Case Studies – Adaptive Facade Network

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EUROPEAN COOPERATION
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Case Studies

Adaptive Facade Network

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This book is based upon work from COST Action TU 1403 adaptive facade network, supported by COST (European Cooperation in Science and Technology).

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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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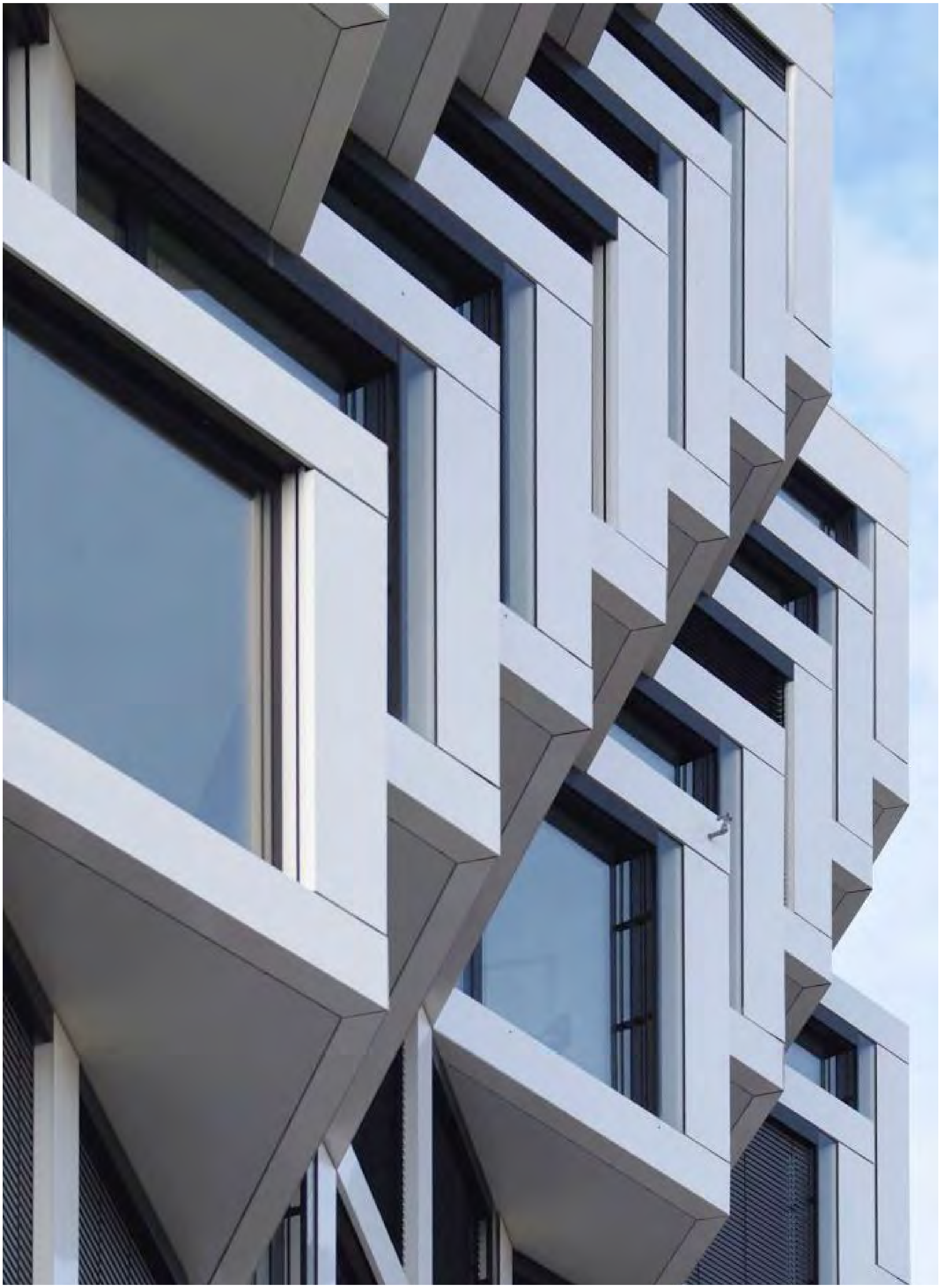
TU Delft for the COST Action 1403 adaptive facade network


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

Contents

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

MATERIAL | **COMPONENT** | FACADE

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	☐

CW | ATF | SG | MFM | BF

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)

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Cost/m2	-
Yearly cost of maintenance	-


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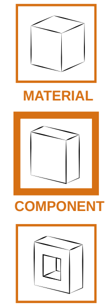
4. Window Prototype
5. Window Prototype
6. Touch-window prototype was exhibited by Ericsson at MWC2013 in Barcelona. Photo: Hans Berggren

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


MATERIAL
COMPONENT
FACADE

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	-

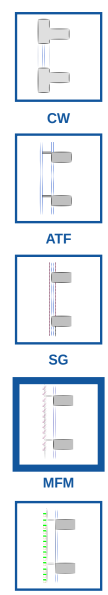
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

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	■

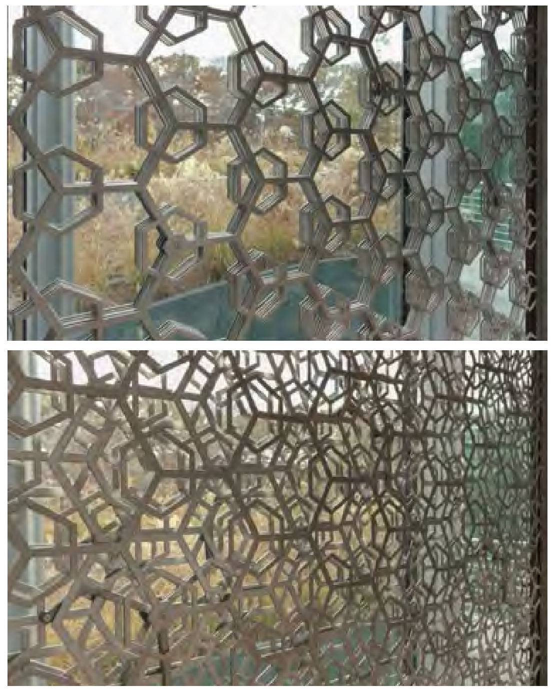
TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

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 kineti-cally	■

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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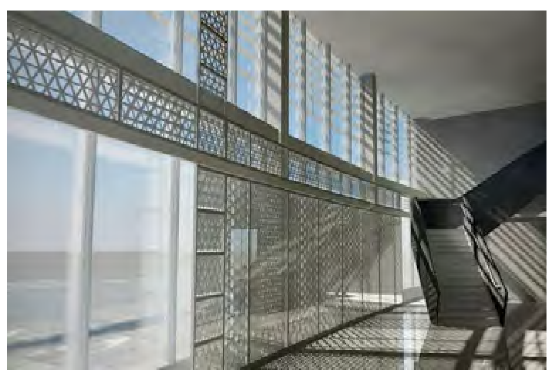

2

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

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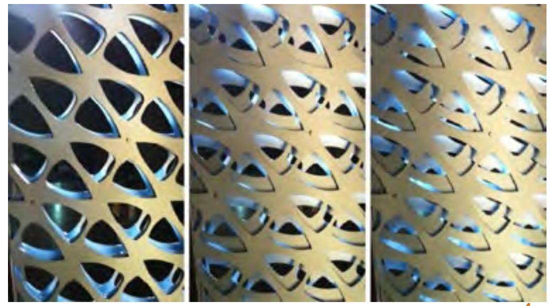
Cost/m2	-
Yearly cost of maintenance	-



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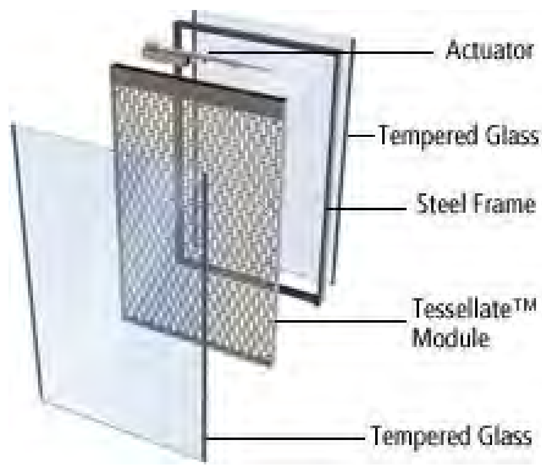

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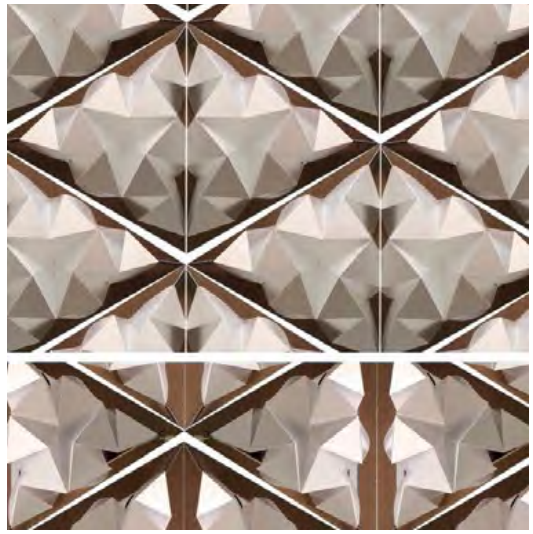
4. Dynamic facade with multilayer panel (metal and glass)
5. Dynamic facade with multilayer panel (metal and glass) - TESSELLATE™
6. TEchnological detail of a glass facade with a shading device realized with Tassellate Module

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

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

MATERIAL
COMPONENT
FACADE

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	■

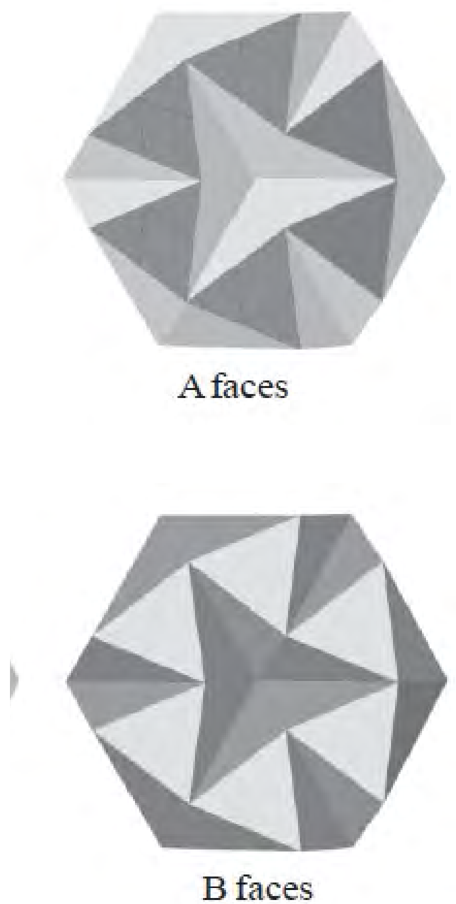
TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify): Deployable screen	■

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	■

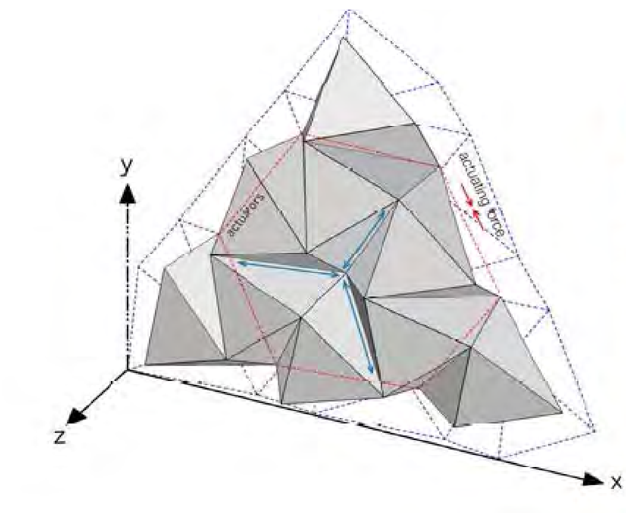
TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

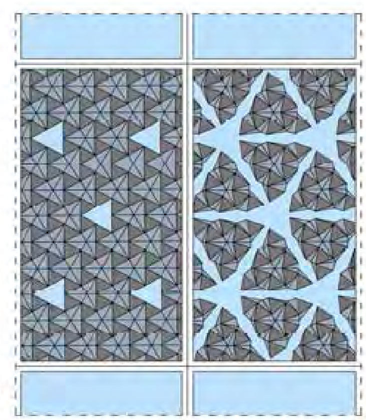


2

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)	□

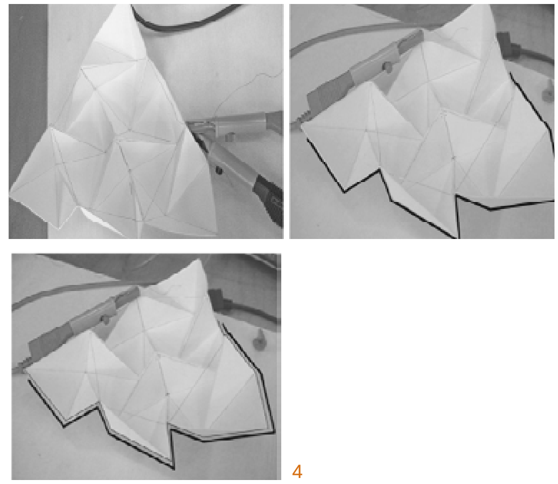
ECONOMICAL ASPECTS

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

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	■



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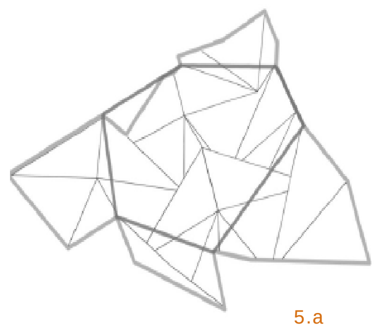
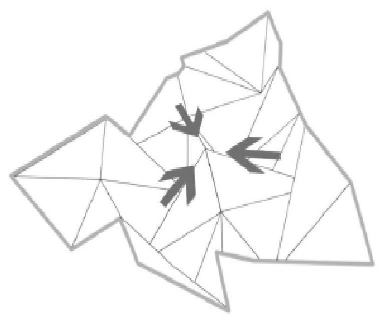


5.a



5.b

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

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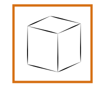
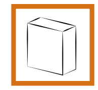
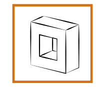
4. The actuators placement allows envisioning the deployment direction
5. The embedded SMA wires define the direction of deployment: 5.a, The actuators placement, 5.b. Deployment direction

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


MATERIAL


COMPONENT


FACADE

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	-

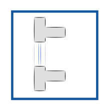
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

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	☐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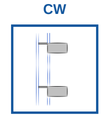
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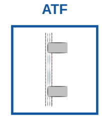
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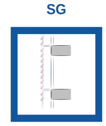
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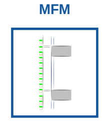

BF

CS_04

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):	☐

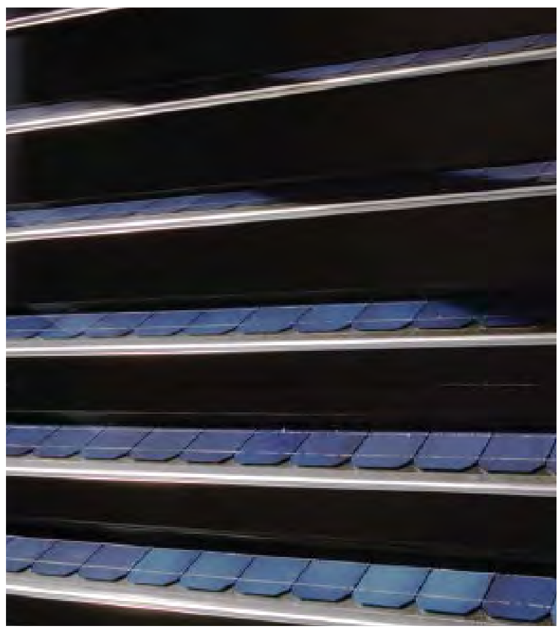
TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

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. 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

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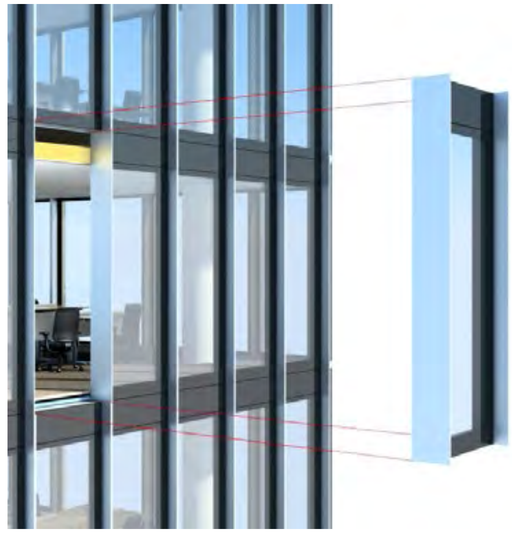
InDeWaG, BAYREUTH (DE), 2015
Prof. Dr. Dieter Brüggemann

MATERIAL

COMPONENT

FACADE

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	☐

CW

ATF

SG

MFM

BF

CS_05

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

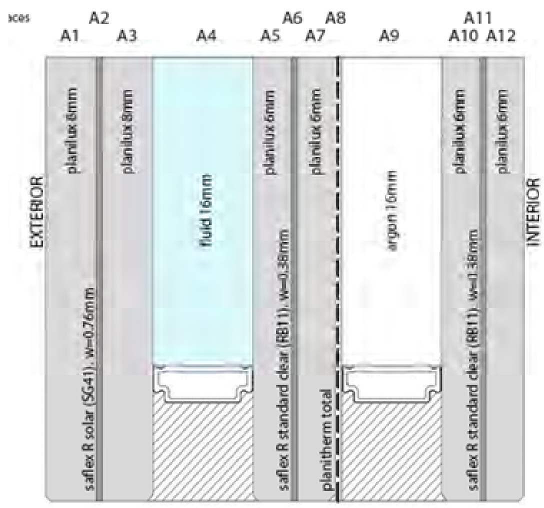
TYPE OF SHADING DEVICE	
Screens / roller shades	☐
Blinds with slat angle control	☐
Bi-directional transmission control	☐
Insulating shutters	☐
Shading with dual-axis tracking	☐
Other (specify):	☐

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

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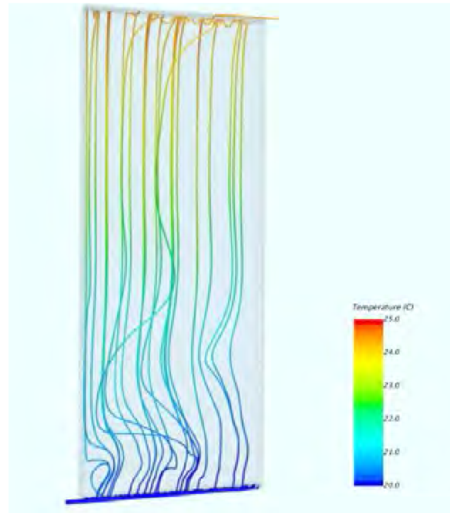
Rosa Romano
Florence University, Department of Architecture

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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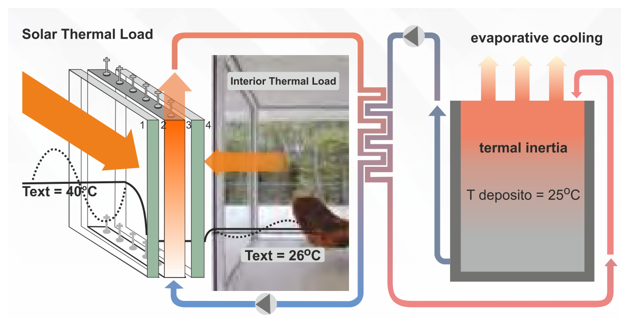

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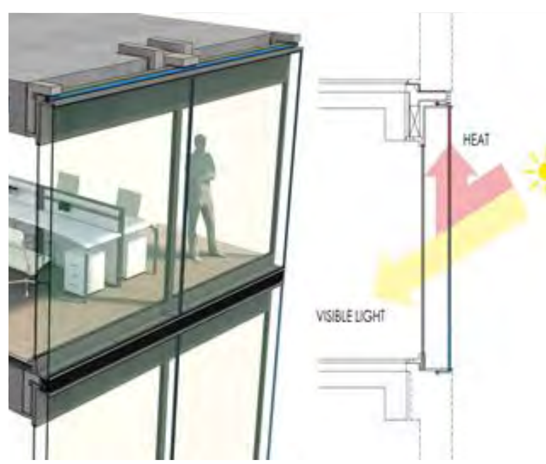
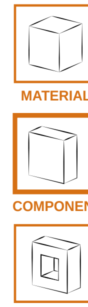


6

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



MATERIAL

COMPONENT

FACADE

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	-

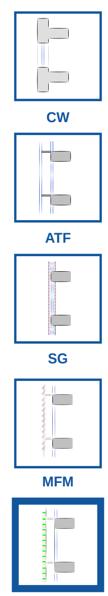
DETAILED DESCRIPTION OF THE CASE STUDY SYSTEM

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	☐



CW

ATF

SG

MFM

BF

CS_06

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): 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	■

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. 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	□

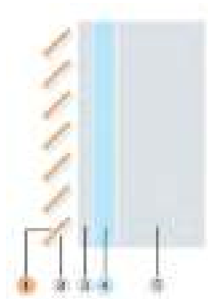
ECONOMICAL ASPECTS

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	☐

Cost/m2	-
Yearly cost of maintenance	-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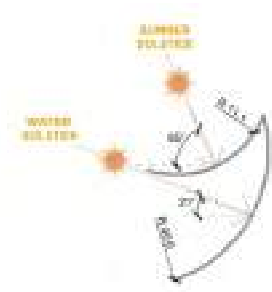
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6

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

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

Author of the sheet info
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Politecnico di Milano, Italy

Rosa Romano
Florence University, Department of Architecture

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

MATERIAL | **COMPONENT** | FACADE

‘ShapeShift’ is an experiment in future possibilities of architectural materialization and ‘organic’ kinetics. The project explores the potential application of Elec-tro 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 exter-nal actuators it is a highly attractive component for architectural solutions. In this proposal, the distinctive material
properties are not merely used as an actuator repla-cement but are also orchestrated for their aesthetic qualities. The thin film functions as a possible alterna-tive 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	☐

CW | ATF | SG | MFM | **BF**

CS_07

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): 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):	☐

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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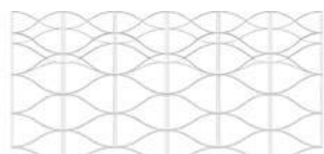
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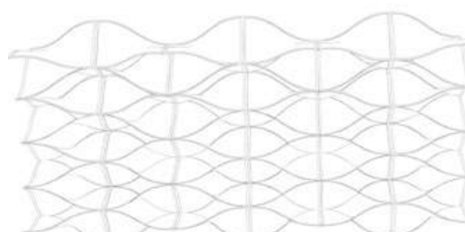
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6

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
© Manuel Kretzer

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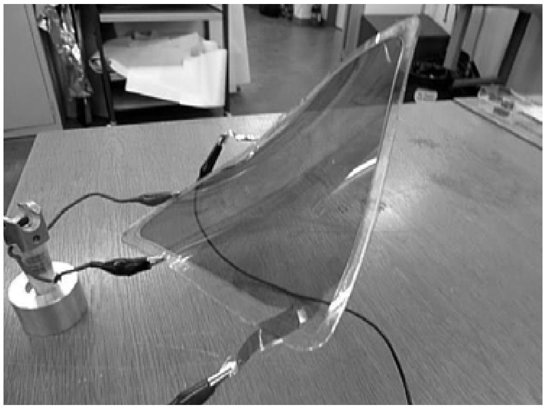
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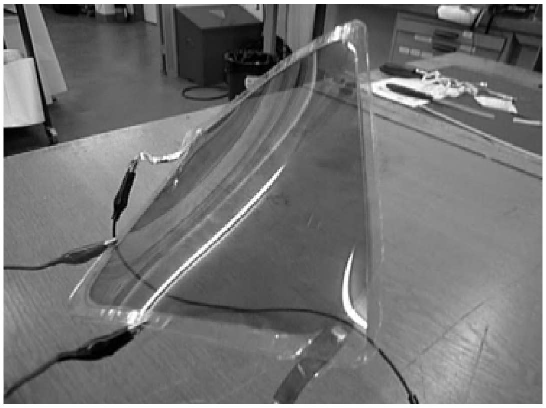
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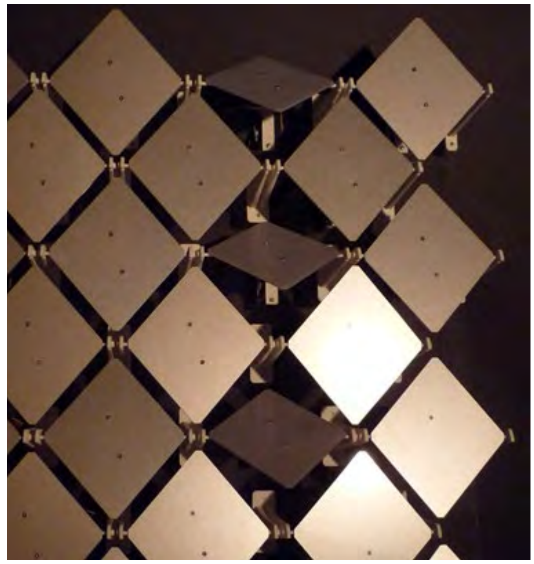
7. Electrical connection
8. Thin layer Prototype
9. Thin layer Prototype

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 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):	☐

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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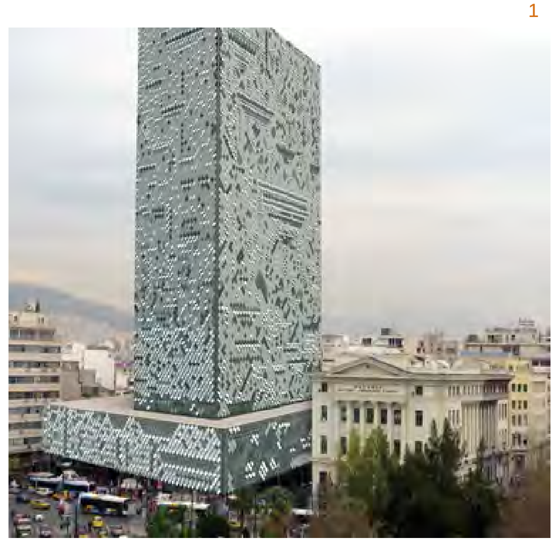

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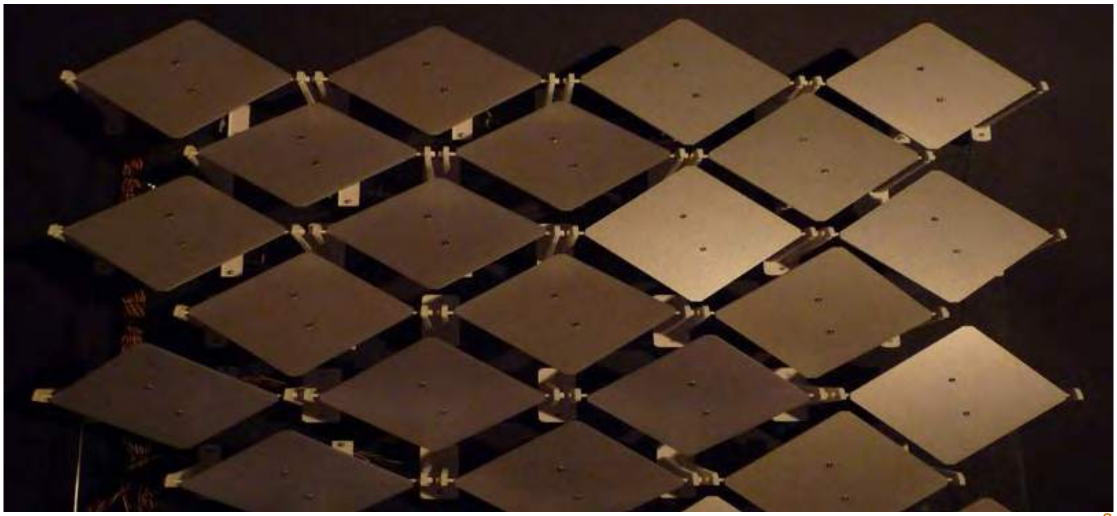
1. Side view of the kinetic prototype showing the 3D-printed armature that supports the kinetic panels. a-g. Various Cellular Automata patterns as manifested on the working prototype
2. Adaptive Fa[CA]de render

CONTROL OPERATION DETAILS



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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)	☐

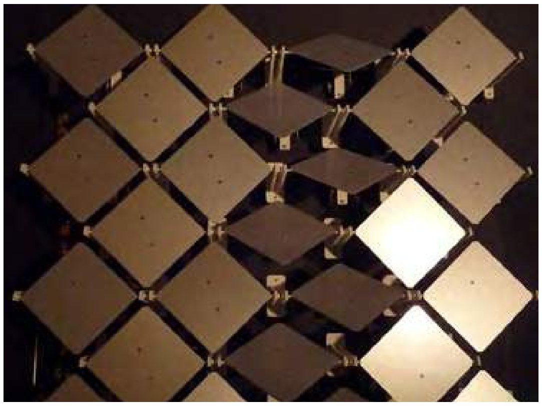
ECONOMICAL ASPECTS

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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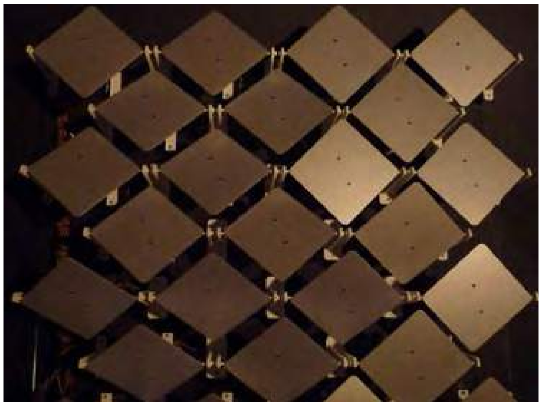
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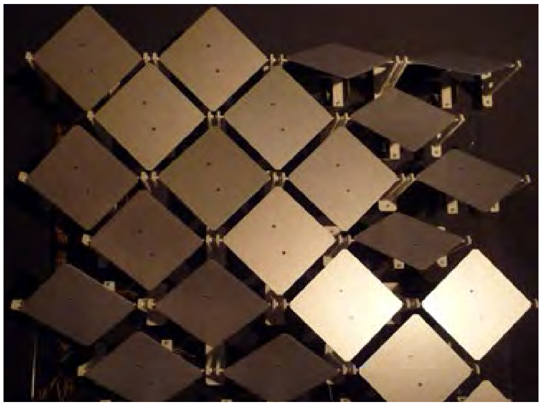
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Reference
Text description provided by: Marilena Skavara

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

Reference to picture:
© Marilena Skavara

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

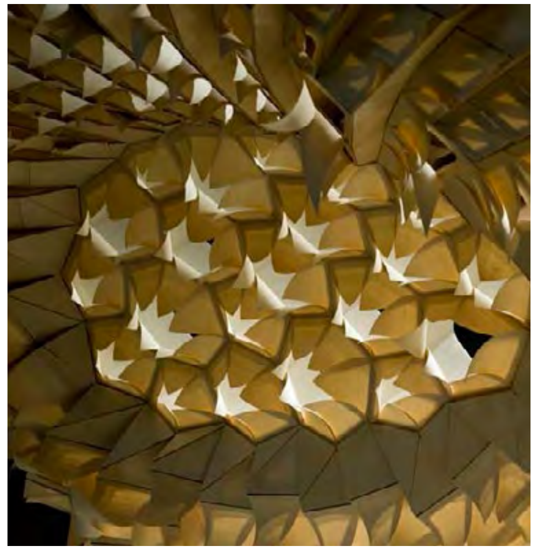
Rosa Romano
Florence University, Department of Architecture

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	☐

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

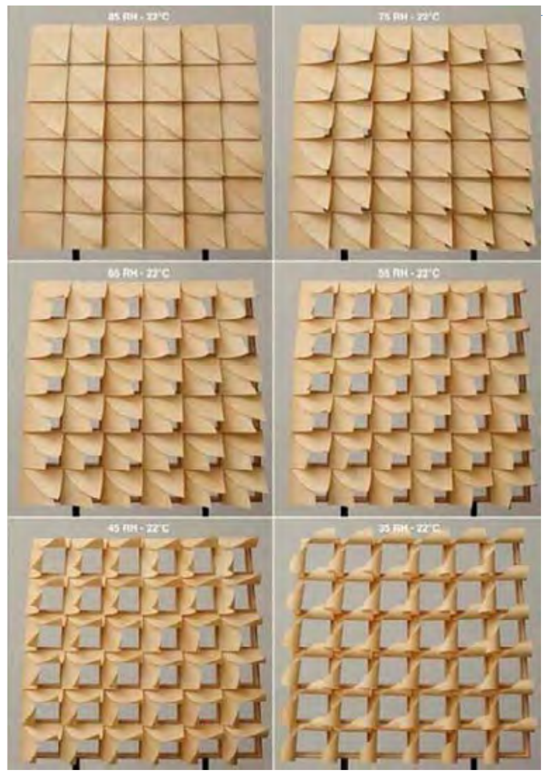
TYPE OF SWITCHABLE GLAZING	
Electro-chromic (EC)	☐
Liquid crystal, SPD	☐
Photo-volta-chromic	☐
Independently tunable NIR-VIS EC	☐
Thermo- tropic / chromic	☐
Photo-chromic	☐
Fluidglass	☐
Other (specify):	☐

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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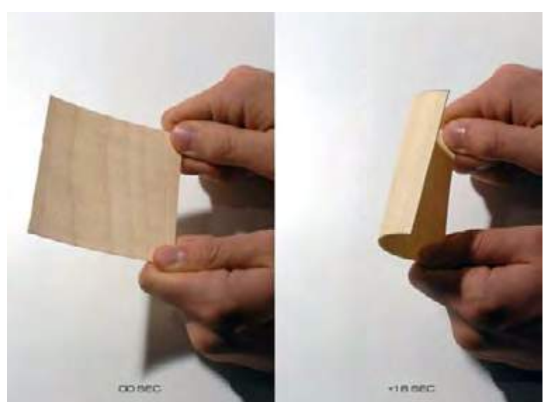

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1. Hygroscope – Achim Mengis/ICD Stuttgart 2012: Understanding material properties of wood – folding with humidity (www.achimmenges.net)
2. Hygroscope – Achim Mengis/ICD Stuttgart 2012: Understanding material properties of wood – folding with humidity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

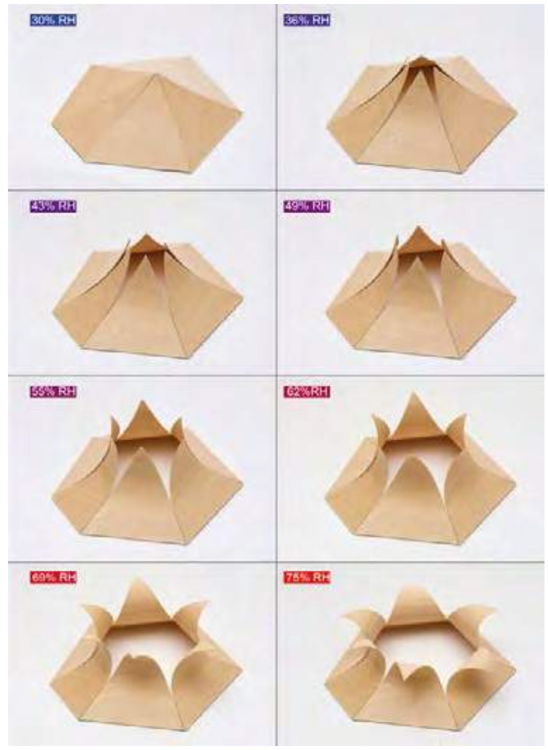
ECONOMICAL ASPECTS

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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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

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CS_10

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): Not present	■

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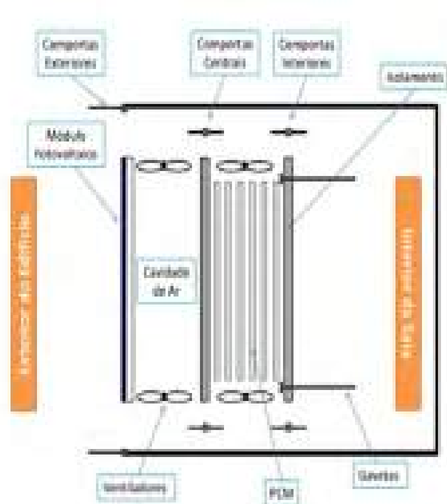

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1. Inside view of the prototype
2. System configuration
3. Views of the prototype installed on the SolarXXI main façade.

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)	☐

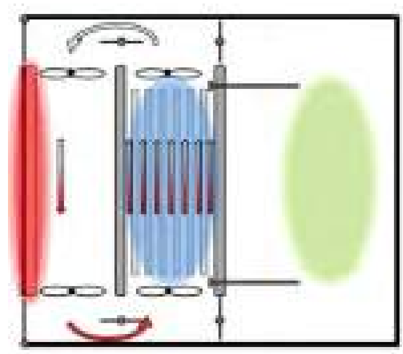
ECONOMICAL ASPECTS

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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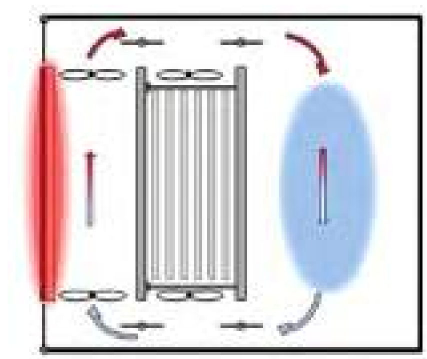
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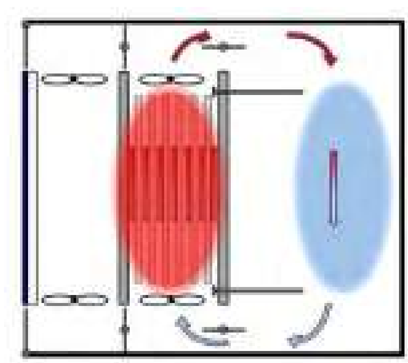
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4. Operating mode 1. Winter configuration. Heat transfer from PV to PCM
5. Operating mode 2. Winter configuration. Heat transfer from PV to the indoor space
6. Operating mode 3. Winter configuration. Heat transfer from PCM to indoor space

Reference

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