Politécnico di Torino

Integration of Solar Systems in Building Envelopes

Roberto Garay Martinez
Lead Researcher, Building Physics
Building Technologies Division, Tecnalia
roberto.garay@tecnalia.com

Online, 2021/05/6

Integration of Solar Systems in Building Envelopes

Index

Tecnalia. Building Envelopes & Energy in the Built Environment Groups

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.

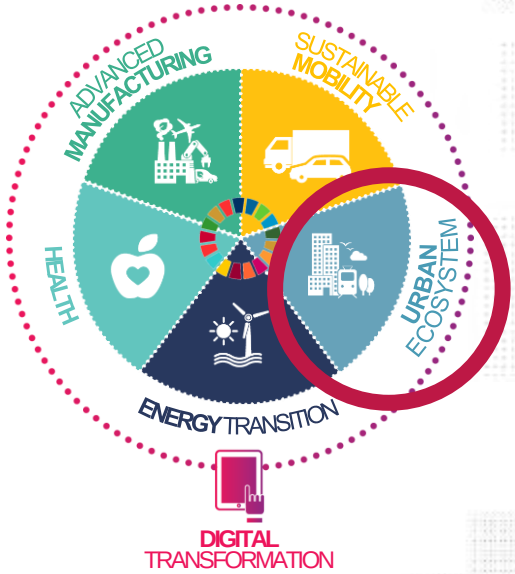
Laboratory Services | **R&D and Innovation** Projects | Development of **Investment Opportunities**

> 7.800 CLIENT COMPANIES

(2011 - 2020)

75% SMEs | **25%** Large companies

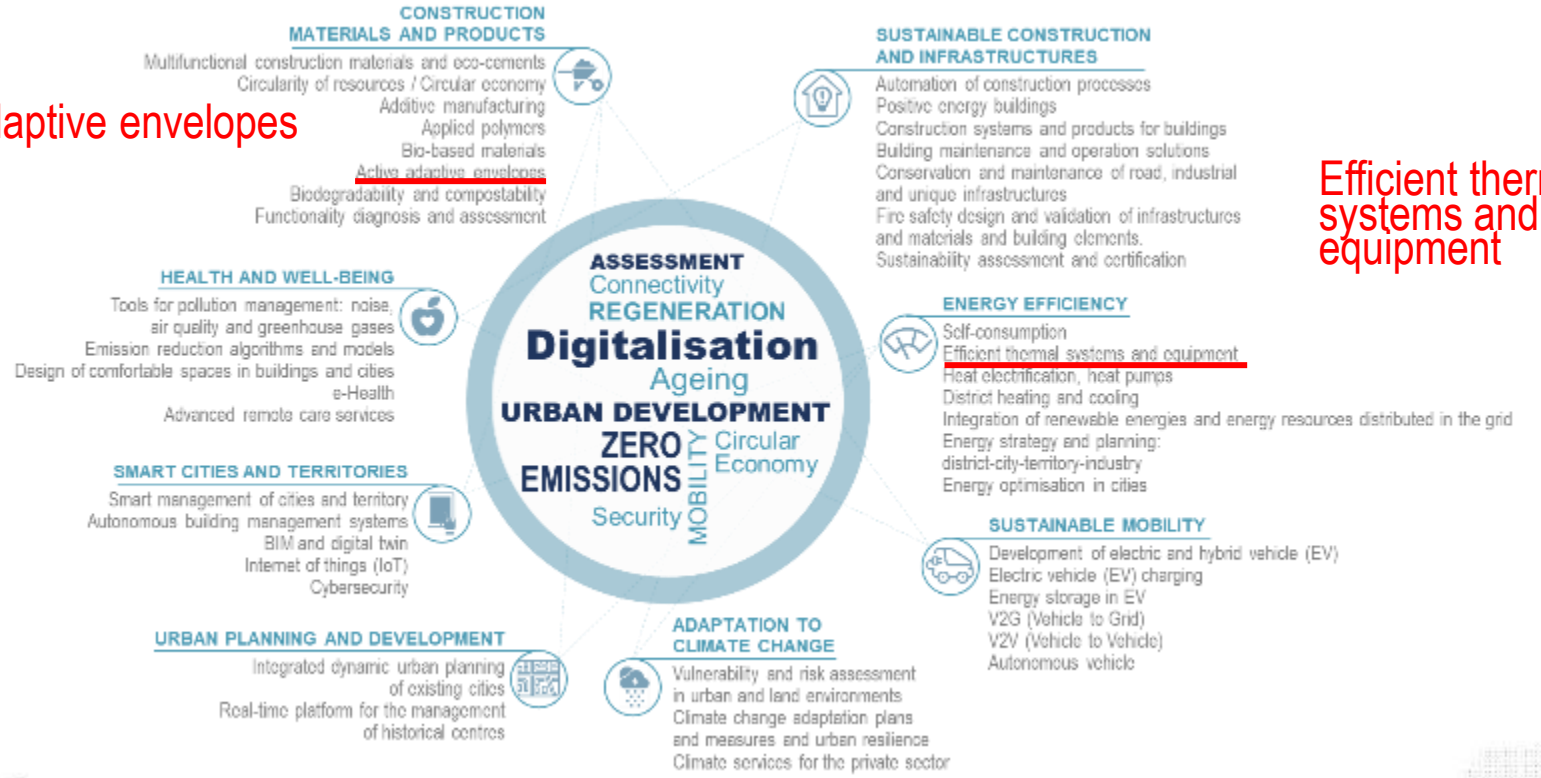
SCOPES OF ACTION



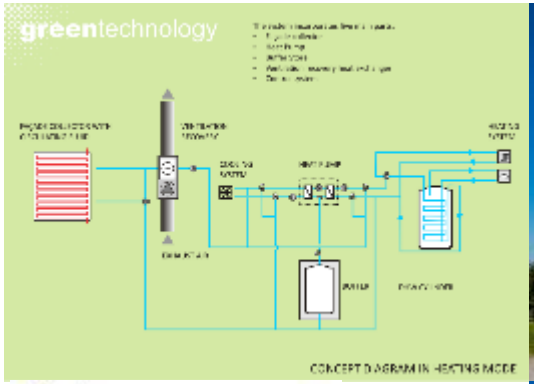
Tecnalia

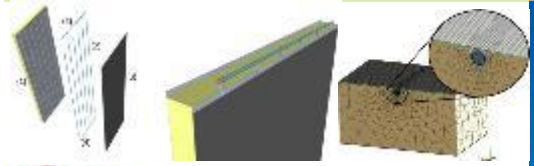
Active adaptive envelopes

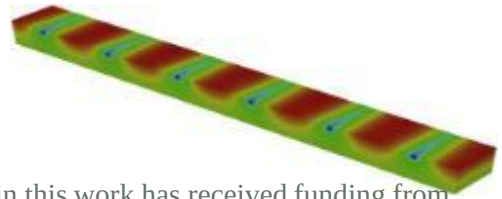
Efficient thermal systems and equipment



Building Envelopes Group



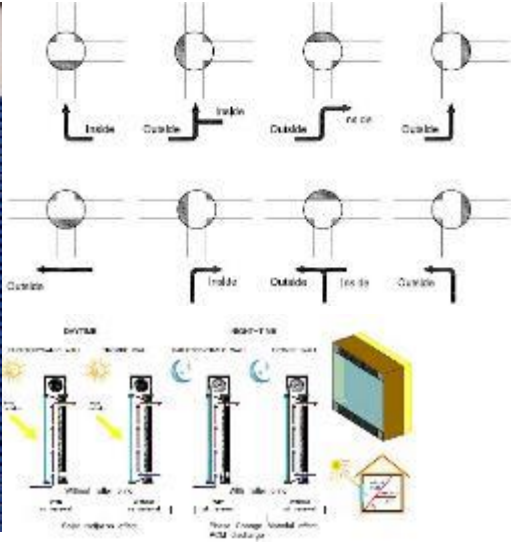




The research leading to the results reported in this work has received funding from the European Union, RFCS Program, Research Fund for Coal and Steel project Building Active Steel Skin (BASSE, Grant Agreement no RFSR-CT-2013-00026).

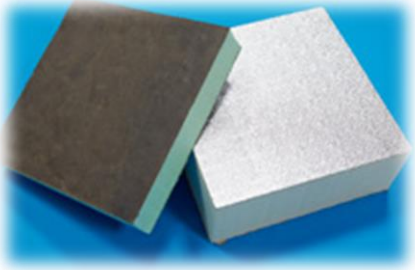
Building Envelopes Group

Building Envelopes Group



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

Building Envelopes Group









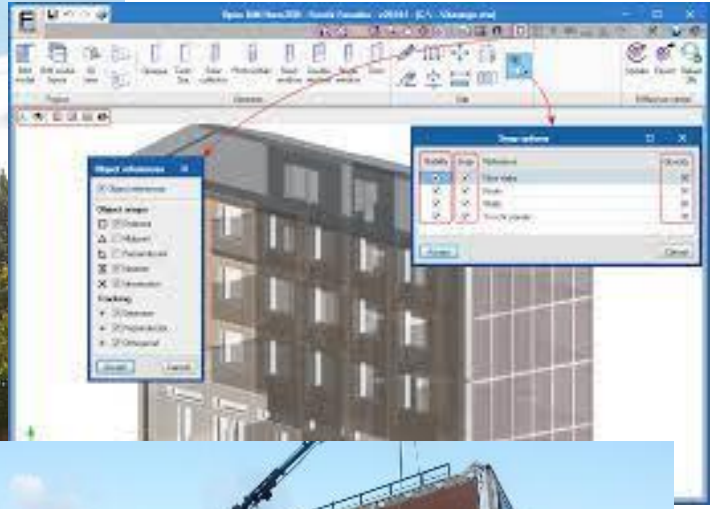
Building Envelopes Group

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 732513.

Energy in the Built Environment Group

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

Energy in the Built Environment Group

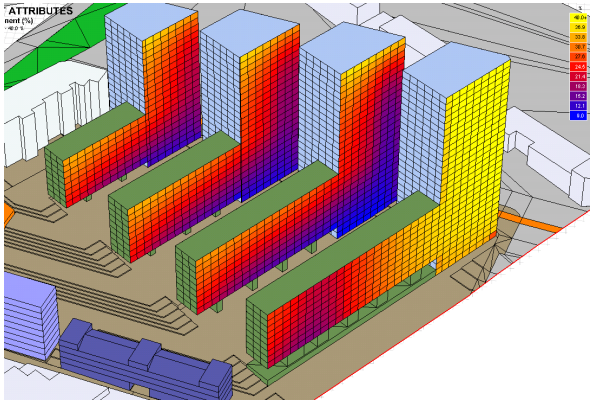


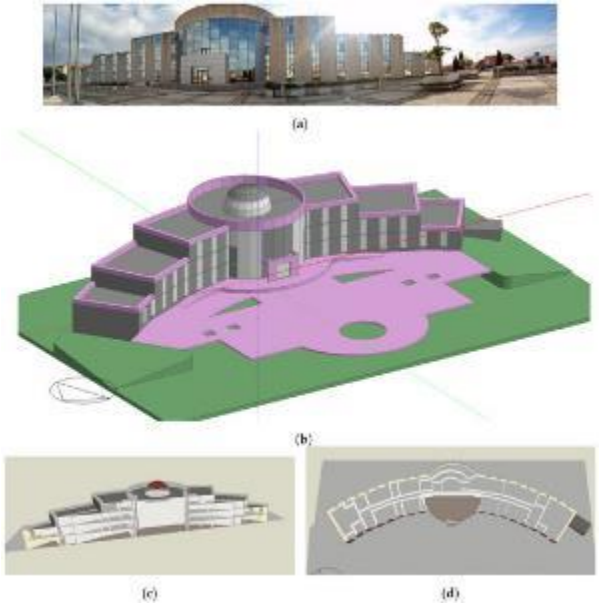
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 768718.

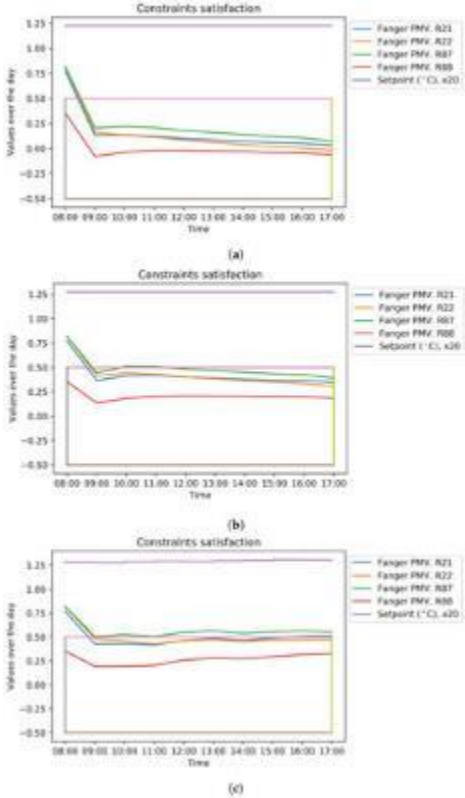
Energy in the Built Environment Group

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 768718.

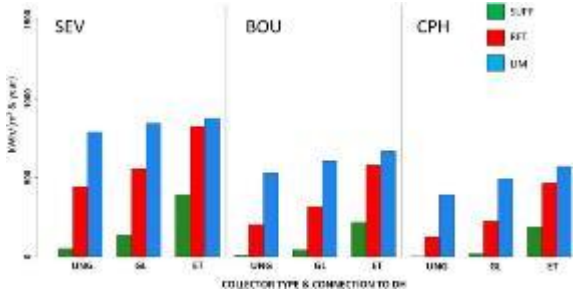
Energy in the Built Environment Group

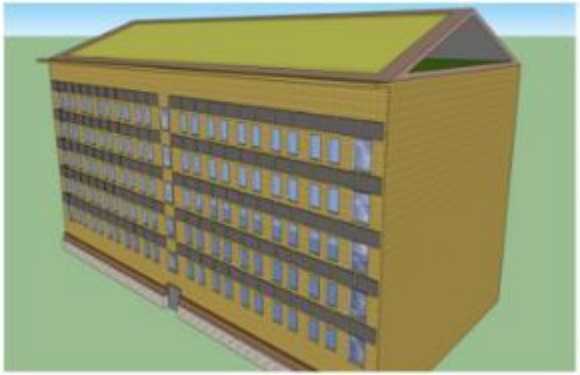




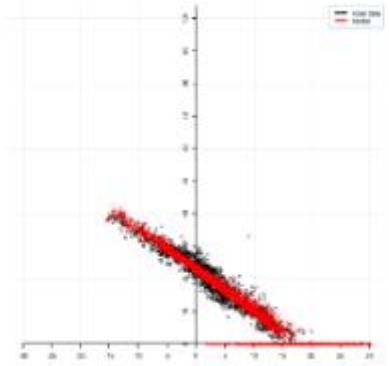


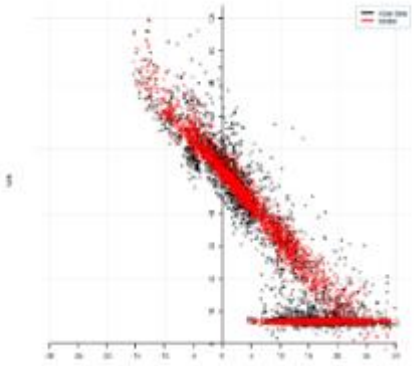
Energy in the Built Environment Group

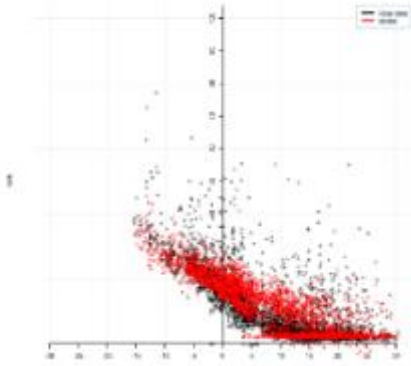




This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 768567



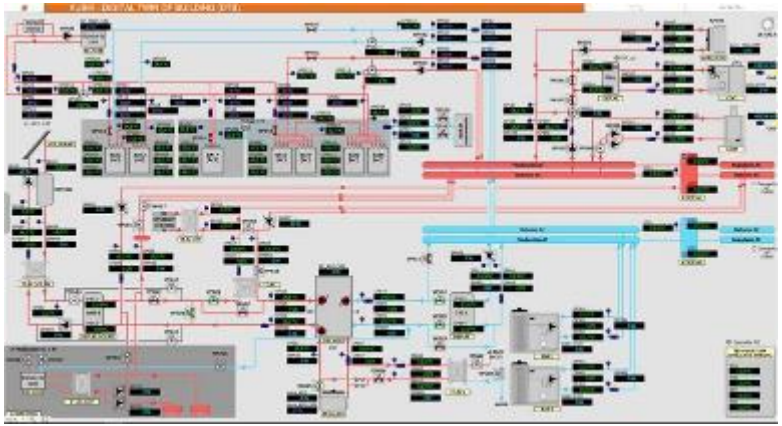


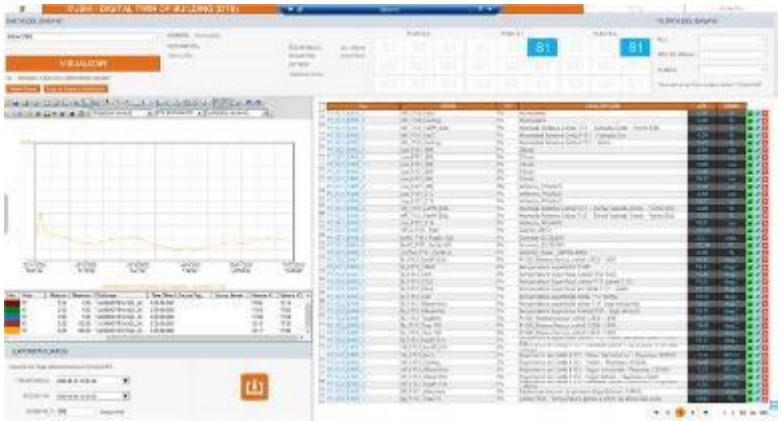


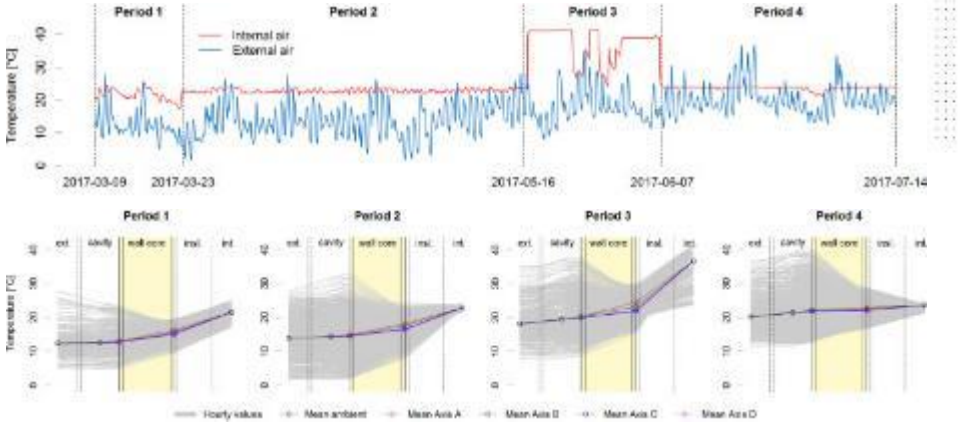
Kubik by Tecnalia Research Facility

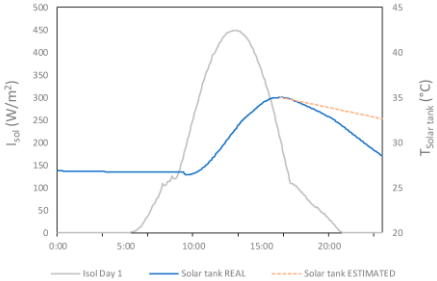
Research Facility for the testing of concepts and systems for the Energy Efficient Building
Operative since 2010

Kubik by Tecnalia Research Facility









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 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 ☺)

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

https://orcid.org/0000-0003-2331-6561

linkedin.com/in/robertogaray https://robertogaray.com/

Overview. Building Integrated Solar Systems

Technologies

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

WIKIPEDIA
The Free Encyclopedia

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

WIKIPEDIA
The Free Encyclopedia

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.

Technologies

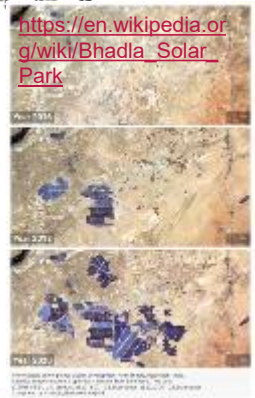
- Potentialities & limitations for building integration
  - Photo Voltaic Systems
    - Electric is the most common source of Energy for household & office appliances
    - Energy balance (production-consumption = 0) needs to be met continously
      - Batteries
      - (Regulated) Connection to network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

History

- Photo Voltaic Systems

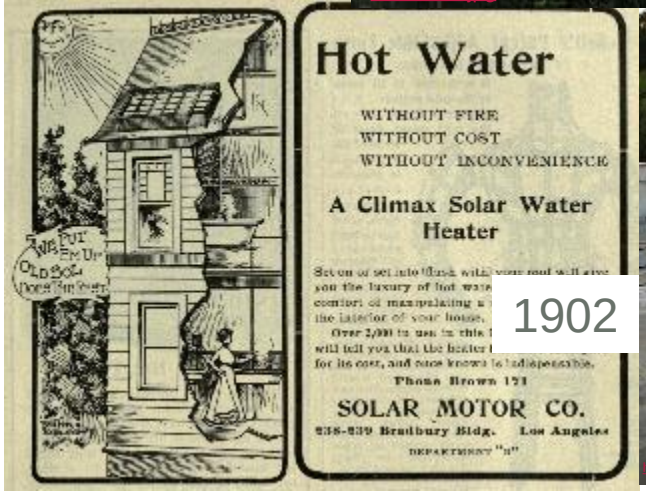
Telstar 1, 1962

https://commons.wikimedia.org/wiki/File:SolarEachwerkhaus.jpg



https://en.wikipedia.org/wiki/Bhadla_Solar_Park

- Solar Thermal Systems



1902

https://en.wikipedia.org/wiki/Solar_water_heating#/media/File:Solarboiler.jpg

Modern systems

- Photo Voltaic Systems

https://upload.wikimedia.org/wikipedia/commons/thumb/6/62/SolarPowerPlantSerpa.jpg/1024px-SolarPowerPlantSerpa.jpg

- Solar Thermal Systems

Building Integrated systems

- Photo Voltaic Systems

https://energypedia.info/images/f/f1/BIPV.jpg

https://www.buildup.eu/en/explore/links/bipv building-integrated-photovoltaics-competence-centre

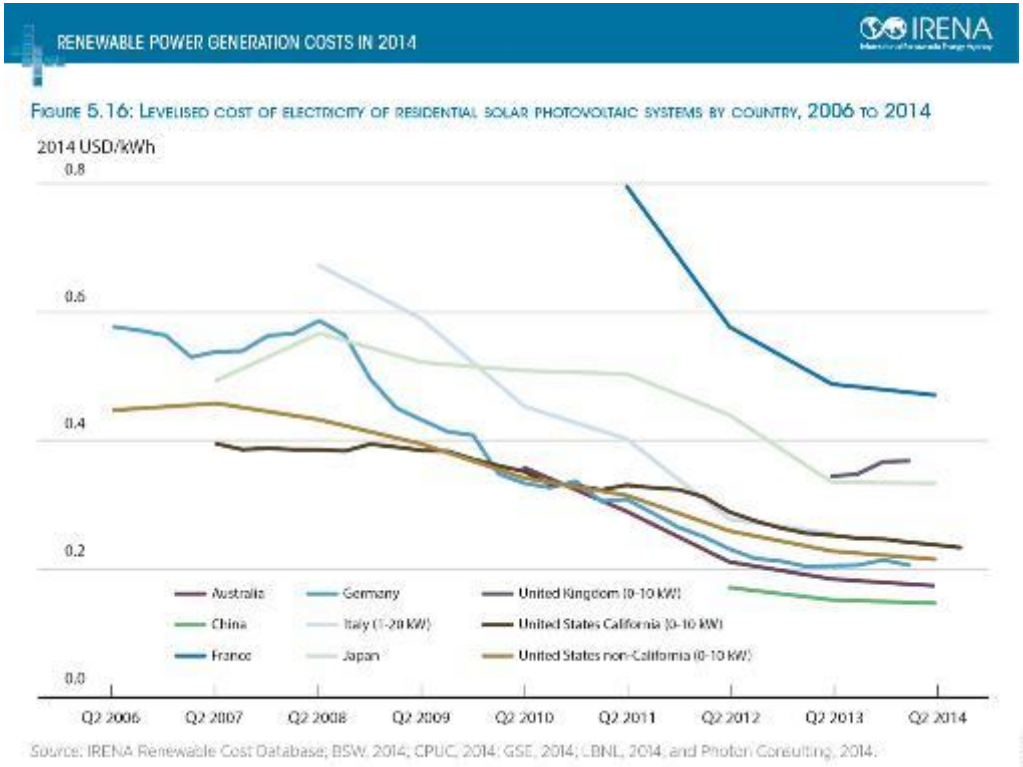
- Solar Thermal Systems

https://www.ims-plan.com/unimet-metallverarbeitung-solar-thermal-collectors.html

https://task56.iea-shc.org/product?ProductID=35

Price evolution

- Photo Voltaic Systems



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

Challenges

Challenges

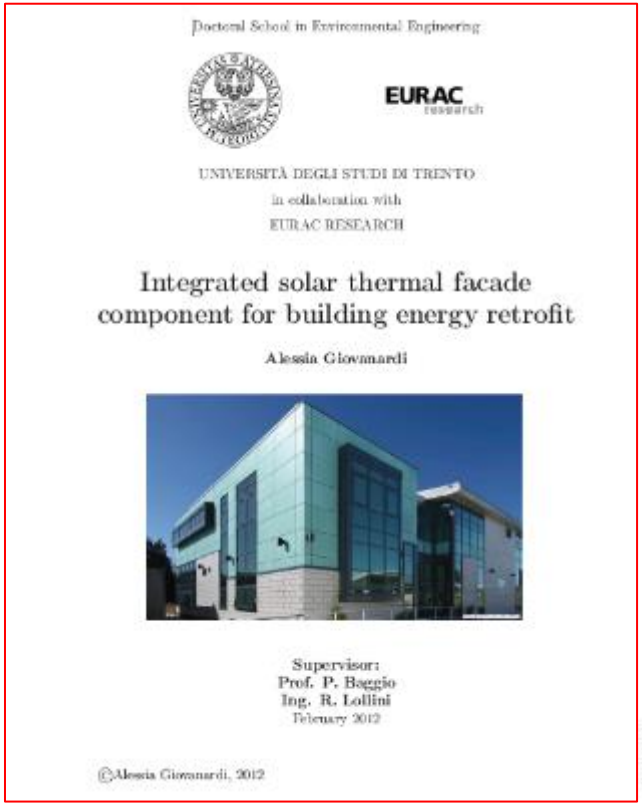
Challenges

Challenges

Technologies

Solar Thermal Technologies

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



Doctoral School in Environmental Engineering

EURAC research

UNIVERSITÀ DEGLI STUDI DI TRENTO
in collaboration with
EURAC RESEARCH

Integrated solar thermal facade component for building energy retrofit

Alessia Giovanardi

Supervisor:
Prof. P. Baggio
Ing. R. Lollini
February 2012

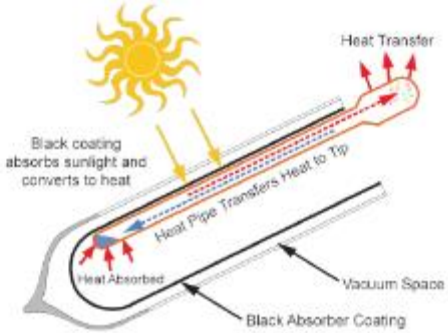
©Alessia Giovanardi, 2012

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

Solar Thermal Technologies

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

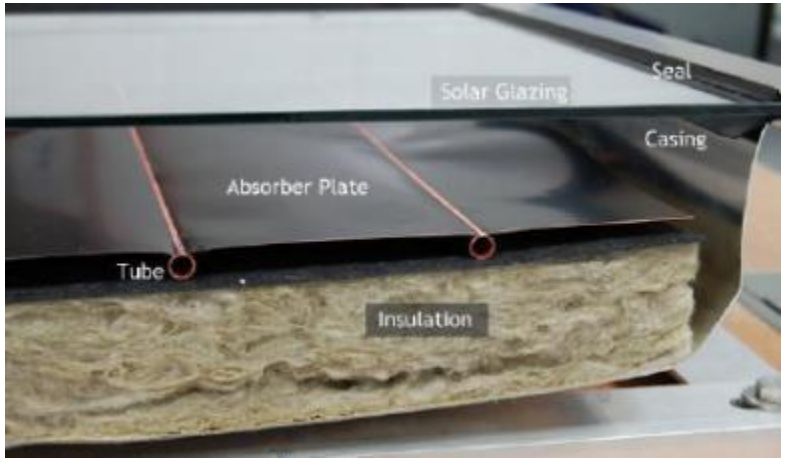
(a) Particular of the heat-pipe tubes



(b) Structure of a heat pipe evacuated tubes collector

Solar Thermal Technologies

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

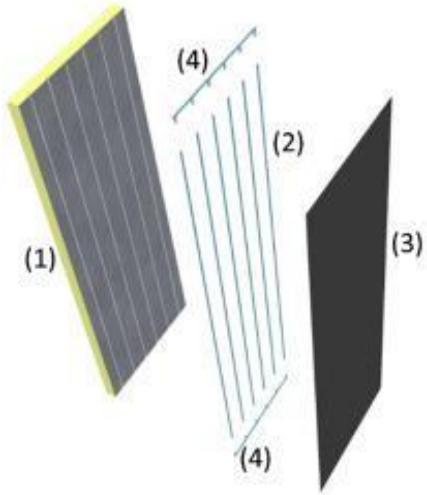


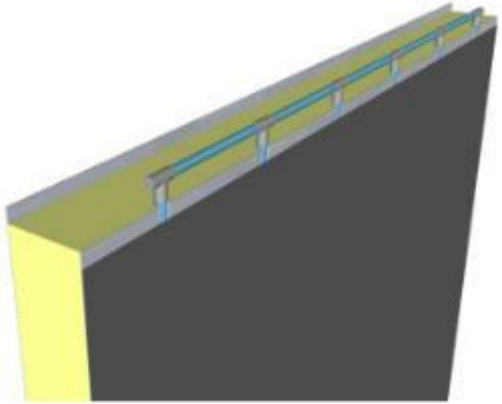
Solar Thermal Technologies

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

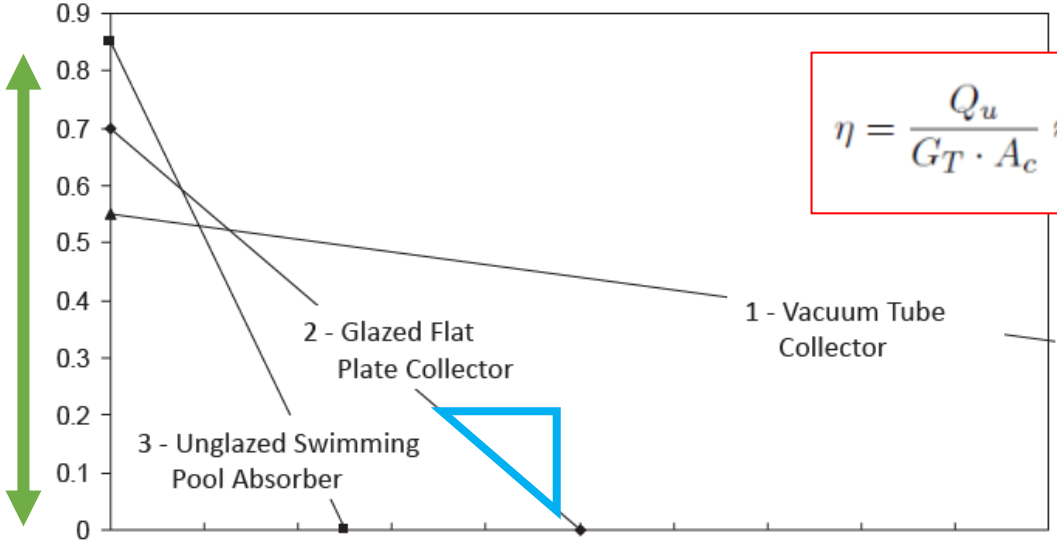
Solar Thermal Technologies

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





Solar Thermal Technologies



$$\eta = \frac{Q_u}{G_T \cdot A_c} \approx \left[F_R \cdot (\tau\alpha) - F_R \cdot U_L \cdot \frac{(T_m - T_{amb})}{G_T} \right]$$

#	$F_R(\ )_e$	$F_R\ U_L$ (W/m²ºC)	(Ti-Ta)/G, (m² ºC) / 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

Photo Voltaic Technologies

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

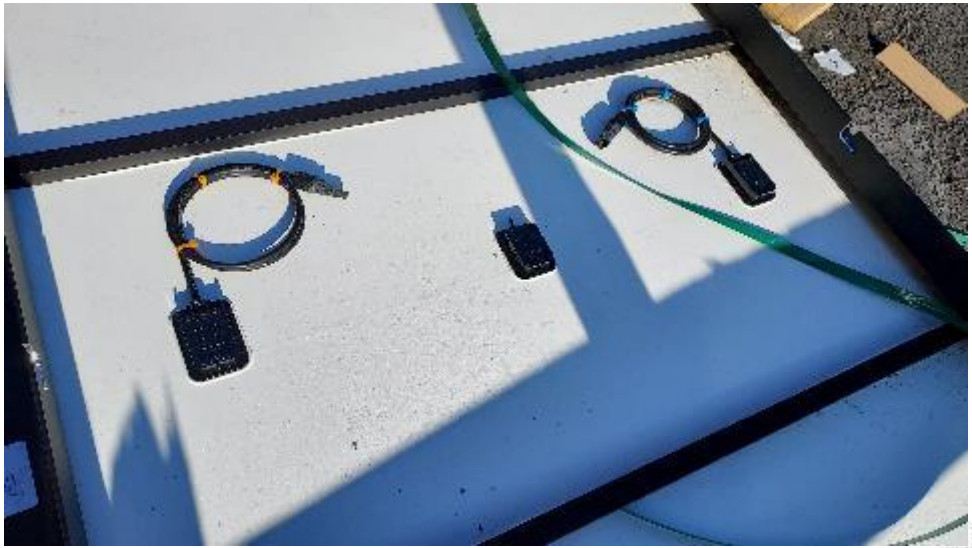
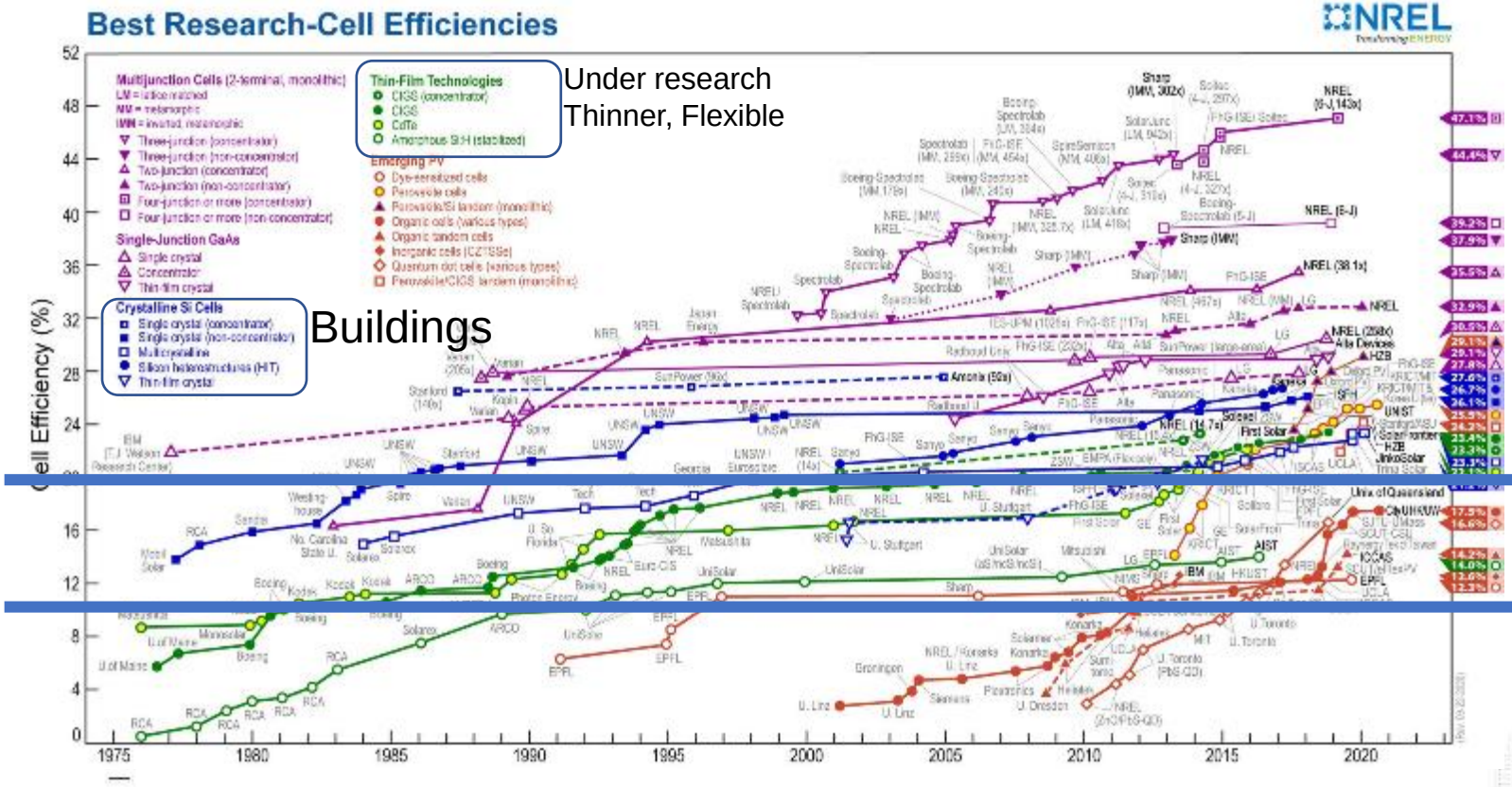


Photo Voltaic Technologies



Barriers

Barriers

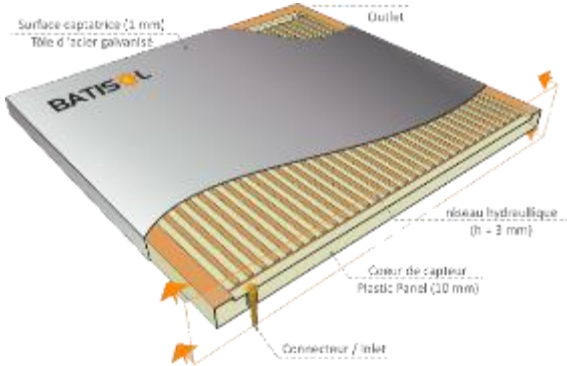
- General
  - Cost — PV, is getting reduced. ST, stable. Design & installation are a large share
  - Size/Shape adaptations — Building envelopes require >10 diferent size/shapes. Costly production, logisticts & material control
  - Connections — ST, requires watertight connections, pressure tests,…
  - Aesthetics — In ~all cases, the building ends-up with a “technological” look in metal/glass
- ST
  - Space for auxiliaries — Pumping system, drainback tanks & storage (~50-60 l/m2)
  - Connection to DHW/SH services — Centralised Domestic Hot Water / Space Heating systems are required (at least partially)
  - Maintenance — Access to leaky pipes & faulty wires/panels for maintenance, repair & substitution

Particular developments for architecture

Particular developments for architecture

- Air-driven systems

- Water driven systems



Air-driven systems

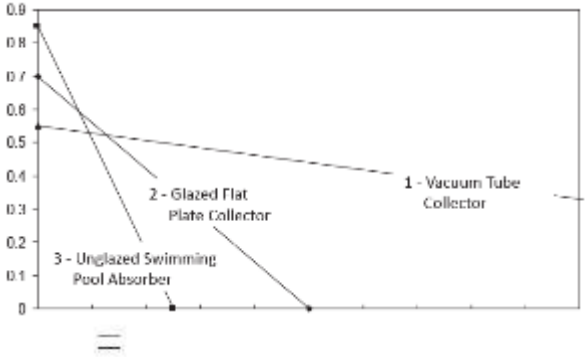
1. Idea

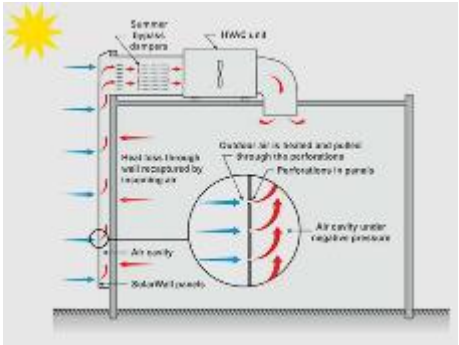
Solar termal perform better at low temperature

Ventilation air needs to be heated barely to ~2XºC

SOLARWALL® systems work nice for opaque envelopes

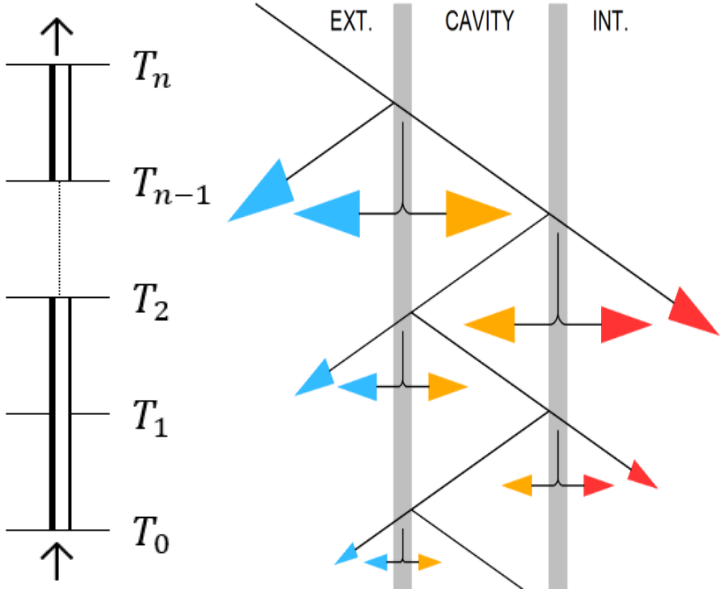
Why not develop something similar for curtain walls?

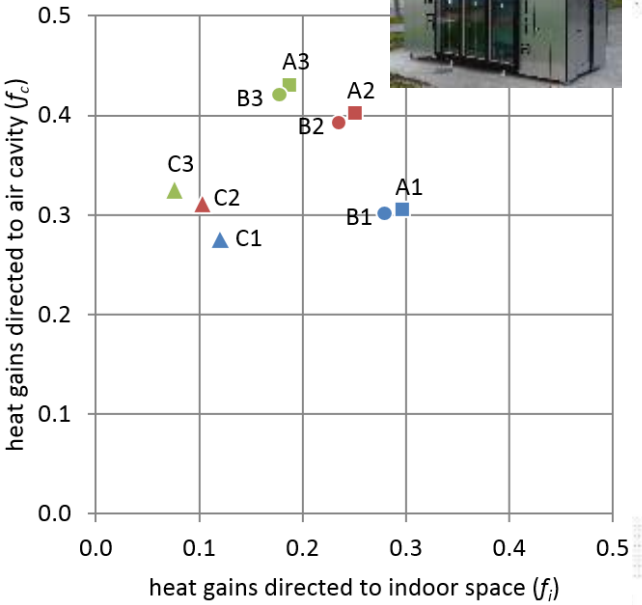




Air-driven systems

1. Idea
2. Parametric Analysis



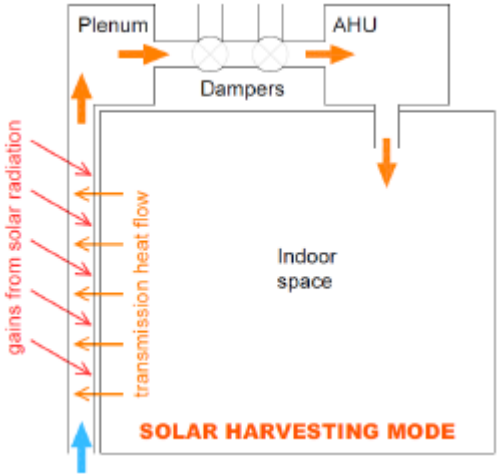


Air-driven systems

1. Idea
2. Parametric Analysis
3. Engineering

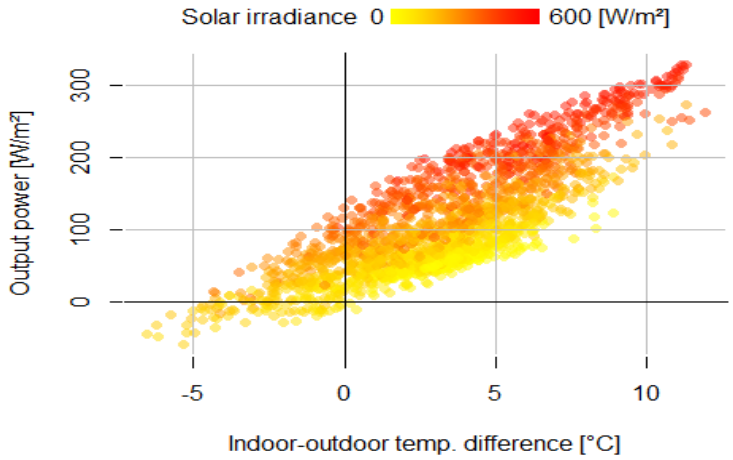
Air-driven systems

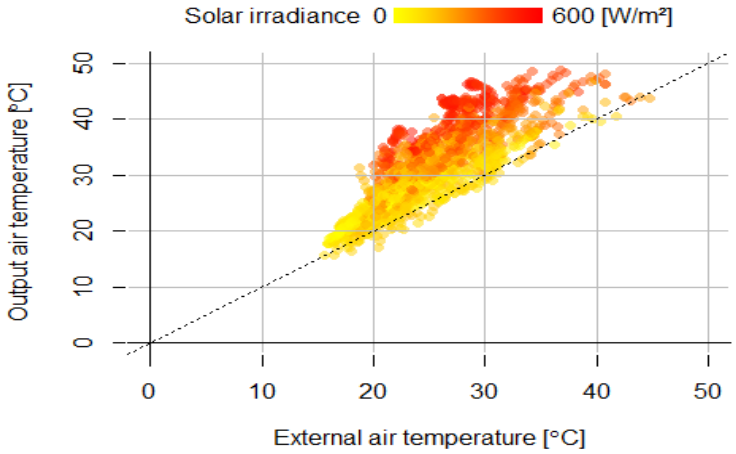
1. Idea
2. Parametric Analysis
3. Engineering
4. Full scale testing

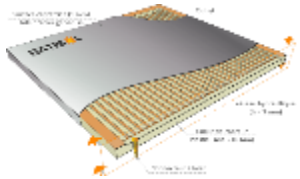


Air-driven systems

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



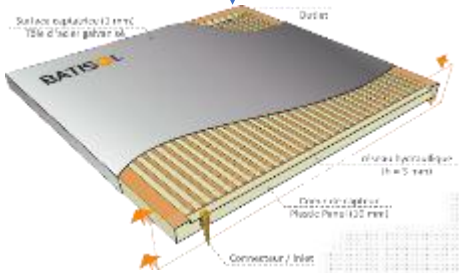




Water driven systems

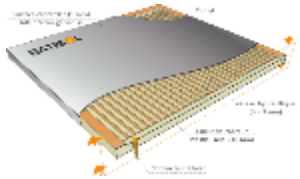
1. Concept

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

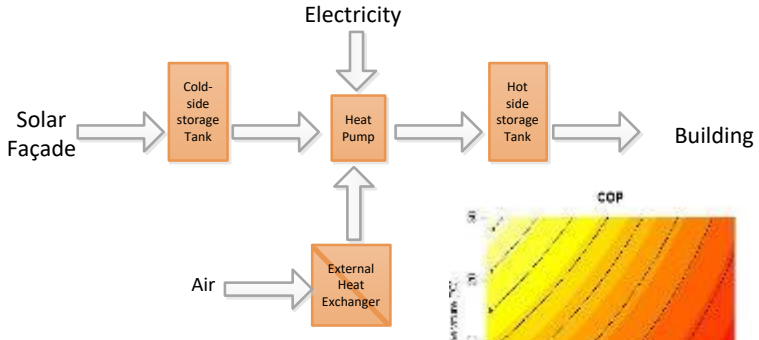


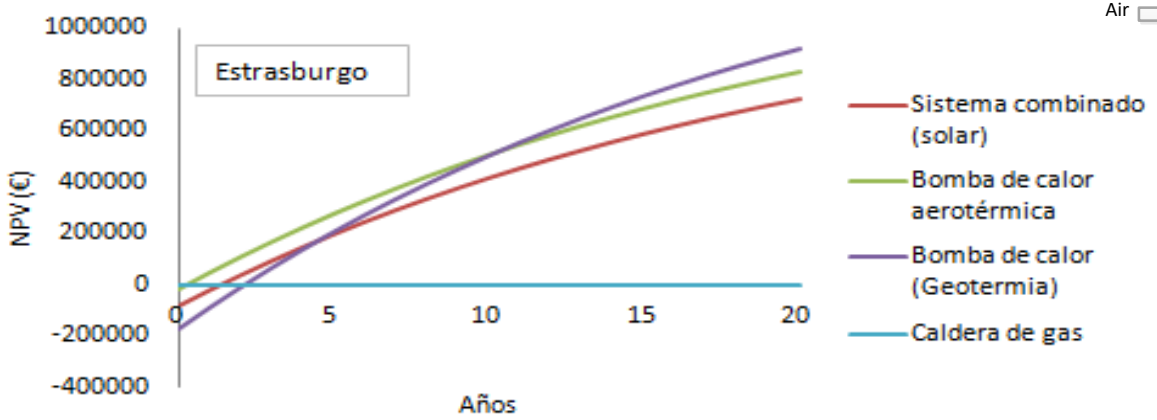
The Batisol project is a collaborative R&D project between Tecnalia and Nobatek INEF4, funded by the ANR and the Aquitaine region

Water driven systems



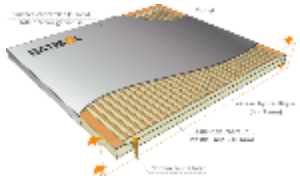
1. Concept
    1. Context & economics



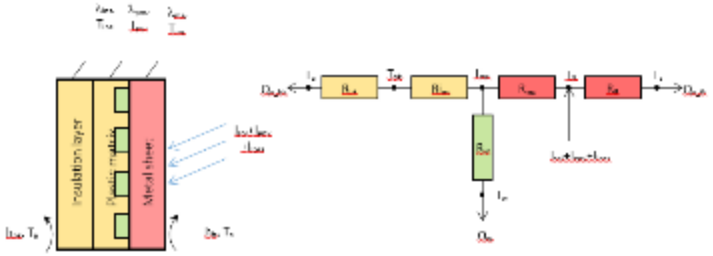


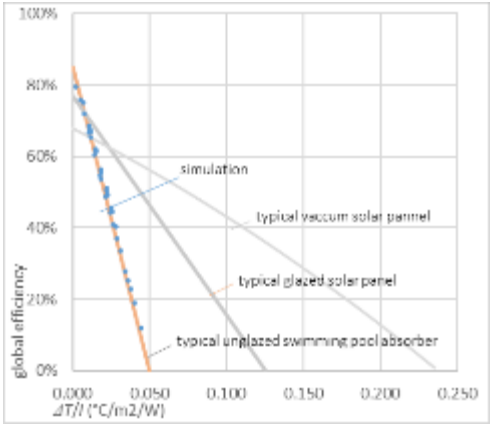
The Batisol project is a collaborative R&D project between Tecnalia and Nobatek INEF4, funded by the ANR and the Aquitaine region

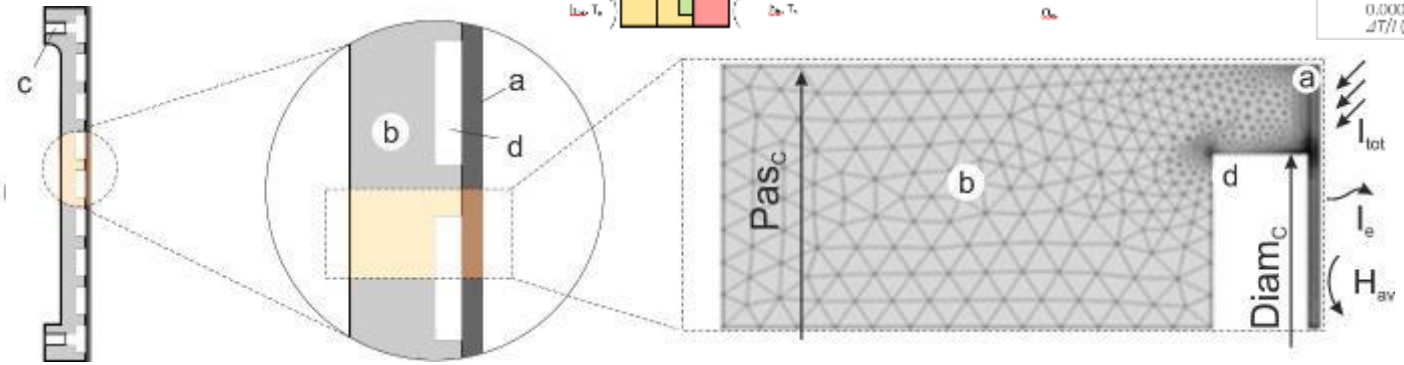
Water driven systems



1. Concept
2. Component level
    1. Simulation



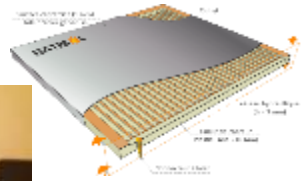


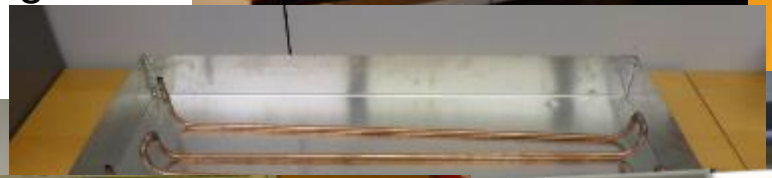


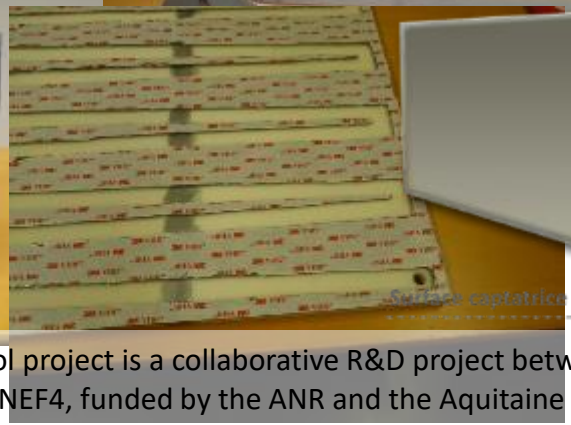
The Batisol project is a collaborative R&D project between Tecnalia and Nobatek INEF4, funded by the ANR and the Aquitaine region

Water driven systems

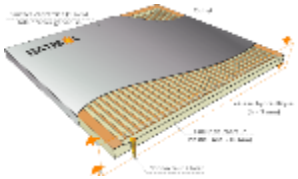
1. Concept
2. Component level
    1. Simulation
    2. Prototyping







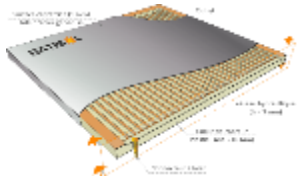
The Batisol project is a collaborative R&D project between Tecnalia and Nobatek INEF4, funded by the ANR and the Aquitaine region



Water driven systems

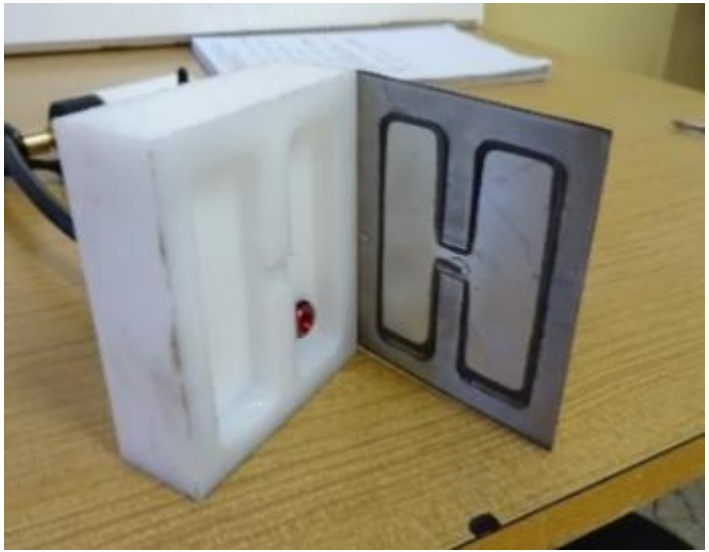
1. Concept
2. Component level
    1. Simulation
    2. Prototyping
    3. Experimental assessment

The Batisol project is a collaborative R&D project between Tecnalia and Nobatek INEF4, funded by the ANR and the Aquitaine region

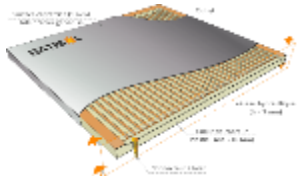


Water driven systems

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

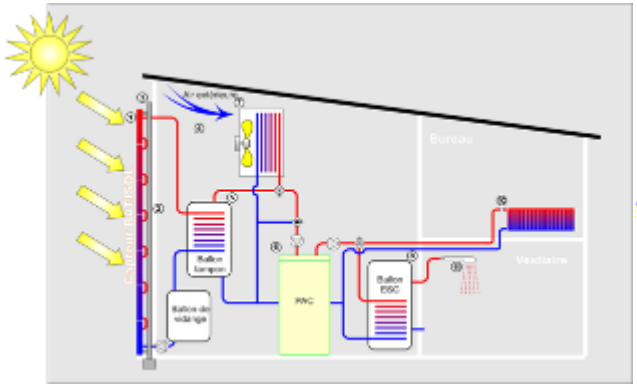


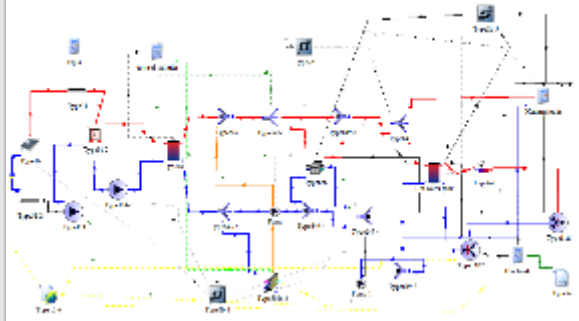
The Batisol project is a collaborative R&D project between Tecnalia and Nobatek INEF4, funded by the ANR and the Aquitaine region



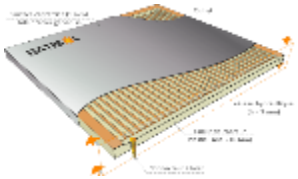
Water driven systems

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





The Batisol project is a collaborative R&D project between Tecnalia and Nobatek INEF4, funded by the ANR and the Aquitaine region

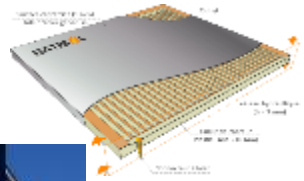


Water driven systems

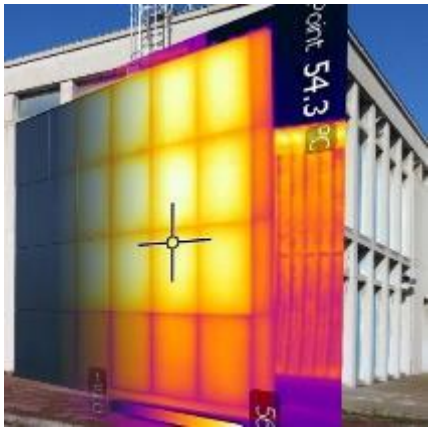
1. Concept
2. Component level
3. System level
    1. Simulation
    2. Manufacture

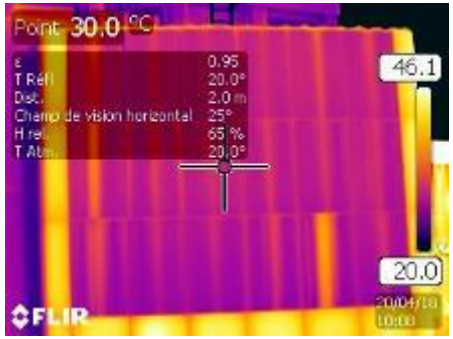
The Batisol project is a collaborative R&D project between Tecnalia and Nobatek INEF4, funded by the ANR and the Aquitaine region

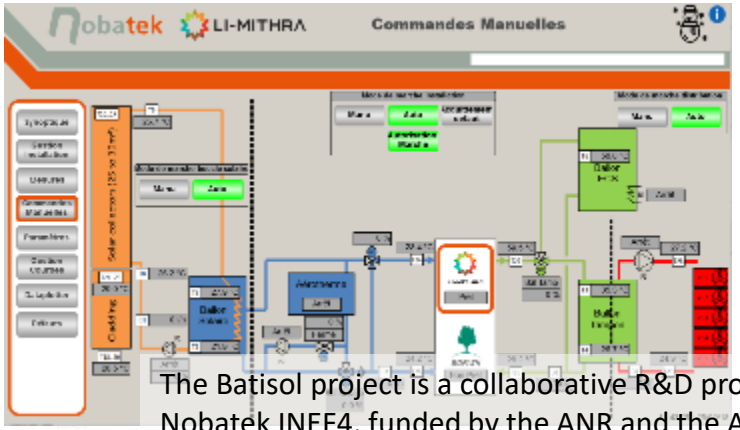
Water driven systems



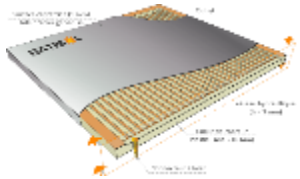
1. Concept
2. Component level
3. System level
    1. Simulation
    2. Manufacture
    3. Experimental assessment







The Batisol project is a collaborative R&D project between Tecnalia and Nobatek INEF4, funded by the ANR and the Aquitaine region



Water driven systems

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

Now in progress

The Batisol project is a collaborative R&D project between Tecnalia and Nobatek INEF4, funded by the ANR and the Aquitaine region

Bonus Materials

Fundamental books

John A. Duffie, William A. Beckman, Solar Engineering of Thermal Processes, 4th Edition ISBN: 978-0-470-87366-3 April 2013

Applied research & knowledge

Giovanardi, Alessia (2012) *Integrated solar thermal facade component for building energy retrofit.* PhD thesis, University of Trento. http://eprints-phd.biblio.unitn.it/782/

IEA SHC Task 56. Report on State-of-the-art and SWOT analysis of building integrated solar envelope systems, 2019, https://doi.org/10.18777/ieashc-task56-2019-0001

IEA SHC Task 56. Report on barriers for new solar envelope systems, 2018, https://www.doi.org/10.18777/ieashc-task56-2018-0001

Research @ Tecnalia

Lumbreras, M., Garay, R., Energy & economic assessment of façade-integrated solar thermal systems combined with ultra-low temperature district-heating (2020) Renewable Energy, 159, pp. 1000-1014. DOI: 10.1016/j.renene.2020.06.019

Garay-Martinez, R., Arregi, B., Curtain Wall with Solar Preheating of Ventilation Air. Full Scale Experimental Assessment (2020) E3S Web of Conferences, 172, art. no. 09007, DOI: 10.1051/e3sconf/202017209007

…

Research @ Tecnalia

…

Garay-Martinez, R., Gonzalez, D., Alvarez, I., Arregi, B., Sagarduy, G., Double envelope unitized curtain wall for solar preheating of ventilation air (2020) Proceedings of the International Conference of Architectural Science Association, 2020-November, pp. 425-431.

Elguezabal, P., Lopez, A., Blanco, J.M., Chica, J.A., CFD model-based analysis and experimental assessment of key design parameters for an integrated unglazed metallic thermal collector façade (2020) Renewable Energy, 146, pp. 1766-1780. DOI: 10.1016/j.renene.2019.07.151 ★

Elguezabal, P., Lopez, A., Blanco, J.M., Chica, J.A., Assessment on the efficiency of an active solar thermal facade: Study of the effect of dynamic parameters and experimental analysis when coupled/uncoupled to a heat pump (2020) Energies, 13 (3), art. no. 597, DOI: 10.3390/en13030597

Elguezabal, P., Lopez, A., Blanco, J.-M., Chica, J.-A., New concept of solar collector integrated into a sandwich panel as an active façade; CFD based parametric assesment and case study [Nuevo concepto de colector solar integrado en un panel sandwich a modo de fachada activa; estudio paramétrico mediante CFD y aplicación a un caso de estudio] (2019) Dyna (Spain), 94 (1), pp. 691-698. DOI: 10.6036/9274

Lumbreras, M., Garay, R., Martin, K., Unglazed solar thermal systems for building integration, coupled with district heating systems. Conceptual definition, cost and performance assessment (2018) Journal of Facade Design and Engineering, 6 (2), pp. 121-133. DOI: 10.7480/jfde.2018.2.2085

…

Research @ Tecnalia

…

Elguezabal, P., Arregi, B., An analysis of the potential of envelope-integrated solar heating and cooling technologies for reducing energy consumption in European climates (2018) Journal of Facade Design and Engineering, 6 (2), pp. 85-94. DOI: 10.7480/jfde.2018.2.2102

Garay-Martinez, R., Arregi-Goikolea, B., Bonnamy, P., Raji, S., Lopez, J., Concept, development and thermal characterization of an unglazed solar thermal collector for façade integration [Conceptualización, desarrollo y caracterización térmica de un colector solar no acristalado para integración en fachada] (2017) Dyna (Spain), 92 (4), pp. 466-472. DOI: 10.6036/8108

Martinez, R.G., Larraz, J.A., Performance assessment of façade integrated glazed air solar thermal collectors (2017) Energy Procedia, 115, pp. 353-360. DOI: 10.1016/j.egypro.2017.05.032

Elguezabal, P., Garay, R., Martin, K., Experimentation under real performing conditions of a highly integrable unglazed solar collector into a building façade (2017) Energy Procedia, 122, pp. 775-780. DOI: 10.1016/j.egypro.2017.07.395

Martinez, R.G., Goikolea, B.A., Paya, I.G., Bonnamy, P., Raji, S., Lopez, J., Performance assessment of an unglazed solar thermal collector for envelope retrofitting (2017) Energy Procedia, 115, pp. 361-368. DOI: 10.1016/j.egypro.2017.05.033

…

Research @ Tecnalia

…

Mikel Lumbreras, Roberto Garay, Simulation of Unglazed Solar Thermal Systems Integrated into Façade & Combined with Ultra-Low Temperature District Heating, IBPSA Building Simulation 19, Rome, Italy, ISBN: 978-1-7750520-1-2, p. 4401-4408. http://www.ibpsa.org/proceedings/BS2019/BS2019_210282.pdf

Patents

WO 2011/080356, Amundarain Suarez, Aitor, Campos Dominguez,Jose María, Chica Páez, Jose Antonio, Meno Iglesias, Sandra, Uriarte Arrien, Amaia, Garay Martínez, Roberto, Herrero Ruiz, Julio Cesar, Oliver Rips, Marc, Pérez Barcenilla, Sergio, Elguezabal Esnarriaga, Peru, Romero Amorrortu, Ander, Apraiz Egaña, Inés, Passive Solar Collector Module For Building Envelope / Módulo Colector Solar Pasivo Para Envolventes De Edificación. http://dsp.tecnalia.com/handle/11556/64

Tecnalia

Garay, R., Chica, J.A., Apraiz, I., Campos, J.M., Tellado, B., Uriarte, A., Sanchez, V., Energy efficiency achievements in 5 years through experimental research in KUBIK (2015) Energy Procedia, 78, pp. 865-870. DOI: 10.1016/j.egypro.2015.11.009

https://www.tecnalia.com/en/infrastructure/kubik-experimental-building

https://www.tecnalia.com/en/scopes-of-action/urban-ecosystem

https://www.tecnalia.com/en/technologies/physics-of-the-building

Politécnico di Torino

Thank you for your attention

Roberto Garay Martinez
Lead Researcher, Building Physics
Building Technologies Division, Tecnalia
roberto.garay@tecnalia.com

Online, 2021/05/06