential. This pivotal role of building control systems for the operation of adaptive façade component is likely to have a substantial impact on the future development of value chains and business models in the field of adaptive façades. Open and extendable standards and a good integration with BIM solutions are desirable to facilitate further development of new adaptive façade components. Due to its interdisciplinary and complex nature, this topic is probably best approached in the context of large research cooperation and thus should be considered as a high priority for future EU-funded research in the field of adaptive façades.

Conclusions

The future technical developments in the area of adaptive façades will be strongly related to digital production and design processes, smart controls, intelligent components and dynamically reacting materials that open new potential research fields. The development of appropriate materials and systems, capable of dealing with adaptive façades, appear therefore as the technical key challenge in future research and industrial development activities. Particularly smart materials may replace current building services technologies or structural elements by intelligently designed material-systems and bio-materials. Moreover, their development may offer the opportunity to innovatively combine high-tech functions and sustainability. This objective follows the outlines to reach the Smart City targets, where energy efficiency is not exclusively achieved by a single building but rather involves the entire infrastructure of a city network.

Other challenges in the field of adaptive façades are not touched in this chapter, but are likewise important. One is the evaluation of adaptive components in a façade, which poses another major challenge in the future. Adaptive façades, allowing to damp external effects or even to match external flux (energy, water, gas) with internal needs, require a complex assessment framework to be reliably used in new buildings or in building refurbishment, depending on the type of construction and building type. The performance evaluation of adaptive components is herein a criterion that must be considered and established in practice in order to predict the full performance capacity of adaptive façades. The question is to what extent can the dynamic behaviour of adaptive façades be made predictable and quantifiable? Do adaptive components require an extended characterization of its properties and new “dynamic” reference values? In any case, there is a need for enhanced standards and test procedures of dynamic components and behaviour in the building sector. To date, standards from other areas are used to evaluate adaptivity, such as material characterizations without integration into the façade system, electrical measurement and control standards, monitoring technologies for safety logging of intelligent control measures, and many more. It requires a combination of these evaluation methods with new approaches to investigate adaptive façades in the context of actual operation.

Modularity and standardization of components are another aspect in the development of adaptive façades. Both promise higher planning, operational reliability, and economic efficiency. “Keep it simple” is often expressed as a concern in this context. Especially with adaptive façades, the desire for simplicity and robustness of the components raises many questions: How can fully integrated, adaptive components be replaced in the event of a change in use of the building? What about the interaction between several active components? Can interfaces and connections of active components be standardized? To what extent can existing constructions be supplemented with high-tech products? And, to what extent can active façades take over building services tasks? Another critical factor herein is surely the cost-effectiveness of adaptive façades. In contrast to passive systems, i.e. static systems and manually operable components, active systems - systems with automatic reactivity - are nowadays usually cost-intensive high-tech products.

Finally yet importantly, the challenges of adaptive façade systems ultimately go far beyond the technical-constructive requirements; they demand new economic models, production methods and a high degree of interdisciplinarity in planning and development. Those who interact with the "intelligent" system on a daily basis - the inhabitants - must also be taken into account. They finally decide whether adaptive façades are successful in practice or not. A close-up towards user acceptance and monitoring while operation is thus another essential development field.

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‘de Baljurk’ / Eric Vreedenburgh – Archipelontwerpers (image: M. Brzezicki)

Biographies

Laura Aelenei

Dr. Laura Aelenei is a head of Energy in Built Environment Research Area, senior researcher at Renewable Energy and Energy Systems Integration Unit of National Energy and Geology Laboratory and Invited Professor of Energy Efficiency studies at the Master of Energy and Environment Engineering at FCUL –Faculty of Sciences of the University of Lisbon. She is a Civil Engineer, Master Degree on Buildings Rehabilitation and PhD Civil Engineering (heat and mass transfer, fluid dynamics through building ventilated envelope systems). She is involved in several national and international research projects as participant or coordinator and participated in buildings national regulation commissions. She was participating as national expert in the International Energy Agency (IEA) SHC Task 40 / ECBCS Annex 52 "Towards Net Zero Energy Solar Buildings". She is reviewer for international Journals: Solar Energy Journal, Renewable Energy Journal, Energies and ASME Journal of Solar Energy Engineering: Including Wind Energy and Building Energy Conservation, evaluator of European Research projects. She is co-author of eight scientific books and author of more than 50 research papers published in scientific journals, conferences and communications.

Daniel Aelenei

Daniel Aelenei is a professor of building physics and building technical services at Department of Civil Engineering and researcher at Center of Technology and Systems at Nova University of Lisbon, Portugal. He is responsible for taught graduate and postgraduate courses in energy efficiency of buildings and for coordinating the Postgraduate Course on Façade Engineering. He is co-author of more than 50 peer reviewed publications (journal, book or conference proceeding) and he has supervised 4 PhD theses. The research of Daniel Aelenei is focused on the low-energy buildings. He is Member of Committee of COST Actions TU1403 "Adaptive Facades Network", co-subtask leader of Annex 67 – "Energy Flexible Buildings" of the International Energy Agency Energy in Buildings and Communities Programme (EBC), member of EU Interreg Project "SUDOKET – Mapping, consolidating and disseminating Key Enabling Technologies (KET) for the building sector in the SUDOE area". He is also the principal investigator of the MIT Portugal Project – "FIRST - Mapping flexibility of urban energy systems" (MITEXPL/SUS/0015/2017).

Mark Edward Alston

Dr Mark E Alston is an assistant professor in composite material design at the University of Nottingham, Faculty of Engineering, UK. Marks PhD (2017) and current research is investigating the challenges in optically clear material science to evaluate heat flow and monitor temperature with time. By advancing the design of synthetic polymers that are hindered by our inability to control transition temperatures for thermally functional material. To progress heat flow management through application in photovoltaics, semi-conducting, optic materials or integration into Multilayer Insulation (IMLI) is the current research path. Mark is an active member of the UK Government material and manufacturing funding agency innovate. In the progression of composite material science to a manufacturing platform through composite design. His teaching covers master and undergraduate levels within the faculty and a distance outreach master's programme at the RIBA, London. Mark is working with a colleague at Sandia National Laboratories, New Mexico, USA in the field of energy material science to advance capture and energy storage.

Marcin Brzezicki

Dr. Marcin Brzezicki, (1972) is an architect and tutor at the Faculty of Architecture, Wroclaw University of Science and Technology, Poland. After receiving his doctorate in 2001, he became an assistant professor in the Faculty of Architecture at his alma mater. His scientific interest was focused on the perception of transparency in architecture, including his monograph entitled Perception of transparency in contemporary architecture: visual and cognitive aspects. After successful application for tenure in early 2015, his interests were broadened to general issues of façade/architectural envelope morphology and aesthetics. In 2015 he joined COST TU 1403 Adaptive Façade Network. Marcin Brzezicki participates in international conferences on the subject of transparency and façade morphology, publishes in journals. He is a motivated and ambitious researcher with a strong interest in the optical properties of architectural envelopes. A passionate and enthusiastic academic teacher with a genuine love of his subject and a drive to help students succeed.

Maria da Glória Gomes

Maria da Glória Gomes graduated in Civil Engineering (5years) in 1999 at Instituto Superior Técnico (IST), Universidade de Lisboa. She worked as a Structural Project Engineer (1999-2001) and received an MSc in 2003 and a PhD in Civil Engineering in 2010, both from IST. She is an Assistant Professor at DECivil-IST/UL, where she has been lecturing for over seventeen years. Her research interests are in the field of Building Physics, in natural ventilation and thermal and energy performance of buildings. Most of studies have both experimental and numerical approaches and focus on the implementation of energy efficient solutions such as, innovative glazing facades and shading devices, green roofs and walls, thermal renders, lightweight concrete and GFRP sandwich panels. She is a member of CERIS, IST-EI and IBPSA-Portugal and has published 24 ISI international journal and over 50 conference papers. She has participated on 10 successful research projects and has supervised 37 MSc and is currently supervising 6 PhD students.

Susanne Gosztonyi

Susanne Gosztonyi works in the field of performative building envelopes with focus on renewable energy, climate-sensitive design and biomimetics. She combines practical knowledge and research methods to investigate energy efficiency principles and their transferability to architectural engineering. Her interest is in combining these findings with human-centred design and digital design techniques to enable novel solutions. Susanne works as lecturer and researcher at the Lucerne University of Applied Sciences and Arts in Switzerland. She is furthermore a Ph.D researcher at the TU Delft, Architectural Engineering and Technology. Previously, she worked at the Lund University, AIT Austrian Institute of Technology and for international architectural offices. Susanne holds a master in architecture and urban planning from the Vienna University of Technology and completed post-graduate studies in the Master ‘Climate Engineering’ from the Danube University Krems, Austria. She is member of advisory boards in EU projects, conferences, networks, and conducts peer-reviews for scientific journals.

Miren Juaristi

Architect and PhD candidate in the University of Navarra, Spain. Between 2014 and 2016 she combined her studies with both architecture and research training. She did architectural internships in Peru (Vértice Arquitecto), Japan (Kengo Kuma and Associates) and in an international office in Spain (AH Asociados) developing projects mainly in the Middle East. She collaborates at SAVIARQUITECTURA research group since 2014. In 2016 she got a scholarship to start her PhD research in “Adaptive Opaque Facades: a design and assessment method”. She participated in the COST ACTION TU1403-Adaptive Facade Network, which gave her the chance to do a STSM in the Facade Research Group of the department of Architectural Engineering + Technology, Technical University of Delft. She is also teaching assistant at the University of Navarra in subjects related to building construction, climate design and prototyping.

Theoni Karlessi

Theoni Karlessi is a building physicist, holding an MSc. in Environmental Physics of the University of Athens, Greece and is now a research associate at the Group of Building Environmental Studies of NKUA, Athens and a PhD candidate in the field of innovative materials for urban structures. Her expertise, activities and key qualifications are in Energy Efficiency, Energy Management, Environmental Impact Assessments, Dynamic Modelling, Integrated Design, Indoor Environmental Quality and Thermal Comfort, Monitoring, Microclimate and Urban Heat Island Mitigation Techniques, Energy and environmental evaluation of outdoor spaces, Development and testing of materials for urban applications. She worked on several projects, has a large number of scientific journals publications and is a reviewer. She was honored with an international research award in PALENC 2007 and with a Commendation at the Green Building Integrated Design Award 2014 at IEECB and is a member of the Center of Renewable Sources and Energy Efficiency (CRES), a Certified Expert in Environmental Impact Assessments and a professional trainer at the Center of Lifelong Learning of the University of Athens.

Aleksandra Krstić-Furundžić

Dr. Aleksandra Krstić-Furundžić, Professor at the University of Belgrade, Faculty of Architecture and several times head of the Department of Architectural Technology and a visiting professor at the Faculty of Architecture, University of Banja Luka, BiH. Professional experience as an educator, architectural design practitioner, researcher, and editor. Expert domains: Architectural constructions, Innovative façade and roof technologies, Energy efficient buildings, Passive and active solar systems, Industrialized construction, Building refurbishment technologies. She participates in the National Energy Efficiency and Technological Development Programs, and was a member, lecturer and trainer in Training Schools within several COST Actions, such as TU1205, TU1104 and TU1403, and for some she was the organizer. She is Co-Founder and Technical Director of International Academic Conference on Places and Technologies, recognized at the regional level and beyond. Member of the Editorial Board of two international journals, and several professional associations. Author of several books, and a significant number of chapters in international and national monographs and scientific papers published in Energy and Buildings Journal, Renewable & Sustainable Energy Reviews and other international journals.

Enrico Sergio Mazzucchelli

Enrico Sergio Mazzucchelli studied building engineering at Politecnico di Milano, degree in 2001. From then on he started collaborating and researching at the Department of Architecture, Built Environment and Construction Engineering (DABC) – Politecnico di Milano. His research is focused on Zero Energy Buildings, façades innovative systems design, energy efficiency, building services integration, timber constructions, refurbishment of existing buildings. In 2012 he spent a research period on low-energy buildings at the University of Gävle (Sweden). Since 2008 he is professor of 'Building Services Design and Integration', School of Architecture Urban Planning Construction Engineering – Politecnico di Milano. He's author and co-author of more than 50 publications (journal, book, book chapter or conference proceedings). Since 2015 he participates in the activities of the EFN European Façade Network. He's member of the 'Journal of Façade Design and Engineering' editorial board and of the commission 'CIBW098 – Intelligent and Responsive Buildings'.

Christophe Menezo

Dr. Ménézo is a Professor Head of the CNRS Research Federation on Solar Energy. He is a professor at Polytech'Annecy-Chambéry since 2008 where he teaches in the "Environment-Building-Energy" sector. He is doing his research at the laboratory LOCIE UMR5271, component of the INES, on the integration of solar components (BIPV/ Hybrid PV/Th) to the frame and the redefinition of the envelope of buildings to include adaptive and active energy functions. Other fields of interest are bio-inspired engineering for energy efficiency and solar power generation in built environment (solar cadaster).

Nikolaus Nestle

Dr. Nikolaus Nestle is a Principal Scientist at BASF SE Advanced Materials and Systems Research, Ludwigshafen (Germany) since 2006. From 2002-2006 he hold a non-tenured faculty position in condensed matter physics at TU Darmstadt (Germany) and from 2002-2003 he was a contract professor at the Faculty of Design and Arts at the Free University of Bolzano (Italy). He received his habilitation in physics from the University of Leipzig (Germany) in 2002 and his PhD in Physics from the University of Ulm (Germany) in 1995.

Jose Miguel Rico-Martinez

Dr. Architect Jose Miguel Rico-Martinez studied in the University of the Basque Country where he presented in 2015 his PhD about daylight performance of expanded metal and, nowadays, teaches in the Building Construction department. He has contributed in several conferences, books, journals and postgraduate programs as Light Facade Master, Sustainable Construction Master, Timber Structures, Construction and Design Master in the University of the Basque Country. Member of the Scientific committees of the Light Facades Master, the International Congress on Architectural Envelopes by Tecnalia, the Journal of Façade Design and Engineering (JFDE) and the EFN European Facade Network (www.facades.ning.com).

Rosa Romano

Dr. Rosa Romano is Architect (2003), PhD (2010), Assistant Professor (2006), with licence for Associate Professor (2014). Currently, she is teaching Architectural Technology at the Schools of Architecture in Florence and in Tirana and working as senior research in ABITA Interuniversity Research Centre, participating in many national and international researches on Environmental Sustainability and Energy Efficiency in Building. Her research is focused in particular on the topic of performances and technological features of the smart envelopes for nZEB. Furthermore, she is working as architect and energy advice (in the field of bioclimatic architecture and innovative technologies for the environment) for public administration and private companies. She is author and co-author of more than 70 publications on sustainability and energy performance of buildings and in 2011, as winner of the “Florence University PhD Press Prize”, she published the book: Smart Skin Envelope: Architectural integration of dynamic and innovative technologies for energy saving.