The ActiveHouse
Active Thermally Insulated Façades

by Stephen Gage
### Project Details

<table>
<thead>
<tr>
<th>Designer:</th>
<th>Stephen Gage</th>
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<tbody>
<tr>
<td><strong>Title:</strong></td>
<td>The ActiveHouse: Active Thermally Insulated Façades</td>
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<tr>
<td><strong>Output type:</strong></td>
<td>Building</td>
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<tr>
<td><strong>Location:</strong></td>
<td>70a Corbyn Street, London N4 3BZ</td>
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<td><strong>Practical completion:</strong></td>
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<td><strong>Dates:</strong></td>
<td>February 2012 – September 2013</td>
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<td><strong>Budget:</strong></td>
<td>£175,000</td>
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<tr>
<td><strong>Area:</strong></td>
<td>80m²</td>
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<tr>
<td><strong>Funding:</strong></td>
<td>Prototype design of DEI Pavilion funded by: UCL's EPSRC-funded Urban Buzz research platform; UCL Graduate School, Bartlett Architecture Research Fund, MAKE Architects, UCL Grand Challenges</td>
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<tr>
<td><strong>Collaborators:</strong></td>
<td>DEI Pavilion: Experimental actuators: Chris Leung, Nick Browne; Fabricator: Trinity Buoy Wharf; Container supplier: Urban Space Management; Research assistants: Fred Gutfield, Joe Moorhouse</td>
</tr>
<tr>
<td></td>
<td>ActiveHouse: Drawings: Stephen Gage, Joe Moorhouse, Dave Di Duca, Carlos Gonzalo; Special fabrications: Stephen Gage, David Scott (roof light and shutter), Carlos Gonzalo (front shutters), Nick Westby (stair); All purpose-made fabrications have been constructed in the Bartlett Workshop.</td>
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<tr>
<td></td>
<td>MyRoom: Concept: Stephen Gage; Interface design: Stephen Gage, Oliver Palmer; Local electronics and software: Adrian Godwin; Programming and network: Paul Tanner with advice from Usman Haque; Learning algorithms: Sean Hanna</td>
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The ActiveHouse in context

Photograph Andy Stagg
Statement about the Research Content and Process

Description

The project explores the possibilities of deployable external insulation in architecture. Its central outcome is the production of a building which incorporates moveable solid insulated shutters and an innovative open source system that monitors climate and occupation patterns, and controls the shutter operation, light levels and heating of the building’s interior. The system has the capacity to learn individual preferences and anticipate user needs. An earlier temporary building, the DEI Pavilion, raised awareness of this area of research and acted as a test prototype for the ActiveHouse.

Questions

The project aims to solve the conflict between large windows providing natural light and the simultaneous loss of heat. Through a novel system of sensing, actuating and control, the shutters close when temperature or occupancy levels drop.

1. What are the aesthetic, spatial and typological consequences of incorporating deployable external insulation in the building, from the points of view of both its interior and its exterior?

2. How can the technical challenges of the project be overcome and what exemplar technical strategies can be generated for the broader use of deployable external insulation in other buildings?
Methods
Design-led research in the form of iterative 1:1 prototype fabrications of components and whole buildings.

Dissemination
The DEI Pavilion was seen by over 5,000 people at the Bartlett Summer Show, London Festival of Architecture, UrbanBuzz opening and a CIBSE natural ventilation seminar (2008). The work has been published in Architects’ Journal, RIBA Journal and The Complete UrbanBuzz. The analogue logic of the controller is the subject of a paper, co-authored with Chris Leung, in Cybernetics and Systems (2008).

Statement of Significance

The ActiveHouse was the subject of a keynote address at the ACADIA (Association for Computer Aided Design in Architecture) 2013 conference on Adaptive Architecture (Cambridge, Ontario).
A thermally stable building without occupants would resemble a modern, state of the art refrigerator. It would not have windows or roof lights.

Except that a building needs to be ventilated - here 24/7 heat recovery is shown.

Most buildings are unoccupied for most of the time and could revert to a thermally stable form when no one is there.

It is generally pleasant to sit in a space with a lot of daylight and sunlight coming into it on a spring day. However, on a cold dark winter's afternoon it is probably desirable to return to a building in its thermally stable form.

In cool weather solar gain is beneficial when the sun is shining. This is not true in hot conditions when a thermally stable form is beneficial.

Windows that face away from the sun are not beneficial in cool conditions. They are, however, a great idea in the summer.

In a hot summer, with no one there, the building stays cool. At night, shutters, windows and rooflights are part opened to purge the building of heat.
This research investigation explores the possibilities of active thermally insulated façades through the production of the ActiveHouse (Active Thermally Insulated Façades), a building that is controlled and monitored by an innovative open source system called MyRoom. It builds on an earlier temporary building, the DEI (deployable external insulation) Pavilion, a design investigation undertaken to raise awareness of this subject area, which acted as a test prototype for concepts that culminated in the ActiveHouse.

Active thermally insulated façades were first proposed in the early 1960s (e.g. for the Wallasey School in the UK) and then extensively studied in the USA after the first ‘Oil Shock’ in the 1970s. There are good reasons to re-examine these ideas today in a global context. The principles underlying the project are as applicable to very hot and humid climates (where cooling based on air conditioning has to be maintained) as they are to temperate and cold climates:

1. The possibility of enhanced glazing areas, especially on the north façades of buildings (or south façades in the Southern Hemisphere).
2. A better understanding of building occupancy patterns.
3. New, easily available sensing, computation and actuation technologies.

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1. This research into thermally insulated façades is distinct from the Velux sponsored Active House performance standards. See www.velux.co.uk/aboutvelux/modelhome2020/the%20challenge.
Aims and Objectives

The research aims to examine the implications of designing buildings where walls and roofs can turn into window and roof light openings when occupancy and environmental conditions suggest that this is a good idea. The principles are described in figure 2. These principles follow commonly accepted ideas about enhanced insulation, beneficial and unwanted solar gain, heat loss and ventilation with heat recovery. The only conceptual addition to these ideas is the concept of dynamic, deployable insulation.

There have been a number of approaches to deployable insulation. These are illustrated in figures 3 and 4. All provide security and insulation when closed, and can also provide solar protection. Hinged systems are vulnerable in high winds. They can also reflect sunlight and daylight.

The objective is to build prototypes that examine the feasibility of applying these principles to the design and occupation of buildings. The investigations address this objective in the context of new construction. It is possible to imagine retrofit applications to buildings where windows slide or open in. These are more common outside the UK. A spinoff research project into retrofit in a UK context has resulted in the development of an advanced internal shutter system.
Aims and Objectives

3 & 4 Approaches to external thermal insulation, adapted from William K. Langdon’s *Movable Insulation* (1980)

Drawings by Carlos Gonzalo
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Al Bahar Towers,
Abu Dhabi,
United Arab Emirates
(Aedas Architects)
Image in the public domain
via Creative Commons
WikiArquitectura

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House in Vignon,
Graubünden,
Switzerland
(Gion Caminada
Architect)
© luciadegonda.ch
The following questions have led the investigation:

**What are the aesthetic, spatial and typological consequences of incorporating deployable external insulation in the building, from the points of view of both its interior and its exterior?**

From an external point of view, the primary issue is whether the building can be taken as being too austere when thermal shutters are closed. There are, in a non-UK context, traditional ways of dealing with this issue by making insert solar shutters of materials that contrast with the general façade. The shutters, in effect, become pseudo windows. Thermal shutters are much thicker and prominent. I have chosen to treat them as movable façade elements. From an internal point of view, the question is then whether, when closed, the shutters induce a sense of claustrophobia in the spaces that they enclose.

**How can the technical challenges of the project be overcome and what exemplar technical strategies can be generated for the broader use of deployable external insulation in other buildings?**

a. Is standard hinging/sliding and actuation equipment available for the purpose at reasonable cost?
b. Are novel passive actuation systems possible?
c. Is standard composite shutter material available at reasonable cost?
d. Can an acceptable level of sealing between the composite shutter material and the building be achieved?
e. Can control systems be developed to drive thermal shutters that are at reasonable cost and preferably open source? There is ample evidence that most spaces in most buildings are unoccupied for most of the time, and that occupants will often seek to close shutters and curtains when they are present. Thermal shutters could be closed in these conditions when there is no beneficial solar gain, with control systems to ensure their use.

**User experience and monitoring**

a. Can users be simply monitored in a research context?
b. How do users react to this form of dynamic building?

This final question will be the subject of further work and is not answered here.
Cooley Residence
(Clinton Sherr, architect)
and William A. Shurcliffe’s
top hinged shutter design,
from William K. Langdon’s
Movable Insulation (1980)
The use of external thermal shutters to insulate the windows of buildings was first investigated in the USA at the time of the first ‘Oil Shock’ in the 1970s. The most authoritative book on the subject is William A. Shurcliffe’s *Thermal Shutters and Shades* (1980). Shurcliffe was an engineer and the examples of external thermal shutters that he describes are crudely detailed and aimed at the American single-storey housing market. William K. Langdon’s *Moveable Insulation* (1980) also includes an illustration of a mighty ‘barn door’ thermal shutter design. [fig. 7]

The ActiveHouse, MyRoom and the DEI Pavilion are part of a wider effort to re-examine these ideas in a 21st-century context. They show that buildings with deployable insulation in active façades can be visually attractive and interesting. Off-the-peg shutter material and actuators can be used at reasonable cost; novel actuating systems are possible. Seals are available but need more development work. A predictive open source control system that links shutter actuation to occupancy, lighting, heating and fire detection can be built.

The ActiveHouse is very solid in its appearance when the shutters are closed. It does not give much away. The aesthetic consequences of the system are a far cry from the dancing active solar shading façades in Aedas Architects’ Al Bahar Towers. [fig. 5] The ActiveHouse’s shutters more closely resemble the sliding security shutters in Gion Caminada’s buildings, but they offer greater benefits in terms of amenity and energy conservation. [fig. 6]

The ActiveHouse project evolved to have its own control and automation system. This has been influenced by the work of Michael Moser at the University of Colorado, who argues that most users do not want complex interfaces and that the design of interactive systems should present them with very simple choices. See, for example, his Adaptive House: www.cs.colorado.edu/~mozer/index.php?dir=/Research/Projects/Adaptive%20house/.
The actuation system used to drive the shutters is original. It is based on the use of a pair of wax-filled cylinders working in opposition in a miniature greenhouse that acts as an environmental emulator.

Photograph Chris Leung

Constructing the pavilion

Photograph Joe Moorhouse
Methods

This research is undertaken through design in the form of iterative studies of 1:1 prototype fabrications of components and whole buildings.

The DEI Pavilion

A requirement for high levels of thermal insulation has driven recent changes in the UK Building Regulations (Part L) and this has led to a significant reduction in window area in many contemporary housing and commercial buildings. Although glass manufacturers have played ‘catch up’ with increasingly expensive and complex glazing systems, these are never as good as walls because light permeability will always mean there is some energy transfer across a glazed boundary. This transfer, if managed, can be beneficial to building occupants, as can enhanced views and spatial extension through windows.

The DEI (deployable external insulation) Pavilion is a 14.4m² prototype. It was constructed between January and June 2008 as part of the Bartlett School of Graduate Studies’ EPSRC-funded UrbanBuzz research platform and publicly exhibited at UCL. The £30,000 design demonstrator re-examines the ideas behind externally insulated shutters in a 21st-century context. The main driver behind the project was polemical: to create a pavilion that would sit in front of the main UCL portico and demonstrate a deployable façade to as many people as possible. A second driver was to examine the possibility of using a semi-passive actuating system to drive façades of this nature. The pavilion was based on a 6m-long road container with one side cut out and replaced with fixed fenestration. Roof ventilators were fitted and a hinged shutter system was adopted. The results are a dynamic system that is visually startling. [fig. 8–10]
The ActiveHouse: Active Thermally Insulated Façades
The DEI Pavilion in operation
Photograph Chris Leung
The ActiveHouse

No. 70a Corbyn Street is a four-storey house with a very small footprint of 6m × 3.4m. [fig. 11–14] Site constraints were considerable, with no access or possible fenestration to the side and rear of the building. There is a small raised front terrace.

The house is constructed out of prefabricated timber panels with cassette floors and roof over an existing concrete basement. Each floor consists of a main room and a service space; the latter can be accessed either from the stair or from the main room on the first and second floors, offering the choice of en suite or shared service facilities. [fig. 15]

Rooms on the ground, first and second floors have glazed screens to the purpose-made staircase. These will be fitted with bifold shutters to provide privacy when needed. [fig. 16]

Heating is underfloor. A whole house heat recovery ventilation system is fitted. The ActiveHouse is a tight infill site project. The dynamic components that take it outside the realm of similar projects are shown in figures 17–20.

Figures 17 and 18 show how proprietary inward-opening tilt and turn windows have been lined externally with Iroko frames and purpose-built shutters (made from insulated truck panelling) that have been constructed to slide over these. The shutters are fitted with polypropylene seals. These are translucent and allow a measure of internal illumination to the edges of the shutters, causing them to appear as if they are ‘floating’ in front of the windows when closed. The shutters are driven using 12-volt linear actuators linked to a sensing and operating system. The actuators are fitted with reed switches, allowing very accurate variable movement limits.
Sections and elevations
The ActiveHouse: Active Thermally Insulated Façades
Main rooms and service spaces on four levels
Photograph Andy Stagg
Views into and down the staircase
Photograph Andy Stagg
Methods

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Shutter detail
Photograph Andy Stagg
Roof light and shutter assembly
Staircase looking up to the roof light and shutter
Photograph Andy Stagg
ActiveHouse elevations: open, closed
Photograph Andy Stagg
ActiveHouse interiors: open, closed
Photograph Andy Stagg
Figures 19 and 20 show a purpose-built hinged roof light over the staircase. This roof light also acts as the access to the roof and opens for purge ventilation to the staircase. The roof light is fitted with a hinged external thermal shutter lined internally with a mirror to act as a heliostat. Both the roof light and the external shutter are driven using 12-volt linear actuators.

Figures 21 and 22 show how the building has a dynamic presence on the street and how this creates a range of possible internal illumination levels.

MyRoom

The ActiveHouse is an experimental building that has been designed to find out how users respond to thermal shutters, both when they operate automatically and when they are directly activated by occupants. The relationships between climate, occupation patterns, mode of shutter operation, light switching, temperature levels and user heating demand will be established through an extended monitoring research period.

In the first instance, it was assumed that a sensing, actuating and control system could be put together using off-the-peg components and that an effective data-logging procedure would be easily found. An inspection of what was available in the market made it clear that this could only be achieved at prohibitive cost using the closed and semi-open systems available. This generated a further design exercise to build a system out of low-cost components that could act as the foundation of an open source approach to building operation. It is called MyRoom.
MyRoom schematic. MyRoom is not a building management system; rooms are semi-autonomous and share information across the web. Drawing by Carlos Gonzalo

Detailed MyRoom schematic. Drawing by Carlos Gonzalo
The overall schematic for MyRoom is shown in figure 23. This indicates how the approach is modular with individual spaces having their own controllers, giving each room in the building a discrete web presence. In addition to each room having an identity, the house as a whole has its own identity. The house’s identity incorporates common parts (e.g. staircases) and the monitoring of external monitors. MyRoom presupposes an Internet of spaces, rather than of things.

Figure 23 also shows a local hub computer to carry protocols that are too complex for the MyRoom controllers. In the long term the local hub may not be necessary. Figure 23 also shows how users, researchers and manufacturers can access MyRoom remotely.

Figure 24 shows the inputs and outputs of a MyRoom controller. Central to the controller is an Ethernet-enabled Arduino, which is linked to a wireless transmitter and a wireless receiver capable of identifying mains voltage appliances that are switched on or off. A range of inputs is shown, some hard-wired, some wireless and some Ethernet. There is a smaller range of outputs, both hard-wired and wireless. Wireless inputs and outputs allow us to safely switch and log mains wired devices.

Computation and data logging

The system has the capacity to learn individual MyRoom preferences and anticipate user needs. In the longer term we envisage a MyRoom app. An outline of the MyRoom specification is as follows:

**Shutter:** Default condition: Shutters are closed unless (a) in spring or autumn there is no daytime occupation and useful solar gain is available, or (b) it is a cool night after a hot summer day, in which case the shutter opens a small amount to permit ventilation, or (c) the electric light is on when it is light outside, in which case the shutter opens a small amount to offer users the opportunity of a free source of light. Users train their shutters by operating a manual switch. Shutters are battery operated and open automatically if triggered by the fire alarm system.

**Heating:** Default condition: The heating is off unless the room temperature falls below a set point of, for example, 10°C. When occupancy is detected, the air temperature in the room is raised to 18°C using fast response radiant floor heating unless the window is open. Users train their heating by operating a manual switch, which can raise and lower the target air temperature. The target air temperature reverts to 18°C at night when occupancy is detected, there is no movement and the light is off.
MyRoom interface
Photograph Andy Stagg
Lighting: Default condition: Lights are off during daylight hours and at night if no presence is detected. There are two light sources in each room. When occupants enter the room in the dark, a low-level light will switch on automatically. Users train their lighting by switching main and low-level lights off and on as required.

Ventilation: MyRoom knows whether windows are open or closed. It also knows when it would be a good idea to open a window (e.g. to purge the building at night, in the summer, after a hot day when the roof vent is open) or to close a window (e.g. when the heat recovery system is in operation). MyRoom indicates these preferences to occupants when appropriate.

Interface

The MyRoom interface is shown in figure 25. Controls are intentionally simple. A rotary switch allows users to open and close the shutter. Rotating this switch to ‘automatic’ puts the shutter, the lighting and room heating into automatic mode. Users call for more or less heat using a rocker switch. A second rotary switch controls the roof light and roof shutter. Light switching is wireless and secondary light switches can be placed anywhere in the room by users.

Experimental data storage

Experimental data will be stored at Xively.com (the current brand name of Pachube). Pachube is a web service that stores real-time sensor, energy and environment data from devices and buildings. It was developed by Haque Design and Research and sold in 2011 to LogMeIn.

It is our intention to publish the MyRoom architecture on the web in order to encourage manufacturers to build control units that can be openly programmed as well as compatible low-cost peripherals.
Dissemination

The DEI Pavilion was seen by over 5,000 people at the Bartlett Summer Show and subsequent events including the London Festival of Architecture, the UrbanBuzz launch and a Chartered Institute of Building Services Engineers (CIBSE) natural ventilation seminar. At the latter event we were approached to put forward a knowledge transfer partnership (KTP) proposal with SE Controls Ltd to develop an internal thermal shutter system.

The DEI Pavilion has been published in *Architects’ Journal*, *RIBA Journal* and *The Complete UrbanBuzz*. The underlying basis for the analogue logic in the controller is the subject of a co-authored paper with Chris Leung.

The ActiveHouse (documented up to October 2013) is the subject of a keynote address at ACADIA (Annual Conference for Association for Computer-Aided Design in Architecture) 2013: Adaptive Architecture in Cambridge, Ontario (Oct 2013).

Bibliography


Related publications by the researcher(s)

pp. 40–45

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Related writings by others

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p. 55
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by AY Architects

Design for London
by Peter Bishop

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River Douglas Bridge
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Déjà vu
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Urban Collage
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Hakka Cultural Park
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55/02
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Modulating Light and Views
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