ADAPTIVE FACADES 2016
HAMBURG

Booklet

Adaptive Façades Training School 2016

12th to 17th of September 2016

HafenCity University, Hamburg, Germany

Organised and sponsored by

COST EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

HCU HafenCity Universität Hamburg

DAAD

CAPES

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1.1. Preface

Our demands concerning the quality of buildings and the room comfort they offer are steadily increasing. Well planned facades with functional technical solutions are a requisite to fulfil our demands under dynamic external environmental conditions while optimizing energy consumption. Therefore the expenditure for planning and erection of building envelopes has increased immensely in recent decades. A multitude of existing façade technologies and those still in research and design phase, driven by the market needs, has considerably expanded.

The next generation of façades (or building envelopes) consists of multifunctional and highly adaptive systems, where the physical separator between the interior and exterior environment (i.e. the building envelope) is able to change its functional features or behaviour over time in response to transient performance requirements and boundary conditions with the aim of improving the overall building performance. Numerous programs on modern universities are today dedicated to the subject of facade design and the number of research groups is steadily increasing. Within the COST program in the European Union (Cooperation in Science and Technology), a project "Adaptive Facades Network" was therefore promoted, which offers European scientists a platform to collaborate and exchange perspectives.

To connect the young generation of scientists, a summer school took place in September 2016 at the HafenCity University, Hamburg with a total of 62 participants from 37 universities. In addition to lecturers from Europe, invited experts from Brazil shared their research practices and findings. Their participation was supported by DAAD (German Academic Exchange Service).

In a very intensive week of lectures and workshops, the participating PhD and Master Students had the opportunity to look beyond the scope of their own research and to follow aspects of parallel research on different case studies. Not only new knowledge was gained and shared, but new long-term cross-border contacts are also established to make a prosperous contribution to continuation of the European science-evolving idea.

Frank Wellershoff

1.2. Organising committee

Prof. Dr.-Ing. Frank Wellershoff
Head of Professorship for Façade Systems and Building Envelopes at HafenCity University Hamburg

M.Sc. Matthias Friedrich
Research Associate at Professorship for Façade Systems and Building Envelopes

Dipl.-Ing. Roman Baudisch
Research Associate at Professorship for Façade Systems and Building Envelopes

M.Sc. Matija Posavec
Research Associate at Professorship for Façade Systems and Building Envelopes

1.3. Schedule

The Adaptive Façades Training School took place from the 12th to 17th of September 2016 in the HafenCity University in Hamburg.
During this week participants were offered opportunities for getting in touch with international researchers. Integrated in the program of the week were following key points:

- frontal lectures from experts in areas related to Adaptive Façades
- PhD workshop about organisation of research projects
- 3 days innovative façade design workshop
- final presentation on Saturday in front of evaluation expert committee

During the week the applicants were also offered a variety of social events reaching from a Hamburg City Tour Guide over a Welcome Dinner at HCU until a Final Party to round off the experiences during an exciting week.

The following schedule gives more detailed information about the detailed content and organisation of the program during the week:

		block 1 9:00 - 10:00	block 2 10:15 - 11:15	block 3 11:30 - 12:30	lunch 12:30 - 13:30	afternoon	evening
Monday	Foyer **Registration 8:15 - 8:50** foyer HCU entrance east	Room 150 **Tillmann Klein** Introduction to adaptive facades: General, history of adaptivity, definitions, the adaptive facade survey	Room 150 **Tillmann Klein** State of the art on adaptive facades	Room 150 **Daniel Aelenei** Design of adaptive facades - Lessons learned from survey case studies	HCU Canteen **Lunch** Use your meal voucher	Room 150 **PhD Progress Report 13:30 - 19:30** Feedback & Discussion	HCU Canteen **Welcome Dinner 20:00** You are invited to enjoy our dinner buffet
Tuesday		Room 150 **Chiara Bedon** Identify structural, fire + safety facade performances where adaptive technologies are useful. Life-cycle cost assesment	Room 150 **Christian Struck** Adaptive facade system design process	Room 150 **Christian Struck** Adaptive facade system performance analysis	HCU Canteen **Lunch** Use your meal voucher	Meeting at HCU foyer **Excursion 14:00 - 18:00** See and learn from the buildings of the international building exhibition (IBA) http://www.iba-hamburg.de/en	
Wednesday		Room 150 **Albert Castell** Evaluate current simulation methods, identify lack of knowledge, perspective for new simulation tools	Room 150 **Jerome Le Dreau** Map out performance metrics and requirements for adaptive facades / Experimental procedures and metrics, mock-up	Room 150 **Frank Wellershoff** Adaptive facade system performance measuring, occupant behavior, natural ventilation	HCU Canteen **Lunch** Use your meal voucher	Room 150 **Workshop Intro 13:30 - 16:00** Definition and scope of the workshop	Elbe Terrace **BBQ 16:00** Relax at the terrace and have a delicious barbecue
Thursday		Seminar rooms 3rd floor **Workshop 9:00 - 12:30** Workshop „Adaptive Facade Design for New Buildings in Different Climate Zones“			HCU Canteen **Lunch** Use your meal voucher	Seminar rooms 3rd floor **Workshop 13:30 - open end** Workshop „Adaptive Facade Design for New Buildings in Different Climate Zones“	
Friday		Seminar rooms 3rd floor **Workshop 9:00 - 12:30** Workshop „Adaptive Facade Design for New Buildings in Different Climate Zones“			HCU Canteen **Lunch** Use your meal voucher	Seminar rooms 3rd floor **Workshop 13:30 - 18:00** Workshop „Adaptive Facade Design for New Buildings in Different Climate Zones“	Reeperbahn **It's Party Time!** Time for party! See the Hamburg nightlife, guided by Locals
Saturday		Seminar rooms 3rd floor **Workshop 10:00 - 13:30** Workshop „Adaptive Facade Design for New Buildings in Different Climate Zones“ **Food** We will have a small Brunch with Snacks, Fruits, Juice, Coffee, Tee and typical „Franzbrötchen“ from Hamburg as well as a lunch				Room 150 **Final Presentation 13:30 - 15:30** Present your workshop results	Foyer **Farewell 15:30 - 17:00**

2.1. Participants

1	**Alatawneh B.**	The Perforated Envelopes: An analytical vision for a sustainable architectural trend
2	**Arantes B.**	Potential on Building Performances Improvements Using Seasonal Adaptable Facades – The Context of Residential Buildings
3	**Basarir B.**	An Approach to Build Adaptive Facades with Standard Products
4	**Baudisch R., Posavec M.**	Development of Double Curved and Twisted Girder Structure made of Glued Laminated Timber
5	**Ben Bacha C.**	Dynamic facades as solar control tool to increase the energy efficiency of administrative buildings in arid climate
6	**Bosserez A.**	Development of a dwelling concept which enables a dynamic way of living throughout the seasonal changes in view of sustainability
7	**Caetano D.**	NZEB and adaptive comfort in hot and humid climate regions in Brazil
8	**Castaneda E.**	Manufacturing digital processes for free-form façade panels.
9	**Charpentier V.**	Co-optimization of shading and interior lighting based on large displacement of shell structures
10	**Contrada F.**	Evaluation of a holistic assessment of building performance in early design phase
11	**Curpek J.**	Thermodynamic Simulation of Ventilated BiPV Facade Coupled with Phase Change Material
12	**Denz P.**	Smart Textile Skin
13	**Dubljevic A.**	Design of tall office buildings from the aspect of energy efficiency in climatic conditions of Belgrade
14	**Fernandez M.**	Biomimetic principles in the design of adaptive building skins. Methodology and application.
15	**Förch M.**	Glass Strength for High Strain Rates
16	**Friedrich M., Schweers K.**	Bypass Double Skin Facade
17	**Ghasempourabadi M.**	Performance assessment for technological design of innovative BIPV façade systems
18	**Giovannini L.**	Transparent adaptive façades: a novel approach to optimise energy and comfort aspects
19	**Grassi G.**	Living wall systems for the retrofit of buildings
20	**Hannequart P.**	Shape memory alloys for adaptive solar shadings

2.1. Participants

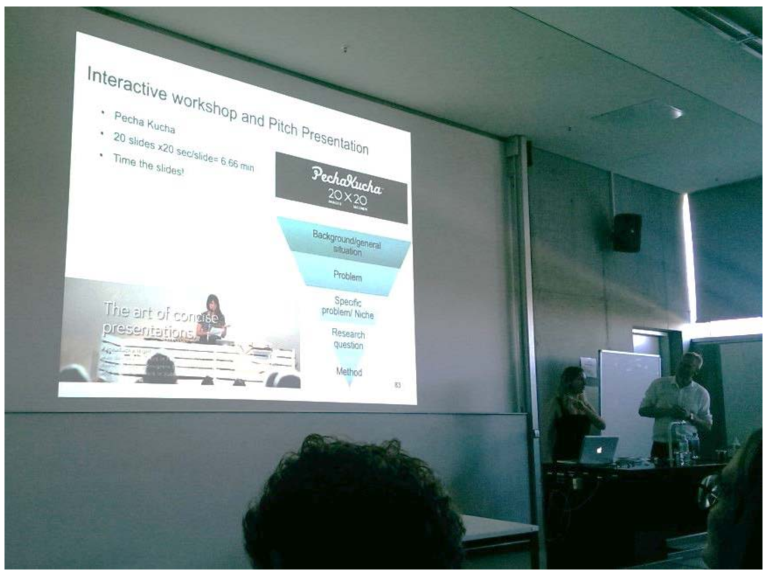
21	**Ives S.**	Security laminated glass with a phosphorescent character; durability of this security laminated glass
22	**Juaristi M.**	Design and assessment of Adaptive facades building upon Atlantic zone resources
23	**Kamari A.**	CHANGE MANAGEMENT IN BUILDING PERFORMANCE: An Engineered Design Methodology for Sustainable Retrofitting
24	**Martin-Consuegra F.**	Energy needs reduction by façade rehabilitation on vulnerable residential neighbourhoods in Madrid
25	**Nguyen P.A.**	Housing Refurbishment for energy efficiency in Vietnam
26	**Pereira J.**	Glazing Systems with Solar Control Films
27	**Rios E.**	Contemporary Interventions in Architectural Heritage and Public Spaces
28	**Saini H.**	Development of advanced computational support for Responsive Building Elements
29	**Santoro G.**	Solar shutter, the shading system for DHW production
30	**Scheuring L.**	Energy-autonomous adaptive façade
31	**Schultz-Cornelius M.**	Face Wythe Made Of Unreinforced UHPC For Sandwichwalls With GFRP Connectors
32	**Silvestru V.**	Glass-metal building envelopes with composite structural behaviour by adhesive bonding
33	**Sousa C.**	Development of a multifunctional composite sandwich panel for the rehabilitation of building facades
34	**Speroni A.**	Adaptive shading devices for high performance envelope
35	**Van Lancker B.**	Structural Closed-Cavity Façades
36	**Vanapalli M.**	Curved Pliable Folding
37	**Villaca A.**	Sustainable upgrades in regional commercial and retail buildings
38	**Wattez Y., Cosmatu T.**	Research through design ‘Double face 2.0’

2.2. Research Posters

As a part of the School, on the first day, there was a PhD / Research Colloquium and Workshop Session aimed at supporting new PhD students and researchers in the development of research methodologies and scientific writing. All PhD students and Researchers were instructed on how to create an overview of their research projects.

The workshop was interactive – participants worked together to re-evaluate their research organisation with the help of expert supervisors.

On the following pages, received research posters are presented.

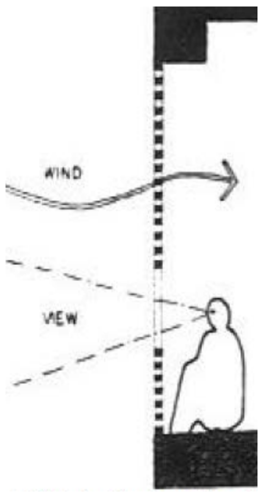


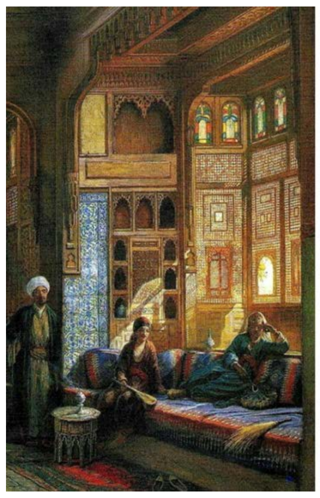
The Perforated Envelopes: An analytical vision for a sustainable architectural trend

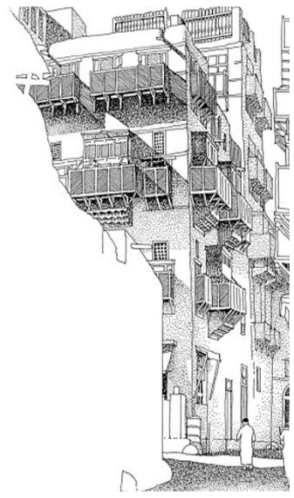
Bader Alatawneh, Department of Architecture, University of Palermo, Italy

Introduction, Background to the Research

It is difficult to design effective buildings without understanding their relationship to their local environmental system, it is also impossible to protect the natural environment without decreasing the human intervention that affect it. Therefore, architects started to seek for minimizing the negative environmental impacts of buildings by searching for the efficient buildings, and for the moderation of the use of building materials, energy, etc. These environmental and socio-economic challenges were inexistent in the past, as the traditional architecture met the cultural, environmental, economic considerations in each community, by employing many different urban and architectural tools to maintain thermal comfort, visual comfort, social integration, cultural identities, etc. For example, the traditional “Mashrabiyah” as an architectural element, played a significant role in maintaining the sustainability in the Arab-Islamic architecture. The integrative use of traditional architectural elements has led to a sustainable urban fabric and sustainable buildings. The traditional “Mashrabiyah” as a successful perforated model, and other traditional perforated models, encouraged some of the contemporary architects to imitate them, to metaphor them, or to develop them in a new innovative solution, which has led recently to the emergence of a global contemporary trend of perforation.

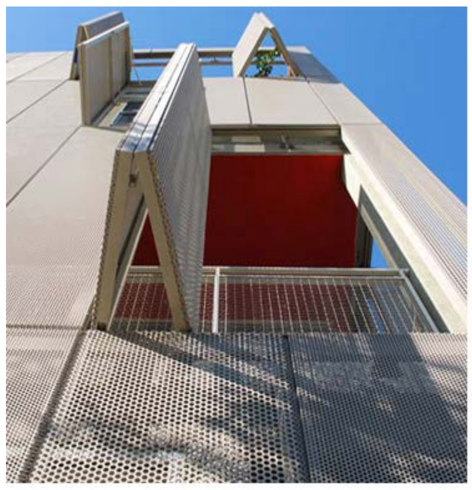


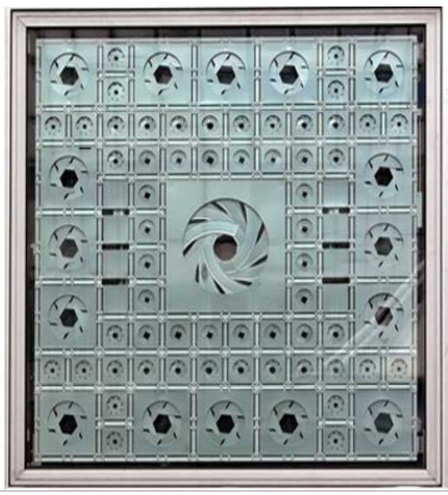




Research problem

The building’s envelop is the most important component to be considered when evaluating or analyzing the building’s sustainability, since the envelope is the tool of controlling natural ventilation, daylight, heat gain and heat loss, visual comfort, shading, etc. Dependently, the building envelope can be considered as the barrier or the shield which has to be effectively-designed to maintain the occupants needs beside saving the environment in parallel by using integrated and sustainable solutions. The different architectural trends have produced different solutions of buildings envelopes. What draws attention here is the increasing global emergence of the contemporary perforated envelopes. This trend is connected -in some circumstances- to the traditional perforated models in different ways to employ different purposes in the building design. The traditional perforations are characterized by sustainability, however, is it the same for the case of contemporary perforated envelopes? Is it going positively, negatively, or it has no significant contribution to the sustainability? Following this point of view, the research significance takes its place by highlighting this issue, to explore the roles and the rules in which the contemporary perforated envelopes maintain the sustainability.





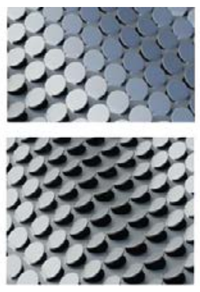
Research Questions (Main Questions and sub question)

Main question

How does the design process of a perforated envelope take the environmental, social and economic dimension into consideration? Or, in other words; what are the characteristics and rules those make the perforated envelope as sustainable?

Sub-questions

1- What are the main technological and environmental guidelines that should be considered in the design of a perforated building’s envelope?
2- What are the main socio-cultural guidelines that should be considered in the design of a perforated building’s envelope?
3- what are the main socio-economic guidelines that should be considered in the design of a perforated building’s envelope?



Research Objectives

The research aims at extracting a set of guidelines for designing a sustainable perforated envelope, which successively contribute to the achievement of future sustainable buildings. The extraction of these guidelines comes after making a holistic analysis for multi-cases of the contemporary trend in a sustainability point of view to come up with a deep understanding for the characteristics and rules that make the perforated envelope as sustainable.

Research Deliverables

The guidelines extraction as a main deliverable, is an important contribution which helps in outlining a clear starting point for architects and students of architecture, to design their future sustainable perforated envelopes, by considering various aspects related to the envelope’s perforation, and taking into consideration the intersections and interrelations between the environmental, social and economic dimensions in their future approaches.

Researcher: Bader Alatawneh
Supervisors: Prof. Maria Luisa Germana’, Prof. Rabee Reffat
Time span: 2014-2016
Contact data: bader.alatawneh@gmail.com

Associated Publications:

- *M.L. Germana’, B. Alatawneh, R. Reffat, Technological and Behavioral Aspects of Perforated Building Envelopes in the Mediterranean Region, 10th Conference on Advanced Building Skins 2015, Bern, Switzerland*
- *B. Alatawneh, M.L. Germana’, R. Reffat, Near Zero Energy House in Palestine: Identification of the future challenges, 5th International energy Conference (ICEP) 2015, Palestine*
- *B. Alatawneh, M.L. Germana’, Earth for Social Housing In Palestine: An alternative for a sustainable refurbishment of buildings’ envelopes, The International Congress on Earth Architecture in North Africa (CIAT) 2015, Marrakesh, Morocco*
- *M.L. Germana’, B. Alatawneh, Reviving Earthen Architecture in Palestine: the added significances of the building sustainability and an opportunity for the future,* 41st IAHS World Congress: Sustainability and Innovation for the Future *2016,* Algarve, Portugal, in press

Potential on Building Performances Improvements Using Seasonal Adaptable Facades – The Context of residential Buildings

Beatriz Arantes, State University of Campinas

Introduction, Background of the Research

Improvements in design, conception and construction of facades play an important role in recent efforts toward energy conservation goals. In particular, climate adaptable building shells can improve building thermal performance by the modification of properties in response to the dynamic environmental boundary conditions. While most work in this field has been focused on short-term adaptation (e.g. hourly), recent research has demonstrated the potential of seasonal (i.e. long-term) climate adaptable building shells in office buildings in moderate climates. In this study, it is proposed to evaluate the potential of seasonal adaptable facades for residential buildings in different climatic zones of Brazil.

Research problem

Buildings are in a dynamic and complex environment. The use of a flexible design in facades, making them adaptable to adverse weather conditions, leads to reduce energy consumption and improve environmental comfort.
The application of short-term adaptive systems requires a high level of complexity during the design, construction and operational phase of the building. Although the use of such technology is mainly studied for commercial buildings those can be adapted to residential typologies, presenting less complex solutions with high potential of applicability.

Research Questions (Main Questions and sub question)

Main question

Which is the potential of applicability of seasonal Climate Adaptable Building Shells for residential buildings in different climatic zones of Brazil?

Sub-questions

1- Which is the relationship between the thermal properties of the facade, the energy consumption for cooling and the hours of discomfort?
2- Which is (are) the most important property (properties)/characteristic (s) to consider for adaptation of the facades of residential buildings?
3- What is the optimal interval of adaptation for each analyzed strategy?

Research Objectives

The aim of the research is evaluate the potential of seasonal adaptable facades for residential buildings in different bioclimatic zones of Brazil. The research intends to analyze the viability of application of Climate Adaptive Building Shells in favor of improving energy performance and living conditions of residential buildings. The optimal seasonal adaptation strategies will be identified.

This will be done through the following objectives:
1- Check the viability of adapting facades each month.
2- Check the viability of adapting facades every six months (summer / winter).
3- Check the viability of adapting facades every three months (spring / summer / autumn / winter).
4- Identify a thermal and energy efficient solution for adaptive facade for residential buildings located in different Brazilian climatic zones.

Research Deliverables

A summary of all the analyzed strategies prioritized by their potential of applicability (energy savings and comfort rates improvements).

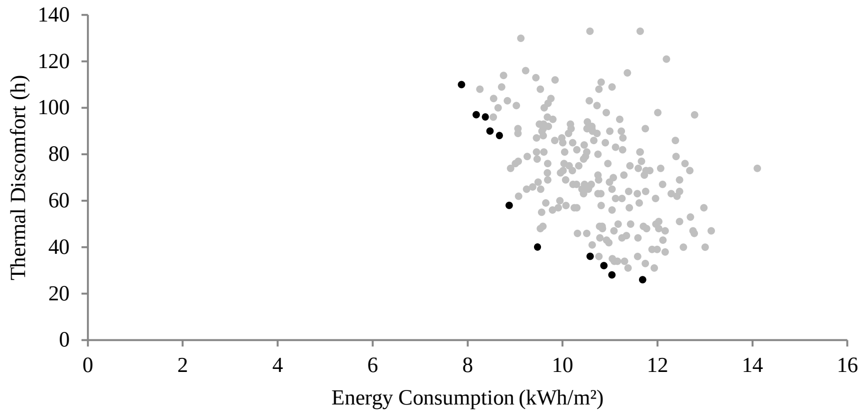
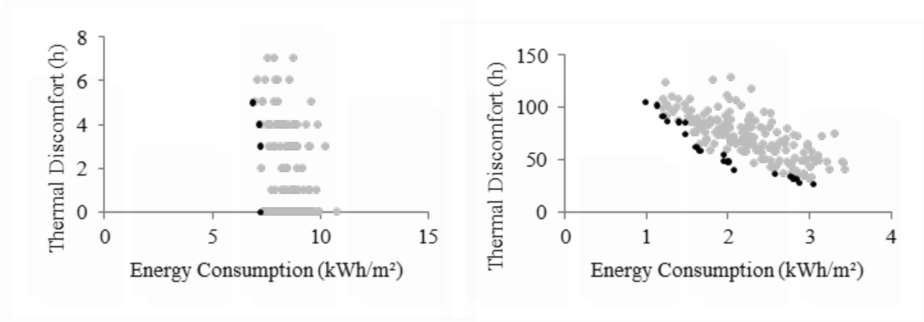
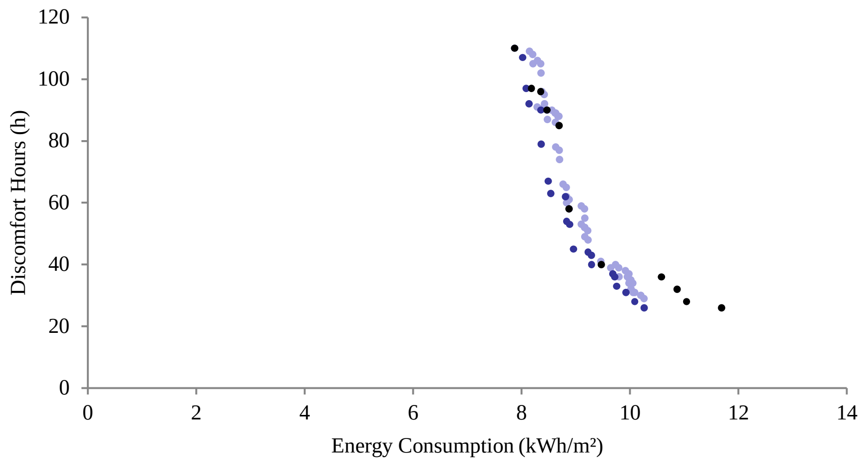


Figure 1: Scatter plots results and fronts of mensal optimization for the room zone model



(A) *(B)*

Figure 2: Scatter plots results of the available solutions and fronts of optimization process conducted for January (A) and July (B)



Legend: Light blue cloud dots: possible combinations of January and July Pareto front.
Blue dots: Adaptive facades - better combinations of January and July Pareto front.
Black dots: Static façade.

Figure 3: Comparison of the monthly Pareto fronts for the static and adaptive facades

Researcher: Beatriz Arantes
Supervisors: Professor Lucila Chebel Labaki / PhD Daniel Cóstola
Time span: 2015-2019
Contact data: beatriz.arantes@live.com
Associated Publications:

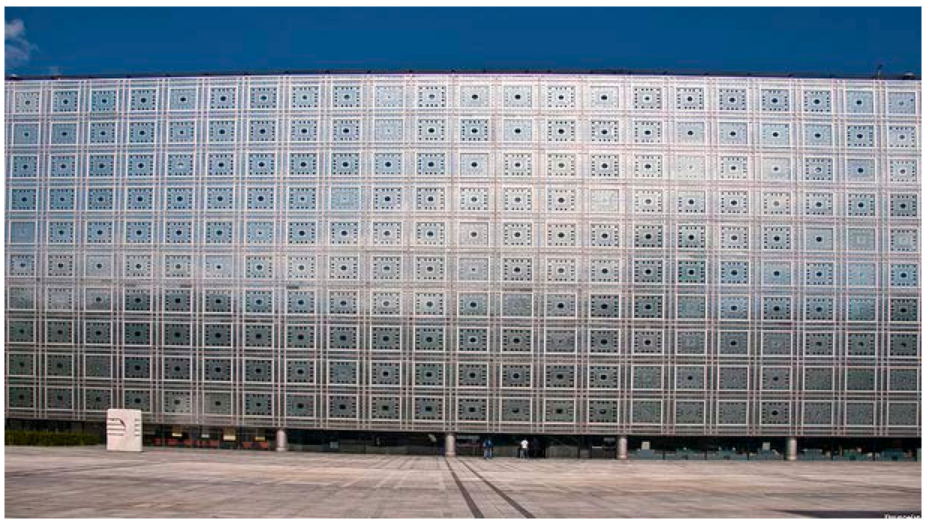
- *B. Arantes; L.C. Labaki,* Fachadas sazonalmente adaptáveis: mapeamento sistemático da literatura*, ENTAC 2016, São Paulo, Brazil.*

An Approach to Build Adaptive Facades with Standard Products

▶ **Bahar Başarır, Istanbul Technical University, Department of Architecture**

Introduction, Background to the Research

Adaptive facades are considered the next milestone in facade technology and receiving increasing attention by researchers and producers on building sector as they combine low energy consumption with good indoor environmental quality. Even though this technology has evolved from simple traditional methods of construction, most of the current examples are custom solutions which include high level of complexity in design, production and maintenance. Simple and reliable solutions are needed to expand feasibility of adaptive facades and widen its application.



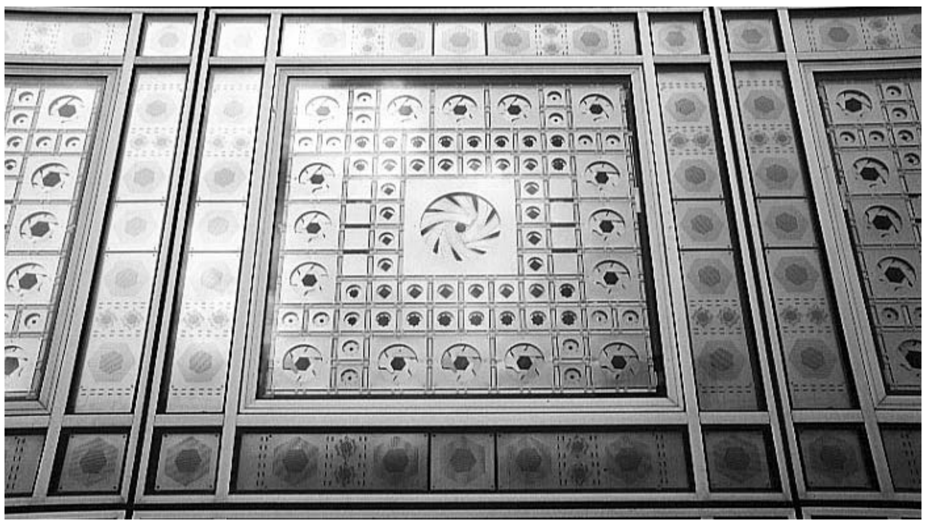
Research problem

Various studies have acknowledged the potential of adaptive facades, but thus far, there is no method available to build them with standard products. The main problem in simplifying the complex adaptive facades to build with standard products is maintaining the same adaptive features and performance of the facade system. Both the facade system (as a product) and manufacturing process has to be simplified to achieve the goal of building adaptive facades with standard products.

Research Questions

Main question

How can a complex adaptive facade system simplified to build with standard products without a significant loss at its performance to increase its feasibility and widening its application area?



Sub-questions

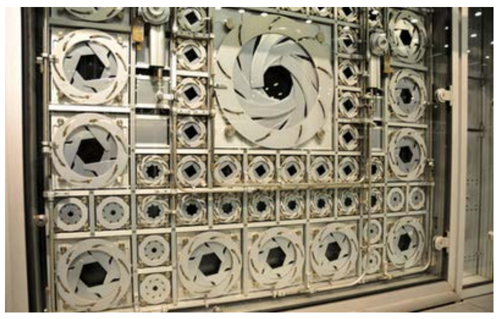
1. What are the components of adaptive facades and their functions in the facade system?
2. Which components of adaptive facades can be replaced by standard products?
3. Which methods can be used to simplify the complex adaptive facades?

Research Objectives

Intention in this research is to build adaptive facades with standard products which are available on market. More broadly, the aim is to develop a low-tech adaptive facade whose components are based on engineered and reassembled standard products with the least number of materials and layers, each of them covering several functions and adaptable performance.

This will be done through the following objectives:

1. Defining the changeable facades.
2. Classifying the adaptive facades.
3. Analysing both high-tech and low-tech adaptive facade case studies.
4. Identifying key problems that complicate the adaptive facade system and manufacturing.
5. Compiling and analysing of systematic innovation, product simplification, lean production, buildability and technology transfer methods.
6. Applying chosen systematic methods to a case study and building an adaptive facade with standard products.
7. Evaluation of the new adaptive facade system.



Research Deliverables

1. Holistic review of adaptive facades.
2. A systematic method for building adaptive facades with standard products.
3. An adaptive facade design build with standard products.

▶ **Researcher:** Bahar Başarır
▶ **Supervisors:** M. Cem Altun
▶ **Time span:** 2014-2018
▶ **Contact data:** baharbasarir@gmail.com
▶ **Associated Publications:**

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Development of Double Curved and Twisted Girder Structure Made of Glued Laminated Timber

Roman Baudisch & Matija Posavec, HafenCity University Hamburg – Department of Architectural Engineering

Introduction – The Challenge!

The aim of the cooperation between HafenCity University and Hess Timber Limitless is the development of a new laminated timber beam system that can be used as basis segment for double-curved freeform surfaces.
Especially the development of a holistic concept for a new, integral, and consistent structural design method and fabrication technology are in the focus of the research project. Altogether a multi-functional laminated timber girder structure for wide spanning double-curved shells will be developed and realized.

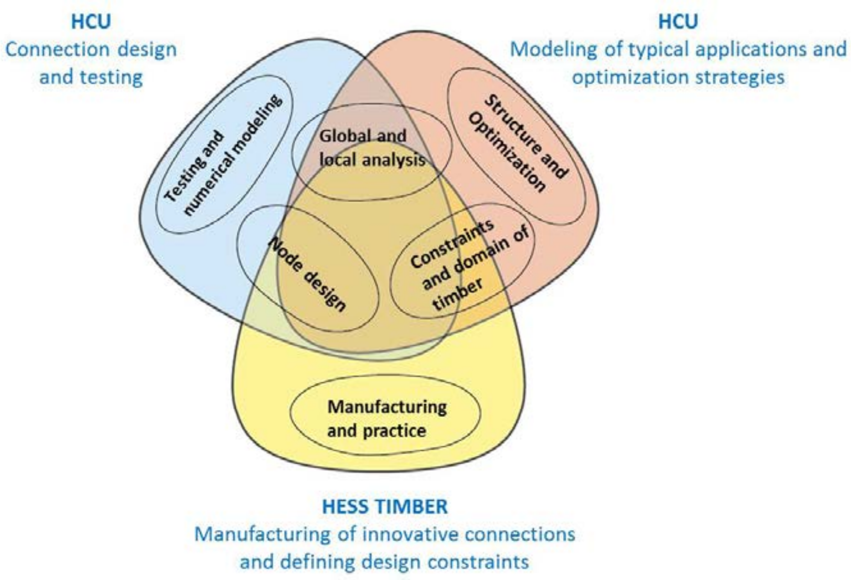
Research problem

1. Complex structural calucations in regards to free-form structure shape
2. Time consuming design process – link: Architect – Engineer – Manufacturer
3. Material limitations – non existing background regarding double axis curved timber
4. Manufacturing constraints
5. Poor mechanical behaviour of the structure connections

Research Guideline

Is it possible to desing and manufacture a free-form timber structure which can be feasible and competitive with structures made of steel?

Research Objectives



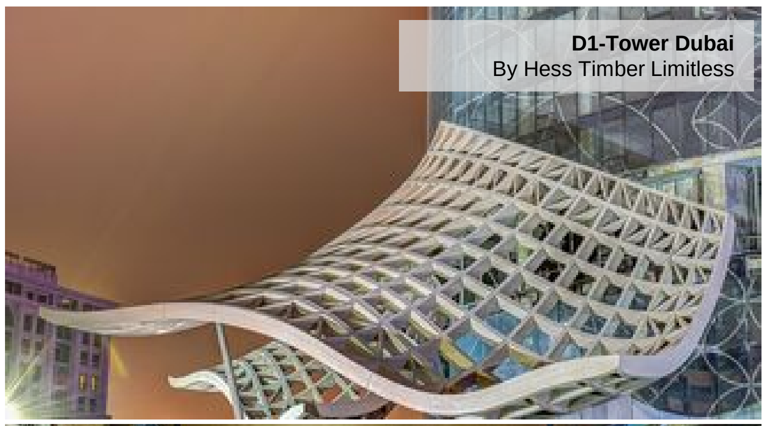
Research Methods and Deliverables

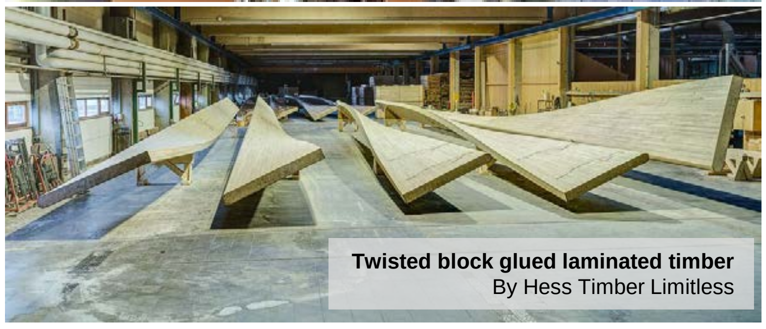
For the development of gluing technology of double curved and twisted beams it is necessary to further improve the production equipment. Another aim of the project is the development of a calculation concept that enables a holistic structural design including the numerical verification of the node-system. By developing a design model of the timber beam structure, consisting of beams and nodes, a numerical analysis system with free defined parameters shall be developed to optimize the variable configuration of double-curved surface timber structures.
Further more a data transfer tool to interchange geometrical and structural data between a geometry tool (Rhinoceros 3D) and a frame-structure calculation tool (R-Stab) shall be programmed with the possibility to integrate a recursive algorithmic optimization system.

Nodes with different configurations will be developed, accompanied with mechanical tests of transversal and longitudinal joints.
The test results about the load-bearing and deformation characteristics of the knots and beams are implemented into a structural model as mechanical constraints. Additional geometrical constraints that are used to evaluate the feasibility of a structural solution, are the maximum component dimensions given by transportation and mount ability in the digital model.

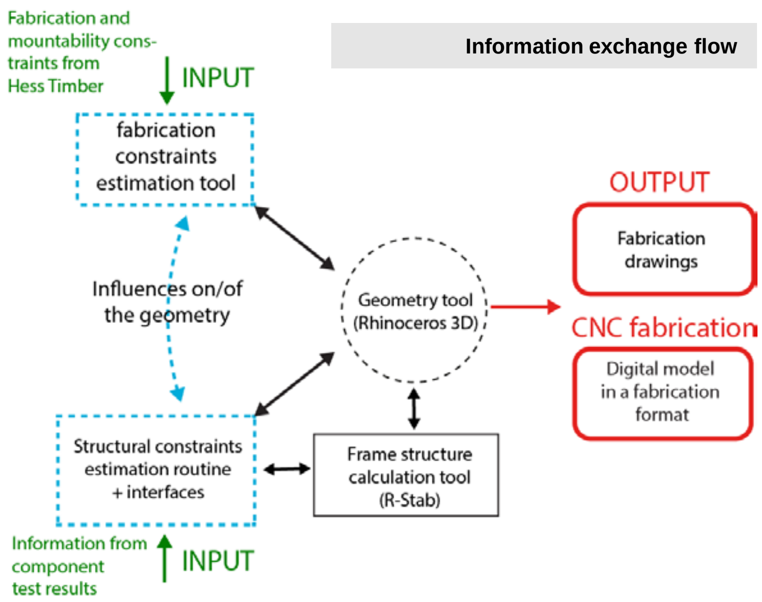
Final outcome

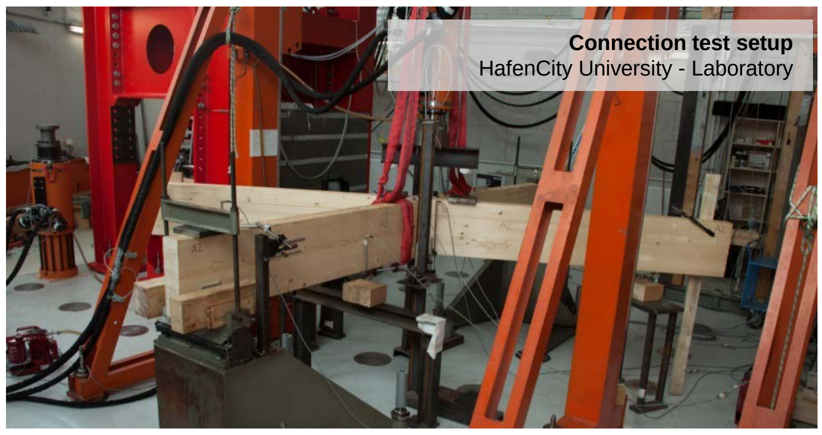
1. New production technology
2. Enhanced correlation between the designers and the manufacturers
3. Automated CNC production files
4. Numerical tool as a link between RSTAB and Rhinoceros = structure optimization
5. Innovative type of crossed timber-timber connection
6. Parametric model of the connection in ANSYS software

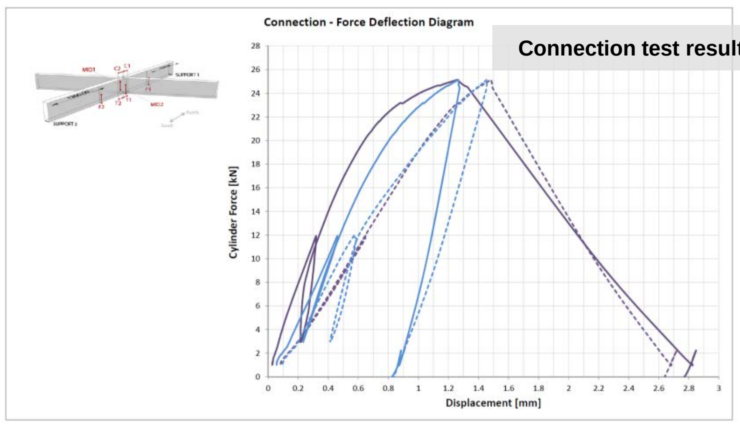

D1-Tower Dubai
By Hess Timber Limitless


Twisted block glued laminated timber
By Hess Timber Limitless

Information exchange flow




Connection test setup
HafenCity University - Laboratory



Connection test results

- **Researcher:** Dipl.Ing-Arch. Roman Baudisch & M.Sc.Eng. Matija Posavec
- **Supervisors:** Univ.-Prof. Dr.-Ing. Frank Wellershoff
- **Time span:** 2015-2017
- **Contact data:** roman.baudisch@hcu-hamburg.de
  matija.posavec@hcu.hamburg.de
- **Partners:** Hess Timber Limitless, Kleinheubach
- **Funding:** Zentrales Innovationsprogramm Mittelstand (ZIM)

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Dynamic facades as solar control tool to increase the energy efficiency of administrative buildings in arid climate

▶ **Cherif Ben Bacha, University of Constantine 3, Faculty of Architecture and urban planning, (ABE) Laboratory**

Introduction, Background to the Research

The aim of the research is to examine and evaluate the effect and performance of adaptive and dynamic façades in the context of the indoor thermal comfort and energy efficiency. These parameters are achieved by controlling the levels of solar radiation and by calculating shading element sizes for sun control in response to environmental changes. In order to ensure the systems autonomy the semi-transparent PV modules has been used as panel's material. The method is applied to the case study of a reference office building with a fixed glazed façade windows-to-wall ratio in hot arid climate zone of Algeria.

Research problem

The main problem related to the adaptive skin research is the complexity of the subject and the lack of information related to the software used and the absence of this kind of technology in Algeria. The **evaluation** of the indoor thermal comfort, using the adaptive façade cannot be assessed for the in-situ measurements.

Research Questions (Main Questions and sub question)

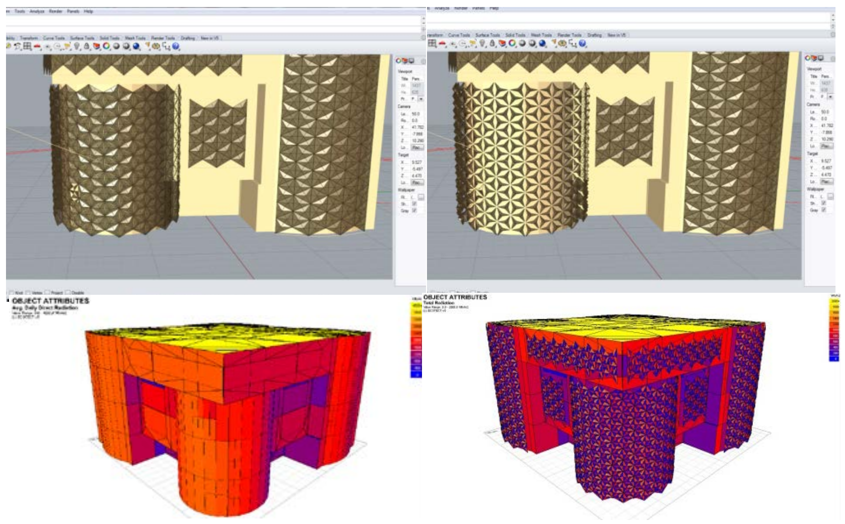
How can the dynamic shading devices be optimized for different building skins, to reduce the energy consumption and improving the indoor comfort levels in hot and dry climate ?

Sub-questions

1. Mechanical shading devices in building envelopes are most suitable for hot -arid climates that non- mechanical shading devices ?

2. What are the advantages of using software for parametric design shading devices and what are the tools available to use during the design phase ?

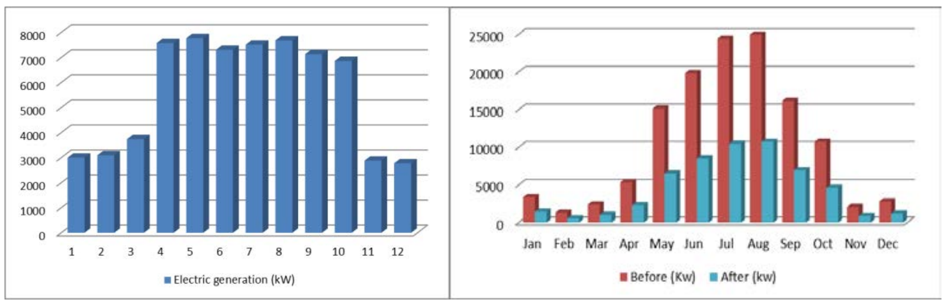
3. Does solar control in buildings helps to define an energy balance in the envelope?



Research Objectives

The design of a dynamic envelope sunscreen and sun control systems are analyzed as an aid to achieve the following objectives :

1. the creation of a new dynamic system in the external envelope that will lower both the cooling and heating demands throughout the year.
2. Reduce the heat gain in buildings while reducing energy consumption.
3. Improve the indoor thermal comfort and increase the satisfaction levels for the inhabitants of the office buildings.
4. Ensure the autonomy of the dynamic adaptive systems with semi-transparent Photovoltaic modules.
5. Provide An optimal visual environment in office spaces, achieved through the use of daylight.
6. Allow exterior views.
7. Provide an aesthetic dynamism in the building envelope.



Research Deliverables

1. 3D modelling of an existing office building in a detailed way with a dynamic simulation (Rhinoceros) .
2. Design with a parametric definition of a dynamic protection system (Grasshopper) .
3. Site measurement for several climatic conditions.

Results

The results showed that after the integration of a dynamic sun protection system, as a second skin, we minimize exposure to direct radiation of **17.9%**. Which directly influence in a positive way the thermal and visual comfort levels, this dynamic shading system contribute to a significant reduction of the energy consumption reaching 43%, with a decreasing of indoor air temperature ranging between **4.0 C°** to **4.8 C°** . In addition, the integration of photovoltaic cells into the kinetic façade has a positive contribution in producing electricity that generate the amount **6000 kW / month.**

▶ **Researcher:** Cherif Ben bacha
▶ **Supervisors:** Pr: Fatiha Bourbia
▶ **Time span:** 2014-2016
▶ **Contact data:** cherif1399@hotmail.fr

▶ **Associated Publications:**

- *C. Ben bacha, F. Bourbia, Effect of kinetic façades on energy efficiency in office buildings - Hot dry climates* , 11th Conference on Advanced Building Skins 2016, Bern, Switzerland.

Development of a dwelling concept which enables a dynamic way of living throughout the seasonal changes in view of sustainability

Ann Bosserez, Sustainability Group, Faculty of Architecture and Arts, Hasselt University

Introduction, Background to the Research

The aim of the research is to develop a dwelling concept which enables a dynamic way of living for the resident throughout the seasonal changes. With a user-centred approach, the dwelling concept will lead to resource-efficient housing concepts that bring forth more energy-efficient occupant behaviour and limits the need for high material consumption (e.g. insulation) and building costs. These new housing concepts serve as an alternative housing model for the traditional, detached single-family Flemish dwelling.

Research problem

- Due to environmental, economic and social developments, the Flemish detached single-family dwelling is under pressure. This common housing model brings forth a high environmental impact, is not cost-efficient and has a low occupancy rate which results into inefficient use of the dwelling.
- With a strong focus on energy-efficiency, the Flemish energy legislation promotes current energy-efficient housing concepts that allow for a reduction of the energy consumption. But these housing concepts also induce new problems such as a high material consumption, higher building costs and inefficient occupant behaviour.
- Due to an object-centred approach, the housing concepts focus mostly on the building skin, structure and services (e.g. insulation and active techniques) while little work has been done on creating an interaction between resident (social layer) and its environment. This leads to a constant, static, controlled living environment that does not support the resident and or sustainable user behaviour.

Research questions

Main question
Can a dwelling concept which enables a dynamic way of living for the resident throughout the seasonal changes, lead to an affordable house with a lower total environmental impact (energy and materials) than an equivalent house while still providing optimal comfort and spatial quality?

Sub-questions

1.How to define a concept for contemporary dynamic way of living throughout the seasonal changes?
2.Can this dwelling concept lead to a more resource-efficient housing concept, with a decrease in total environmental impact and lower building costs, than an equivalent dwelling while still providing spatial quality and optimal comfort?
3.How can this resource-efficient housing concept which enables a dynamic way of living be implemented in the Flemish context as an alternative housing model for the underused, large detached single-family dwelling?

Research objectives

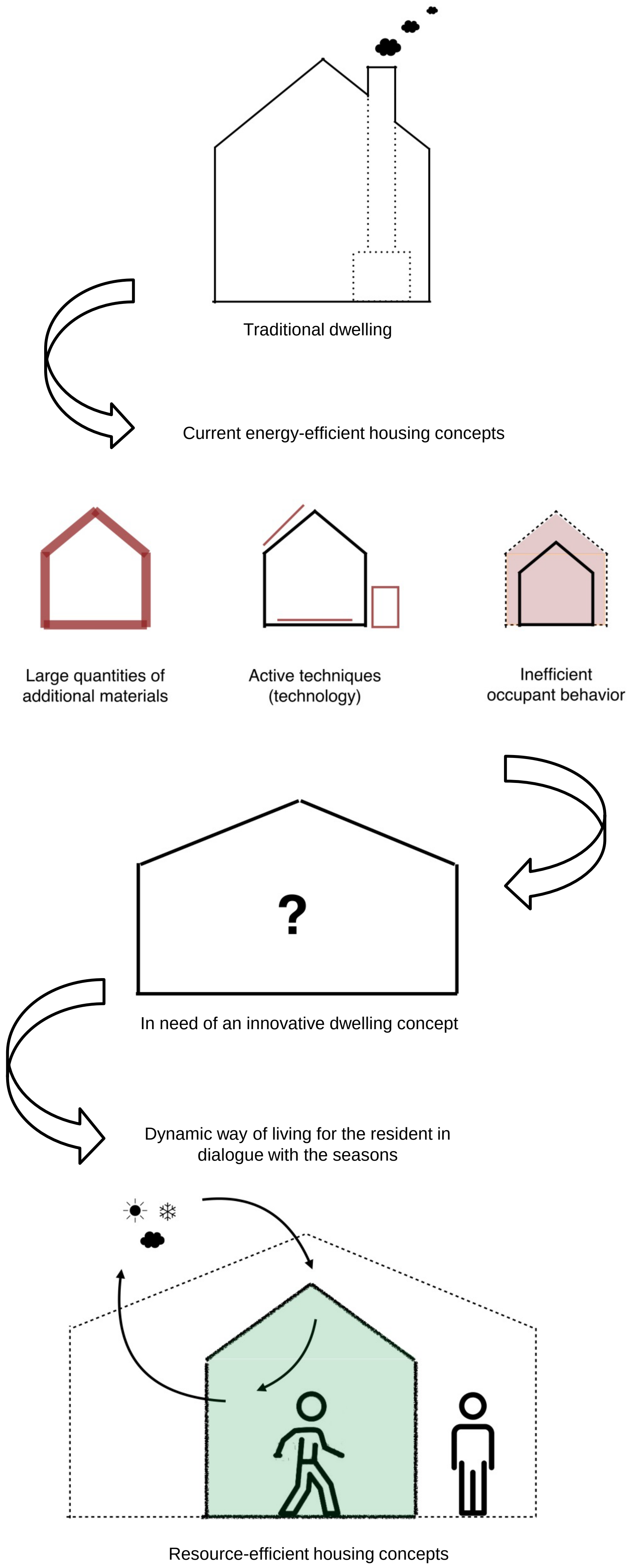
Main objective
Developing and evaluating a dwelling concept which enables a dynamic way of living in view of sustainability

Sub-objectives

1.Defining a conceptual framework for a contemporary dynamic way of living for the resident in dialogue with seasonal changes
2.Developing resource-efficient housing concepts that enable a dynamic way of living while still providing optimal comfort, spatial quality, lower building costs and a decrease in environmental impact (energy and materials)
3.Investigating if the developed dwelling concept can serve as an alternative housing model for the underused, large, detached single-family dwelling in Flanders

Research deliverables

1.Literature review about the interactive relationship between the resident and its environment
2.A critical overview of relevant design strategies and principles
3.Contemporary living and user patterns throughout the seasonal changes
4.Architectural design projects that induce a dynamic way of living and meet the boundary conditions under which these housing concepts work
5.Architectural design projects as an alternative housing model for the detached single-family dwelling and design guidelines for designers to create resource-efficient dwellings which enable a dynamic way of living



Researcher: Ann Bosserez
Supervisors: Griet Verbeeck and Jasmien Herssens
Time span: 4 Years
Contact data: ann.bosserez@uhasselt.be

NZEB and adaptive comfort in hot and humid climate regions in Brazil

Diego Caetano M.Sc., Federal Fluminense University Niteroi Brazil, Graduate Program in Architecture and Urbanism

Introduction, Background to the Research (Research Theme)

Energy-efficient buildings and the initiation of the use of renewable energy in the private and commercial sector challenge significantly future infrastructure projects in Brazil. The cooling of residential and nonresidential buildings is an important contribution to the overall electricity consumption of the country and its continuous growth is motivated mainly by the rising standard of living and working. At the same time, people's requirements on comfort have increased. The aim of the research is to investigate strategies to realize nearly zero-energy non-residential buildings in the hot and humid climate regions of Brazil.

Research problem

The scope of the research is to analyze if the concept of adaptive thermal comfort in buildings is applicable to non-residential buildings in hot and humid climate regions in order to reduce the cooling demand while maintaining thermal comfort requirements.

Research Questions (Main Questions and sub question)

Main question

- "How can we achieving low-energy or even net zero-energy buildings in in hot and humid climate regions in Brazil. Is the adaptive thermal comfort model, as one measure in order to reduce the cooling demand, applicable in Brazil?"

Sub-questions

1. How do occupants in office buildings perceive and assess the higrothermal comfort?
2. How much cooling is necessary in order to achieve certain room temperature conditions considering occupant requirements and behavior in hot and humid climate regions?
3. Which passive measures help to reduce the cooling demand in buildings?

Research Objectives

Results of my thesis will be conducted by thermal dynamic building and plant simulations, by long-term field monitoring of interior thermal comfort conditions in ten office buildings, and by intensive questioning of occupants with respect to their perception of temperature and satisfaction with thermal comfort.

The following methodology is applied to my research:

1. Collecting information of the state of the art of buildings and plants by a comprehensive field survey and by a literature review.
2. Monitor indoor temperature and humidity in six office buildings during occupancy and analyze occupant perception of and satisfaction with thermal comfort;
3. Analyze passive measures that help to reduce the cooling demand in buildings, through building thermal dynamic building and plant simulations;
4. Discuss the theme with the perspective to incorporate the NZEB's concept in RTQ-C Brazilian Energy Non-Residential Building Guidelines;

Research Deliverables

1. Identify thermal comfort requirements of occupants in Rio de Janeiro and Niteroi and develop recommendations of the national thermal comfort guideline for the hot humid climate regions in Brazil;
2. Identify the potential for application of NZEB concept and the passive measures in office buildings in Brazil;
3. Suggestions for Brazilian Energy Non-Residential Building Guidelines.

COPPETEC - Rio de Janeiro: Office buildings analized. 2015.

NAB - Niteroi: Office buildings analized. 2015.

CISCEA - Rio de Janeiro: Office Standard Room in the analyzed buildings. 2015.

Researcher: Diego Souza Caetano
Supervisors: Dr. Sc. Louise L.B. Lomardo; Dr.-Ing. Doreen Kalz
Time span: 2015-2018
Contact data: diego.caetano@gmail.com

Associated Publications:

- *Doreen E. Kalz, Louise L. B. Lomardo, Diego S. Caetano, Evaluation of thermal comfort and occupant satisfaction in office buildings in hot and humid climate regions, AREQ 2017, Barcelona, Spain. Submitted for publication.*

Manufacturing digital processes for free-form façade panels.

▶ **Estefana Castañeda, Technical University of Madrid, Department of Construction and Technology in Architecture.**

Introduction, Background to the Research

Free-form architecture is one of the major challenges for architects, engineers, and the building industry. This is due to the inherent difficulty of manufacturing double curvature facades at reasonable prices and quality The main purpose of the research is to discuss the possibility of developing geometry complex façade panels through several digital processes, especially those that avoid the use of mould, thus reducing the final cost.

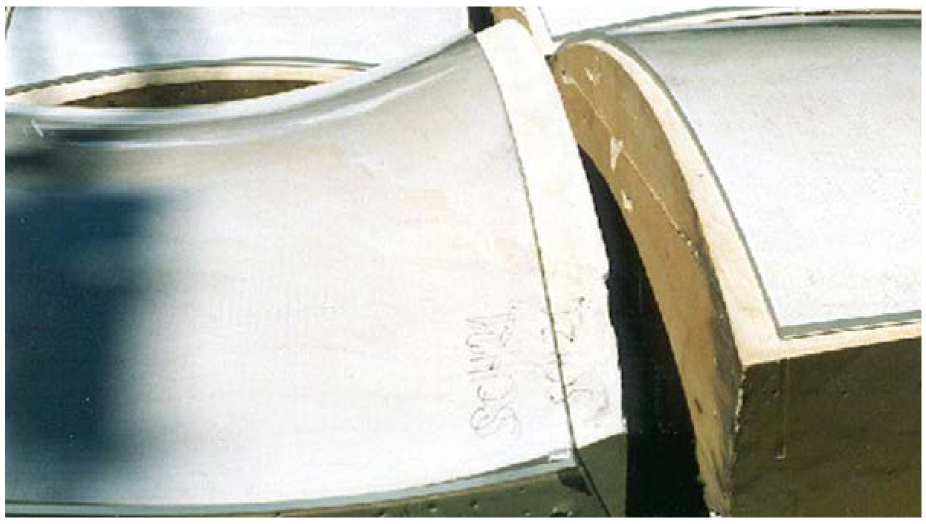
Research problem

The main problem in free-form façade panels is that every single panel of the envelope usually is unique, which means that every piece has to be manufactured using a like no other mould, and therefore the price is increased.

Research Questions (Main Questions and sub question)

Main question

How can we manufacture double-curved architectural façade panels in an affordable price and quality?



Sub-questions

1.What are the main obstacles to the production of free-form façade panels?
2.How the digital processes can face these drawbacks?
3.What are the possibilities to avoid the use of mould for reduce the final price and to make an affordable method for all kind of projects?

Research Objectives

Manufacturing double-curved panels is an as yet unresolved issue in construction industry. The existing procedures for obtaining complex forms are costly and offer a limited quality results.

This will be done through the following objectives:
1.Defining currently digital processes that can afford the manufacturing of free-form façade panels.
2.Identify main limits and restrictions of complex forms panels fabrication that cause the high prices and low quality.
3.Analyse the 3D printing process as a possible solution to the main drawbacks, due this method avoid the mould necessity.
4.Develop a prototype free-form panel.
5.Identify the main problems of manufacturing the prototype free-form panel.
6.Appraise the desirable goals for industrialize this process as a final product.

Research Deliverables

1.Review of digital processes that can produce free-form facade panels.
2.A summary of all key problems prioritised by importance and a list of desirable performance parameters.
3.Prototype mould 3D printed.

▶ **Researcher:** Estefana Castañeda
▶ **Supervisors:** Benito Lauret
▶ **Time span:** 2012-2016
▶ **Contact data:** estefanacastaneda@gmail.com

▶ **Associated Publications:**

• Alonso, L., Lauret, B., Castañeda, E., Dominguez, D., & Ovando, G. (2014). Free-Form Architectural Façade Panels: An Overview of Available Mass-Production Methods for Free-Form External Envelopes. In Construction and Building Research (149–156). Springer Netherlands.
•Castañeda, E., Lauret, B., Lirola, J. M., & Ovando, G. (2015). Free-form architectural envelopes: Digital processes opportunities of industrial production at a reasonable price. Journal of Facade Design and Engineering, 3(1), 1–13.
•Patent: Reinforced panel for opaque envelopes. P201530690, May 2015.

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Co-optimization of shading and interior lighting based on large displacement of shell structures

▶ **Victor Charpentier, Civil and Environmental Engineering Department, Princeton University, USA**

Introduction, Background to the Research

The benefits of adaptability in façade energetic performance has been proven. However adaptive façade systems most implemented today remain variations and adaptations of movable horizontal or vertical slats. The proposed research hypothesizes that more energy-efficient and durable design for adaptive building skins may come from elasticity of structures and materials.

Research problem

This research aims at harnessing elastic deformations in the particular case of shell structures to create an adaptive building skin that will reduce the operational energy consumption through shading as well as improve the occupant's experience of the building (thermal and visual comfort, ease of use).

Research Questions (Main Questions and sub questions)

Main question

How elastic deformation of thin flexible shells can be tailored to achieve site-specific large displacements in adaptive building skins to reduce energy consumption and improve thermal comfort and access to daylight inside buildings?

Sub-questions

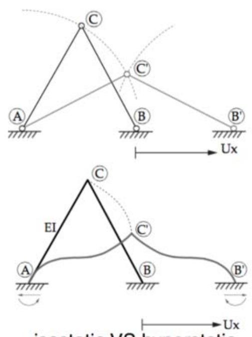
1.Shell deformations are among the most complex structural problems. How can we identify typologies of structures that would serve the intended shading function?
2.The tailoring of intended structural deformation demands the assessment of deformation in a large variety of structures. What are the available methods to refine the identified flexible shell geometries?
3.The end goal is to improve the user's experience of the building as well as the energy consumption. How can those two objectives be integrated in the exploration of forms to guarantee their equal representation in the system?
4.Although they have been around for several years, advanced adaptive façade systems have not been extensively implemented. Can the resulting façade be simple enough to become both economically and energetically attractive in the built environment?

Research Objectives

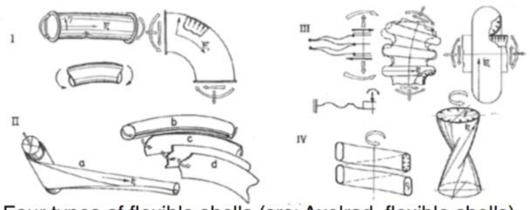
1.Identify elastic deformation mechanisms in shell structures
2.Model, parameterize and characterize the mechanisms
3.Design an analysis framework to optimize the flexible shells
4.Tailor the shape of the shading modules to adapt to the site-specific sun exposure and daylight requirements.
5.Evaluate the elastic behavior and intended low-actuation with large displacements of the proposed geometries by:
  a. Design and manufacture prototypes with actuation, supports and weather resistance
  b. Test the influence of the full scale shading modules on a study case building

Research Deliverables

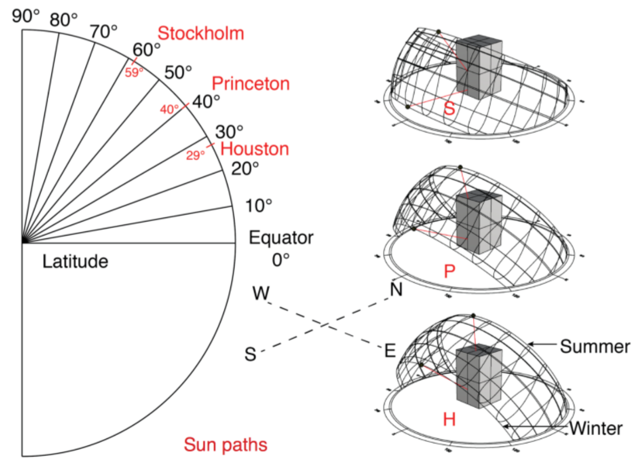
•A catalogue of shell typologies which displacements can be harnessed for shading of buildings.
•A new understanding of how actuation can be integrated to the structure to produce a multi-purpose and simpler shading system
•A prototype of adaptive shading that presents excellent thermal and light performances.

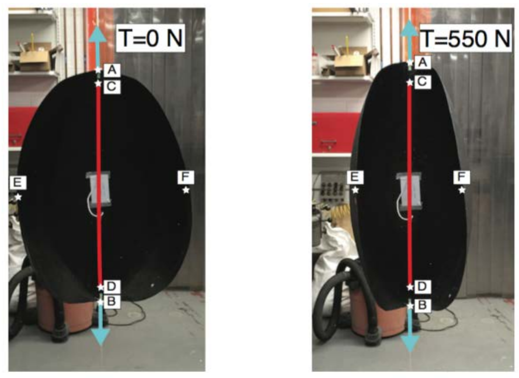


isostatic VS hyperstatic mechanism

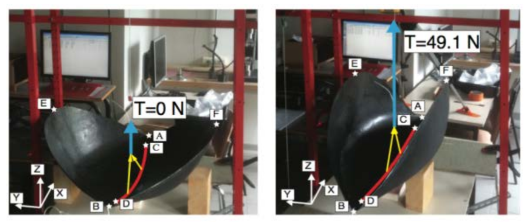

Four types of flexible shells (src: Axelrad, flexible shells)


Space reflector in deployed and folded configuration (credit:space.gc.ca)





Actuation by distributed force



Actuation by point load

▶ **Researcher:** Victor Charpentier
▶ **Supervisors:** Sigrid Adriaenssens
▶ **Time span:** 2015-2018
▶ **Contact data:** vc6@princeton.edu
▶ **Associated Publications:**

- *Charpentier, V., Hannequart, P., Viglino, E, Adriaenssens, S., & Baverel, O. (2016), An overview of mechanical principles of plant movements and their applications, (to be submitted)*
- *Charpentier, V., Adriaenssens, S., & Baverel, O. (2015). Large Displacements and the Stiffness of a Flexible Shell. International Journal of Space Structures, 30(3-4), 287-296.*
- *Adriaenssens, S., Rhode-Barbarigos, L., Kilian, A., Baverel, O., Charpentier, V., Horner, M., & Buzatu, D. (2014). Dialectic form finding of passive and adaptive shading enclosures. Energies, 7(8), 5201-5220.*

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Evaluation of a holistic assessment of building performance in early design phase

Francesca Contrada, Université Paris EST – IRC ESTP Ecole Doctorale en Science, Ingénierie et Environnement

Introduction, Background to the Research

Nowadays it is necessary to choice, in early design stages, techniques and procedures which are capable of univocally and efficiently assessing building performance towards an holistic approach. Holistic approach relates at the same time: Indoor Environmental Quality (visual comfort, acoustic comfort, indoor air quality, thermal comfort), the energetic performance (cooling, heating and lighting), Life Cycle Assessment (environmental impacts) and Life-cycle Cost Assessment of the building. At the same time new dynamic technologies are proposed in order to ensure a high performance level for all the building life-cycle. Adaptive façade systems have dynamic behaviour which requires the definition of novel specific bespoke indices.

Research problem

Two main problems : the difficult characterisation of adaptive facades through adapted performance indices; facilitate the decision-making process in the early design stage through a holistic approach able to consider several performance indices. The PhD project intends to suggest a methodology to investigate the performance indices of adaptive façades and their link with building performance.

Research Questions

Main question

How can the holistic assessment of building performance be realised starting from the characterisation of an adaptive envelope component?

Sub-questions

1. How to consider the adaptive façade dynamic characteristics in modelling phase?
2. Which is the relationship between the dynamic component characteristics and building performance ?
3. How to consider benefits and drawbacks for a considered solution and propose easier indices for early-design stages?

Research Objectives

This research aims to provide a methodology for the assessment of the holistic assessment of building performance and the characterisation of the adaptive envelopes. Adaptive envelope components will be analysed by means of numerical modelling in order to consider, at first, the façade dynamic behaviour and later the whole-building performance.

This will be done through the following steps:

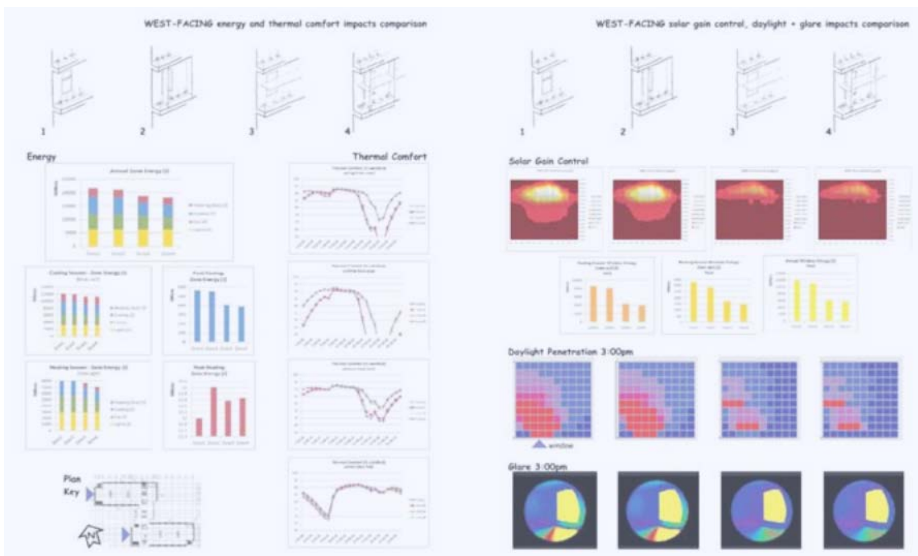
1. Choice of a case study integrating one or more kinds of adaptive façade;
2. Simulation of component's dynamic behaviour through a numerical tool such as EnergyPlus;
3. Implementation of energetic simulation by LCA, LCCA and comfort approaches;
4. Development of the holistic assessment linking the specific performance indices;
5. Definition of easier indices for the decision-making in the early design stages.

Research Deliverables

1. Review of performance assessment methodologies and their limits faced with adaptive envelopes;
2. Review of numerical tools and methods for a holistic assessment;
3. Summary of required performance parameters for a case study, concerning the envelope component and the whole-building;
4. Methodology development and proposition for a case study.

The holistic performance in the early design stage
(source : http://www.jhdarchitects.co.uk)

Dynamic facade (Kiefer Technic Showroom) Bad Gleichenberg, Autriche
(source: https://www.architonic.com/fr)



Performance results for a case study analysed by several modelling tools
(source: http://info.aia.org/EnergyModeling.aspx)

Researcher: Francesca Contrada

Supervisors: Christophe Gobin, Andrea Kindinis, Jean-François Caron,

Time span: 2015-2018

Contact data: fcontrada@estp-paris.eu

Associated Publications:

- *F. Contrada et al, Bâtiville: conception d'un îlot urbain optimisé. IBPSA 2016, Champs sur Marne, France*

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Face Wythe Made Of Unreinforced UHPC For Sandwichwalls With GFRP Connectors

▶ Milan Schultz-Cornelius, TU Kaiserslautern, Institute of Concrete Structures and Structural Engineering

Introduction, Background for the Research

Recent developments in the field of innovative materials in construction enable to build filigree, energy efficient and sustainable architectural concrete façades with only a few centimeters thickness. Due to removal of reinforcement materials, it is possible to build economic and completely recicleable façades of Ultra High Performance Concrete (UHPC). Remarkable characteristic of the used UHPC is its high > 20 Mpa bending tensile strength. It allows to build filigree façades with large dimensions. Other resulting advantages are: saving of CO_2, reduction of transportation costs and increase of the building's living space.

Motivation

Realistic description of the structural behavior of pin-supported, unreinforced UHPC façade panels is a challenging task. Therefore more research is required on material and structural system level. The resistance of the façade is limited by the tensile and flexural tensile strength of the concrete, which is crucial for the design of a façade and its support system in form of a grid of connectors. The currently existing calculation concept is based on a mechanical behaviour of natural stone façades.

Research Questions (Main Questions and sub questions)

Main question

How to design an economic, unreinforced, filigree UHPC façade?

Sub-questions

1. What influence have the component dimensions and the stiffness of the supporting structure on the load-bearing behavior?
2. How to determine the mechanical properties of the material and what effects must be considered?
3. How to calculate the internal forces?

Objectives

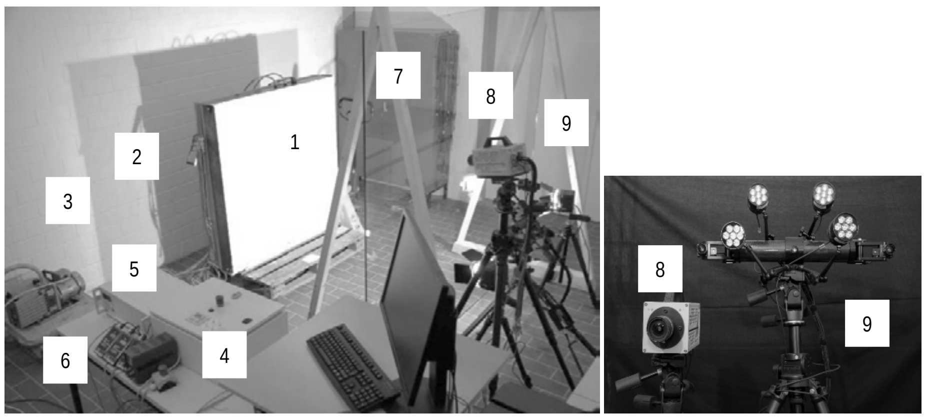
The objective is to examine the realistic load-bearing behavior of ureinforced, filigree UHPC façades. In order to do that a special test set-up, including Digital Image Corelation system, had to be developed.

Deliverables

Based on the results, a design model will be derived.

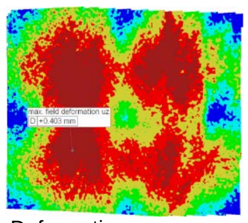
Sandwich panel with a UHPC face wythe

UHPC face wythe
GFRP connector
support structure

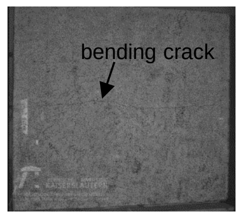


The developed test set-up: 1- specimen, 2- steel frame, 3- vacuum pump for wind load simulation, 4- controller, 5- measurement amp., 6- manometer, 7- safety glass, 8- high-speed camera, 9- 3D measurement system

The façade after failure and results from optical measurement



Deformation u_z



Crack pattern

- ▶ **Researcher:** Milan Schultz-Cornelius
- ▶ **Supervisors:** Prof. Dr.-Ing. Matthias Pahn
- ▶ **Time span:** since 2013
- ▶ **Contact data:** milan.schultz-cornelius@bauing.uni-kl.de
- ▶ **Associated Publications:**

- *Pahn, M.; Schultz-Cornelius, M.: Hochleistungsbetonfassade mit energieeffizienter Verankerung, in: 60. BetonTage Neu-Ulm, Tagungsband, 2016, S. 102–103.*
- *Schultz-Cornelius, M.; Pahn, M.: Investigation of Filigree (U)HPC-Facades with an Innovative Experiment Set-Up, in: "Architecture-Civil Engineering-Environment journal – ACEE", Schriftenreihe der Silesian University of Technology, Band 8, Gliwice, 2015, S. 87-90.*
- *Pahn, M.; Schultz-Cornelius, M.: Filigree (U)HPC-Facades, 8th Analytical Models and New Concepts in Concrete and Masonry Structures Conference, Wrocław, Poland Juni 2014, Book of Abstracts, Full Paper on CD, Paper ID 30.*

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Thermodynamic Simulation of Ventilated BiPV Facade Coupled with Phase Change Material

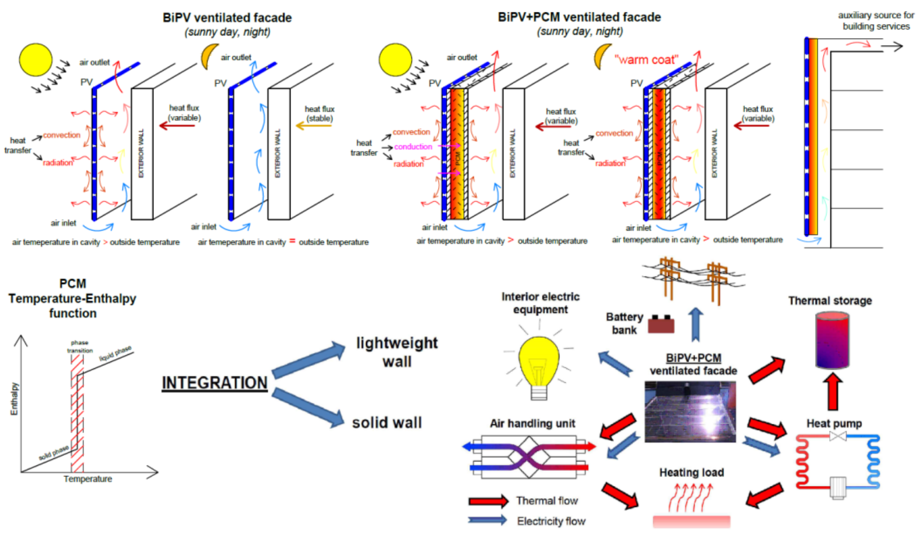
Jakub Čurpek, Department of Building Construction, Faculty of Civil Engineering, Slovak University of Technology in Bratislava

Introduction, Background to the Research

Activating the building facade by incorporating solar technology is necessary due to insufficient area on the roof, for meeting standards of EPBD from the European union. Building integrated photovoltaic (BiPV) ventilated facade coupled with phase change material (PCM) is the certain type of building responsive element in the whole envelope, designed by using selective approach. PV system provides electricity production and PCM could provide mitigating PV operating temperature, storing heat energy and consequently releasing it during night time, as well as decreasing of whole overheating of urban space during hot sunny days. This material combination signifies correlation between facade engineering and building services. Decentralized energy production by facade could be directly used for heating/cooling loads. PCM can provide good thermal inertia of outer layer well it can be considered as some „warm coat" for building. Facade air cavity can be used as low-temperature energy source by additional decentralized building component such as heat pump or air conditioning systems. Generally, indirect solar expansion solar assisted heat pump (air source) can be considered as combined system with BiPV+PCM solar collector in many ways. The main intension of research is detailed investigation of performance and efficiency of this novel adaptive facade as the effort to achieve net-zero energy building.

Research problem

Thermo-physical properties of this adaptive facade are changing over time as well as energy production from renewable resource. In order to, computing simulations would provide suitable outputs, simulation process have to be pursue in narrow time-steps. In addition to, simulation of the electricity production by PV does has to take into account the heat transfer process between PCM and PV and rear-side ventilation as well. Heating of circulating air in the cavity of facade by releasing latent heat from PCM is nonlinear due to diurnal solar intensity that determinates charging process. Air temperature in the cavity is varying over time and it is difficult to establish efficiency of air source heat pump. Commonly, air cavity have high temperature than outdoor air so intensity of heat transfer from inside to outside changes over time.



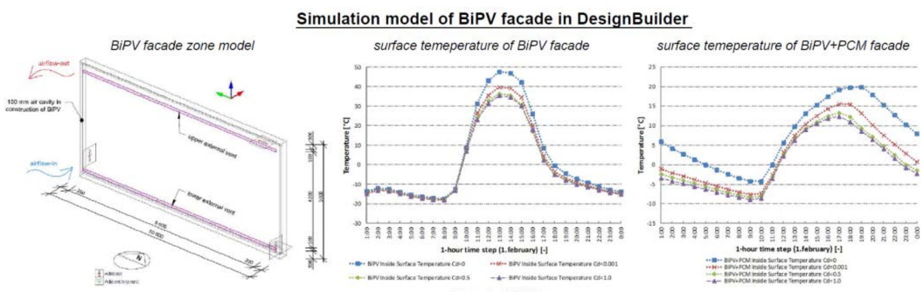
Research Questions (Main Questions and sub question)

Main question

-"How can the investigated adaptive facade influence energy performance of smart or net-zero energy building in the path to meet the requirements of the European union?"

Sub-questions

-"Which type of PCM with intrinsic enthalpy function is the most suitable for efficiency of the facade in the certain location of building?"
-"How can PCM and rear-side ventilation influence the operating temperature of PV cell and consequently electricity production?"
-"How much thermal energy can be utilized by discharging process of PCM in the air cavity during night time?"
-"What is intensity of heat flux between inside and outside through the facade?"
-"Does investigated facade play important role in the efficiency of adjoined building services, if yes, in which way?"
-"When the heating/cooling loads are the most affected by this facade?"



[Curpek, 2016]

Research Objectives

Many researches have been done in the separate fields yet, how to decreasing PV temperature by PCM, effect of ventilated BiPV facade, interconnection of PV as evaporator of heat pump. However, no one tried to investigate these research in the whole one and to create certain type of high performance adaptive facade.

This will be done thorough following objectives:
1.Analyze diurnal thermodynamic performance of PCM in the narrow time-step.
2.Define electricity production of PV cell coupled with PCM accordance to operating temperature function .
3.Estimate amount of releasing thermal energy by discharging process of PCM.
4.Analyze hypothetical thermal barrier as „warm coat" through heat exchange.
5.Evaluate the efficiency of air source heat pump connected to the air cavity.
6.Experimental analyze of investigated facade in the real dynamic climatic conditions and laboratory testing in a climate chamber and twin boxes.
6.Assess the overall performance of BiPV+PCM adaptive facade.

Research Deliverables

1.Worldwide outlook of BiPV facade systems and PCM thermal management.
2.Eligible control strategy methods enable the integrated adaptive facade to work in an efficient way in cooperation with HVAC systems under various climatic conditions.
3.Mathematical interpretation of non-linear changes of facade thermal performance in accordance to weather changes in the investigated climatic zone.

Researcher: Ing. Jakub Čurpek
Supervisors: prof. Ing. Jozef Hraška, PhD.
Time span: 2015-2019
Contact data: jakub.curpek@gmail.com
Associated Publications:

- *J. Curpek, J. Hraska, Simulaton Study on Thermal Performance of a Ventialted PV Façade Coupled with PCM, enviBUILD 2016, Brno, Czech Republic*
- *J. Curpek, J. Hraska, Simulation on influence of PCM melting point temeperature on thermodynamic behaviour of ventilated BiPV facade, ATF 2016, Leuven, Belgium*
- *R. S. Kamel et al., Solar systems and their integration with heat pump: A review, Energy and Buildings 87 (2015) 395-412*
- *T. Ma et al., Using phase change materials in photovoltaic systems for thermal regulation and electrical efficiency improvement: A review and outlook, Renewable and Sustainable Energy Reviews 43 (2015) 1273-1284*

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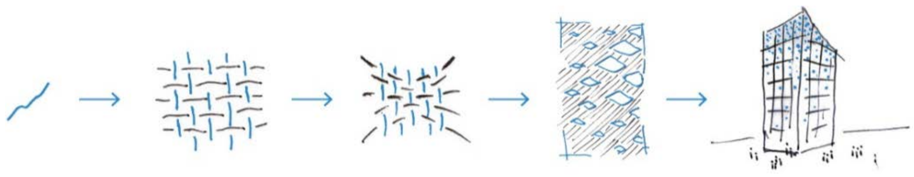
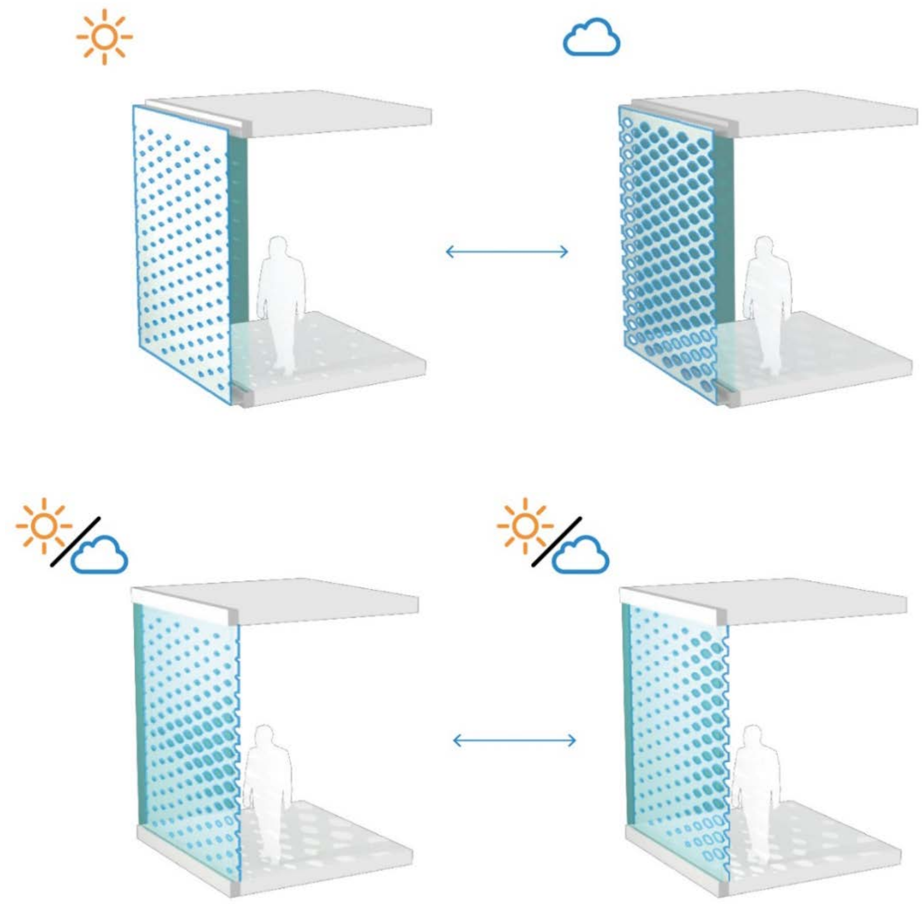
Smart Textile Skin

Paul-Rouven Denz, TU Delft / Facade-Lab GmbH





Introduction, Background to the Research

The building skin as layer between interior and exterior has to fulfil many functions and at the same time be flexible to adapt to environmental conditions and user needs. Smart Textiles with its multifunctional, adaptive and/or self-sufficient character would therefore be a highly interesting material to be integrated into the building skin. But so far smart textiles are not used in the façade in contrast to automotive industry, medical technology or mechanical engineering.

Research problem

In building industry, responsible for approximately 10% of Europe's GDP, Smart Textiles are almost never used. High requirements in durability and stability as well as the large-scale of building elements have so far prevented an integrative usage of Smart Textiles for smart building components or smart surfaces.

Research Questions (Main Questions and sub question)

Main question
How can Smart Textiles be executed within the building skin?

Sub-questions
What kind of functions and requirements can be covered by Smart Textiles?
What are limits and restrictions for Smart Textiles in building skins?
How can these Smart Textiles be integrated constructively?
What surplus may these Smart Textile Skins have to currently used façade solutions?

Research Objectives

The research examines general drivers and barriers for textile building skins and aligns these with the new development. Based on these the construction of the Smart Textile, its functionality and its holistic integration into the building envelope is developed and tested by simulations and prototypes. Thus showcasing the possible usage of Smart Textiles in building construction and especially façades.

1. Analysis of smart textiles and textile constructions
2. Definition of smart textiles in the context of the built environment
3. Functional integration of smart textiles into the building skin
4. Constructional integration of smart textiles into the building skin
5. Fabrication and measuring of prototypes of smart textile building skin
6. Marketability of smart textile skin based on previous development

Within the PhD a Research & Development project called ADAPTEX is executed with the support of research institutes and industrial partners developing a specialized smart textile for and its integration into the building envelope.

Research Deliverables

1. Definition of smart textiles in the context of the built environment
2. Matrix on smart textiles in accordance to building integration and properties
3. Constructional concepts for smart textile skins
4. Smart textile skin prototype

Researcher: Paul-Rouven Denz
Supervisors: Prof. Dr.-Ing. Ulrich Knaack, TU Delft/TU Darmstadt
Prof. Dipl.-Ing. Christiane Sauer, KH Berlin
Prof. Dr.-Ing. Tillmann Klein, TU Delft/TU Munich
Time span: 2016 - 2021
Contact data: paul.denz@facade-lab.com

Associated Publications:

- *Sauer, C.; Denz P.-R.: ADAPTEX, Entwicklung eines textilen Halbzeuges zur Anwendung als Basisprodukt für intelligent-adaptive Hüllen im architektonischen Kontext durch technische und funktionale Integration von Formgedächtnislegierungen in der textilen Werkstoffebene. Smart³ Netzwerkbericht, Bautzen (2016)*
- *Haase W. ; Sedlbauer K.; Klaus, Th. Sobek W., Schmid, F; Synold, M.; Schmidt T.: Adaptive textile und folienbasierte Gebäudehüllen. In : Bautechnik 88 (2011), Nr. 2 S. 69-75*

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Design of tall office buildings from the aspect of energy efficiency in climatic conditions of Belgrade

Andjela Dubljevic, University of Belgrade – Faculty of Architecture, Department of Architectural Technologies

Introduction, Background to the Research

The aim of this research is to investigate possibilities for design and construction of tall buildings in Belgrade, Serbia. Last significant tall buildings in Belgrade where built 40 years ago and since than there were some projects for development of city but none of them was realized, not only because of political and economic issues, but also due to problems in the technological development. The aim of the research is to create recommendations for tall office buildings design particularly from the energy efficiency aspect.

Research problem

The main problem is to consider the possibilities of adapting and improving common designs concepts of tall buildings, taking into account Belgrade conditions.

Research Questions (Main Questions and sub question)

Main question

"In what way does the form, building materials and facade concepts of tall buildings affect energy consumption for cooling and heating in climatic conditions of Belgrade?"

Sub-questions

1. "What are the most common types of tall buildings in the world?"
2. "What are the specifics of certain typologies from the aspect of energy efficiency?"
3. "Which are the key issues of the facade concepts of tall buildings in terms of thermal comfort?"

Research Objectives

Firstly, research includes making of typologies based on form, building materials and facade concepts of existing tall buildings in the world. In addition, intention is to make several models based on the previous typologies and examine them through simulations, considering aspects of energy efficiency. The final step is to analyze and compare results that have been gathered through simulations, in order to give recommendations for designing of tall office buildings in climatic conditions of Belgrade.

This will be done through the following objectives:

1. Review of the state of art of the most common types of tall buildings built worldwide.
2. Identification of different typologies of tall buildings based on form, building materials and facade concepts.
3. Design of hypothetical models of tall buildings in Belgrade climate conditions.
4. Numerical simulations of different hypothetical models from the aspect of energy consumption.
5. Comparison of results.
6. Creation of recommendations.

Research Deliverables

1. Review of tall building typologies.
2. A summary of criteria for the analysis of models of tall buildings from the aspect of energy consumption for cooling and heating.
3. Recommendations for the design of tall buildings based on comparison of previous results.

Researcher: Andjela Dubljevic, ing.- arch.
Supervisors: Professor, Aleksandra Krstic-Furundzic, PhD, ing. - arch.
Time span: 2014-2020
Contact data: andjela.dubljevic@arh.bg.ac.rs

Associated Publications:

- *Sudimac, B., Dubljevic, A. (2015) "Solar energy - design element", International Conference Education, Research & Development Science and Education Foundation, Bulgaria, 04. – 08. September 2015., Elenite Holiday Village, Bulgaria. Materials, Methods & Technologies - Journal of International Scientific Publications, Volume 9, 2015, 626-634. (ISSN 1314-7269).*
- *Krstic-Furundzic, A., Sudimac, B., Dubljevic, A. (2014) "Energy And Environmental Aspects Of Improvement Of Office Building By Application Of PV Modules", in the Proceedings of the Fifth International scientific-professional symposium Installations & Architecture, Faculty of Architecture, University of Belgrade, Belgrade, Serbia, 12-22. (ISBN 978-86-7924-133-7, COBISS.SR-ID 212389900).*

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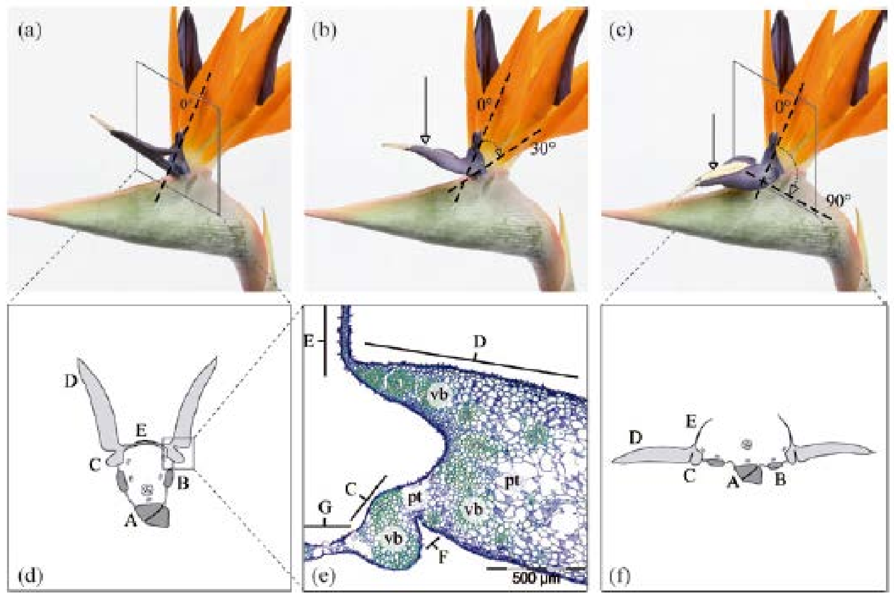
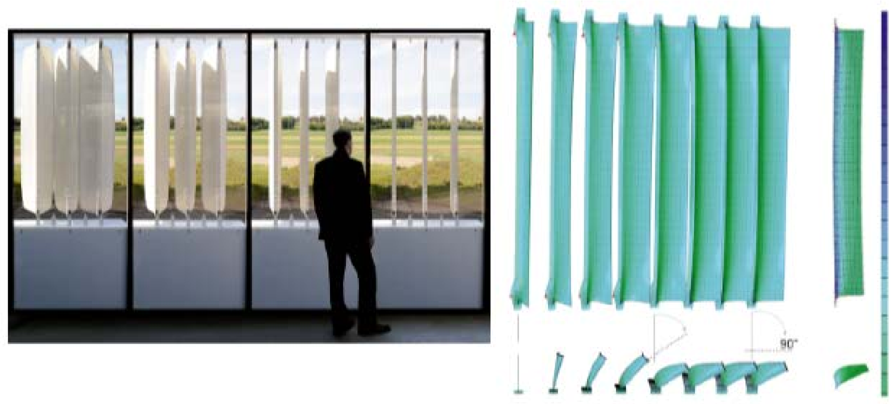
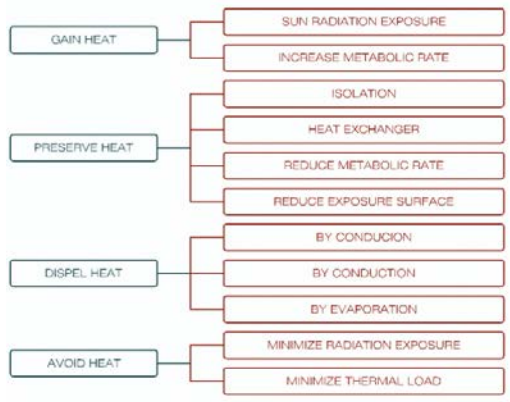
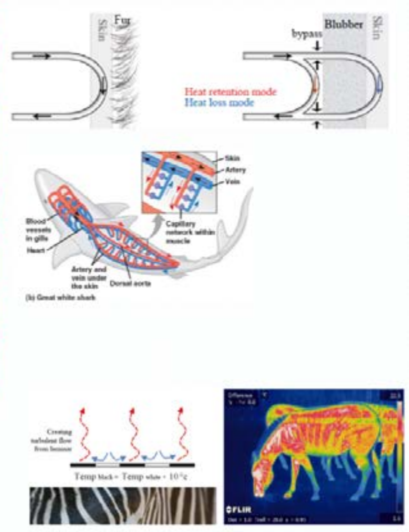
Biomimetic principles in the design of adaptive building skins. Methodology and application.

Mario Fernández. Department of Architectural Technology and Construction, Polytechnic University of Madrid.









Introduction, Background to the Research

Adaptive building skins emerge as a necessary evolution of facades, for their ability of adaptation to climate, environment and changing uses of buildings, improvement of energy performance and greater efficiency in the use of materials.
The development of adaptive building skins is just beginning to raise. Despite the increasing number of scientific papers and research projects, it's still limited mainly to experimental prototypes.
Adaptive behavior is new to building skins; given its parallel with the adaptive behavior of natural organisms, it seems logical to look for adaptive strategies of natural organisms as a source of inspiration, so that, according to current researches, adaptive behaviour of building skins is improved; could serve as a tool for finding better solutions and as a driver of innovation in architectural technology, and would allow us to take advantage of the great amount of knowledge of evolution.
Nevertheless, creating a suitable design process is still a challenge.

Research problem

The problem that this research tries to solve is how to use and exploit the source of knowledge of adaptive strategies of natural organisms in a systematic way, so that they can be applied in the design of architectural building skins.

Research Questions

Main question

How to systematize the application of natural adaptation strategies in the design of adaptive building skins?

Sub-questions

1. How to draw a parallel or correlation between architectural functions and biological functions of natural organisms,
2. How to select adaptation strategies appropriate to each case depending on the functional requirements of architectural envelopes.
3. How to integrate into the design process strategies that respond to different and/or conflicting requirements.
4. How to abstract the underlying principles and integrate them into the design process.
5. How to simulate adaptive behavior of envelopes with current design tools.
6. Which criteria should be used to evaluate the results obtained, following biomimetic principles.

Research Objectives

1. Establish classification criteria for adaptive strategies, from the point of view of its architectural application.
2. Define behavioral patterns of natural organisms in relation to environmental adaptation strategies.
3. Establish design criteria for selecting adaptation strategies and integrate them into the design process.
4. Develop a methodology for implementing adaptation strategies and patterns of natural organisms in the design of adaptive building skins.
5. Analyze current technologies and development possibilities for its use in building skins.
6. Propose de use of digital simulation tools for adaptive behaviour.
7. Establish criteria for evaluating adaptive building skins from the point of view of biomimetic principles and environmental regeneration,
8. Develop a prototype of an adaptive building skin according to biomimetic criteria.

Research Deliverables

1. A taxonomy of adaptive strategies according to the requirements of adaptive building skins, so that it can represent a useful biological knowledge in the design of architectural envelopes.
2. A methodology to select strategies, manage conflicting requirements, and systematize the application of a biomimetic approach to the design of building skins.
3. An application protocol of modeling and simulation tools, suitable to adaptive and changing behavior of adaptative building skins.
4. A prototype as an application model which will allow to compare, validate and improve this methodology in a process of continuous improvement.

Researcher: Mario Fernández Cadenas
Supervisors: Francisco Javier Neila González
Time span: 3 years.
Contact data: mf@ofaa.eu

Associated Publications:

- *M. Fernandez, F.J. Neila. Biomimicry in climate adaptive building skins. Relevance of applying principles and strategies. 2015, VII International Congress of Architectural Envelopes, San Sebastian, Spain,*

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Glass Strength for High Strain Rates

Matthias Förch, HafenCity University Hamburg

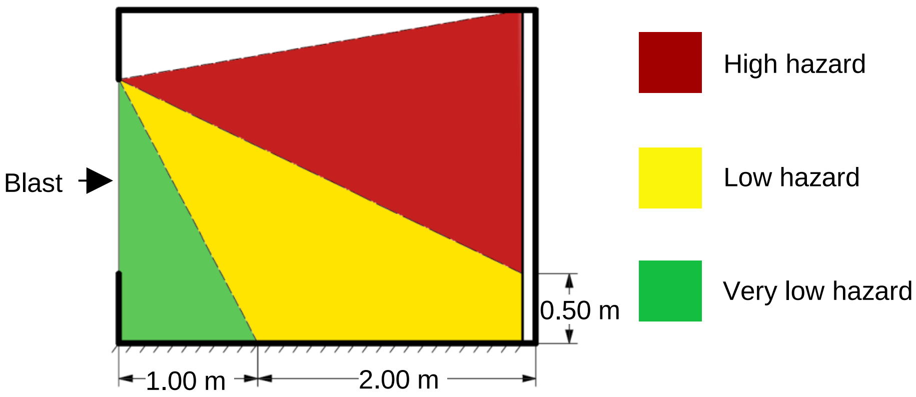
Introduction, Background to the Research

Main target in building and facade design is to protect people inside the building and to reduce damages in the facade and main structure to minimize the risk of building collapse. Investigations of bomb blast attacks show that the large part of fatal casualities were caused by glass splinters of broken windows acting as missiles. Therefore, the glazing system is an important issue within the design of blast enhanced facades. Basically it is required that the glass panels remain in the facade frames during a bomb blast event and that hazard criteria are fulfilled if specified. E.g. ISO 16933 specifies hazard criteria for windows during arena tests, where a witness panel is installed behind the tested window. After the blast test the witness panel is inspected for perforations and indents resulting from the blast.

Facade of Brussels airport after the terror attack on 22.03.2016 [nzz.ch].

Research Problem and Objectives

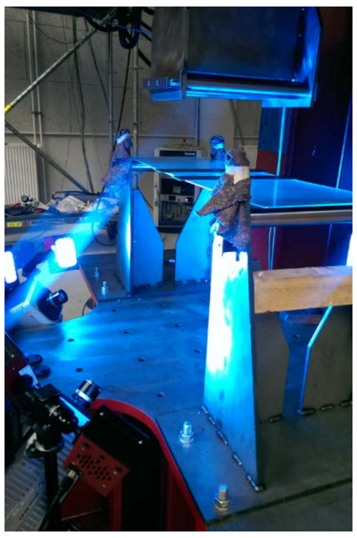
Aim of the research project is to determine short time design values for glass surface strength of glass products used for windows and facades that are required for impact or blast loading. Beside other aspects load duration and tempering level influence the glass surface strength. Microscopic surface flaws can grow under permanent load, e.g. dead load, before glass fracture occurs with delay. Therefore every glass code offers surface strength design values for untempered glass products depending on the load duration. The shorter the load duration is, the higher is the design surface strength. Usually long term (dead load), mid term (snow) and short term loading (wind) is distinguished. The German glass standard DIN 18008 considers the load duration by k_{mod} factors, which are based on fracture mechanical model. For long term load duration the fracture mechanical model can be verified by long term tests.
Due to high complexity of such tests for short load duration, occuring during impact or bomb blast events, there are only limited test data available to confirm the theoretical fracture mechanical model. The available test data result from complex pendulum or shocktube tests, but these data are not sufficient for a solid statistical determination of characteristic fractile values (5 % fractile, 95 % quantile). Therefore there is a lack in the verification of the theoretical fracture mechanical model, especially in terms of high strain rates.

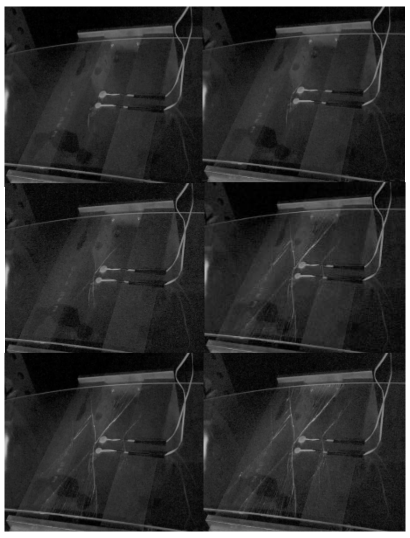


Hazard criteria for windows according to ISO 16933.

Research Methods

200 glass specimen with the dimensions 1100 mm x 360 mm are tested by four point bending test. The tests are run with standardized strain rate (2,9E-05 s^{-1}) as well as with high strain rate (2,3E-02 s^{-1}) on the same testing machine in order to investigate strain rate behaviour of glass surface strength. All common glass types in building sector, untempered glass (Float), heatstrengthened glass (HST), and fully tempered glass (FT) are subjected for testing.
In order to achieve a predamage of the glass surface comparable to long term site conditions and to reduce the variation of the test results, the glass specimen are treated with corundum. Another positive effect of such predamage treatment is, that the initial crack of the specimen is avoided to start from the edge. The high-speed tests are performed up to surface stress rates of 2000 $Nmm^{-2}s^{-1}$, which are typical for impact or bomb blast events. The surface strains during testing are investigated by strain gauges and high-speed measurement amplifier. In addition high-speed cameras are used to monitor the location of initial crack.





Left: Four-point-bending-test setup in high-speed testing machine. Right: Untempered float glass specimen in breackage phase during high-speed test monitored with high-speed camera in 30.000 fps mode.

Researcher: Dipl.-Ing. Matthias Förch
Supervisor: Prof. Dr.-Ing. Frank Wellershoff
Funding: Fachverband Konstruktiver Glasbau e.V.
Time span: 2015-2016
Contact data: matthias.foerch@hcu-hamburg.de

Bypass Double Skin Facade

Matthias Friedrich & Klaus Schweers, HafenCity University Hamburg

User Comfort and Double Skin Facades

Due to the lack of sufficient design guidelines for double skin facades the energetic and acoustical aspects are often not sufficiently considered and the design is primarily driven by aesthetic perspectives. Complex thermal effects in the facade cavity often lead to losses in energy efficiency and user comfort.

The Bypass Double Skin Facade

The main aim of the bypass double facade is to maintain the user comfort and to protect the interior against overheating in summer without active cooling or mechanical air ventilation. Therefore the focus of this facade are bypass air channels through which the external air will be directed into the interior without absorbing additional thermal energy in the regular facade cavity. In winter time this absorbed energy in the facade cavity will be used to reduce the demand of heating energy. The energetic conception of the facade and the dimensions of the bypass channels and all louvers is based on four climatic design cases.

Climatic Case I – cloudy winter day
Limitation of the air exchange rate to the hygienic required minimum to minimize heat losses. For the intelligent control of the louvers, the CO2-level of the room air will be measured. A heat recovery system will be used.

Climatic Case II – sunny winter day
The inlet air is preheated by the heat recovery system. Then the inlet air is directed through the facade cavity to gain additional thermal energy before it reaches the opening to the interior.

Climatic Case III – hot summer day
Limitation of the air exchange rate to the hygienic required minimum to reduce heat gains in summer. The inlet air flows is directed through the bypass channel directly to the interior to avoid additional heating in the cavity.

Climatic Case IV – summer night cooling
Maximize the heat convection from inside to outside. The air exchange rate is limited by air velocities which may occur damages during the night or by user comfort (draught) during the morning.

Dynamic facade control system

Electromotive adjustment of the facade openings based on decision data. A field bus system records air temperatures, concrete core temperatures and CO2-data for the control system. The systems aim is to keep the room air temperature in the comfortable zone according to the adaptive comfort model in DIN EN 15251 and to maintain a hygienic CO2-level. Additional data like humidity, air velocities, surface temperatures of walls and glass, solar radiation, illuminance and pressure differences will be recorded for verification of transient models that can be used for parameter studies.

Target results of the research project

It is aimed to provide simple design tools for dimensioning of double facades with natural ventilation for building planners. Recommendations for advanced dynamic control methods will be given.

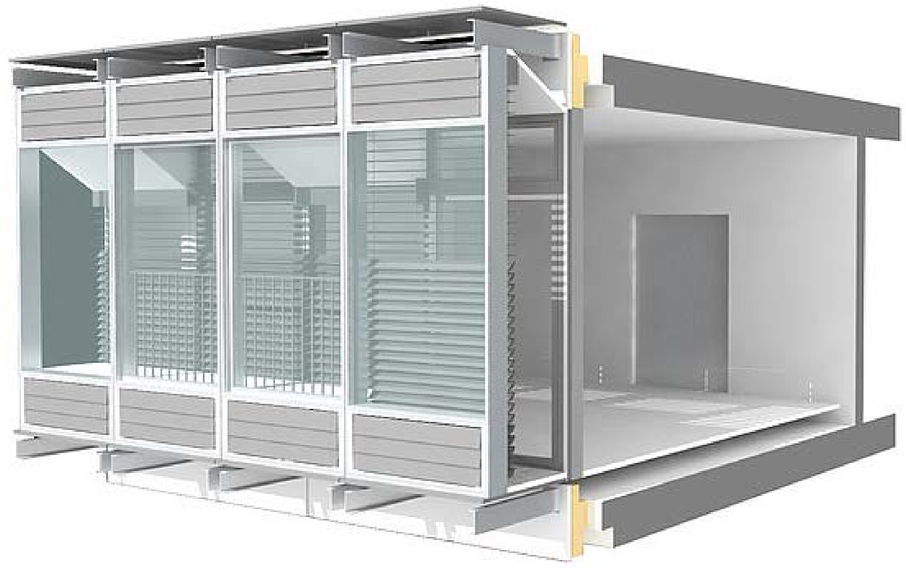


Fig. 1: Rendering of the test room equipped with a bypass double skin facade

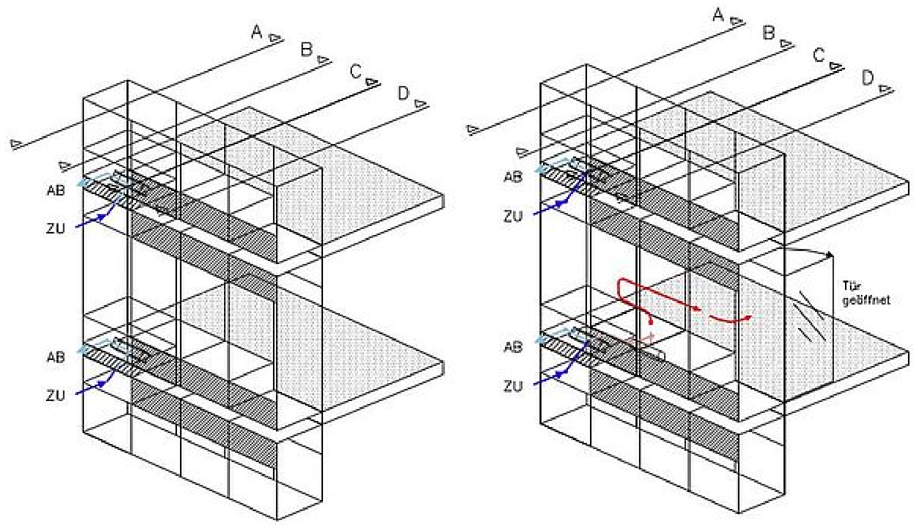


Fig. 2: Variable air flow directions in climatic case I (left) and II (right)

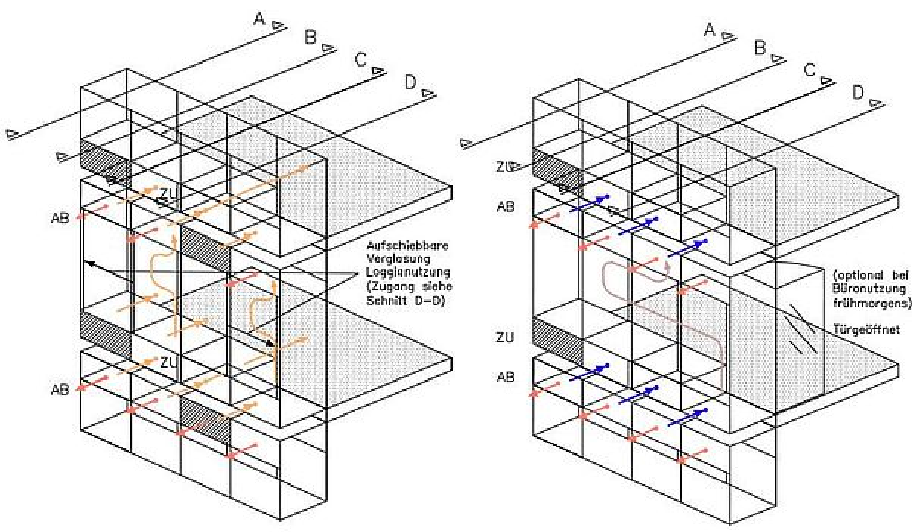


Fig. 3: Variable air flow directions in climatic case III (left) and IV (right)

- **Researcher:** M.Sc. Matthias Friedrich & M.Eng. Klaus Schweers
- **Supervisors:** Univ.-Prof. Dr.-Ing. Frank Wellershoff
- **Time span:** 2014-2017
- **Funding:** Bundesministerium für Wirtschaft und Energie (BMWi)
  Forschung für Energieoptimiertes Bauen (EnOB)
- **Contact data:** frank.wellershoff@hcu-hamburg.de

Performance assessment for technological design of innovative BIPV façade systems

Mohammadhossein Ghasempourabadi,
Graduate Research Assistant,
SEAC-TU/Eindhoven-TU/Delft- 3TU, The Netherlands

Introduction, Background to the Research

This PDEng project is related to the development of two of types of building-integrated photovoltaic (BIPV) façade systems: SoloWall and ZigZagSolar. SoloWall is a modular type of BIPV for integration in vertical facades, developed by SCX Solar. ZigZagSolar, developed by Wallvision, uses a series of slanted reflectors and solar modules to augment the PV yield of vertical BIPV while giving special attention to architectural integration.

Research problem

Experiments: After scaling up from conceptual ideas and initial mock-ups to a full-scale prototype, real characteristics and benefits of the technology can be investigated and demonstrated under realistic operational conditions.

Modelling and simulation: Complementary to experiments, the development of a reliable enough simulation model can help the developers to understand the performance of their product under different what-if scenarios, since such a virtual testbed allows us to apply changes in simulation parameters and predict the outcomes for variant situations. The simulation model can be calibrated with inputs from the experiment.

Understand the needs of stakeholders: The first step is to identify performance aspects and indicators (e.g. the amount of radiation that is received by PV panels, the amount of electricity generated by the PV panels, payback of the system) that are actually of interest to the end user, in relation to system design considerations and physical principles. Such a study will give insight into what should be measured and modelled, and will later also help to propose design variants in response to promising business strategies.

Research Questions (Main Questions and sub question)

- Which of the two façade systems is performing better in one year period? (And have related comparison with the help of simulation)

Sub-questions

1) What are the performance indicator of each system?
2) How we can improve the performance of each system?
3) Find out each system suites for where, and with what orientation and characteristics?

Research Objectives

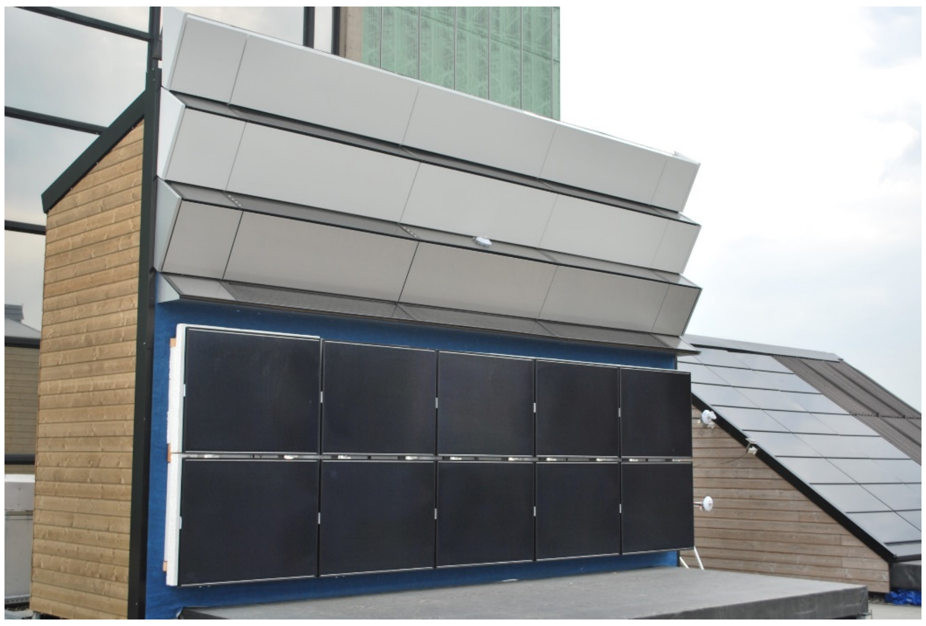
This project aims at supporting the development of two innovative BIPV façade systems by making the connection between research outcomes and technological design opportunities. The following three objectives are identified:

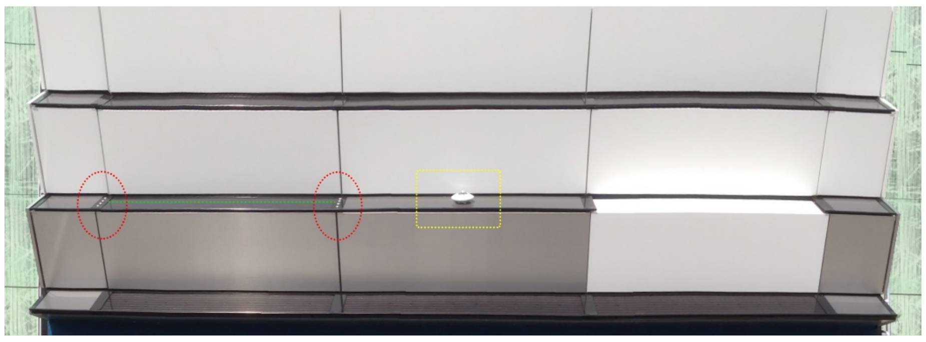
- Further investigation of PV integrated solar façade systems and their potential to generate power, with the help of experimental validation and calibration of a simulation model.
- Generate and suggest new ideas as an approach to whole system design for this type of BIPV façades.
- Find business applications based on scientific data from simulation and experiment to provide better understanding of the whole project and a better value proposition to the owners and to future customers.

Research Deliverables

Related to the project scope and objectives as identified in the previous section, the following deliverables are planned:

- Further development of the existing simulation models, validated with experimental data.
- A report with analysis of measurement data in relation to meteorological observations and sky conditions.
- A database with clear estimations of whole system performance to introduce a technological design fact sheet and design support approach to empower Wallvision and SCX Solar and customers to easily interpret performance information for desired climate, façade orientation and etc.
- Business plan explorations for proposing this new generation of façades to the market. This report includes strategic information about the benefits of this type of BIPV façades, possibilities for customization of the façade systems, and market evaluation and potentials.





- **Researcher:** Mohammadhossein Ghasempourabadi
- **Supervisors:** Jan Hensen, Roel Loonen, Roland Valckenborg
- **Time span:** 2014-2017
- **Contact data:** M.Ghasempourabadi@tue.nl
- **Associated Publications:**

- *M.Ghasempoorabadi, Xin Xu, Roel C.G.M. Loonen, Jan L.M. Hensen, Roland M.E. Valckenborg, Development and validation of a discretized solar irradiance model for tilted collectors augmented by planar reflectors. Solar Energy, under review, July 2016.*
- *M.Ghasempourabadi, K.Sinapis, R.C.G.M. Loonen, J.L.M. Hensen,Towards simulation-assisted performance monitoring of BIPV systems considering shading effects, 43rd IEEE Photovoltaic Specialists Conference, June 5 - 10, 2016, Portland, USA*

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Transparent adaptive façades: a novel approach to optimise energy and comfort aspects

▶ **Luigi Giovannini, Politecnico di Torino, DENERG - Department of Energy, TEBE Research Group**

Introduction, Background to the Research

The research is aimed at bridging the existing methodological gap between novel transparent adaptive façade components characterisation and their application to real spaces with occupants. Starting from the most recent findings in literature, this study proposes to identify new strategies and concepts concerning the integration between energy and comfort issues, as well as new testing procedures and evaluation methodologies to asses them.

Research problem

Adaptive façades, often relying on novel materials and concepts, are particularly complex to be comprehensively characterised, due to their dynamicity and the high level of interdependency among different performance aspects: requirements concerning energy, lighting and acoustical behaviour have to be contemporarily satisfied and priority criteria need to be identified.
Presently, these different aspects are not addressed through a synergic approach and most analyses are focused on the performance of the façade components only, without considering their application to real spaces.

Research Questions (Main Questions and sub question)

Main question

- "How can dynamic components be characterized in a synergic way so as to simultaneously take into account their performance in different aspects and at different levels?"

Sub-questions

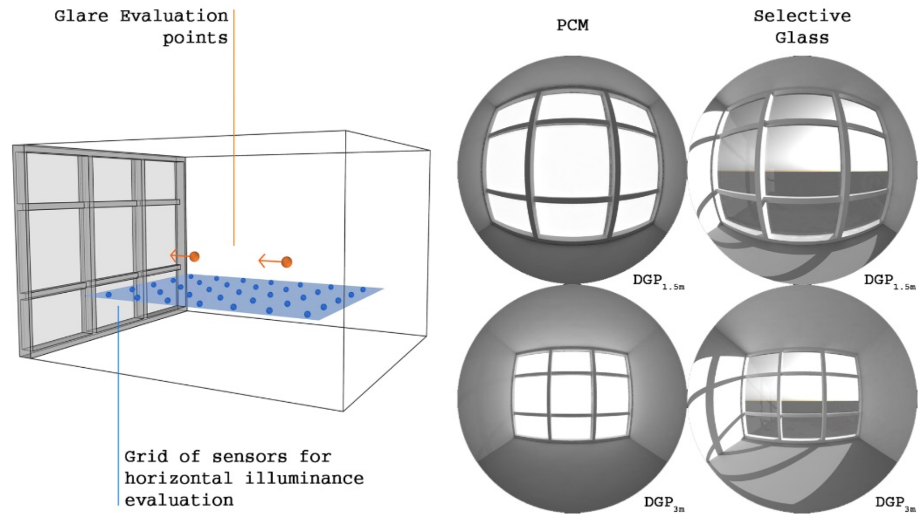
1. "How can the visual comfort be assessed from the adaptive component point of view?"
2. "How can visual and thermal comfort be assessed with a synergic approach?"
3. "How can the comfort aspects be linked to the component (and the building) energy performance?"

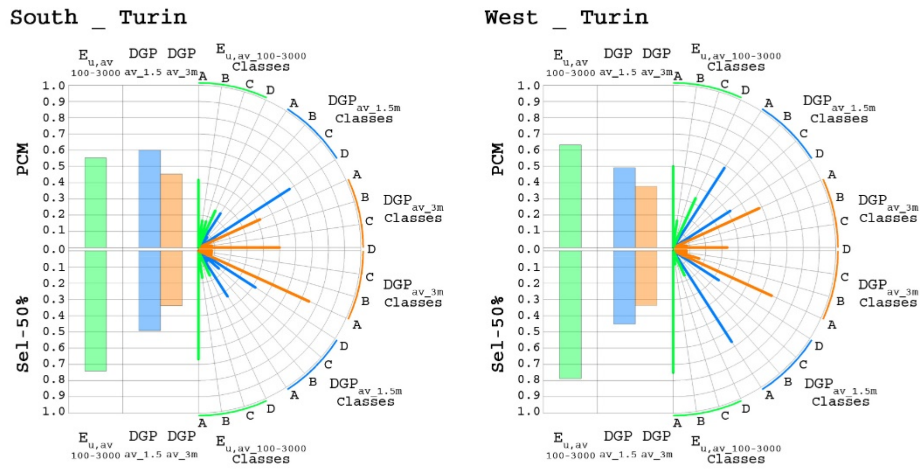
Research Objectives

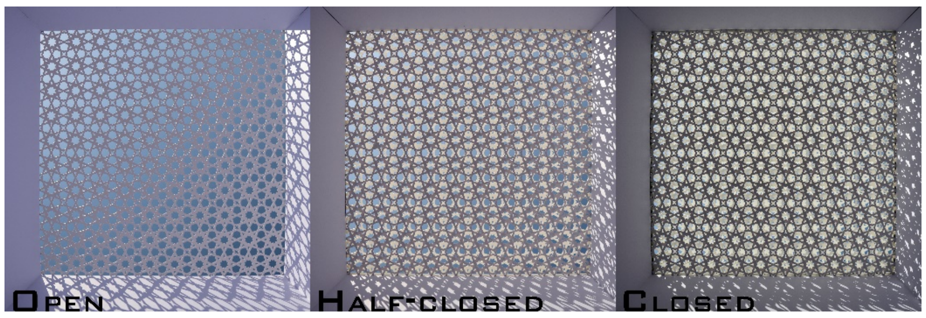
In the field above defined, a systematic approach from different points of view at a time has a limited literature background, being addressed at present time mainly the thermal aspects, without much regard for visual comfort problems. The objectives of this research, which will imply both architectural and energetic benefits, are therefore the following:
1. Characterisation of the adaptive components from the visual comfort point of view
2. Study of the correlation between visual comfort and thermal comfort provided by the adaptive components
3. Definition of a novel methodology to assess the performance of transparent adaptive façades, with regard to the component alone and to sample rooms, as a trade-off between energy performance and comfort for the occupants
4. Definition of ad hoc metrics to robustly and comprehensively characterise these new adaptive technologies
5. Validation of the research outcomes by means of experimental campaigns and modelling activities

Research Deliverables

1. A novel methodology for the optimisation of dynamic façade components as most viable trade-off between the energy use optimisation and the comfort issues
2. New performance metrics both for the component performance (with particular attention to the visual behaviour) and for the environmental performance, as well as for end users' acceptance







▶ **Researcher:** Luigi Giovannini
▶ **Supervisors:** Valentina Serra, Valerio RM Lo Verso, Anna Pellegrino
▶ **Time span:** 2015 - 2018
▶ **Contact data:** luigi.giovannini@polito.it
▶ **Associated Publications:**

- *Giovannini L, Goia F, Lo Verso VRM, Serra V. Phase Change Materials in glazing: implications on light distribution and visual comfort. Preliminary results. SEB-16, Turin, Italy. Accepted for Publication*
- *Giovannini L, Lo Verso VRM, Karamata B, Andersen M. Lighting and Energy Performances of an Adaptive Shading System for Arid Climates. IBPC 2015, Turin, Italy. In: Energy Procedia 2015, vol. 78, pp. 370-375.*
- *Karamata B, Giovannini L, Lo Verso VRM, Andersen M. Concept, Design and Performance of a Shape Variable Mashrabiya as a Shading and Daylighting System for Arid Climates. PLEA 2014, Ahmedabad, India.*
- *Lo Verso VRM, Serra V, Giovannini L, Iennarella S. Light versus Energy Performance of Office Rooms with Curtain Walls: A Parametric Study. SEB-14, Cardiff, Wales. In: Energy Procedia 2014, vol. 62, pp. 462-471.*

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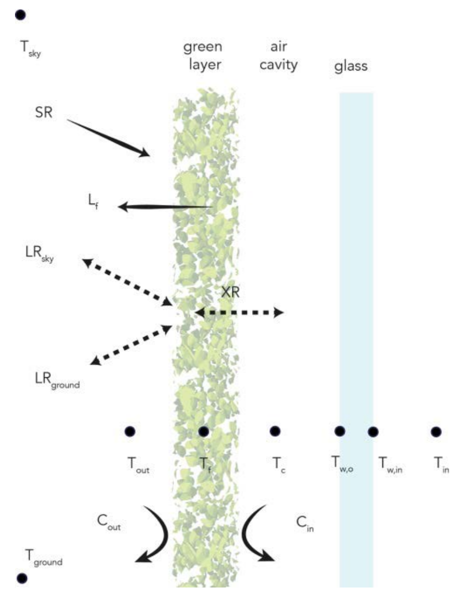
Living wall systems for the retrofit of buildings

▶ **Giulia Grassi, Pisa School of Engineering, Building Engineering and Architecture**

Introduction, Background to the Research

This study wants to show the effective benefits of a green facade developing a sustainable living wall system for the retrofit of existing buildings.
The effects of plants on thermal performance of a building are evaluated with a mathematical model that takes into account all the processes happening in the wall heat exchange. The reduction of heat flux is evaluated in comparison to the bare façade.
A case of study is developed as an example of application of the system proposed.



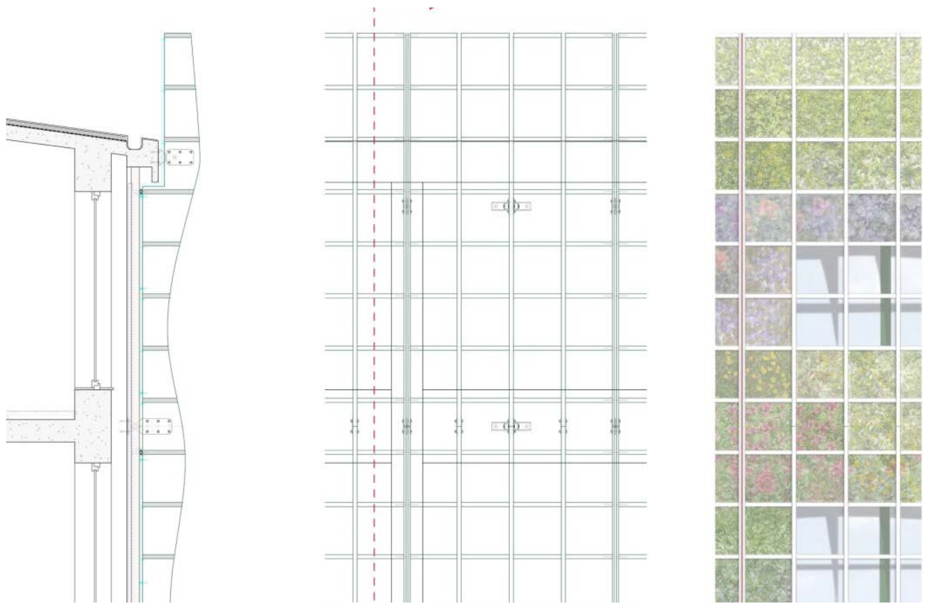
Research problem

The main issue for the calculation of benefits gained from the retrofit is to find an appropriate mathematical model to describe heat transfer processes inside the green layer. The challenges to design the façade system are: the integration of devices for energy production and storage, water distribution, structural and environmental features of materials employed.

Research Questions (Main Questions and sub question)

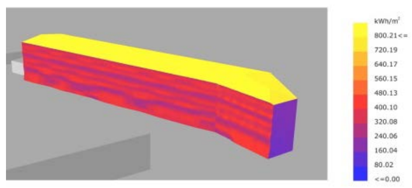
Main question
How much can we gain in terms of flux reduction?
How can we design a sustainable living wall?

Sub-questions
Which are the parameters that affect more the flux reduction?
Which are plants needs and how can they be related with the building needs?
Can we produce and harvest energy from plants?
Which material can be employed that has good structural characteristics and can be easily assembled?



Research Objectives

1)Definition of a mathematical model
2)Model sensitivity analysis
3)Parametric architecture that integrates plants needs and varieties, and building's features
4)Digital fabrication as a process of design
5)Bio electrochemical systems based on plants for energy production



Research Deliverables

1)Review of greening wall systems and in particular of LWS features
2)Results in terms of flux reduction trough the installation of a living wall on an existing building, comparison between different kind of existing walls, comparison with a bare wall, comparison between parameters that affect the leaf temperature.
3)Design of a living wall (strategy, drawings, technical data)

▶ **Researcher:** Giulia Grassi
▶ **Supervisors:** Francesco Leccese, Rodrigp Rubio, Lorenzo Secchiari
▶ **Time span:** 2015-2016
▶ **Contact data:** grassi.giulia@hotmail.it
▶ **Associated Publications:** none

Shape memory alloys for adaptive solar shadings

▶ **Philippe Hannequart, Université Paris-Est, Laboratoire Navier – ENPC, Arcora (Ingérop Group)**

Introduction, Background to the Research

Buildings with high glazing ratios often rely on shading devices to avoid summer overheating. Fixed devices are efficient only for specific orientations, and mobile devices, besides limiting architectural expression, require an expensive maintenance program. For this reason, new materials which could change shape without mechanical linkages and bypass the use of motors and complex actuation systems are investigated.

Research problem

Assessing the potential of composite structures with shape memory alloy actuators as morphing solar shading devices for buildings is the core of the research. This will be done through the development of material behaviour models, numerical simulations, experimental investigations and full-scale prototyping.

Research Questions

Main question

- "How to integrate shape memory alloy actuators and fibre reinforced polymers in order to design deformable solar shadings for facades, with controlled, reversible and cyclic movements?"

Sub-questions

1. Which shape memory alloy thermomechanical model should be used?
2. Which alloy composition for which phase change temperature should be used?
3. Which kinematics comply with the material parameters of all constituents and with the shading requirements?
4. How to fulfill the constraints of facade integration? (respecting building codes, fire safety requirements, etc…)"
5. How to control the precise movement of the shading system?
6. Retrofitting old facades or integrating in new projects?

Research Objectives

After a comprehensive survey on current facade shading systems, the specifications of a morphing solar shading system have been listed. Some key technical constraints as well as constraints of use are being traduced in terms of specifications of material behaviour and design constraints.

In parallel, a fine understanding of the thermomechanical behaviour of composites and shape memory alloys has to be reached. Thus, some existing thermomechanical models will be reviewed, new ones will be proposed, and some calculation tools will be developed in order to model and simulate these smart structures. Besides, experimental campaigns will be carried out in order to validate these tools.

The final objective is the application of the developed concepts: in strong collaboration with a facade engineering consultancy firm, the system's potential for controlling the sunlight and the energy supply in building projects will be demonstrated with energy simulation tools, prototypes and detailed integration proposals.

Research Deliverables

1. A one-dimensional polycrystalline thermomechanical model for shape memory alloy wires, validated by experimental testing, which could be numerically implemented at low computational cost.

2. Enriching a multilayer finite element code (commercial or developed by the laboratory) with a tool for calculations including embedded shape memory alloys.

3. A full-scale prototype highlighting the architectural integration of the novel solar shading system, for communication in scientific journals as well as in technical and architectural reviews.

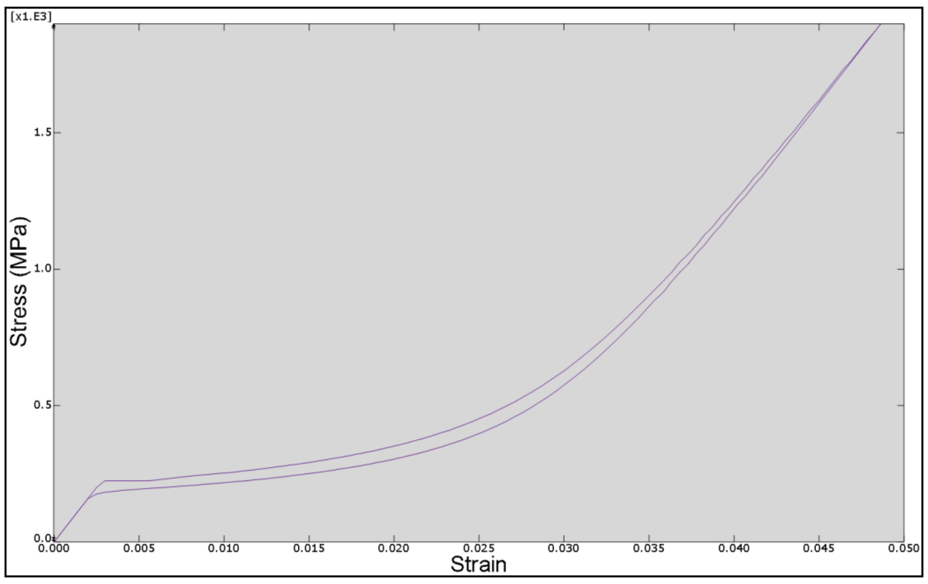


Fig. 1: Tensile Stress-Strain curve, polycrystalline shape memory alloy model

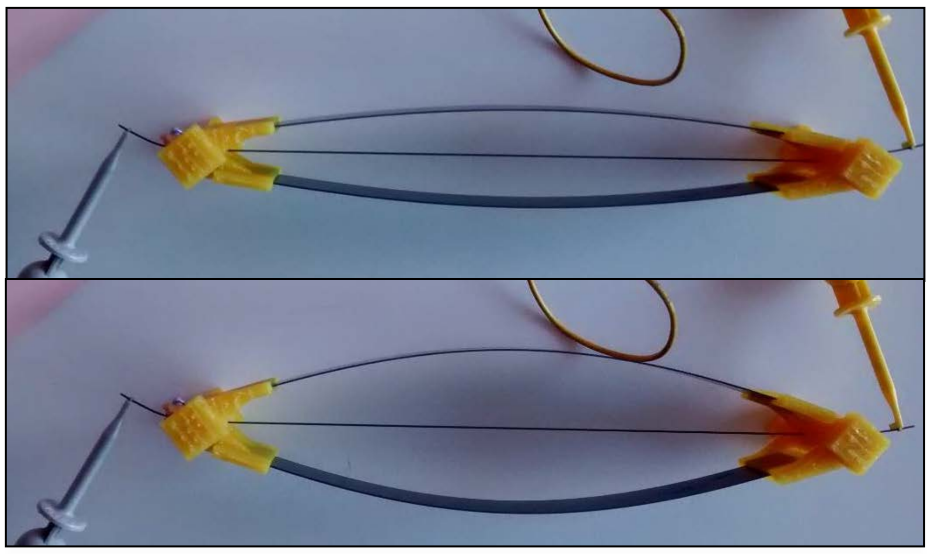


Fig. 2: Shape Memory Alloy wire actuator with bent steel plates

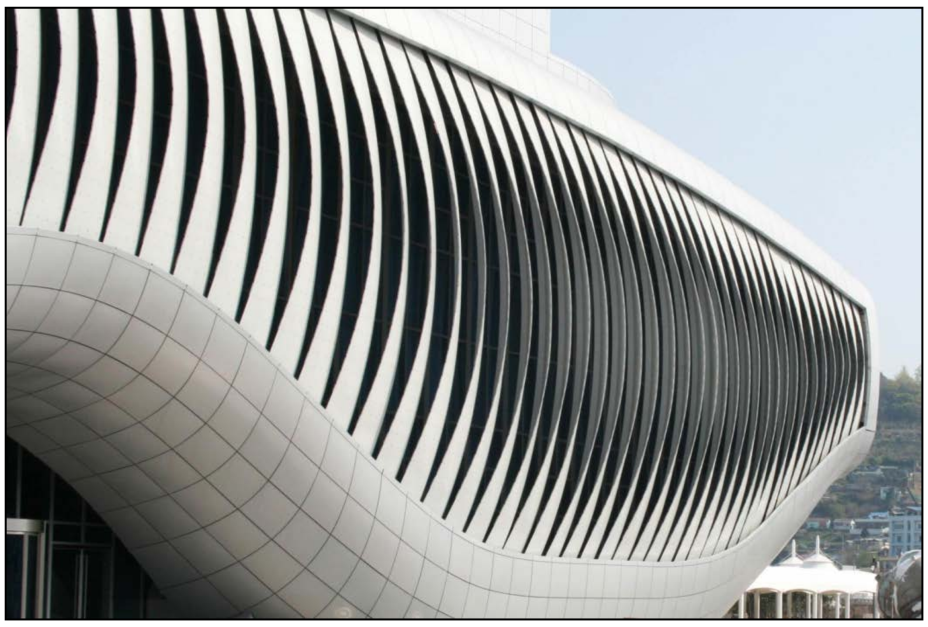


Fig. 3: One Ocean Pavillon in Yeosu, kinetic facade, Knippers Helbig, Soma architecture

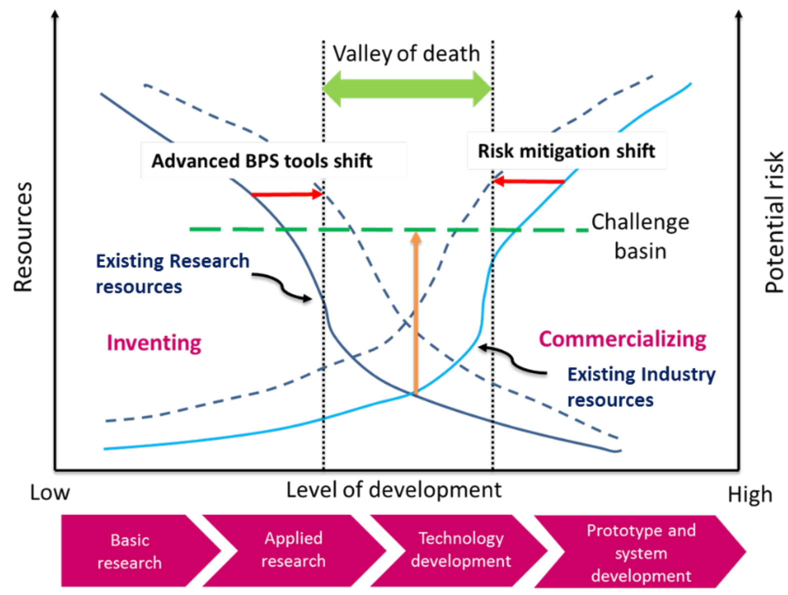
▶ **Researcher:** Philippe Hannequart
▶ **Supervisors:** Jean-François Caron, Michael Peigney, Olivier Baverel, Emmanuel Viglino
▶ **Time span:** 2015-2018
▶ **Contact data:** philippe.hannequart@enpc.fr
▶ **Associated Publications:**

Development of advanced computational support for Responsive Building Elements

Hemshikha Saini, TU Eindhoven, Department of Built Environment, Unit Building Physics and Services

Introduction, Background to the Research (Research theme)

The aim of this research is to investigate the potential of advanced decision-making support approaches for responsive building elements which reduce the time-to-market of such concepts, and promote adoption and their cost-effective replication in practice. A flexible framework will be proposed whose characteristics and application domain will be demonstrated through case studies in varying states of the product development process.



Research problem

Despite the high potential of RBE systems in terms of energy and comfort, as reported in scientific publications and technical documentation, the uptake of such dynamic, energy harvesting building components in actual buildings remains limited. Lack of information regarding expected effects of RBEs on whole-building performance and their associated risks have been prime impediments in their adoption in real buildings.

Research Questions (Main Questions and sub question)

Main question

-"How can building performance simulation and decision-making tools translate potential RBEs at early developmental stage into successful and marketable products?"

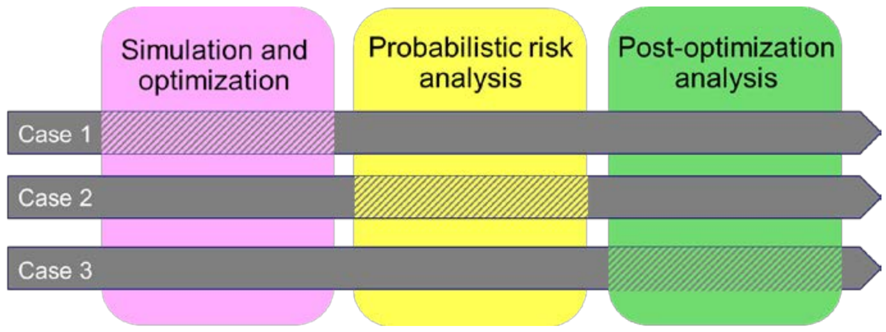
Sub-questions

1. "What are the main barriers to adoption of responsive building elements into real buildings?"
2. "What are the indirect benefits of installing responsive building elements and how can they be quantified?"
3. "How can building performance simulation tools assist in R&D of new innovative RBEs?"

Research Objectives

The main objective of this project is to develop and test a computational performance framework that can be used to analyse the direct (e.g. energy, emissions, comfort) as well as indirect performance benefits (e.g. renewable energy integration and multivariate indoor environmental quality) of buildings with RBE systems. The application potential of this framework will be demonstrated using a series of case studies. Apart from this, in this project, concepts such as uncertainty and risk mitigation will also be analysed to explore the potential of RBEs as viable building components.

The following will be the three main elements of this research:
1.Simulation and optimization: Model development and co-simulation for integrated daylight and thermal performance of RBEs and integration of simulation with dynamic optimization algorithms
2.Probabilistic risk analysis: Sensitivity analysis and uncertainty propagation based on weather conditions and occupant's influence will be used to investigate if RBEs lead to robust buildings
3.Post-optimization analysis: Mapping between design and performance aspects will be done using data mining and advanced data visualization techniques for identification of most influential design parameters



Research Deliverables

1. Multi-variate performance analysis of RBEs
2. Whole-building performance evaluation of RBEs
3. A flexible framework to assess risk versus opportunities associated with RBEs

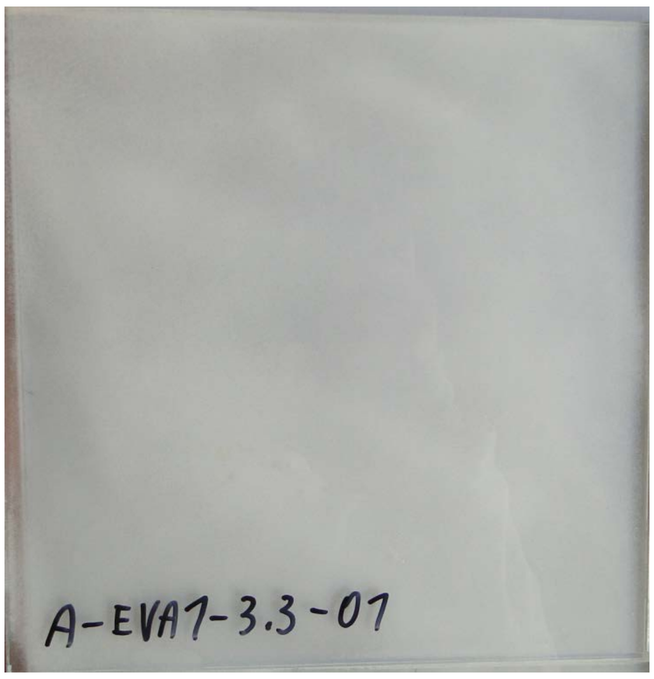
Researcher: Hemshikha Saini
Supervisors: Prof. J.L.M. Hensen
Time span: 2016-2020
Contact data: h.saini@tue.nl

Security laminated glass with a phosphorescent character; durability of this security laminated glass

Shawn Ives, Hochschule Anhalt, Architecture, Facility Managment, Geoinformation

Introduction, Background to the Research Arial

This research's aim is to give a phosphorescent character to laminated glass using phosphorescent paints. The aim is to find the best combination between the films and paints and an optimised process to have a laminated glass with the same characteristics as standard laminated glasses. These tests are around the durability of the glass (humidity, temperature, adhesion between the different layers). Another point is to know how long this phosphorescent characteristic will last in time.
After that, the aim will be focused on the processes for different kind of applications and design.



Research problem

The main problems concern durability. Obtaining a laminated glass with the standard characteristics and also an ability to be phosphorescent in the long term.

Research Questions

Main question

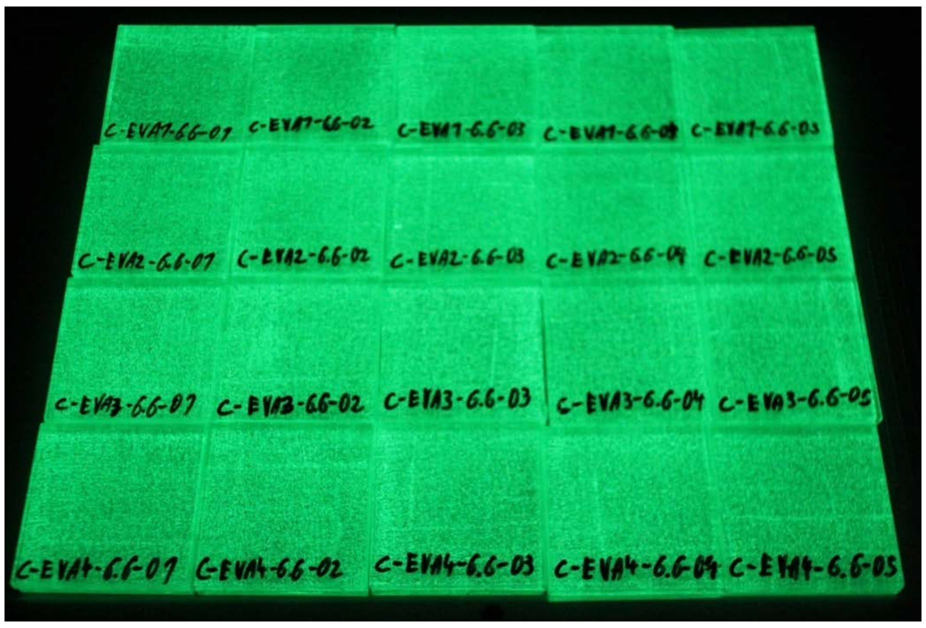
-"How can we produce a laminated glass with a phosphorescent character which will match the security requirements with the use of paint?"

Sub-questions

1."What is the limit of the phosphorescent surface part of the glass to get a safe glass?"
2."How long will last the phosphorescent character?"
3."Will it be possible to use one or several kind of process which will answer several needs?"

Research Objectives

1.Finding compatible paints
2.Finding the limit surface
3.Finding the optimal number of layers
4.Identifying and defining what to avoid during the process in order to get a final product free from defects
5.Defining a process/several processes to achieve a phosphorescent laminated glass which respect European safety norms and have a long-lasting phosphorescent character



Research Deliverables

1.A report of the research with all the steps which lead to a solution
2.A working process to produce phosphorescent laminated glass
3.Demonstration products

Researcher: Shawn Ives
Supervisors: Professor Doctor Stephan Reich
Time span: 2015-2017
Contact data: Shawn.Ives@hs-anhalt.de
Associated Publications:

Design and assessment of Adaptive facades building upon Atlantic zone resources

▶ **Miren Juaristi, School of Architecture, University of Navarre, Department of Construction, Structures and Facilities**

Introduction, Background to the Research

The Atlantic Area is characterized by climatic conditions with mild temperatures, smooth temperature fluctuations, high humidity, significant wind conditions, and solar radiation with a large indirect component.

Traditional buildings have responded by protecting against high and uncomfortable relative humidity and windy condition. The chances of an adaptive façade not only protecting from adverse weather conditions but taking advantage of these conditions have not been sufficiently exploited and have great potential.

Research problem

A correct time-scales in an adaptive facade is essential for its optimal operation. Temperate climates demands adaptability to short-term fluctuations, as wind variations or cloud covering and uncovering. The system must be very flexible and quick without being theatrical or loosing its architectural quality. Besides, adverse conditions increase the need of maintenance in façade system.

Research Questions (Main Questions and sub question)

Main question

- “Could adverse climatic conditions in Atlantic zone become a favourable resource to reduce energy demand by an adaptive façade system?”

Sub-questions

1.“How do different façade systems change with natural variable conditions?”
2.“Which are the main barriers in adaptable façade in temperate climates?”
3.“How can be combined boundary conditions to reduce discomfort and get energy saving?”
4.“Will the façade system be designed considering new climatic scenarios due to climate change?
5.“Can the façade been changed by the variable condition itself without any computerized action?
6.“How and how much should the user be involved in the adaptability of the façade?
7.“Which is the relation between energy saving and economy saving?”

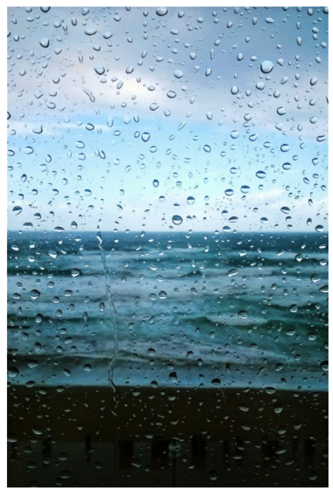
Research Objectives

Adaptive façades in temperate climate have not been researched in a detail and there are few building experiences. This research looks to develop a system suitable for Atlantic zone, which turns unfavourable boundary conditions into a protection system through the resilience of materials and dynamic changes in the façade.

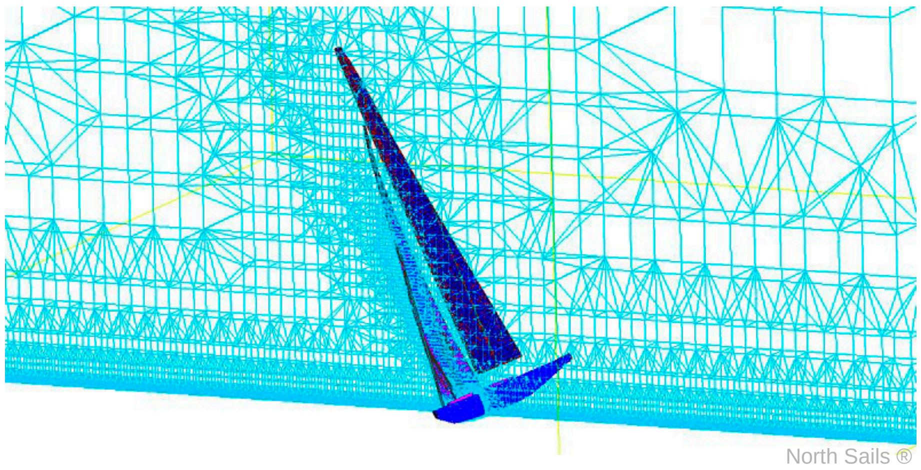
This will be done through the following objectives:
1.Defining the State-of-the-art of adaptive façade in temperate climates.
2.Identify existing building solutions to protect from the wind and humidity. Analysed key problems that they deal with.
3.Study architectural limitation and the optimal user interaction with the system.
3.Analyse given current connection details in adaptable façade system.
4.Design the system and test it with computerized simulations (Energy+, Fluent)
5.Develop a mock-up
6.Monitorized the mock-up and analyse the results.
7.Identify key challenges that must be resolved to implement the system in buildings.

Research Deliverables

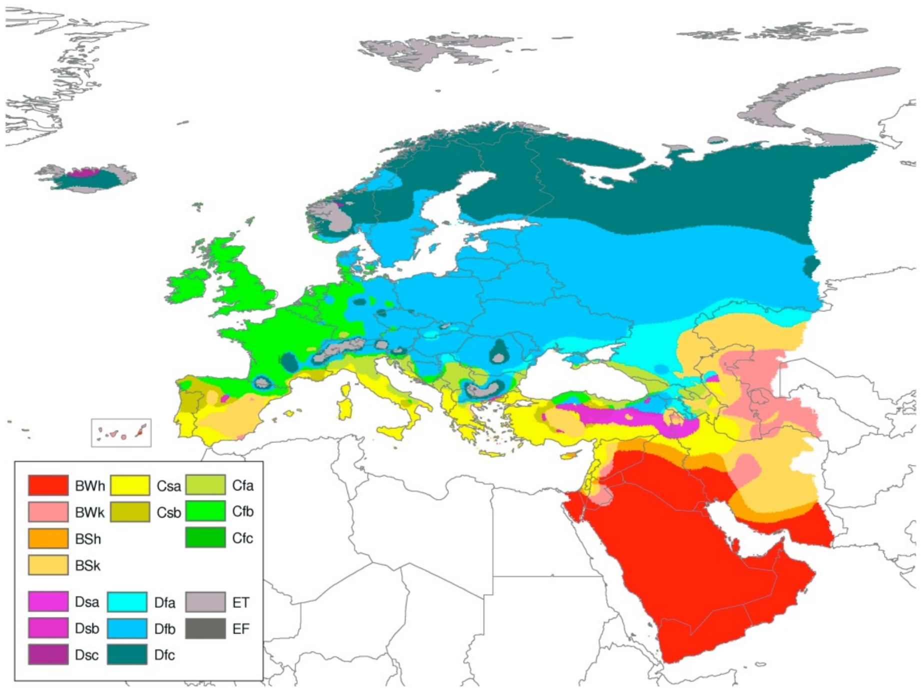
1. Reviews / state of the art / previous studies applied to Atlantic climate. (Year 1)
2. Design of adaptive prototypes (Year 1)
3. Mock-up manufacturing (Year 2)
4. Monitoring and analysis of its results (Year 2-3)
5. Calibrated simulation (Year 2-3)
6. Implementation through simulation (Year 3-4)
7. Results and conclusions (Year 3-4)



Adverse conditions will not be considered as weakness points but as potentials.



Natural sources and their potential will be analysed in different fields.



Koppen-Geigger European classification

▶ **Researcher:** Miren Juaristi
▶ **Supervisors:** PhD Aurora Monge-Barrio, PhD Tomás Gómez-Acebo
▶ **Time span:** 2016-2020
▶ **Contact data:** mjuaristi@alumni.unav.es
▶ **Associated Publications:**

•Loonen n, M. Trčka, D. Cóstola, J.L.M. Hensen, *Climate adaptive building shells: State-of-the-art and future challenges,2013*

CHANGE MANAGEMENT IN BUILDING PERFORMANCE: An Engineered Design Methodology for Sustainable Retrofitting

Aliakbar Kamari, 'Department of Engineering, Aarhus University' & 'Department of Architecture, University of Palermo'

Introduction, Background to the Research (Research Theme)

Overview of Danish and Italian recent researches and challenges for the future of building renovation context has revealed that present takes on objectives accomplishment at any rate in this context is not fully in accordance with the sustainable development paradigm. The aims of the research is to develop a methodology which reflects the conflicting nature of the criteria guiding decision makers in retrofitting projects via the support of design decision making processes during the conceptual design phase using metric and visual analysis holistically.

Research problem

Compounding the typical challenges of a sustainable retrofitting from theory to implement stages is the lack of an appropriate methodology and decision support tool which takes into account the nature of retrofitting projects initially in order to 'Learning Improvement' among the different stakeholders and then 'Multiple Optimization' through sustainable perspective in its full sense. It should be able to identify, manage, and evaluate the building objectives among different retrofitting alternatives during the early design stages.

Research Questions (Main Questions and sub question)

Main question

- "How can a multi-methodology throughout mixing certain techniques be equipped that primarily influences the society in retrofitting context and secondarily identifies and addresses the sustainability in building renovation? [Due to the diversity of the related design dependencies, prioritization of the most critical elements may be necessary. To this end, the research would be centralized on the envelope retrofitting of the existing buildings components.]"

Sub-questions

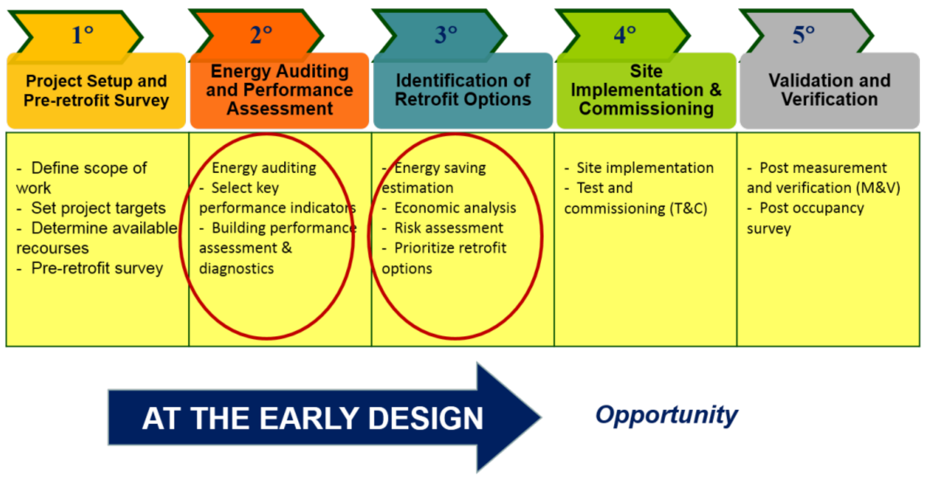
1. "How can existing Engineering Design and Decision Making methods from other domains be applied in buildings to benefit retrofitting projects and its stakeholders specifically architects concentrating conceptual design phase?"
2. "The second question seeks to address how can a methodology be extended based on application of the mix methods so as to function as a decision support systems to dissolve the main discovered issues in retrofitting domain, including 'learning improvement' and 'multi-optimization'?"
3. "What are the characteristics of envelopes in existing buildings and a sustainable retrofitting in terms of their specific change requirements? The outcomes of the previous stage will inform the second research question, which explores and develops a change management methodology and method that addresses the unique requirements of retrofitting projects in a sustainable perspective."
4. "The final question seeks to explore how this methodology can allow designers to explore and utilize retrofitting alternatives during the conceptual design stage to support decision making in terms of functionality (performance), feasibility, accountability, or sustainability in its totality. The focus here is on the first stage of the developed methodology."

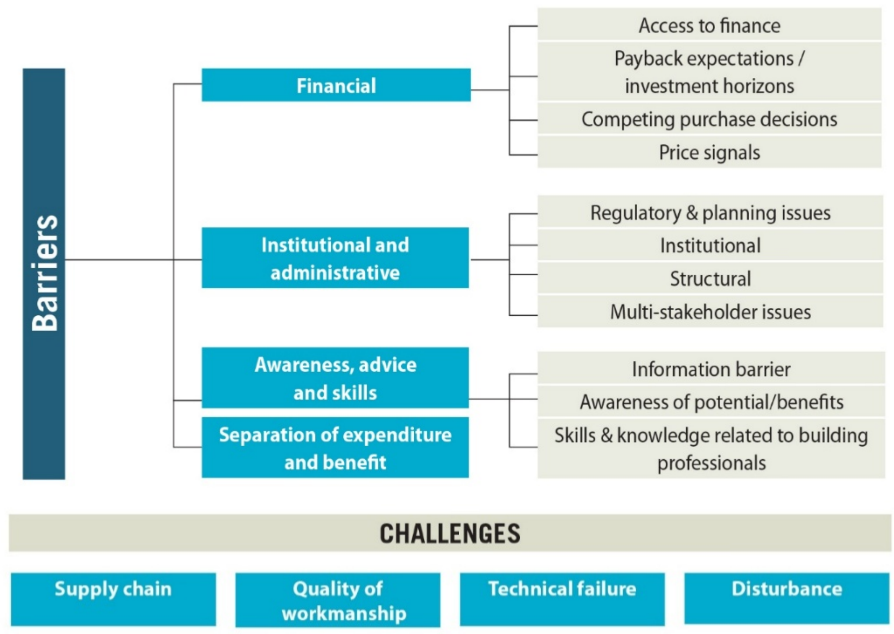
Research Objectives

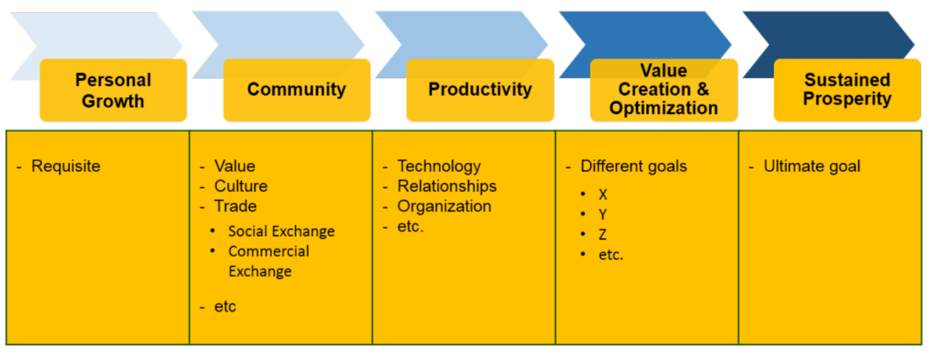
- To explore current conflicts against retrofitting of existing buildings process concerning 21st century and rise of complexity in connection with sustainability in its totality.
- To develop a holistic environment and method which initially may both guide and facilitate architect's work via support of design decision making processes during the conceptual design stages indicating the features, constraints, and classification/leveling upon different criteria.
- To demonstrate of how combinations of methods that are parts of soft systems methodologies and MCDM may support multiple perspectives representations of complex managerial problems.
- To promote a methodology to be synchronized specially upon the nature of retrofitting process in order to improve the communication and collaboration through leaning among stakeholders and carry out a real sustainable retrofitting.
- To facilitate designers in their assessment of the benefits and risks concerning to different retrofitting alternatives in retrofit decision making processes and buildings' operation.

Research Deliverables

1. Review of the issues of existing buildings
2. Develop a mix method methodology
3. Develop a Characteristic Diagram and Value Map
4. Study a case in order to validate and enlarge the results







Researcher: Aliakbar Kamari
Supervisors: Poul Henning Kirkegaard - Rossella Corrao
Time span: 2015-2018
Contact data: ak@eng.au.dk , aliakbar.kamari@unipa.it

Associated Publications:

- *Kamari, A., Jensen, S.R., Corrao, R. and Kirkegaard, P.H. (2017), "Towards a holistic methodology in sustainable retrofitting: Theory, Implementation and Applications", in Transforming Our Built Environment through Innovation and Integration: Putting Ideas into Action proceedings of the SBE 2017, Hong Kong, China.*
- *Kamari, A., Corrao, R. and Kirkegaard, P.H. (2017), "A Holistic Building Environment Method of Evaluating Sustainable Retrofitting", Building and Environment, under review.*
- *Jensen, S.R., Kamari, A., Strange, A. and Kirkegaard, P.H. (2017), "Towards a holistic approach to retrofitting: A critical review of state-of-the-art evaluation methodologies for architectural transformation", in Transforming Our Built Environment through Innovation and Integration: Putting Ideas into Action proceedings of the SBE 2017, Hong Kong, China.*

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Energy needs reduction by façade rehabilitation on vulnerable residential neighbourhoods in Madrid

▶ Fernando Martín-Consuegra. Universidad Politécnica de Madrid. Instituto Eduardo Torroja de ciencias de la construcción

Introduction, Background to the Research

Urban areas renovation may lead to problematic situations associated with financing of the works in absence of a detailed analysis of the distribution of resources. An analysis of the needs and the obstacles in achieving buildings refurbishment to improve their energy efficiency must be observed.

The building's energy demand is assumed to be a suitable indicator for quantifying building-related energy vulnerability, for it determines the energy needed to establish indoor thermal comfort and depends largely on geometric and construction characteristics of buildings and urban fabric.

Nearly 70 % of the city's primary residences were built between 1941 and 1980 and are considered as the most inefficient stock (Oteiza et al. 2015). Multi-dwelling housing units are the main target for energy refurbishment since just 4 % of its total housing stock of 1.080.306 primary residences were single family homes in 2001 (INE 2001). These buildings' façades improvement is the improvement measure with a highest potential of energy needs reduction.

Monitoring of different façade solutions at test cells (Alonso et al. 2016) show that, for Mediterranean climates, ventilated facade is optimal during summer at the orientations that receive sun radiation. Instead, ETICS based solutions works best in winter on northern orientations and shaded facades.

Research problem

Low cost solutions are needed. Buildings requiring energy refurbishment will be those with poor construction quality, not adapted to the new energy efficiency requirements and probably constructed between 1941 and 1980. People with insufficient resources to deal with such actions will inhabit many of them. 83 % of all dwellings are occupied by their owners, 86 % of whom have low incomes and 12.6 % are over the age of 65 (ENTRANZE 2008).

In the first part of the research, urban areas have been characterized from an indicator of energy demand for heating based on the official Spanish energy classification system. Vulnerable quarters (Hernandez Aja et al 2014) with high energy demand, which are at risk of fuel poverty, are located.

Solutions based on payback periods of the investment are not suitable in a high amount of cases.

Research Questions

Main question
Does high scale urban refurbishment have enough potential to reduce energy consumption and improve air quality of European cities?

Sub-questions

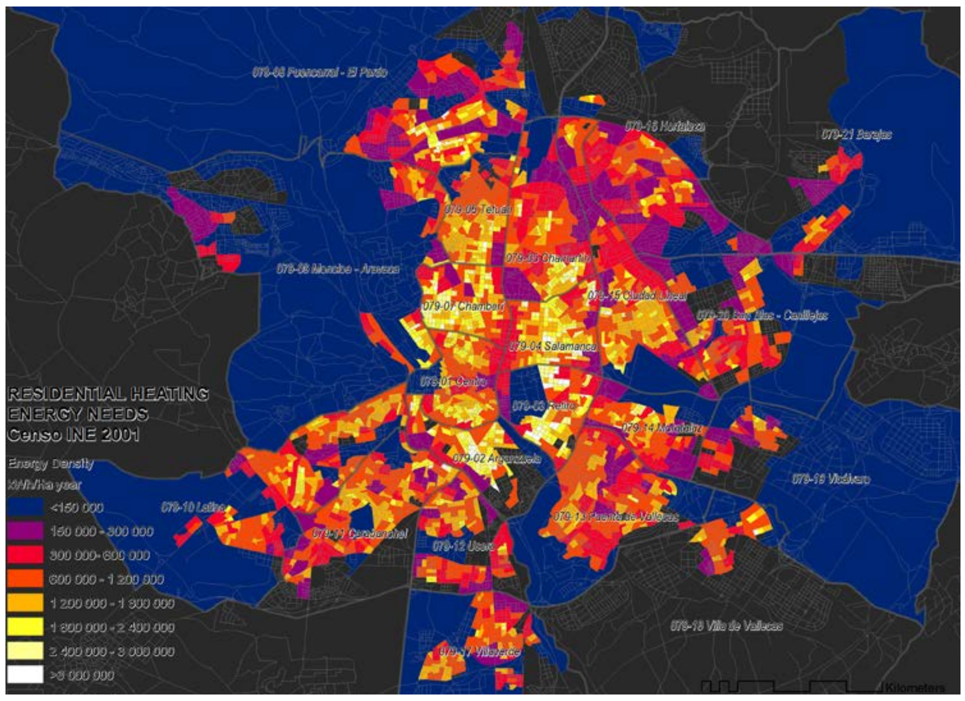
1. What's the optimal solution for a low-cost large-scale façade rehabilitation acording to urban fabric and existing building construction characteristics in Madrid?
2. Is it posible to generate an energy-related urban fabric parametrisation in order to estimate energy needs at a large-scale for Mediterranean climates?
3. Can renewable energy generation through buildings' façades with radiation incidence help to achieve the viability of the refurbishment project in vulnerable quarters?

Research Objectives

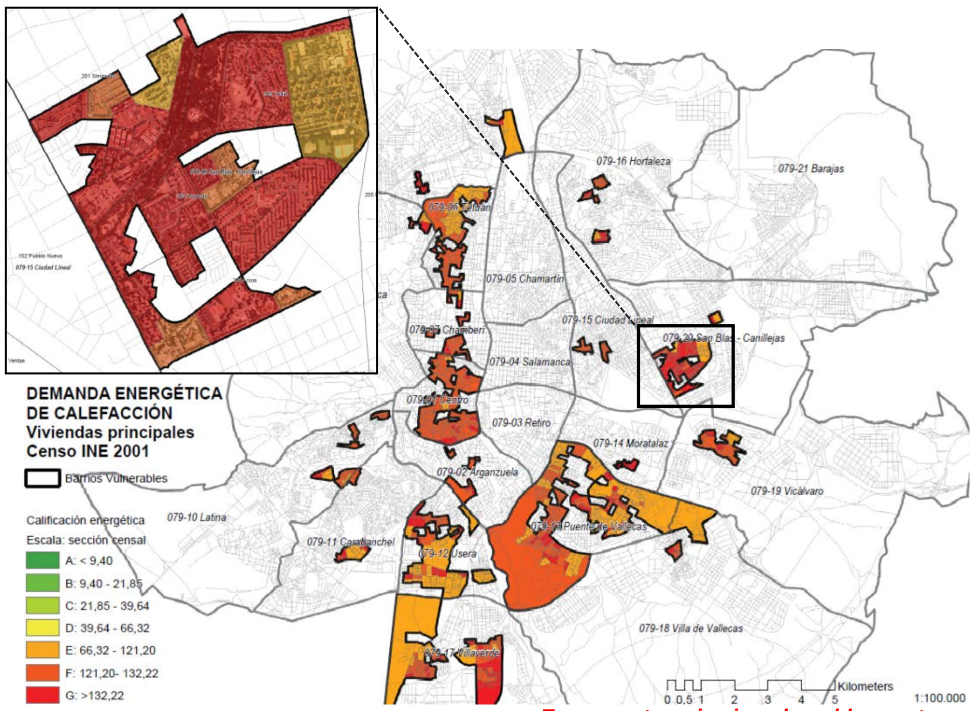
The main objective is the reduction of energy dependence on vulnerable social housing quarters' inhabitants.
The aim is to design a system for multifamily residential buildings facades rehabilitation at an urban scale. An ability for environmental adaptation is needed.

Research Deliverables

1. Heating and cooling energy demand calculation of a residential vulnerable quarter in Madrid, by simulation.
2. Best practice for social housing façades rehabilitation catalog.
3. Energy demand improvement potential by the rehabilitation of facades at an urban scale.
4. Estimation of renewable power generation potential in a social housing residential neighborhood in Madrid.



Heating demand density (MWh/Ha year)



Energy categories in vulnerable quarters

Urban existing fabric and typical façade construction characteristics

▶ **Researcher:** Fernando Martín-Consuegra
▶ **Supervisors:** Agustín Hernandez Aja / Ignacio Oteiza
▶ **Time span:** 2015-2018
▶ **Contact data:** fernando@martin-consuegra.com
martin-consuegra@ietcc.csic.es

▶ **Associated Publications:**

F. Martin-Consuegra, et al. 2016 .*"Energy needs and vulnerability estimation at an urban scale for residential neighbourhoods heating in Madrid (Spain)* " Conference proceedings of PLEA 2016 Los Angeles - 32th International Conference on Passive and Low Energy Architecture.

F. Martin-Consuegra, 2014. "*Vulnerabilidad energética asociada a la edificación. Estudio de caso para la periferia urbana del sur de Madrid*" *Territorios en Formación N06", Madrid, Spain, pp. 105-118,*

I. Oteiza et al. *"Energy Retrofitting for Social Housing by Improving the Building Envelope: Madrid, 1939-1979". 2015.The Sustainable Renovation of Buildings and Neighbourhoods. Bentham Science Publishers LTD. ISBN 978-1-68108-065-9*

F. Martín-Consuegra et al. 2015. *"User utility as the financial justification for low energy refurbishment"* Conference proceedings of 10th Energy Forum: Advanced Building Skins

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Housing Refurbishment for energy efficiency in Vietnam

Phan Anh Nguyen, TU Delft Faculty of Architecture, Department of Architectural Engineering and Technology

Introduction, Background to the Research

Accounting for more than 31% of the total energy consumption in 2012, the residential sector has been addressed as one of the most important sector that can potentially reduce the total energy consumption in Vietnam. In order to tackle the issue of energy shortage in the future, the Vietnamese government has performed several actions including the National Energy Efficiency Program for the period 2006-2015 (Decision No. 79/2006/QD-TTg, April 2006). In this program, as one of the key aspects, a legal framework for energy efficiency in construction management, industrial production and energy-using equipment is established. In 2013, the Ministry of Construction has issued the National technical regulation on energy efficiency buildings (QC:09/2013/BXD) which applies both to newly constructed buildings and renovation of existing buildings.

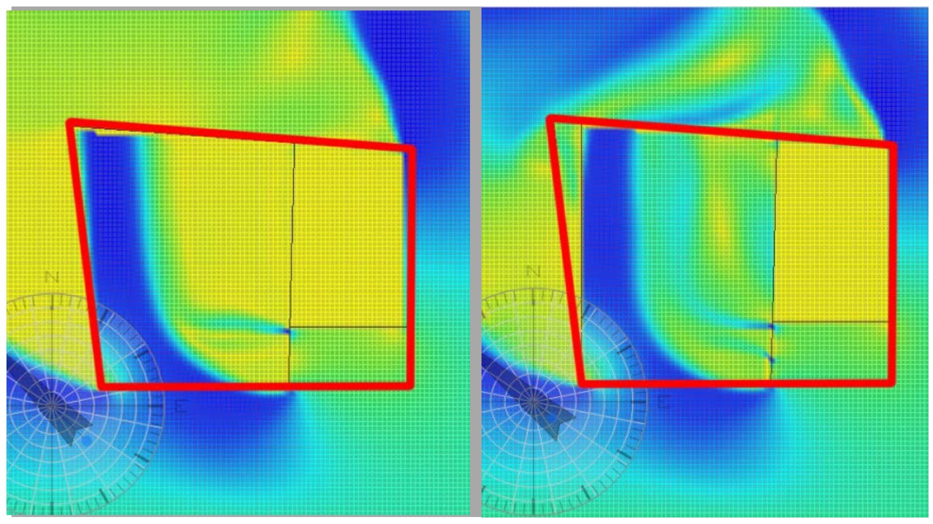
Research problem

Though refurbishment activities are being carried out regularly in Vietnam, little effort was seen in improving the energy performance of the building. One of the reasons is that the contemporary construction methods in Vietnam are still quite simple and do not incorporate energy efficiency measures. Moreover, little research has been done on the actual effectiveness of modern techniques.

Research Questions

Main question

How can refurbishment design strategies improve the energy performance of current existing houses in Vietnam?

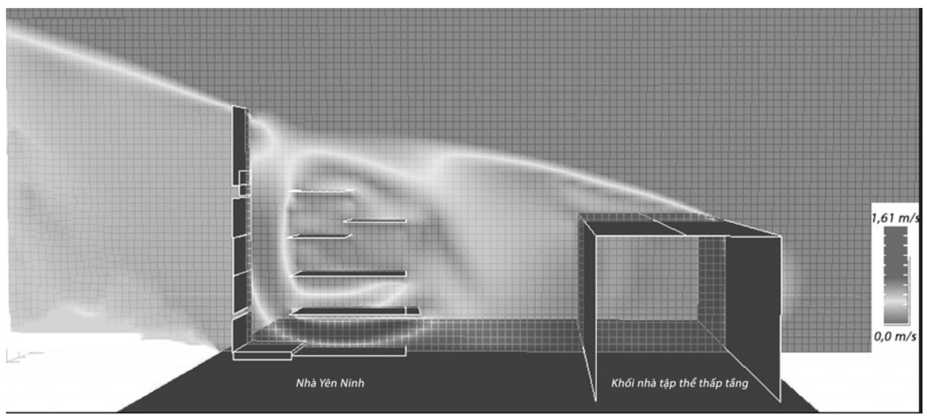


Sub-questions

- What is the current condition of the existing housing stock in Vietnam?
- What are the potential refurbishment strategies for existing housing in Vietnam?
- What are the incentives and challenges for energy efficient refurbishment in Vietnam?
- How to minimize the differences between the planned and real performance of housing?
- What are the outcomes of the strategies, in terms of energy upgrade and improved living comfort?
- What are the costs and benefits of energy efficiency refurbishment? Do they fit the user expectation?
- What governmental actions are required and recommended to facilitate the implementation of refurbishment strategy in Vietnam?

Research Objectives

This research aims to develop design strategies for tube house refurbishment projects in Vietnam to achieve better energy performance. The design strategies should be in different refurbishment levels and indicate their energy saving potential . On the other hand, the cost-benefit analysis is also an important part to assess the application of a potential refurbishment action. Apart from the strategies, the research also establishes a set of recommendations for the legalisation of energy efficiency requirements for private housing for the coming years. These recommendations are expected to be used by the architects to help them in decision making in the early design stage and as a guideline to persuade their clients to follow a more sustainable way of design.



Research Deliverables

1. Review of energy efficiency strategies and energy performance of existing houses
2. Refurbishment design strategies for energy efficiency in Vietnam, including consideration of cost-benefit analysis
3. Recommendation for construction technical regulation for energy efficiency

Researcher: Phan Anh Nguyen
Supervisors: Andy van den Dobbelsteen
Time span: 2015-2019
Contact data: p.a.nguyen@tudelft.nl
Associated Publications:

- Nguyen, P. (2016). Towards a sustainable plan for new tube houses in Vietnam. International Planning History Society Proceedings, 17(2).

Glazing Systems with Solar Control Films

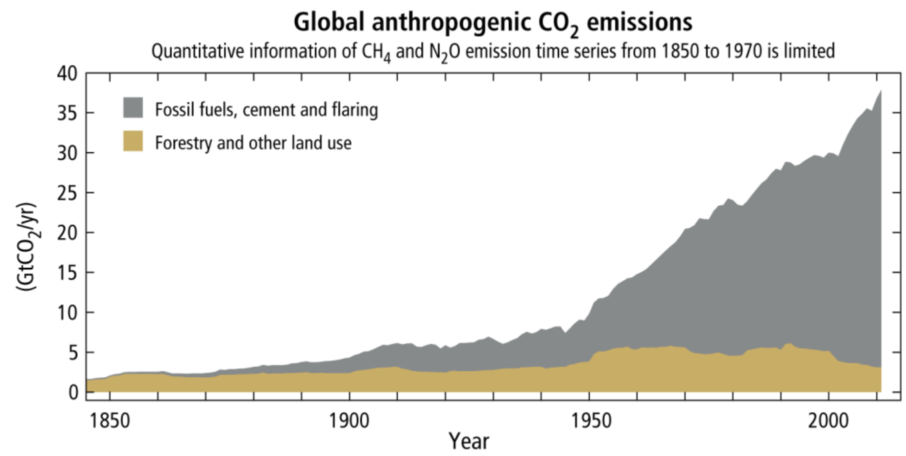
Júlia Oliveira Pereira, Instituto Superior Técnico – Department of Civil Engineering, Architecture and Georesources

Introduction, Background to the Research

Due to global environmental and energy conservation concerns, new directives from the European Union have been created these last years that reinforces the initial target of a 20% improvement in energy efficiency by 2020. According to several directives and papers, Buildings, Industries and Transportation systems are the major contributors in energy consumption. The Building sector is already responsible for 30% of the total energy consumption in the planet and is expected to grow. The aim of this research is to investigate thermal, daylighting and energy performance of glazing systems with solar control films (SCF) and shading devices and it's viability in rehabilitation of heritage buildings.

This research contemplates two major strategies, measurement and simulation, and they both present specific problems.

•Measurement Strategy (experimental method): implicates a long period of data collection and a wide coverage of multiple buildings for a representative data base. Another major problem is the access to private buildings that need permission from the owners and specific reserved places for the experimental equipment;
•Simulation Strategy (simulation method): the major problem with the data collected from simulation programs will be to re-create the actual characteristics of the buildings (detailed information) as well as occupants' behaviours throughout the whole experimental campaign.



IPCC. (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)].* IPCC, Geneva, Switzerland.

Experimental campaign in Instituto Superior Técnico, in two similar offices, one with SCF and the second without SCF

Main question

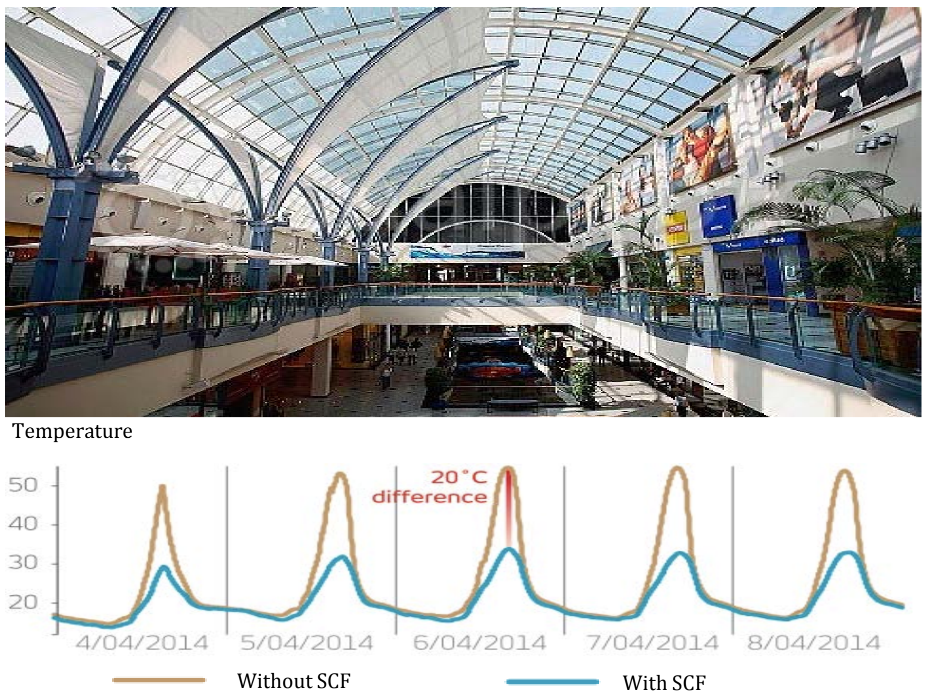
-"How can SCF influence thermal, daylighting and energy performance of a glazing system?"

Sub-questions

1."What types of SCF are available in the market that are adequate to reduce energy consumption in existing commercial and residential buildings. What are there main characteristics."
2."How do this different types of window films influence thermal and optical characteristics of a glazing systems."
3."Are they appropriate for any kind of building renovation. What are the major disadvantages/limits of this application regarding other available solutions in the market."
4."When is it cost-efficient to implement this solution in the short and long run."

SCF presents a huge potential for further investigation, specially in a rehabilitation point of view. As a market in expansion, new kinds of SCF are introduced in the market each year, with different thermal and optical characteristics that try to solve nowadays problems of energy consumption, illuminance, glare and thermal comfort. The aim of this research is to study the available solutions in the market of SCF in order to achieve the best possible equilibrium for thermal comfort, iluminance, glare and energy consumption, for that, the following objectives were set:

1. Analyze and build two cell tests in order to study the behavior of glazing systems with and without SCF throughout experimental campaigns. Conduct experimental campaigns, in real life conditions, in typical residential houses in Lisbon with high ratio of window-to-wall façades;
2. Identify and characterize optical and thermal parameters that influence the thermal, daylighting and energy performance of glazing systems with SCF;
3. Use the experimental data to calibrate the models in EnergyPlus (DOE – U.S Department of Energy) that depend on input parameters such as ambient parameters, material properties and occupants related factors;
4. Analyze the performance of different types of SCF for different: positions (inside or outside the window glass), orientations and climate;
5. Compare the results with shading devices;
6. Establish recommendations for professionals in the area for Portugal's climate.



Hanita Coatings. (2014). *Skylight film installation upgrades Barcelona mall comfort – and saves on cooling costs.*

This research work will deliver an extensive in-field experimental and numerical study of different types of SCF in different types of window glass, different positions, orientations and climate. This kind of approach will demonstrate the potential in terms of thermal, lighting and energy performance of SCF and compare the results with other solutions, e.g. shading devices. Review of the results

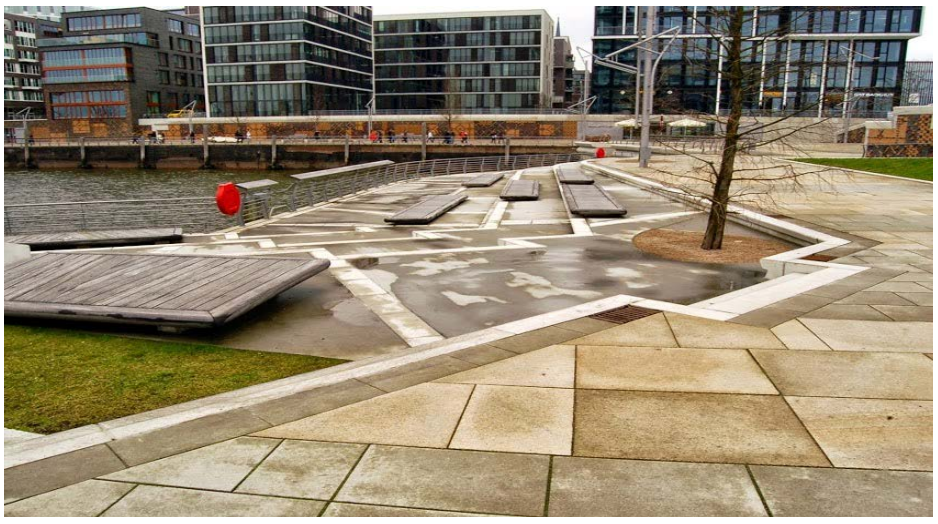
Researcher: Júlia Oliveira Pereira
Supervisors: Maria da Glória Gomes, Manuela Almeida, António Moret Rodrigues
Time span: 2016 - 2020
Contact data: julia_pereira_acores@hotmail.com
Associated Publications:

Contemporary Interventions in Architectural Heritage and Public Spaces

Elida Rios , University Polytechnic of Madrid UPM PhD in Architectural Heritage

Introduction, Background to the Research

The objective of the research is to analyze the current developments in the use of materials on the facades in regards to historical buildings in heritage sites and its use of brick and Reinforced Concrete as a coating material . It also seeks to analyze its public spaces along with the materials used in outdoor flooring for better compatibility and accessibility to the historic building. To achieve this, it is proposed to explore the possibilities of new applications and, at the same time, assess the current state of some examples such as the project of urban recovery of HafenCity.



Research problem

The main problem is the adaptation of materials in historical buildings and that these are compatible have with contemporary materials such as concrete that have a visual impact, or types of tile, the use of materials and the design of pavement in public spaces with patrimonial value.

Research Questions (Main Questions and sub question)

Main question

-"How or what kind of materials can be compatible and good in the restoration of buildings and spaces with patrimonial value?"

Sub-questions

1. "What are the main barriers for the use of concrete or brick facades of historic buildings?"
2. "How can outside spaces be treated so that the typology of local history is not lost?"
3. "What are the new intervention methods in the recovery of the architectural heritage, new methods and new products and building systems in buildings and public spaces?"

Research Objectives

Interventions in public spaces and buildings of historical value have not been investigated in detail regarding materials, functionality for greater efficiency in facades and replacing traditional materials formerly used.
This research focuses on options for finding design solutions and technical details that allow a more flexible design, and interventions in architectural heritage with contemporary materials.
This will be achieved through the following objectives:

1. Freeform coating forms.
2. Identify key problems that prevent or limit their architectural intervention
3. Existing solutions.
4. Identify key challenges that must be resolved to enable the loss of these buildings.
5. Examples of recovery buildings with desirable results.

Research Deliverables

1. Search coating solutions facades of Historic Buildings
2. Search of compatible materials in Public Spaces with history
3. Architectural heritage and regeneration of Public Spaces with contemporary materials.


- **Researcher:** Architect Elida Rios
- **Supervisors:** Jose Luis Garcia Grinda
- **Time span:** 2015-2016
- **Contact data:** luzelida14@gmail.com
- **Associated Publications:**

- Associated Publications: (Articles of paper at Congress 2016)

- Contemporary interventions in historic spaces: Hafencity Hamburg, Speicherstadt District in Hamburg Germany.
- Museums Interventions: International Maritime Museum of Hamburg and Tate Modern Museum of London
- Interventions analyses in Heritage Cities in South America: Public Spaces and Architectural Heritage in Cusco-Perú

Patent: Techniques and methods of intervention in Architectural Heritage Buildings and Public Spaces

Solar shutter, the shading system for DHW production

Giulia Santoro, Politecnico di Milano – School of Architecture Urban Planning Construction Engineering, Department ABC

Introduction, Background to the Research (Research Theme)

Nowadays, the gap between energy supply and demand leads us to deal with important energy challenges. Building sector, as responsible for one third of the total, primary energy demand, asks for research in energy efficiency focused on technologies that promote integration of responsive building elements with the building services and renewable energy systems. Among others, solar energy could be considered the most widespread renewable energy source, characterized either by passive and active strategies depending on how solar energy is captured, distributed or converted into thermal energy.

Research problem

Among active solar technologies, solar thermal collectors are heat extracting devices that convert solar radiation into thermal energy through a flowing fluid and are generally used for domestic hot water (DHW) heating. To being technically and structurally efficient, solar thermal collectors, like the other renewable energy technologies, must satisfy requirements for architectural integration. It consists on replacement of conventional building elements, parts of the building envelope, with systems able to enhance energy building efficiency, while maintaining innovative design and consistency to the context of the building. Building integrated solar thermal collectors have a great potential for future development, but they still have some weaknesses to deal with: large size, dimension inflexibility, dark irregular looking make building integration difficult.

Research Questions (Main Questions and Sub Questions)

Main question

1. How to make solar thermal collectors suit for building integration in high quality architecture?

Sub-questions

1. How to integrate functional and constructive aspects with aesthetics?
2. How to deal with the low flexibility of solar thermal collectors, in terms of size, dimension and shape?
3. How to reduce thickness and weight of solar thermal collectors?
4. Solar thermal collectors could be mounted only on opaque areas of the building envelope. How to deal with the opacity of these systems? Or how to increase their translucency?
5. How to enhance production, storing heat produced by solar thermal collectors close to where it is to be used?

Research Objectives

The shortage of solar technologies that really suits for building integration, along with lack of knowledge among architects, leaves the research opened to future development. In order to address these issues here is presented a possible new alternative solution for building integrated solar thermal collector that would allow for the use of these technologies on building façades. The goal is to make them invisible, aesthetically appealing and appearing as an architectural concept.

Research Deliverables

Solar shutter is a roller shutter that works as a solar thermal collector. It exploits the overheating of shading systems, otherwise lost or re-irradiated to the building, providing shadow and thermal insulation at the same time.
The shutter is made of different layers:

- Water-filled gap: water, heated thanks to conductive, convective and radiative processes, will serve as DHW;
- Absorber: water, in contact with the absorber (dark-coated surface with high emissivity) increases its temperature thanks to conductive processes;
- Solar radiation: solar rays hit the water, producing convection currents; heat is transferred through the entire thermal mass much quicker than in other materials;
- Insulation: a flexible (non-rigid) insulated layer is placed behind the absorber to avoid the heat to be re-irradiated where undesired (toward the window);
- Air-gap: a non-ventilated air gap protects water-filled gap from heat losses toward the exterior;
- Low-E coating: applied on the outer internal surface of the water-filled gap, it prevents heat from re-irradiating out, greatly reducing the amount of heat loss.

The system is thought to use thermosyphon circulation, adopted in passive direct solar water heating systems, which is based on natural flux convection, which circulates water without the necessity of a mechanic pump. The collector must be installed below the storage tank so that warm water will rise into the tank. The storage tank will be located inside the insulated roller shutter box, much closer to where DHW is needed than in common hot water supply. When needed, water, coming from the storage tank to the collector, will unroll the shutter by gravity. In summer, system's efficiency decrease, when the requested hot water temperature is lower. In winter, solar rays could reach the best orientation to enhance system's efficiency. The research is still at an embryonic stage and needs for further development.

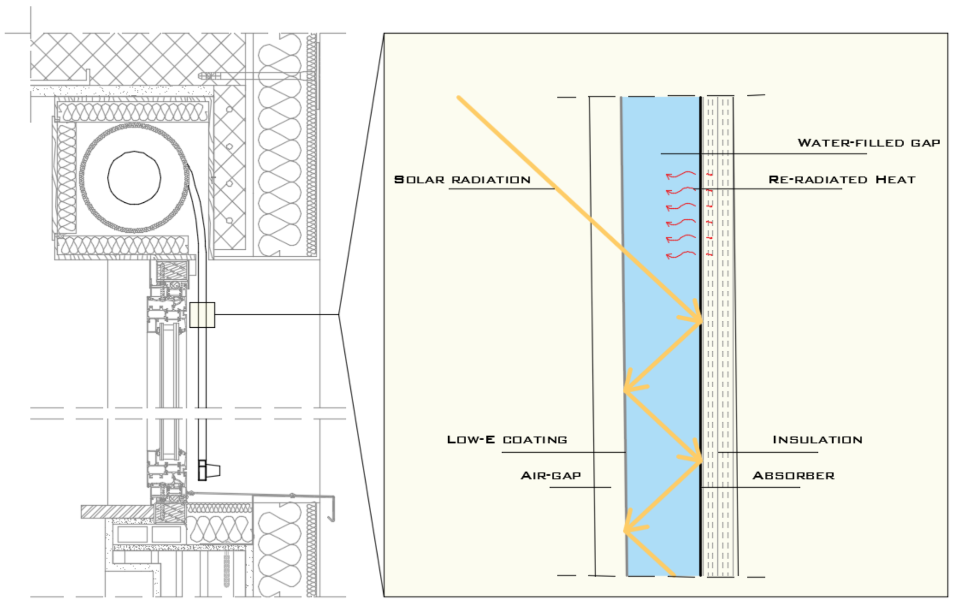


Fig. 1: System's components and thermodynamic processes

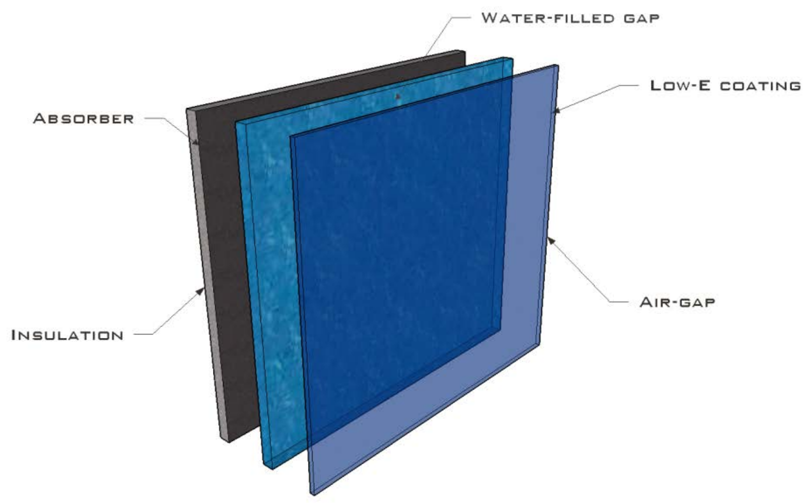


Fig. 2: System's layers

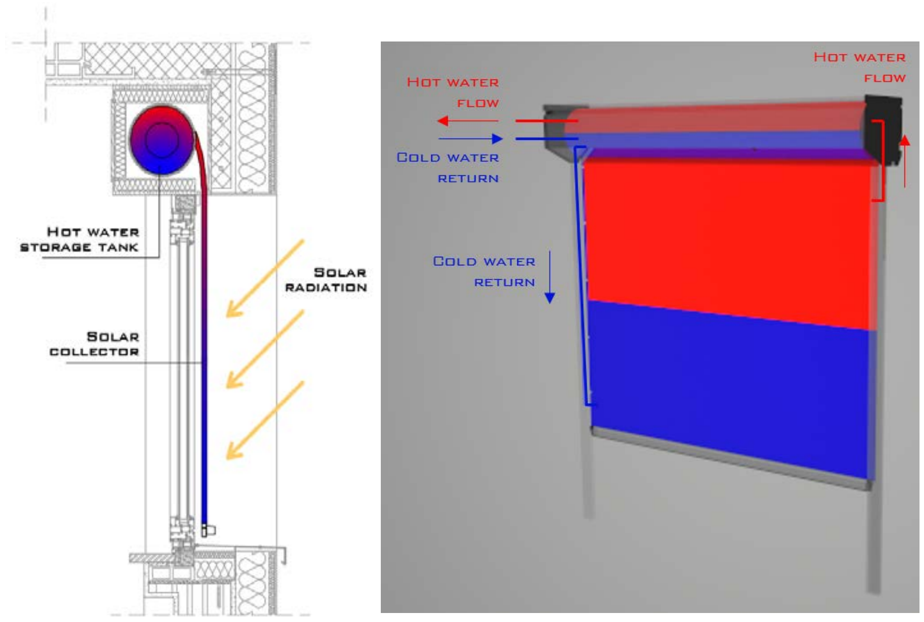


Fig. 3: Thermosyphon water circulation

Researcher: Giulia Santoro
Supervisors: Prof. Enrico Sergio Mazzucchelli
Time span: ongoin
Contact data: giulia.santoro.mi@gmail.com

Associated Publications:

G. Santoro, Systems integration for the exploitation of renewable sources in the requalification of the Queensway, in New York City, Bachelor thesis, School of Architecture Urban Planning Construction Engineering, Politecnico di Milano, A.A. 2013-2014

Energy-autonomous adaptive façade

▶ **Leonie Scheuring, TU Dresden Faculty of Civil Engineering, Institute of Building Construction**

Introduction, Background to the Research

The building sector is responsible for about 40 % of the global energy consumption. In order to reduce the global energy consumption, the European Directive 2010/31/EU on the energy performance of buildings targets the nearly zero-energy building standard in European countries. To achieve this target adaptive façade systems get more and more in the design focus. The façade changes the form, the geometry or the material properties in order to adapt to changing climate conditions and to reduce energy demand of cooling, heating and lighting systems. However, most of today's adaptive façade systems needs the supply of external energy to achieve adaptability. By combining the use of smart materials and integrated photovoltaic panels, an energy autonomous transparent adaptive façade system can be established.

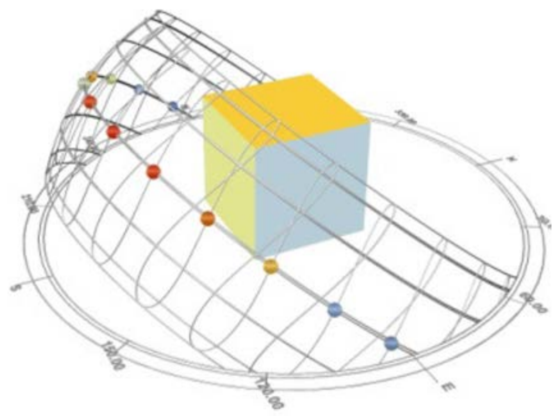
Research problem

The façade system developed in the research, which is composed of various small openings, shall control the indoor air temperature and the indoor CO_2 level. This leads to the main problem in the research. The design of e.g. shape-memory alloy systems and PV-panels does not just have to satisfy constructive requirements, it also deals with indoor climate changes, which largely depend on weather conditions, user behavior, building properties, architecturally desired façade openings, etc. The interaction between façade and the aforementioned elements in combination with an yet unresearched application field for shape-memory alloy systems and PV-panels will be the main challenge of the research.

Research Questions (Main Questions and sub question)

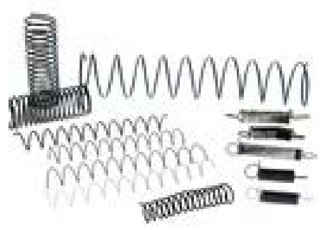
Main question

"How do the innovative components of the system, including the shape-memory alloy and the PV-panel, have to be dimensioned and integrated into the system to achieve an energy-autonomous adaptive façade system for different weather conditions and building properties?"



Sub-questions

What are the potentials and limits of shape-memory alloy systems used in this façade system?
How can the best PV yield be achieved despite using an highly transparent PV-panel?
How many opening cycles are needed to achieve comfortable room conditions?
How much energy is necessary to guarantee the required opening cycles?
How should the energy storage system be dimensioned?
How can the energy storage system, the PV-panels, the control system be integrated into the façade system?



Research Objectives

- Simulations to define the number of opening cycles depending on the opening dimensions in order to guarantee comfortable room conditions
- Identify a shape-memory alloy system which satisfies the requirements of the façade system
- Simulations to define the PV yield and the needed energy storage system
- Design of a prototype
- Experimental analyses of the prototype

Research Deliverables

- A prototype of the façade system including the design of an opening drive
- Monitoring results

▶ **Researcher:** Leonie Scheuring
▶ **Supervisors:** Prof. Bernhard Weller
▶ **Time span:** 2016-2018
▶ **Contact data:** leonie.scheuring@tu-dresden.de

Glass-metal building envelopes with composite structural behavior by adhesive bonding

Vlad Alexandru Silvestru, Graz University of Technology, Institute of Building Construction

Introduction, Background to the Research (Research Theme)

The perception of transparency in building envelopes is often limited by structural elements supporting the glazing, which are generally made of opaque materials. A reduction of the cross section dimensions of these linear structural elements by activating a composite structural behavior between the glass panes and the metal framing could increase the transparency and result in more elegant transparent building envelopes with filigree opaque framing and highly efficient material use. The aim of this research is to investigate the possibility of using adhesive bonding to obtain this kind of composite structural behavior. Possible concepts with structural silicones as well as with stiffer acrylate adhesives are investigated for this purpose in close collaboration with Waagner-Biro Stahlbau AG and with additional funding from the Austrian Research Promotion Agency (FFG).

Research problem

A composite system aims to activate the advantages of its components in order to obtain more efficient properties. In the case of the glass-metal elements with composite structural behavior this can be obtain by joining the metal framing with the glass pane with suitable load transfer mechanisms and materials. Although a significant amount of knowledge and data is available for the structural behavior of the different materials, the interaction of these materials in a composite element has yet to be investigated regarding manufacturing, structural and functional performance.

Research Questions (main questions and sub-questions)

Main questions

1. How can adhesive bonding be used to connect a glass pane with a filigree metal framing in order to obtain an element with composite structural behavior?
2. What are the structural performance and the failure limitations of glass-metal elements with composite structural behavior by adhesive bonding?

Sub-questions

1. What are the limitations (mechanical properties, durability, compatibility, etc.) of existing adhesives which are used for structural glass applications with respect to the use in glass-metal elements with composite structural behavior?
2. How can structural silicones be used in glass-metal elements with composite structural behavior?
3. What is the overall performance of a glass-metal element with composite structural behavior by adhesive bonding under multiple loading directions and how does the adhesive behave in this system?
4. How can the modelling and the structural design of glass-metal elements with composite structural behavior by adhesive bonding be simplified for the use in engineering offices?
5. How can the investigated glass-metal elements with composite structural behavior be further developed to fulfil functional façade requirements?

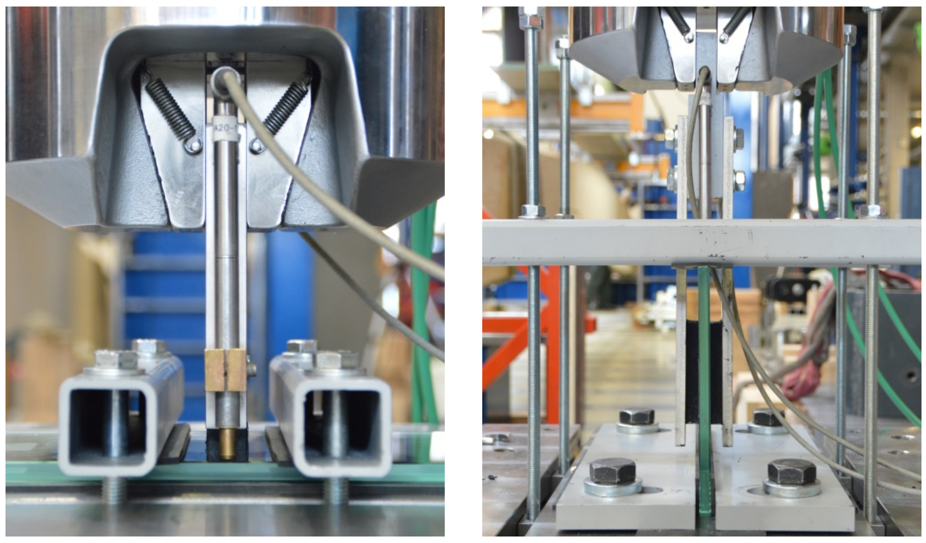
Research Objectives

The structural behavior of in-plane loaded glass panes as well as the mechanical properties of several structural adhesives were investigated in previous research projects, but the structural performance of a combined application of these two together with a filigree metal framing has not been approached yet. The following objectives will bring a significant contribution for this topic:
1. Define possible application situations for glass-metal elements with composite structural behavior
2. Identify suitable adhesives for this application and their limitations
3. Analyze different load transfer possibilities between glass pane and metal framing
4. Develop and assemble a glass-metal element with composite structural behavior
5. Perform experimental testing on the glass-metal element with composite structural behavior under combined in-plane and out-of-plane loading
6. Develop simplified modelling techniques and design recommendations

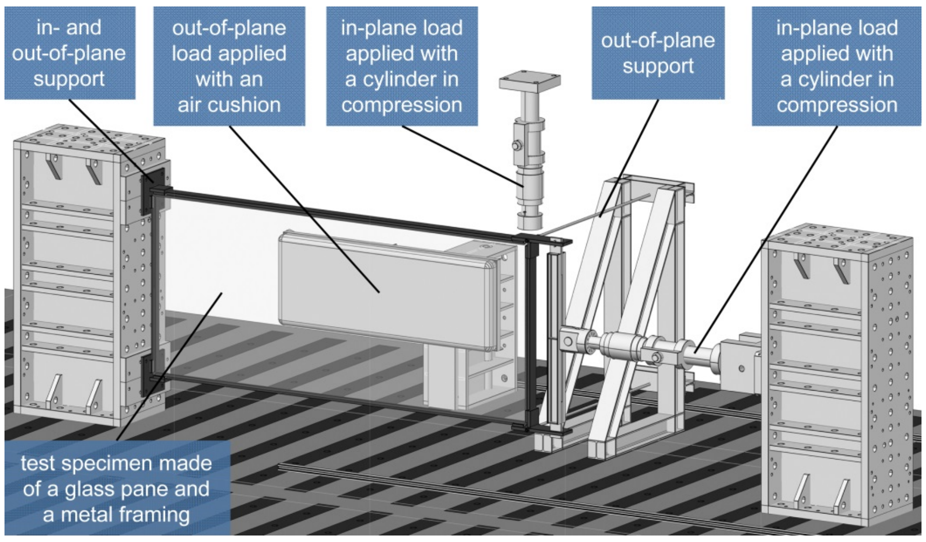
Research Deliverables

1. Review of completed research on in-plane loaded glass panes as well as on the mechanisms and materials used to transfer in-plane loads into glass panes
2. Extensive results on the structural performance of adhesive joints between glass and stainless steel with different joint geometry under tensile and shear loading
3. Findings from manufacturing large-scale glass-metal elements with composite structural behavior as well as results on the mechanical performance of such elements under combined in-plane and out-of-plane loading
4. Recommendations for simplified modelling and structural design of glass-metal elements with composite structural behavior by adhesive bonding

Glass façade with metal bracings at the John Joseph Moakley U.S. Courthouse in Boston, Massachusetts, United States



Linear adhesive joints with structural silicones and acrylates tested under tensile loading (left) and under shear loading (right)



Test setup for experimental investigations on a 3.5 x 1.5 m large glass-metal element with composite structural behavior under multiple loading directions

Researcher: Vlad Alexandru Silvestru
Supervisors: Oliver Englhardt
Time span: 2013-ongoing
Contact data: silvestru@tugraz.at

Associated Publications:

- *V.A. Silvestru, G. Kolany, O. Englhardt, Glass Building Skins – Presentation of the Research Project and Intermediary Findings, Advanced Building Skins Conference 2015, Graz, Austria*
- *V.A. Silvestru, O. Englhardt, Adhesion of a two-part structural acrylate to metal and glass surfaces, engineered transparency 2016, Düsseldorf, Germany*

Development of a multifunctional composite sandwich panel for the rehabilitation of building facades

Christoph de Sousa, University of Minho, Institute for Sustainability and Innovation in Structural Engineering

Introduction, Background to the Research

Reinforced concrete (RC) construction accounts for approximately 50% of the Portuguese building stock. The biggest rise on the construction of RC buildings took place between 1960 and 1990. This corresponds to a period of time when: (i) the available structural design codes considered only overly simplified earthquake provisions and (ii) thermal regulation was not yet available. The aim of this research is to develop a multifunctional rehabilitation solution for the structural and thermal retrofit of RC frame buildings, built during the referred time period (target buildings).

Research problem

The main problem is to develop a reliable and cost competitive prefabricated solution that allows for both structural (vulnerable buildings when subjected to lateral/seismic actions) and energetic (buildings with inadequate/absent thermal insulation and susceptible to the occurrence of thermal bridges) refurbishment of existing buildings.

Research Questions

Main question
“Can facade panels with sandwich configuration constitute a valuable solution for the structural and thermal retrofit of existing multi-storey RC frame buildings, built during the 1960-80 decades?”

Sub-questions
1.“What is the best synergetic configuration of materials and components for ensuring both structural and thermal insulation requirements?”
2.“What is the most suitable option to ensure reliable panel-building connectivity?”
3.“How is the behaviour of the proposed facade panel solution when subjected to fire exposure?”
4.“What are the main barriers to the manufacture of precast sandwich panels using fibre reinforced cementitious composites (FRCC) and an insulation core layer?”
5.“What are the main barriers concerning the installation of the proposed facade panel solution in the construction site, during the rehabilitation process?”
6.“How can Building Information Modelling (BIM) platforms be applied to assist a multi-criteria design/decision method?”

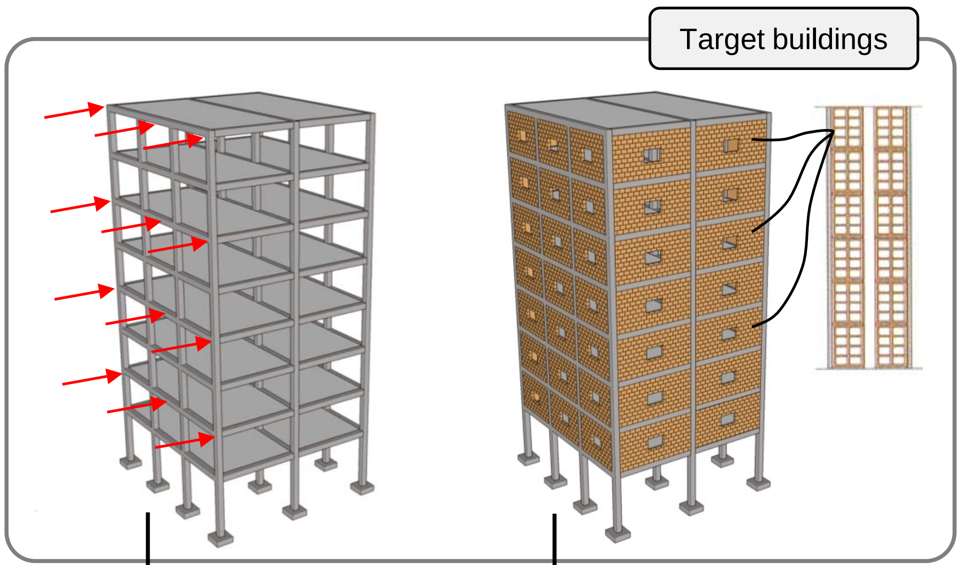
Research Objectives

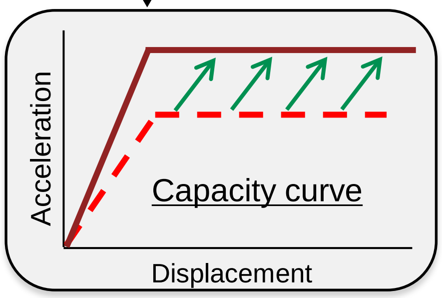
The main objective consists on the development of a multifunctional composite sandwich panel, specifically designed for structural and thermal retrofitting of identified target buildings, through intervention on their envelope (refurbishment of building facades).

The main goal is to be achieved through the partial objectives that are listed below:
1.Definition of the structural and thermal requirements for the facade panels;
2.Selection of the most adequate synergetic configuration of materials (e.g. FRCC and polymeric foam insulation) and other components (e.g. panel-building connectivity and connectors within the panel itself);
3.Analyse the fire resistance of the proposed sandwich panel solution (facade panel as a protection against fire exposure conditions);
4.Thorough analysis of casting/assembly and installation on site: the prefabricated panel should be easy to assemble during fabrication and on construction site;
5.Direct application of Building Information Modelling (BIM) methodologies (interoperability between BIM platforms and simulation software).

Research Deliverables

1.Assessment of the degradation condition of target buildings: Literature review dedicated to the characterization of the built patrimony;
2.Review of both structural and/or thermal retrofit solutions adopted in the construction industry for the rehabilitation of existing RC frame buildings;
3.Survey on existing target buildings: identification of their limitations in terms of structural behaviour and thermal comfort;
4.Assembly of sandwich panel prototypes and evaluation of material properties by experimental tests;
5.Assessment of the structural performance of the sandwich panels when subjected to in-plane and out-of-plane loading conditions;
6.Characterization of the sandwich panels in terms of building physics criteria (thermal and acoustic insulation performance);
7.Execution of fire resistance tests (in accordance with the standard EN 1365-1) for evaluation of the fire resistance of the proposed facade panels.





Envelope walls

Actual U-value **~1.0 W/m².ºC**

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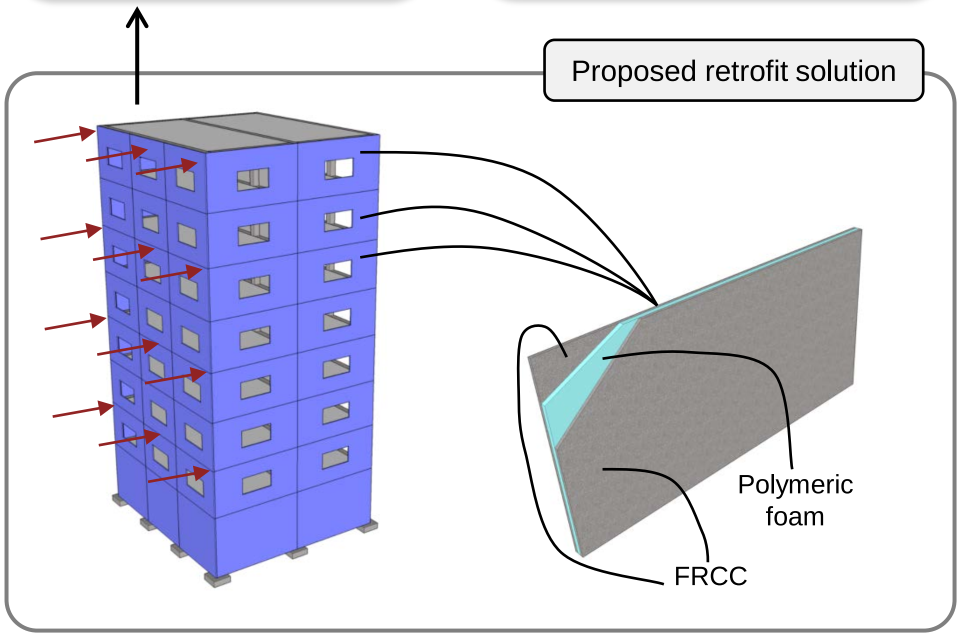
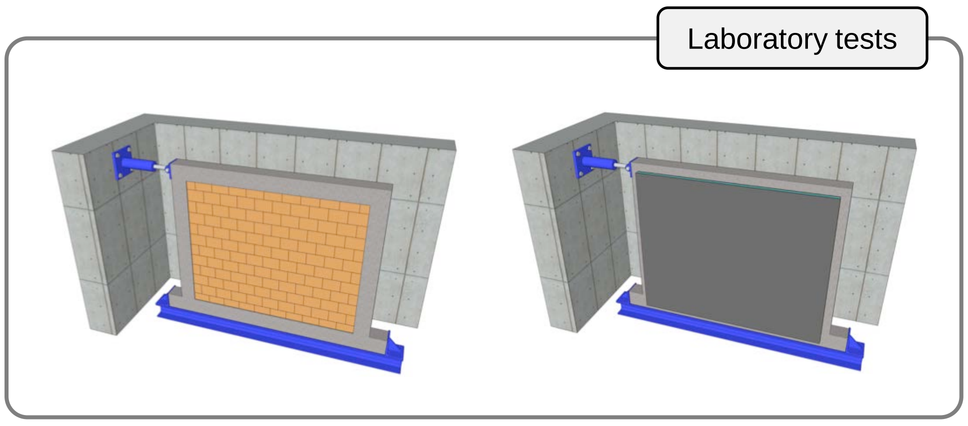
Reference value = **0.4 W/m².ºC**





Researcher: Christoph de Sousa
Supervisors: Joaquim A. O. Barros; João Ramôa Correia
Time span: 2014-2018
Contact data: christoph@civil.uminho.pt

Associated Publications:

•*C. de Sousa, Joaquim A. O. Barros, M. Azenha, R. Lameiras, ”Polymer and cement-based fiber-reinforced composite materials for sandwich slabs”, 2014, BFT International: Concrete Plant + Precast Technology, Vol. 80, pp. 64-73*

Adaptive shading devices for high performance envelope

Alberto SPERONI, Politecnico di Milano - Architecture, Built environment and Construction engineering Department

Introduction, Background to the Research

Sunlight is a natural resource which we need to allow into our buildings through glazed apertures as daylight for visual tasks. The sunlight energy density varies over a huge range, and it has to be controlled to prevent overheating but, at the same time, a vital connection with the world outside should be maintained (feeling of users of external environment) [1]. A large proportion of buildings' energy consumption is due to lighting (37% of total energy usage for commercial buildings) and cooling (25% of total energy usage for commercial buildings) [2], so it is important to modulate sunlight [3], and possibly to re-distribute it spatially to supply a glare-free working illuminance for a minimum summer heat gain. This is what solar control should address, and it is achieved by elements (shading devices) in or close to the window opening that, if efficiently designed, can reduce commercial building energy requirements for lighting and cooling of 10-20% [4,5].

Research problem

The use of dynamic shading devices gives a further added value to the system increasing both the systems performance and the users comfort. Nowadays these systems reach its dynamicity through engines. The direct consequence is an higher risk of failure (due to the intrinsic complexity of the system and an high number of components) and higher costs for maintenance. A current school of thought is trying to solve these problems replacing the engines with smart materials. The results are promising (Fig.1 a/b/c/d) but still need to be further developed (complex, expensive).

Research Objectives

The aim of my PhD research is to develop a passive-dynamic shading system that could be tailored to respond to standard project parameters, complemented by behavioral models that describe its performance characteristic profile (in term of both energy performance and daylighting). These results can be achieved designing a shading system that integrates Smart Materials (SM) connected to 3D micro-geometry materials. Both of these have particular properties: Smart Materials change their shape in response to external stimuli (temperature, electricity and light) while 3D micro-geometry materials are characterized by solar transmittance properties that have a wide variation depending on the incident angle of solar radiation. Their combination within a shading system allows to exploit their particular features better than the individual use of the two: this produces a variation of the solar transmittance in response to the external stimuli. The integration and application of these new shading systems within buildings' context should:

- reduce or remove the energy need for the shading system movement, while ensuring adequate daylight performance, fulfilling users' requirements;
- minimize system's complexity through an optimization of the number of components reducing the risk of failure and considering the aspects of maintenance and management;
- Optimize the integration (increasing the produced movement of the shading device) and use (reducing the amount of the used alloy) of the smart material .

Research Deliverables

In order to define the parameters (input) required for the development new shading device components, I performed three main activities: Energy and daylighting simulations, optical measurements for shading materials (Fig.3 a/b) and smart materials tests (Fig.4).

The Energy and daylighting simulations allowed me to define the parameters related to geometry, finishing and arrangement of shading devices that mainly affect the system performance in terms of lighting, cooling and heating. The optical measurements for 3D micro geometry materials, performed using an integrating sphere, were necessary for me to identify the shading material that maximizes the system performance.

Results of the tests that I performed on SMs suggested that Shape Memory Alloys, in the form of wires, are the most promising. This is due to the higher specific force (ration between force and mass) that they can generate as a consequence of an applied stimulus. Basing on their operational principles, I defined functional models (Fig.2) and, among these, I selected the one showing better performances (Fig.2-a). For this model I built a preliminary prototype (Fig.4) which was necessary to perform a more focused and detailed set of tests. This prototype was useful to define the required working current, the produced stress and strain and the design life of the system.

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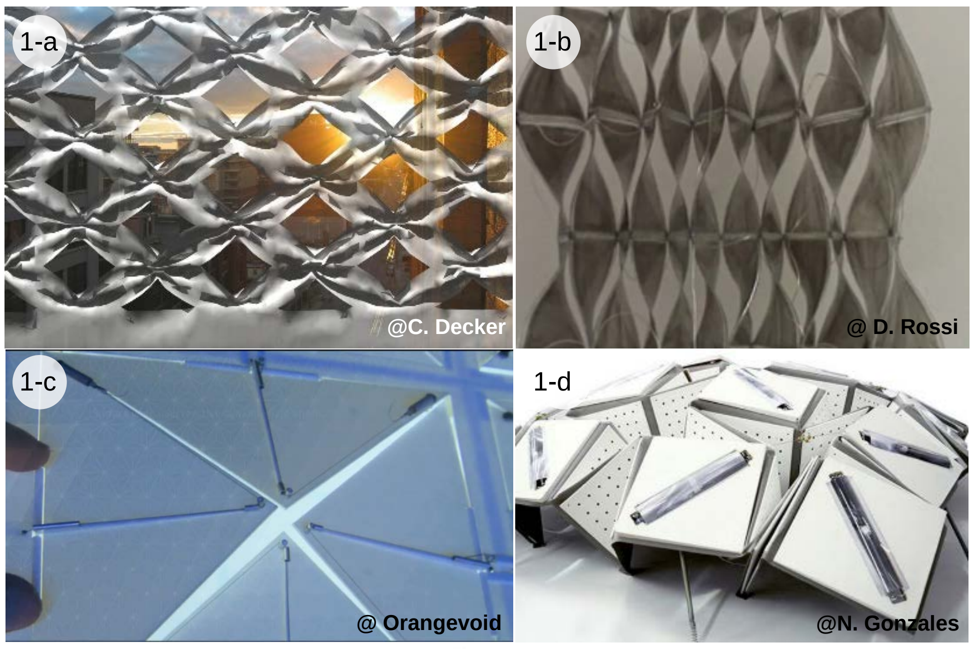
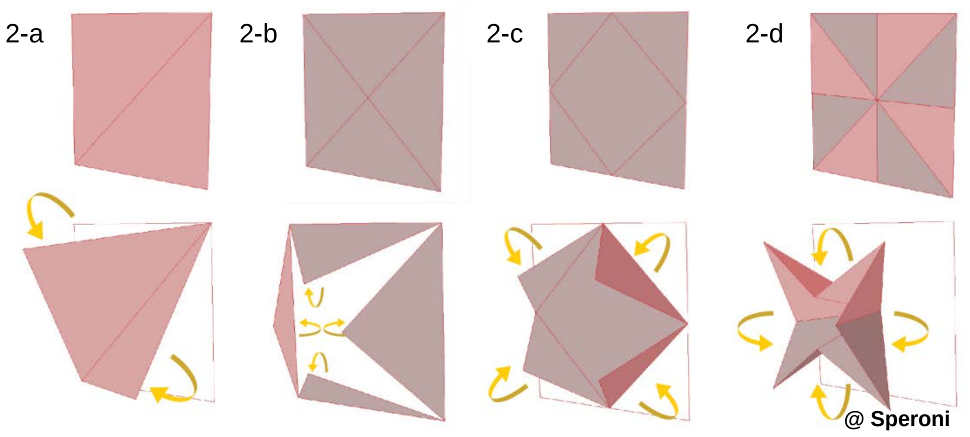
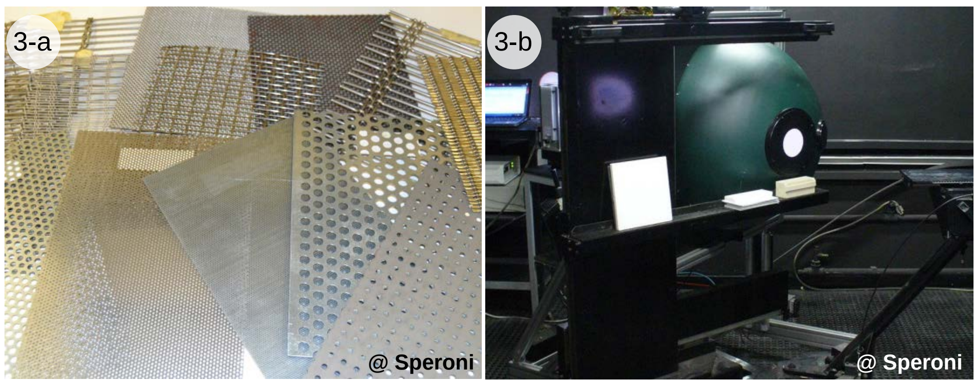
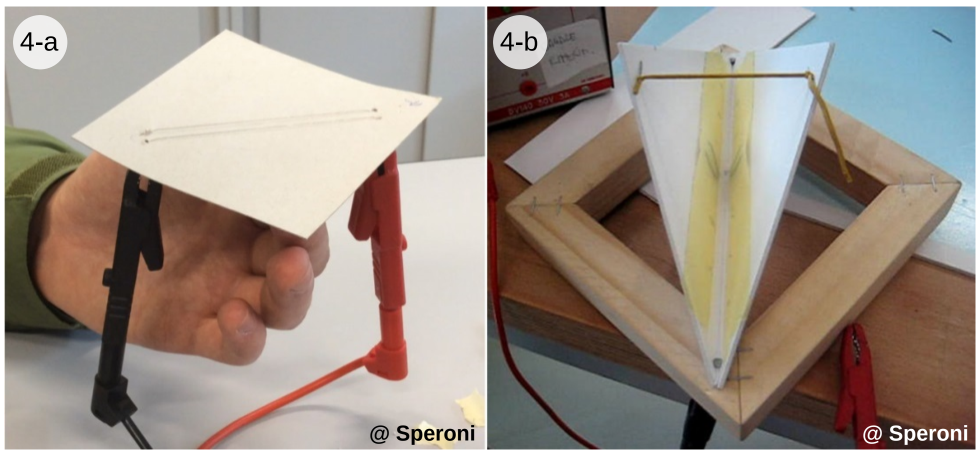
[1] International Energy Agency, Daylight in Buildings - A source book on daylighting systems and components.
[2] U. D. of Energy, Energy Efficiency Trends in Residential and Commercial Buildings, 2008.
[3] ES-SO, Energy efficiency watch, 3.
[4] A.I. Palmero-Marrero, A.C. Oliveira, Effect of louver shading devices on building energy requirements, Appl. Energy. 87 (2010) 2040–2049. doi:10.1016/j.apenergy.2009.11.020.
[5] G.F. Menzies, J.R. Wherrett, Windows in the workplace: examining issues of environmental sustainability and occupant comfort in the selection of multi-glazed windows, Energy Build. 37 (2005) 623–630. doi:10.1016/j.enbuild.2004.09.012.









Researcher: Eng. Alberto SPERONI
Supervisor: Prof. Tiziana POLI
Time span: 2013-2016
Contact data: alberto.speroni@polimi.it

Associated Publications:

•*A. G. Mainini, T. Poli, M. Zinzi, A. Speroni (2015). Metal mesh as shading devices and thermal response of an office building: parametric analysis.*

•*R. Paolini, A. G. Mainini, T. Poli, A. Speroni, A. Zani (2015). Optical and radiative properties of textiles used for light temporary structures: performance assessment and decay over time.*

•*A. G. Mainini, G. Avantaggiato, A. Zani, A. Speroni (2015). Metal mesh shading devices optimization by parametric approach design.*

•*A. Speroni, T. Poli, A.G. Mainini, R. Paolini, M. Zinzi, I. Renzi, et al. (2014). Shading devices with 3D geometry: Characterization of optical and radiative properties and evaluation of energetic efficacy for different exposures. Istea.*

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DAAD
CAPES

Structural Closed-Cavity Façades

Bert Van Lancker, Ghent University, Faculty of Engineering and Architecture, Department of StructuralEngineering

Introduction

In the second half of the twentieth century, Double Skin Façades (DSF) were developed to improve the thermal and acoustic performance of traditional glass envelopes. This system of building, consisting of two skins, combines aesthetic value with good thermal and acoustic performance. However, with cavity widths varying from 50 cm up to 2 m, DSFs are rather space-consuming and conflict therefore with the number one requirement of tremendous economic importance in most building projects, namely maximum net usable floor area. For this purpose a Closed-Cavity Façade (CCF) was developed as a specific DSF system. A CCF consists of an outer single glass layer, an inner insulating glass unit (IGU) and a fully sealed cavity in between. This cavity is pressurized with dry and clean air to prevent condensation at all times and to minimise cleaning operations. As a result, the width of the closed cavity is only determined by the wind load acting on the façade and can therefore be reduced, typically to about 20 cm.

Research problem

Closed-cavity façades are characterised by a reduced cavity width compared to traditional double skin façades. However, a true optimisation in terms of reducing cavity width in favour of net usable floor area is still possible if the structural performance of the glass-framing system is optimised. This optimum can be achieved by using stiffer materials, such as cold-formed stainless steel, and/or by utilising the load-bearing capacities of the glass, by making it integrally part of the structural unit. The connection between steel and glass has to ensure a durable and reliable transfer of the occurring loads and also to absorb constraining forces (e.g. from temperature loads). Therefore, structural adhesives are considered. The innovative result is a Structural Closed-Cavity Façade (SCCF), which is the main topic of this research.

Research Questions

Main question

"How can the development of an innovative structural closed-cavity façade unit that complies with contemporary energy requirements and environmental standards, enable a real optimisation of net usable floor area?"

Sub-questions

1. How can the structural behaviour of a closed-cavity façade unit be optimised by utilising the load-bearing capacities of glass and by using cold-formed stainless steel?
2. What are the fundamental parameters influencing the structural behaviour (i.e. stiffness, strength and failure modes) of a basic structural closed-cavity faççade unit?
3. How can a basic unit be adapted to comply with contemporary energy requirements and environmental standards?
4. What is the economic profit and the environmental impact of a structural closed-cavity façade unit compared to traditional solutions?

Research Objectives

The main objective of this research is developing innovative façade technology in terms of structural closed-cavity façade units that comply with the most strict energy requirements and environmental standards, enabling a real optimisation of net usable floor area, the number one concern in most building projects.

1. Defining structural closed-cavity façade units and determination of possible adhesive candidates for structural linear adhesive glass-metal connections.
3. Identification of fundamental parameters, influencing the translational and rotational stiffness, and the strength of structural linear adhesive glass-metal connections.
4. Identification of environmental influences (e.g. humidity, temperature, etc.) on durability and long-term behaviour of linear adhesive glass-metal connections.
5. Determination of the structural behaviour (i.e. stiffness, strength and failure modes) of an elementary hybrid glass-steel unit under wind pressure or suction.
6. Investigation of the effect of measures taken to comply with energy requirements (e.g. thermal brake) on the structural behaviour of the basic hybrid glass-steel unit.
7, Determination of the economic profit and assessement of the environmental impact of a structural closed-cavity façade unit.
8. Fabrication of a prototype of a structural closed-cavity façade unit.

Research Deliverables

1. A review of state-of-the-art façade design concepts, structural glass, adhesive glass-metal connections and building physics.
2. An overview of the fundamental parameters for the design of a structural glass-metal façade unit.
3. An assessment of the economic profit and environmental impact of a hybrid unit.
4. A prototype of a structural closed-cavity façade unit.

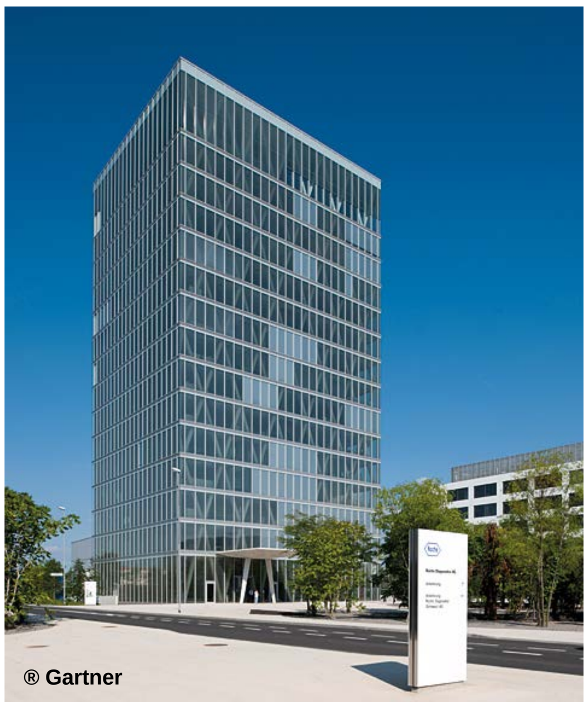


Figure 1: Roche Bau 5 with the first CCF in Basel .

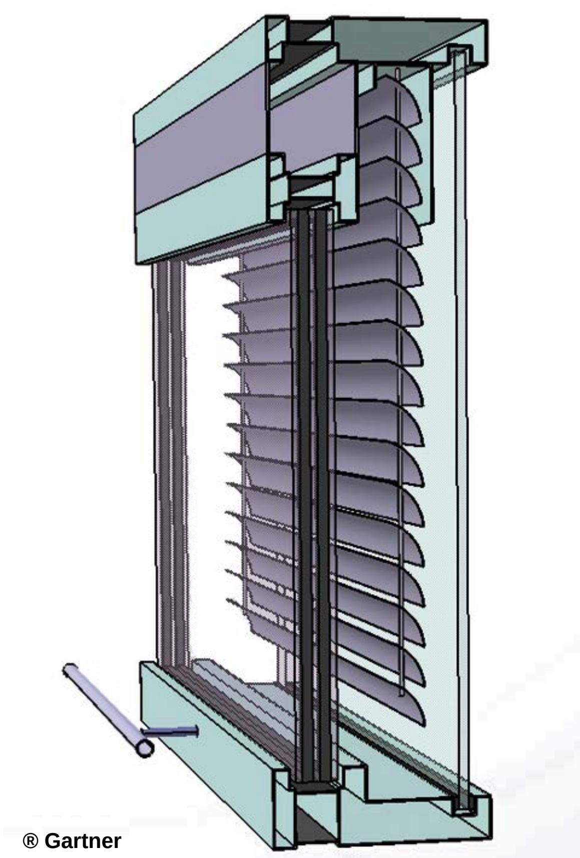


Figure 2: Closed-Cavity Façade (CCF) unit.

Researcher: ir. Bert Van Lancker
Supervisors: Wouter De Corte, Jan Belis
Time span: 2014-2019
Contact data: Bert.VanLancker@UGent.be

Associated Publications:

•*Van Lancker, B., Dispersyn, J., De Corte, W., Belis, J. (2016). "Durability of adhesive glass-metal connections for structural applications". Engineering Structures, 126(2016), 237-251.*

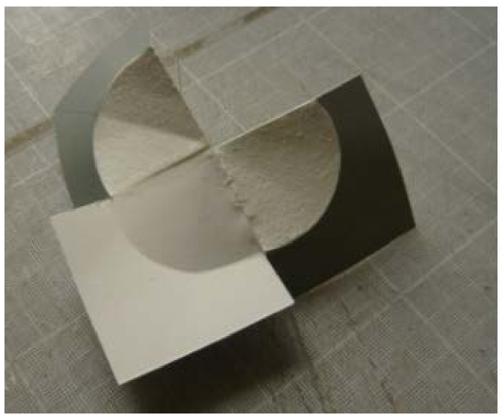
•*Van Lancker, B., De Corte, C., Belis, J. (2016). "Material properties of a structural silicone for linear adhesive glass-metal connections". Proceedings of Challenging Glass Conference 5, 16-17 June, Ghent, Belgium.*

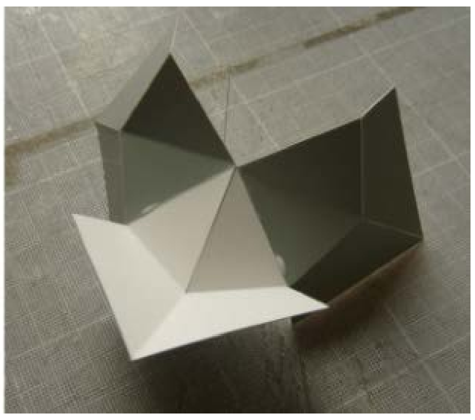
•*Van Lancker, B., Dispersyn, J., Martens, K., De Corte, W., Belis, J. (2015). "Translational stiffness of adhesive connections between cold-formed steel members and glass panels." Proceedings of the Glass Performance Days, 26-29 June, Tampere, Finland. 291-296.*

•*Van Lancker, B., Belis, J., De Corte, W. (2014). "Rotational stiffness of linear adhesive connections between cold-formed steel members and glass panels." 2014 GlassCon Global Conference Proceedings, 7-10 July, Philadelphia, PA. 729–746.*

Curved Pliable Folding

Manikanta Raghu Sagar Vanapalli, Institute for Membrane and Shell Technology, Hochschule Anhalt



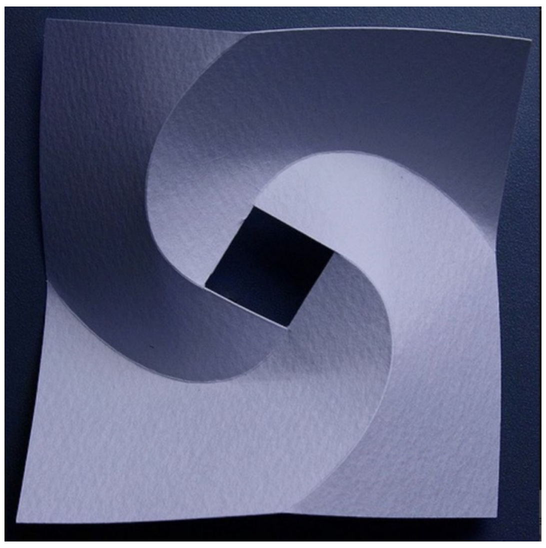


Introduction, Background to the Research

Curved Pliable folding is the act of folding a flat sheet of material along a curved crease to develop a three dimensional shape. Although a lot of curved folded paper models have been explored, very little has been focused on contemporary designs due the complexity of the topic. Also an interesting subject of this topic is the kinematic connection that exist between the surfaces linked through a curved fold. As one surface area is bent, the other deforms elastically. Using this elastically deformed surface a kinetic façade can be developed which is the aim of the research.

Research problem

The complexity of the curved folding lies in Form Finding but thanks to the advance 3d modelling software's which help in visualising the form. Another important research problem is to materialise the models from a prototype scale to a real time usable scale. Since the behaviour of the thin sheet in a small scale differs widely upon increasing the scale.



Research Questions (Main Questions and sub question)

Main question

How to create a curved fold with a polymer sheet and to make it a possible application in building construction, either as a wall partition, fair stand, dynamic facade system ?

Sub-questions

- How to fabricate a curved fold?
- How is the stress distribution along the fold?
- If polymers are used as a façade panel, what properties have to be altered in order to make it more durable?

Research Objectives

- Defining appropriate material properties
- To describe different possibilities to obtain a curved fold
- Development of fabrication techniques
- Development of different geometric models
- Optimization of material properties with the required geometry
- Development of an end user prototype for manufacturing

Research Deliverables

- Definition of material criteria required for curved folding
- Different approaches for fabrication of curved folding
- End product from material selection to assembly of a building element which can either be wall partition or a façade system.

Researcher: Manikanta Raghu Sagar Vanapalli; Henning Dürr
Supervisors: Prof. Robert Off; Prof. Marijke Mollaert
Time span: 2016-2018
Contact data: m.vanapalli@afg.hs-anhalt.de

COST EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY
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Sustainable upgrades in regional commercial and retail buildings

Ana Cristina Villaca, CAPES, University of Wollongong / Sustainable Buildings Research Centre (SBRC)

Introduction, Background to the Research

Retrofits can benefit existing buildings by providing energy savings, reducing greenhouse gases and improving both thermal comfort and quality of the built environment. Measuring building performance is the first step to understand the potentialities and constraints of a specific building during the retrofitting process. To date, the potential within the commercial building sector to retrofit high-rise office buildings and shopping centres has been extensively investigated, but the retrofitting of smaller scale commercial and retail buildings still needs attention, particularly in regional centres where these buildings are ageing.

Research problem

While there is a plethora of rating tools and certification schemes, and some government incentives, to address different types and uses of buildings, a review of the literature shows that very little research has been done on the environmental performance of and retrofitting process for smaller scale commercial and retail buildings. Therefore, this research aims to achieve a better understanding of the retrofit dynamics in this building sector, including the identification of drivers, potentialities and limitations to the upgrading process, to ultimately identify the barriers that may prevent retrofitting of these buildings.

Research Questions (Main Question and Sub-questions)

Main question

How can the uptake of the retrofit process by the smaller scale commercial and retail buildings in regional centres be improved to comply with the new environmental standards?

Sub-questions

1. What are the main drivers, constraints and potentialities to retrofit identified in this building sector?
2. How do the existing rating tools fail to accommodate this building sector?
3. Which is the best strategy to measure and control the environmental performance of buildings in this sectoral and regional context?
4. What are the 'most effective' retrofit techniques, strategies or actions for this building sector in regional centres?

Research Objectives

1. Identify the drivers, constraints and potentialities for the upgrading process;
2. Develop a method to assess building performance in the research context;
3. Apply the method in a pilot study area to characterize the smaller retail building stock performance;
4. Validate the method by replicating it in another regional centre;
5. Identify the most effective upgrading strategy in this context; and
6. Identify opportunities for improvements to the existing commercial and retail building stock, considering the inherent characteristics of this sector.

Research Deliverables

1. Create a method to assess the building's environmental performance;
2. Potentially, create a benchmark for commercial and retail buildings;
3. Develop a tool to support the decision making process during the early stages of the upgrade design;
4. Blueprint guidelines for future policies to enhance the uptake of buildings' upgrades.

Fig. 1 Aerial view of the pilot study area. Adapted from Google Maps. Accessed: 05-08-2016

Fig. 2 Facades on Crown Street. Source: Google Maps. Accessed: 05-08-2016

Fig. 3 Commercial building before (above) and after (below) upgrading.

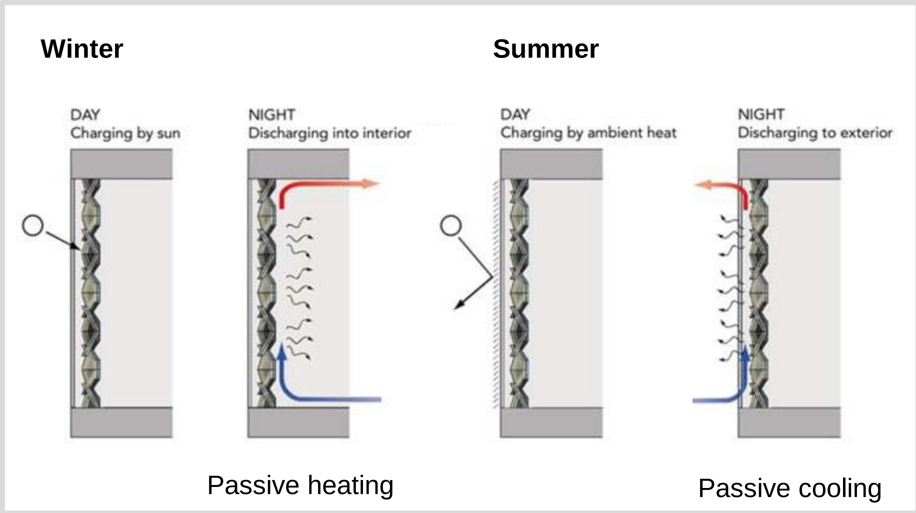
Researcher: Ana Cristina Villaca Coelho
Supervisors: Prof. Dr. Paul Cooper , Prof. Dr Tim McCarty
Time span: July/2014 to June/2017
Contact data: acvc600@uowmail.edu.au

Research through design 'Double face 2.0'

Tudor Cosmatu & Yvonne Wattez, TU Delft Faculty of Architecture, Chairs of Design Informatics & Building Physics

Introduction, Background to the Research

Few architectural works take aesthetic advantage from technical aspects; they are often seen as constraining requirements limiting creativity rather than inspiring principles triggering design concepts and being integral part of the design identity. Due to the current urgency of sustainability, technical aspects related to energy use deserve special attention. While advocating the use of technical performances as integral part of the design identity, this research focuses on a system for passive climate control.



Research problem

The research will focus on a specific demonstrator: a novel type of Trombe wall. It consists of a new system that passively improves thermal comfort using new lightweight and translucent materials for latent heat storage, like phase change materials. We will use novel production techniques, like 3D printing, to explore their potential for creating high quality translucent and highly performative products. Our approach is unique in that we aim for a system with high levels of adjustability to the specific conditions at hand and that we aim for a system in which the functioning will be part of the identity of the product. This latter aim will be realized by a.o. the adjustability and shape of the system and by the materials that have a changing appearance depending on their physical state (solid or liquid).

Research Questions

Main question
How can we design a building product for passive climate regulation in which its engineering performances are part of its identity?

Design component:
A system in which the functioning of thermal mass is part of the identity of the product

Technological component:
A system that is lightweight, translucent and has high levels of adjustability to tune it to the specific conditions and needs at hand

Research Method:
Research through design with a novel Trombe wall as case.

Research Objectives

The research will be performed based on the initial development of 3 innovative design concepts for the system. A combination of intuitive design and evolutionary and form-finding computer algorithms will be used to generate and select design alternatives within the 3 concepts. These alternatives will be evaluated and further elaborated upon soft and hard variables. Key soft variables are: design identity, usefulness and applicability in buildings. Key hard variables are: thermal and daylight performance. Secondary criteria are: manufacturing possibilities and structural performance.
The soft variables will be assessed in a series of workshops with architects and industrial designers or users respectively. The hard variables will be assessed based on physical tests and simulations. Continuous feedbacks form the workshops and computational assessments will be used in an iterative manner to feed the design process and to generate improved concepts.

Research Deliverables

While dealing with the use of engineering performances as principles to trigger design creativity, ultimately, this research will result in a set of design concepts and in general knowledge on thermal performances.

- Three innovative design concepts for the system
- Final design + prototype
- Extracting scientific knowledge from creative design as such informing the learning process of the designer
- Report and papers

This research is funded by STW.

Researcher: Tudor Cosmatu & Yvonne Wattez
Supervisors: Dr. MScArch. Michela Turrin, Dr. ir. Martin Tenpierik.
Time span: 2 years
Contact data: t.cosmatu@tudelft.nl, y.c.m.wattez@tudelft.nl
Associated Publications:

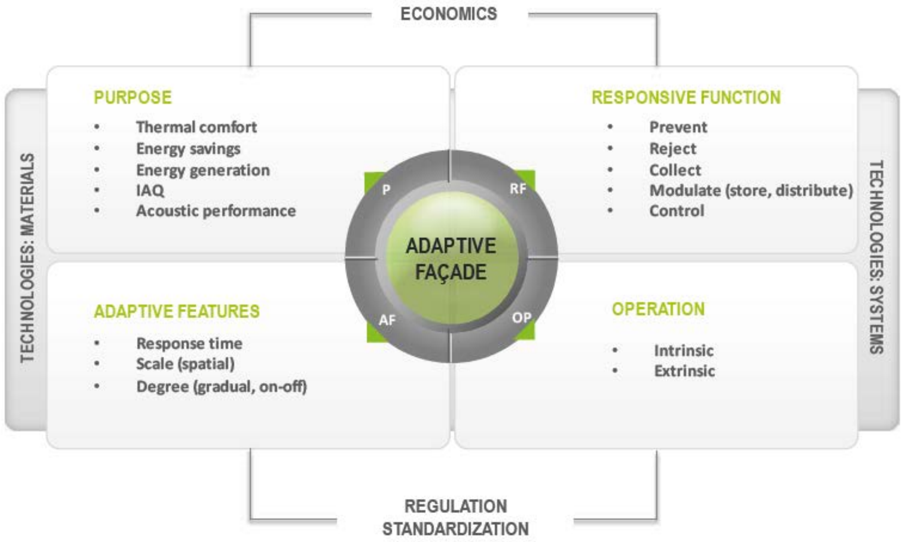
Video of the 3TU.Bouw project Double Face: http://www.3tu.nl/bouw/en/lighthouse2014/doubleface/. This video shows the development of the Double Face project which was the starting point of this proposal.

3.1. Task

Under given design conditions using state-of-the-art knowledge, workgroups had to design a conceptual solution for an adaptive façade system that would serve as a building's envelope with the possibility of performance adaptation in regards to outdoor (and indoor) conditions.

There were 9 workgroups assembled based upon educational and working background. The main topics of the workshop were three different case studies (Fig 1).

Of these 9 workgroups 3 were randomly chosen per case study to study and develop a solution for the task. Design was evaluated by the expert group. The workgroup with the best design solution per case study was awarded with a prize certificate.



(Source: COST – Adaptive façade network – Europe)

Case study 1 – Saint Petersburg
Layout 1 + Humid continental climate I

Case study 2 – São Paulo
Layout 2 + Humid subtropical climate

Case study 3 – Chicago
Layout 3 + Humid continental climate II

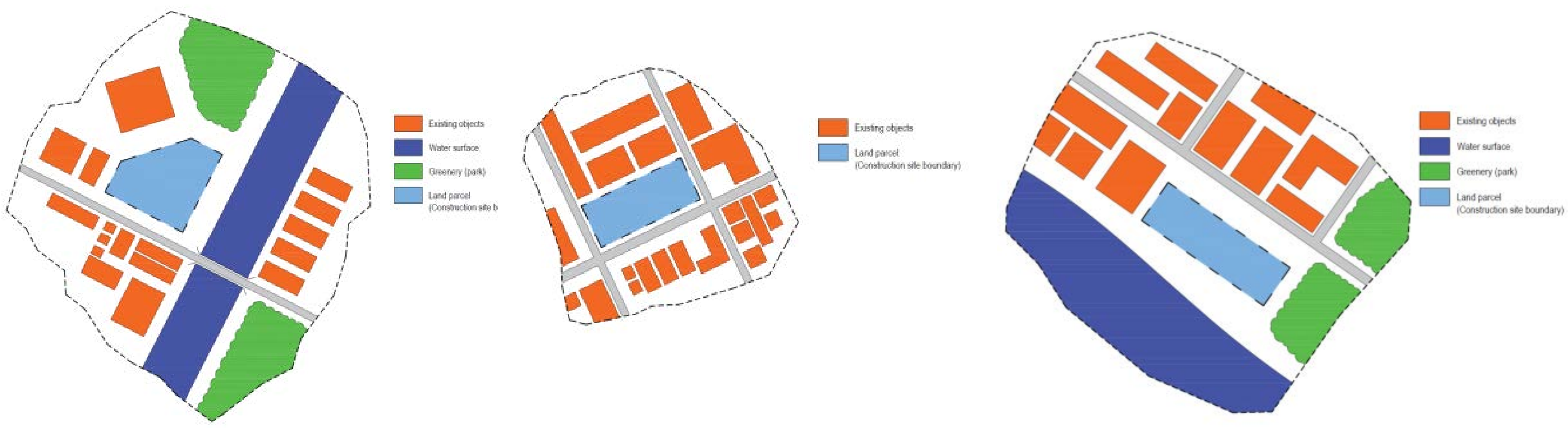
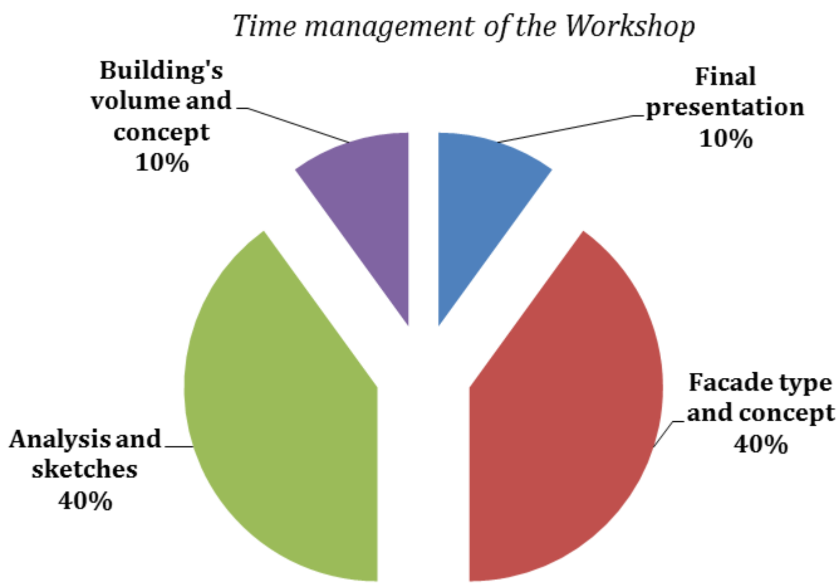


Figure 1: Case studies

All buildings had to be designed as an office building located in area without high noise sources (high noise reduction was not a criteria). Specific climate conditions were given per each case study and are consisted of:

- Temperature range
- Diurnal averages of solar radiation and temperatures
- Relative humidity
- Global horizontal radiation
- Precipitation
- Weather data summary



Using the diverse know-how experience of the participants, workgroups had to develop a realistic and feasible solution of an adaptive façade system capable to harness benefits from its performance adaptation in regards to outdoor conditions.

The final outcome of the workshop was a conceptual design of an adaptive façade system.

On the following pages, the ideas and solutions of the participants are presented.

3.2. Teams

Case Study I – St. Petersburg

Team 3	Bacha Ben Cherif	University of Constantine
	Bosserez Ann	Hasselt University
	Friedrich Matthias	HafenCity University
	Juaristi Miren	University of Navarra
	Schultz-Cornelius Milan	Technische Universität Kaiserslautern
	Van Lancker Bert	Ghent University
Team 5	Arantes Beatriz	State University Of Campinas
	Cakaric Ivan	Ostwestfallen-Lippe Hochschule
	Rios Elida	University Polytechnic of Madrid
	Schweers Klaus	HafenCity University
	Speroni Alberto	Politecnico di Milano
	Valdenebro Esaiy Antonio	HafenCity University
Team 9	Ghasempourabadi Mohammadhossein	Eindhoven University of Technology
	Contrada Francesca	SIE Paris EST – IRC ESTP
	Cosmatu Tudor	Delft University of Technology
	Meloni Marco	University IUAV of Venice
	Reina Kathia	HafenCity University
	Vanapalli Manikanta	Hochschule Anhalt

Case Study II - São Paulo

Team 4	Denz Paul	Delft University of Technology
	Fernandez Mario	Polytechnic University of Madrid
	Hannequart Philippe	Ecole Nationale Des Ponts et Chaussees
	Posavec Matija	HafenCity University
	Santoro Giulia	Politecnico di Milano
	Scheuring Leonie	Technische Universität Dresden
Team 6	Abdellatif Mostafa	HafenCity University
	Carcassi Olga Beatrice	University of Pisa
	Ives Shawn	Anhalt University of Applied Science
	Nguyen Anh Phan	Delft University of Technology
	Saini Hemshikha	Technische Universiteit Eindhoven
	Souza Caetano Diego	Federal Fluminense University Niteroi RJ Brazil
Team 8	Alatawneh Bader	University of Palermo
	De Michele Giuseppe	Free University of Bolzano
	Giovannini Luigi	Politecnico di Torino
	Martin-Conseuegra Fernando	Universidad Politecnica de Madrid
	Milkova Aleksandra	Lund University
	Wattez Yvonne	Delft University of Technology

Case Study III - Chicago

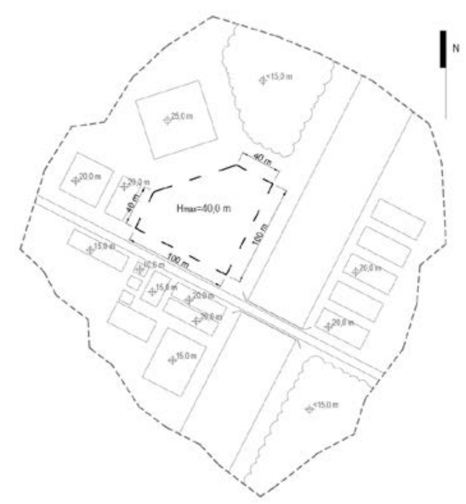
Team 1	Baudisch Roman	HafenCity University
	Castaneda Estefana	Technical University of Madrid
	Charpentier Victor	Princeton University
	Dubljevic Andjela	University of Belgrade
	Grassi Giulia	University of Pisa
	Soliman Mohamed	University of Lund
Team 2	Förch Matthias	HafenCity University
	Fallahi Amin	University of Bath
	Khoont Mehul	HafenCity University
	Pereira Julia	Universidade Técnica de Lisboa
	Sousa Christoph	University of Minho
	Villaca Ana	University of Wollongong
Team 7	Basarir Bahar	Istanbul Technical University
	Campos-Morales Beatriz	HafenCity University
	Curpek Jakub	Faculty of Civil Engineering STU Bratislava
	Kamari Aliakbar	University of Palermo + Aarhus University
	Silvestru Vlad	University of Technology Graz
	Tugrul Asli	Ostwestfallen-Lippe Hochschule

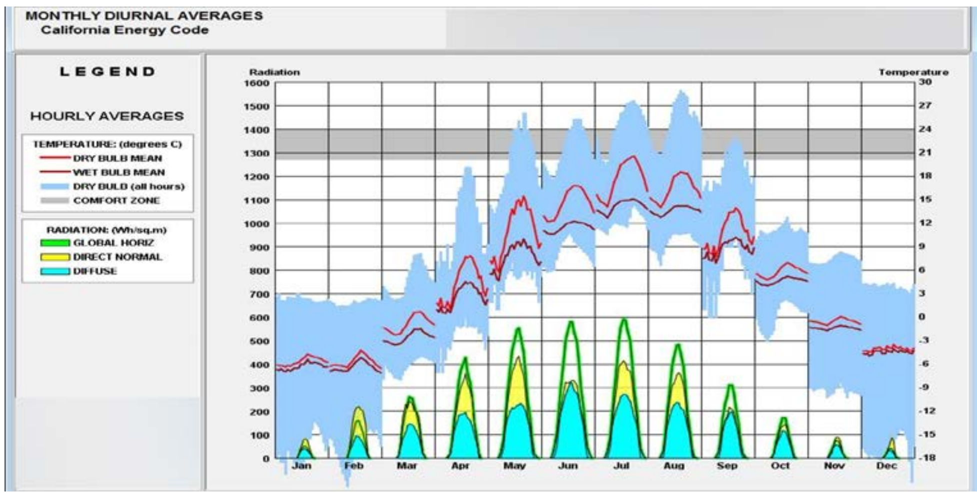
3.3. Case Study I – Saint Petersburg

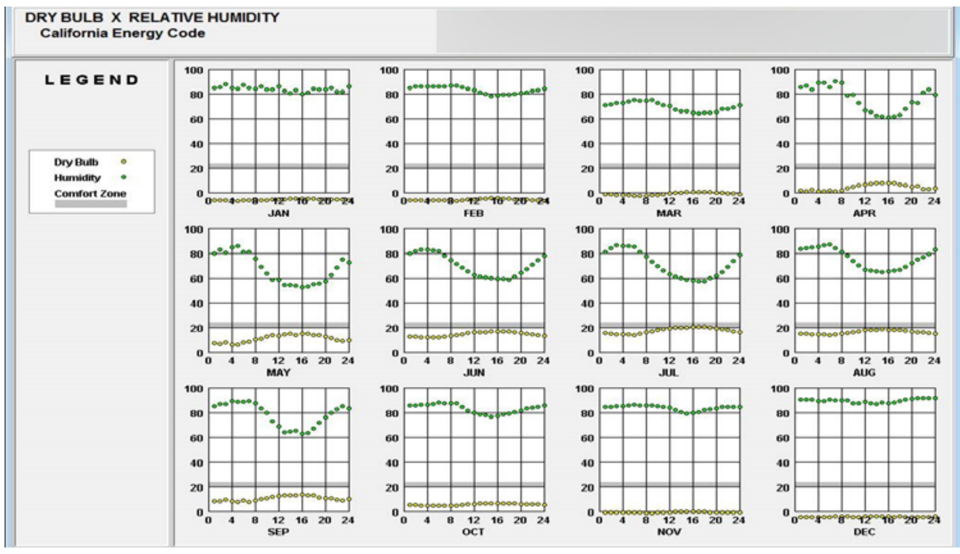
Case study 1 – Saint Petersburg

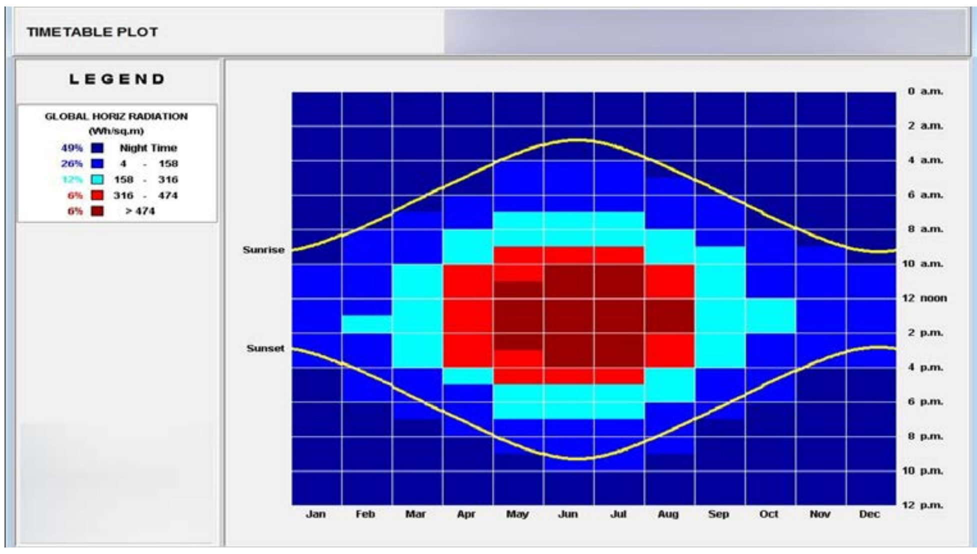
Layout 1 + Humid continental climate I

LOCATION:	**SAINT-PETERSBURG, -, RUS**
Latitude/Longitude:	59.97° North, 30.3° East, **Time Zone from Greenwich** 3
Data Source:	IWEC Data 260630 WMO Station Number, **Elevation** 4 m









WEATHER DATA SUMMARY

MONTHLY MEANS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Global Horiz Radiation (Avg Hourly)	34	100	154	224	285	294	303	258	168	97	45	26	Wh/sq.m
Direct Normal Radiation (Avg Hourly)	51	156	158	191	214	177	218	197	108	81	51	44	Wh/sq.m
Diffuse Radiation (Avg Hourly)	26	61	93	122	148	177	162	145	115	70	36	21	Wh/sq.m
Global Horiz Radiation (Max Hourly)	171	343	499	668	741	758	745	670	542	369	172	102	Wh/sq.m
Direct Normal Radiation (Max Hourly)	615	796	819	833	718	720	757	700	613	512	461	409	Wh/sq.m
Diffuse Radiation (Max Hourly)	85	165	273	390	402	431	420	419	311	196	108	57	Wh/sq.m
Global Horiz Radiation (Avg Daily Total)	223	879	1807	3245	4865	5397	5331	3945	2139	961	324	148	Wh/sq.m
Direct Normal Radiation (Avg Daily Total)	337	1387	1872	2787	3692	3261	3851	3003	1391	815	355	252	Wh/sq.m
Diffuse Radiation (Avg Daily Total)	175	535	1087	1759	2515	3253	2851	2222	1462	692	266	122	Wh/sq.m
Global Horiz Illumination (Avg Hourly)	3750	10708	16754	24464	31129	32358	33309	28414	18553	10698	4980	2873	lux
Direct Normal Illumination (Avg Hourly)	3208	12402	14389	18476	20940	17060	20723	18465	10097	6953	3395	2308	lux
Dry Bulb Temperature (Avg Monthly)	-5	-5	0	4	11	14	17	16	10	5	0	-4	degrees C
Dew Point Temperature (Avg Monthly)	-7	-7	-5	0	4	8	11	11	6	3	-2	-5	degrees C
Relative Humidity (Avg Monthly)	84	83	69	76	67	70	70	75	78	83	84	89	percent
Wind Direction (Monthly Mode)	270	240	150	150	270	270	0	0	210	270	290	270	degrees
Wind Speed (Avg Monthly)	3	2	2	3	2	2	1	2	3	2	2	2	m/s
Ground Temperature (Avg Monthly of 3 Depths)	2	0	-2	-2	0	3	7	11	12	12	9	5	degrees C

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average precipitation mm (inches)	44	33	37	31	46	71	79	83	64	68	55	51	661
	-1.73	-1.3	-1.46	-1.22	-1.81	-2.8	-3.11	-3.27	-2.52	-2.68	-2.17	-2.01	-26.02
Average rainy days	9	7	10	13	16	18	17	17	20	20	16	10	173
Average snowy days	17	17	10	3	0	0	0	0	0	2	9	17	75

Case Study I: St. Petersburg – Team 3

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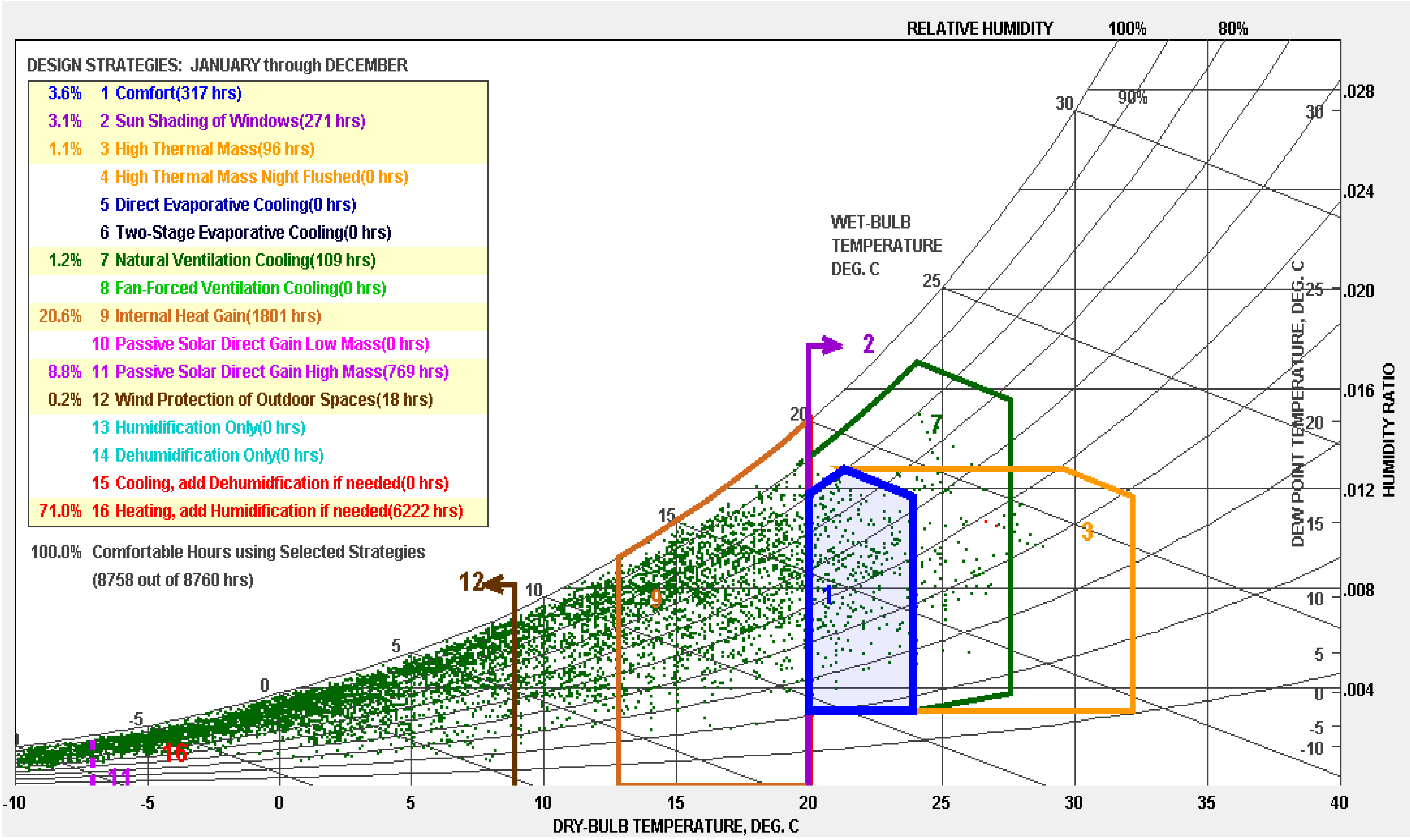
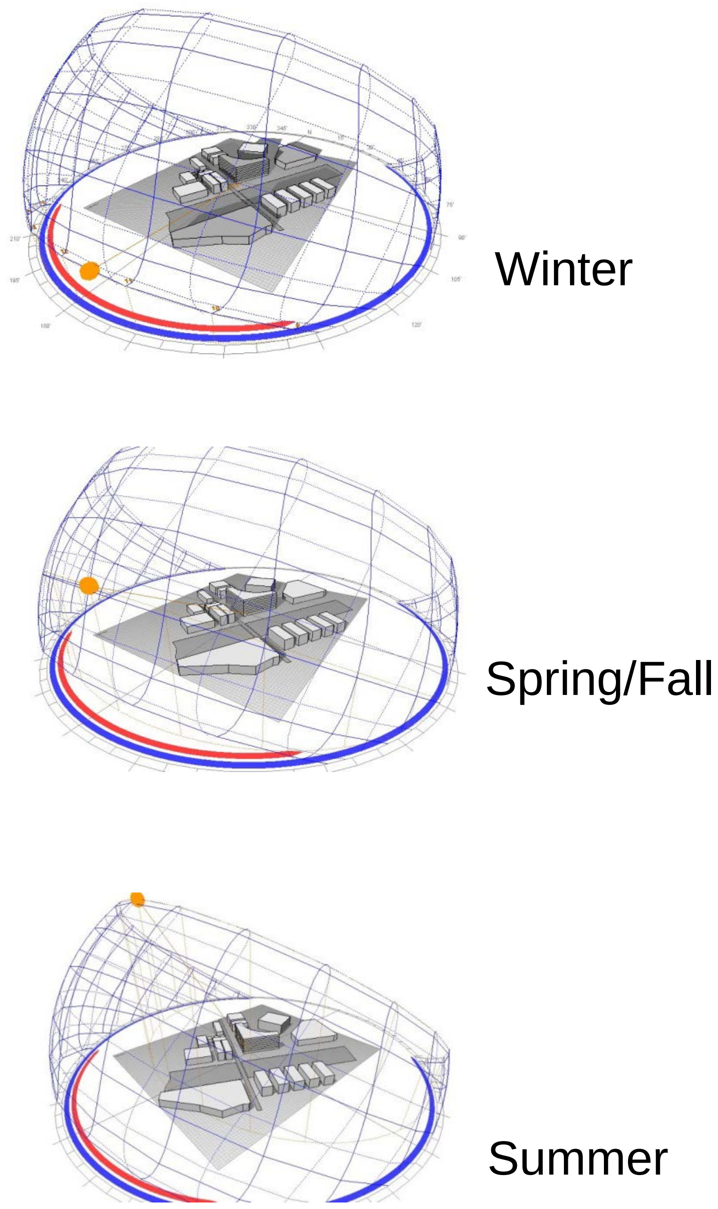
▶ Juaristi, Ann Bossarez, Bert Van Lancker, Cherif Ben Bacha, Milan Schlutz-Cornelius, Matthias Friedrich



SITE PLAN

SUN INCLINATIONS



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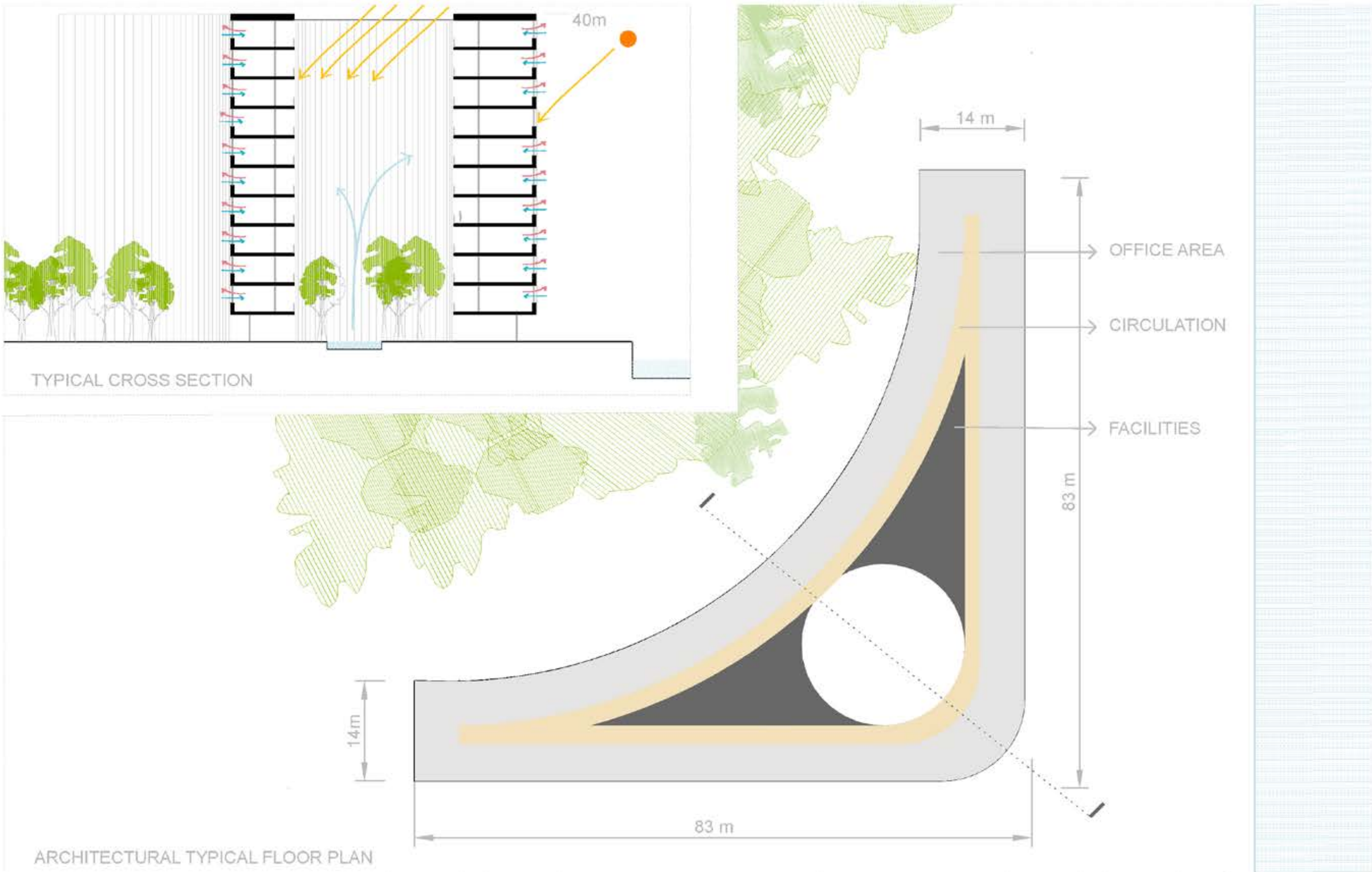
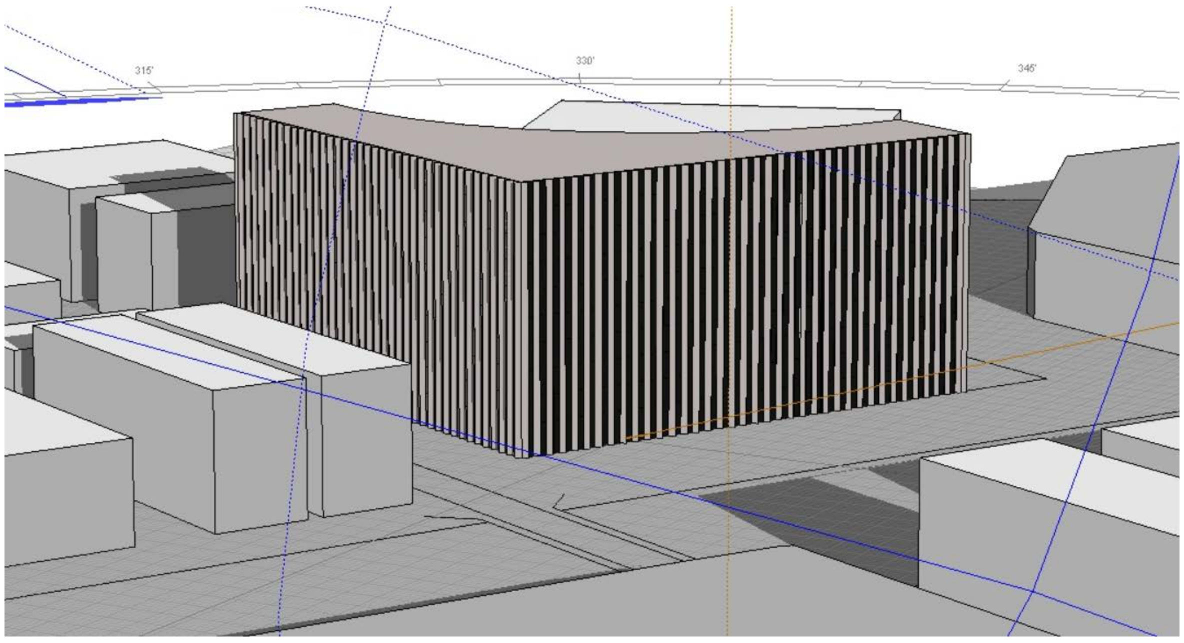
ARCHITECTURAL CONCEPT



BUILDING NEEDS



Electricity

Humidification

Ventilation

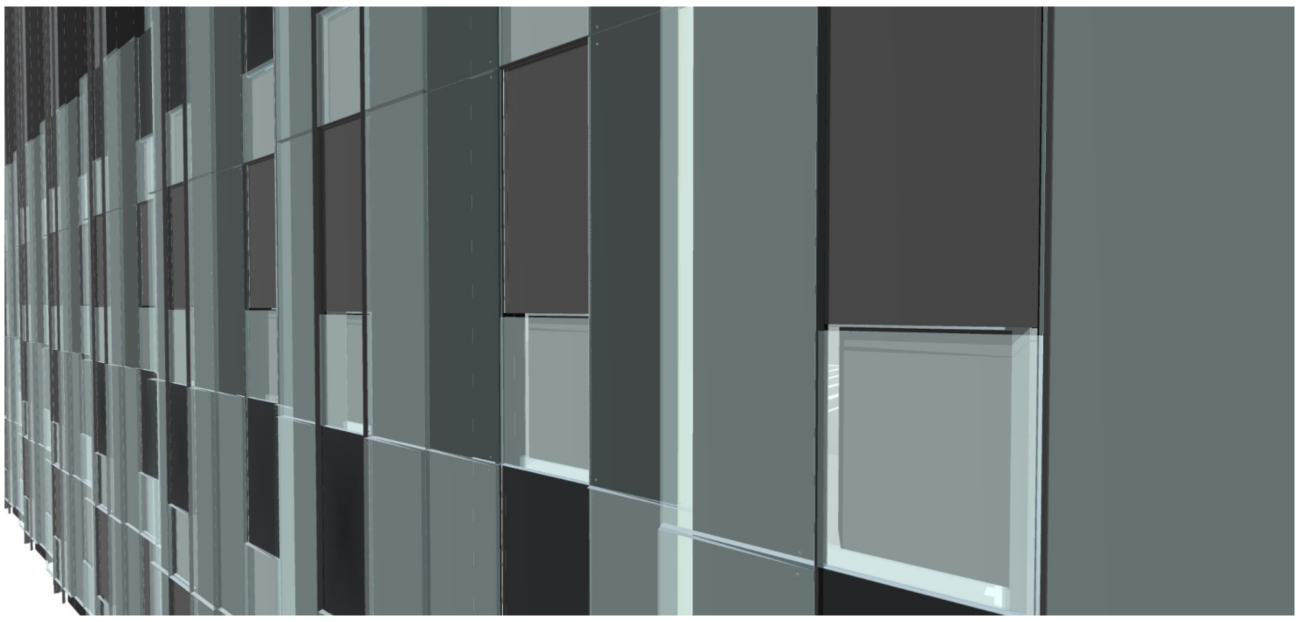
Heating

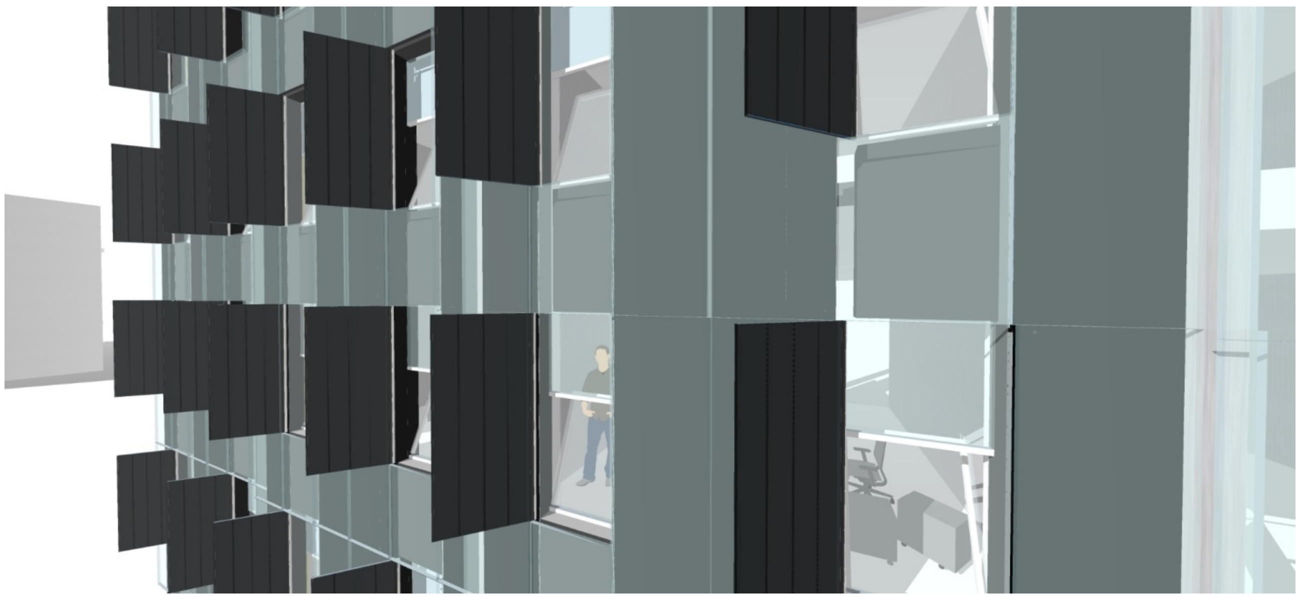
Daylight

<u>Net Floor Area:</u>	Ground Floor 2,900 m²			
	9 Office Floors	2,500 m² each		
	Gross Floor Area	<u>25,400 m²</u>		
	Office Area	14,400 m²	12 m²/Person	1,200 Persons
<u>Electrical Demand:</u>	Equipment	250 W/person		
	1,200 Persons x 250 W/Person	= **300 kW → 50,000 kWh / month**		
Lightning	10 W/m²			
	25,400 m² x 10 W/m²	= **254 kW** (without daylight)		

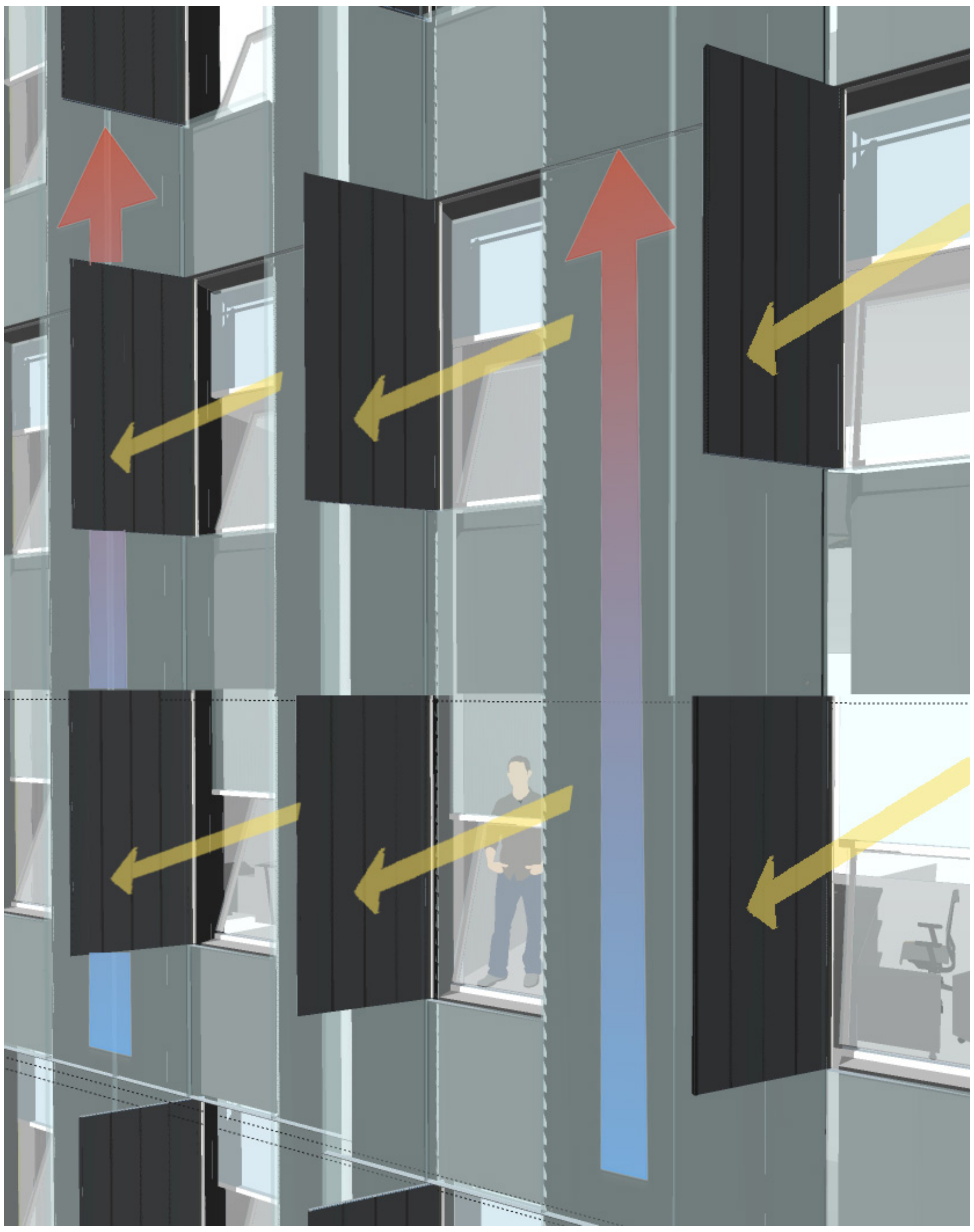
▶ Juaristi, Ann Bossarez, Bert Van Lancker, Cherif Ben Bacha, Milan Schlutz-Cornelius, Matthias Friedrich

ADAPTIVE FACADE CONCEPT





VENTILATION



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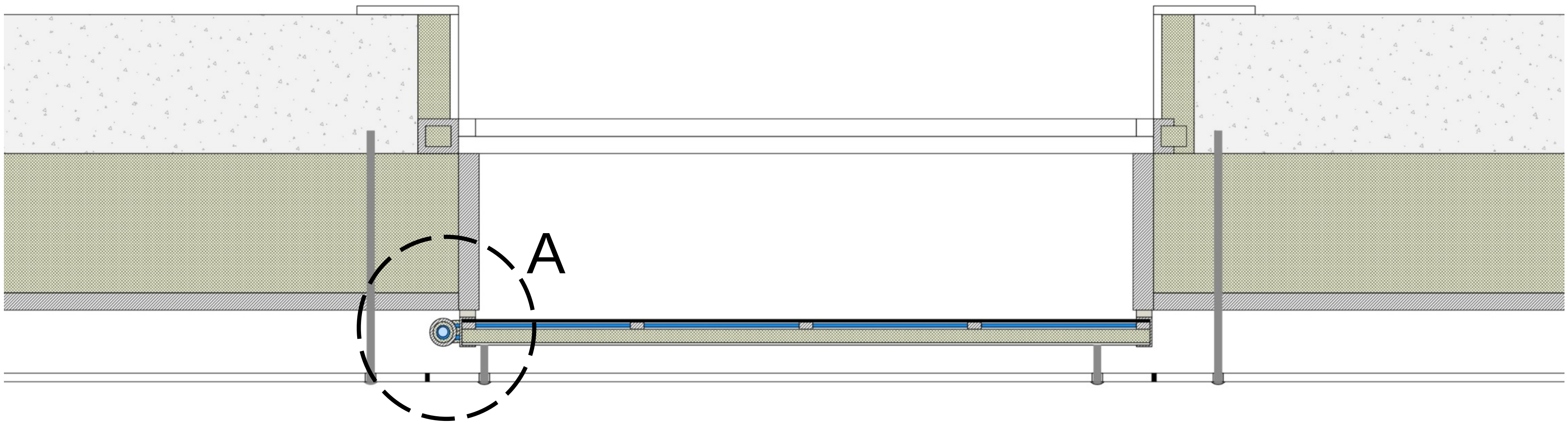
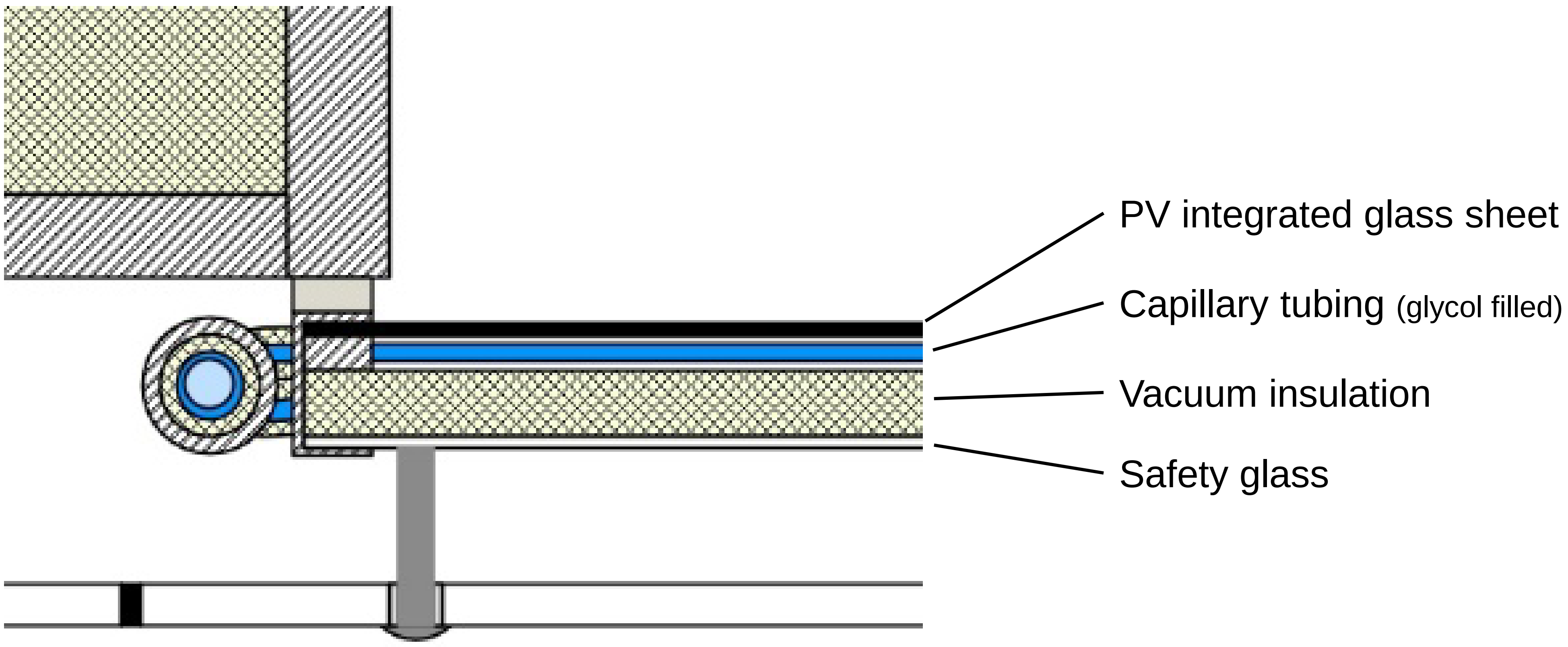
ENERGY SAVING AND GAINING ELEMENT



Detail A

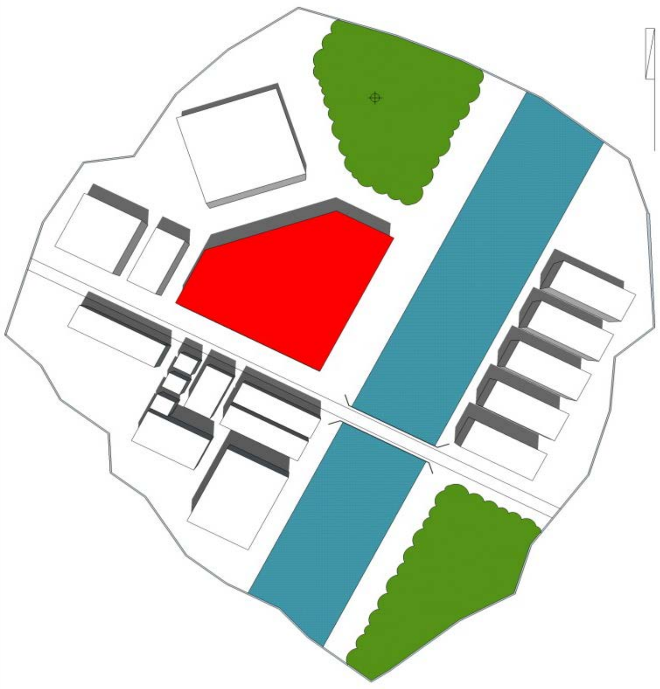


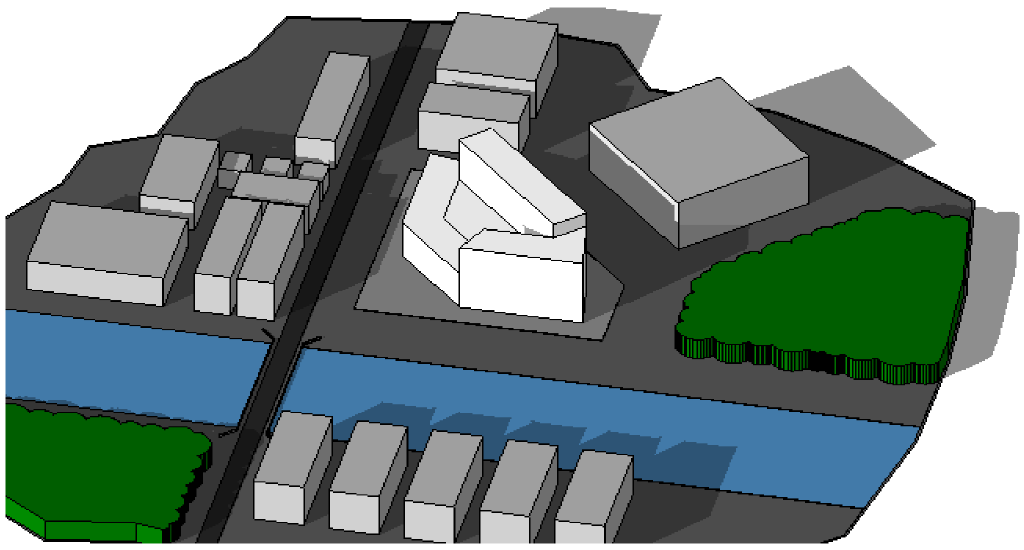
Case Study I: St. Petersburg – Team 5

▶ Beatriz Arantes, Ivan Cakaric, Elida Rios, Alberto Speroni , Klaus Schweers, Esaiy Valdenebro

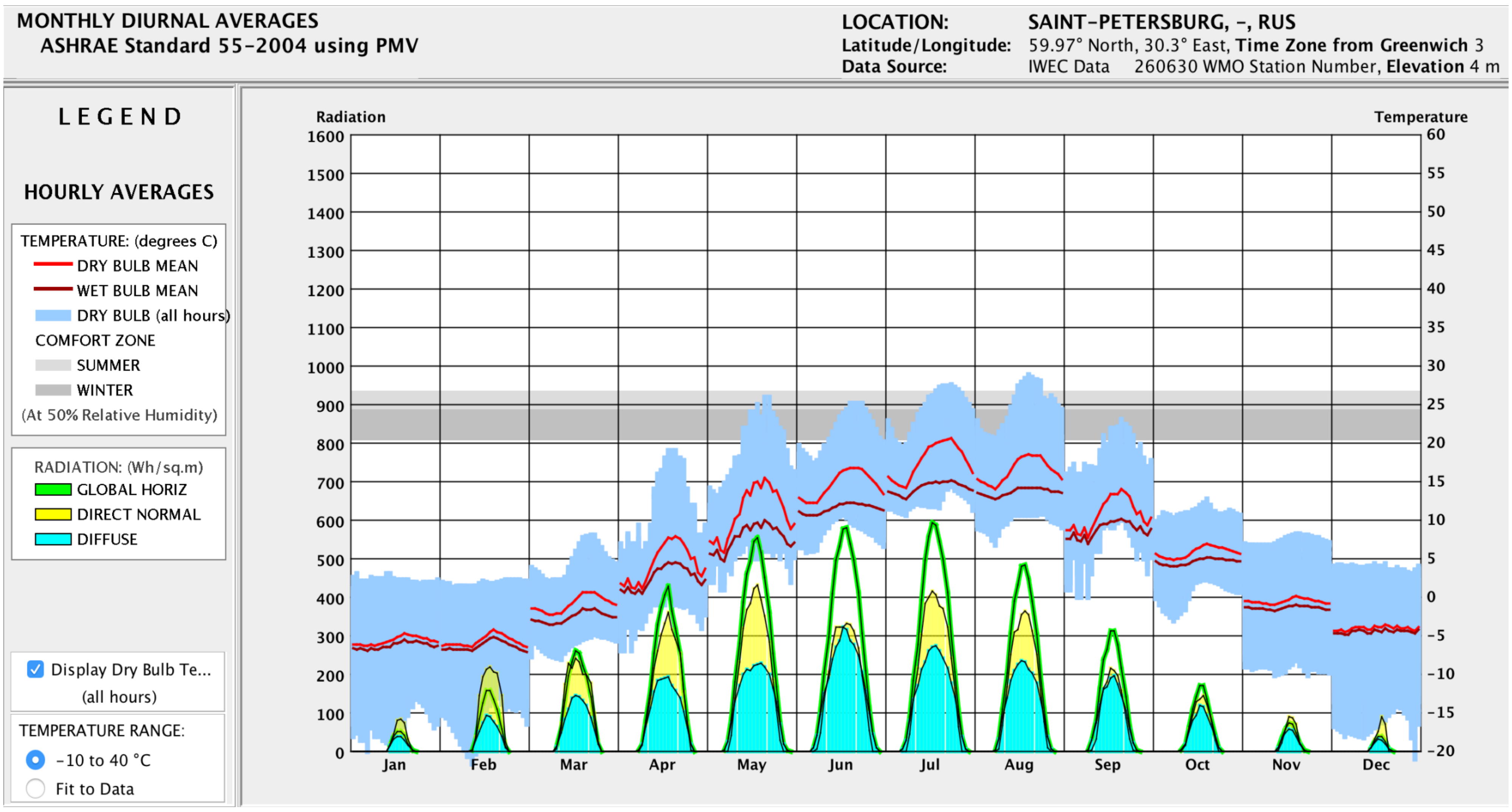
LOCATION

Latitude / longitude 60.0 ° North, 30,3 ° East | Humid continental climate



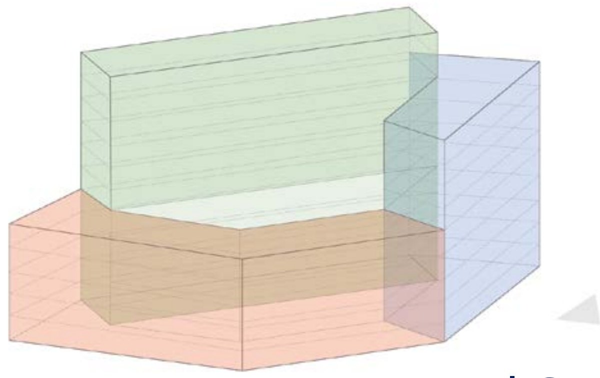


Existing Objects
Water Surface
Greenery - Park
Land Parcel

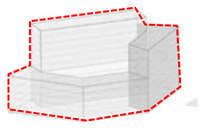


▶ Beatriz Arantes, Ivan Cakaric, Elida Rios, Alberto Speroni , Klaus Schweers, Esaiy Valdenebro

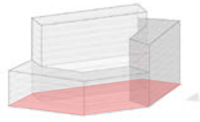
BUILDING CONCEPT



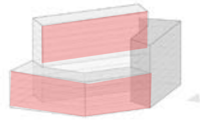
Total GFA: 25, 415 m²



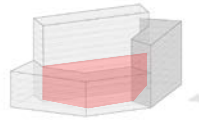
Compact



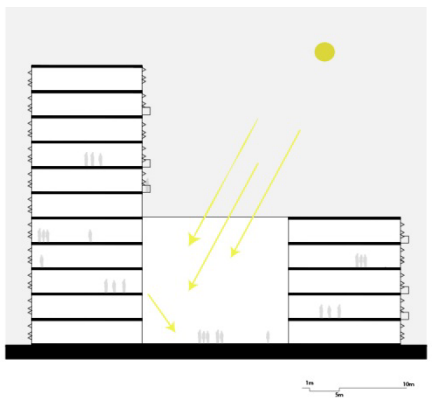
Extensive

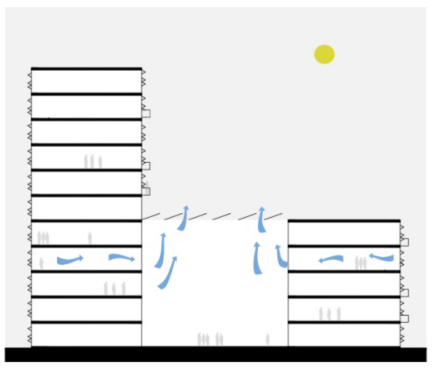


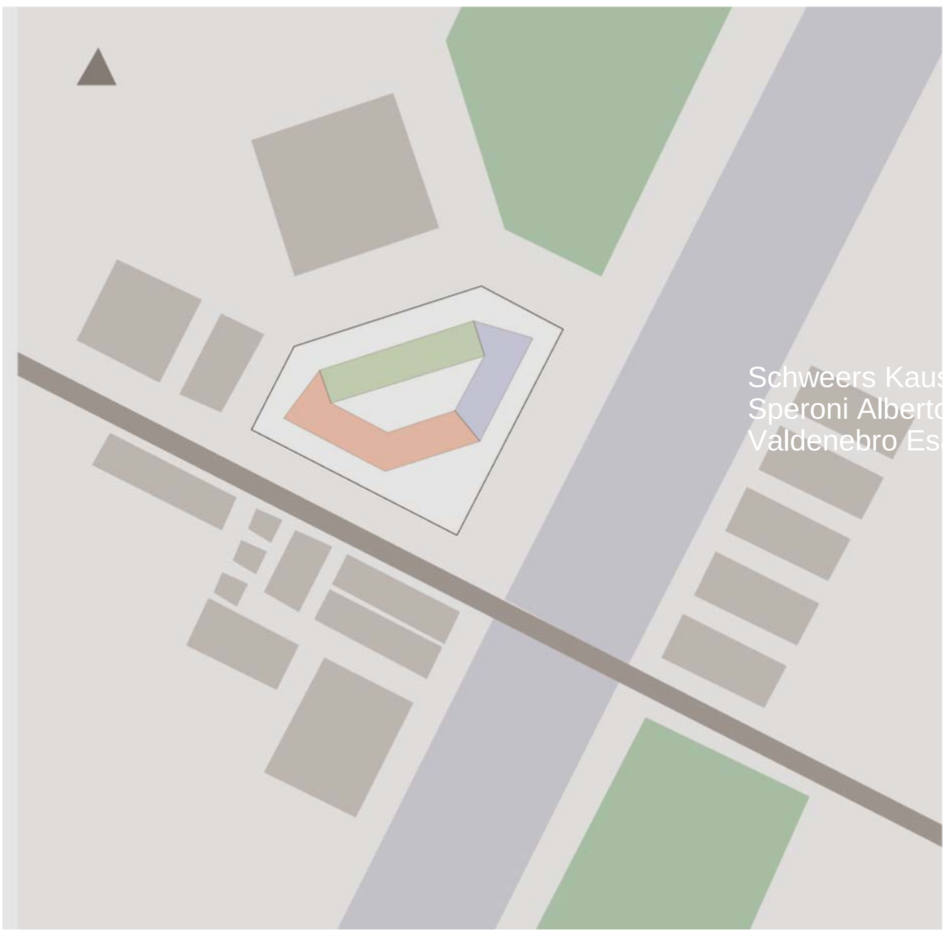
South facade



Court yard

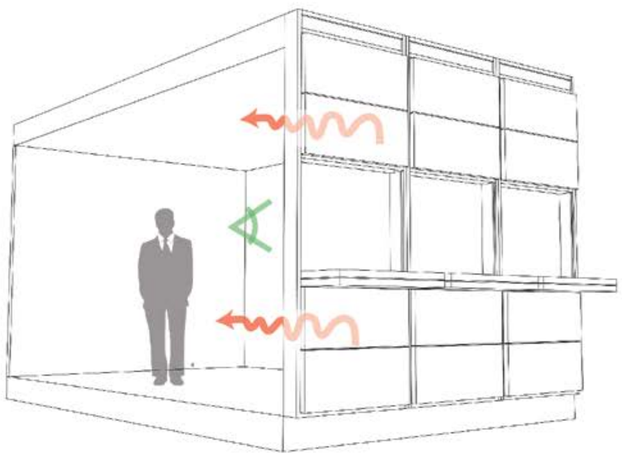


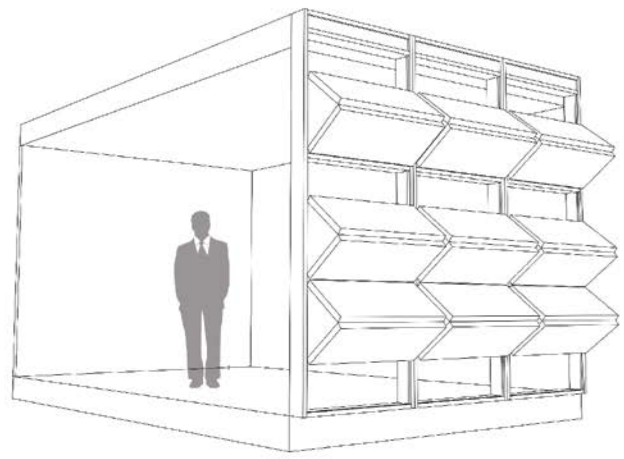


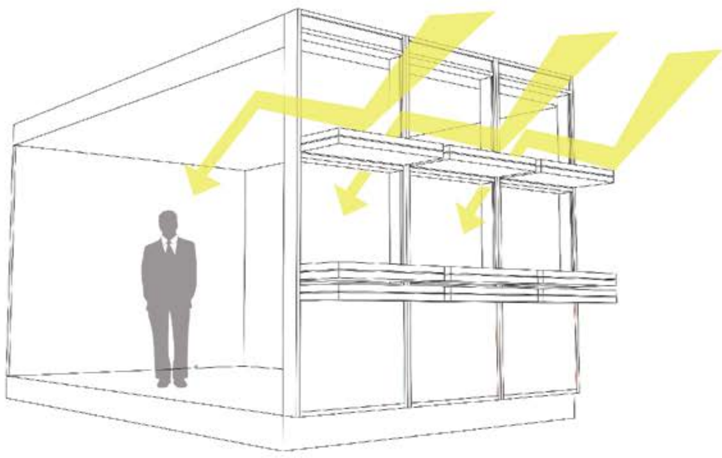


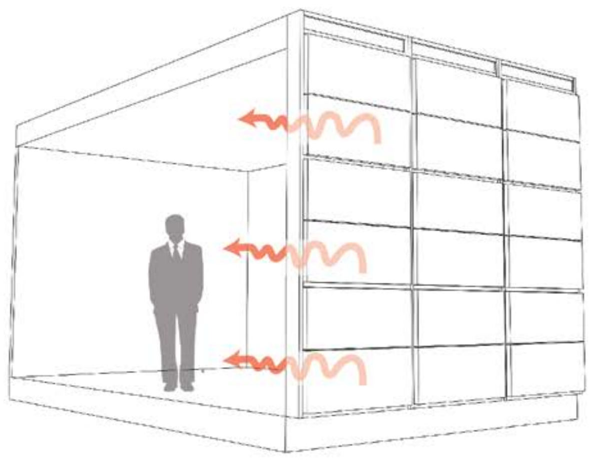
Beatriz Arantes, Ivan Cakaric, Elida Rios, Alberto Speroni , Klaus Schweers, Esaiy Valdenebro

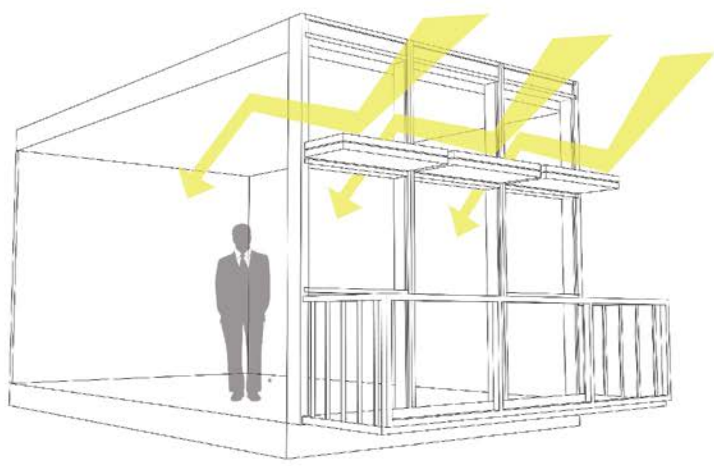
FACADE CONCEPT

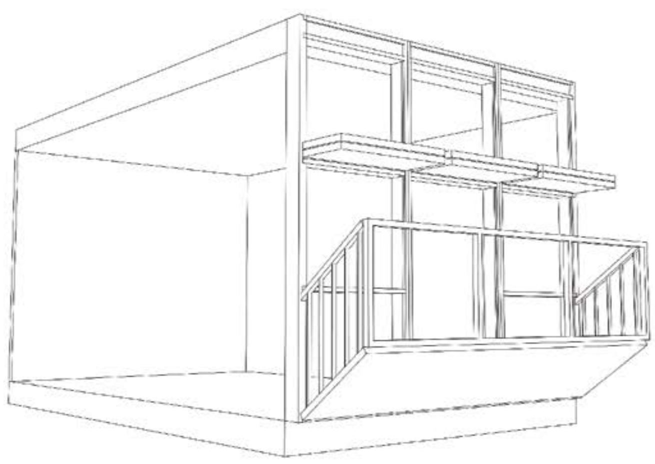


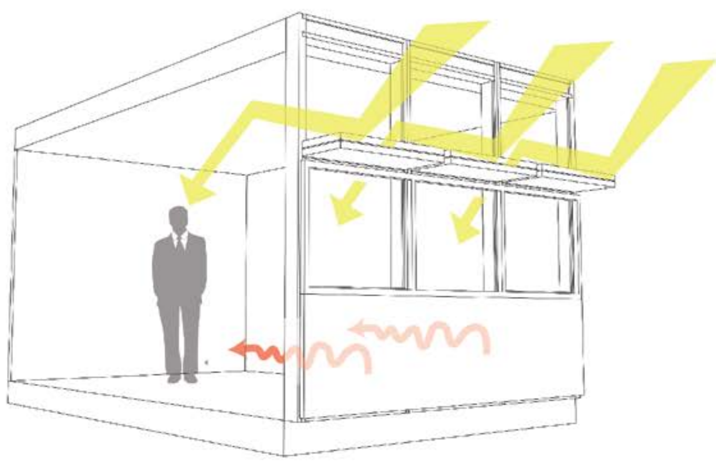












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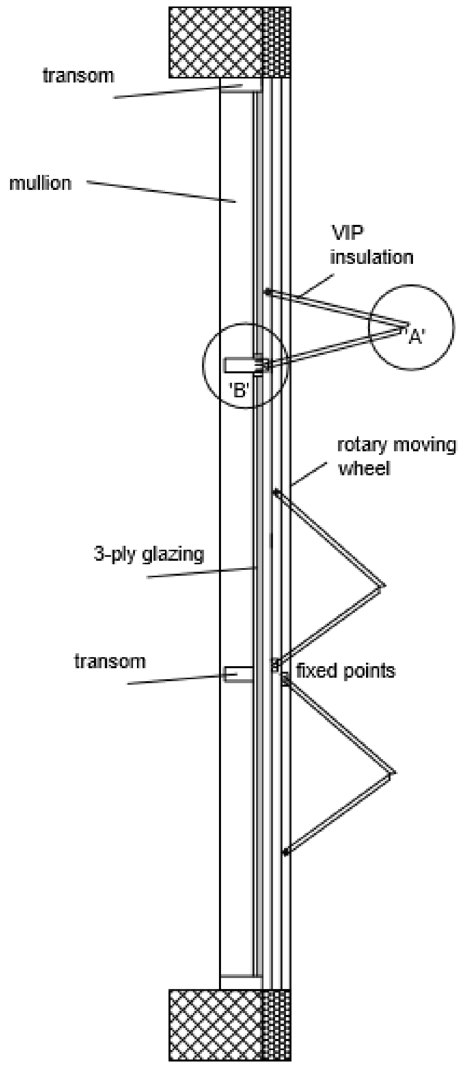
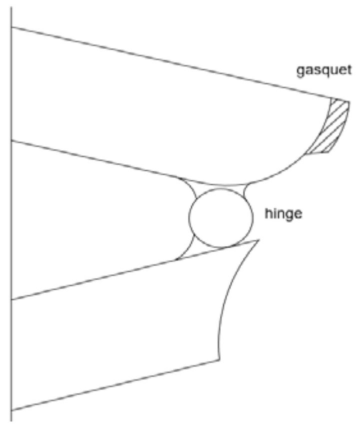
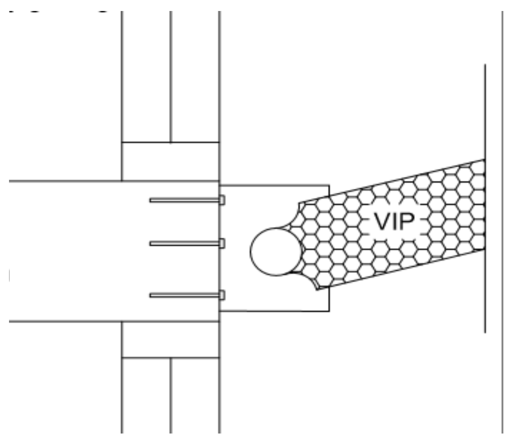
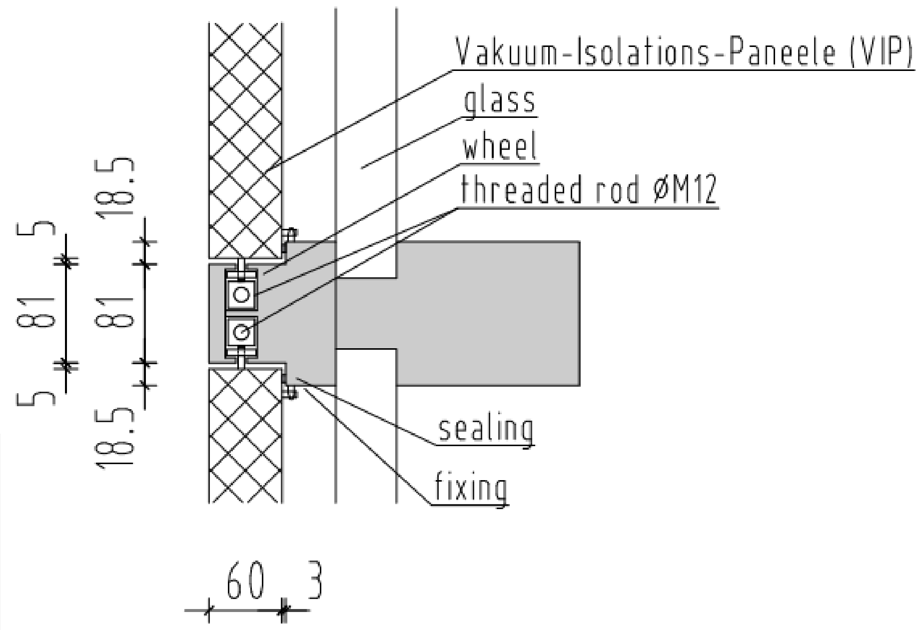
TECHNICAL DETAILS



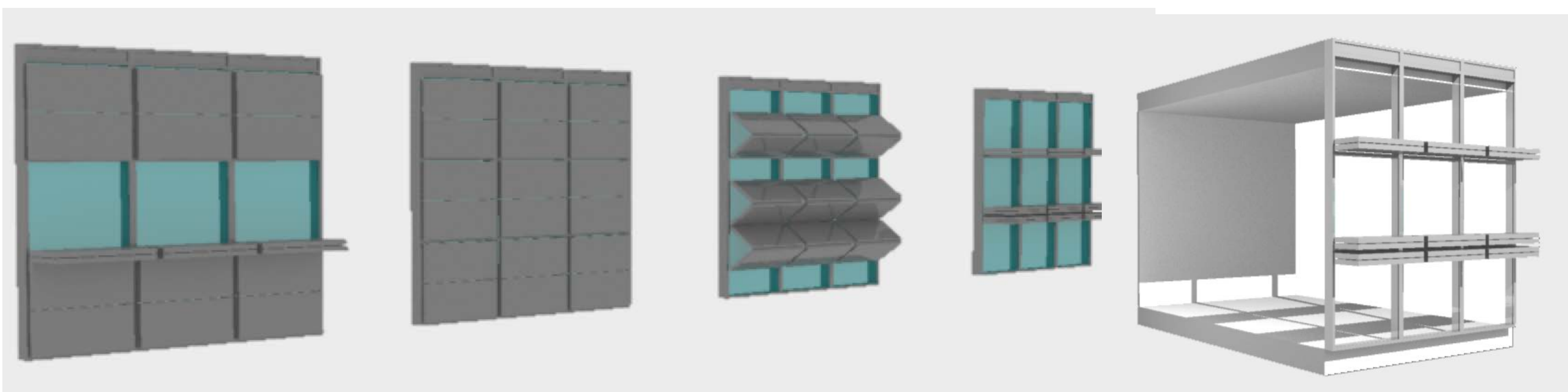






CONCLUSION

PROS	CONS
•Thermal resistance •User comfort •Redirecting daylight •Vision outside	•Mechanical elements •Expensive •Durability



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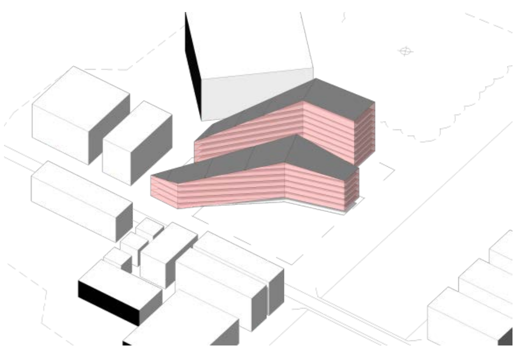
FACADE ORIENTATION



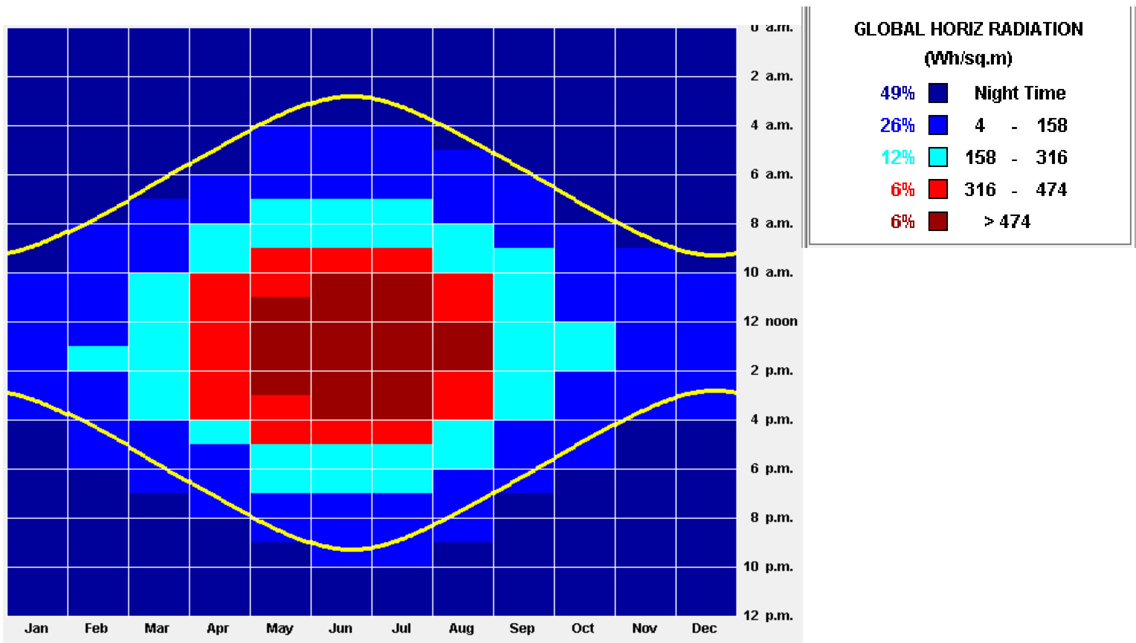
BRAINSTORM

PROJECT DETAILS

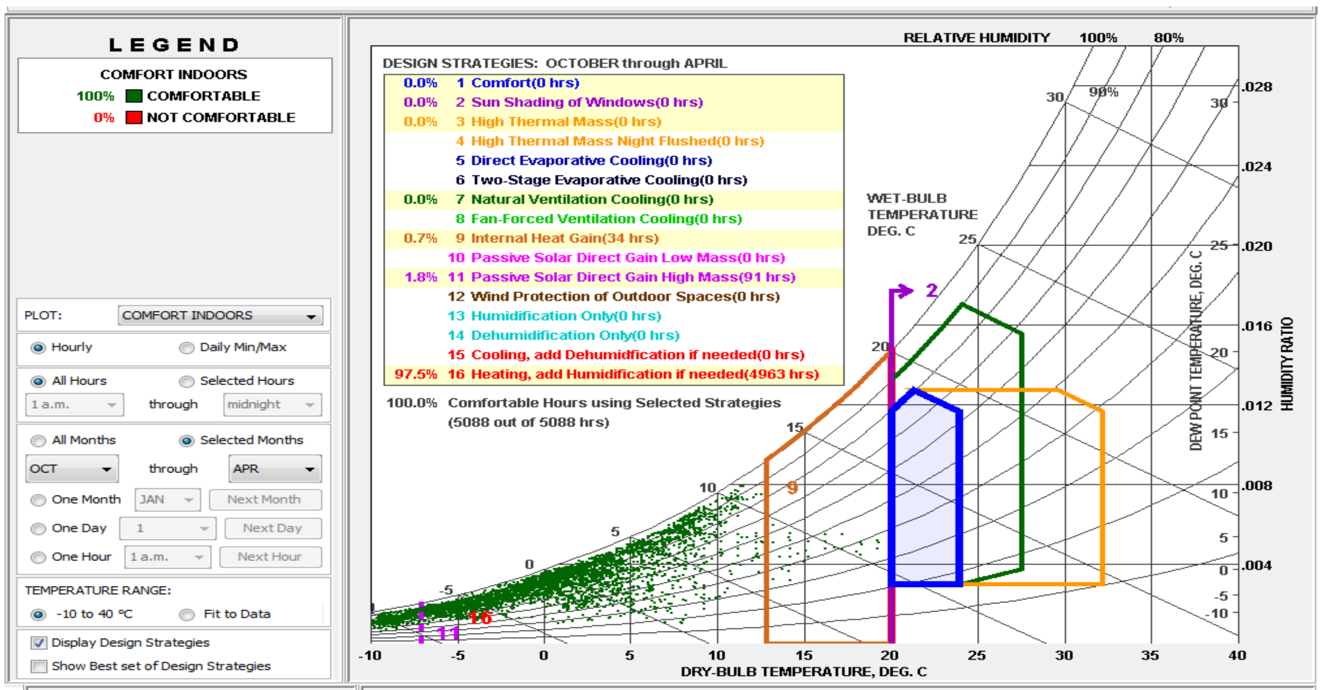
- Type of use: Office
- Footprint: 3500 m^2
- Average story height: 3,5 m
- Building height: 40 m
- Floor area: 850- 3500 m^2
- Number of floors: 11

CLIMATE AND DECISION

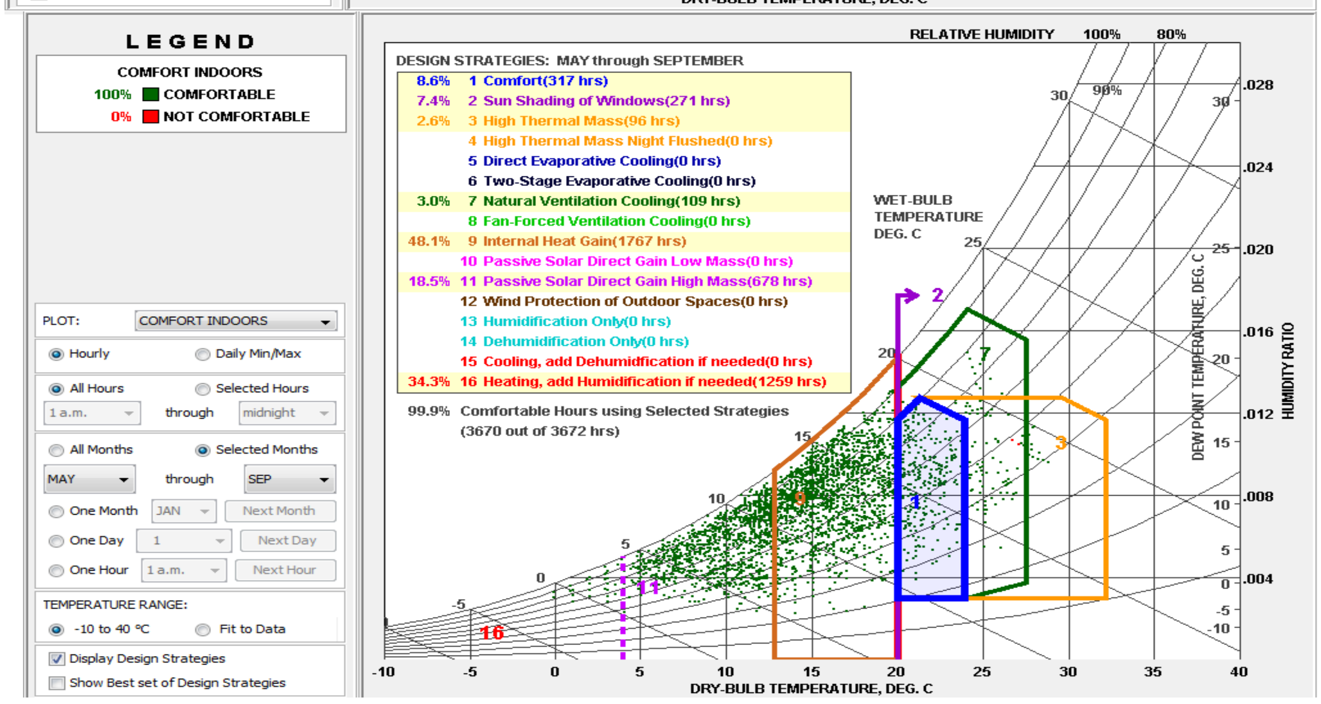
SUMMER	WINTER
◦ WARM/HOT > 24°C	◦ WARM/HOT > 24°C
(SHADE NEEDED) 91 Hours Exposed 0 Hours Shaded	(SHADE NEEDED) 21 Hours Exposed 0 Hours Shaded
◦ COMFORT > 20°C	◦ COMFORT > 20°C
(SHADE HELPS) 219 Hours Exposed 0 Hours Shaded	(SHADE HELPS) 70 Hours Exposed 0 Hours Shaded
◦ COOL/COLD < 20°C	◦ COOL/COLD < 20°C
(SUN NEEDED) 2114 Hours Exposed 0 Hours Shaded	(SUN NEEDED) 2203 Hours Exposed 0 Hours Shaded



WINTER COMFORT



SUMMER COMFORT



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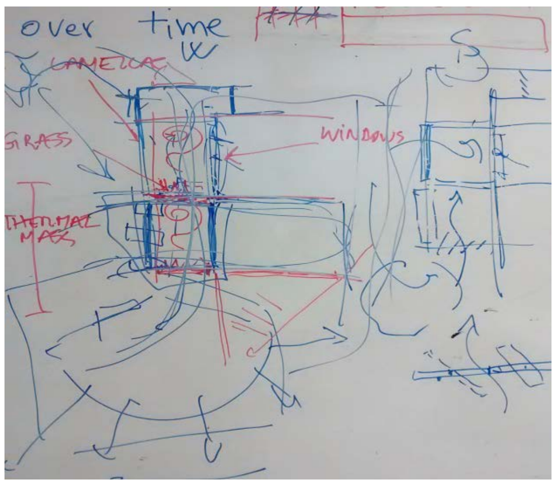
PROJECT DEVELOPMENT PROCESS

NEEDS:

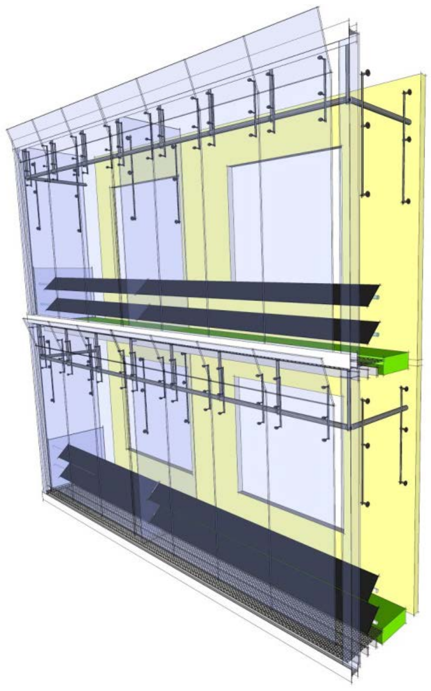
- ❑ Heating for winter
- ❑ User control
- ❑ Glare control
- ❑ No overheating in summer
- ❑ Thermal mass
- ❑ Natural ventilation
- ❑ Snow

FACADE SOLUTION:

- ❑ Heating air cavity/insulation
- ❑ Modular strategy & whole-building strategy
- ❑ Electrochromic fenestration components
- ❑ Shutters for heat control
- ❑ Concrete building structure
- ❑ Natural ventilation by user control
- ❑ Roof geometry to minimize loads

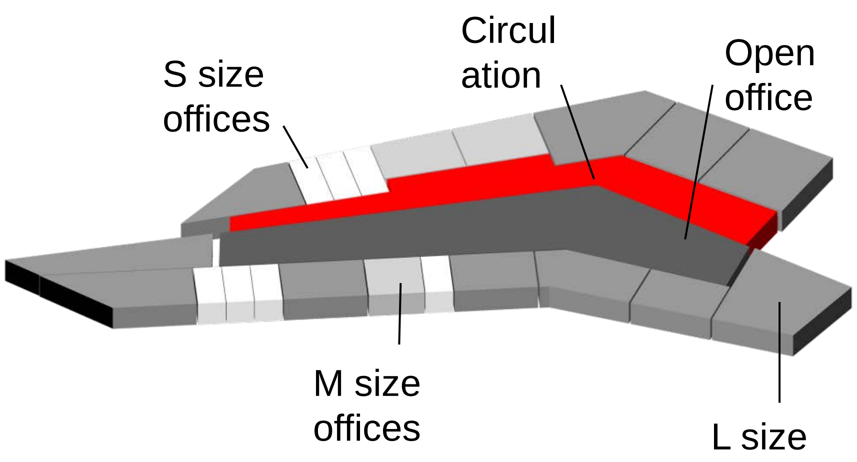


Sketches

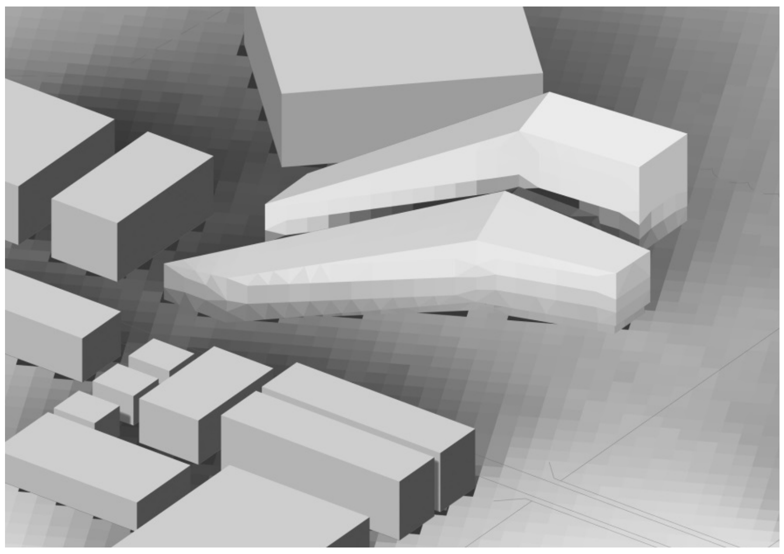


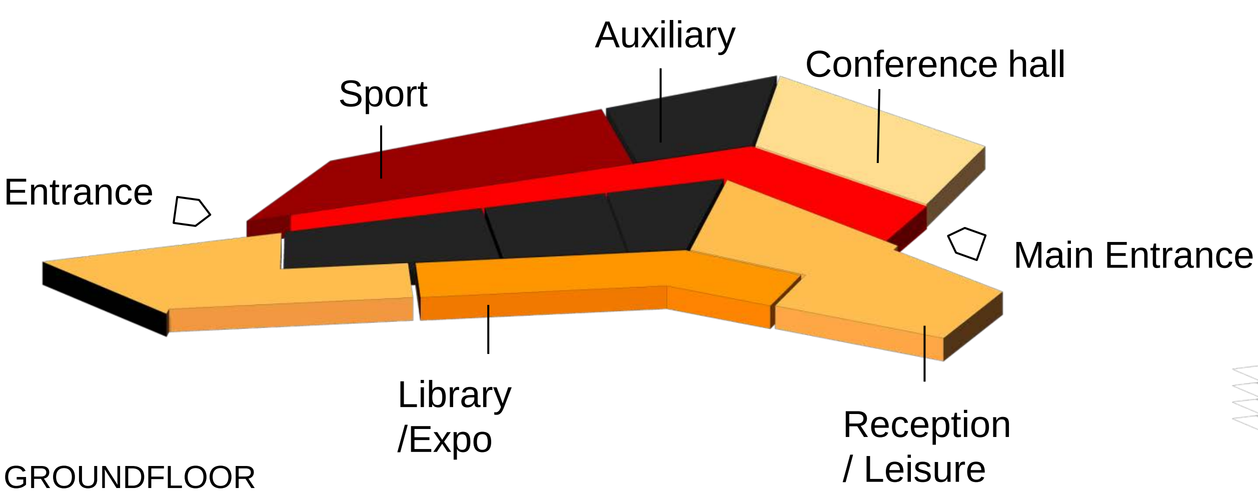
First option facade + PV panels

PLAN ORGANISATION AND FUNKTIONS

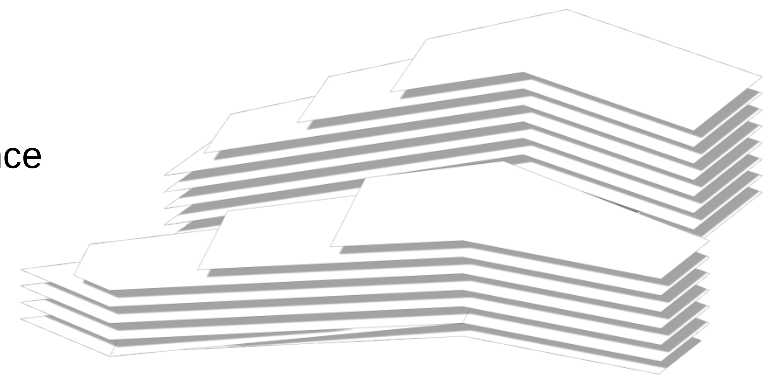


GENERAL FLOORPLAN





GROUNDFLOOR



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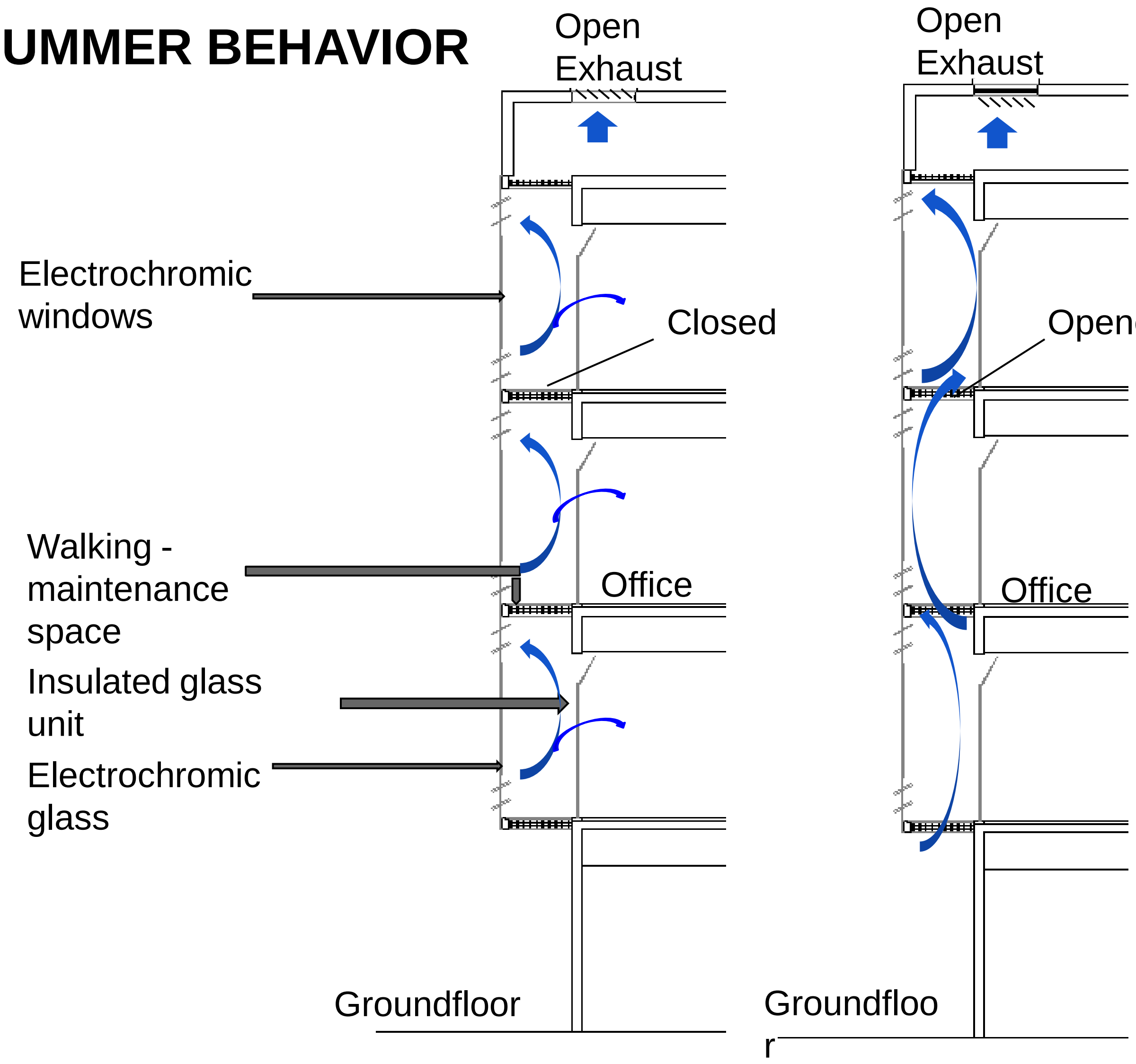
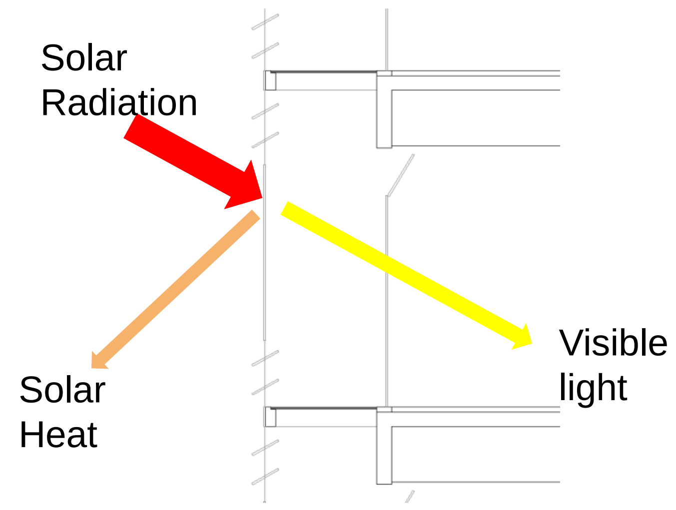
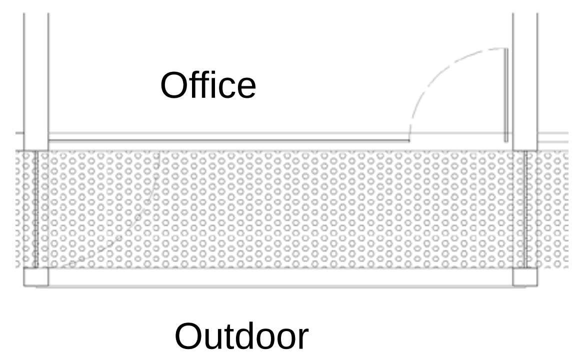
SUMMER BEHAVIOR



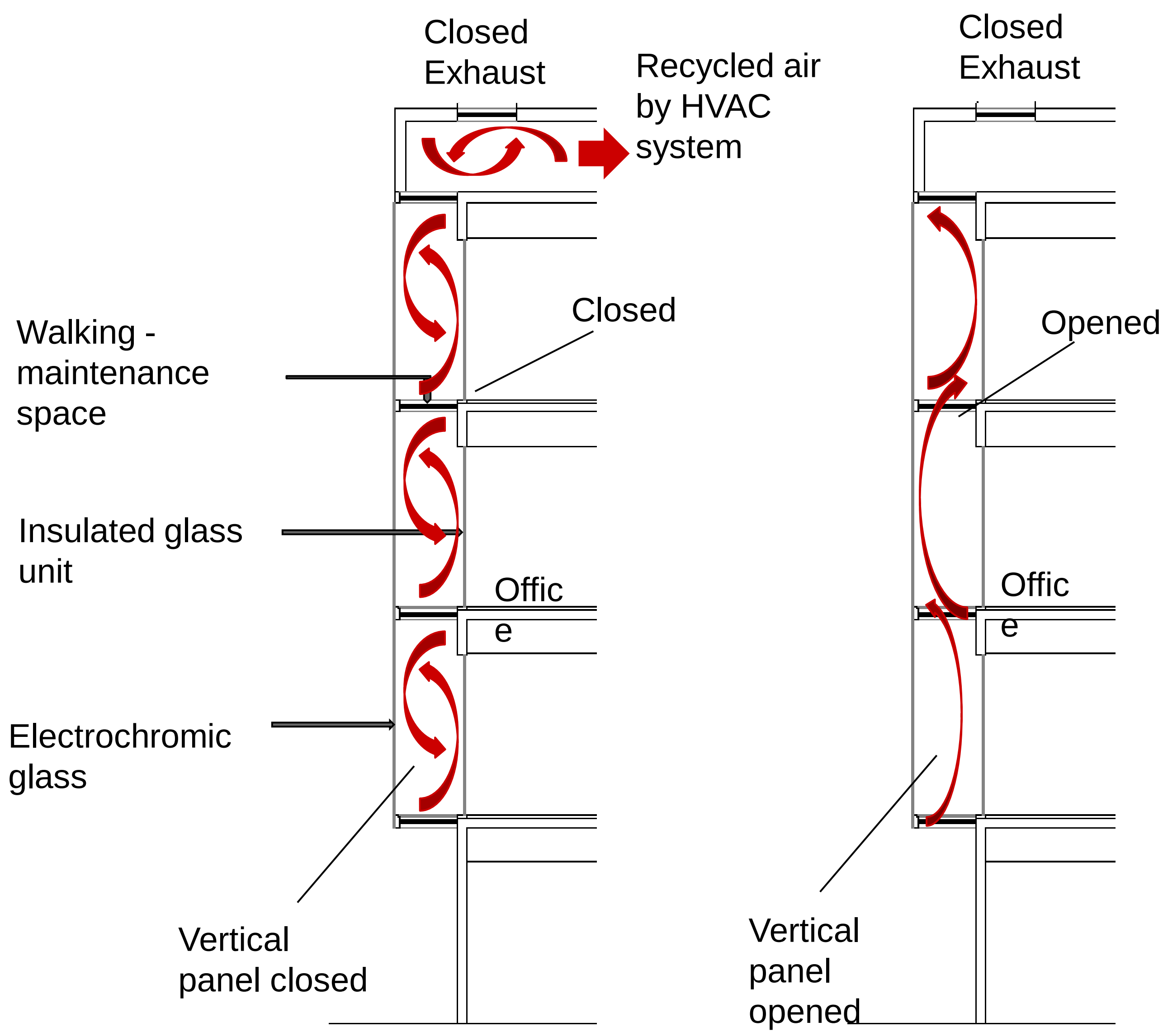
MODULAR STRATEGY

WHOLE-BUILDING STRATEGY





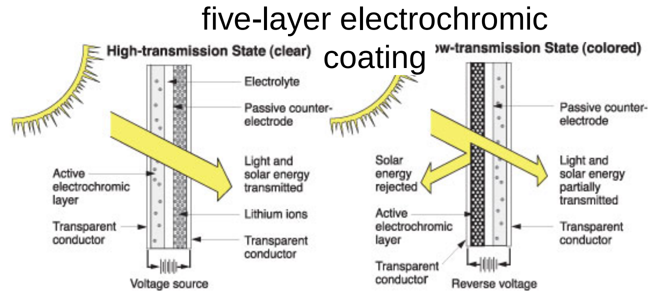
WINTER BEHAVIOR



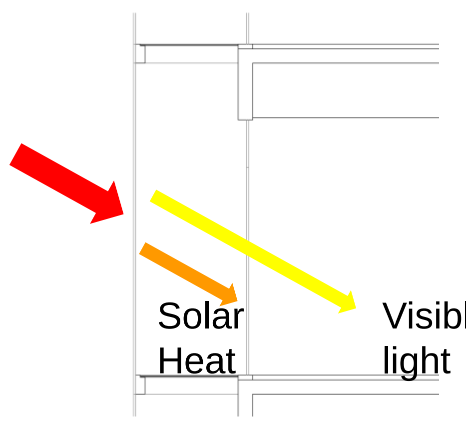
MODULAR STRATEGY

WHOLE-BUILDING STRATEGY

Schematic diagram of a five-layer electrochromic coating



Source: http://www.commercialwindows.org/electrochromic.php



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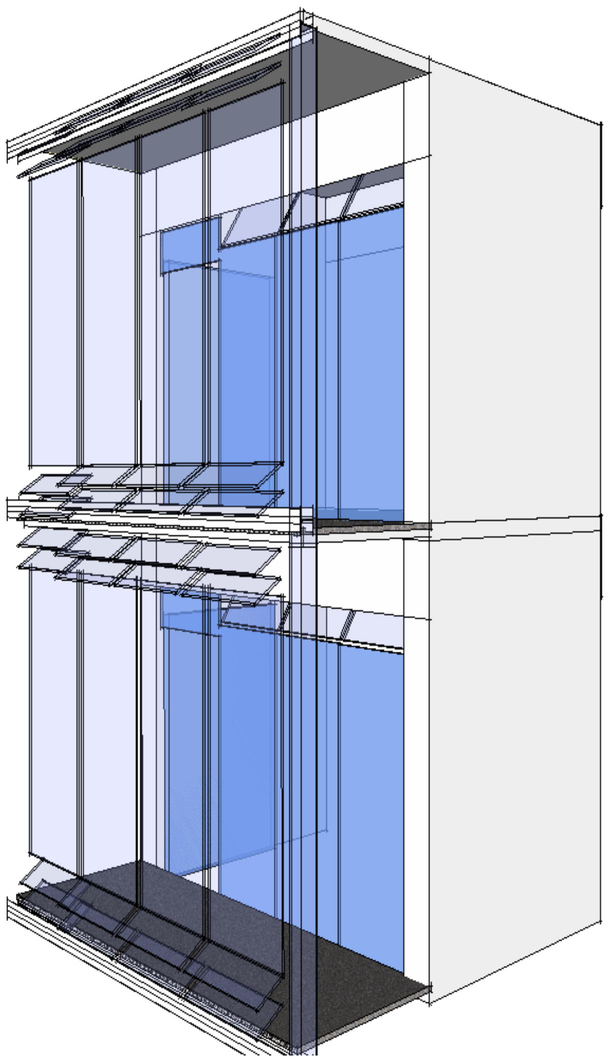
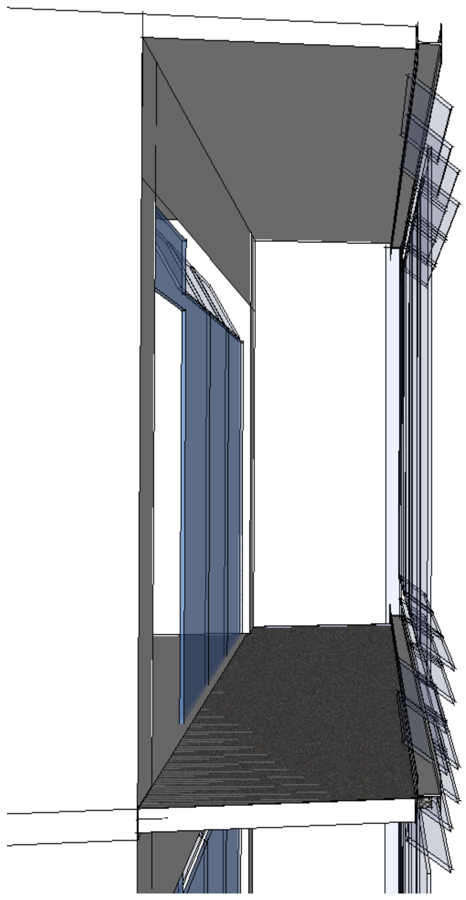
MODEL SKETCH

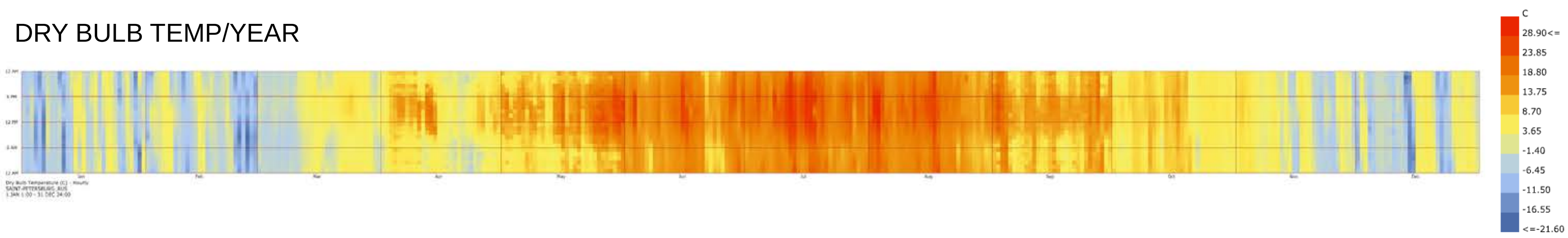




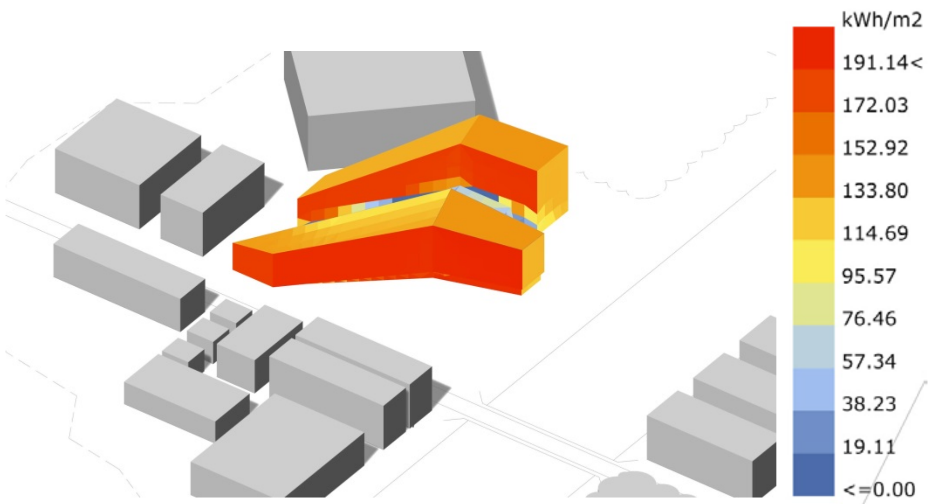
CONCLUSION

- Double skin facade is used to decrease the energy consumption and improve the insulation
- Heavy rainfall and snow makes it possible to harvest water, using it for in toilets and landscape irrigation
- Since its an office building, user comfort is prioritised with the help of user controlled climatic systems
- Architectural project enhances the external views (waterfront and greenery)
- Further steps: materials, elements size and distribution should be validated in order to guarantee the best solution
- Adaptability through the usage of glass material (visual comfort) for winter and summer situations, a multi-cellular flexible facade system oriented towards thermal comfort and indoor air quality

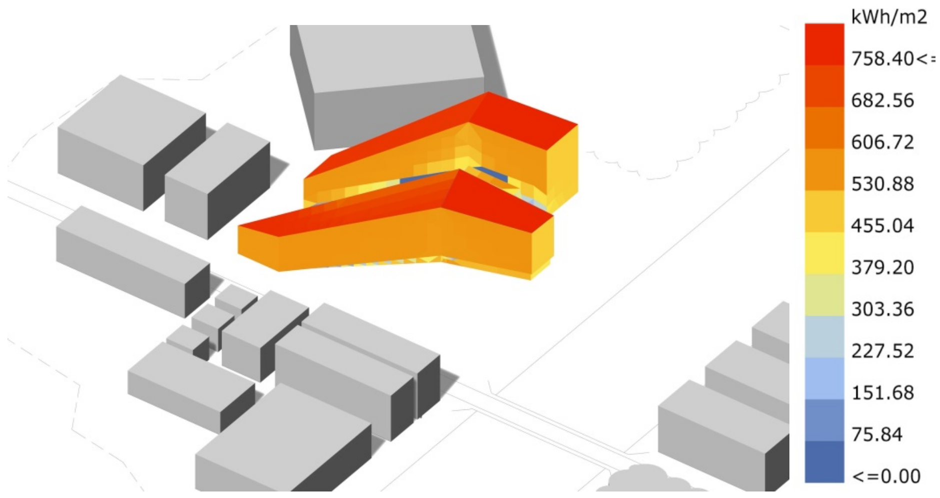
DRY BULB TEMP/YEAR



WINTER RADIATION



SUMMER RADIATION



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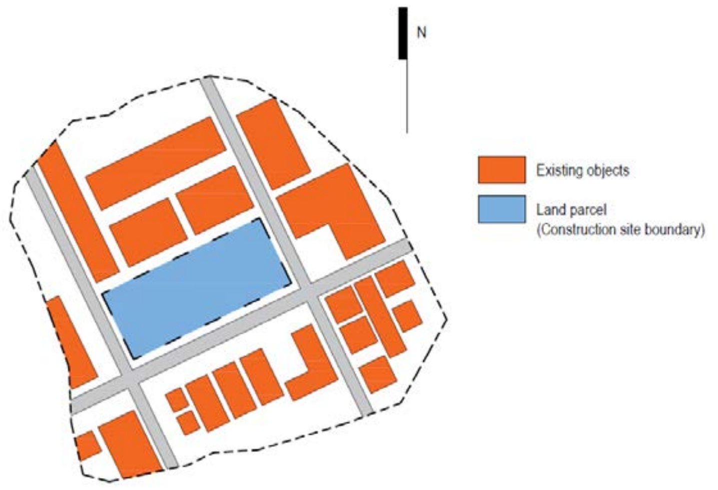
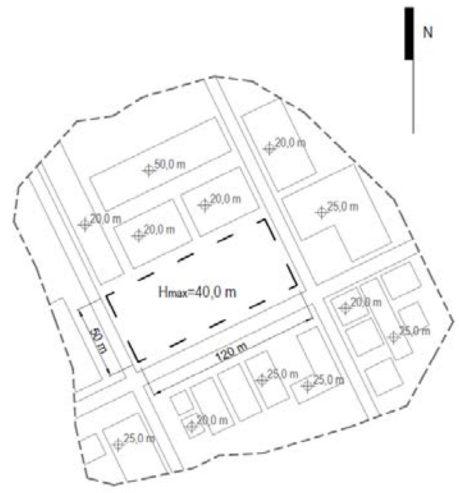
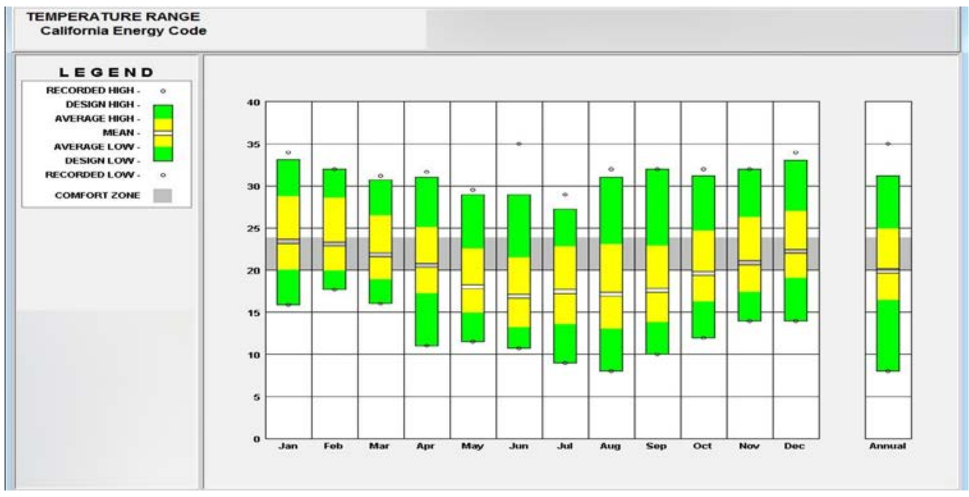
3.3. Case Study II – São Paulo

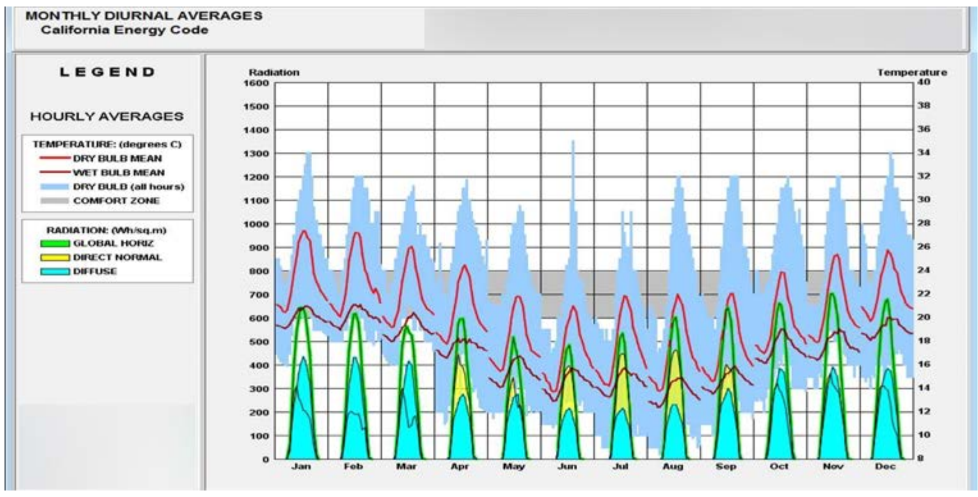
Case study 2 - São Paulo
Layout 2 + Humid subtropical climate

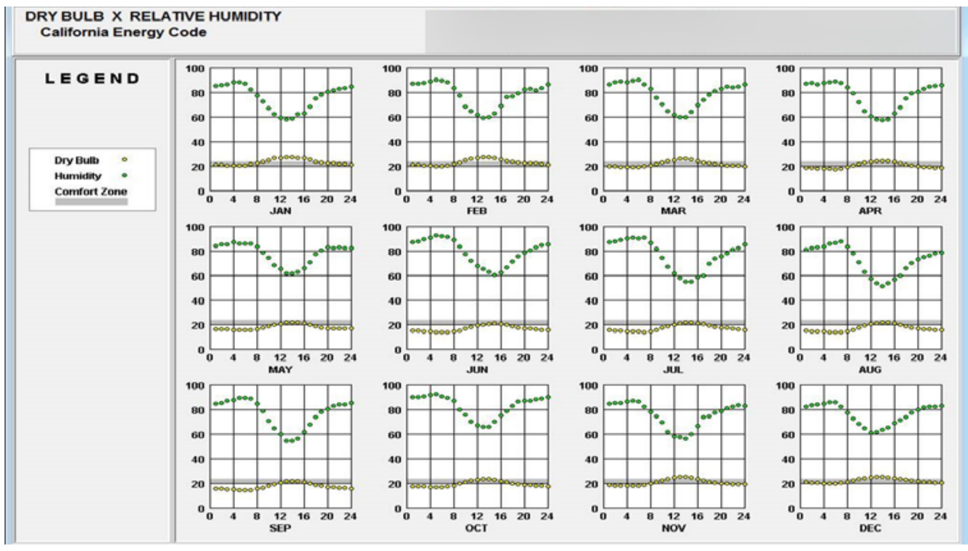
LOCATION: **SAO PAULO, -, BRA**
Latitude/Longitude: 23.62° South, 46.65° West, **Time Zone from Greenwich** -3
Data Source: IWEC Data 837800 WMO Station Number, **Elevation** 803 m

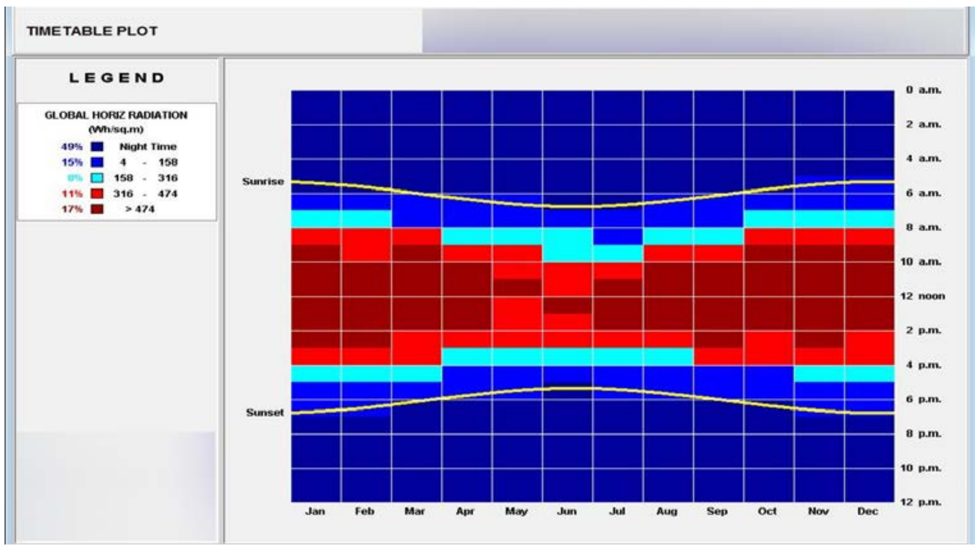












WEATHER DATA SUMMARY

MONTHLY MEANS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Global Horiz Radiation (Avg Hourly)	386	353	350	352	292	276	295	338	360	372	402	380	Wh/sq.m
Direct Normal Radiation (Avg Hourly)	170	132	156	262	196	240	259	284	241	176	221	183	Wh/sq.m
Diffuse Radiation (Avg Hourly)	256	251	241	176	174	140	142	152	185	231	229	235	Wh/sq.m
Global Horiz Radiation (Max Hourly)	1116	987	937	908	774	642	704	864	938	1040	1084	1090	Wh/sq.m
Direct Normal Radiation (Max Hourly)	986	808	890	920	871	777	792	880	907	929	981	1003	Wh/sq.m
Diffuse Radiation (Max Hourly)	608	585	458	427	370	343	364	400	472	591	594	549	Wh/sq.m
Global Horiz Radiation (Avg Daily Total)	5132	4540	4248	4038	3174	2922	3172	3803	4275	4692	5286	5107	Wh/sq.m
Direct Normal Radiation (Avg Daily Total)	2251	1706	1892	3012	2147	2540	2781	3206	2853	2231	2911	2460	Wh/sq.m
Diffuse Radiation (Avg Daily Total)	3405	3228	2932	2015	1887	1486	1522	1711	2207	2913	3017	3161	Wh/sq.m
Global Horiz Illumination (Avg Hourly)	43467	39887	39265	39099	32480	30624	32703	37281	39911	41822	44862	42720	lux
Direct Normal Illumination (Avg Hourly)	15780	12013	14274	25296	18348	22773	24790	27752	23460	16714	21256	17337	lux
Dry Bulb Temperature (Avg Monthly)	23	23	21	20	18	16	17	17	17	19	20	22	degrees C
Dew Point Temperature (Avg Monthly)	18	18	17	15	13	12	12	11	12	16	15	17	degrees C
Relative Humidity (Avg Monthly)	75	78	78	77	77	79	76	72	76	82	75	76	percent
Wind Direction (Monthly Mode)	330	120	150	150	160	150	180	180	150	150	150	130	degrees
Wind Speed (Avg Monthly)	2	1	2	2	2	1	2	2	2	2	2	3	m/s
Ground Temperature (Avg Monthly of 3 Depths)	20	21	21	21	21	19	18	18	17	17	18	19	degrees C

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average rainfall mm (inches)	237.4	221.5	160.5	72.6	71.4	50.1	43.9	39.6	70.7	126.9	145.8	200.7	1,441
	-9.346	-8.72	-6.319	-2.858	-2.811	-1.972	-1.728	-1.559	-2.783	-4.996	-5.74	-7.902	-56.73
Average rainy days (≥ 1 mm)	15	14	11	7	6	4	4	4	7	10	11	14	107

Case Study II: São Paulo – Team 4

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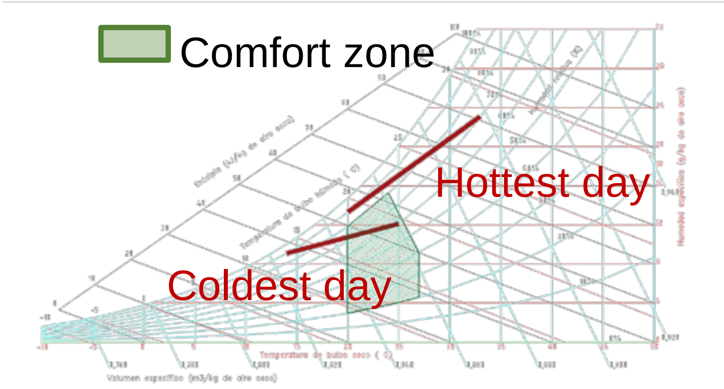
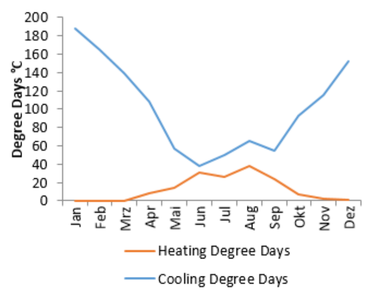
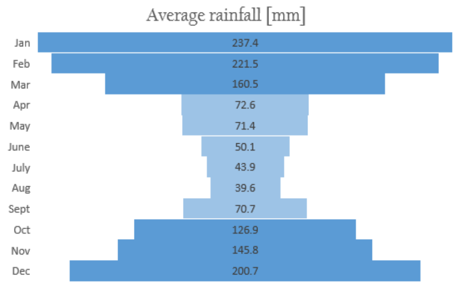
CLIMATE & CONTEXT ANALYSIS

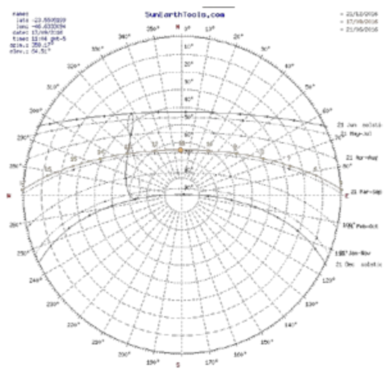
Temperature, Humidity, Rainfall

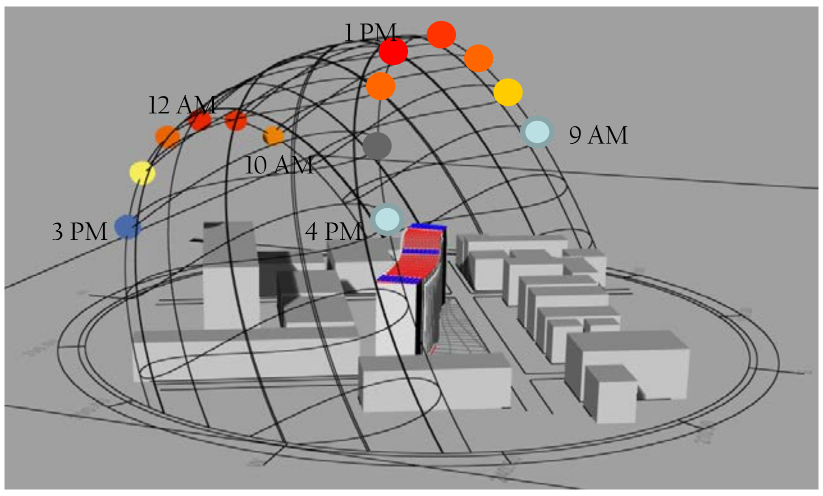






Solar radiation



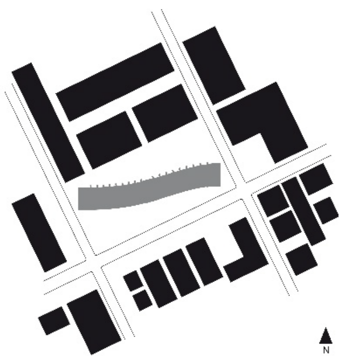


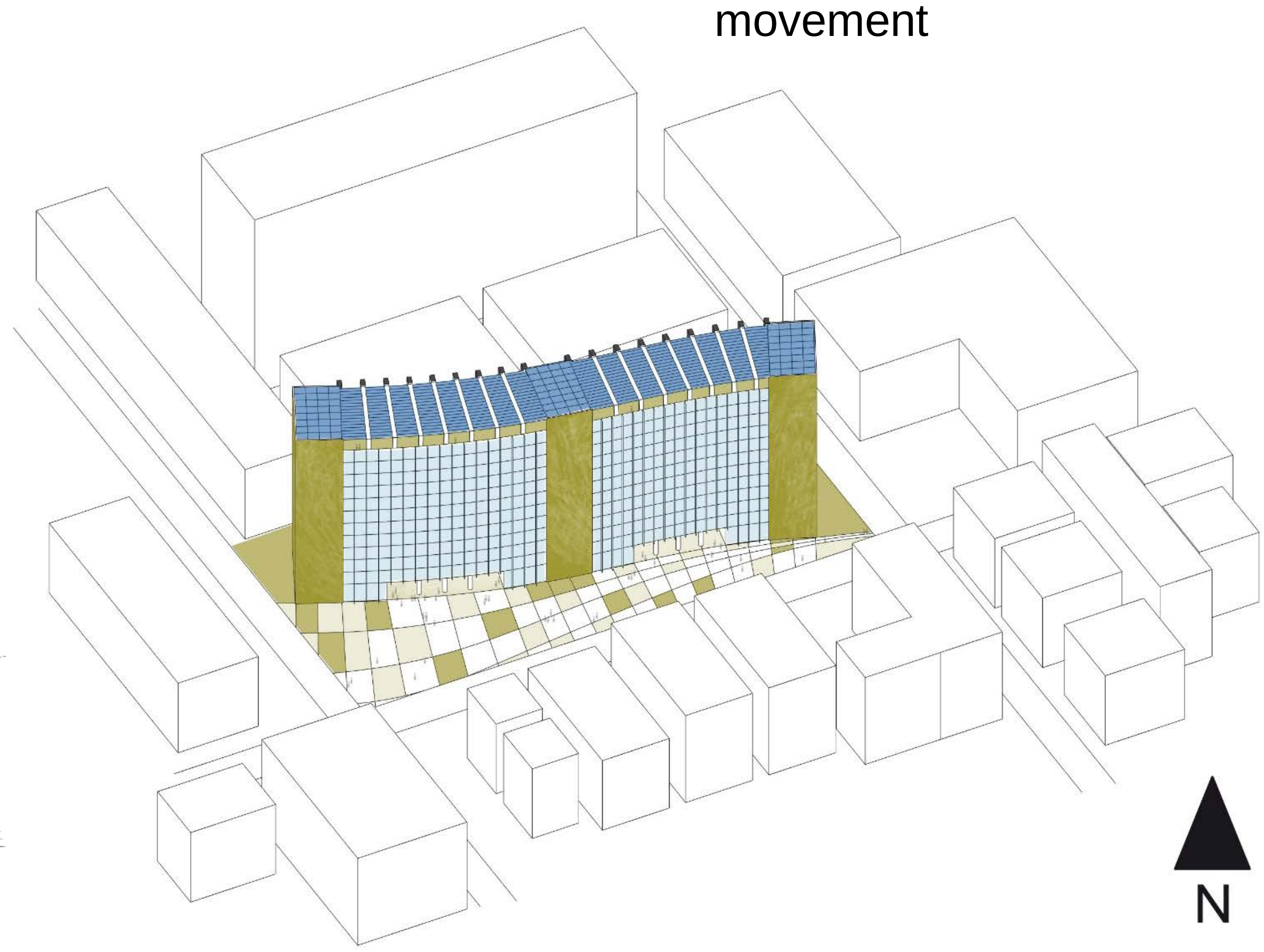
Architectural Context

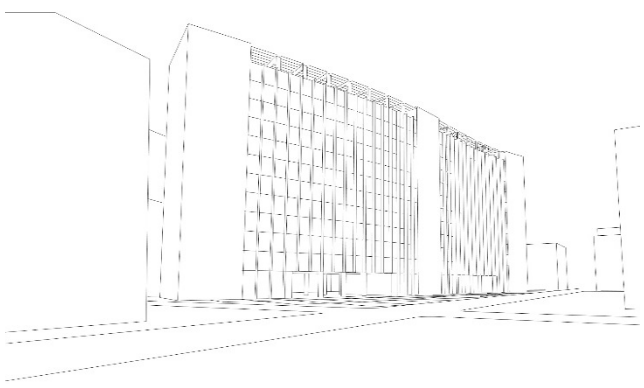
Flood problems

Concrete high

Green façade movement







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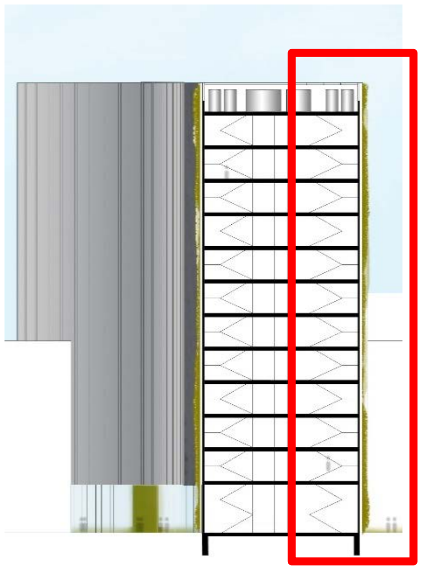
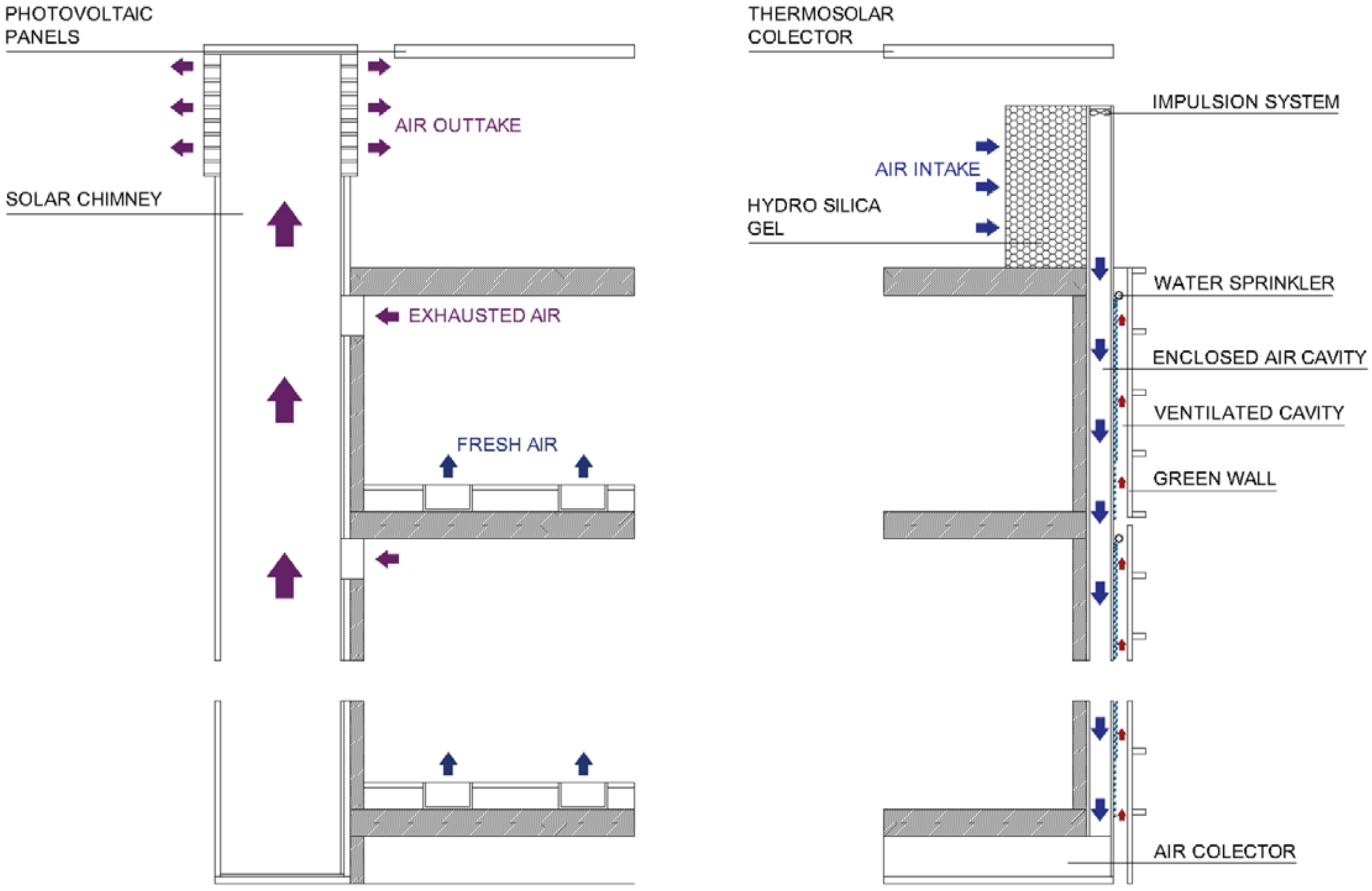
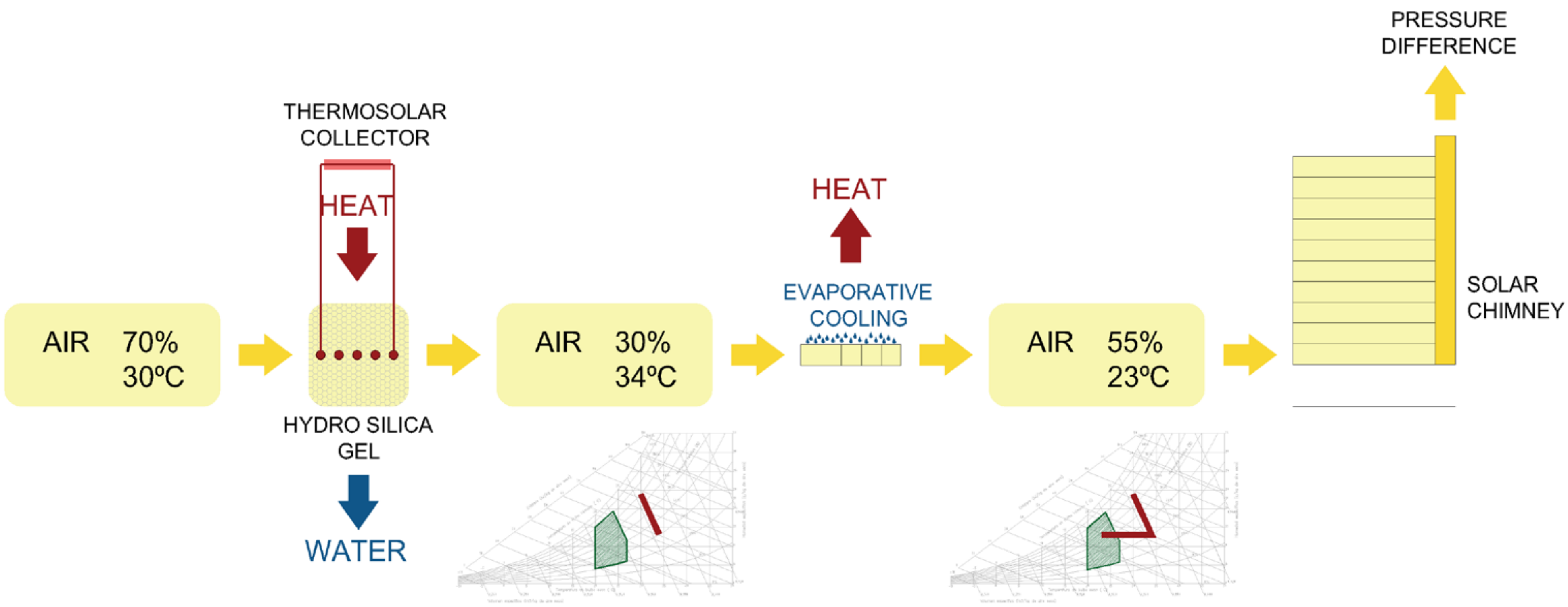
CONCEPT





OPERATING PROCESS

Silica gel's high specific surface area (around 800 m2/g) allows it to adsorb water readily, making it useful as a desiccant (drying agent).



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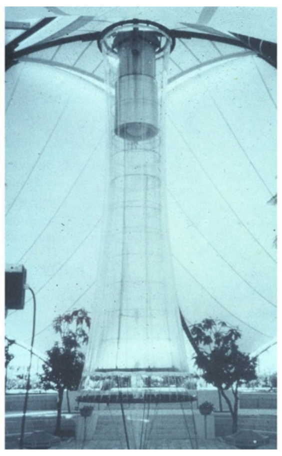
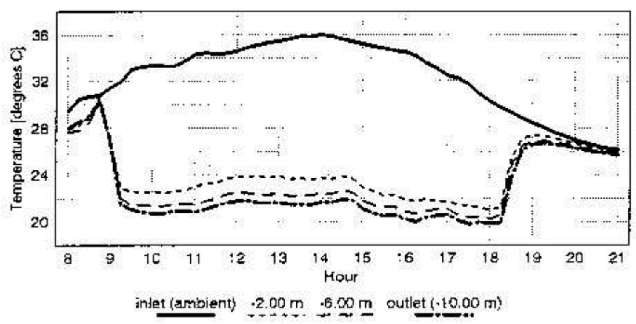
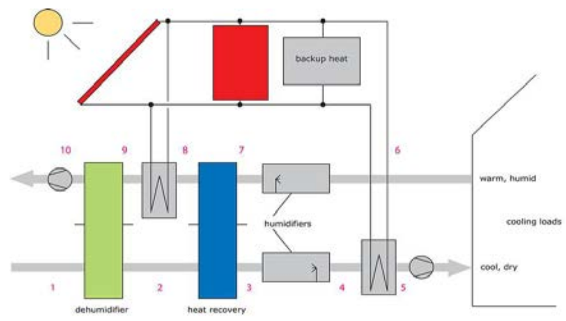
EVAPORATIVE COOLING

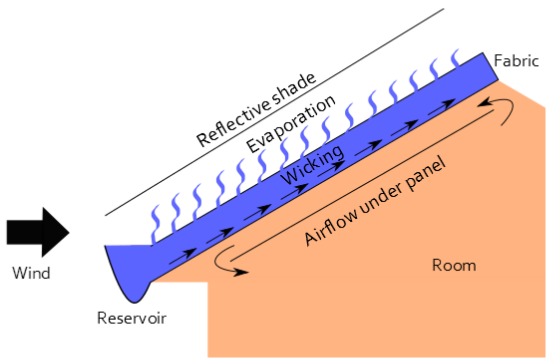
Inspiration





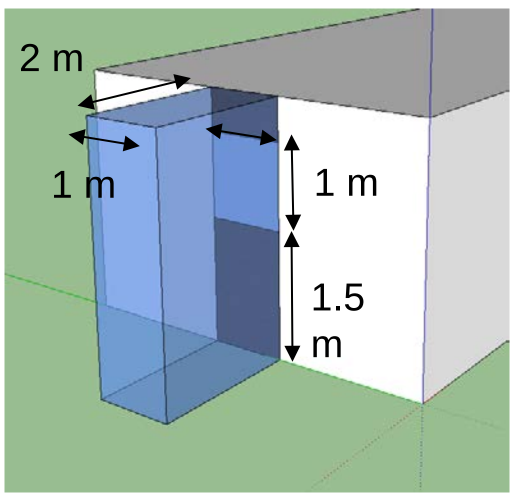


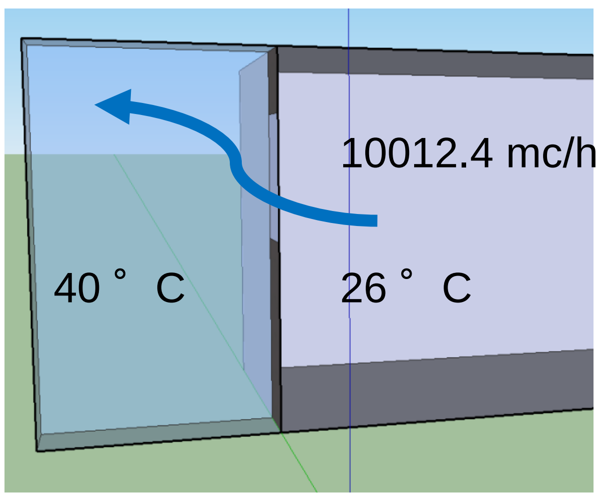
If the droplets of water had size 14 µm – the temperature dropped by 12 ° C in the first meters of the tower.
If the droplets of water had size 62 µm – the temperature dropped by 11 ° C in the whole tower length.



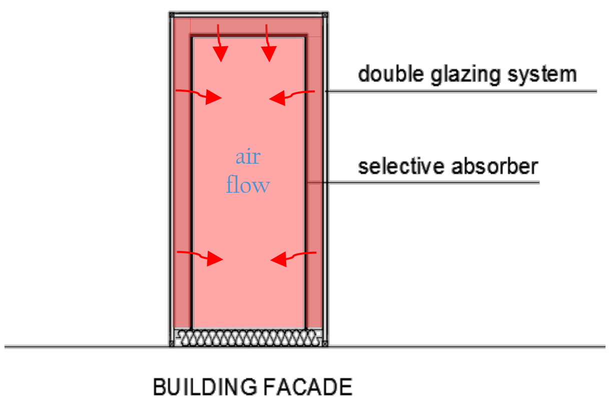
An evaporative cooler (also swamp cooler, desert cooler and wet air cooler) is a device that cools air through the evaporation of water. Evaporative cooling works by employing water's large enthalpy of vaporization.

SOLAR CHIMNEY

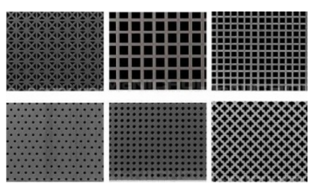




Neeed air flow rate/floor: 10800 m^3/h
Natural air flow rate/floor: 10012.4 m^3/h



Selective absorber:
perforated steel plate with solar absorber coatings



usage:	office building
flow rate/pers:	36 m^3/h pers
crowd:	0.2 p/sqm
people/floor:	300 people/floor
flow rate/floor:	10800 m^3/h
floor area:	1500 sqm/floor
floor volume:	4500 m^3
n.air change/h:	2.4 h^{-1}
n. storey:	11
speed velocity:	0.05–0.2 m/s

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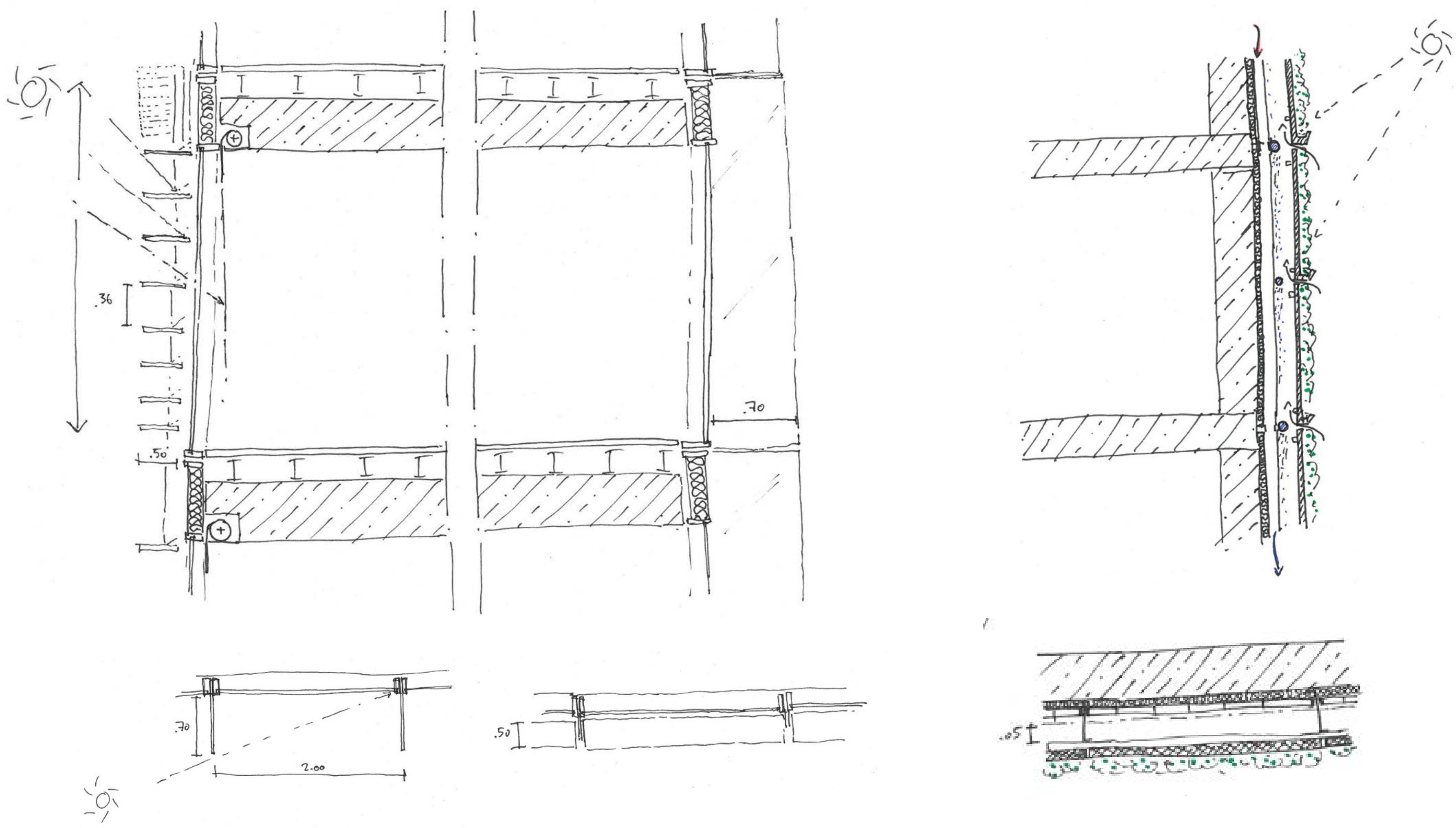
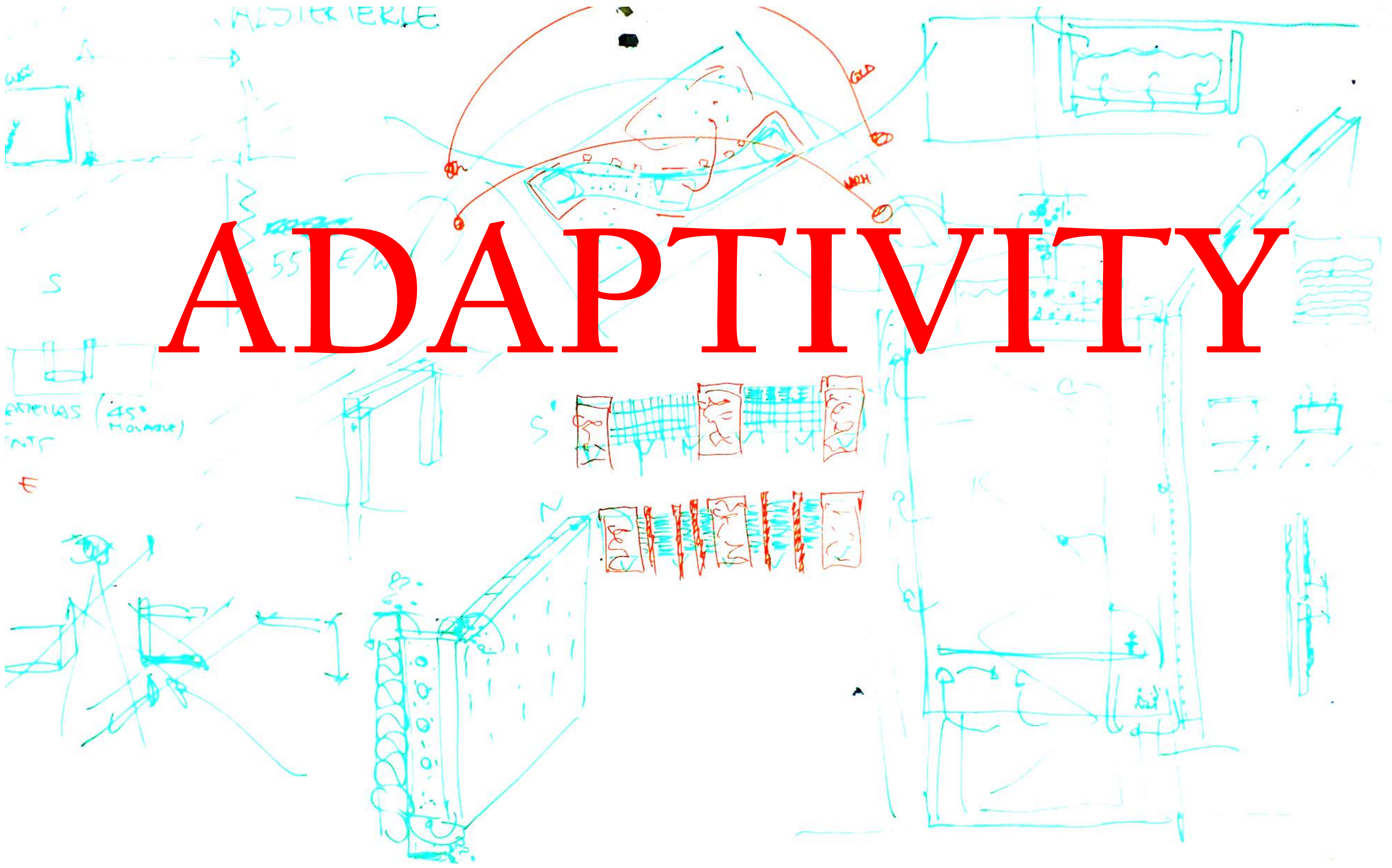
SOLAR CHIMNEY





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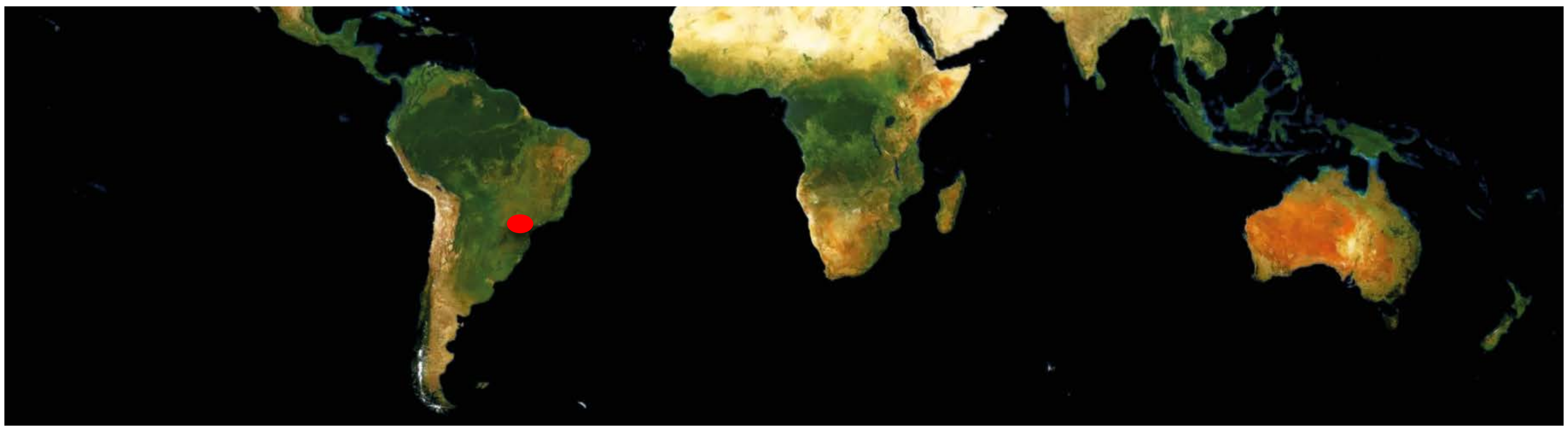
HYGRO

OPORTUNITIES	PROBLEMS	PURPOSES
high Solar Radiation	high Solar Radiation	Product energy
high average rainy days (173 days/year)	high pollution (natural ventilation)	Purify the air
	Humidity	Dehumidify
		Reuse of rain water



TECHNOLOGY PROPOSAL

BACTERIAL SPORES → humidity

T_iO_2

PLANTS → air quality

RAIN WATER → irrigation and cooling

PVM SOLAR PANEL → energy production

Solar radiation

Humidity

Pollution

Design concept

Case Study II: São Paulo – Team 6

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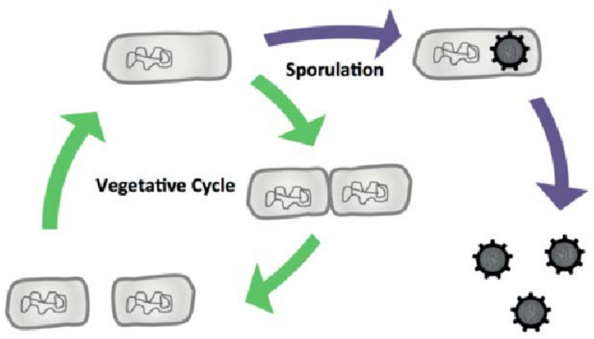
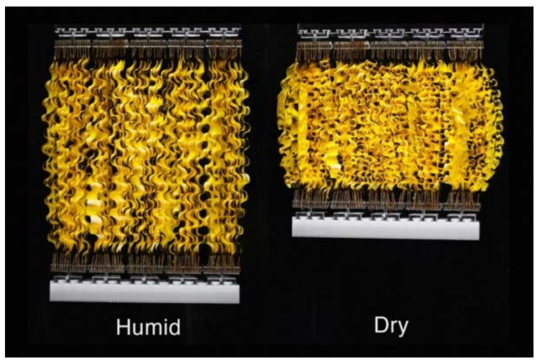
BACTERIAL SPORES_*BACILLUS*

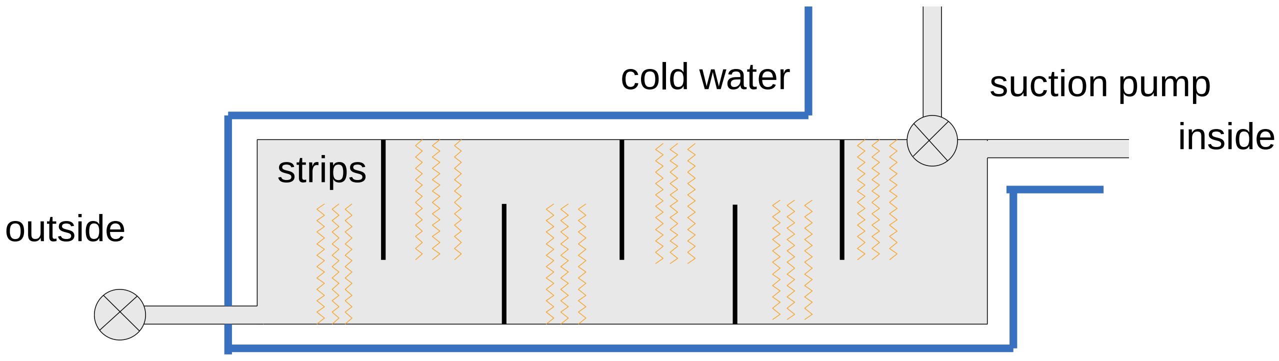
Spore formation (Sporulation) is a method for bacterias to survive under ***unfavorable conditions***
(es: lack of nutrients)



As ***hygroscopic material*** they respond to change in RH by expanding / shrinking anisotropically changing volume by 12%



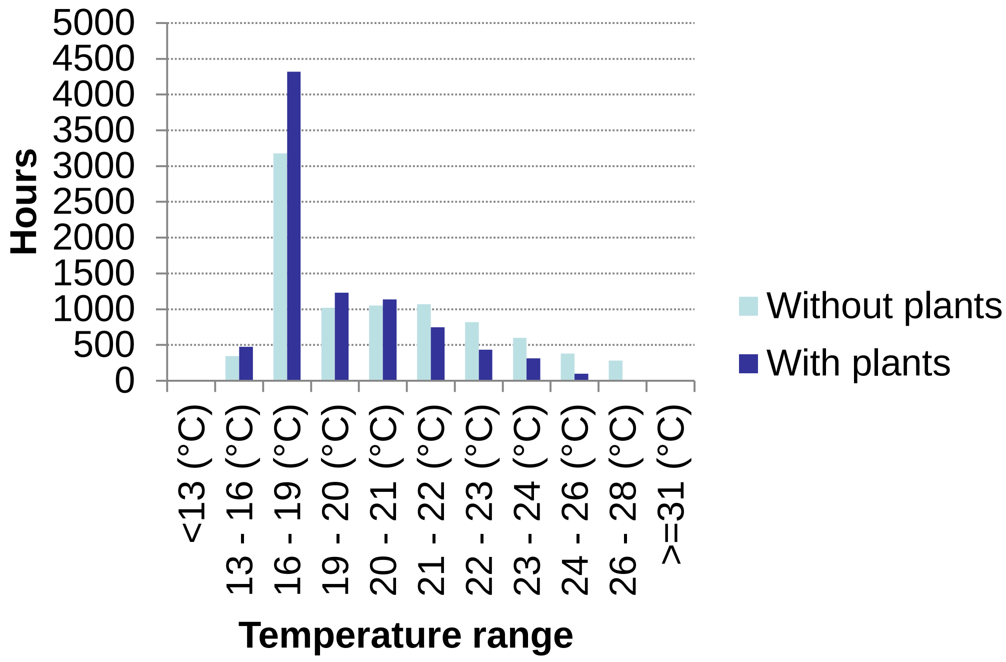
https://www.google.com/patents/US9234508

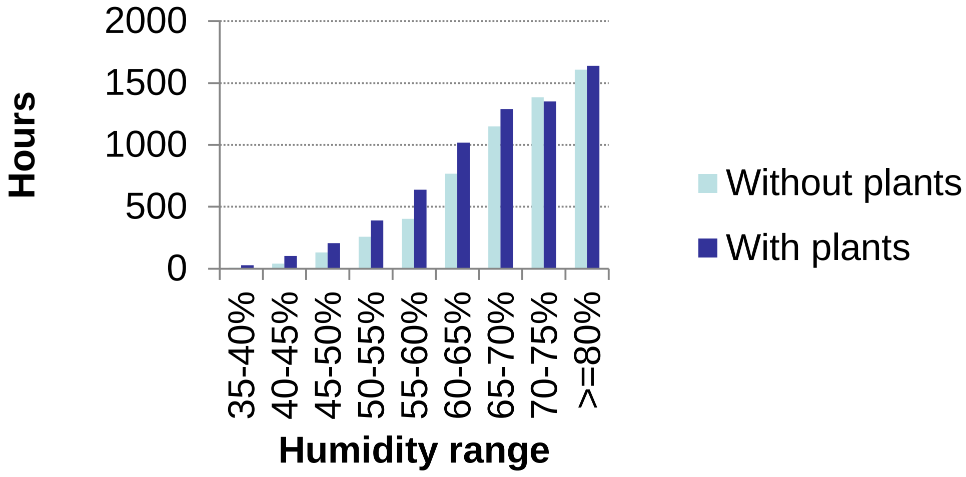


TYPICAL PLANTS

CAETANO, FERNANDO D. N.,
Influence of living walls on the thermal performance of buildings. 2014**.**

Humidity influence in North and West facades between 2% to 5%. Similar results you can find in Boa Sorte, Pedro D. 2016 and ALMEIDA, Marco A. M. 2008





Trandescatia spathacea

Arachis repens

Evolvulus glomeratus

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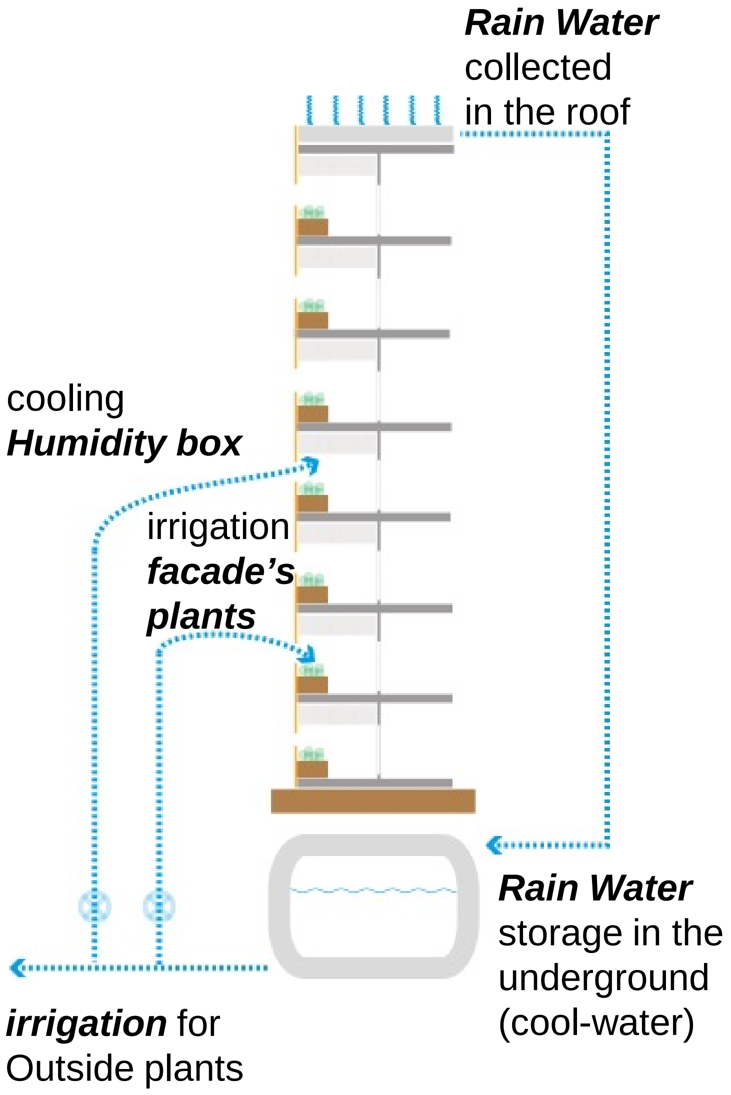
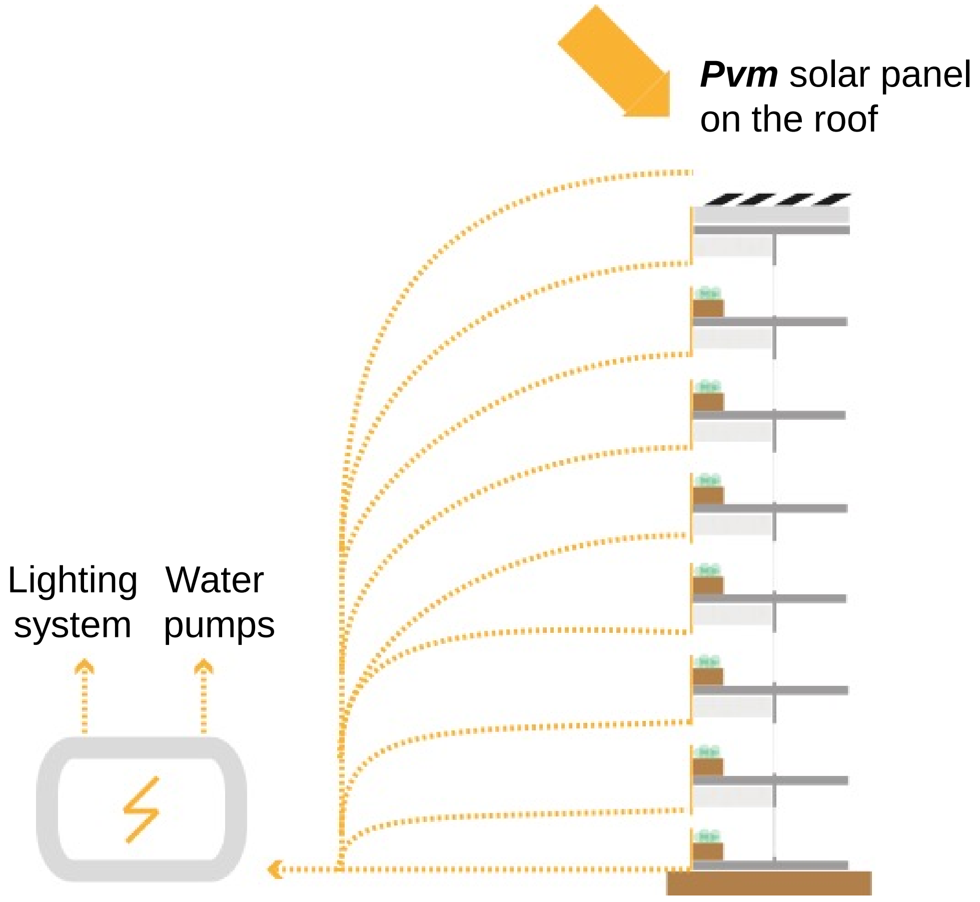
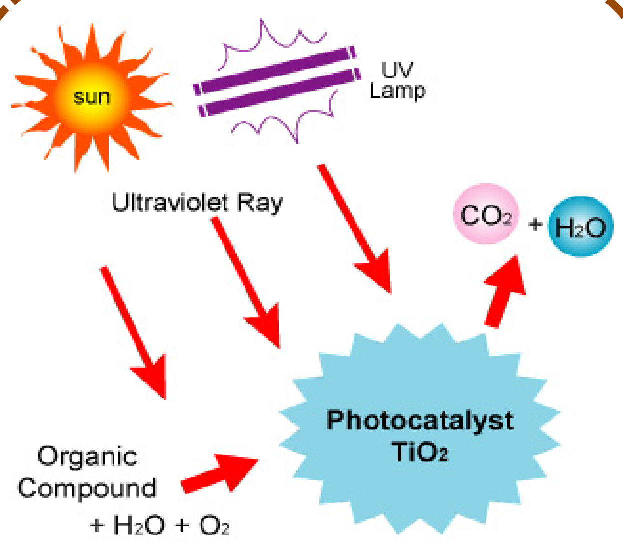
RAIN WATER



Energy production

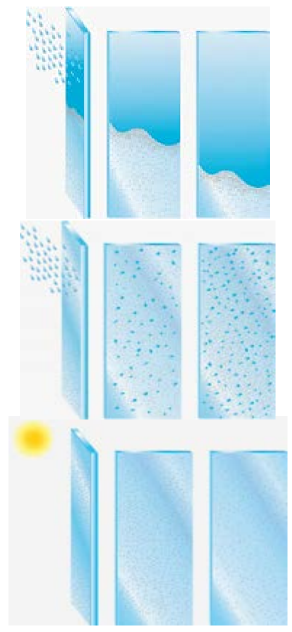


DEPOLLUTION WITH TITANIUM DIOXIDE (*TIO_2*) COATED GLASSES



Source: http://www.daybreakdogs.co.uk

With the energy of the sun (UV), NO_x and VOC can be decomposed



Source: Smart Materials, Axel Ritter

Glasses coated with the nanoparticles of TiO_2 will also benefit of an self-cleaning effect

Around 50% of the NOx and 70% of the Volatile Organic Compound (VOC) are decomposed

All the panels (except 50% of the northern facade) would be coated with TiO2 as well as all the windows. All of this represents more than 8500m² . According on the weather conditions, this surface would have the capacity to eliminate more than 16 000m³ of each VOC per hour

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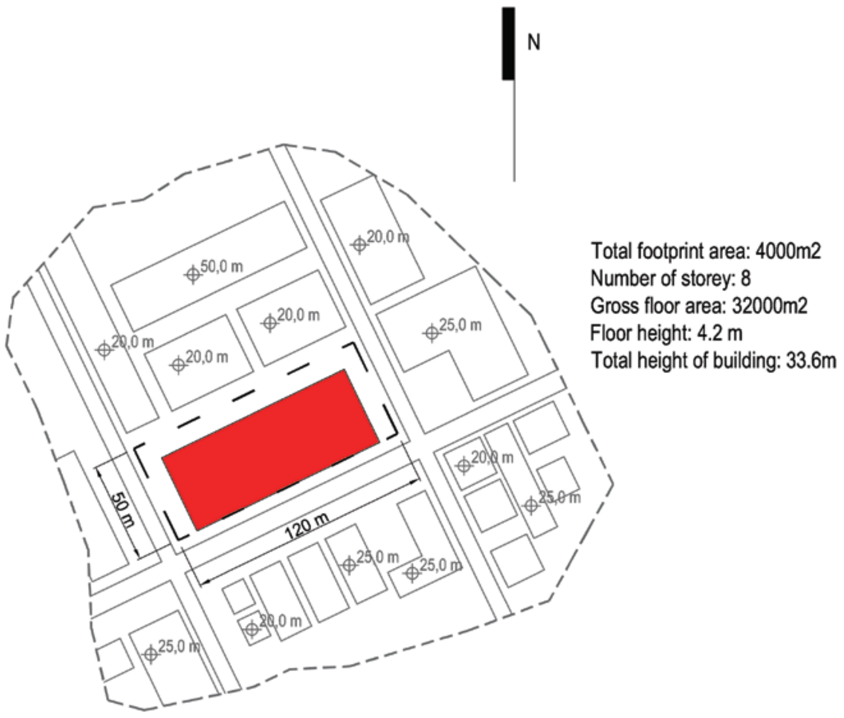

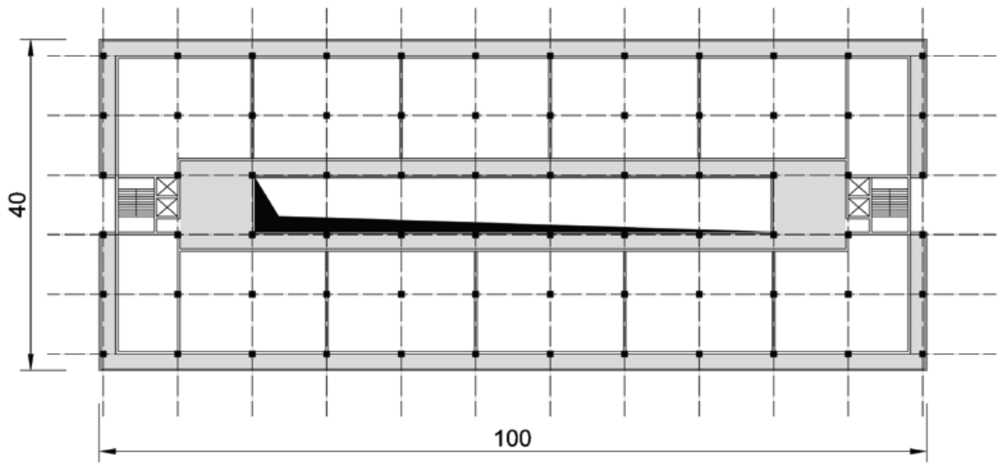

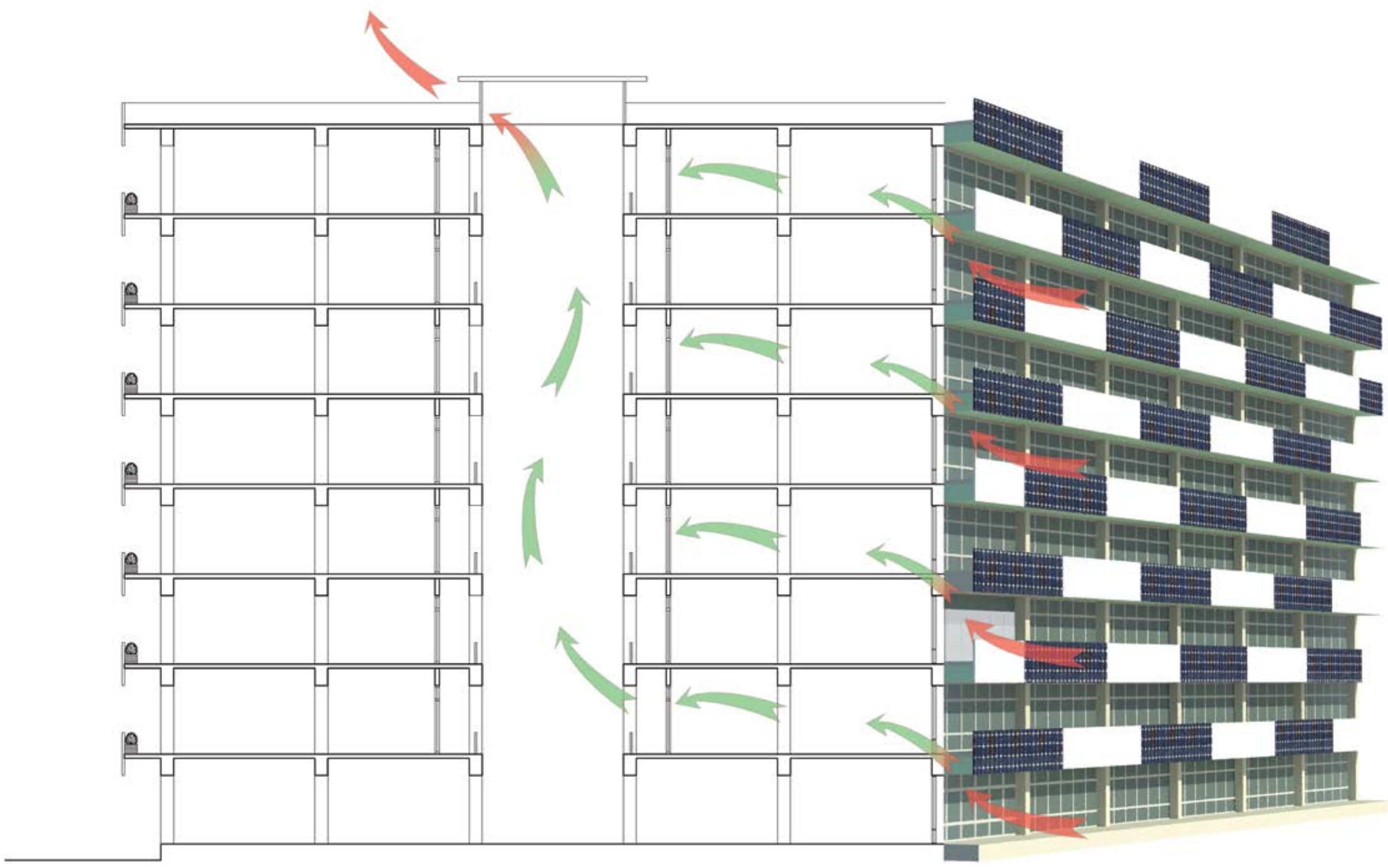

Case Study II: São Paulo – Team 8

Aleksandra Milkova, Bader Alatawneh, Fernando Martin-Consuegra, Giuseppe De Michele, Liugi Giovannini, Yvonne Wattez

LOCATION

CLIMATE

Humid subtropical climate

Lat/Long: 23.6 N / 46.7º E
Elevation 760 m

Climate problem

The main stresses of this climate are:

- high humidity level
- temperature
- intensive solar radiation
- 4 seasons in one day: variation of sky cover, wind and temperature within the day

Other sustainability aspects:

Natural lightning, glare and visual comfort
Water collection

Case Study II: São Paulo – Team 8

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LESS ENEGRY CONSUMPTION

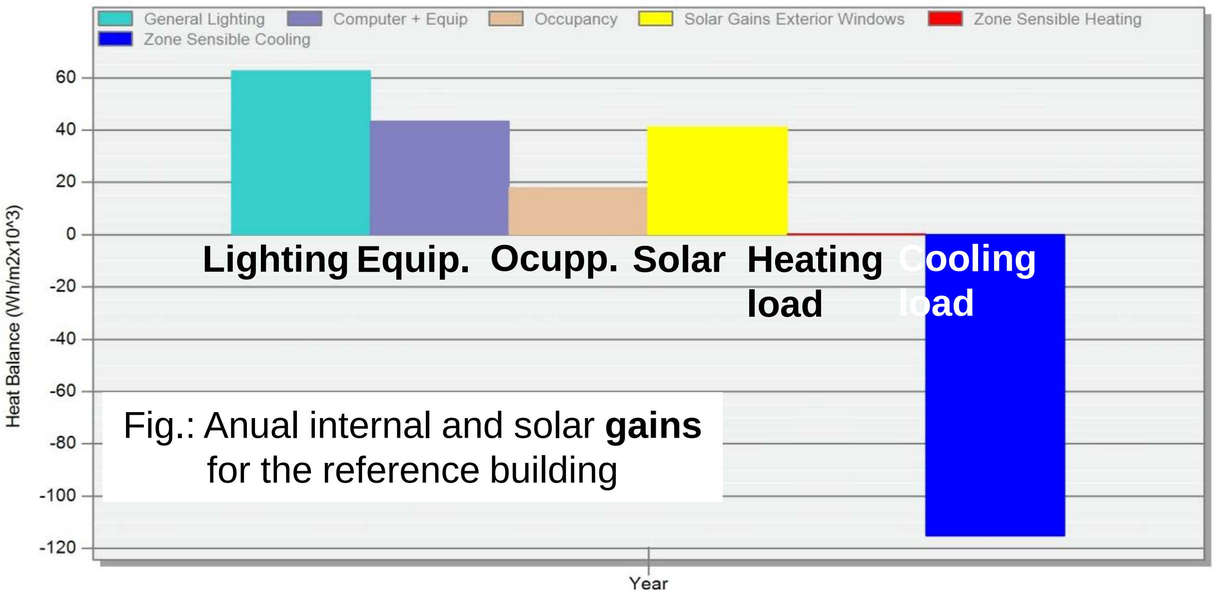
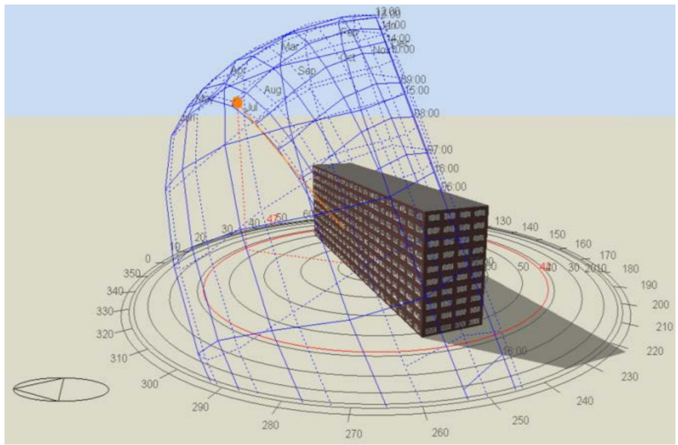


Fig.: Anual internal and solar **gains** for the reference building



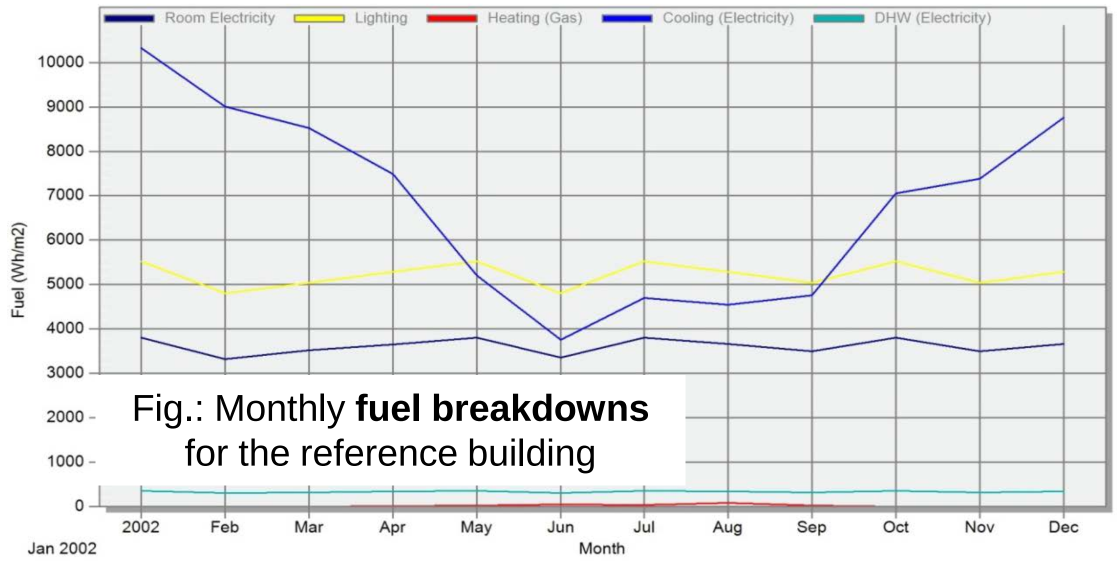


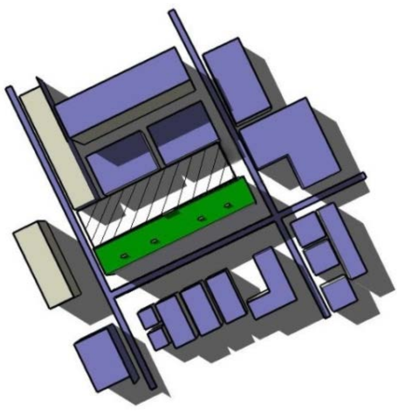
Fig.: Monthly **fuel breakdowns** for the reference building

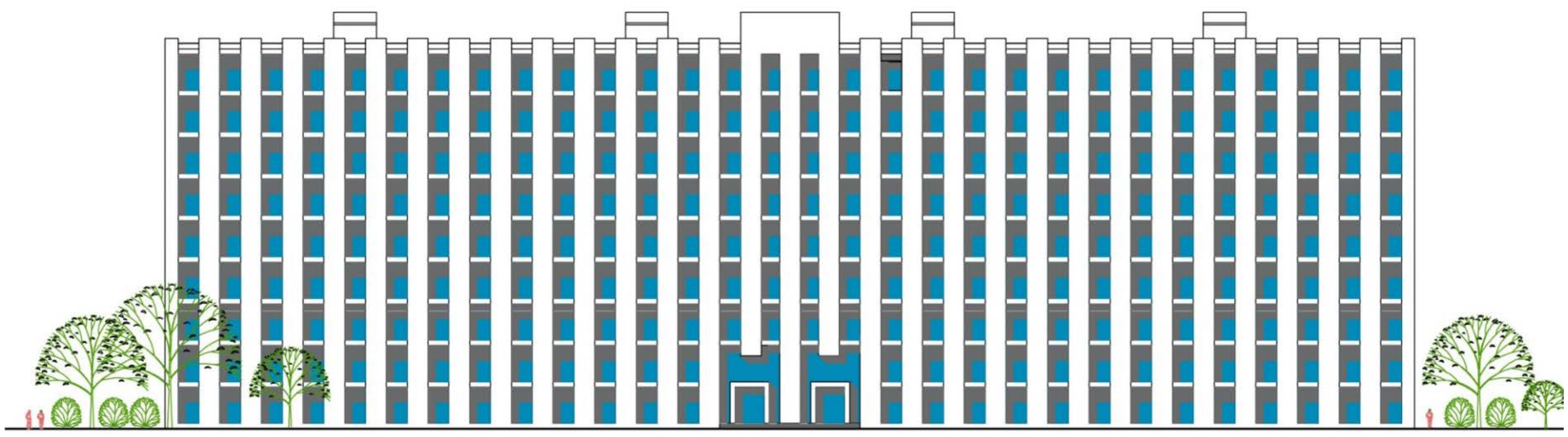
Objectives

Humidity reduces cooling via evaporation as the air is already saturated, so by ventilating a space, the saturated air is removed.

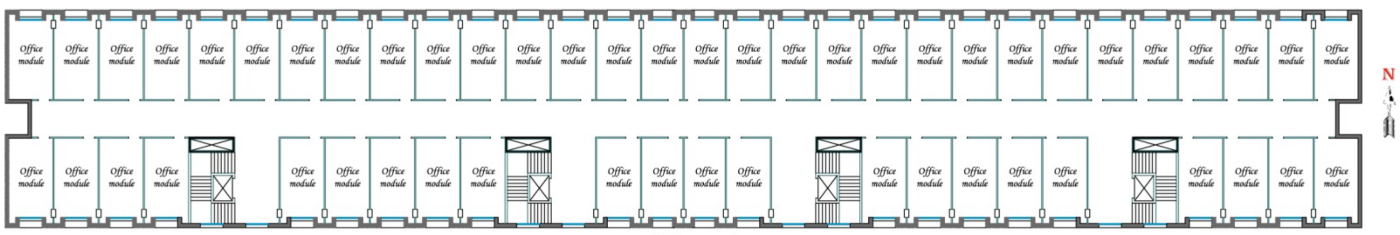
1. Natural ventilation
2. Natural lighting
3. Solar shading

DRAWINGS





North Facade



Building Plan

EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

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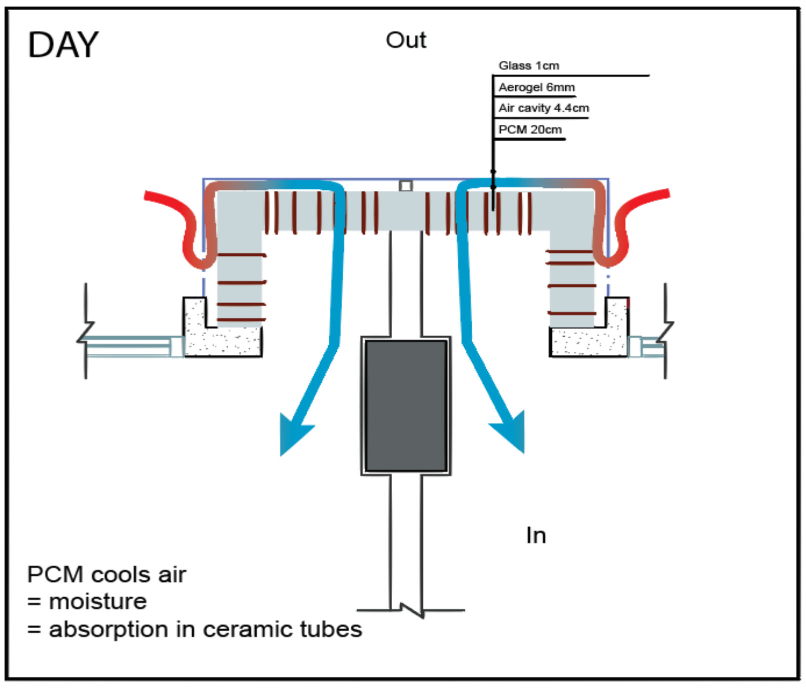
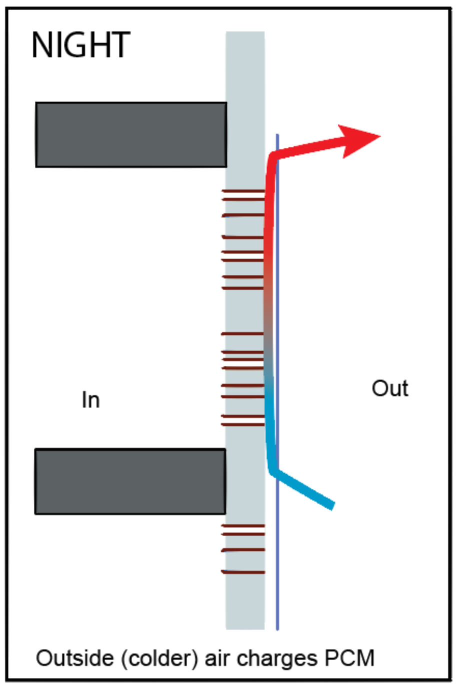
CAPES

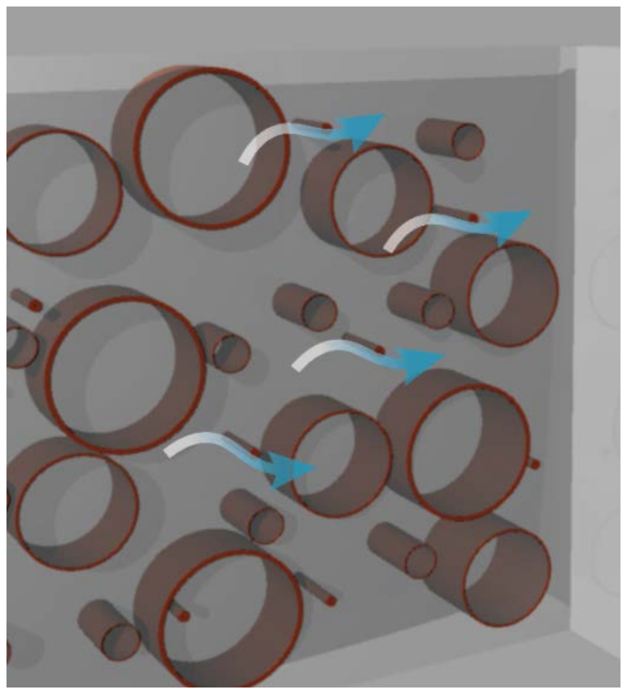
Aleksandra Milkova, Bader Alatawneh, Fernando Martin-Consuegra, Giuseppe De Michele, Liugi Giovannini, Yvonne Wattez

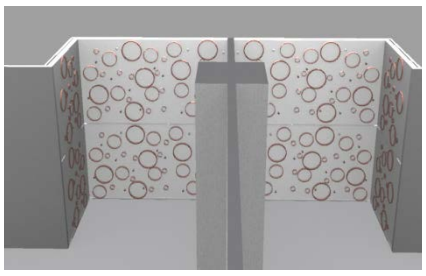
VENTILATION & HUMIDIFICATION

Outside: 80% RH → Goal inside: 50% RH
Dehumidify 3,2 litres per office per day (ventilation for 3 persons)
Absorption by ceramic: 30 tubes of 6 cm diameter per office

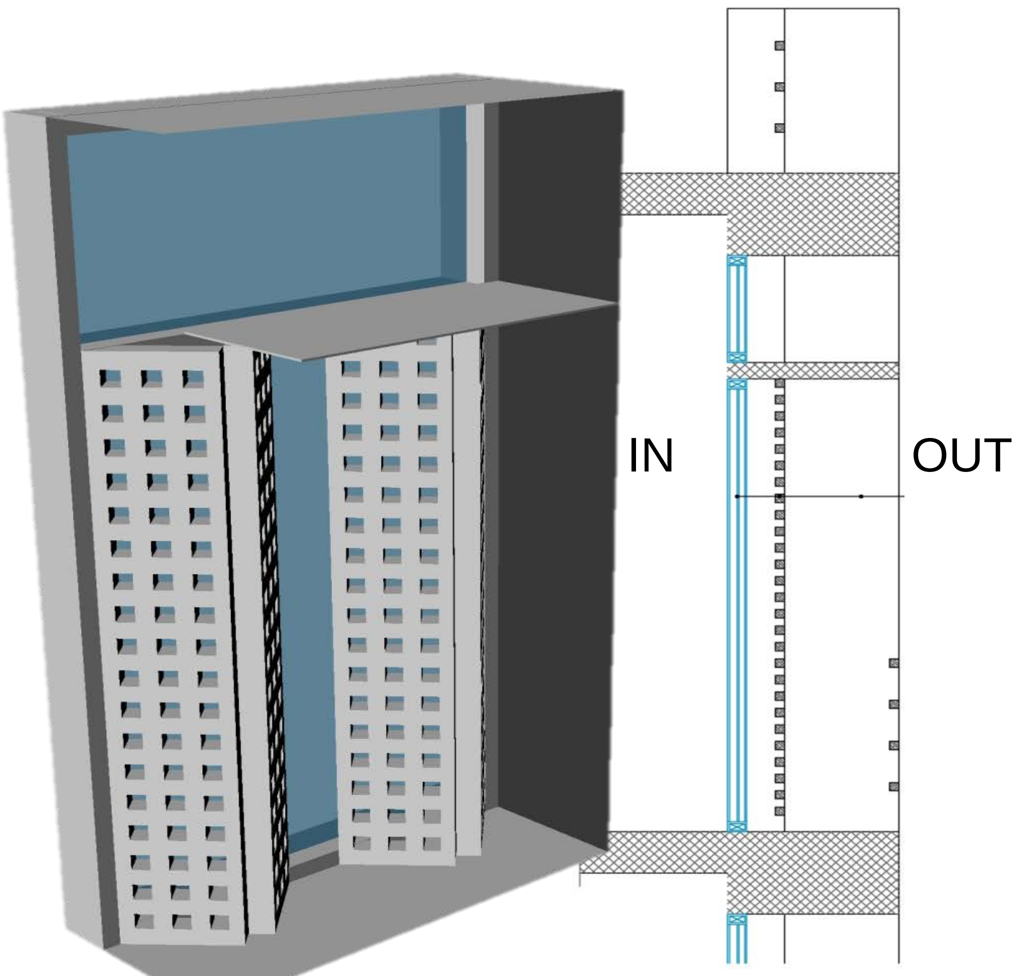




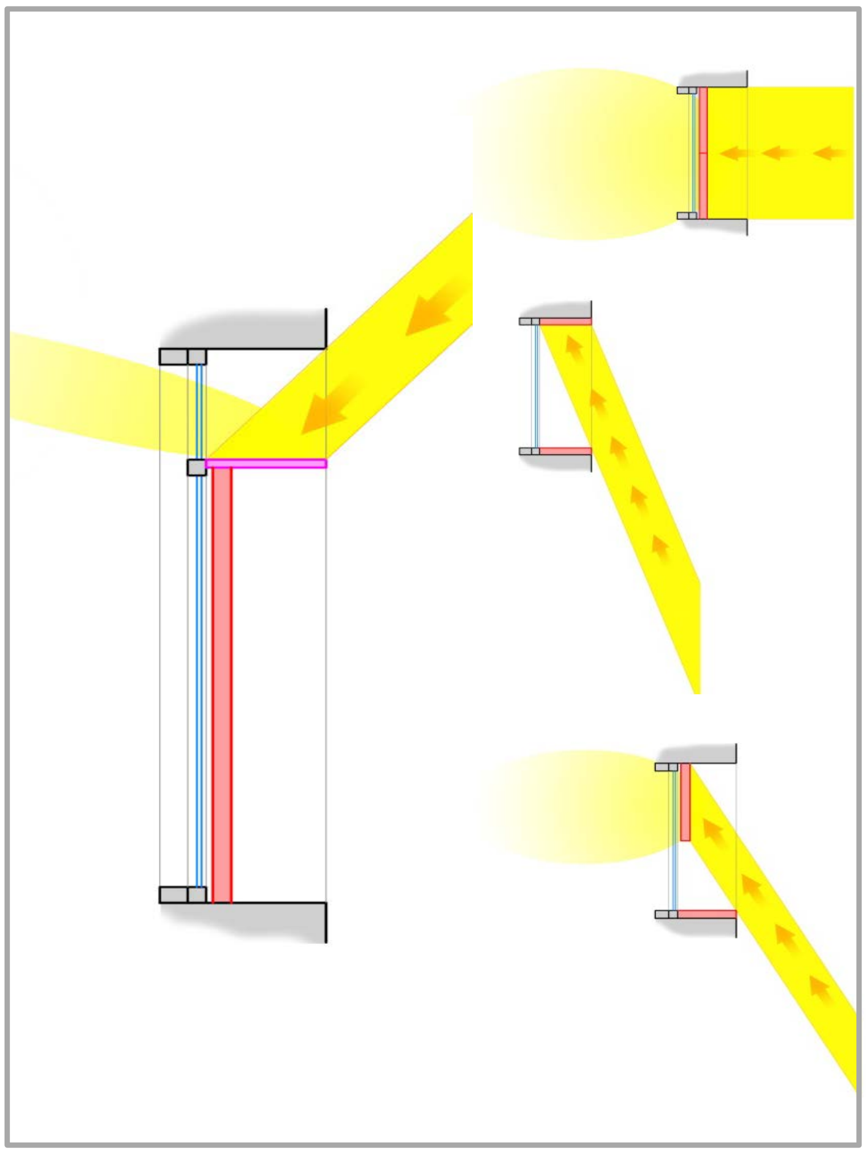




SOLAR RADIATION

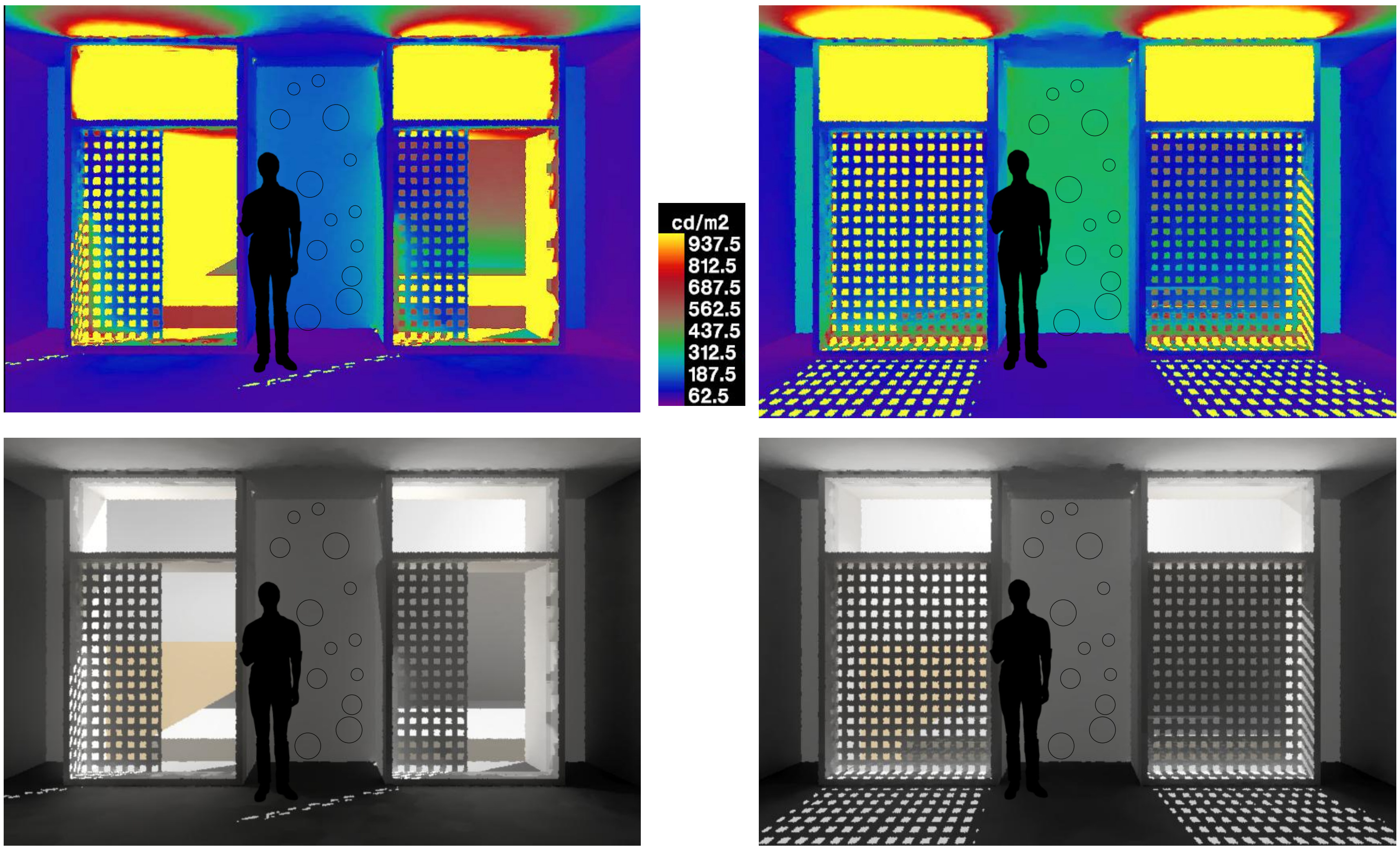


Section A-A



Aleksandra Milkova, Bader Alatawneh, Fernando Martin-Consuegra, Giuseppe De Michele, Liugi Giovannini, Yvonne Wattez

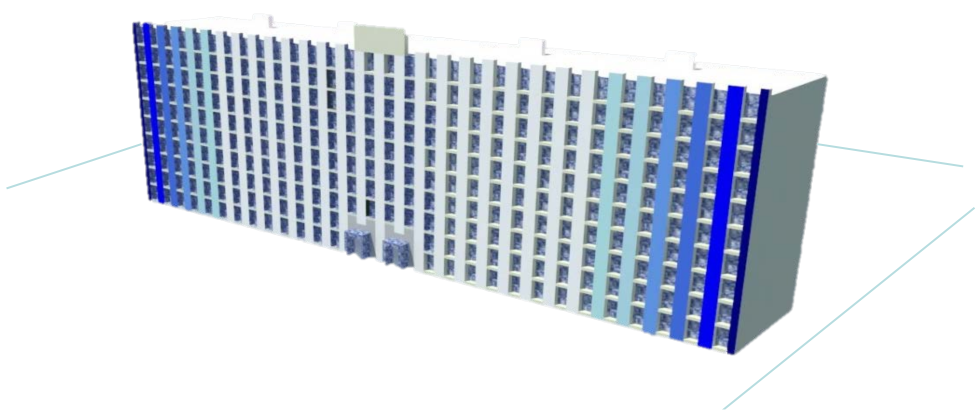
VISUAL COMFORT

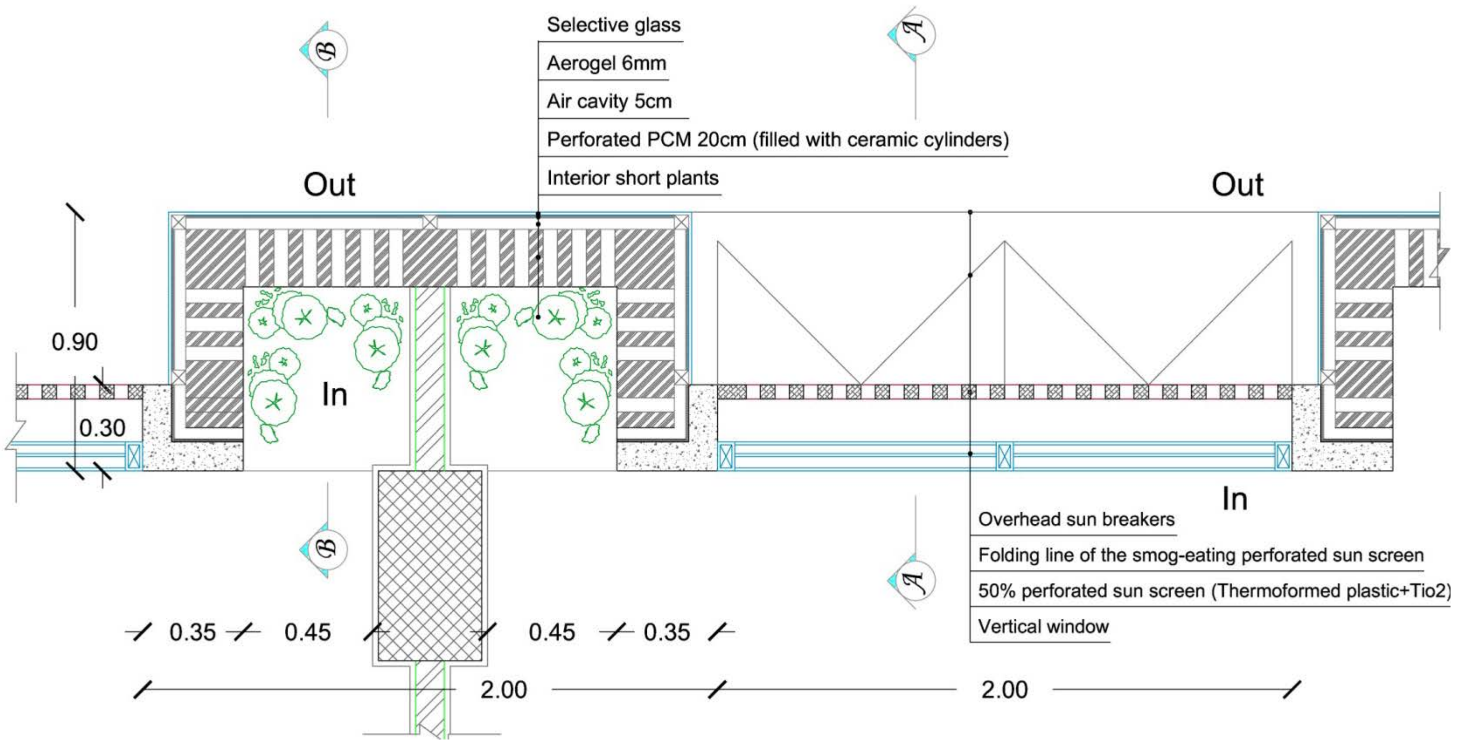


21 June, 10:00

21 June, 14:00

FINAL CONCEPT

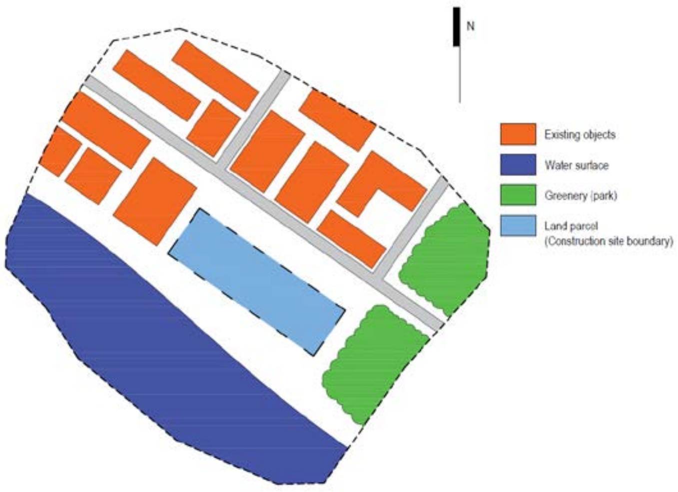


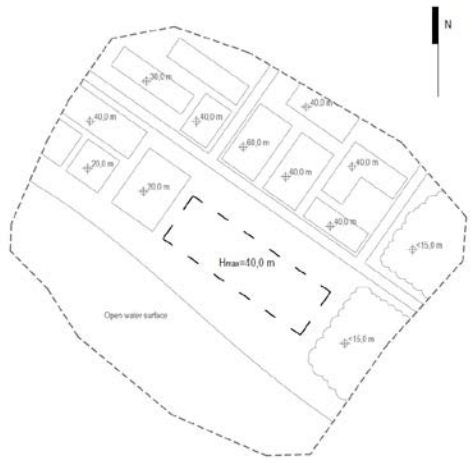


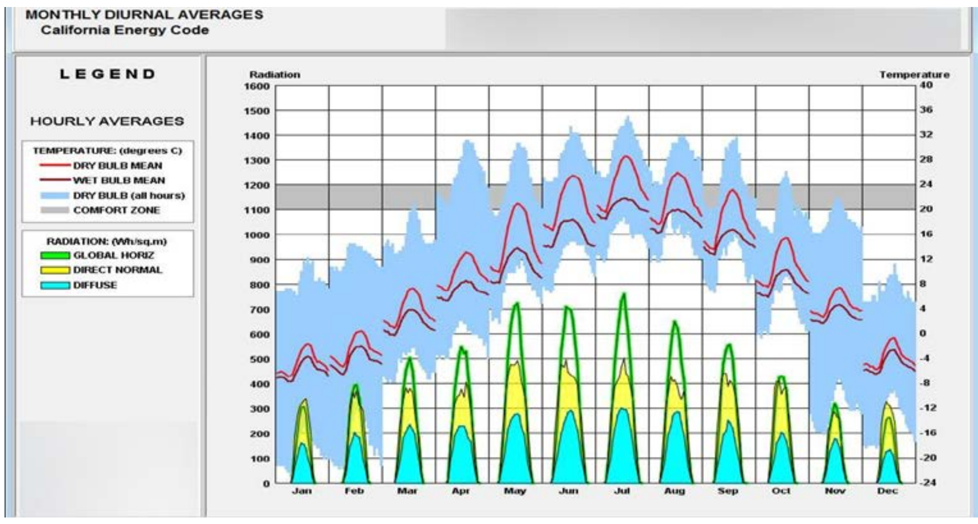
3.3. Case Study III – Chicago

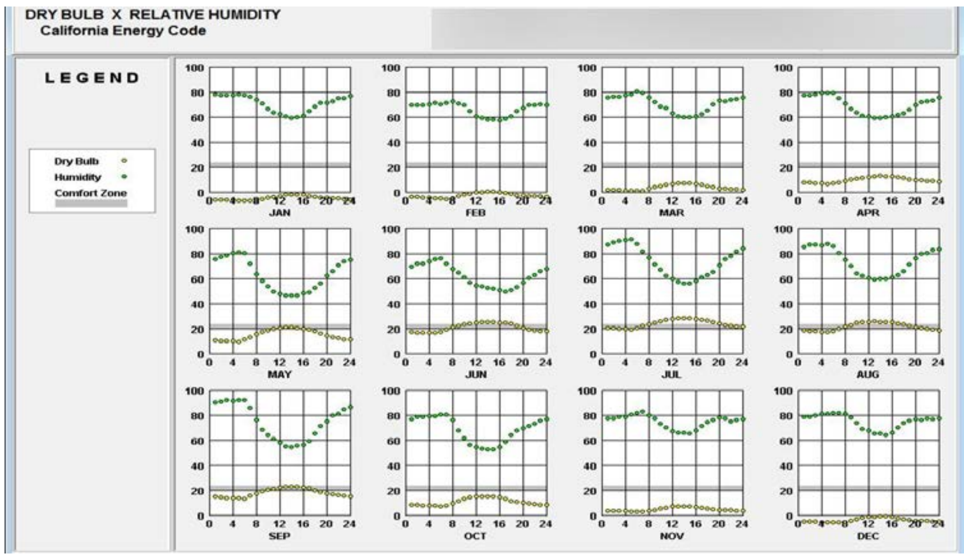
Case study 3 – Chicago
Layout 3 + Humid continental climate II

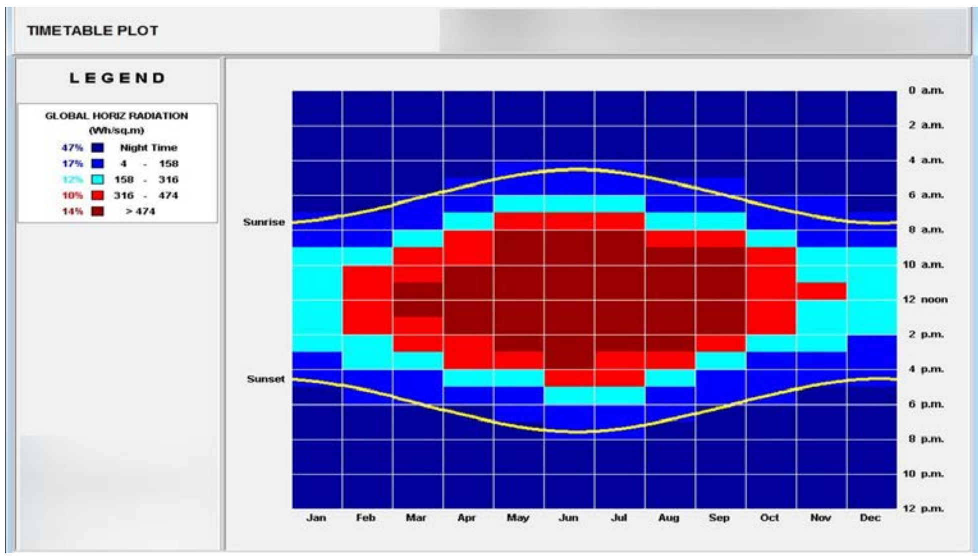
LOCATION:	**Chicago Ohare Intl Ap, IL, USA**
Latitude/Longitude:	41.98° North, 87.92° West, **Time Zone from Greenwich** -6
Data Source:	TMY3 725300 WMO Station Number, **Elevation** 201 m











WEATHER DATA SUMMARY

MONTHLY MEANS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Global Horiz Radiation (Avg Hourly)	189	243	292	332	414	419	420	377	340	272	189	167	Wh/sq.m
Direct Normal Radiation (Avg Hourly)	252	270	269	277	347	347	329	305	325	305	196	246	Wh/sq.m
Diffuse Radiation (Avg Hourly)	102	129	147	156	176	179	190	177	151	128	113	88	Wh/sq.m
Global Horiz Radiation (Max Hourly)	513	652	798	925	964	950	969	925	831	697	500	437	Wh/sq.m
Direct Normal Radiation (Max Hourly)	921	907	942	869	933	907	844	885	854	893	823	890	Wh/sq.m
Diffuse Radiation (Max Hourly)	293	294	407	414	450	459	465	440	410	299	261	212	Wh/sq.m
Global Horiz Radiation (Avg Daily Total)	1763	2493	3440	4394	5975	6293	6176	5161	4192	2941	1818	1504	Wh/sq.m
Direct Normal Radiation (Avg Daily Total)	2334	2737	3146	3668	5013	5205	4828	4193	4004	3268	1879	2210	Wh/sq.m
Diffuse Radiation (Avg Daily Total)	956	1330	1739	2057	2538	2689	2799	2421	1860	1394	1088	798	Wh/sq.m
Global Horiz Illumination (Avg Hourly)	20256	26172	31773	35841	44490	45132	45204	40582	36415	28943	20184	17729	lux
Direct Normal Illumination (Avg Hourly)	22434	25078	25958	27212	34282	34313	32795	30173	31585	28795	17962	21349	lux
Dry Bulb Temperature (Avg Monthly)	-4	-2	3	9	15	21	24	21	18	10	4	-3	degrees C
Dew Point Temperature (Avg Monthly)	-9	-8	-1	3	7	12	18	16	12	4	0	-7	degrees C
Relative Humidity (Avg Monthly)	70	66	70	69	63	62	73	74	74	68	74	75	percent
Wind Direction (Monthly Mode)	330	240	270	200	50	210	190	220	270	190	250	310	degrees
Wind Speed (Avg Monthly)	4	5	5	4	3	4	4	3	3	4	5	4	m/s
Ground Temperature (Avg Monthly of 3 Depths)	2	0	1	2	8	13	17	18	18	15	10	5	degrees C

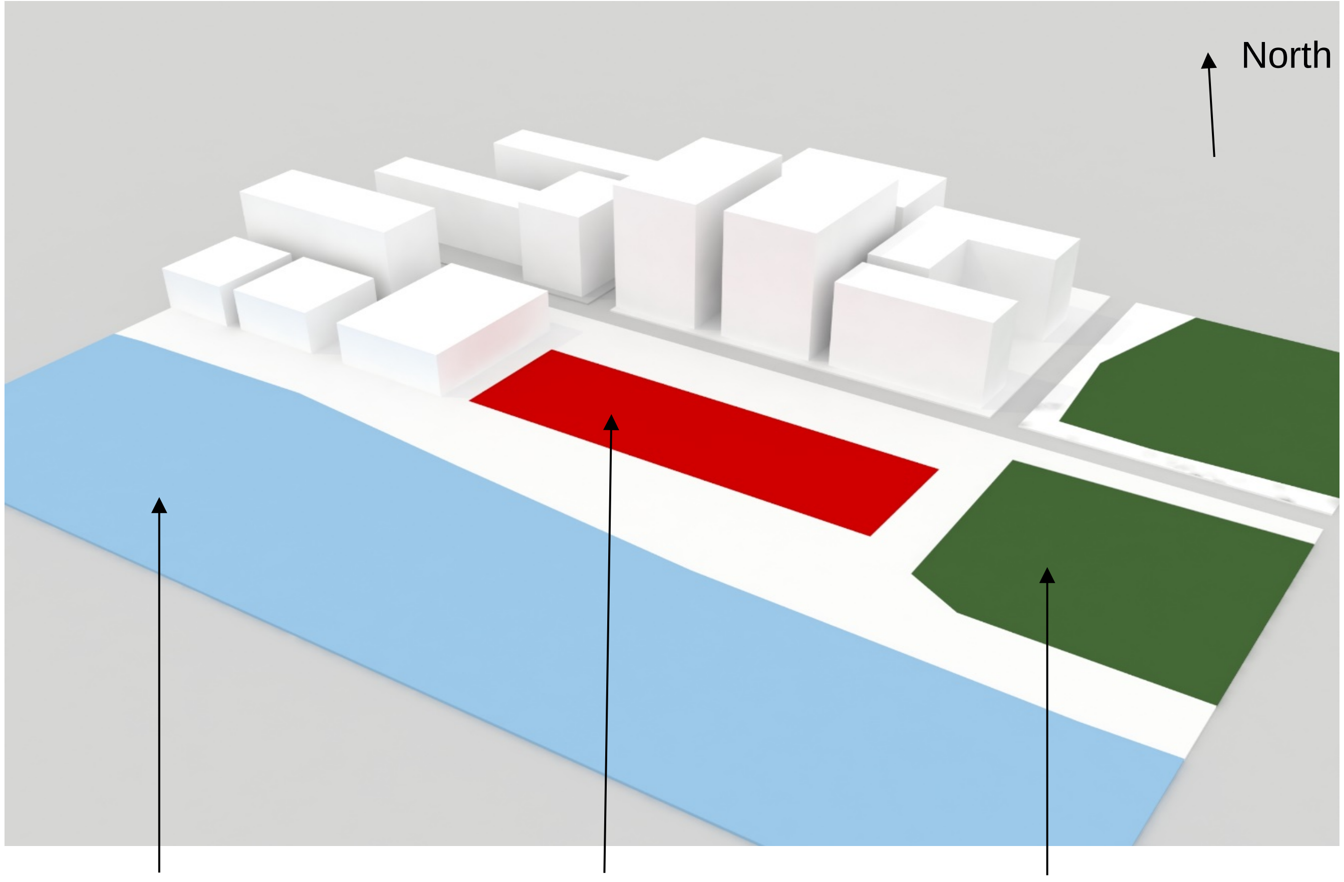
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average precipitation inches (mm)	2.06	1.94	2.72	3.64	4.13	4.06	4.01	3.99	3.31	3.24	3.42	2.57	39.09
	-52.3	-49.3	-69.1	-92.5	-104.9	-103.1	-101.9	-101.3	-84.1	-82.3	-86.9	-65.3	-992.9
Average snowfall inches (cm)	11.5	9.1	5.4	1	trace	0	0	0	0	0.1	1.3	8.7	37.1
	-29.2	-23.1	-13.7	-2.5		0	0	0	0	-0.3	-3.3	-22.1	-94.2
Average precipitation days (≥ 0.01 in)	10.7	8.8	11.2	11.1	11.4	10.3	9.9	9	8.2	10.2	11.2	11.1	123.1
Average snowy days (≥ 0.1 in)	8.1	5.5	3.8	0.7	0	0	0	0	0	0.1	1.8	6.7	26.7

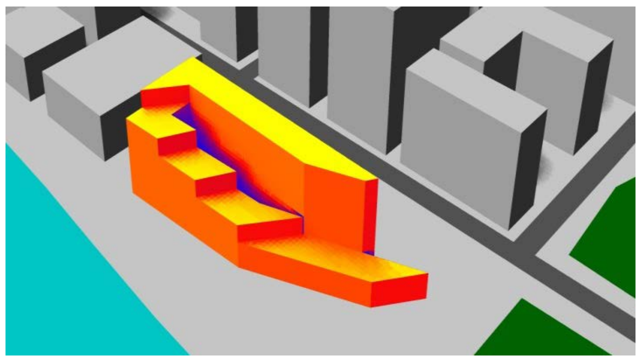
Case Study III: Chicago – Team 1

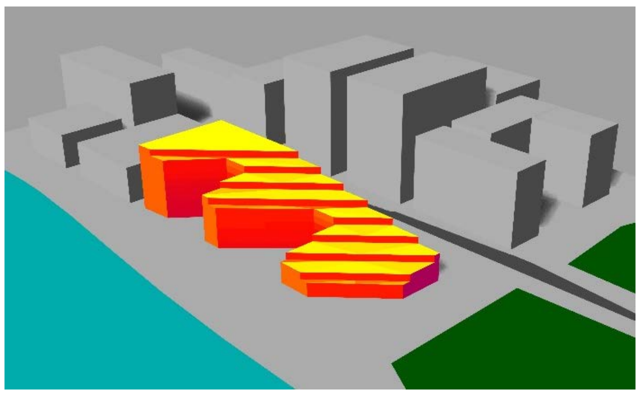
ADAPTIVE FACADES 2016 HAMBURG

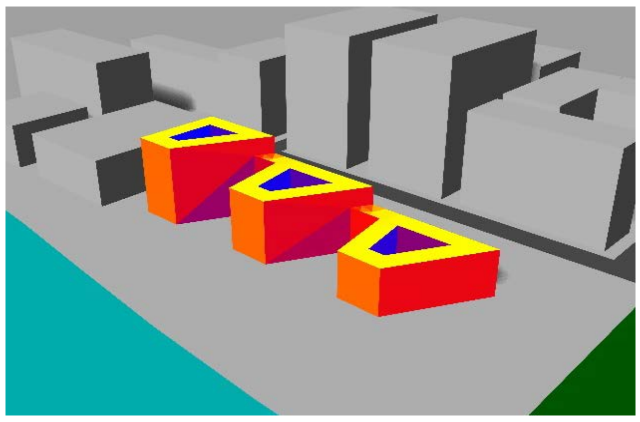
Andjela Dubljevic, Giulia Grassi, Estefana Castaneda, Roman Baudisch, Victor Charpentier, Mohamed Soliman

CONTEXT




Option 1


Option 2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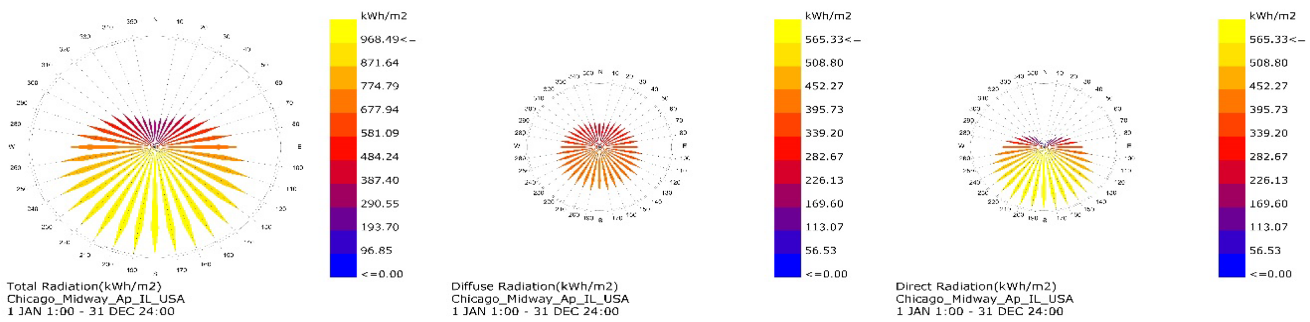
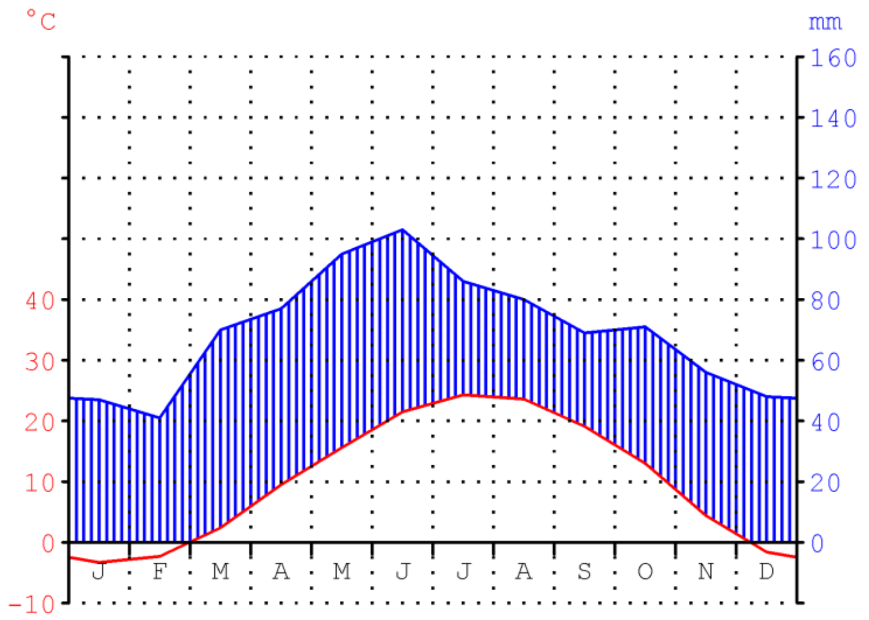


Radiation Rose

Erstellt mit Geoklima 2.1

Chicago/USA
41°47'N/87°47'W
185m

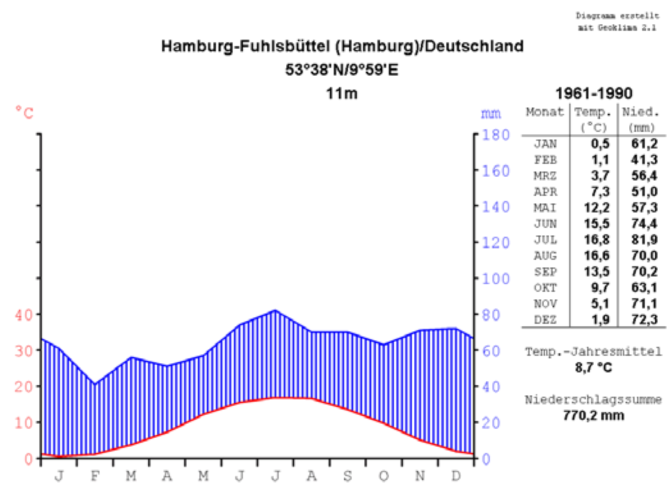


Monat	Temp. (°C)	Nied. (mm)
JAN	-3,3	47
FEB	-2,3	41
MRZ	2,4	70
APR	9,5	77
MAI	15,6	95
JUN	21,5	103
JUL	24,3	86
AUG	23,6	80
SEP	19,1	69
OKT	13,0	71
NOV	4,4	56
DEZ	-1,6	48

Temp.-Jahresmittel
10,5 °C

Niederschlagssumme
843 mm

Reference



	Jan	Feb	March	April	May	June	July	Aug	Sept.	Oct.	Nov.	Dec.
Av. Temperature [°C]	-5	-3	4	10	15	22	25	22	18	12	5	-3
rel. Humidity [%]	80	72	76	67	74	69	70	76	77	76	67	75

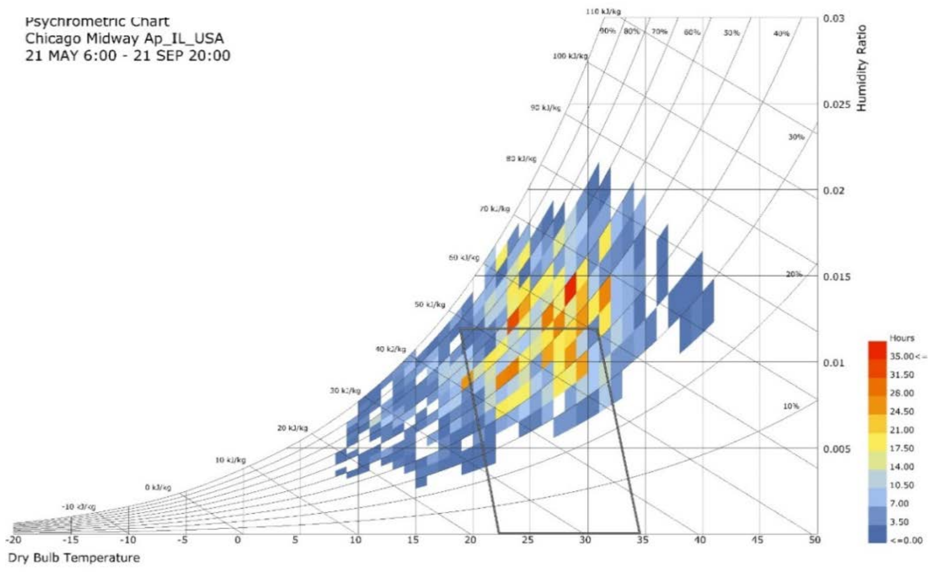
Case Study III: Chicago – Team 1

▶ Andjela Dubljevic, Giulia Grassi, Estefana Castaneda, Roman Baudisch, Victor Charpentier, Mohamed Soliman

CONCEPT

What are the challenges of climate?

SUMMER

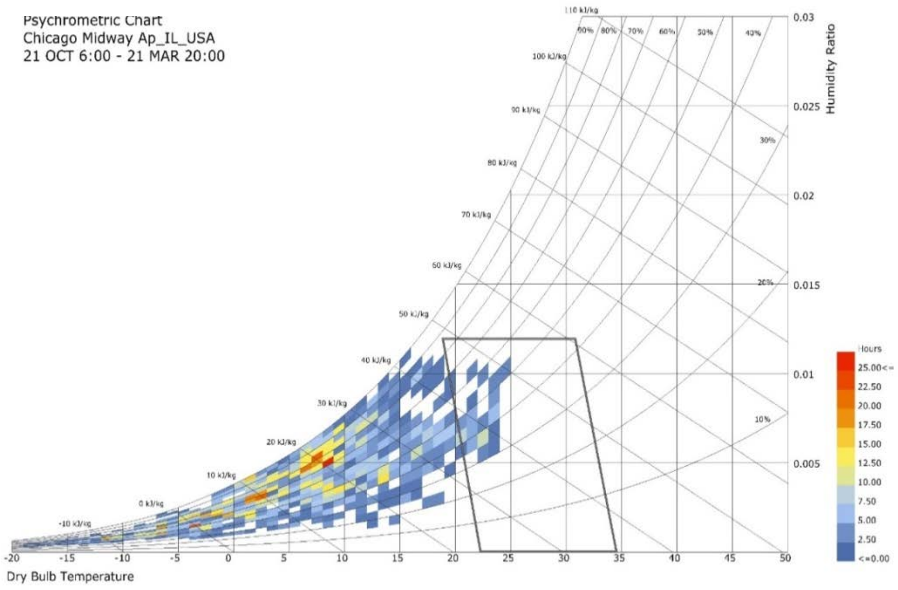


- Hot summer air temperature
- High relative humidity

Strategy:

- External shading system
- Using the water body for cooling of fresh air in the atrium
- Dehumidify air on cold surface of the cooling pipes

WINTER

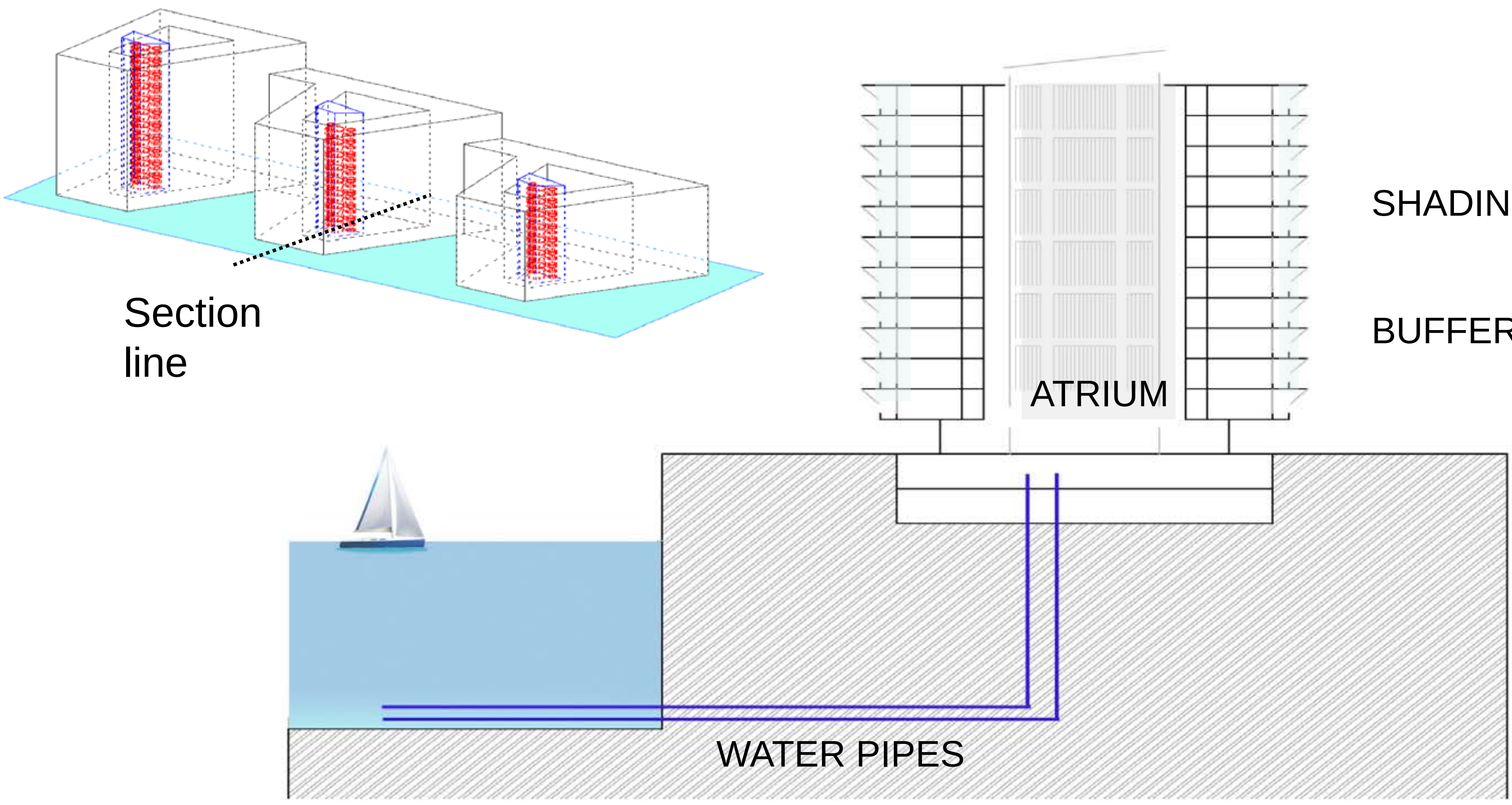


- Very cold air temperature

Strategy:

- Create a buffer zone in front of the facade to reduce energy consumption in the building
- Heat the fresh air before it enters the room

SYSTEMS



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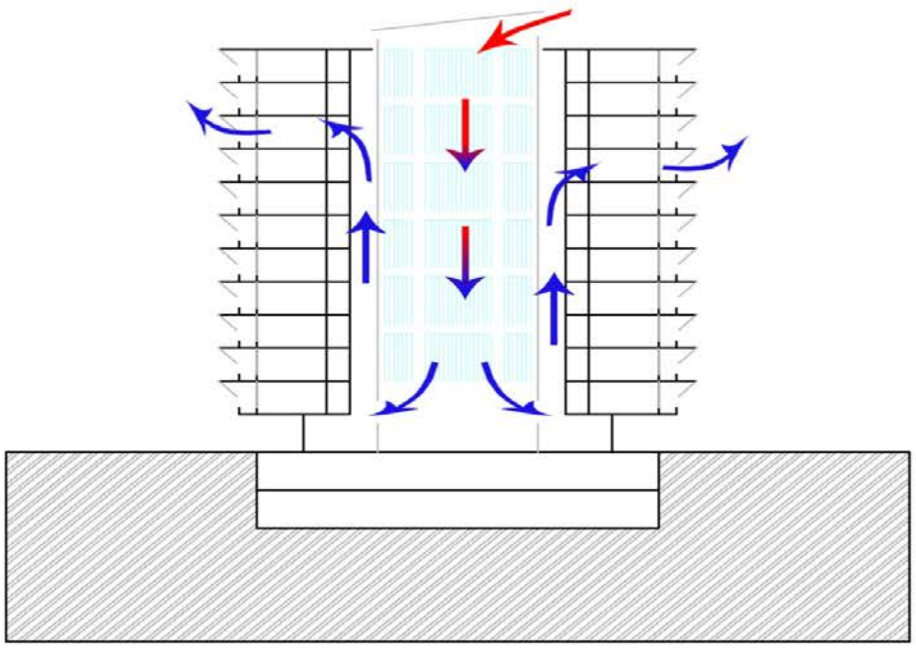
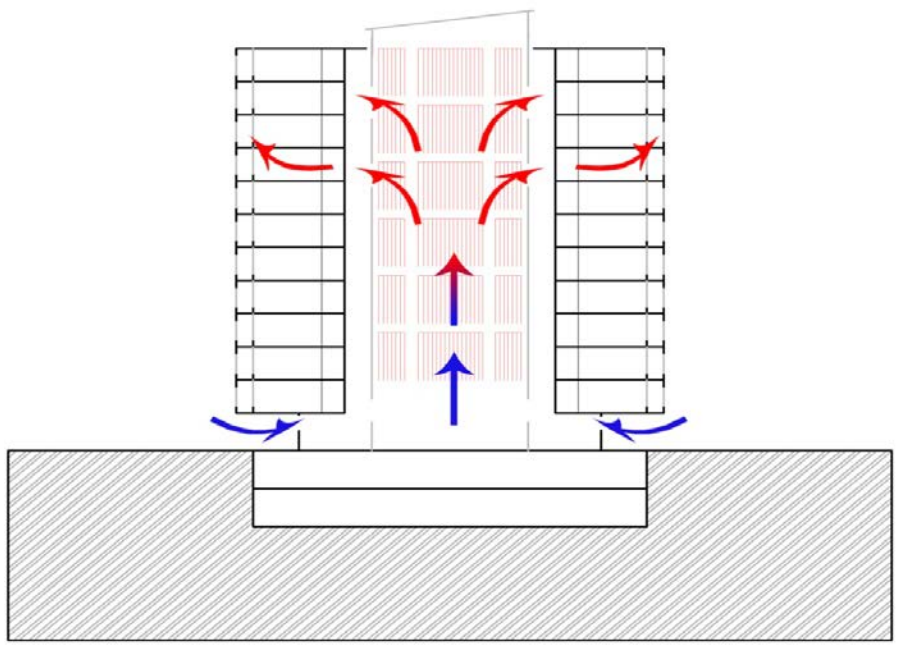
AIR FLOW

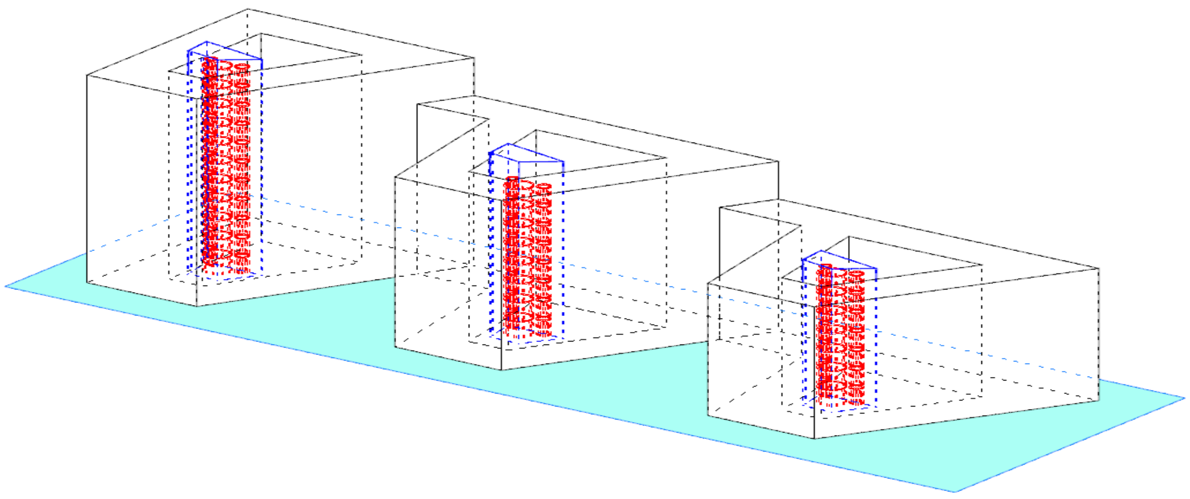


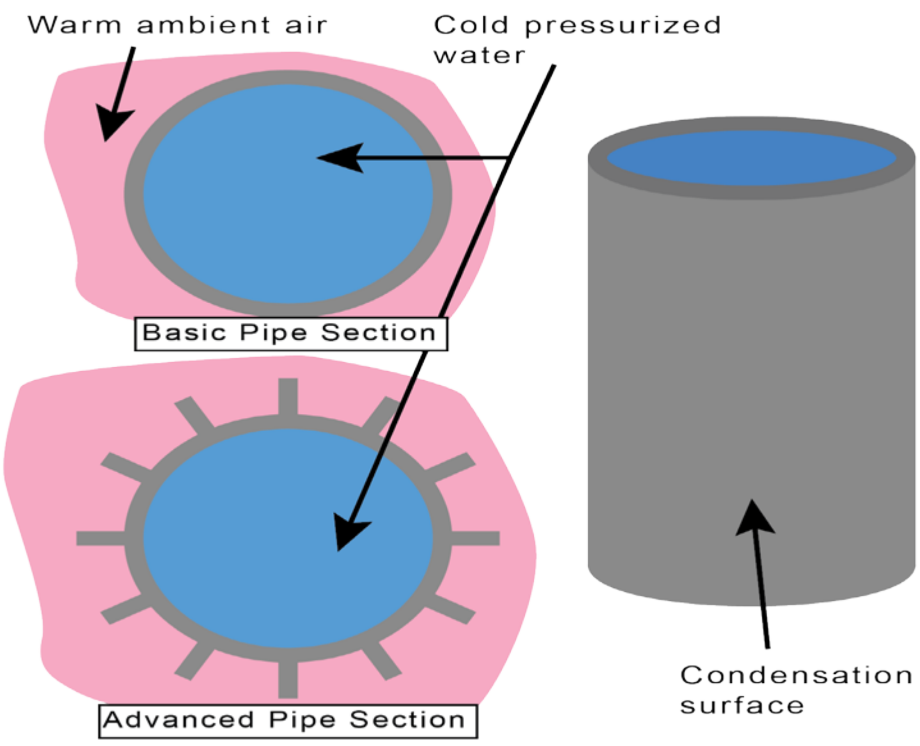
SUMMER



WINTER

COOLING AND DEHUMIDIFICATION





<u>July In Chicago: extreme</u>

$T_{dryBulb\_avg}$=24°C

R_h=74%

<u>Water extraction rate</u>

bring R_h to 45%

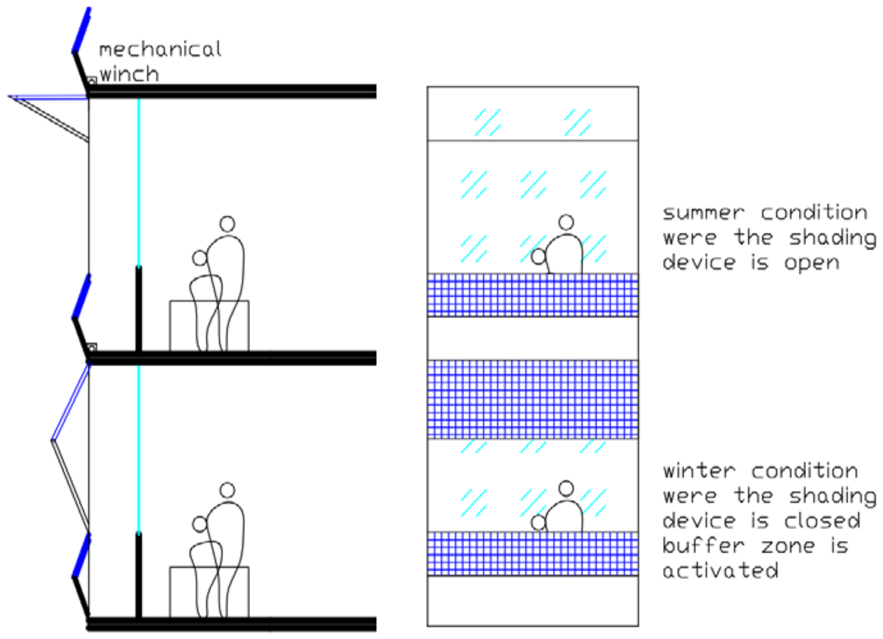
1.5*V air flow

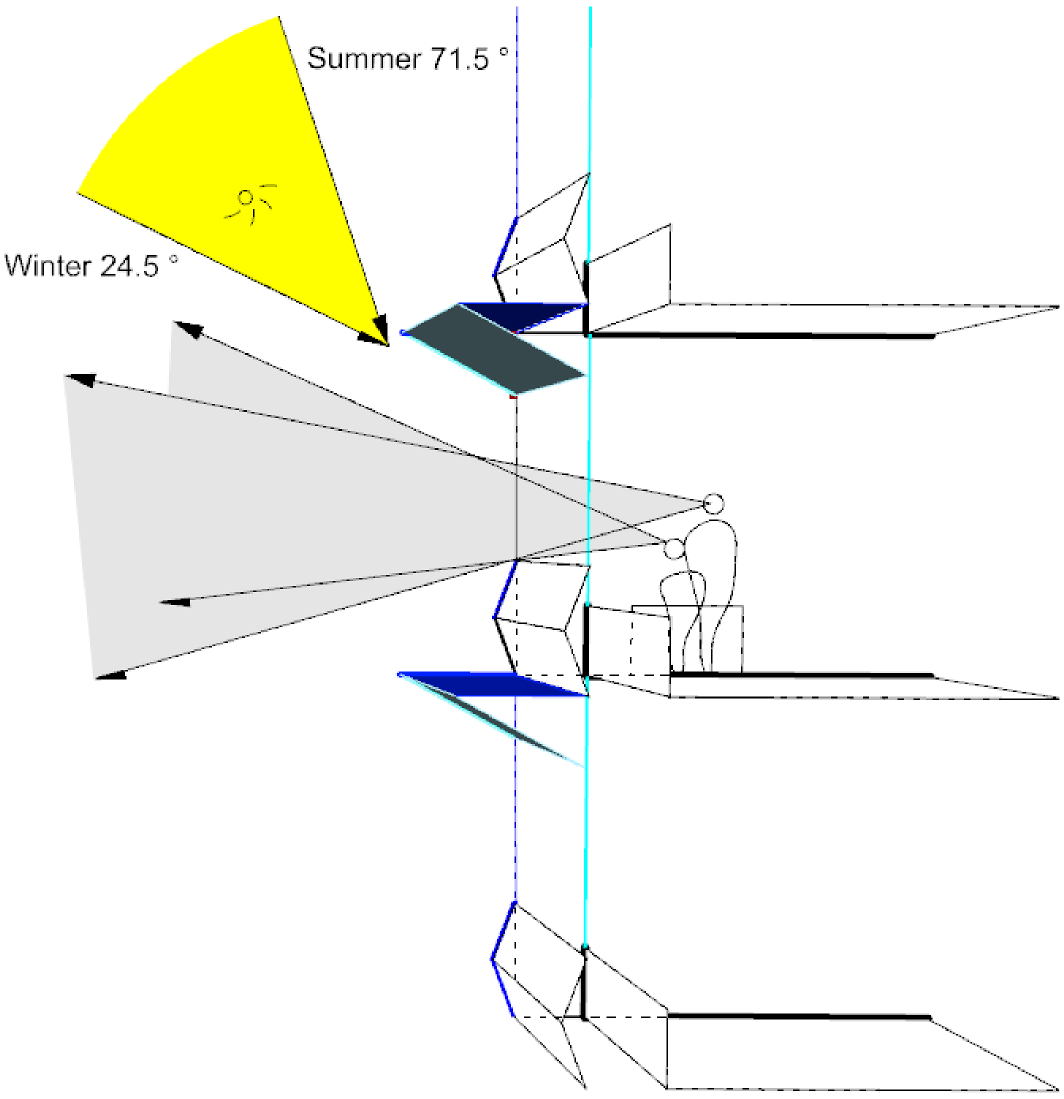
m_w= 828.5 kg/h

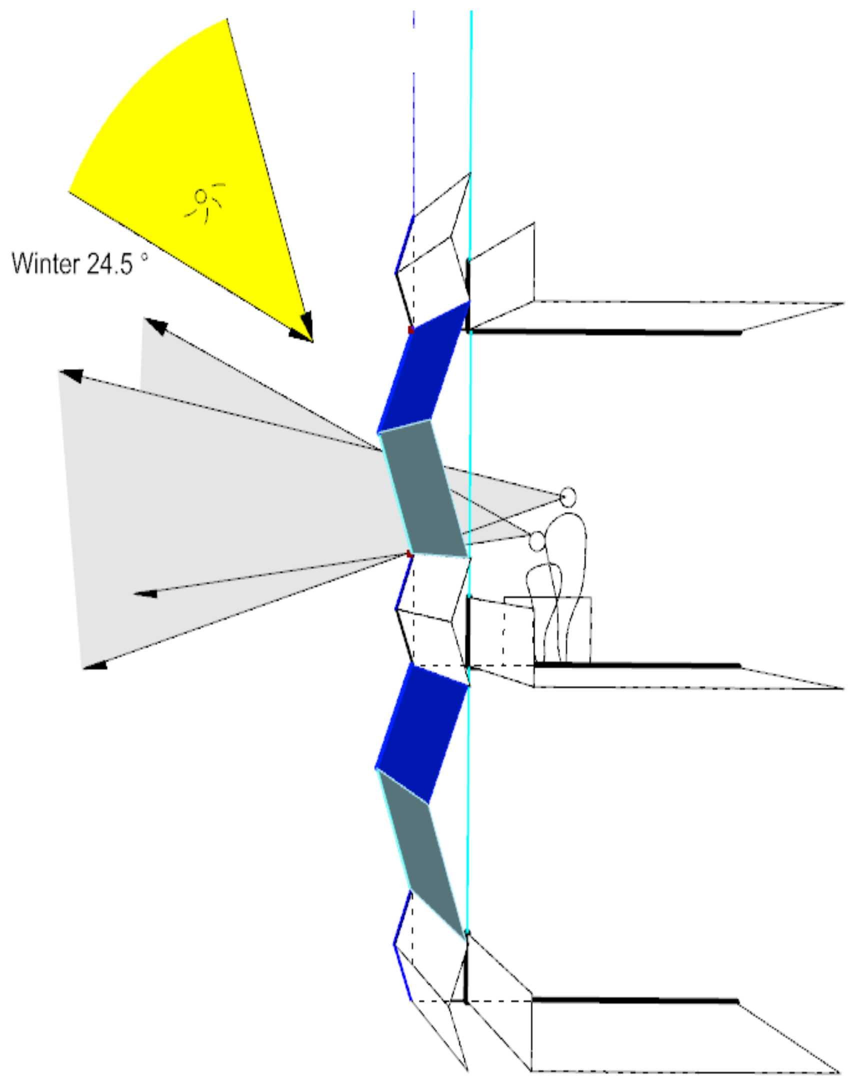
Andjela Dubljevic, Giulia Grassi, Estefana Castaneda, Roman Baudisch, Victor Charpentier, Mohamed Soliman

FACADE

Shading and buffer zone







Case Study III: Chicago – Team 2

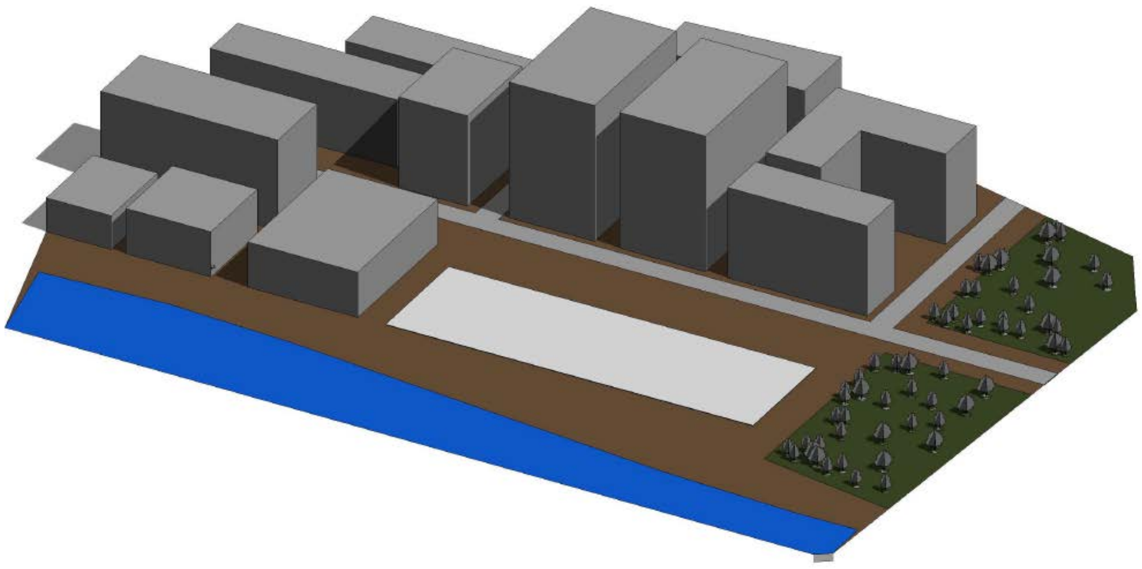
Matthias Förch, Amin Fallahi. Mehul Koont, Júlia Pereria, Christoph Sousa, Ana Villaca

BOUNDARY CONDITIONS

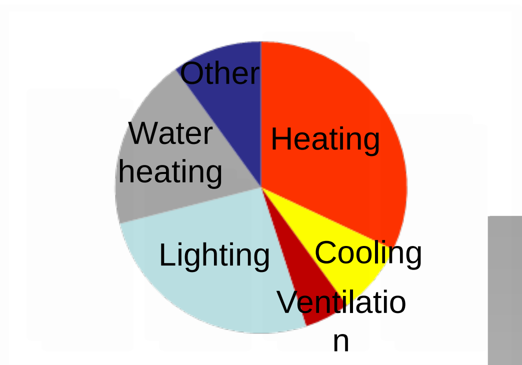
Köppen-Geiger: “Dfa”

- Humid continental climate (Dfa)
- Severe winter
- Dry season
- Hot summers
- Strong sesonality

Existing buildings in
the surrounding areas
Waterfront Greenery



OUR STRATEGY



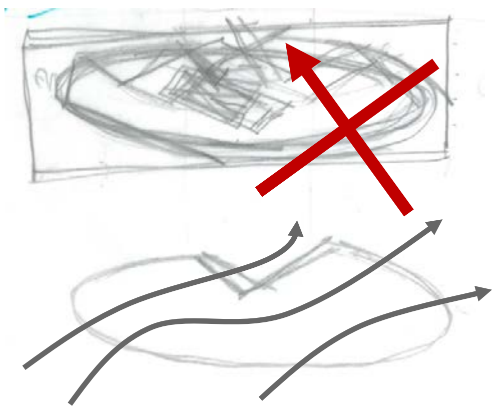
	PRIORITY →	
HEAT R	Sustain heat	Efficient heat gain
LIGHT	Maximize daylight	Optimize artificial light
AIR	Natural ventilation	Effective mechanical ventilation
COLD	Prevent overheating	Discharge heat
POWER	Reduce energy use	Gain power

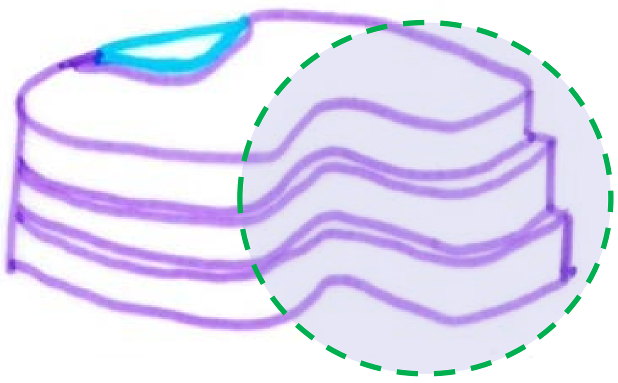
[Adapted from: Hegger et. al, Energie Atlas, 2008]

Case Study III: Chicago – Team 2

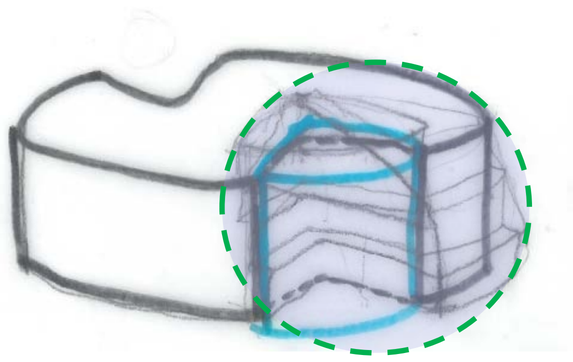
▶ Matthias Förch, Amin Fallahi. Mehul Koont, Júlia Pereria, Christoph Sousa, Ana Villaca

BUILDING CONCEPTS

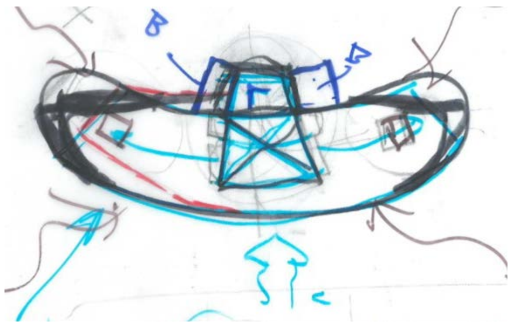


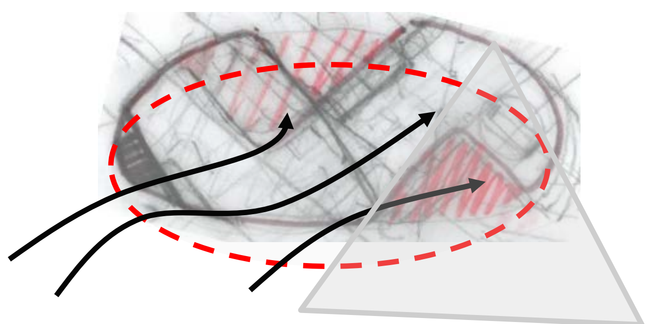


South facade



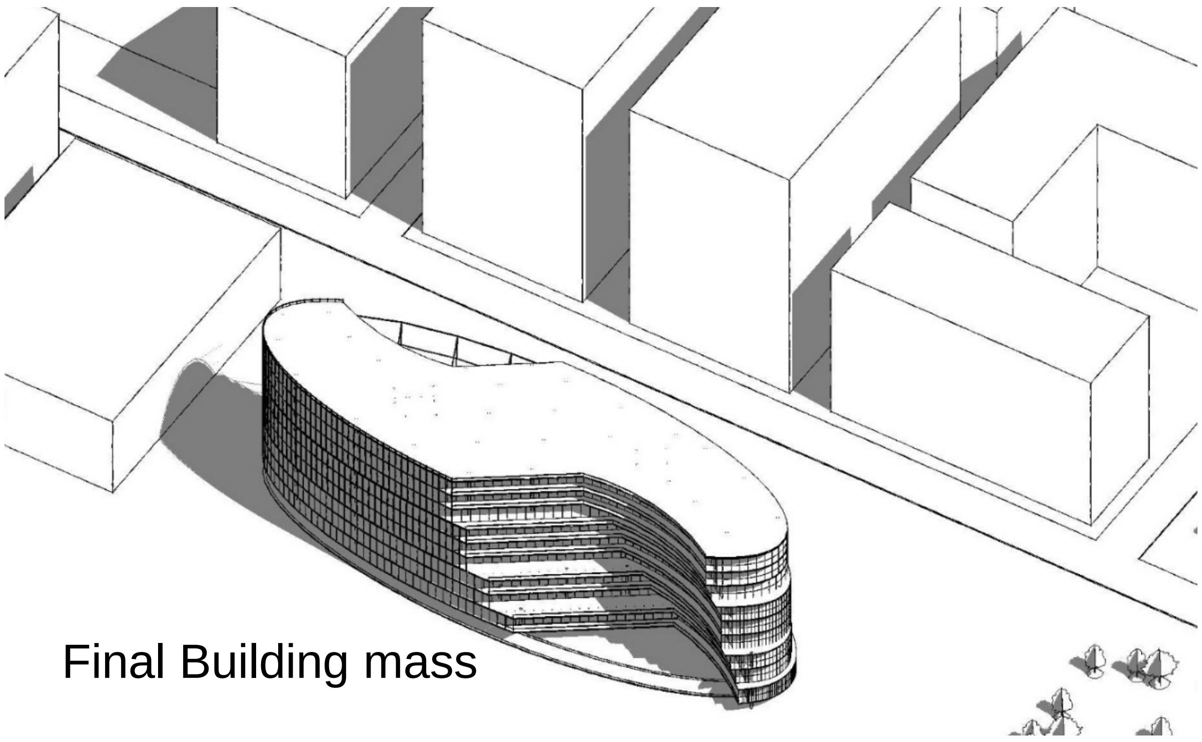
North facade





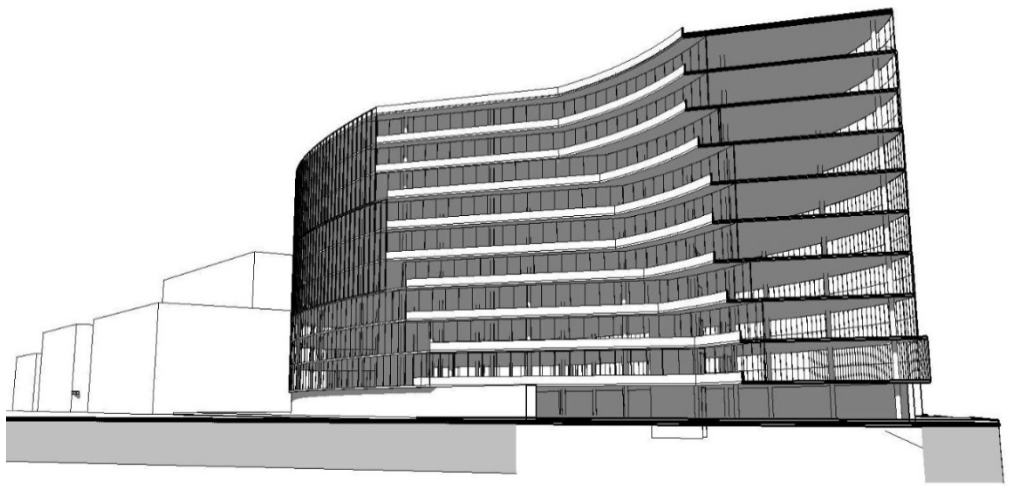
Building shape concept

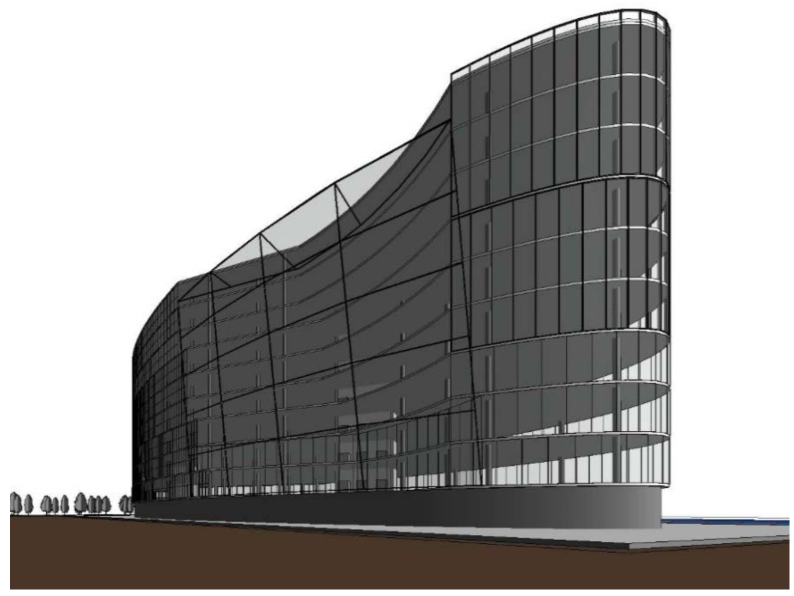
Building mass concepts

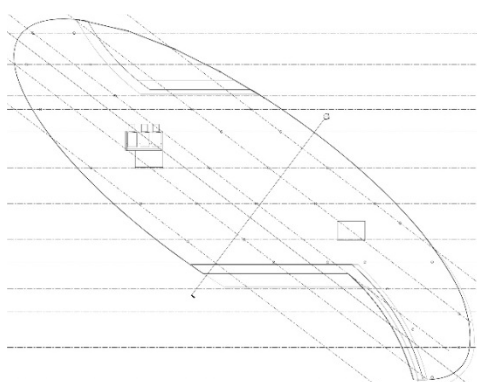


Final Building mass

FINAL BUILDING MODEL



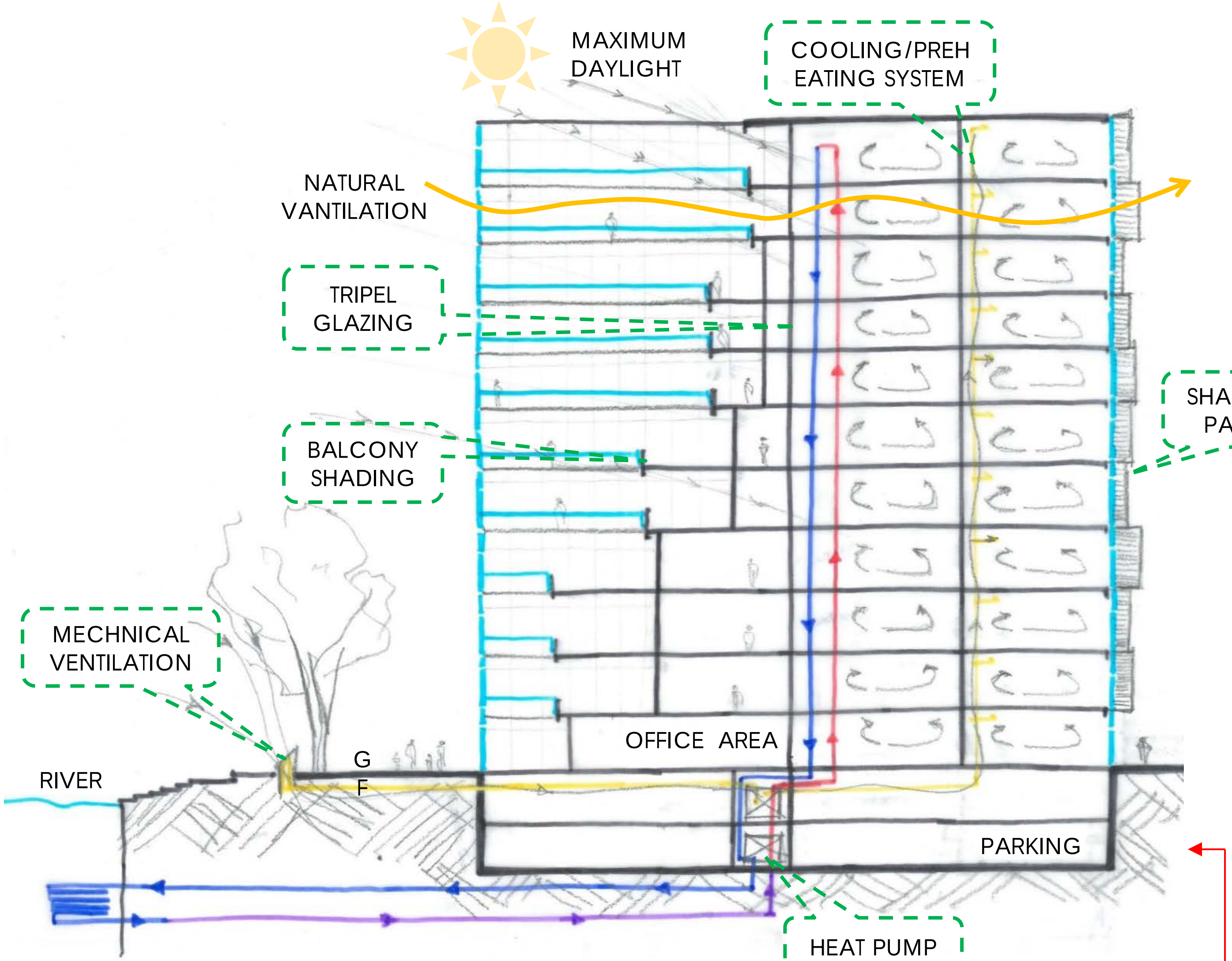




Case Study III: Chicago – Team 2

Matthias Förch, Amin Fallahi. Mehul Koont, Júlia Pereria, Christoph Sousa, Ana Villaca

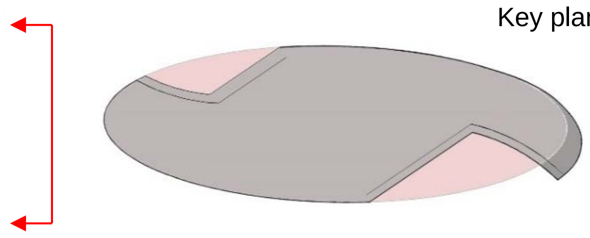
ENERGY CONCEPT – PART I



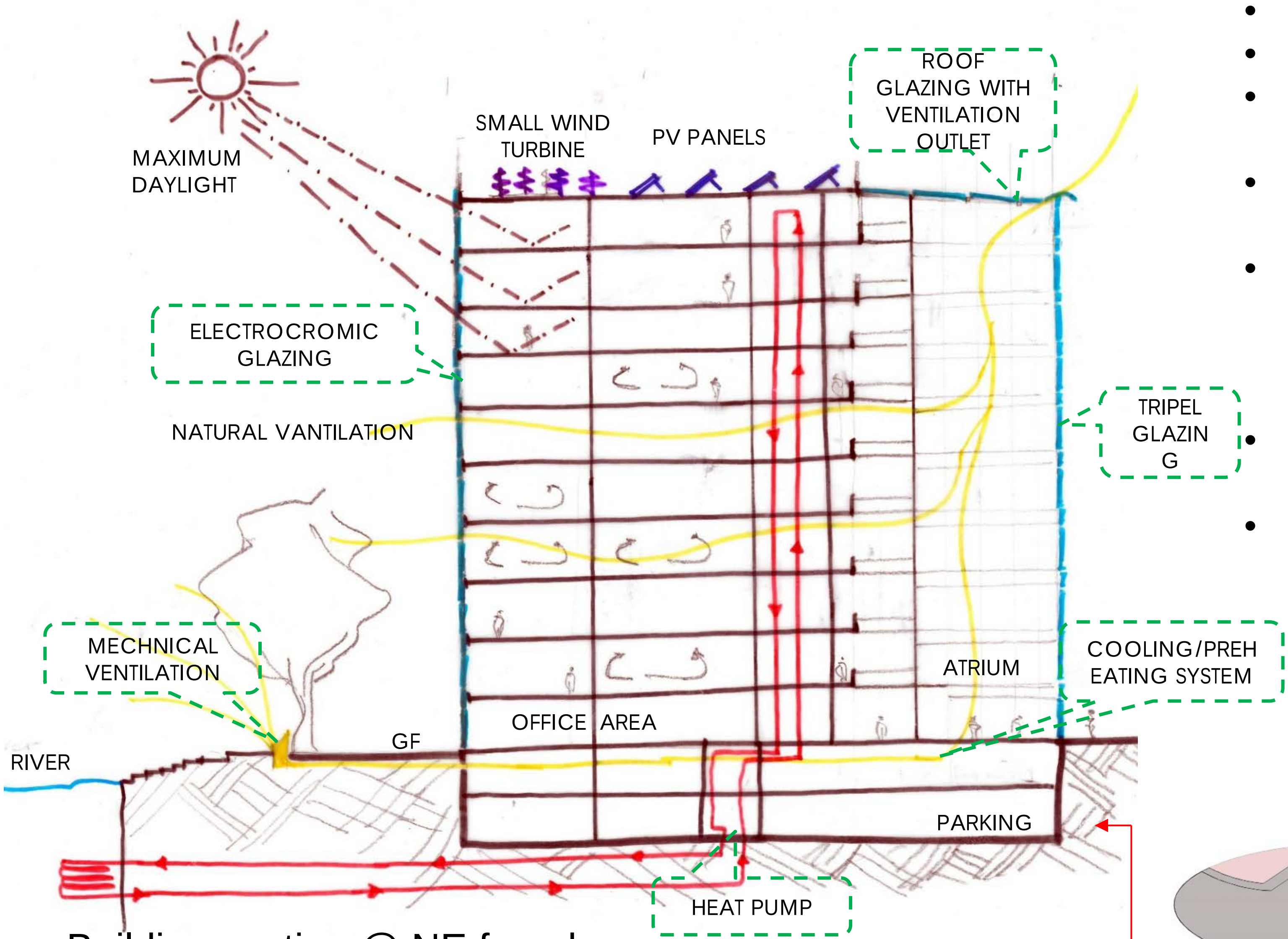
Building section @ SW facade

- Maximum daylight
- Natural ventilation
- Optimise energy consumption
- More renewable energy options
- Efficient heating system integrated with geothermal energy
- Multiple glazing technology
- Mechanical ventilation for extreme weather condition (cold/heat)

Key plan



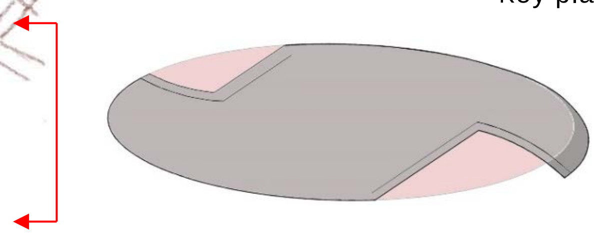
ENERGY CONCEPT – PART II



Building section @ NE facade

- Maximum daylight
- Natural ventilation
- Optimise energy consumption
- More renewable energy options
- Efficient heating system integrated with geothermal energy
- Multiple glazing technology
- Mechanical ventilation for extreme weather condition (cold/heat)

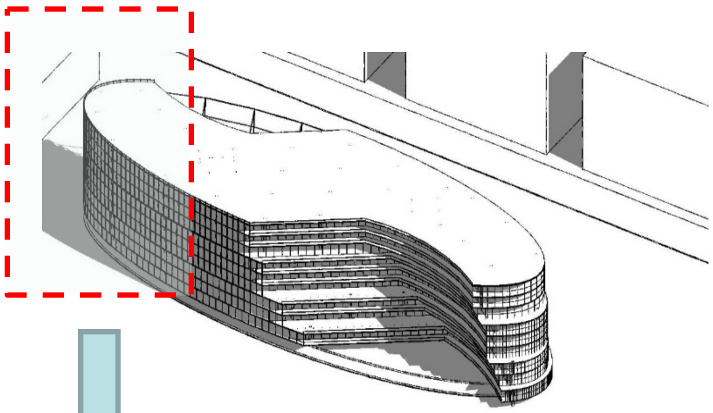
Key plan

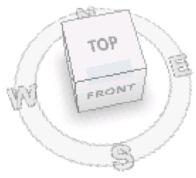


Case Study III: Chicago – Team 2

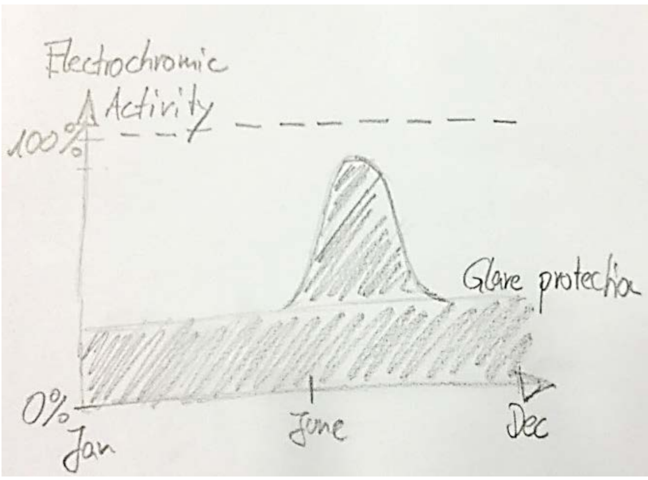
Matthias Förch, Amin Fallahi. Mehul Koont, Júlia Pereria, Christoph Sousa, Ana Villaca

CORE-FACADE SOLUTIONS – PART I





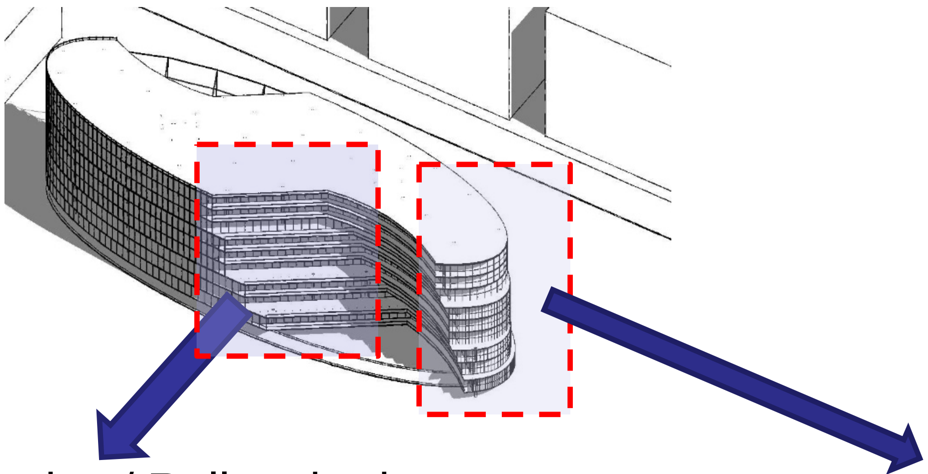
Electrochromic windows

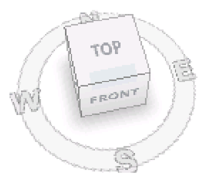


- Increase solar gains performance;
- Avoid glare;
- Reduce energy consumption;
- Can be controlled by user´s preferences or by a sunlight sensor;
- Privacy;
- Convenience;

- Cost intensive solution

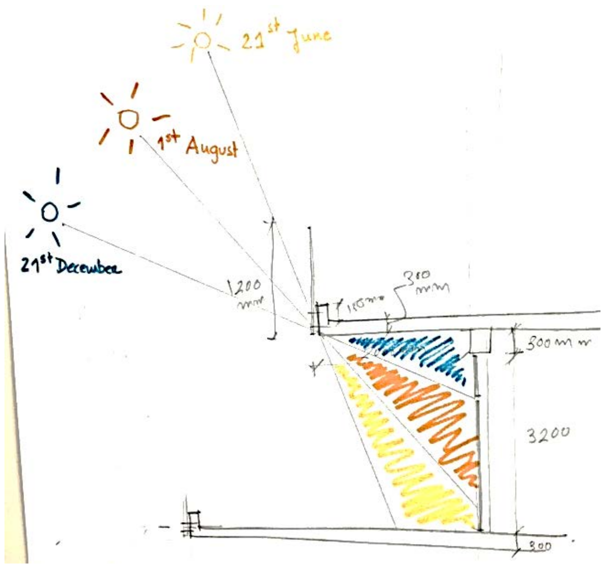
CORE-FACADE SOLUTIONS – PART II

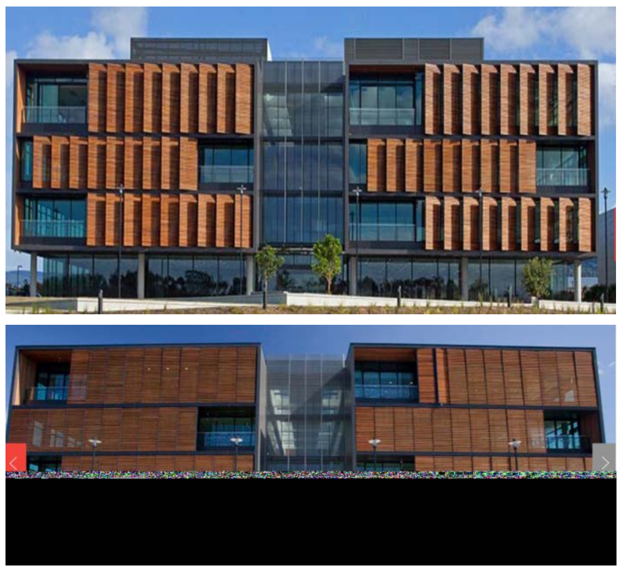




Balconies / Roller shades

Pivoted timber shading device





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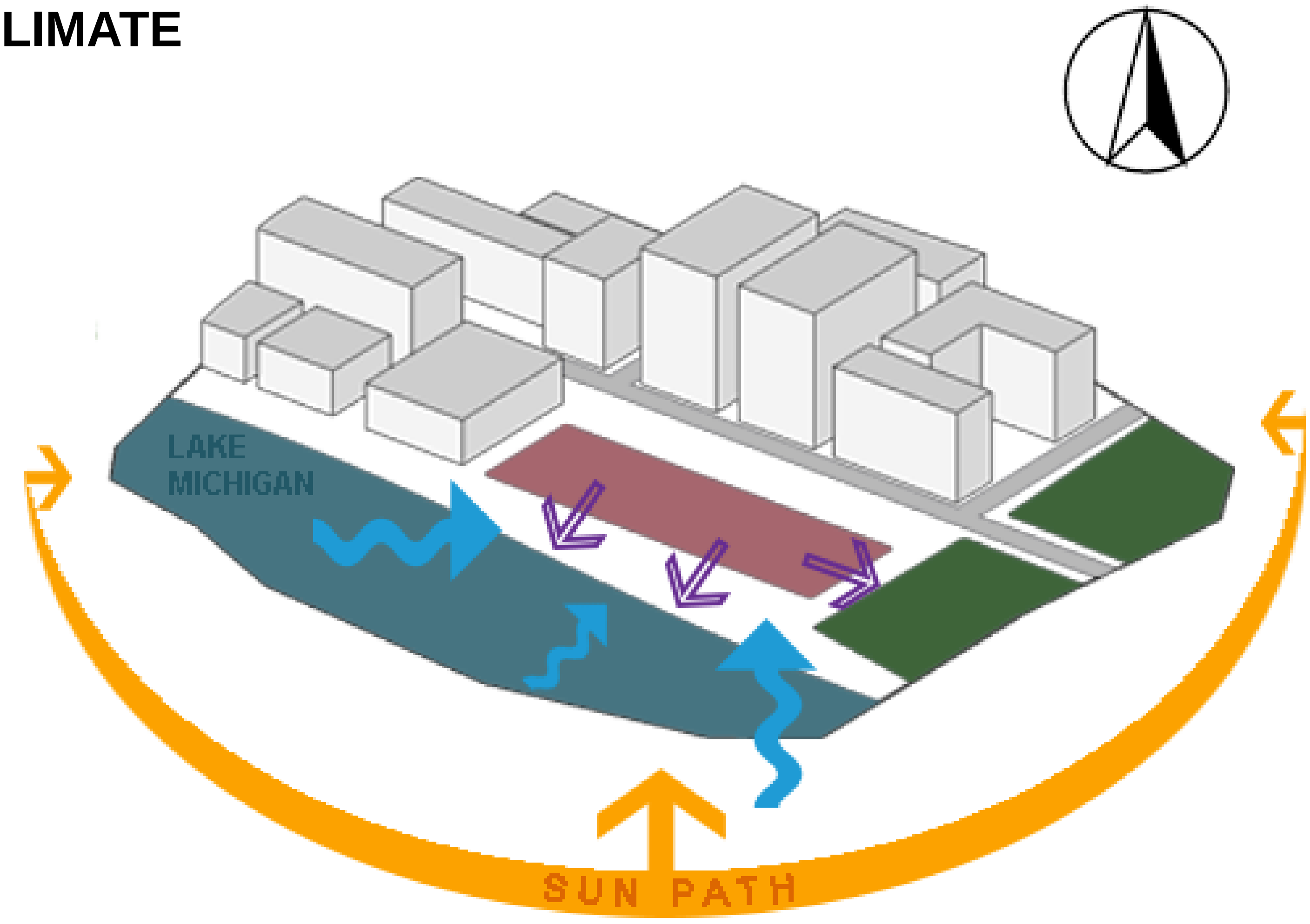
CLIMATE



Main constrains:
Office Building
Footprint = 2,270 m^2
Height = 40 m
Number of floors = 11

Humid Continental Climate

Annual Temperature
Average 2-8° C
Design High 26° C
Design Low -22° C

Annual Precipitation
Average 661mm

Annual Humidity
Average 67-89%

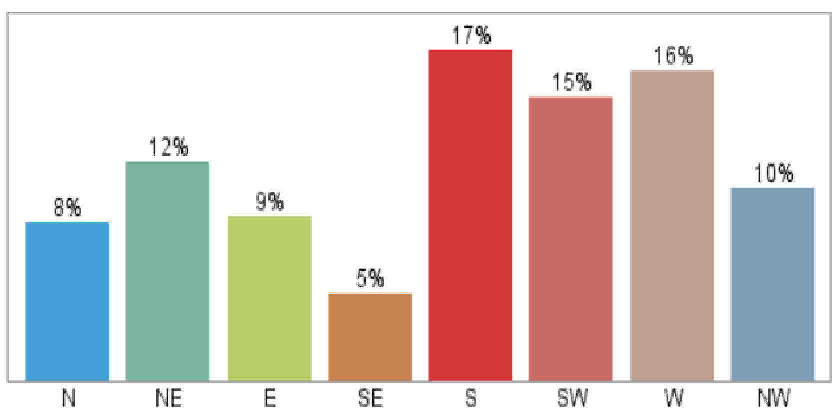
Lake Michigan moderates temperatures and influences wind direction

Cooler summers and warmer winters

Annual Wind Speed
Average 2.2 m/s

Annual Wind Direction
Average 180°

Wind Direction over the entire Year



[Prairie Research Institute, University of Illinois at Urbana-Champaign]

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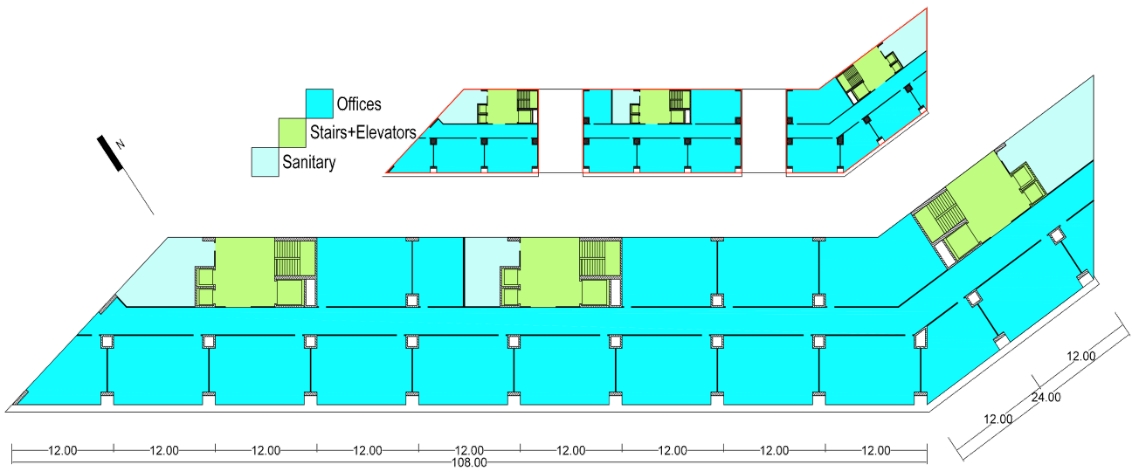
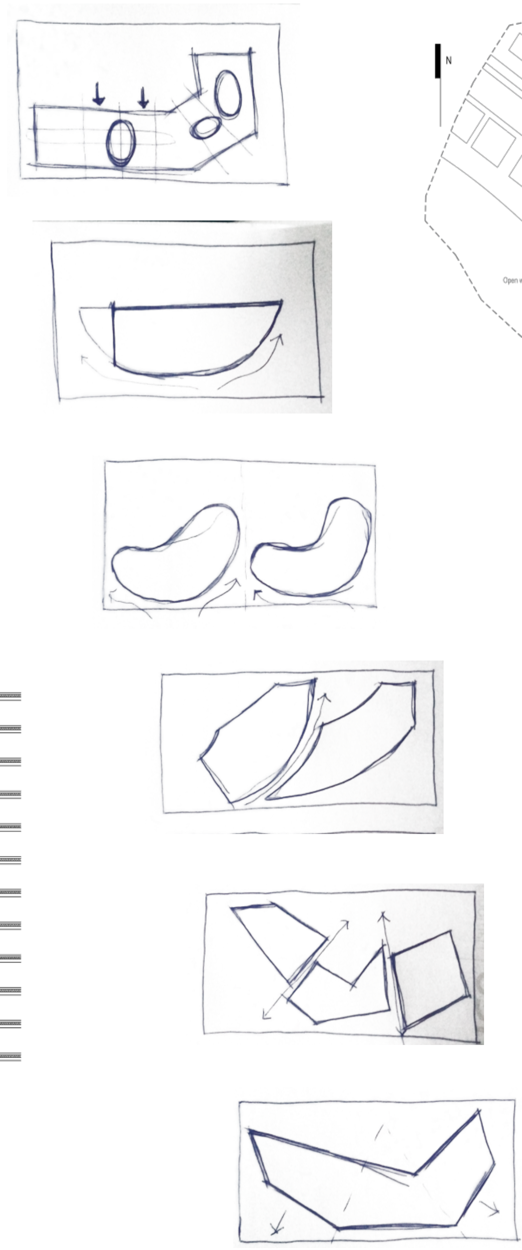
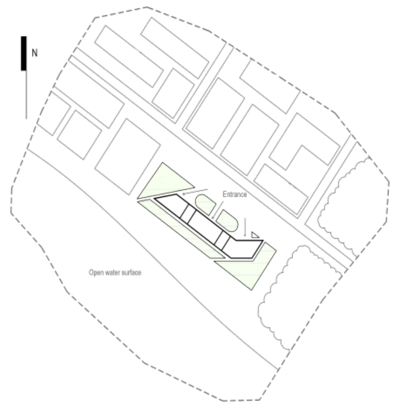
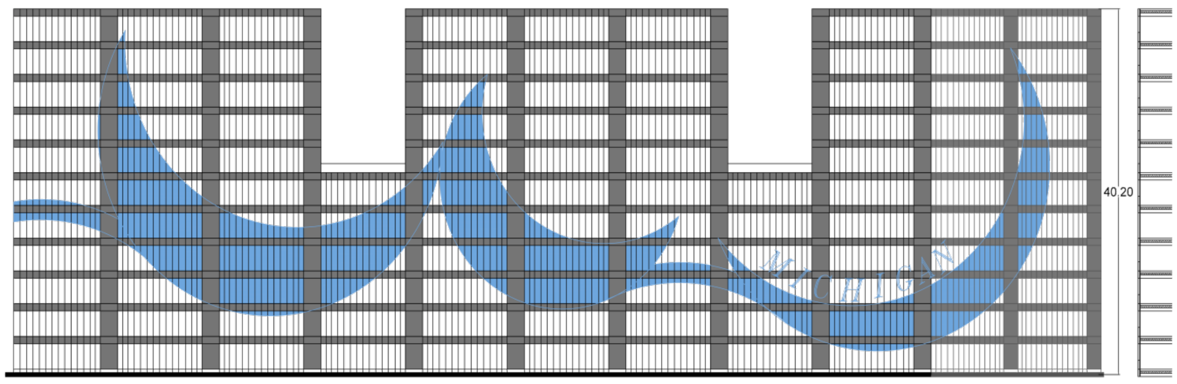
GENERAL PLAN



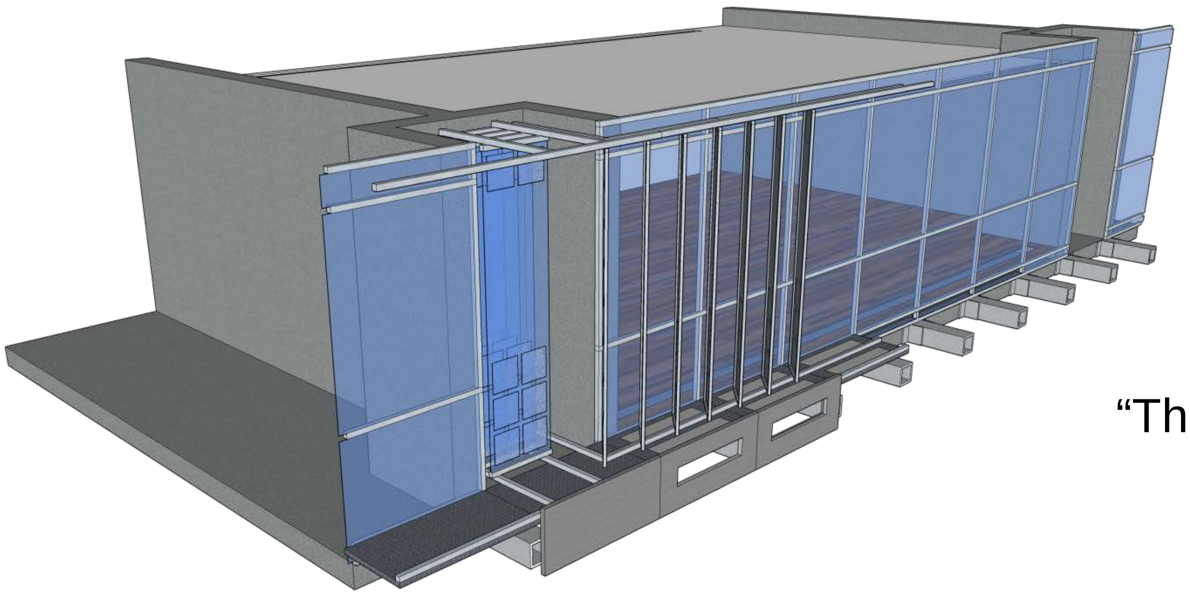




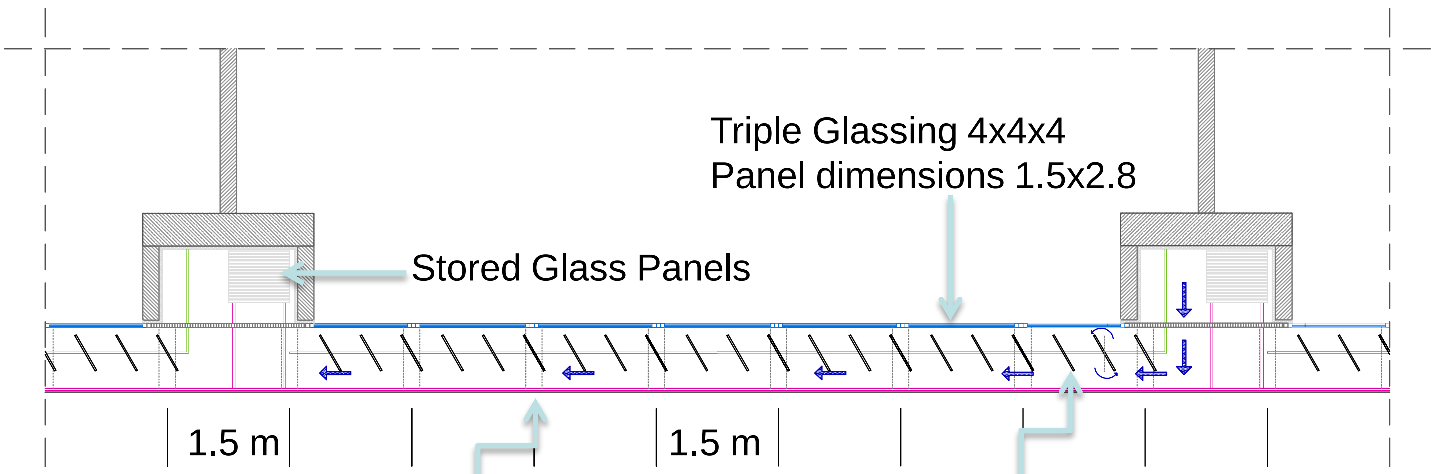
South-West Facade



FACADE SYSTEM FOR SUMMER



“The Jacket Facade Concept”



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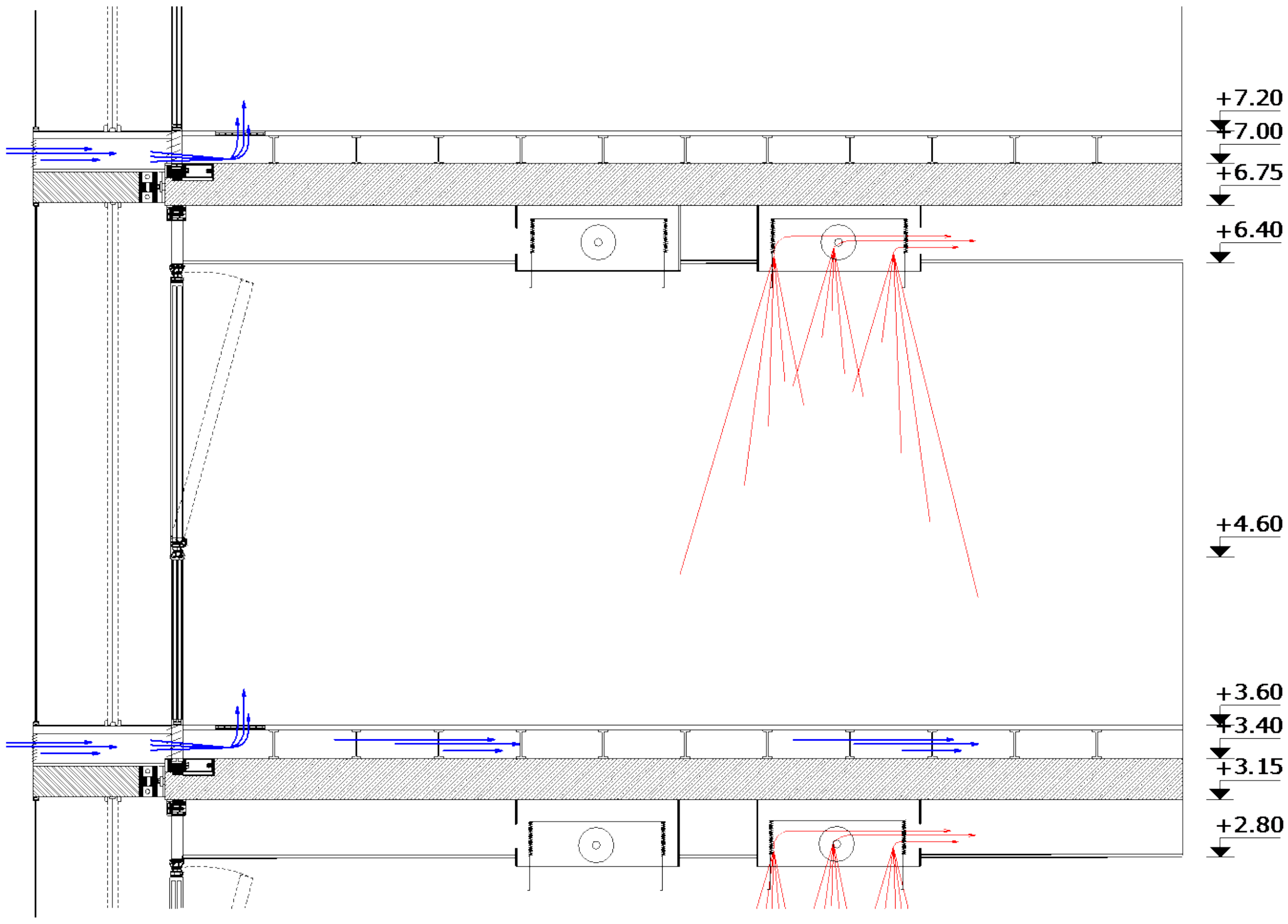
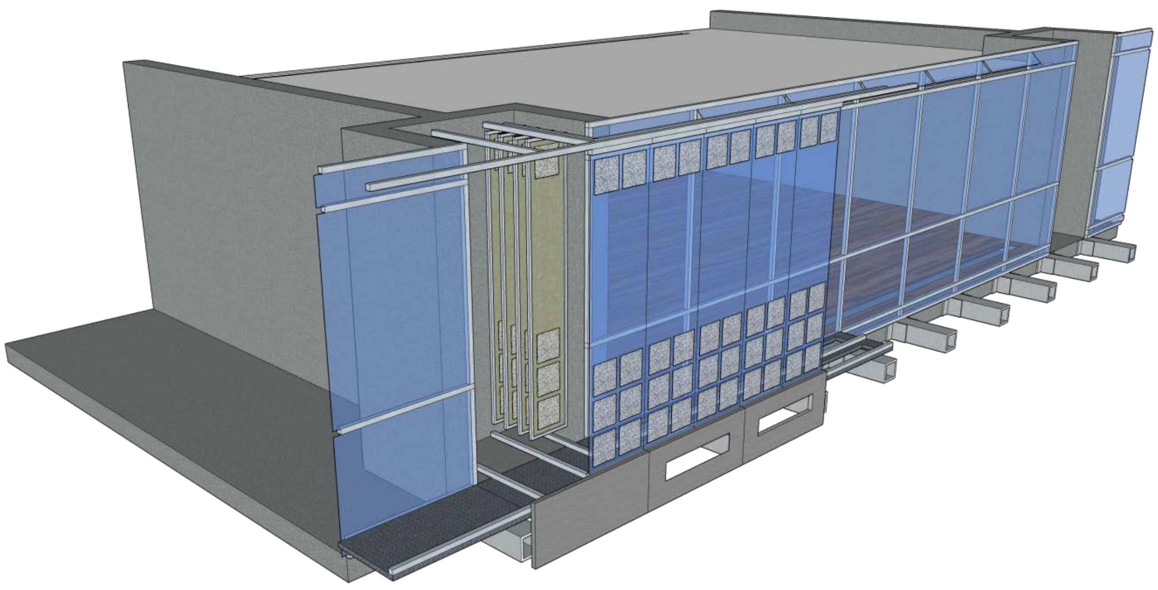
FACADE SYSTEM FOR SUMMER

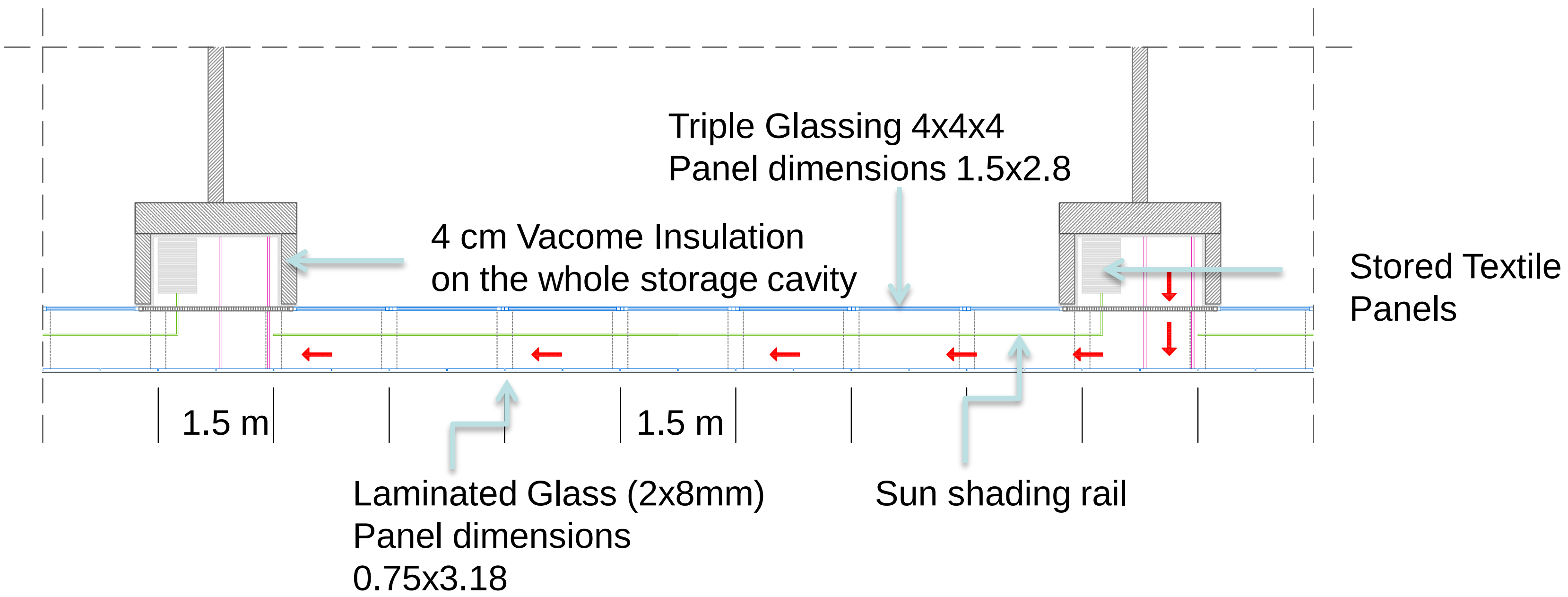
“The Jacket Facade Concept”



FACADE SYSTEM FOR WINTER

“The Jacket Facade Concept”





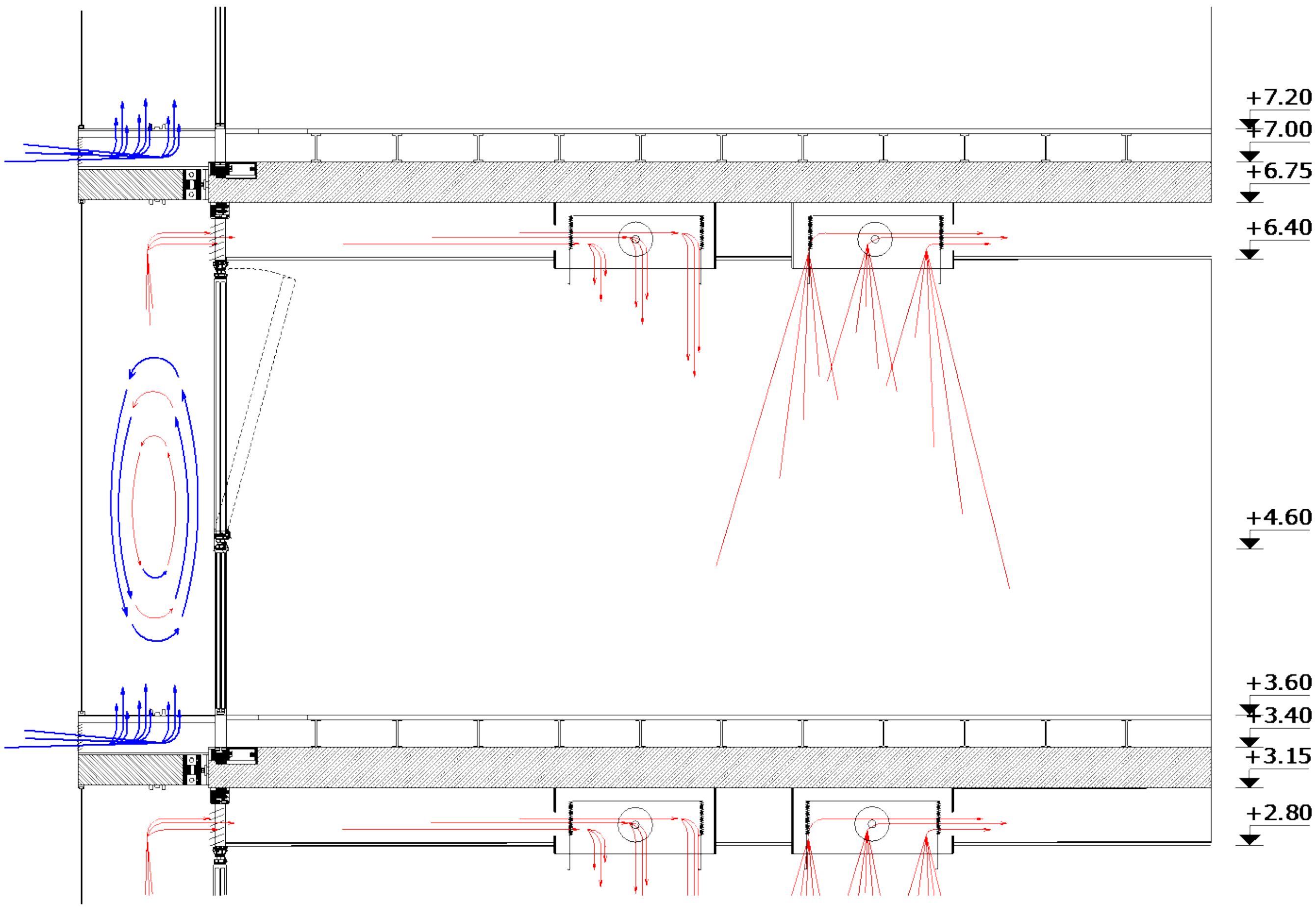
EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY
HCU HafenCity Universität Hamburg
DAAD
CAPES

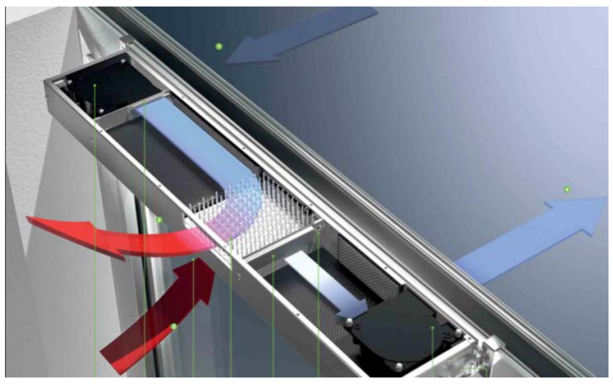
Case Study III: Chicago – Team 8

ADAPTIVE FACADES 2016 HAMBURG

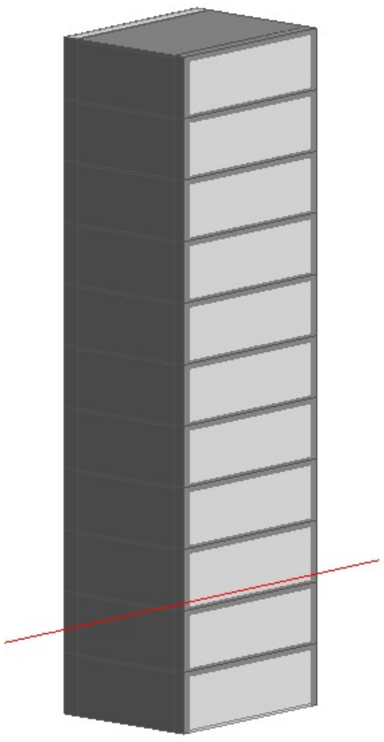
Bahar Basarir, Beatriz Campos, Jakub Curpek, Aliakbar Kamari, Vlad Silvestru, Asli Tugrul

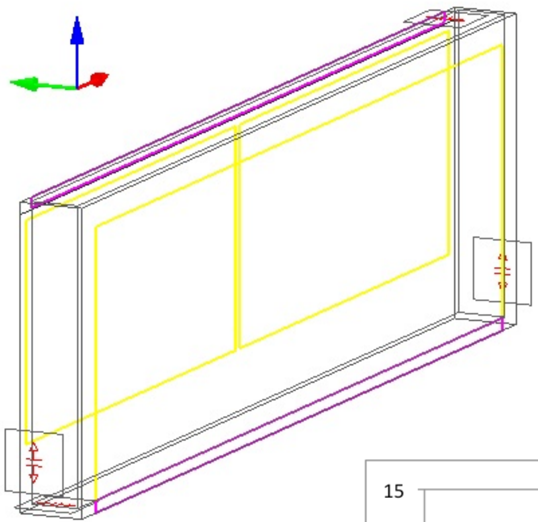
FACADE SYSTEM FOR WINTER



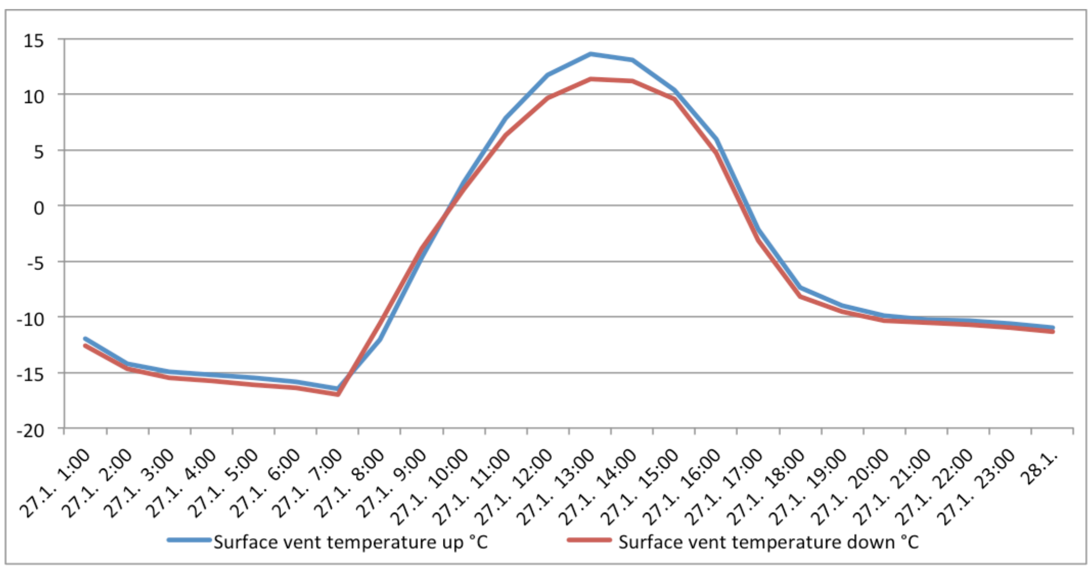


SIMULATION MODEL





DesignBuilder SOFTWARE



3.4. Awarded workgroups

Case Study I:

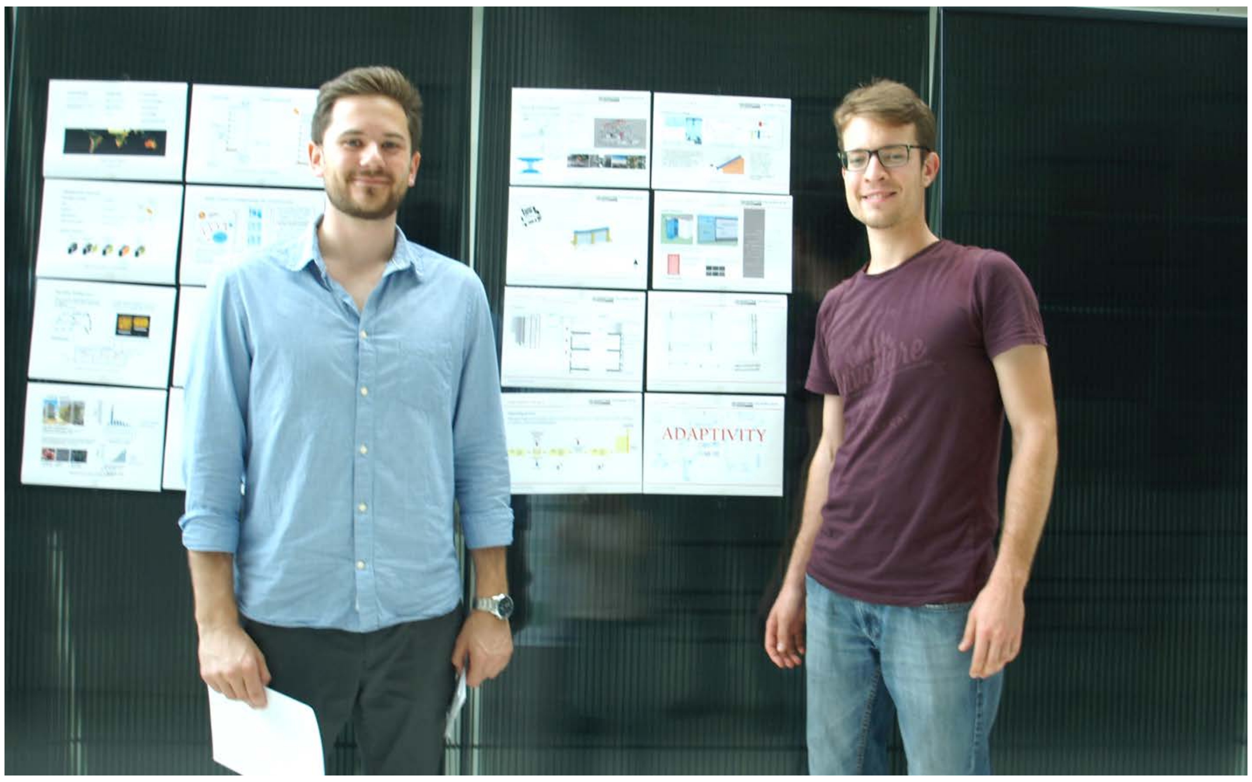
St. Petersburg

Team 5

Case Study II:

São Paulo

Team 4



Case Study III:

Chicago

Team 1

3.5. Experts committee

Prof. Dr.-Ing. Frank Wellershoff

Prof. Dr.-Ing. Wolfgang Willkomm

Prof. DSc. Lucila Chebel Labaki

Prof. Dr. Léa Cristina Lucas Souza

Dr.-Ing. Marcin Brzezicki

Dr. Luciana Oliveira Fernandes

Pictures of Training School

Miscellaneous

Picture 1: Teambuilding - BBQ Party at the terrace of HCU

Picture 2: Teambuilding - BBQ Party at the terrace of HCU

Picture 3: Excursion to IBA area in Hamburg visiting the case study houses for energy efficiency

Picture 4: Excursion to IBA Area in Hamburg visiting the Case Study houses for energy efficiency

Picture 5: Excursion to IBA Area in Hamburg visiting the case study houses for energy efficiency

Picture 6: Final presentation of workshop results in front of all participants and the Experts comittee