TERRE

Training Engineers and Researchers to Rethink geotechnical Engineering for a low carbon future

European Commission – Horizon 2020
Marie Skłodowska-Curie European Training Networks (ETN)

1st TERRE School

Sustainable architecture: the key role of facades

Antoine Dugué
adugue@nobatek.com

Agenda

1) **Context**

2) **Architectural point of view**

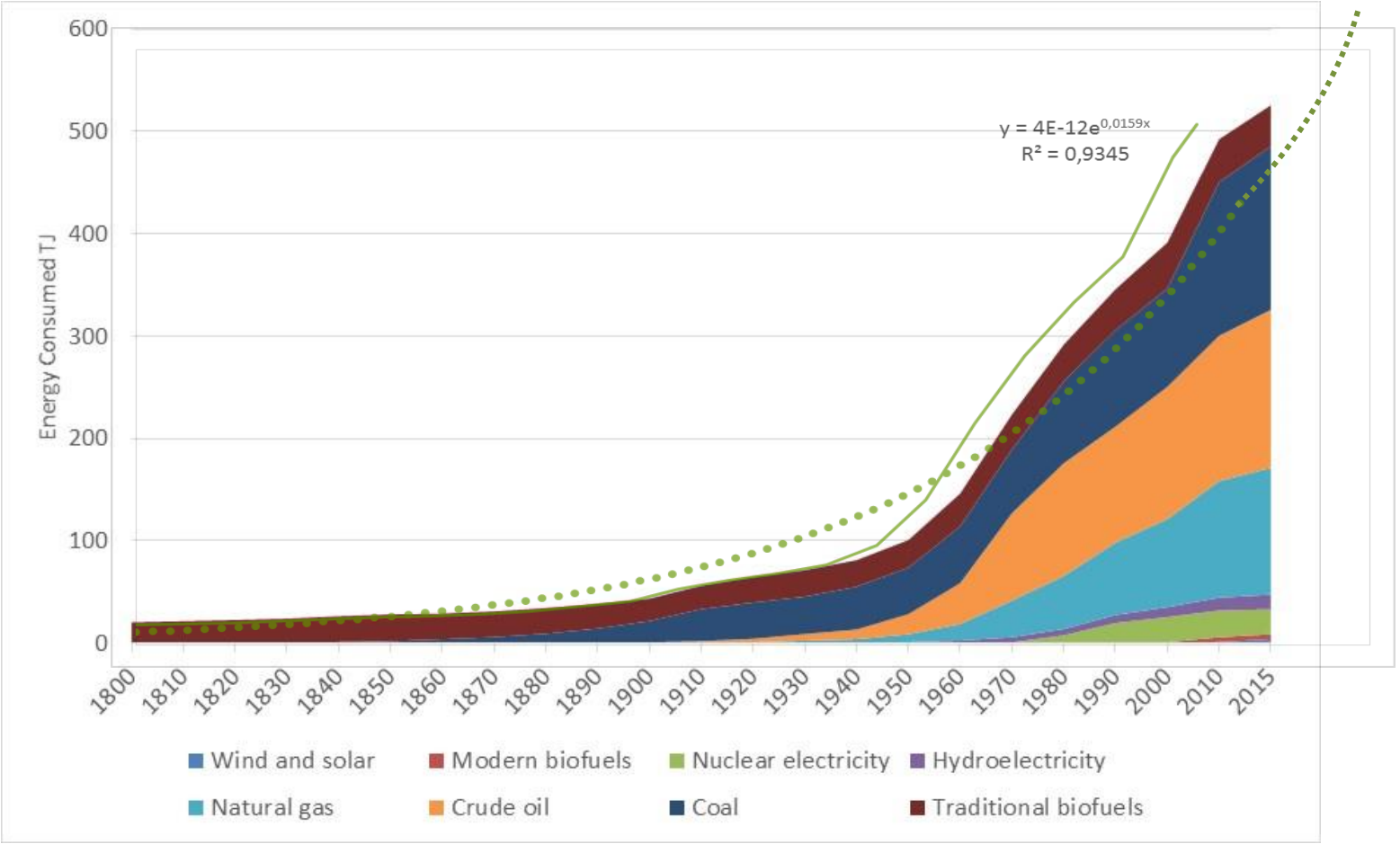
3) **Energy considerations**

4) **Tendencies**

5) **Examples**

CONTEXT

Context: energy consumption



Exponential law :
exp(0,0159*year+…)
so doubling every 40 years…

Evolution of primary energy consumption (extrapolation before 1960)
energy transitions : global and national perspectives. (V Simil 2017)

Context: energy consumption

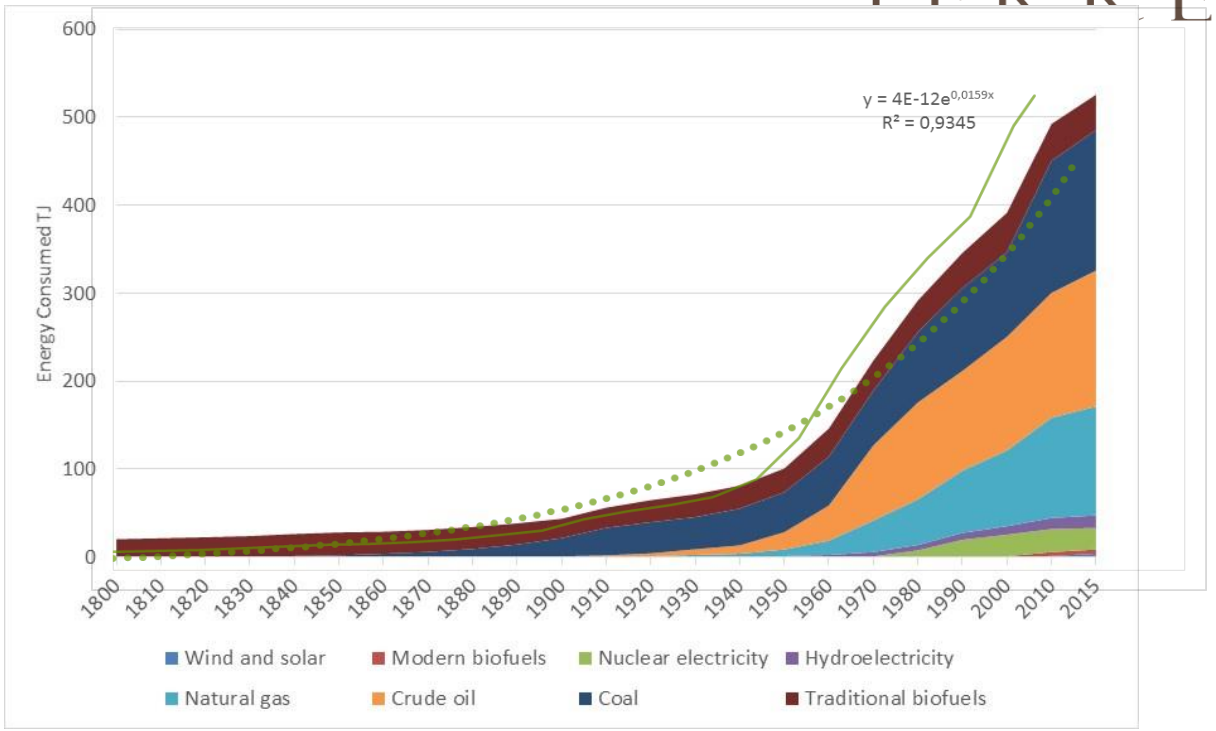
If we maintain this pace,

…

in 500 years, our energy consumption = the total power coming from the sun

…

And in 2500 years, the total energy coming from the sun…

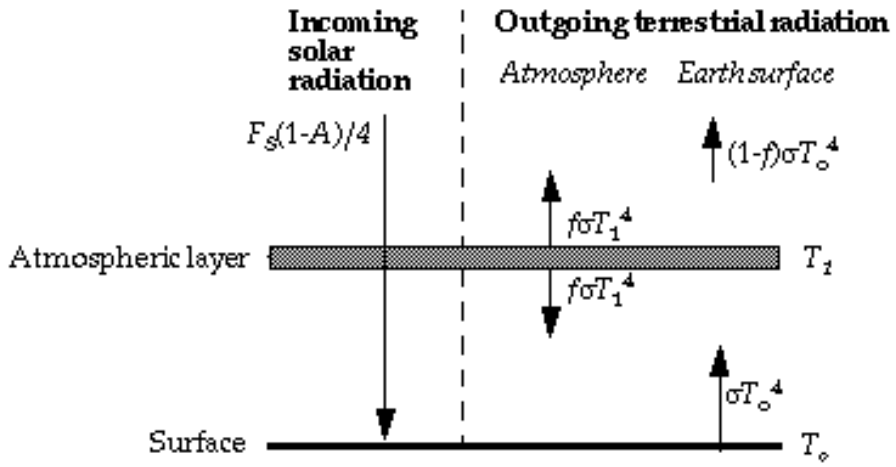


Context: energy consumption

As a corollary, with this hypothesis, the surface temperature of earth will rise.

Simple model using Stefan Boltzman law:

In 2000 the Tsurf would be 100°C !!!



Stefan Bolztamn law applied to energy balance on Earth Surface + Atmosphere

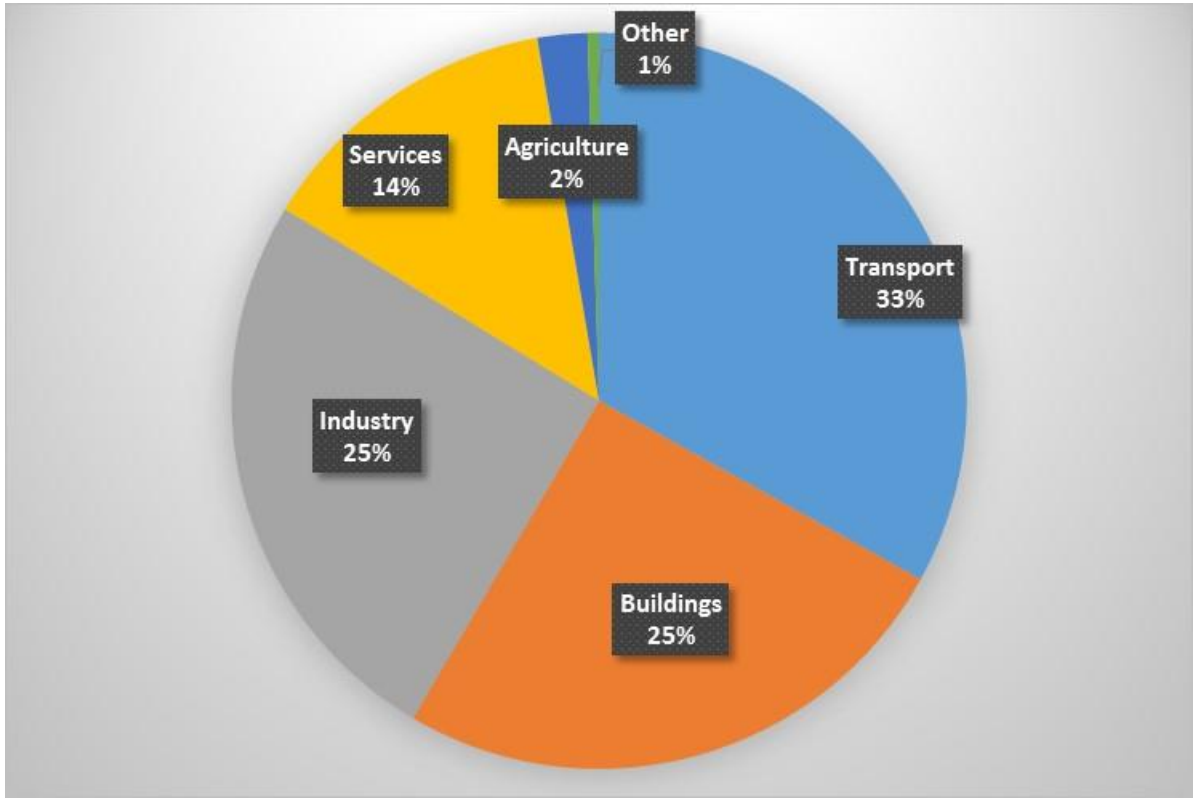
→ Not only a need to turn to renewable energy but also to drastically reduce our energy consumption

Through Efficiency but more importantly by not using it

Source: Tom Murphy blog « Do the math »

Context: energy consumption

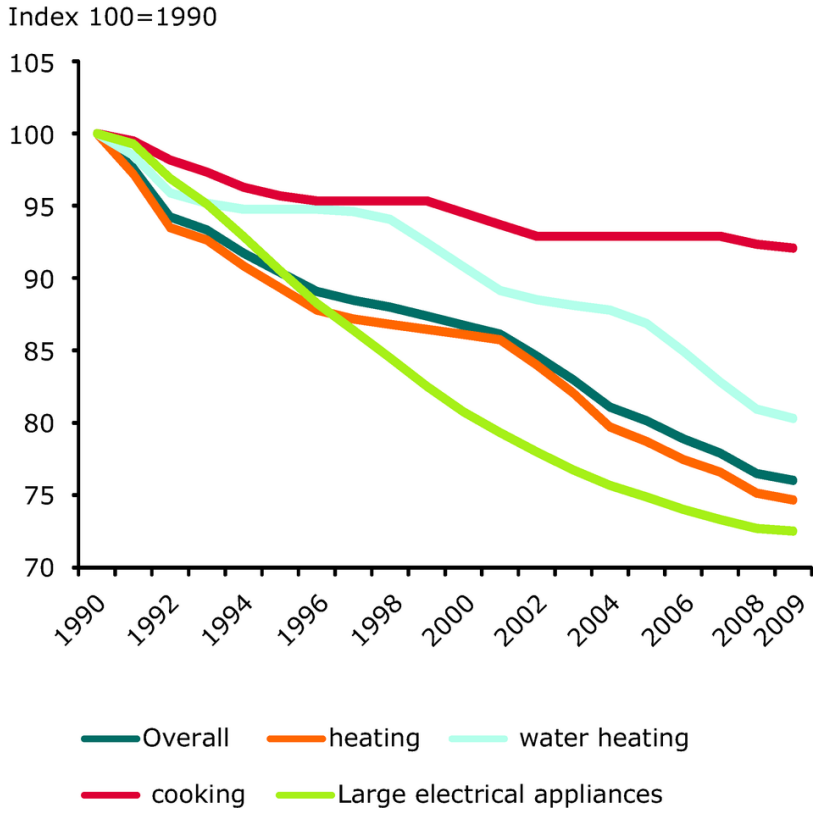
Final energy consumption, EU-28, 2015



http://ec.europa.eu/eurostat/statistics-explained/index.php/Consumption_of_energy

Context: energy consumption

Reduction for new buildings
(Partly due to high improvement in the envelop performance)



Source: ODYSESE MURE project

Reduction of energy consumption
Increase in energy independency
85% of the buildings in 2050 are already built

Huge stakes and ambitions:

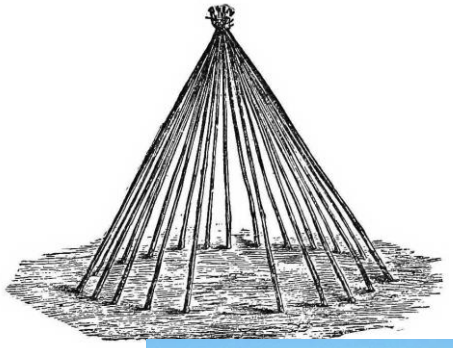
- Renovation of existing buildings
- Autonomous buildings / local grids

Architectural point of view

History of façade

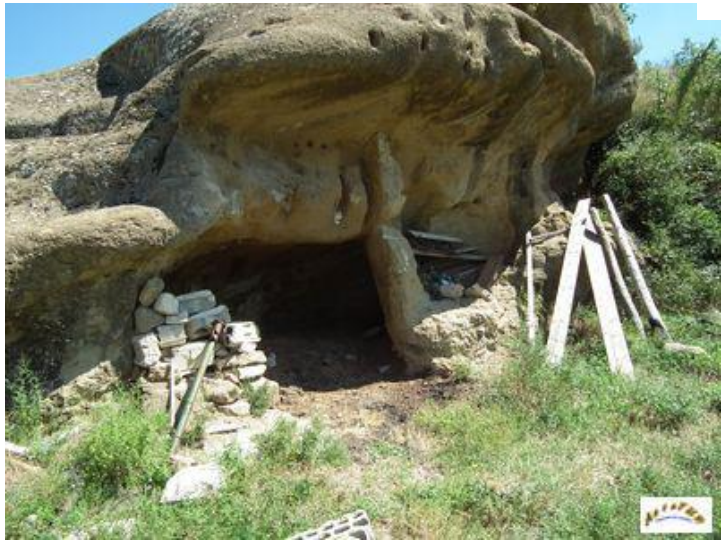
from

Provide a shelter



to

Provide a place where comfort is ensured while the environmental impact is limited



Rocher de Rocalineau, France

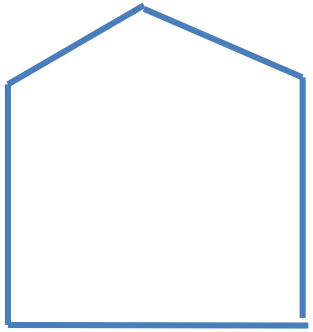
James Law's technosphere project

Definition of façade / envelope

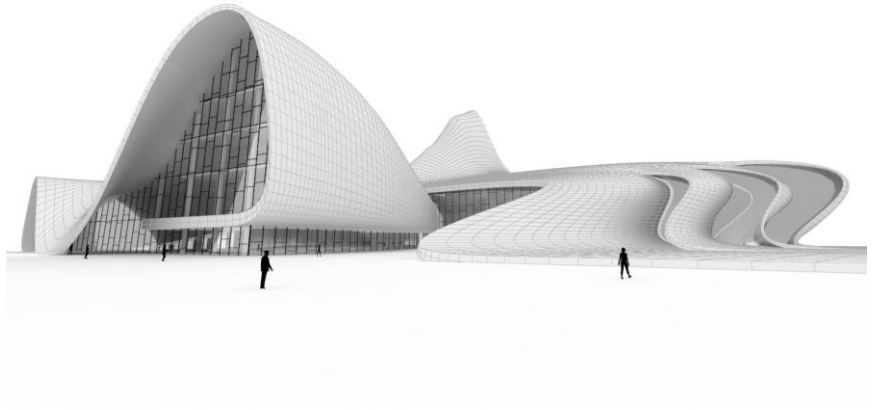
What is the façade ?

Delimit the household (*foyer*)

Interface between inside and outside.
Enclosure.



A volume: different layers and function: structural, protection



Architectural point of view: aesthetics

Façade as the architectural expression of the building:

- View from the inside, and from the outside
- For the building to express an idea

- Often presented as the last way for the architectural expression:
- Key element for an architectural competition

→ Less technical but key to understand modern architecture

Champagnes Piper & Charles Heidsieck building

Architectural point of view: aesthetics

Cité du Vin, Bordeaux. X-TU architecture

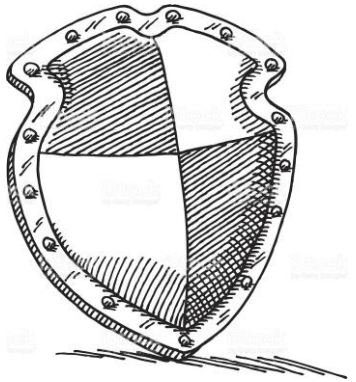
Architectural point of view: aesthetics

- But typical representation of houses is quite universal:

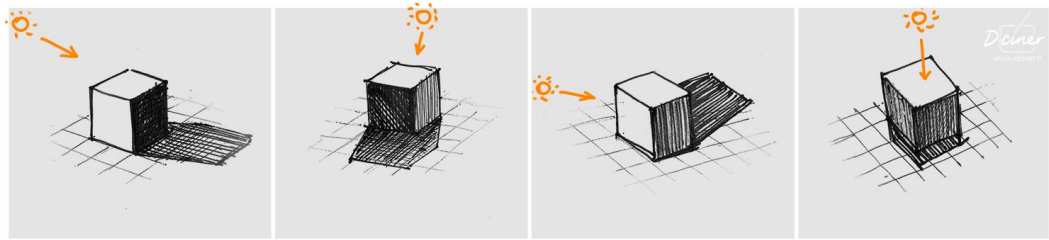
Normal children

Very skilled children

The different roles of the façade



- To « protect » from the outside:
  - Temperature variation, acoustic, water, fire, structural damages…
- To ensure the communication of the building (aesthetics)
- But also
  - To bring light
  - To manage solar gains
  - Possibly to integrate HVAC systems (BIPV…)



→ to protect from external solicitations while taking advantage of some

The different roles of the façade

- While respecting
  - Energy Regulations
  - Health regulations
  - Standards (structure, confort…)
  - Assurance authorization (DTU, ATEC)
  - Requirements and specifications as set by building owner

RÉGLEMENTATION THERMIQUE 2012

standards

regulations

ÉMISSIONS DANS L'AIR INTÉRIEUR

A+ A B C

NF BÂTIMENTS TERTIAIRES

DÉMARCHE HQE

breeam

Energy considerations

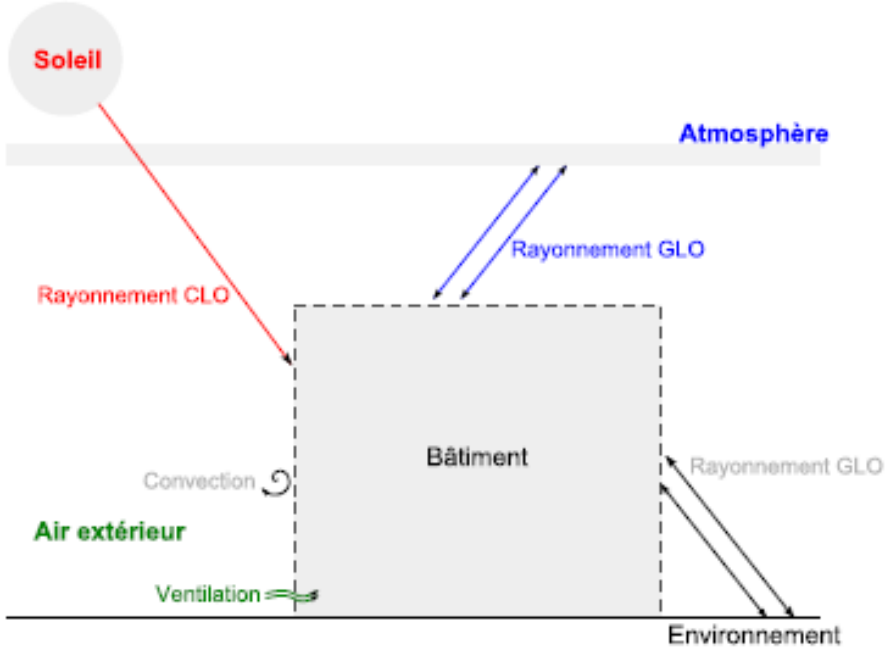
Different ressources

- The different energy sources:
  - sun
  - External air
  - Sky - atmosphere
  - Environment

- How to collect this potential energy ?

- concurrent: resource available when there is a need ?

→ Once collected, need to store it.



Représentation des interactions entre un bâtiment et son environnement. Extrait thèse Lou Chesné

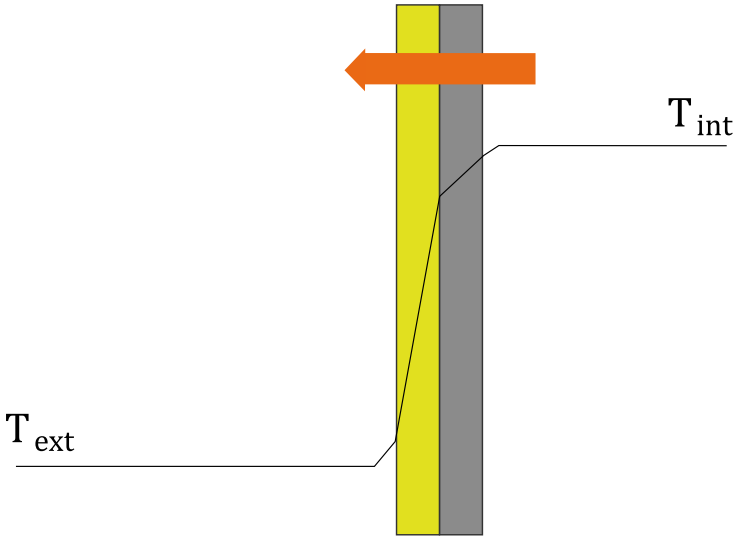
Energy considerations

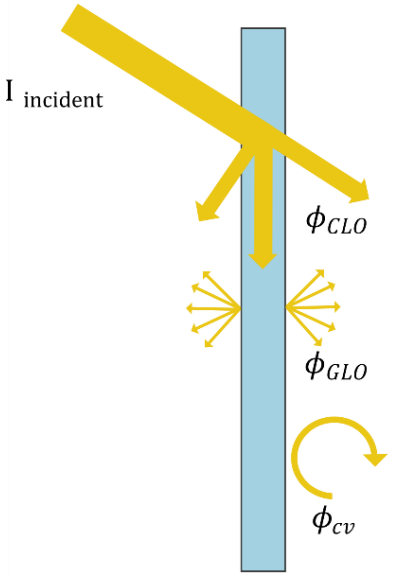
Objective for the envelope	Winter	Summer
Night	Minimize losses	Maximize losses
Day	Maximize gains	Minimize gains

- Currently, passive building as an objective
- But how can you answer to a dynamic problem with a static answer?
- How to have a high performance both in summer and winter ?

Basic heat transfer at the scale of the façade

- Basic characterization of a wall thermal behaviour performance





Solar factor

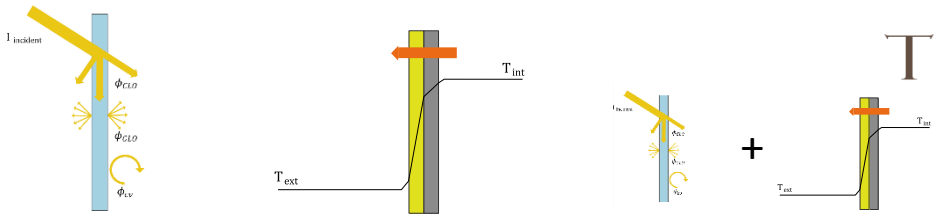
$$fs = \frac{\phi_{CLO} + \phi_{GLO} + \phi_{cv}}{I_{incident}}$$

Flux:

$$\emptyset_{heat\ loss} = U_w * (T_{ext} - T_{int}) * S$$

$$\emptyset_{solar\ gains} = fs * Ir * S$$

Toward dynamic walls



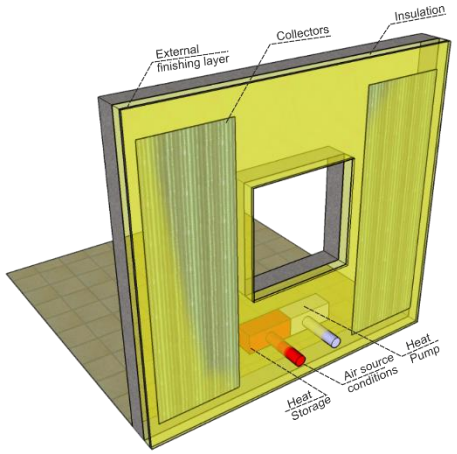
Enveloppe	U value (W/m².K)	Solar factor	Solar gains (Wh/m²)	Heat lossed through conduction-convection (Wh/m²)	Total (Wh/m²)
A) Opaque wall	0,4	0	0	-3917	-3917
B) Glazed surface orientated toward south	2	0,6	41880	-19589	22291
C) Glazed surface orientated toward west	2	0,6	16900	-19589	-2689
D) Smart façade, orientated toward south	if Ir=0 W/m², then 0,4 if not, 0	0,6	55840	-8667	47173

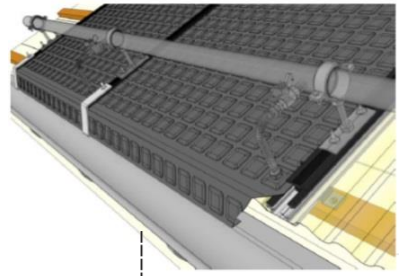
Energy considerations

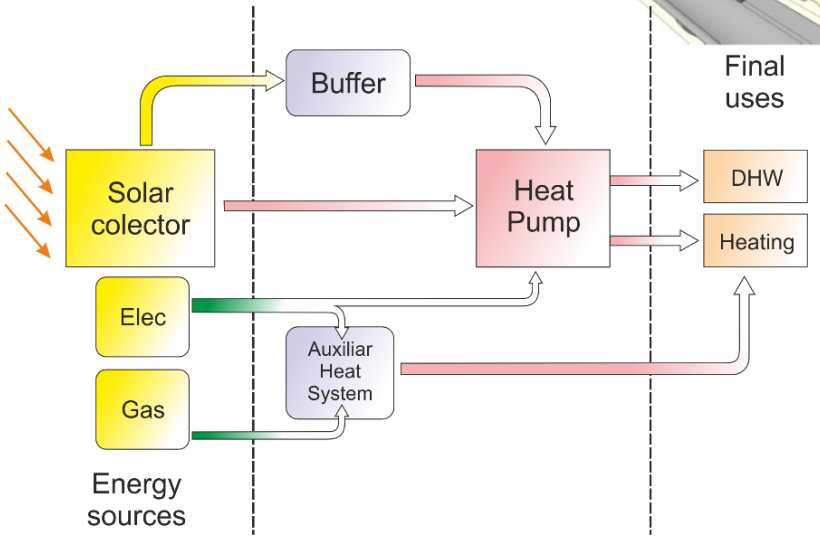
- Not only to limit the energy consumption, but also to transform renewable energy
  - To collect
  - To store
  - To distribute

  → toward autonomous buildings

- Not to consider the building on its own, but in its neighborhood
  - smartgrids
  - Demand response



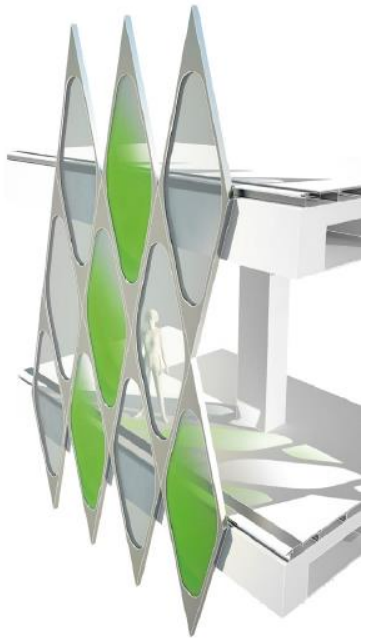




Tendencies

Materials
Renewable energy sources
Measurements and piloting
Conception tools
Bench test

New materials

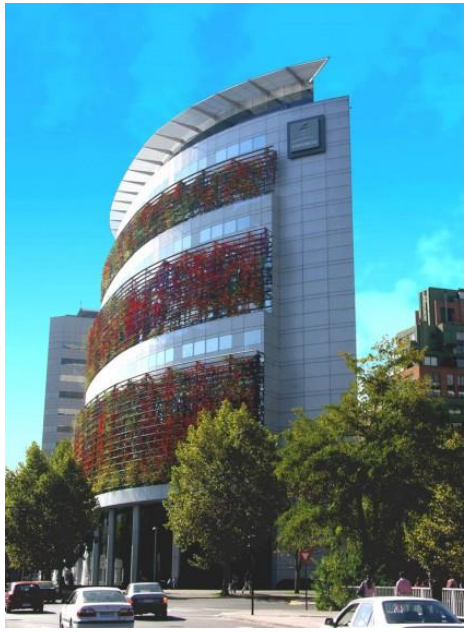


Algae in the façade. X-Tu, project

Consorcio building, Santiago, Chile, Architecte : E. Browne

Summer

Winter



New ways for manufacturing

- **New manufacturing capacity**

3d printing for new connectors

- **Prefabrication**:

Huge stakes, especially for the renovation of existing buildings

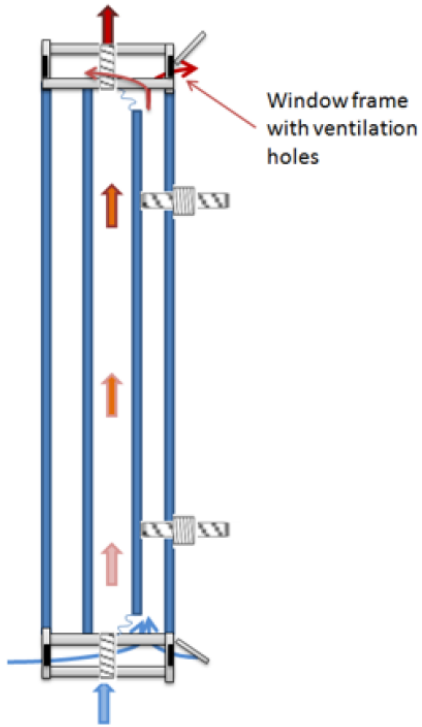
Rénovation R+15 in Grenoble by Techniwood

Passive dynamic systems in façade

Pavillon Corée du Sud. Expo Univ 2012

Dynamic system that opens with the external relative humidity

Solar captors integrated in façade.



Passive dynamic systems in façade

Facade with solar shading device that expand when there is sun. Powered by PV cells

Concept by Julian Eberhart & David Gautrand I Technische Universität München

Passive dynamic systems in façade

- Specific opening for natural ventilation

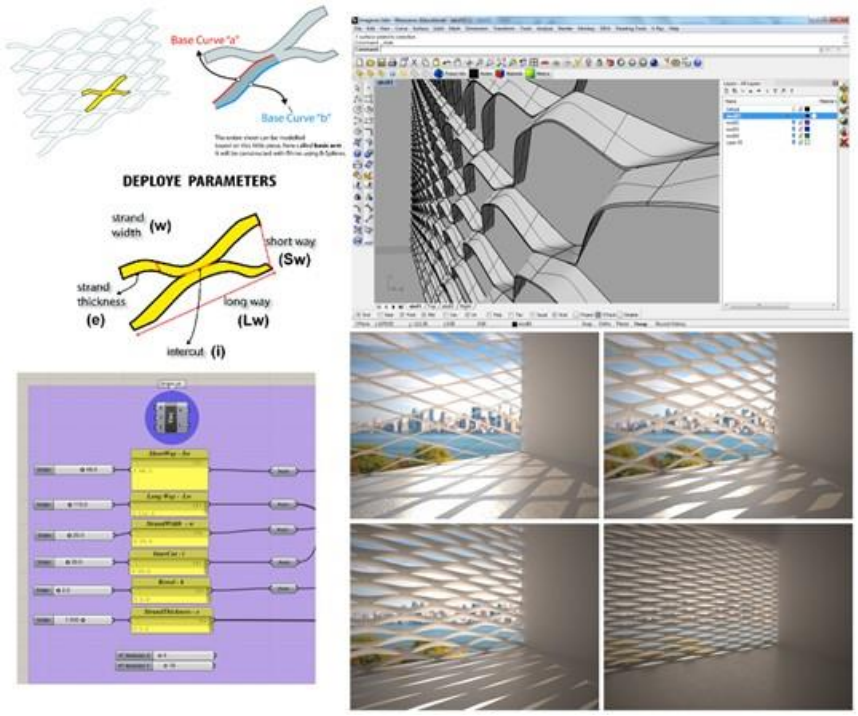
Sensors and piloting

- Autonomous sensors

Projet de recherche Tecnalia

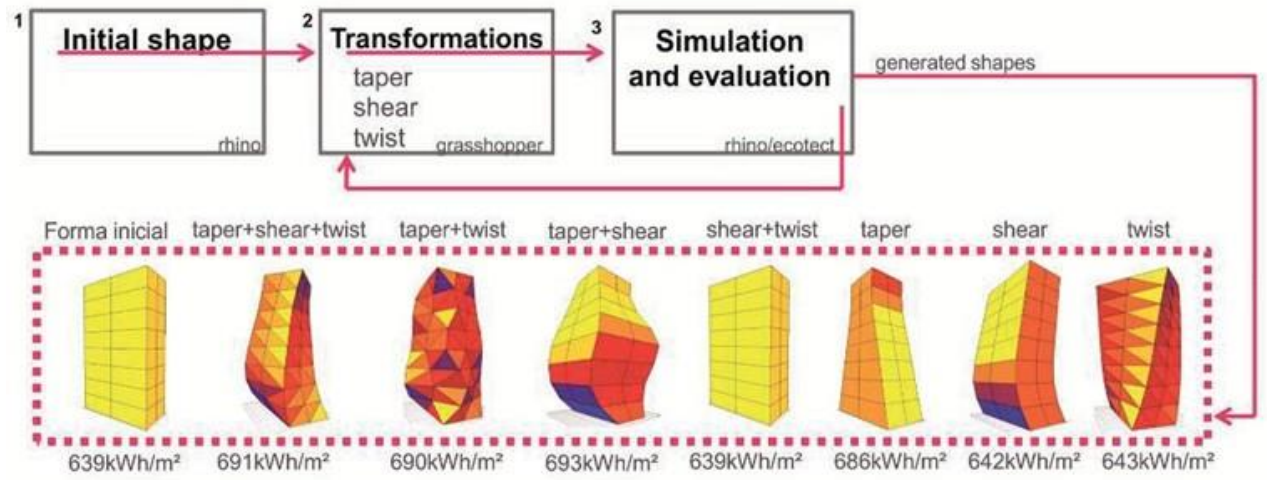
New tools for design helping

- Parametric design coding and generation



Metal déployé. Jose Miguel Martinez Thesis

Coupling with optimization models



Virginia Vanini

Tendancies: test bench for evaluation

Cellules FCBA (Bordeaux, 2000)

Kubik de Tecnalia (Bilbao)

Réseau cellules Passys (Chambéry, 1988)

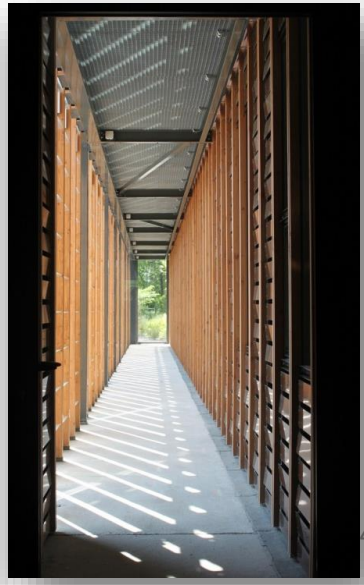
BestLAB de EDF (Moret sur Loing, 2009)

BEF de Nobatek (Anglet, 2015)

Example of few projects

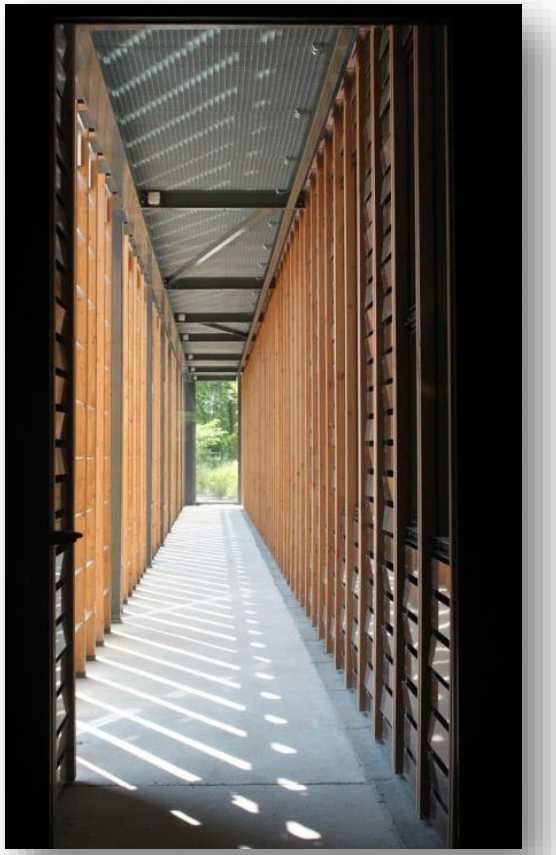
Office 64, Bayonne

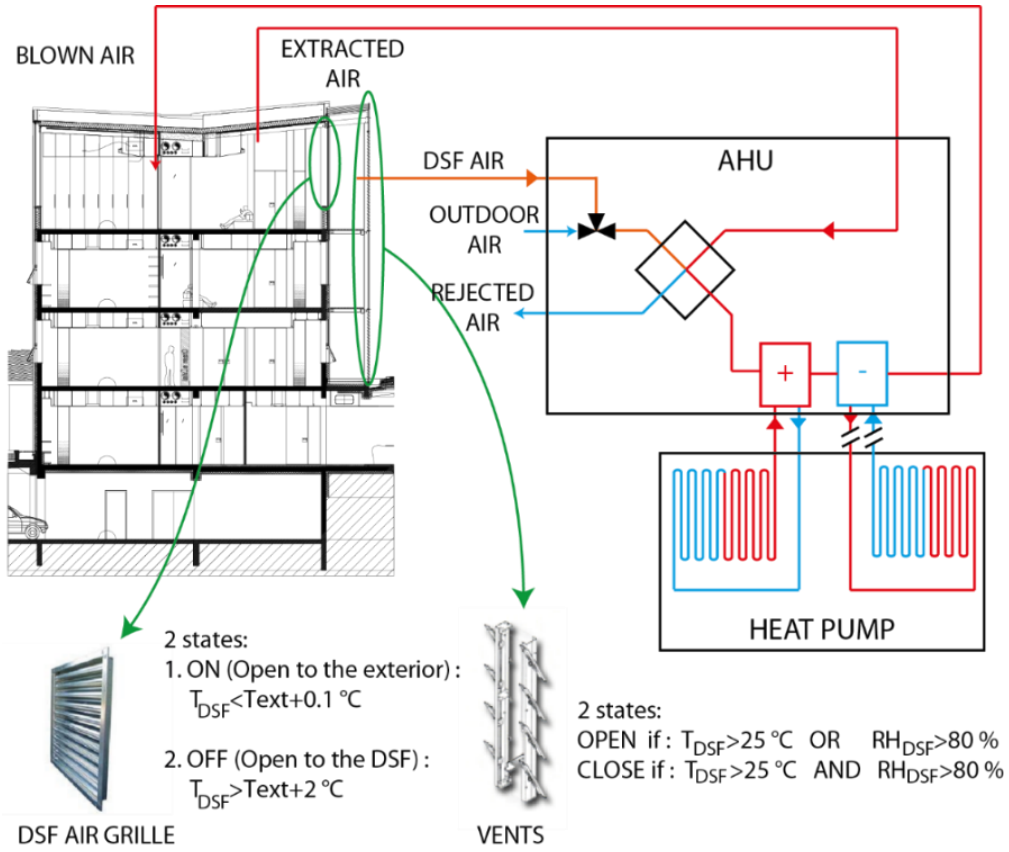
- New building with a double glazing façade



Office 64, Bayonne

- In winter, use of the hot air in the double skin to preheat the new air for the building





Opération campus, Bordeaux

- Bordeaux University

Opération campus, Bordeaux

- ***Conception :*** *AUA Paul Chemetov, Agence Debarre-Duplantiers, ECCTA, Franck Boutte Consultants*
- ***Réalisation :*** *Bouygues Construction*

Etudes et Travaux : 95,7 M€ (HT)

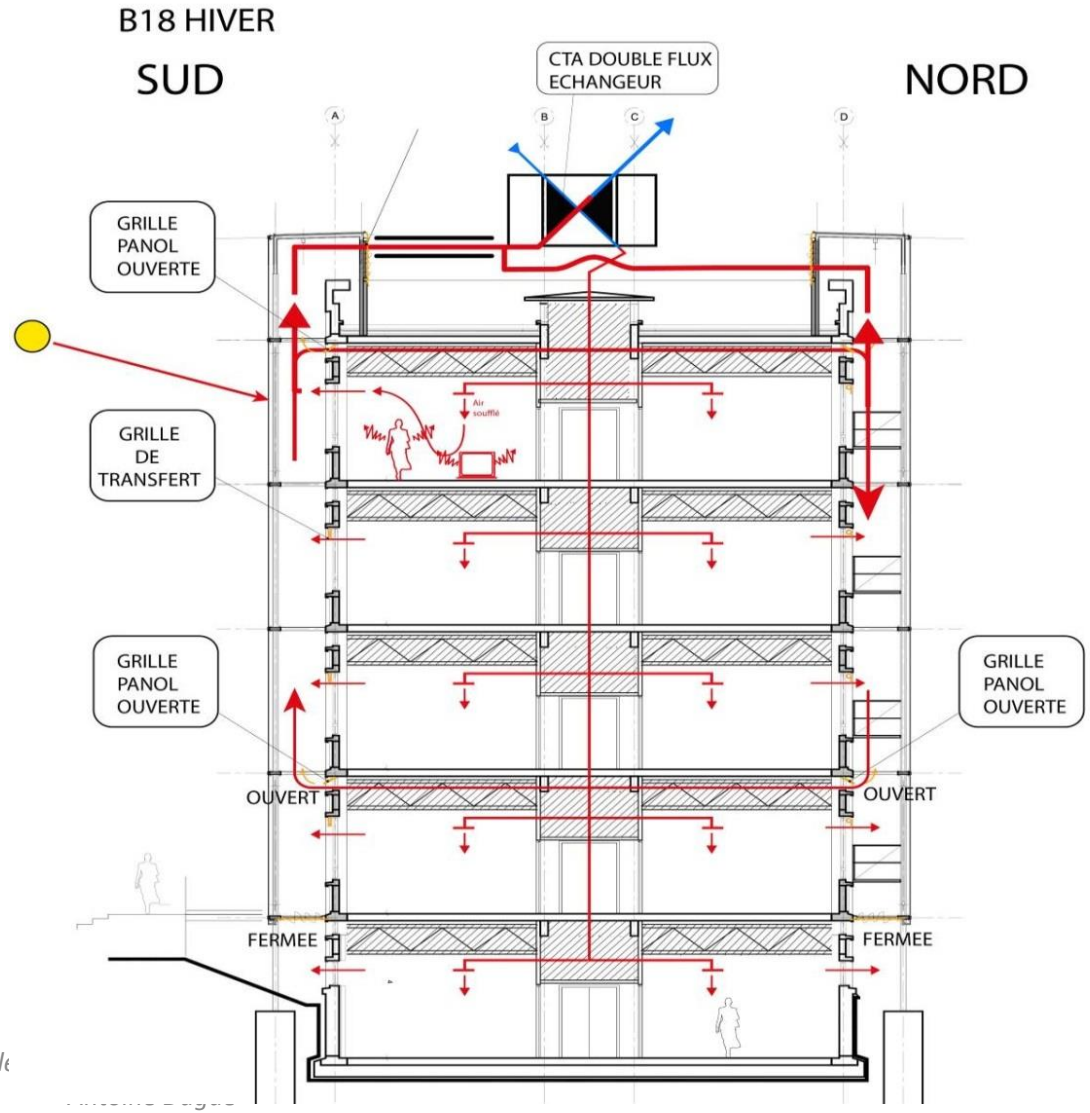
Maintenance : 13,3 M€ (HT)

GER : 12,4 M€ (HT)

Total : 121, 4 M€ (HT)

Opération campus, Bordeaux

Functioning in winter

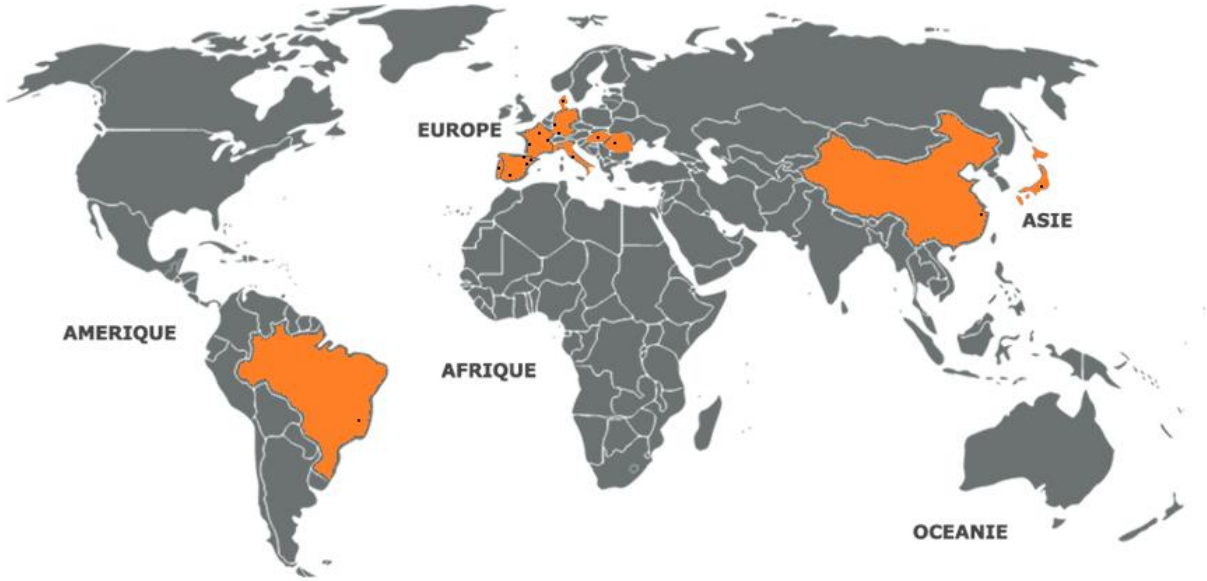


Opération campus, Bordeaux

Solar Decathlon, World

- International student competition originated from the US
- Prototypes designed, brougth and assembled for a 3 weeks competition
- To showcase new technologies
- 10 events/tests with rankings

Architecture	Architecture	120	200
	Engineering & Construction	80	
Energy	Energy Efficiency	100	220
	Electrical Energy Balance	120	
Comfort	Comfort Conditions	120	240
	House Functioning	120	
Social Economic	Communication & Social Awareness	80	160
	Industrialization & Market Viability	80	
Strategic	Innovation	80	180
	Sustainability	100	



Solar Decathlon, World

Solar Decathlon, World

Solar Decathlon, Focus Patio 2.12 : Sevilla, Spain

House with
4 modules

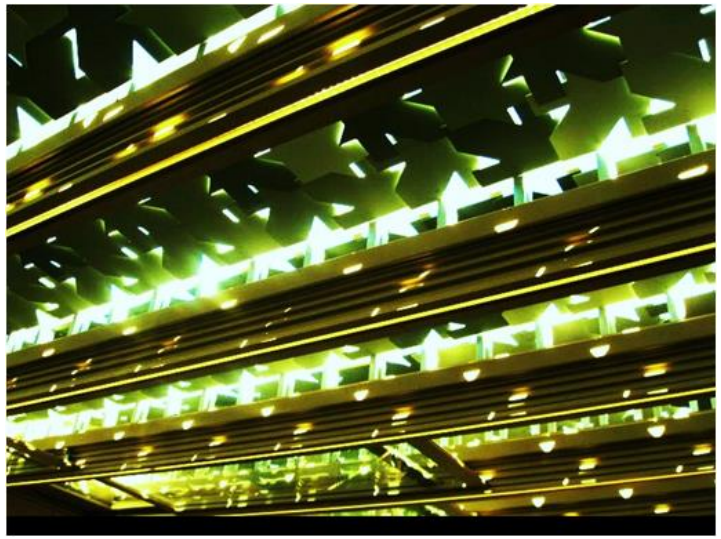
Assembling with 3d modules

Solar Decathlon, Focus Patio 2.12 : Sevilla, Spain

Botijo

Walls covered with a ceramic cladding in front of a ventilated cavity
Water is pulverized to the wall to cool it dows (evaporation).

Triple glazing with a dynamic metallic solar shading as leaves.



E2VENT module

42 Months project

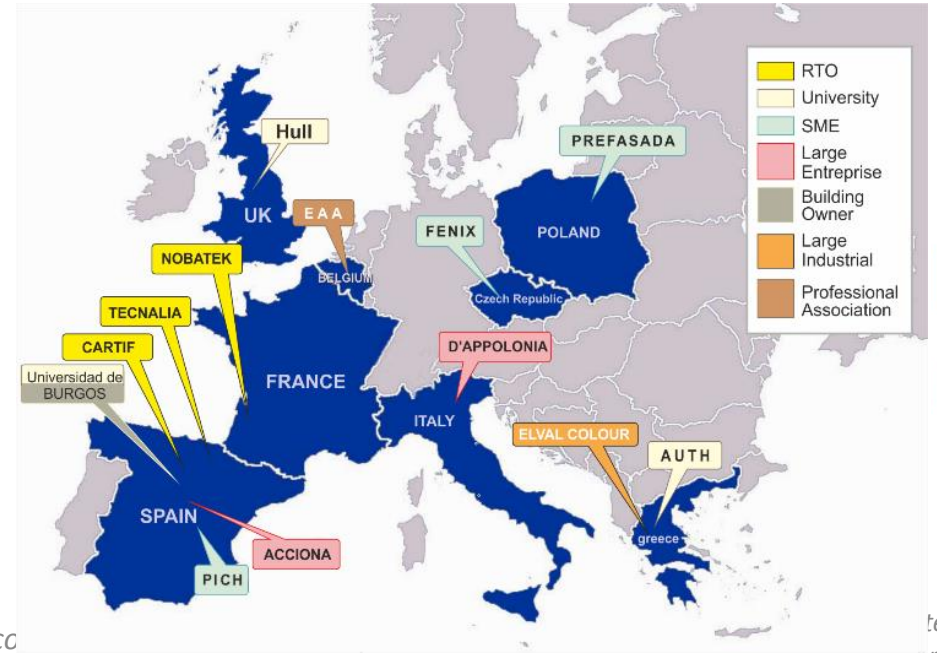
13 Partners

7 Work packages

3,4 € Million budget

Call EeB2014-Topic2-H2020: Adaptable envelopes integrated in building refurbishment projects

E2VENT main goal is the development of an energy efficient ventilated façade retrofitting system designed for an optimal and adaptable refurbishment of existing buildings.

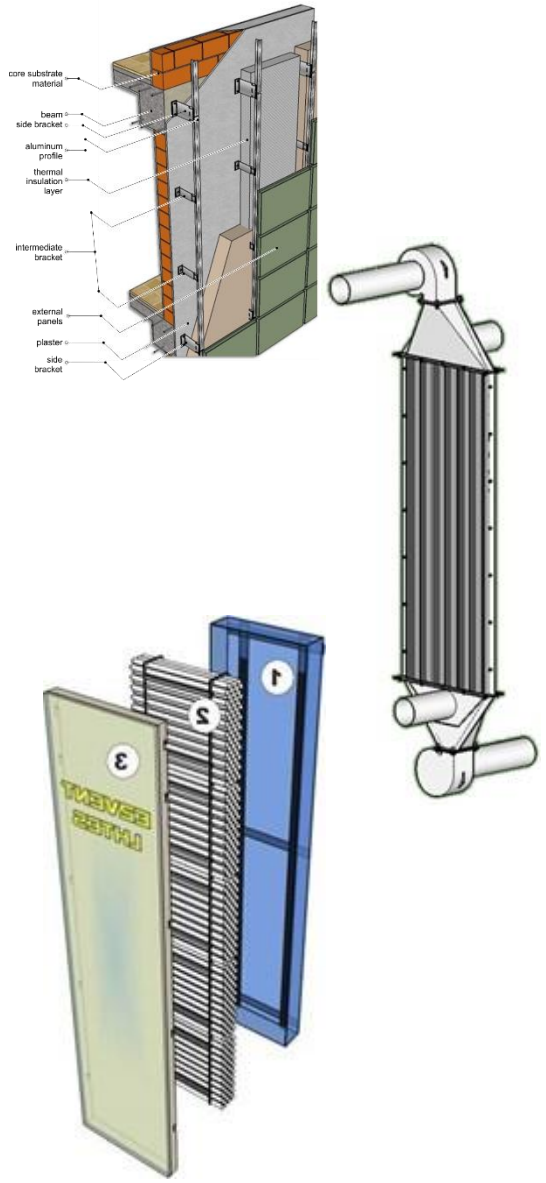


E2VENT module

- We consider the 60's – 80's multi storey residential building stock characterized by:
  - High energy loss through the envelope
  - Bad Indoor Air Quality (no mechanical air renewal)
  - Poor aesthetics

E2VENT module

- The E2VENT system is an external thermal refurbishment solutions with external cladding and air cavity embedding:



✓ **Smart Modular Heat Recovery Unit:** for air renewal with a double heat exchanger

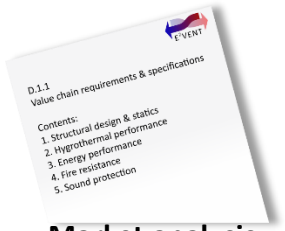
✓ **Latent Heat Thermal Energy Storage:** based on phase change materials, for heating and cooling for peak shaving

✓ A building energy management system that controls the systems

Systems: methodology for conception

1. Definition of requirements & specification

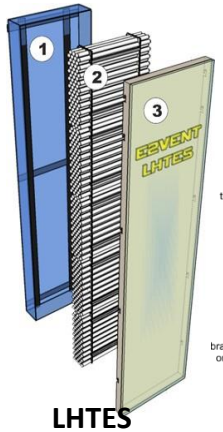
Questionnaires



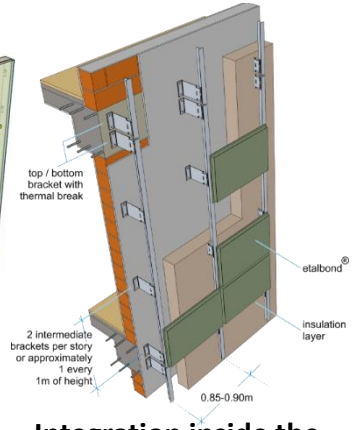
Market analysis

Specification report

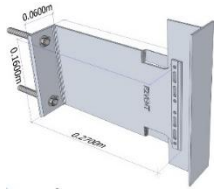
2. Designs of the elements composing the system



LHTES



Integration inside the cladding air cavity



anchoring

3. Prototypes

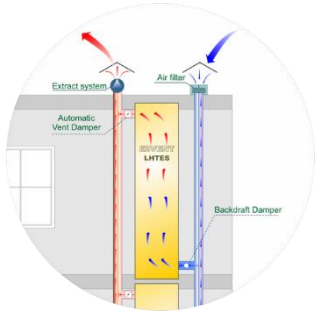
Prototype v1

4. Testing in laboratory

Systems: methodology for conception

5. Overall design of the E2VENT module and its integration in the façade

Façade view

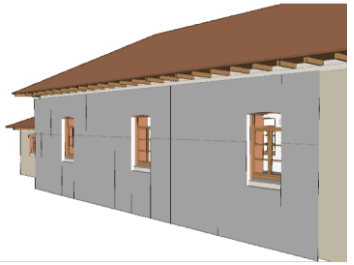


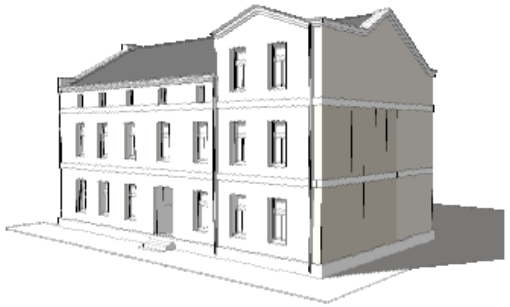
In/Outlet

6. Installation and testings on the test bench

Real scale test bench

7. Design & renovation plan for the pilots building





Demo-site: Burgos, Spain

Demo-site: Gdansk, Poland

49

OVERALL CONCLUSION

Conclusions

Why is it so difficult ?

- People in it : confort, psychology, subjectivity of the acceptance
- Physics, simple, but a lot: mechanical, acoustic, energy, environmental analysis
- Cost aspect remains key
- Artistic aspect: (almost) all different buildings

But those are also the reasons why it makes it interesting ☺

Questions?

Antoine Dugué
adugue@Nobatek.com