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# Integration of Solar Systems in Building Envelopes

Politecnico di Torino. Faculty of Engineering

Master of Building Engineering



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# Tecnalia. Building Envelopes & Energy in the Built Environment Groups



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# Tecnalia

- Benchmark Research and Technological Development Centre in Europe, with 1,472 experts of 31 nationalities, oriented towards transforming technology into GDP to improve People's quality of life, creating business opportunities in Companies.
- 1st private organisation in Spain in project contracting, participation and leadership under the EU Horizon 2020 Programme.

**Laboratory**  
Services

**R&D and Innovation**  
Projects

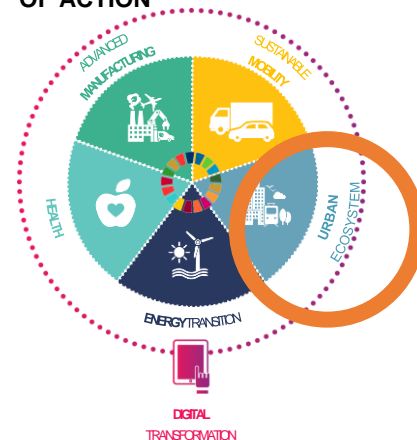
Development of  
**Investment Opportunities**

**> 7.800 CLIENT COMPANIES**  
(2011 - 2020)

<b>75%</b>	<b>25%</b>
<b>SMEs</b>	<b>Large companies</b>



## SCOPES OF ACTION





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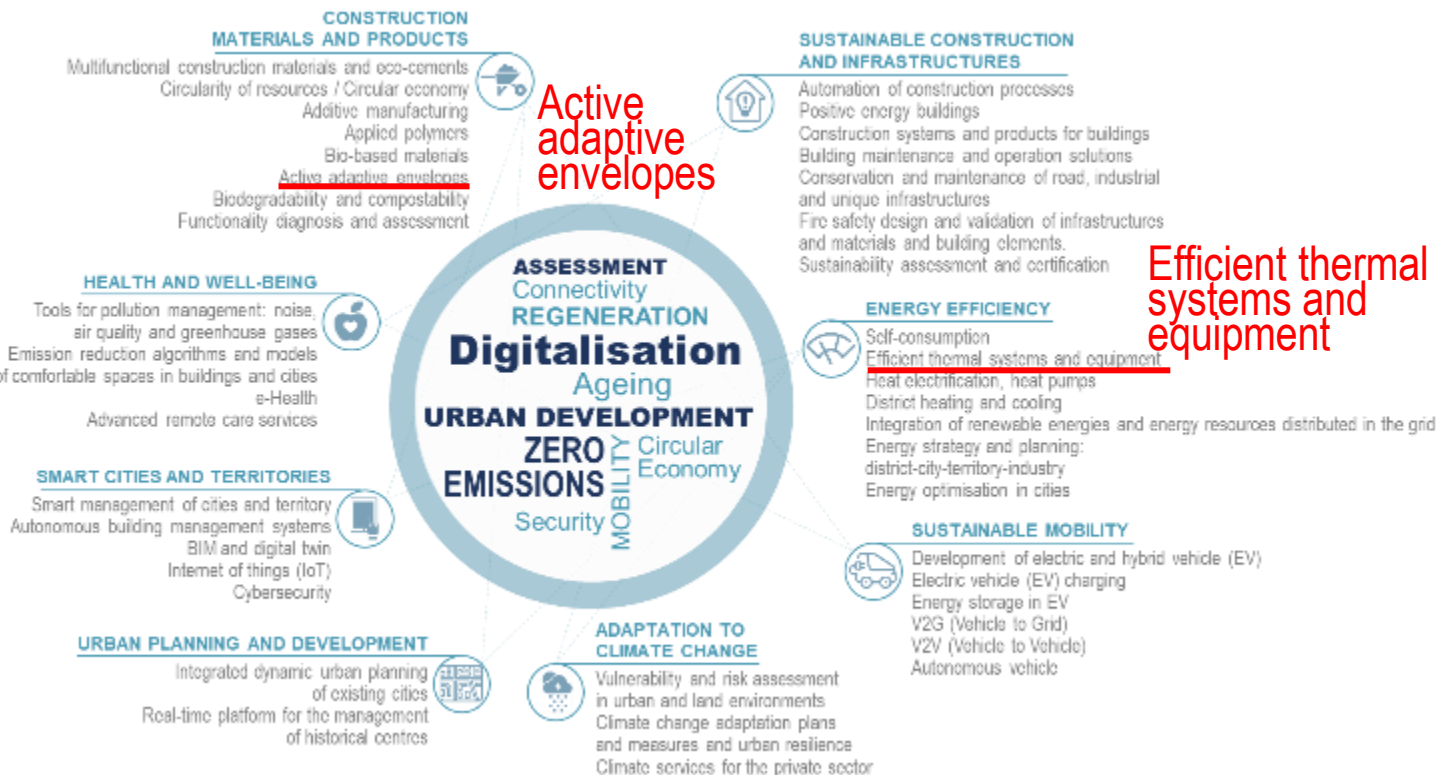
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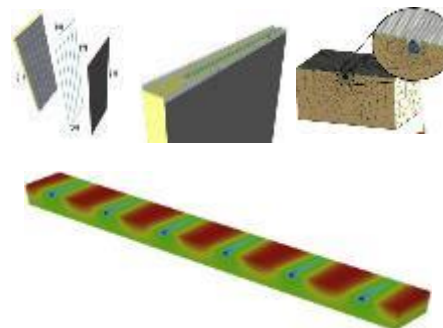
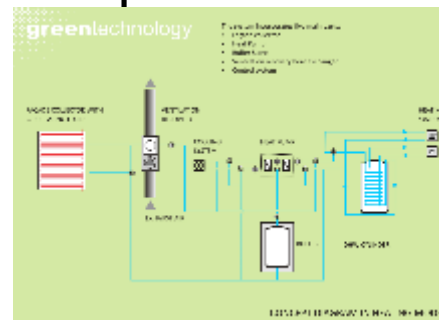
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The research leading to the results reported in this work has received funding from the European Union, RFCS Program, Research Fund for Coal and Steel project Building Active Steel Skin (BASSE, Grant Agreement no RFSR-CT-2013-00026).



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# Building Envelopes Group







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# Building Envelopes Group

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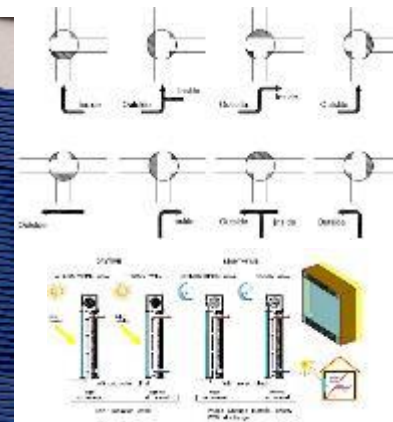
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This study has been financially supported by the E.C. in the frame of the FP7 project 'MeeFS: Multifunctional Energy Efficient Façade System for Building Retrofitting' (EeB.NMP.2011-3, Grant No.285411).



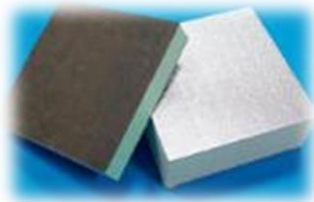


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# Energy in the Built Environment Group



<https://cordis.europa.eu/project/id/285091/es>





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# Energy in the Built Environment Group



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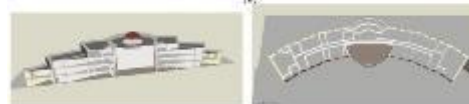
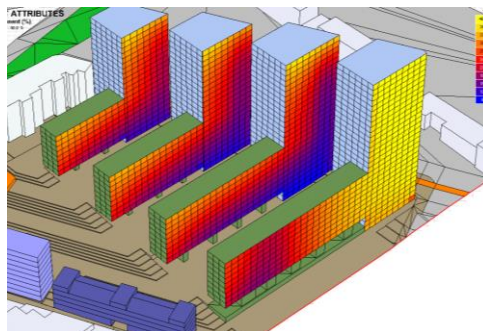


# Energy in the Built Environment Group

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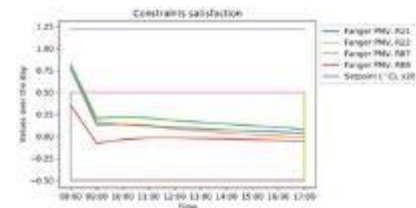
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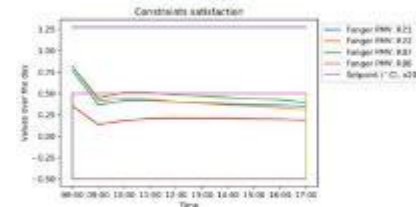


(c)

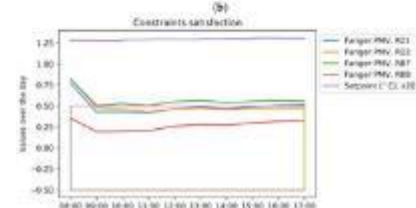
(d)



(a)



(b)



(c)



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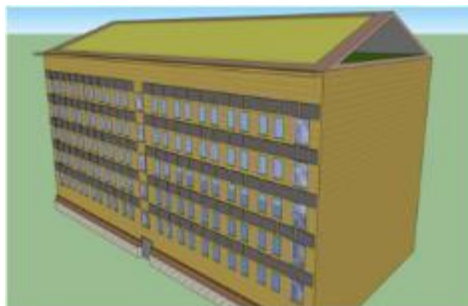
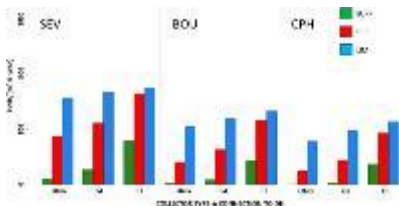
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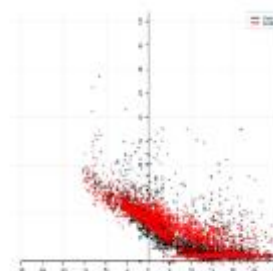
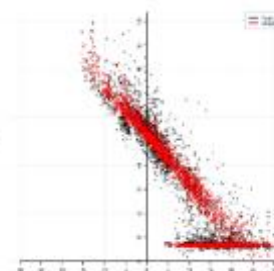
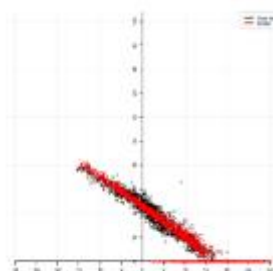
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# Kubik by Tecnalia Research Facility

Research Facility for the testing of concepts and systems for the  
Energy Efficient Building  
Operative since 2010





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# Kubik by Tecnia Research Facility

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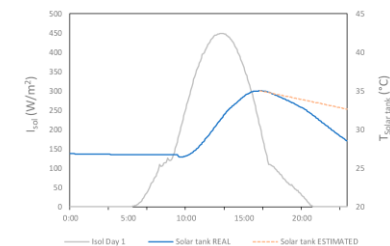
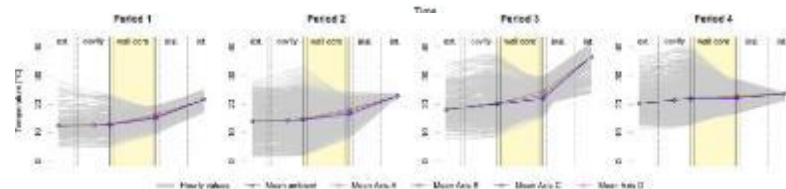
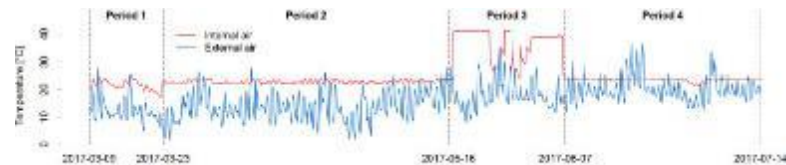
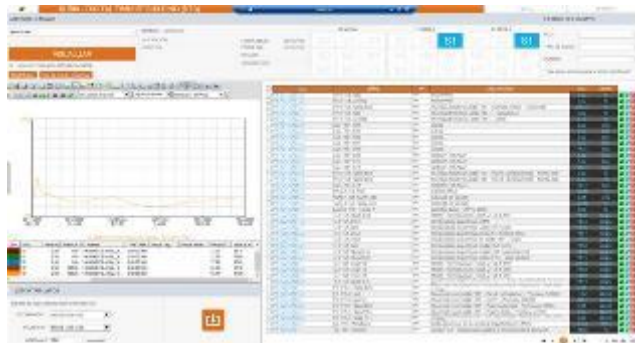
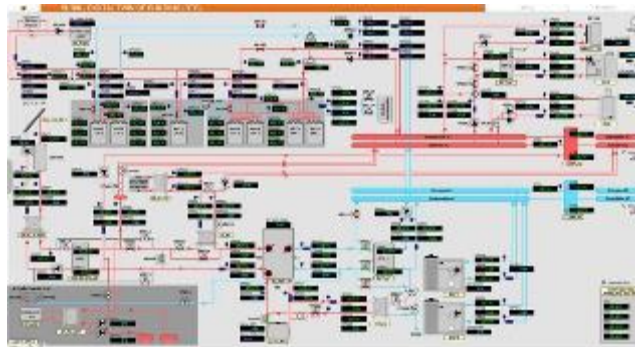
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# Dr. Roberto GARAY MARTINEZ, PhD

Lead Researcher in Building Physics and Project Manager at Tecnalia.

Expert in experimental procedures for building physics and solar systems. Staff member of the KUBIK test facility since 2011. External consultant for the development of facilities & experimental processes in several countries.

“Certified Energy Manager” (CEM), “Certified Energy Auditor” (CEA) and “Certified Measurement & Verification Professional” (CMVP) by the US Association of Energy Engineers (AEE).

Co-author of many Journal Papers (12, 6 High Impact), conference papers (>40), books (3), patents (3) and IEA & CEN reports (3).

Occasional Guest lecturer (POLITO, 2021 & 2022 ☺)

**Has participated in the development of many building envelope systems, in a multidisciplinary environment, leading to 3 patent applications (1 granted, 2 pending).**

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# Overview. Building Integrated Solar Systems



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# Technologies

- Two main technologies
  - Photo Voltaic Systems: Solar Energy is transformed into (DC) electricity



**Photovoltaics (PV)** is the conversion of light into electricity using **semiconducting materials** that exhibit the **photovoltaic effect**, a phenomenon studied in **physics**, **photochemistry**, and **electrochemistry**. The photovoltaic effect is commercially utilized for electricity generation and as **photosensors**.



- Solar Thermal Systems: Solar Energy is transformed into heat



**Solar thermal energy (STE)** is a form of energy and a **technology** for harnessing **solar energy** to generate **thermal energy** for use in **industry**, and in the residential and commercial sectors.





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# Technologies

- Potentialities & limitations for building integration
  - Photo Voltaic Systems
    - Electric is the most common source of Energy for household & office appliances
    - Energy balance (production-consumption = 0) needs to be met continuously
      - Batteries
      - (Regulated) Connection to network
        - Excess production can be exported
  - Solar Thermal Systems
    - Basic technology
    - Allows for storage
    - There is a relevant mismatch between Solar heat & heat loads in buildings
    - Isolated systems
      - Excess production can NOT be exported\*





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# History

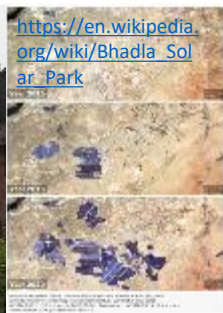
- Photo Voltaic Systems



Telstar 1, 1962

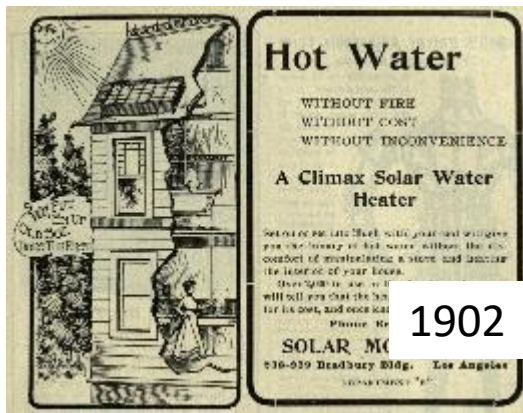


<https://commons.wikimedia.org/wiki/File:SolarFachwerkhaus.jpg>



[https://en.wikipedia.org/wiki/Bhadla\\_Solar\\_Park](https://en.wikipedia.org/wiki/Bhadla_Solar_Park)

- Solar Thermal Systems



1902



[https://en.wikipedia.org/wiki/Solar\\_water\\_heating#/media/File:Solarbiller.jpg](https://en.wikipedia.org/wiki/Solar_water_heating#/media/File:Solarbiller.jpg)





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# Modern Systems

- Photo Voltaic Systems



- Solar Thermal Systems





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# Building Integrated Systems

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- Photo Voltaic Systems



- Solar Thermal Systems





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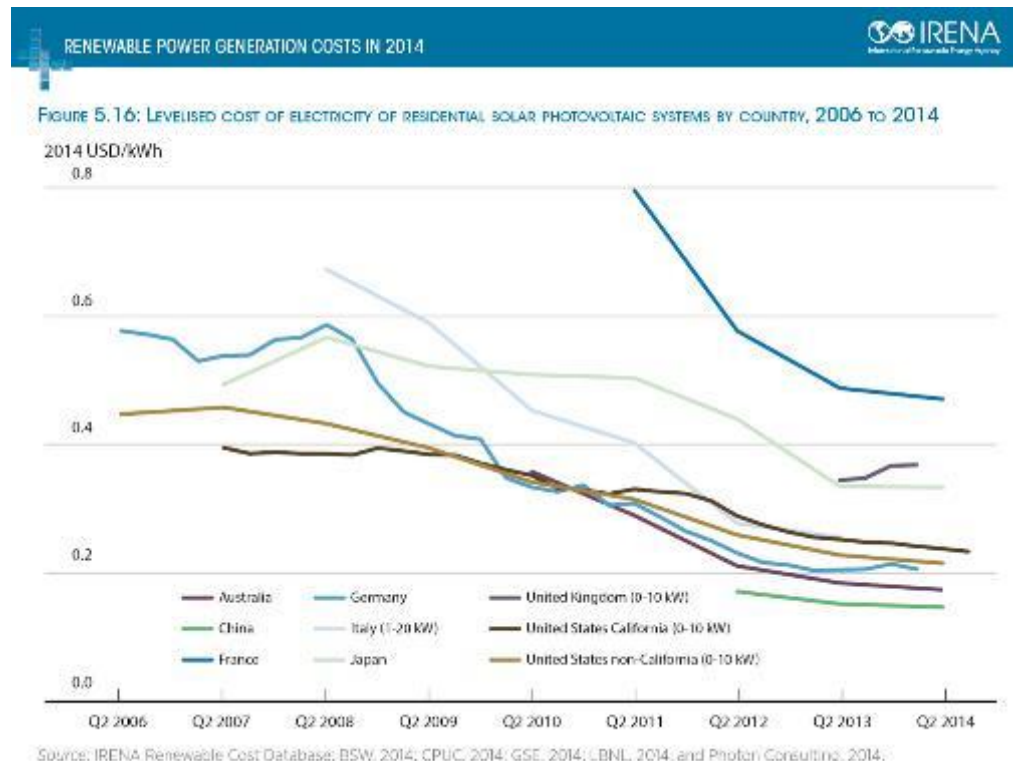
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# Price Evolution

- Photo Voltaic Systems





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# Challenges

- Architectural
  - Aesthetic Integration
  - Adaptation to existing geometry \*\*
  - Size adaptations
  - Piping \*
  - Space for technical rooms \*/\*\*
  - Connection with building services \*/\*\*
- Technical
  - Partial shading
  - Frosting / Boiling \*
  - Heat loss \*
- Maintenance
  - Availability of supplies for replacement
  - Access to pipework \*

\* Solar Thermal

\*\* Renovation



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# Challenges

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# Challenges





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# Challenges







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# Challenges





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# Technologies



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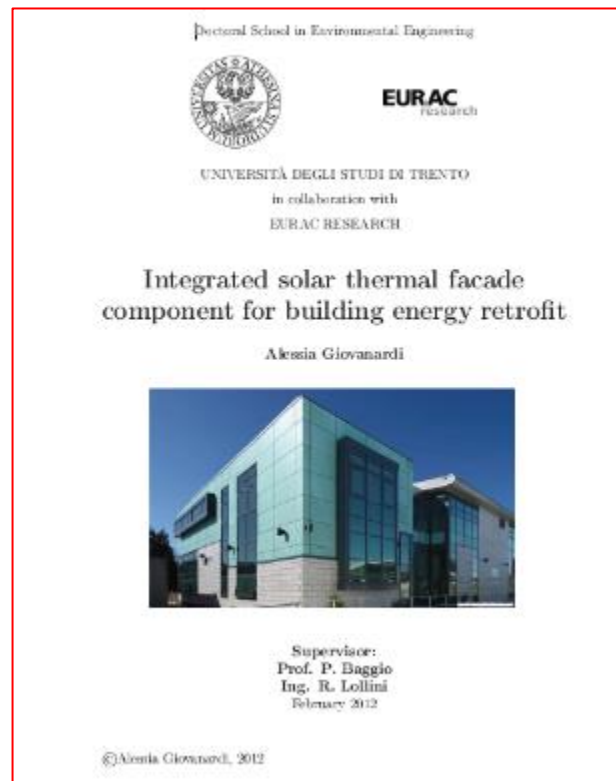
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# Solar Thermal Technologies

- Evacuated tubes
- Parabolic concentrators (Out of scope)
- Flat plate
- Unglazed flat plate



<http://eprints-phd.biblio.unitn.it/782/>



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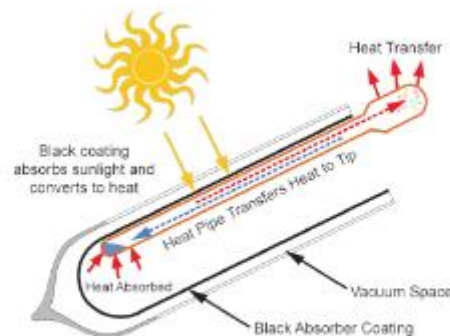
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- Evacuated tubes
- ~~Parabolic concentrators~~
- Flat plate
- Unglazed flat plate



(a) Particular of the heat-pipe tubes



(b) Structure of a heat pipe evacuated tubes collector



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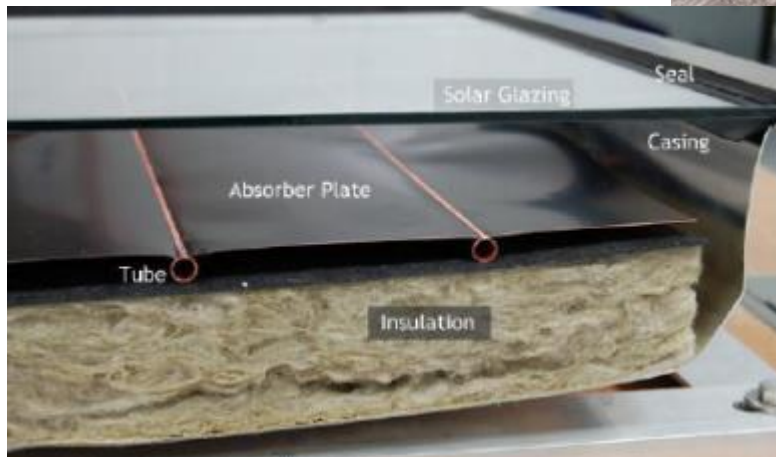
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- Evacuated tubes
- ~~Parabolic concentrators~~
- **Flat plate**
- Unglazed flat plate





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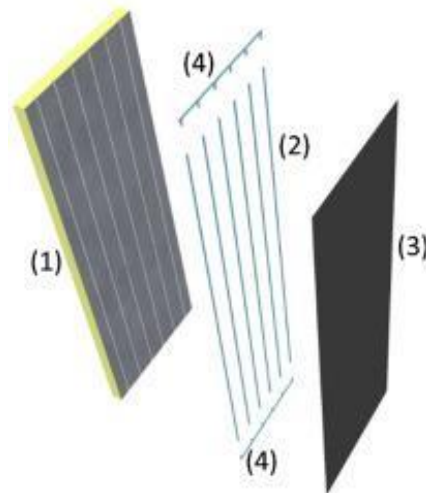
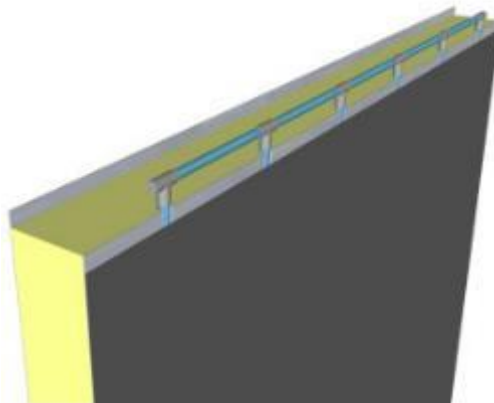


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- Evacuated tubes
- ~~Parabolic concentrators~~
- Flat plate
- **Unglazed flat plate**



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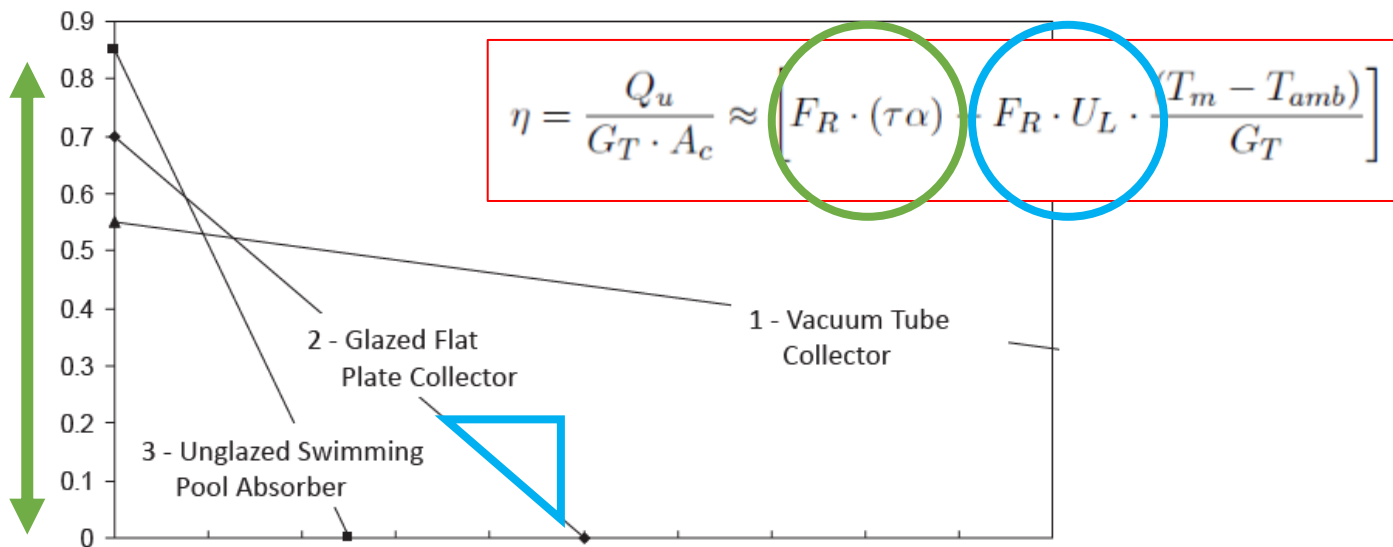
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#	$F_R (\tau \alpha)_e$	$F_R U_L (W/m^2 \cdot ^\circ C)$	$(T_i - T_a)/G, (m^2 \cdot ^\circ C) / W$
1	0.5 - 0.75	1 - 2	Depends on tube spacing
2	0.65 - 0.8	3 - 8	Depends on # of covers and absorber coating
3	0.8 - 0.95	10 - 20	Depends on wind speed



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# Photo Voltaic Technologies

- Flat, glazed panes
- A variety of formats & cell sizes
- Now transparent & colored alternatives







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# Barriers



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- General

- Cost
- Size/Shape adaptations
- Connections
- Aesthetics

- ST

- Space for auxiliaries
- Connection to DHW/SH services
- Maintenance

PV, is getting reduced. ST, stable.

Design & installation are a large share

Building envelopes require >10 different size/shapes

Costly production, logistics & material control

ST, requires watertight connections, pressure tests,...

In ~all cases, the building ends-up with a “technological” look in metal/glass

Pumping system, drainback tanks & storage (~50-60 l/m<sup>2</sup>)

Centralised Domestic Hot Water / Space Heating systems are required (at least partially)

Access to leaky pipes & faulty wires/panels for maintenance, repair & substitution





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# Particular developments for architecture



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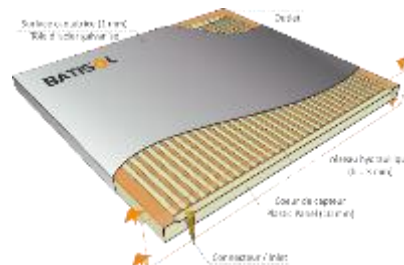
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- Air-driven systems



- Water driven systems



- Integration in Energy Systems





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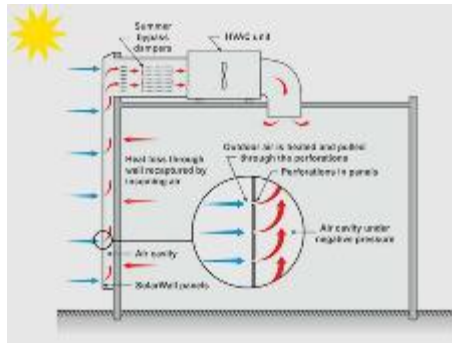
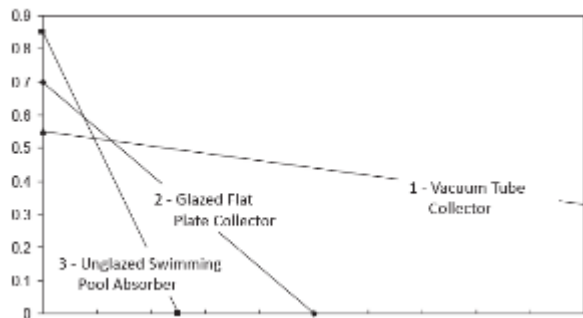
## 1. Idea

Solar thermal perform better at low temperature

Ventilation air needs to be heated barely to  $\sim 2X^{\circ}\text{C}$

SOLARWALL<sup>®</sup> systems work nice for opaque envelopes

Why not develop something similar for curtain walls?





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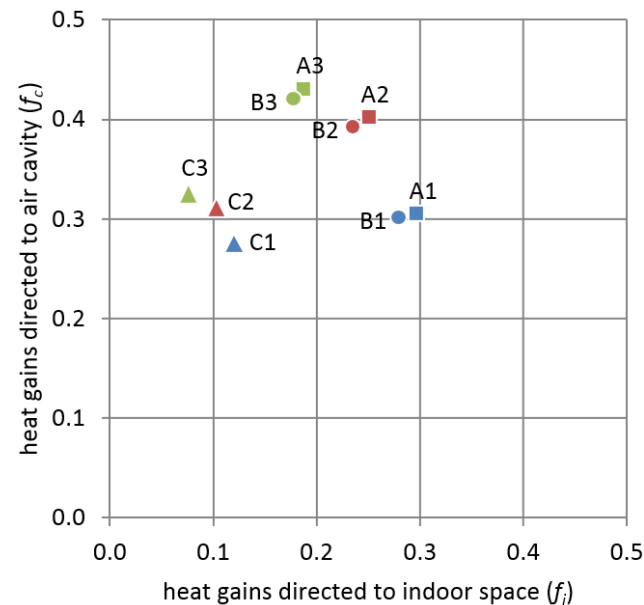
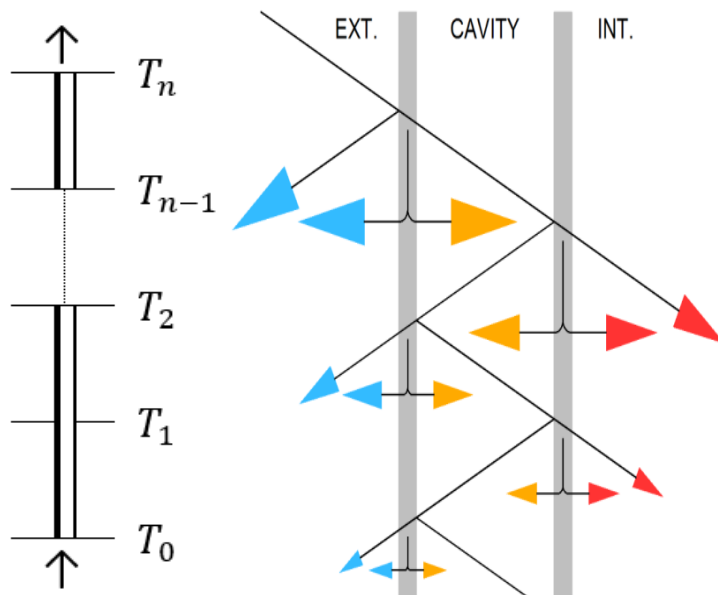
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1. Idea
2. Parametric Analysis





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1. Idea
2. Parametric Analysis
3. Engineering

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1. Idea
2. Parametric Analysis
3. Engineering
4. Full scale testing
5. Experimental Assessment





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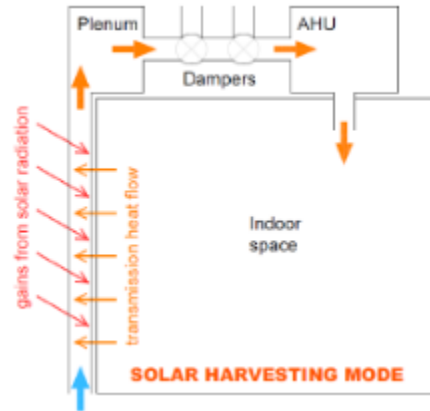
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1. Idea
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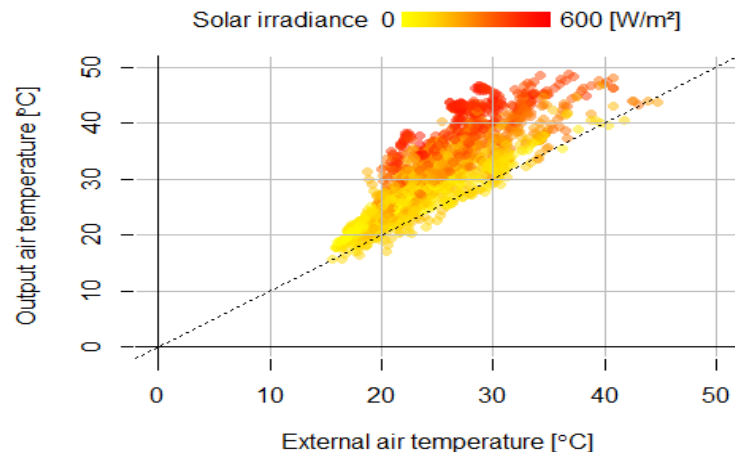
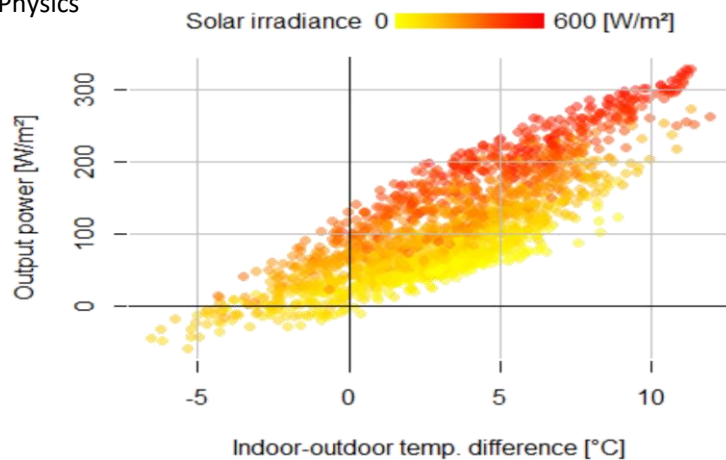
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1. Idea
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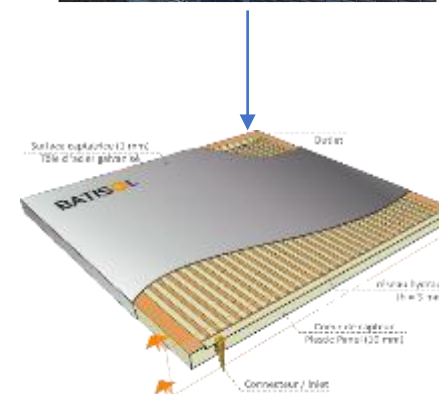
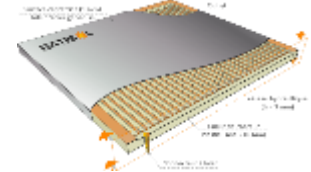
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## 1. Concept

Characteristics	SOLABS	Cost-Effective	Mac SHEEP	WAF	BATISOL
Low-Cost	✓	✓	✓	✓	✓
Adjustable angle	✗	✗	✗	✓	✓
PnP	✓	✗	✓	✓	✓
Easy maintenance	✓	✗	✓	✓	✓
Modular	✗	✗	✗	✗	✓
Multi-Colors	✓	✓	✓	✗	✓
Selective paints	✓	✗	✓	✓	✓
Perfect irrigation	✓	✗	✓	✗	✓
Aesthetic	✓	✗	✗	✓	✓



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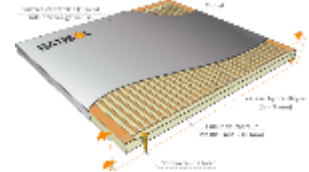
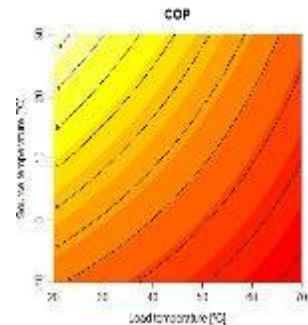
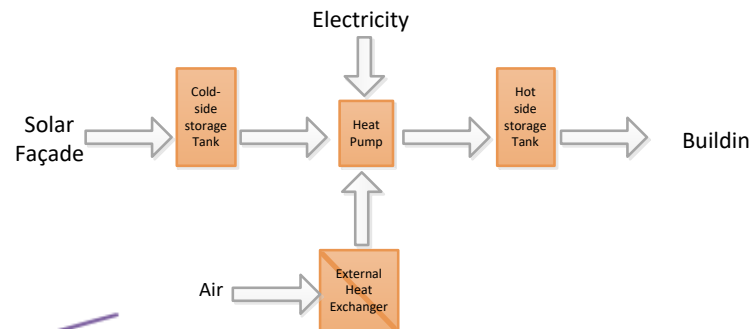
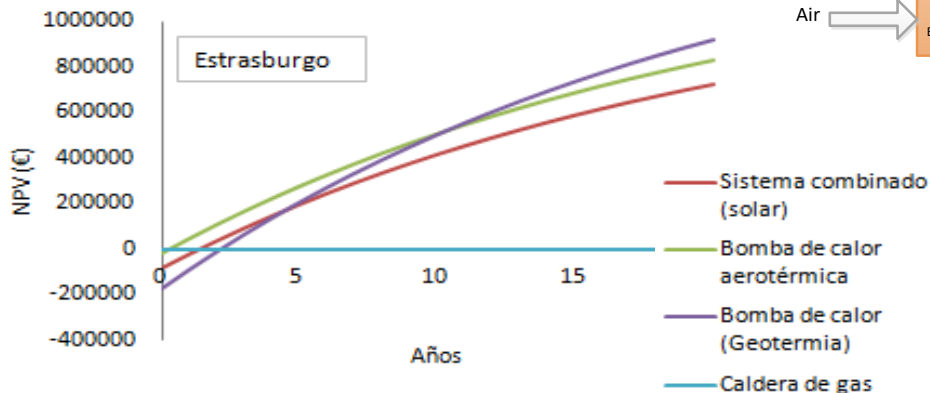
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## 1. Concept

### 1. Context & economics



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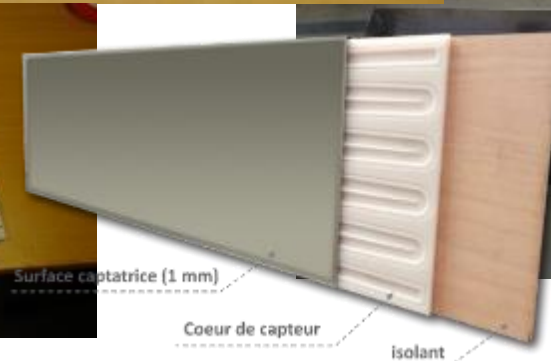
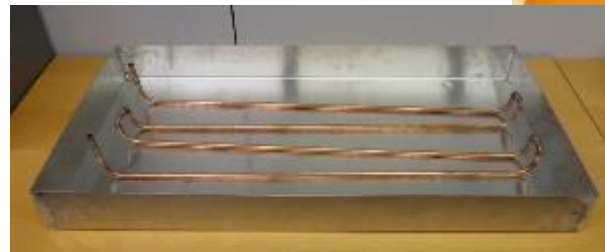
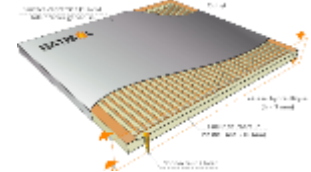
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1. Concept
2. Component level
  1. Simulation
  2. Prototyping



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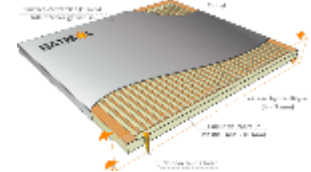
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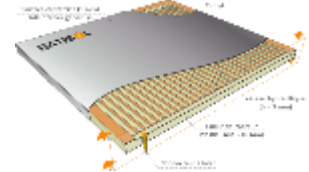
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1. Concept
2. Component level
3. System level
  1. Simulation
  2. Prototyping
  3. Experimental assessment
  4. Re-engineering



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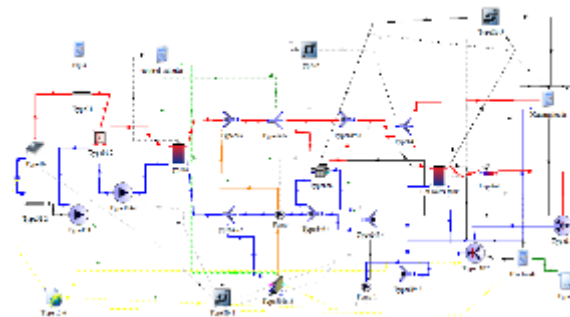
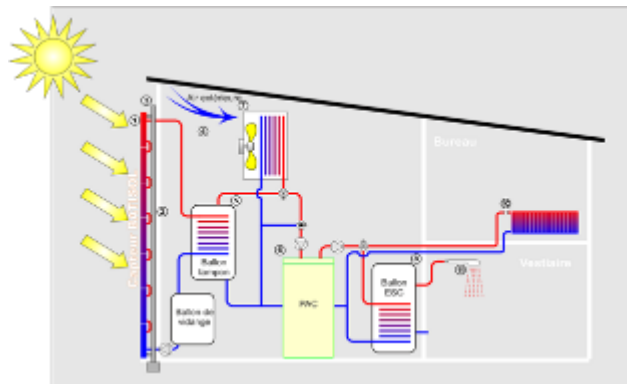
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1. Concept
  2. Component level
  3. System level
1. Simulation



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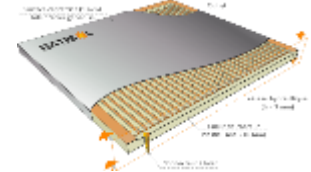
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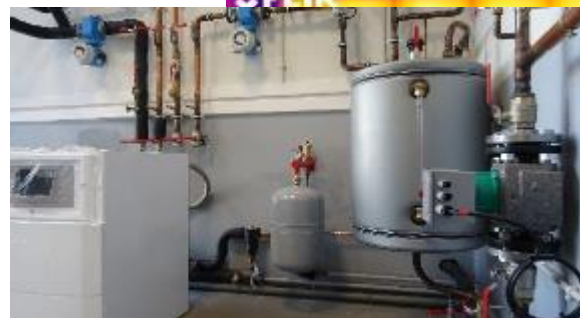
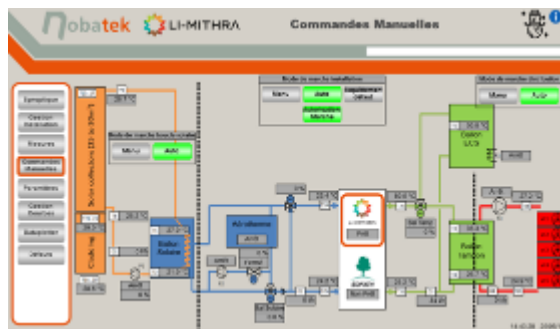
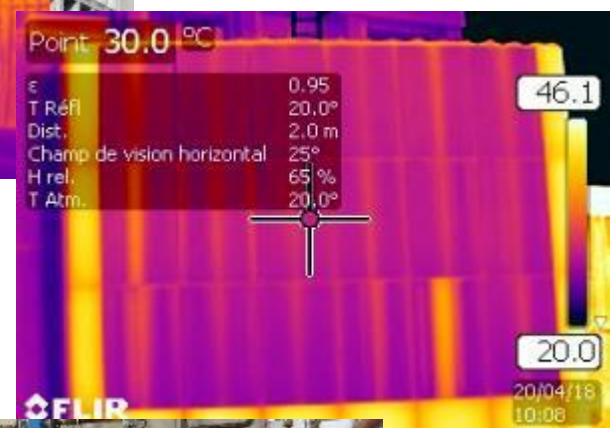
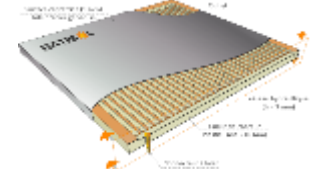
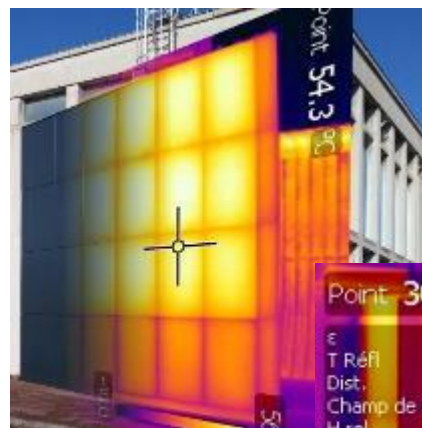
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1. Concept
2. Component level
3. System level
  1. Simulation
  2. Manufacture



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1. Concept
2. Component level
3. System level
  1. Simulation
  2. Manufacture
  3. Experimental assessment



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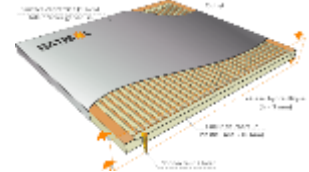
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1. Concept
2. Component level
3. System level
4. Upscaling

Now in progress



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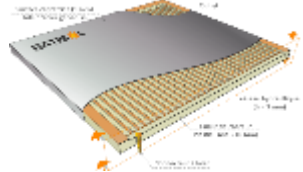
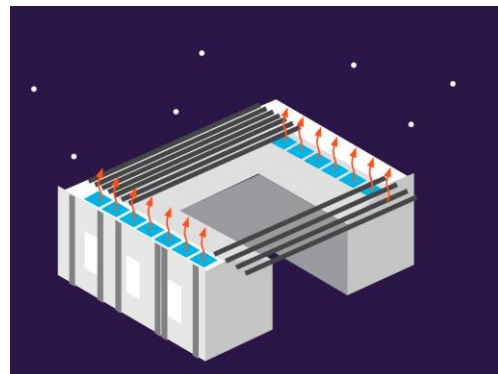
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1. Concept
2. Component level
3. System level
4. Upscaling
5. Alternative uses



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Applied Thermal Engineering

journal homepage: [www.elsevier.com/locate/apthermeng](http://www.elsevier.com/locate/apthermeng)



Development of a night-time radiative sky cooling production & storage system: A proposal for a robust sizing and potential estimation methodology

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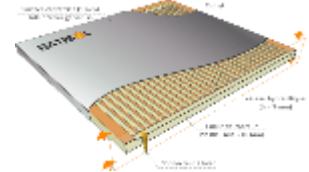
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# RELaTED

Solar Thermal Systems integrated in District Heating  
Deployment in 3 sites

- Belgrade. UN School
- Iurreta. Corporate District Network
- Denmark. Energy Flex Houses

(+ many other issues with relation to energy in the  
built environment and district energy systems)



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No [768567](#)





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# RELaTED



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# RELaTED

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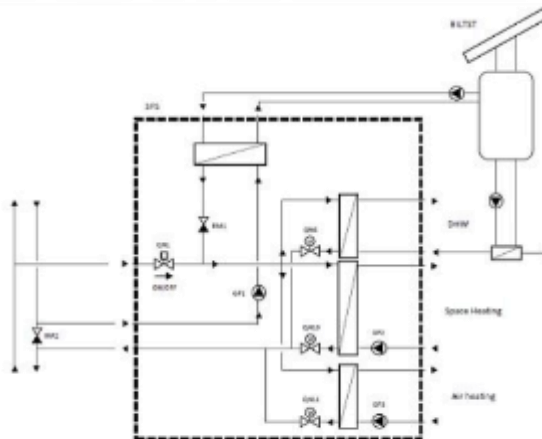
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# RELaTED

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# Bonus Materials



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# Key References

## Fundamental books

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## Applied research & knowledge

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# Research at Tecnalia (excerpt)

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