Overview of 100 climate adaptive building shells

Loonen, R.C.G.M.

Document license:
Unspecified

Published: 01/07/2010

Document Version
Publisher’s PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:

• A submitted manuscript is the author’s version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher’s website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

Citation for published version (APA):

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

• Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
• You may not further distribute the material or use it for any profit-making activity or commercial gain
• You may freely distribute the URL identifying the publication in the public portal

Take down policy
If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Download date: 17. Dec. 2018
Overview of 100 Climate Adaptive Building Shells
Overview of 100 Climate Adaptive Building Shells

part of MSc. Thesis

CABS – What can we simulate?

21 June 2010

Student | R.C.G.M. Loonen
---|---
id | 0570677
Master | Building Services
Faculty | Architecture, Building & Planning
Eindhoven University of Technology

Advisors

prof. dr. ir. J.L.M. Hensen
dr. dipl.-ing. M. Trčka
D. Cóstola, MSc
Preface

This booklet presents the overview of 100 climate adaptive buildings shells (CABS) that was developed as part of the MSc project “CABS – What can we simulate?”. The overview is preferably read in conjunction with the main body of the thesis, however, it was drafted in such a way that it also invites to be examined in a stand-alone manner.

The concept of CABS is very broad and described by a multitude of different terms. Many building envelopes do exhibit some form of dynamism; in this overview only those concepts were included that fulfill the following definition:

*A climate adaptive building shell has the ability to repeatedly and reversibly change its functions, features or behavior over time in response to changing performance requirements and variable boundary conditions. By doing this, the building shell effectively seeks to improve overall building performance in terms of primary energy consumption while maintaining acceptable thermal and visual comfort conditions.*

Beside being used as reference book for the thesis, the material presented in this booklet serves more purposes. By synopsizing case studies, prototypes and research projects it offers a technology scan that shows the state-of-the-art in adaptive façade technology. This information can be used by professionals engaged in development of building envelopes, and also provides a point of inspiration for designers exploring possibilities to enrich the domain of adaptive building shell technology.

The overview of 100 CABS is the result of an extensive literature survey, collected from different kinds of information sources. It attempts to provide a comprehensive database that covers the whole spectrum of CABS, ranging from built examples that successfully operate for many years, to the wildest utopian concepts. The field of CABS is relatively young and in a continuous state of flux. Therefore the expectation is that this compilation will soon be superseded by even more appealing concepts and better performing technologies.

Before starting the actual overview, the next page first provides a short introduction that (i) helps to understand the logic of classification, and (ii) shows a legend to the symbols and abbreviations used in the overview.
Introduction

► In two or three sentences, this section gives a short description of the working principles of the concept.
► The functions and performance aspects of the concept are indicated and substantiated with claims by the author or developer.
► For more details and additional information, the interested reader is encouraged to investigate the references in the bottom right corner.

The relevant physics of Chapter 4 is presented in this section.

This area features some pictures and schematic drawings that demonstrate the working mechanisms and appearance of the concept.

Adaptive surface, indicated via thick lines
State of development, indicated via colors
Active Building Envelope

In ABE systems, photovoltaic (PV) cells are used to transform solar energy directly into electrical energy.

This electrical energy is subsequently used to power thermoelectric (TE) heatpumps. Both TE and PV systems are integrated in one enclosure surface.

Depending on the direction of electrical current applied to the TE system, ABE systems can either operate in a heating or cooling mode.


Active window / micromirror

University of Kassel | Germany

- Large-areas of micromirror arrays (150 x 400 μm²) enable translucent protection from solar glare and sunshading, controllable both in terms of time and activation area.
- Each mirror can be moved within a prescribed angular range, by application of small voltages between the mirror layer and a planar ITO electrode.
- In contrast to macroscopic solutions, such micromirror-based solutions are nearly invisible, weatherproof and maintenance free.

Adaptive Fritting

- Integrated glass units with movable fritted patterns that allow for a broad range of possible transparencies.
- Utilizes a graphic pattern surface treatment, inspired by nature, in order to control heat gain and modulate light, while allowing sufficient transparency for viewing.
- Winner of the Wyss Prize for Bioinspired Adaptive Architecture 2009.


The biomimetic surface is inspired by the color change of cephalopod skin.
- Elastic membranes change volume between two layers of the façade and in this way control levels of daylight and solar gains.
- Pneumatic pressure is the driving force behind the adaptive mechanisms, and the ventilation tubes are integrated into the external layer.

---

Aegis Hyposurface
Mark Goulthorpe | dECOi Architects | 1999-2001

- The system consists of transformable triangulated metal plates, driven by a bed of 896 pneumatic pistons.
- Deforms in real-time, based on various environmental stimuli, including the sounds and movement of people, weather and electronic information.
- The piece marks the transition from autoplastic (determinate) to alloplastic (interactive, indeterminate) space.

The grid system provides panels of controlled permeability that vary smoothly between a covered state and a largely open state.

In its covered configuration, the shading roof appears similar to a traditional coffered Islamic roof.

When retracted, the roof becomes a slender lattice that complements the designs by the Foster team for fixed shading.
When the slats are open, heat is prevented from building up in glazed rooms and conservatories because warm air can escape via the chimney effect.

In winter, when the roof is closed, the infrared radiation (IR) can pass through in only one direction. The warmth thus remains under the roof.
Aperture

Frédéric Eyl and Gunnar Green | University of the Arts Berlin, Germany | 2005

► This façade installation consists of a matrix of iris diaphragms.
► Like the human eye's iris and irises in camera objectives, they react to light, widening and contracting with corresponding increases and decreases in intensity of incoming light.
► The degree of opening is controlled via Light Dependent Resistors (LDR) that actuate servo-motors.


Arabe Intitute du Monde
Jean Nouvel | Paris, France | 1987

► Arabe Institute du Monde is perhaps the most widely known example of a building with a climate adaptive building shell.
► The automatically controlled shutters are a technical interpretation of the traditional Arabic sun screens in integrated pane systems.
► The mechanical irises open and close in response to different light conditions over the course of the day.


Arab World Institute, Jean Nouvel, Projects, Paris. Website: http://www.jeannouvel.com
Balloon Sun Shading

Marcel Bilow, Tillman Klein | TU Delft, The Netherlands | 2006

- The entire system is a combination of deflated (façade) and inflated (balloons) construction elements.
- Inflating the balloons creates an integrated active mechanism for daylight regulation and solar protection.
- An additional positive feature is that the shading system also makes profit of the acoustic qualities of the balloons.

[Knaack et al, 2008]
A form of movable insulation and shading that uses tiny polystyrene beads blown into the space between two window panes.

Beadwall windows are a great application for greenhouses with the ability to drain and let the sun in during the day and then fill up to maintain temperature at night.
Bengt Sjostrom Starlight theatre
Studio Gang Architects | Rockford, Illinois | 2003

► The faceted roof consists of six triangular, stainless-steel-clad panels.
► Under the folded, origami-like roof, an intimate social setting is created with a porous boundary to the landscape.
► The roof can provide weather protection, if necessary. But when the roof is fully open, the panels form a six-point star through which the audience views the starlit sky.

[http://rockvalleycollege.edu]
[http://archdaily.com]
[http://archdaily.com]
[Fox and Kemp, 2009]

► Starlight Theatre, Uni-systems, featured projects, Website: http://www.unisystems.com/Projects/FeaturedProjectDetails.aspx?ProjectID=3&PN=Starlight%20Theater


Bi-directional thermodiodes
Cheju National University| Republic of Korea

- Like electric diodes, thermodiodes have a favorable direction of heat flow. This forward direction can reversibly be changed via rotatable joints.
- The tested thermal conductivity of the thermodiode panels in forward mode is 3–5 times higher than that in backward mode.
- Three different system types have been studied: tilted rectangular loops (see figures), bayonet-shaped diodes and loop-and-tank diodes.


The envelope transforms into a distributed ventilation system via contractions and expansions of an elastic membrane.

The skin performs a process of inhaling and exhaling via lung-like chambers inspired by the respiratory surface of sea sponges.

The constantly changing rate of deformation of the functional units is controlled via piezo-electric actuators.


BioTower

Dennis Dollens,

- BioTower adds value to the building with its leaf-cluster systems for air filtration, sound baffling and heat control.
- The cladding consists of a series of branch panels with an origami-like folded paper skin modeled from the observation of leaves.
- The outer biomechanical sensor-node pods embed biological filters, and passive cooling system embodied in digital leaf panels.

Rather than only blocking the sun’s rays, the design re-envisions blinds as sun-soaking solar panels that store energy during the day and illuminate the interior at night.

With the revolving blades, the course of the sun is followed in order to catch a maximum of energy and convert the energy in PV cells.

The electricity is stored in a battery, and re-emitted at night via electroluminescent foil.
Bloomframe Balcony
Hurks Geveltechniek | The Netherlands | 2007-2010

► An innovative window frame that can be transformed into a balcony-on-demand: users can add light, air and space to a space with a single push on a button.
► The dynamic balcony offers an opportunity to add outdoor space to compact apartments, offices or hotels in inner city areas.
► Winner of the prestigious Red Dot design award 2008 and Wallpaper design award 2009.


Breathing wall

Breathing wall or “dynamic insulation” panels form the basis for a distributed ventilation air supply system where the wall functions as (i) a supply source, (ii) heat exchanger and (iii) filter for airborne pollutants.

The building fabric is used as cross-flow heat exchanger through which the movement of air from outside to inside is controlled. As a consequence, the U-value is a function of the air-flow. The amount of airflow can be both passive, or actively controlled.


The two storey tall aluminum shutters transform this circular building into a real eye-catcher.

While individually adapting in response the sun, the fins take care of an optimized balance between daylight utilization and solar gains.

The whole system is controlled via a coupling to the overall building energy management system.

Bremtex

VOW architecten | Oisterwijk, The Netherlands | 1996

Bremtex, VOW architecten, projecten. Website: http://www.vowarchitecten.nl/architecten/projecten/project03/project03-buiten.htm

The brise soleil covering a museum pavilion is made up of 72 steel fins, ranging in length from 8 to 32 meter, which makes that its span is comparable to that of a Boeing 747-400.

The “wings” open Tuesday–Sunday at 10 a.m. with the Museum, close/reopen at noon, and close again with the Museum at 5 p.m.

Whenever wind speeds exceed 37 km/h for more than 3 seconds, the wings close automatically.
LED elements are combined with the steel mesh and sandwiched between layers of switchable PRIVA-LITE glass.

This innovative system allows the building to take on different appearances during the course of the day.

During the day, the electrooptic glass is switched to the transparent or translucent state, but at night, the façade becomes a projection screen for the 700,000 LEDs.

Hexagonal shading units will occupy the central circular atrium as well as the eight peripheral atria of the judicial complex.

When extended, the system will cover the entire triangulated roof grid. When retracted, their profile will ‘disappear’ into the structural profile of the roof.

A custom algorithm combining historic solar gain data with real-time light-level sensing will control the shading units.


Climate Adaptive Skin


► All functions for heating, cooling, solar control, energy storage, ventilation and electricity generation are integrated in a single skin.
► The system is universally applicable on every building because it is able to operate independently of building services.
► Maintenance and servicing is kept as low as possible because the number of moving parts is limited.


Curtain Wall House
Shigeru Ban Architects | Tokyo, Japan | 1995

► The pliable fabric used in the walls’ construction makes it possible for them to fully retract, channeling more light and air into the core of the house. In winter, the curtains close to retain heat.
► In cold weather, a set of glazed doors can completely enclose the house for insulation and privacy.
► The building shell is described as the literal interpretation of a curtain wall façade.

Da Vinci Rotating Tower

David Fisher | Dubai | 2010-2011

- The floor segments rotate independently and individually; one rotation can take place in 90 minutes.
- The rotating tower is the first skyscraper to be entirely assembled from factory-produced pre-fabricated parts.
- The technology that will enable the floors to rotate autonomously is triggered according to tenants' wishes via voice commands.


Rotatable blinds and a translucent insulation material together form this functional roof that is covered by a single ETFE layer.

Adaptivity of the roof allows for maximum flexibility of interior and furnishing in the windowless conference rooms below.

Because thermal insulation and the blinds are sandwiched between polymer layers, these systems are protected from rain and maintenance is minimized.


Deployable External Insulation offers the possibility of actively modulating building fabric thermal performance.

The movement of insulative shutters is passively controlled via phase change wax piston actuators.

One piston (the ‘cold’ piston) opens the shutter when the temperature rises above a minimum. A second piston (the ‘hot’ piston) closes the shutter when the temperature exceeds the maximum threshold.
The kinetic external cladding acts as shading device and produces electricity via thin film solar cells.

The degree of shading is automatically controlled via a thermal expansion material (linear actuator) with PTC thermistors.

The expansion material is wrapped with insulation in order to ensure that light is the only controlling stimulus.

Dr. Jockisch Building
Architecten HBH | Landshut, Germany | 2000

► The mobile photovoltaic sunshading system covers 3/8 of the façade and follows the sun while it floats around the building.
► Motorized wheels support the structure of 182 PV-panels on its way around the building.
► A sloped ‘solar shield’ mounted on the roof provides additional electricity generation.

Eclipsis shutter shade
Virginia Tech’s entry to US DOE Solar Decathlon competition | 2009

- *Eclipsis shutter shade* is made from stainless steel and a translucent polycarbonate panel filled with aerogel.
- The shutter shades can slide along the north and south façades, providing protection from direct sunlight while simultaneously allowing for indirect, natural lighting, views to the exterior and privacy to those inside.
- The home’s smart system gathers information from its rooftop weather station to automatically control the screens.


Lumenhaus homepage, a brighter way, everyday. [http://www.solar.arch.vt.edu/](http://www.solar.arch.vt.edu/)
These imaginary devices are perhaps the building’s environmental control system of the future.

Their function would be to patrol building façades by regulating energy consumption and indoor comfort conditions.

Basic duties of these autonomous agents include closing unattended windows, checking thermostats, activating movable insulation panels and adjusting blinds.

[Sullivan, 2006]


Electrochromic glazing

- An electrochromic coating enables the glass to switch its optical properties and hence color, while maintaining transparency.
- The optical properties can be controlled on-demand or via intelligent supervisory control systems.
- Because of the adaptability, thermal and visual comfort can be improved while energy consumption is minimized.


Electrically heated glass

- The window can perform three functions: heating, anti-condensation and snow melting.
- Active insulating glazing with low-emissivity coating and embedded electrodes also improves the thermal distribution in the room.
- This concept offers highest potential in regions with extreme climates, like Scandinavia, Siberia and Russia.


Quantum Glass Brochure – inspiring solutions by Saint-Gobain.
ETFE roofs

- ETFE (ethylene tetrafluoroethylene) is increasingly used in buildings because of its lightweight properties, high daylight transmittance and the potential for energy savings.
- Compared to conventional glazed roofs, ETFE cushions can provide thermal insulation with reduced initial costs and less structural supports.
- Application of a reflective frit to an inflatable intermediate cushion can dynamically alter the roof’s optical properties.


The integrated photovoltaic shading system creates a temporary double skin façade while floating around the building. The kinetic PV-wall provides shading when and where desired, and at the same time maximizes electrical output. Daylight and view to the outside are unobstructed in the rooms that are not exposed to direct sunlight.

Flare façade

WhiteVoid interactive art and design | Berlin, Germany

- Acting like a ‘living skin’, flare façade allows a building to express, communicate and interact with its environment.
- The system consists of a number of tiltable metal flake bodies supplemented by individually controllable pneumatic cylinders.
- By reflecting ambient or direct sunlight, the individual flakes of the FLARE system act like pixels formed by natural light.


Flare – kinetic ambient reflection membrane, Website: http://www.flare-facade.com

The concept consists of a four layer glazing element with two fluid filled chambers and one gas filled chamber in the middle. Colored water in the external cavity is used for control of solar gains; water in the inner cavity serves as transparent large area heating or cooling element. Heating, cooling and shading levels are regulated by controlling fluid flow levels and water color.

Gemini Haus

ArchBüro Kaltenegger | Weiz, Austria | 2001

► About 40 m² of window-area is always orientated towards the sun for maximum passive solar heating.
► The solar curtain at the front (output 4.0 kWp) rotates uni-axially around the vertical axis of the building and helps to avoid overheating.
► The PV modules integrated in the façade receive the sunlight via hologram foils, thus enhancing the electrical output.

ArchBüro Kaltenegger, Projekte, Wohnbau. Website: http://www.erwin-kaltenegger.at/projekte/wb_ef.php?was=090915_1547

'Mit dem Energieüberschuss die Hypothek abzahlen', Frankfurter Allgemeine Zeitung, 16 July 2002, page T6
The first building in the world that uses a single layer of transparent film, which spans the complete height of the façade.

This was the only way to create the double curvature spiral form that covers a multi-story void.

During the night, vents in the façade open up which enables effective stack-ventilation of the heat that is built up during the day.


Girasol

COLT international Ltd. | United Kingdom

► Girasol (Italian for sunflower) is a controllable external shading system consisting of glass louvers with photovoltaic cells integrated into the glass.

► The innovative, autonomous passive sun-tracking system does not consume any electricity.

► Two absorber evaporator tubes cause different expansion or contraction of a working fluid. This difference in pressure in turn actuates the thermohydraulic drive mechanism.


GlassX crystal integrates four functionalities into a single unit: transparent insulation, overheating protection, energy conversion and thermal storage.

The key component is the slim transparent PCM heat storage module which has a storage capacity equivalent to about 20 cm concrete.

Solar heat is stored in the PCM by means of a melting process. At night, the stored heat is delivered to the interior during re-crystallization.


GlassX – Speichern, Wärmen, Kühlen, Website: http://www.glassx.ch
The world’s largest display area (2200 m² - 2292 LEDs) combines sustainability with digital media technology.

The system is also called ‘Zero Energy Media Wall’ since no external power is required to fuel the diodes.

In addition, the photovoltaic panes provide a means for both natural ventilation and solar shading.


GROW

► GROW is a hybrid energy delivery device that provides power via the sun and wind.

► The solar leaves act as micro-power stations by employing thin film photovoltaics with piezoelectric generators and screen printed conductive ink encapsulated in ETFE fluoropolymer laminates.


SMIT - Sustainably Minded Interactive Technology, Website: http://www.S-M-I-T.com

This concept is exploring the possibility of using sensitive textile skins on buildings to create energy independent structures.

Electronics and bio-chemical functionalities are being introduced in the building shell.

The membrane is used as transporter for collecting and channeling air, water and light, from the outside feeding into the inside space.

Off the grid: Sustainable Habitat 2020. Website:
http://www.design.philips.com/probes/projects/sustainable_habitat_2020/index.page

The building has been named after heliotropism which refers to plants that grow in response to the stimulus of the sun.

Via a powerful engine, the building is able to vary its orientation in response to the sun.

One-half of the building is highly glazed, the other side is well insulated. A central control system decides which side will be exposed to the sun.


Heliotrop, Robert Disch, Projects, Website: http://www.rolfdisch.de/project.asp?id=45&sid=-1402147115
The environment-responsive kinetic glass façade consists of an array of transparent lamellas and panels of six LEDs embedded in the window sills. Each lamella responds to temperature and wind signals from roof-mounted weather sensors. The whole façade moves slowly when the weather is quiet, and faster when it is windy. Color patterns and shades of each hue are programmed to change subtly with time and temperature.
Because the envelope acts as ‘thermometer’, it gives a special aesthetic appearance to the building.

Each node of the steel mesh consists of one photovoltaic cell, a battery, CPU and a RGB LED which creates an artificial light cloud around the hotel.

The light mesh has sensors that will read the daylight sun amplitude and then at night each node will give off color according to how much that node had absorbed.
每面垂直百叶窗可以强制弯曲，从而控制进入建筑的自然光和热能。
- 在运行过程中，百叶窗的作用非常像鱼的鳃。
- 每到晚上，膜会改变颜色以显示人们接近建筑的情况。
IC solar façade system
Rensselaer Polytechnic Institute | Troy, New York | 2007-2010

- Solar concentrating tracking technology is transferred to a day-lighting system within a ‘double-skin’ façade.
- The lens directly concentrates the light (>400:1) onto a high-efficiency multi-junction PV cell that recently demonstrated an efficiency of 39.4%.
- Absorbed power that is not converted to electricity is captured via a coolant flow and is used for domestic hot water generation and space heating.


RPI, Center for Architecture, Science and Ecology, Website: http://www.case.rpi.edu/projects/ICsolar.html
Kameleon Concept

Sublean | Sliedrecht, The Netherlands | 2009

- The concept consists of a rotatable aluminium box girder with four different surfaces and replaceable coffers.
- Depending on the prevailing weather, the façade can perform different functions: e.g., energy generation, heat storage, air purification, advertising and rainwater drainage.
- The system is designed to create maximum value, 24 hours a day.


Submission to the competition: Het ei van Columbus, ‘Kameleon concept’, Website: http://www.ei-van-columbus.nl/inzendingen/inzending/419
Kinetic light

Christian Möller and Rüdiger Kramm | Frankfurt, Germany | 1992

- Behind a screen of perforated aluminum, 120 floodlights fade from blue to yellow, illuminating the front of the building.
- The overall image is directed by a weather station on top of the building: The ambient temperature determines the amount of yellow on the blue wall; The yellow patches move in line with the direction of the wind and rain; LED lines in the upper area of the façade visualize noise in the street in real-time.

Kinetic roof Medina house

Because the sun changes position, the roof keeps moving like a living structure.

Winter day: the kinetic structure opens to the sun and its warm light.

Winter night: the roof closes to keep the heat inside.

Summer day: the roof “denies” the sun while facilitating cross ventilation.

Summer night: the kinetic roof opens for night ventilation.


Le mur neutralisant

Le Corbusier | 1929

- Le mur neutralisant is often considered as the revolutionary predecessor of the double skin façade.
- It consists of two glass panels within which tempered air is flowing at a constant temperature of 18 degrees Celsius.
- This air layer neutralizes the effects of the cold downdraught in winter or keeps solar heat outside in summer, thereby enhancing thermal comfort conditions throughout the whole year.


Living glass
The Living | New York | 2005

- Elastic shape memory alloy (SMA) wires control the level of carbon dioxide in a room.
- High CO₂ concentrations force SMA wires to contract and pull open slits etched in the window to allow fresh air to flow in.
- Inspired by the gill, the respiratory organ that controls the absorption of oxygen and the secretion of carbon dioxide in most aquatic organisms.

Living walls and roofs

► These self-sufficient vertical or horizontal surfaces restore the level of flora and fauna in the urban context.
► The systems add mass and thermal insulation to the building shell and are also useful for controlling rainwater runoff.
► The plants can help to reduce overall temperature of building surfaces via evaporative cooling which reduces energy consumption.


L’hemisferic
Santiago Calatrava | Valencia, Spain | 1998

- A large shelter over a spherical IMAX theatre that opens up in the same way as a retractable eyelid.
- The aluminum awnings can fold up individually or collectively over the full breadth (90 meter) of the building.
- The system is actuated via telescoping hydraulic cylinders which allow fresh breezes to enter the inside.

City of sciences and arts in Valencia, Santiago Calatrava, Recent projects, Website:
http://www.calatrava.com

Liquid façade

► Water is used for its thermal mass and energy storing capabilities and the system also has a load bearing capacity.
► Insulation values can be controlled pneumatically by changing the position of the water-filled chamber.
► In future generations the water can be used for collection of thermal energy to supply heating and cooling to the building systems.

Metal shutter houses
Shigeru Ban Architects | New York, USA | 2007-2010

► The building can literally become a uniform minimal closed cube, or it can open completely.
► Perforated metal shutters on the outside can modulate incoming light and acts as privacy screen.
► Additionally, sliding glazed doors on the inside can be opened to further blur the boundary between inside and outside.

Metal Shutter Houses, Shigeru Ban West Chelsea, Website: http://www.metalshutterhouses.com/
‘Eyes wide open - Shigeru Ban’s "metal shutter houses" under construction in Manhattan’, World Architecture News: editorial 28 October 2007
An array of overhanging pre-stressed ‘invisible’ microblinds with a size of 100 micrometer covers the window.

Curling of microblind-electrodes is electrostatically activated.

Arrays can be deposited on the flat glass by magnetron sputtering like regular low-E coatings, and then patterned by laser.

The microblinds have several advantages including switching speed (milliseconds), UV durability, customized appearance and transmission.

[Lamontagne and Py, 2006]


[Lamontagne, B. (2009) Next generation of smart windows based on micro-blinds (MEMS) and Silicon photonics at IMS-NRC: from bio-sensing to space applications, Lecture in Mininova, Helsinki University of Technology]
Nano Vent Skin

Augustin Otegui | 2008

- This conceptual project tries to make (existing) objects greener with a skin made out of micro windturbines.
- Kinetic energy of the wind is converted into electricity and at the same time, CO$_2$ is absorbed via organisms inside the turbines.
- The outer skin of the structure absorbs sunlight through an organic photovoltaic skin.


Nocturnal ventilator

Nick Browne | Bartlett School of Architecture | London, UK | 2005

- The system stores thermally induced movement of a wax piston over a day’s temperature change in a spring mechanism.
- The spring is then released during the night via an ingenious mechanism, and this creates a breeze that lasts for hours.
- Arrays of ventilators can be retrofitted to existing dwellings, and provide energy-free localized ventilation.


The façade of the museum consists of translucent glass-fiber-reinforced panels that can be pivoted over their whole length.

By opening the stacking shutters and awnings (shitomido), a spatial continuity between the interior and exterior is achieved.

This enables outside air to freely flow into the building while at the same time protecting the building from overheating via solar shading.


Calatrava designed a symmetrical system, covering the glazed roof of a largely underground building.

Two arched tubes position the articulated slats on each side of the roof, and in this way dynamically control daylight.

The system was the first application of a movable roof cover based on slats in combination with a mechanical hoist system.

Pfalzkeller
Santiago Calatrava | St. Gallen, Switzerland | 1998

Pfalzkeller Emergency Service Center, Santiago Calatrava, Past projects, Website: http://www.calatrava.com

'Santia Calatrava St Gallen', Kinetic Architecture blog. http://kineticarchitecture.blogspot.com/2008/05/santiago-calatrava-stgallen_27.html
The roof consists of a deployable shelter that can serve two functions: 1) collecting rainwater and 2) providing sunshading.

Water sensors on the roof double the areas able to catch rainwater when necessary and store the water for use in toilets and the garden.

The house has a dynamic overhang which allows valuable solar gains in the winter but avoids overheating in summer.


Photochromics

► These materials reversibly change their color when exited by the effect of light (electromagnetic energy).
► A common application is its use in self-adjusting sunglasses, but architectural implementation is also pursued for a long time.
► Relatively high costs, sensitivity to heat and poor long-term behaviour have prevented large scale use of these systems.

The system consists of a combination of electrochromic glass and ultra-bright electroluminescent tubes controlled by a distributed network of microcomputers and sensor consoles.

The architectural surface is designed to switch between a conventional window and a display/advertising/communication screen.

Pyroelectric sensors on each disk are used for controlling transparency.


A matrix of interconnected pixel tiles that are controlled interactively via embedded controllers.

- The system utilizes two-state material SMA wires for actuating each pixel in one of 255 potential states.
- The surface can also be used to generate dynamic low resolution images.


PV honeycomb glass façade
Daisuke Nagatomo and Minnie Jan | Japan | 2006

► Display skin and structural design are integrated in Honeycomb system.
► The energy generated by photovoltaic panels will be used to illuminate high-efficiency LED lights at night.
► The system mimics nature: honeycomb structure has durability, like Radiolaria, and optical efficiency, like fly’s eyes.

Responsive kinetic façade
SOM and Sci-Arc | 2008

► A composition of hinged glass panes and spandrel panels laminated with solar cells.
► The flexible skin is capable of changing its shape, controlled via magnetic switches that are powered via the PV cells.
► The building skin is considered as a pump: depending on the season, air is supplied to or extracted from the room.

Roof pond Hammond house
Jonathan Hammond | Winters, California | 1975

- Large water storing bags are covered by insulating hinged lids which are opened and closed by a hydraulic ram.
- When the panels are raised on sunny winter days, water bags are exposed to the sun, while the panels act as reflectors to enhance absorption of solar radiation.
- In summer, the panels are raised at night. Absorbed warmth from the inside is released to the cool night sky, via radiation and convection.

Sagami bay house
Foster + Partners | Tokyo, Japan | 1987-1992

► This modern dwelling is designed according to the high transparency guidelines of traditional Japanese architecture.
► The architects brought even more light into the main house by conceiving the roof as a fifth façade of glass.
► The roof creates a theatre of shifting light inside, adding another dimension to the variety of light admitted by the perimeter of glass.


House in Japan, Tokyo, Japan, Foster+Partners Projects. Website: http://www.fosterandpartners.com/Projects/0411/Default.aspx
Self-regulating ventilation

- Via a combination of pivoting and bending mechanisms, the ventilation grille installed in the window frame becomes ‘self-regulating’.
- These vents can achieve stable ventilation levels in spite of the highly irregular variations in natural driven conditions.
- The system also allows for users intervention via a manually controlled ventilation flap.


Showroom Kiefer technic
Ernst Giselbrecht + Partner | Bad Gleichenberg, Austria | 2007

- The shades of this dynamic façade can be adapted individually to changing conditions and needs.
- The façade changes continuously; each day and each hour shows a new “face” - the façade is turned into a dynamic sculpture.
- A video clip featuring a choreography dedicated to this ‘dancing façade’ already attracted more than 160,000 viewers on YouTube.

Showroom Kiefer technic, Giselbrecht + Partner projekte, Website: http://www.giselbrecht.at/sect01_projekte/gewerbe_industriebauten/kiefer(frames_unten.html

e-architect, Kiefer Technic Showroom: Architecture Information, Website: http://www.e-architect.co.uk/austria/kiefer_technic_showroom.htm
Skytherm solar roof pond

Harald Hay | Atascadero, California | 1973

► The system consists of a large mass of water, packed in containers and placed on top of a metallic corrugated ceiling deck.

► The flat roof also holds an insulation panel that moves on rails to cover and uncover the water to the atmosphere.

► Depending on season and time of the day/night, the roof pond system can act as source of heating and cooling to the zone below.

Heating cycle

Cooling cycle

Smart Energy Glass

- An innovative coating allows the window to switch its optical properties in three different states: dark, bright and privacy.
- Part of the sunlight is captured and converted into electricity in PV-cells mounted at the edges of the window.
- When equipped with batteries, the system becomes autonomous and can be integrated in the building envelope without the need for external wires.

Peer+ | Eindhoven, The Netherlands

[www.peerplus.nl]

Peer+ Smart Energy Glass, Website: http://www.peerplus.nl

SmartScreen
Martina Decker and Peter Yeadon | New York

- The shading device is automatically activated by changes in local interior air temperature.
- The R-Phase SMA (shape memory alloy) smart material simultaneously acts as both a sensor and a motor.
- Adaptation is triggered automatically and consequently does not consume any fuel or electricity.


Smart shade
Lance Hosey | ATMO / Atelier Modern | Washington DC | 2005

- A passive solar shading device that automatically adjusts to changing light and heat conditions.
- Smart shade employs the thermodynamics of zinc and steel to control the amount of sunlight passing into a building's interior.
- Expansion and contraction of these sandwiched materials in response to temperature cause the blinds to curl up in winter (allowing more sunlight in) and curve down in summer (allowing less).


SmartWrap™


- Rolled and printed onto fabrics and plastics to fulfill the following functions: shelter, climate control, lighting, information display and power supply.
- The construction material features organic photovoltaics, thin film batteries and OLED’s, all inspired by the printing industry.
- The inner skin supports thermal storage and insulation via pockets filled with phase change material and aerogel.


Solar barrel wall

Steve Baer | Corrales, New Mexico | 1971

- During the day, thermal energy from the sun is collected and stored in a stack of 200 liter water-filled steel oil drums.
- At night, the external lids are closed while the internal lid is opened, so the stored energy is discharged to the room.
- The ends of the barrels are painted black, and the shutter is made highly-reflective; both effects together improve storage of thermal energy.


Bubbles in the transparent building cavity can provide insulation or shade as required.

A liquid film instead of bubbles acts as solar energy harvester or liquid cooling film.

The generation and movement of soap bubbles and the rainbow color reflection of soap bubbles provides a fascinating and charming atmosphere.


SolarBubbleBuild SolaRoof technology, Website: http://www.solarbubblebuild.com/
Solar Ivy

- A system of solar powered panels disguised to look like ivy leaves and made out of 100% recyclable polymer solar cells.
- Solar Ivy's unique visual appeal and flexibility brings a technology traditionally restricted to the roof to almost any architectural surface.
- It has the ability to provide varying degrees of opacity to modulate heat gain, actuated by the vagaries of the wind.

Solar Ivy, Website: http://www.solarivy.com
The system consists of an innovative reversible frame, incorporating two glazing assemblies: a clear glazing to provide a weatherproof seal, and an absorptive glazing to provide solar control. The two glazing assemblies and the ventilated channel between them rotate together through 180° to enable the transformation from winter mode to summer mode.

In winter, the glazing system allows passive solar space heating.

In summer, penetration of unwanted radiation is reduced, thus reducing overheating and visual glare. External shading devices are made unnecessary.


Sonomorph
Natasa Sljivancanin | 2007

- Sonomorph is a kinetic building system that changes its behavior in response to various acoustic stimuli.
- It consists of cellular components with aluminum outer panels and glass-reinforced plastic inner panels.
- By opening or closing these panels, the façade can change from a sound reflective to a sound absorptive state.


Stomata Inspired Skin

Michael Murauer | Austria, Vienna | 2004

- A functional biomimetic translation of stomata, the openings that control the gas exchange in the leaves of plants.
- At high relative humidity, the blue Cithosan polymer swells and separates the two layers of fabric, which increases airflow through the façade.
- The self-regulating smart material provides distributed ventilation and enhances the quality of the internal climate.

The key to the Sunbender’s performance is the adjustable reflector that can be mounted to every existing skylight.

In the lowered summer position, it shades the skylight and greatly reduces heat gain, while still allowing diffuse light to enter.

Sunbender allows collection of desirable heat during cold weather months, the curved shape of the reflector concentrates the reflected sunlight.

Sunbender
ZomeWorks Passive Energy Products | New Mexico, USA

Zomeworks Passive Energy Products, Sunbender Brochure

The round buildings and turnable roofs ensure optimal utilization of solar radiation.
The heliotropic horizontal sun-tracking roof produces a 25% surplus of electrical energy compared to a static configuration.
A central electro-hydraulic unit drives the system via small wheels on rails.
Super Cilia Skin (SCS) is basically a surface for displaying haptic and visual information but is also envisioned as dynamic cladding material.

Electromagnetic energy generators make it possible to harness energy from the wind blowing over the building’s exterior.

SCS can be both a billboard-like ambient display surface and a source for alternative energy that is also visually appealing.


The basic configuration consists of a horizontally pivoted window that is hinged just above mid-height.

The window starts moving when the wind blows, hence, the natural ventilation rate is a function of wind speed and direction.

Shock absorbers and a balancing weight ensure calm operation and a steady ventilation flow rate.


The system is based on the controllable release and re-absorption of hydrogen in metal hydride, which changes thermal conductivity.

Thermal conductivity can reversibly be changed by a factor 40, after applying a small amount of electricity.

Passive solar heat is transferred to the inside, but only at times when this is desired and advantageous.


The B&W house

Universidad Politécnica de Madrid | US DOE Solar Decathlon competition | 2009

- The Roof is self-orientating along the day, following the sun. Moving the PV roof gives 10.3% extra power compared to a horizontal fixed roof.
- The movable façades are clad with semi-transparent PV-cells. These façade panels are also oriented towards the sun in order to maximize the capture of solar energy.

Solar Decathlon, Team Spain, Universidad Politécnica de Madrid. Website: http://www.solardecathlon.org/2009/team_spain.cfm

UPM Solar Decathlon 2009, Website: http://www.solardecathlon.upm.es/
The esplanade

Movable triangular sunshades admit diffuse daylight while at the same time excluding direct sunlight.

The shapes and sizes of each of the 7139 shutters were determined on the basis of solar optimization studies.

Provides the building with climate control mechanism, much as an animal can raise the hair on its back.


Thermochromics

- Thermal energy (heat) to the material alters its molecular structure. Which in turn changes spectral reflectivity of the thermochromic material.
- The ‘smart material’ found its way in architecture via applications in switchable windows, concrete and wallpaper.
- Thermochromic windows become opaque in warm environment. Unfortunately, the system does not allow for manual override.


The Sliding House

dRMM architects | Suffolk, United Kingdom | 2008

- A 20 ton mobile roof-and-wall enclosure traverses the site on recessed railway tracks, and in this way gives the building envelope its adaptive properties.
- Sliding house offers radically variable spaces, and also provides different levels of shelter, insulation and ingress of daylight throughout the day.
- Winner of: RIBA 2009 award, Grand design award 2009 and WAF09 award.


dRMM projects, ‘Sliding house’, Website: http://www.drmm.co.uk/dRMM/projects/by%20name/sliding%20house/sliding%20house.pdf
“Turning the place over”

Richard Wilson | Liverpool, United Kingdom | 2007

- This piece of public artwork is a slowly rotating circle of the façade itself, offering recurrent glimpses of the interior during its constant cycle during daylight hours.
- The oval section cuts back into the building and veers out over the pavement as it goes round.
- The revolving façade rests on a specially designed giant rotator, usually used in the shipping and nuclear industries.


Wall integrated PCM

- Encapsulated latent heat storage material is incorporated in the construction elements of the building.
- Heat or cold is stored and automatically released when indoor or outdoor temperature rises or falls beyond the melting point.
- Phase change materials also have the ability to dampen temperature fluctuations without consuming energy.


Wall street ferry terminal
Smith-Miller + Hawkinson Architects | New York | 1995

► The fully retractable wall diminishes the threshold to the city and its living waterfront.
► In fair weather, the building opens to the south, erasing the line between inside and out.
► The terminal can also provide shelter, a place not only for the traveler, but for the local community as well.

Pier 11 Wall Street Ferry Terminal and Transit Hub, SMH+, Website: http://www.smharch.com/project_template.php?id=29&bgId=&category=planning

Weather Sensitive Envelope

Axel Ritter | 1997

- A polyreactive mechanomembrane, bionically inspired by the various functions of the human skin.
- This technology demonstrator has the ability to change color, exploit evaporative cooling and “raise hairs” in response to changes in temperature and humidity of the surrounding air.
- The concept works via a complex system of thermobimetals, water absorbing ceramics, color filters, springs and elastics bands all attached to a flexible textile membrane.

Wind Shaped Kinetic Pavilion

► Each of its six main segments twists freely around its central support frame in response to fluctuations in the wind.
► The rotation of the light-weight slices generates enough electricity as it moves to light the pavilion at night.
► The view from inside literally changes at the whims of the weather.


The wall construction only consists of a 30 cm single leaf concrete layer with embedded heating ducts, acting as ‘active thermal insulation’.

Symbiosis is achieved because excess mine-water at 30°C that is pumped from a nearby colliery to prevent collapse of the mine, is fed to the radiant tube heat exchanger to modulate heat transfer across the envelope.

This circulation of warm water does not only serve as heating supply in winter, but it also renders conventional thermal insulation superfluous.


Zon-Wel SmartFacade
SenterNovem EET project | The Netherlands | 2007

- Zon-Wel concept improves daylight entrance with window integrated retroreflective lamellae, saves energy with high insulating vacuum panels and generates energy with integrated photovoltaic modules.
- The ‘smartbox’, part of Zon-Wel, is a small, façade integrated, unit that incorporates all climate control functions like cooling, heating and ventilation with heat and moisture recovery in the building envelope.

[www.smartfacade.nl]