From Net-Zero to Plus Energy Buildings: Designing Buildings for Climate and Cultural Diversity

Cultural-E Mid-term Conference
11:00 - 13:00 CET

28 September 2022
Brussels and online

European Sustainable
Energy Week
#EUSEW2022

cultural E+

European Commission

Important information before we start

Your microphone will be muted and your camera will be off. If you would like to speak, please raise your hand and we will give you the floor

We will use Sli.do for real-time polls/ Q&A/ chat box. Further instructions will be give later

cultural E+ syn.ikia | Sustainable plus energy neighbourhoods EXCESS

Important information before we start

This workshop will be recorded

Join at slido.com
#CulturalE

ⓘ Start presenting to display the joining instructions on this slide.

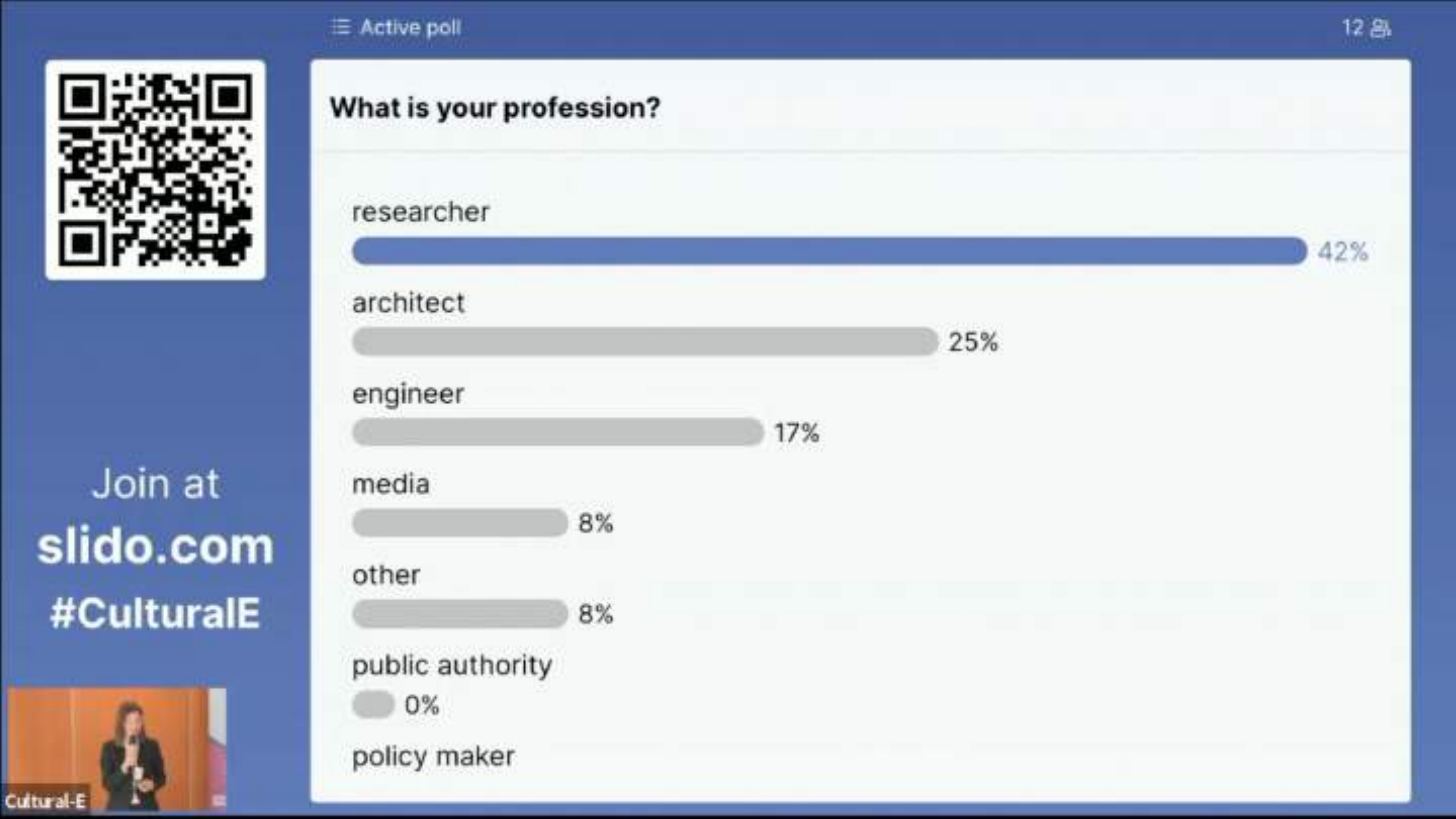
Active poll

12

Join at
slido.com
#CulturalE

Where are you joining us from?

Brussels & Copenhagen
Venice
Online
Beussels
Brussels
France
Madrid
Lille
Brusselshy


Active poll
12
What is your profession?
researcher
42%
architect
25%
engineer
17%
media
8%
other
8%
public authority
0%
policy maker
Join at
slido.com
#CulturalE
Cultural-E

Welcome to the Cultural-E Mid-term Conference

Annamaria Belleri, project coordinator - EURAC

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 870072

Path to market valuable Plus Energy Buildings

COSTS

First PEH: Heliotrope

First Plus Energy neighborhood: Solarsiedlung

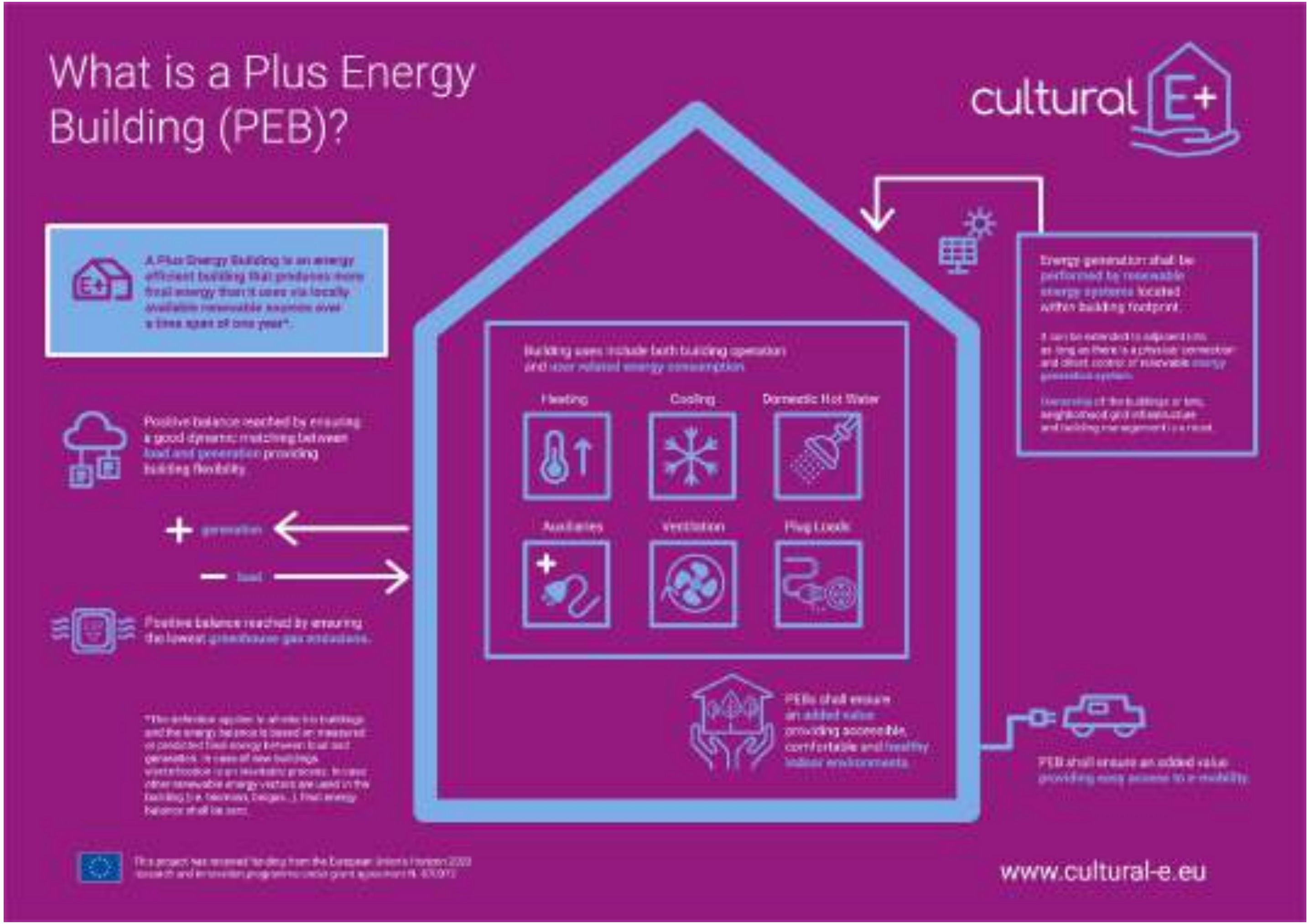
EPBD
Nearly Zero Energy Buildings

First multifamily PEH
Activ-Stadhaus, Frankfurt

Multi-storey Plus Energy Buildings as power plant for the neighborhood

1994 | 2005 | 2010 | 2015 | 2024 | 2026

EPBD
Plus Energy Buildings


What is a Plus Energy Building (PEB)?
cultural E+
A Plus Energy Building is an energy efficient building that produces more final energy than it uses via locally available renewable sources over a time span of one year*.
Positive balance reached by ensuring a good dynamic matching between load and generation providing building flexibility.
+ generation
– load
Positive balance reached by ensuring the lowest greenhouse gas emissions.
Building uses include both building operation and user related energy consumption
Heating
Cooling
Domestic Hot Water
Auxiliaries
Ventilation
Plug Loads
Energy generation shall be performed by renewable energy systems located within building footprint.
PEBs shall ensure an added value providing accessible, comfortable and healthy indoor environments.
PEB shall ensure an added value providing easy access to e-mobility.
www.cultural-e.eu

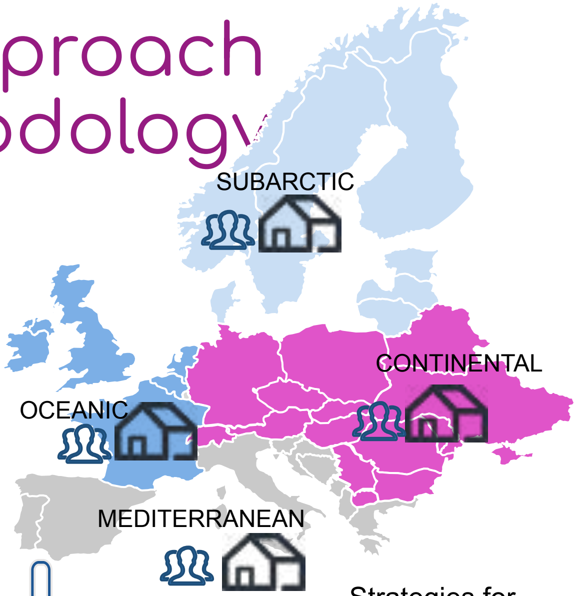
How can PEB become the new building standard?

cultural E+

- Put **user/households at the center** i) understanding user's needs and ii) guiding them towards better energy practices
- Defining **viable and tailorable technology concepts**
- **Integrated climate and cultural approach** that encompasses overall building configuration, technology selection, and user/systems interaction.
- Define **viable business models** that include attractive financial mechanism and co-benefit evaluation

Overall approach and methodology

1) Mapping of climate and cultural geo-clusters



cultural E+

DECARBONIZE EU BUILDING STOCK

INCREASE THE SHARE OF PLUS ENERGY HOUSES

2) Key technology developments

Cloud-based HMS

Smart hybrid ventilation

Smart air movement

Decentralized packed HP

Strategies for building flexibility

3) Definition of solution sets for each climate-cultural geocluster

need

acceptance

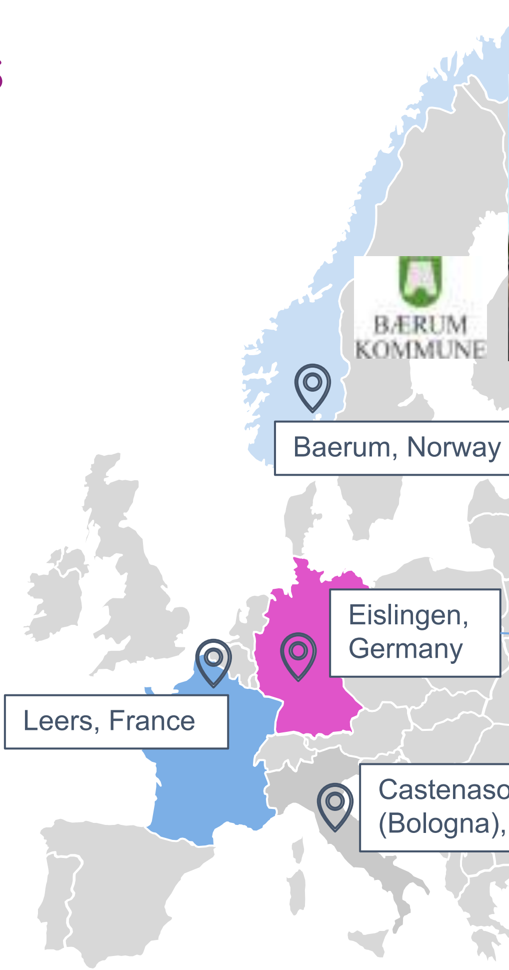
energy

value

4) Demonstration in 4 demo cases

2019-2024

Demo cases



BÆRUM KOMMUNE

cultural E+

Elgfaret 80-82
Apartment building for assisted living

wohnbau Studio

Private real estate

Private social housing

vilogia

abitcoop

Private cooperative

Agenda

11:30 – 11:40 Welcome to the conference by the project coordinator
(Annamaria Belleri, EURAC Research)

11:40 – 12:20 User centered technologies for PEB:

- Cloud-based House Management System – user interface
(Jose de las Heras, Advanticsys)
- Active window system
(Giovanni Toniato, Eurofinestra)
- Packed heat pump system and hybrid storage capacity
(Tom Lipinski, VENTIVE)
- Smart ventilation through ceiling fan
(Giulia Torriani, EURAC Research)
- Enabling building flexibility
(Enrico Dalla Maria, EURAC Research)

12:20– 12:30 Cultural-E solution sets for Plus Energy Buildings: performance analysis and harmonized control strategies
(Francesco Isaia, EURAC Research)

12:30 – 12:40 Understanding cultural and climate drivers for plus energy building design
(Ralph Horne, RMIT)

12:40 – 12:50 Life cycle environmental impact assessment of Plus Energy Buildings
(Roberta Di Bari, University of Stuttgart)

12:50 – 13:00 Q&A session

13:00 – 14:00 Lunch break and Networking

Thank you for you attention!

Annamaria Belleri

Eurac Research

annamaria.Belleri@eurac.edu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 870072

User-centered technologies for Plus Energy Buildings

Cloud-based HMS - user interface

Jose de las Heras, Advanticsys

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 870072

Objectives

Monitoring and IEQ evaluation

to demonstrate:
- PEB target
- IEQ
- user acceptance

HMS and Cultural-E technologies interaction

- to ensure interaction between building energy systems
- to enable advanced control strategies
- to demonstrate Cultural-E technologies performance

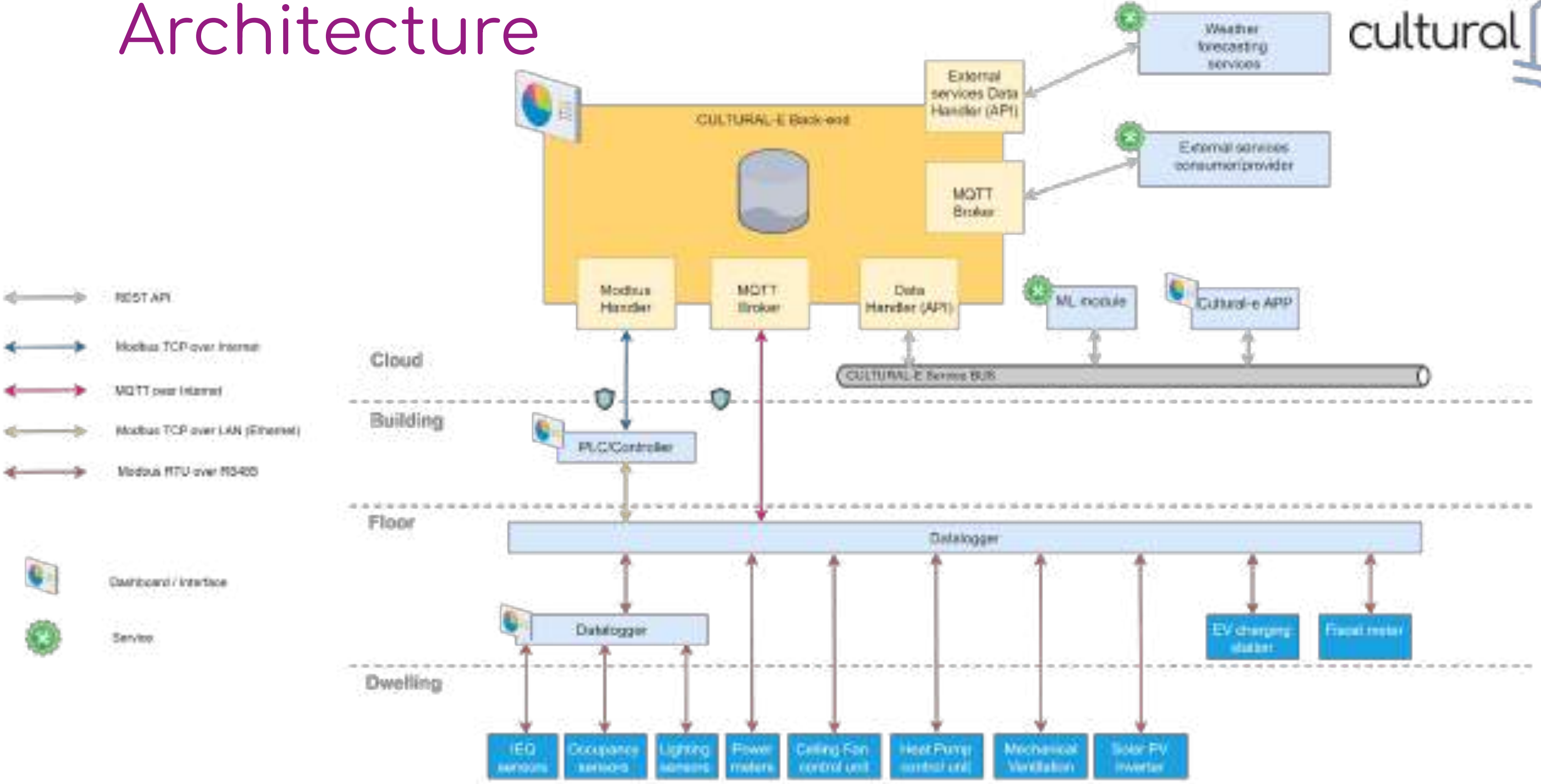
HMS and user interaction

- to understand users’ needs and preferences
- to present meaningful information on energy consumption and IEQ
- to engage users toward better energy practices

Other requirements specific to each demo case

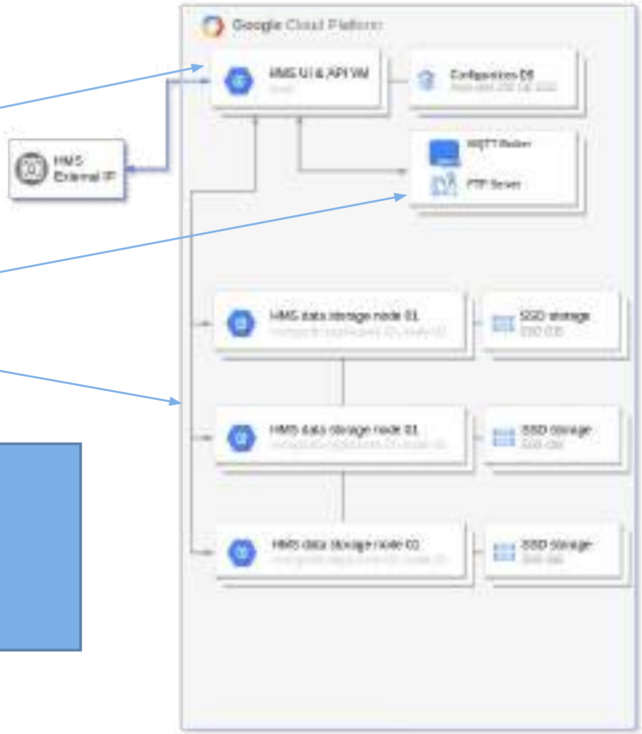
- to define services specific to each demo either on user control or on technologies implemented other than Cultural-E technologies

Architecture



Cloud infrastructure

- HMS User Interface and API virtual machine
- HMS Data Storage nodes
- MQTT Broker and FTP server



- Deployed in private cloud environment
- Encrypted data following GDPR
- Bidirectional encrypted communication with on site equipment

Features

The Cloud HMS is able to:

- collect streaming and batch data from any source (Modbus TCP, MQTT, KNX, OPC-UA and FTP)
- perform massive storage, retrieval, and management of data that is being generated at each of the demo sites
- handle graphs, aggregation and filtering of data
- create SCADA like widgets that can be integrated into any dashboard
- perform control actions over demo sites equipment through Modbus TCP or MQTT
- run dedicated ML components for forecasting and improved building control

Key elements

cultural E+

Cloud based system compatible with different field solutions to improve the overall performance ensuring bidirectional communication

Integrates **the User Interface for the occupants** to present meaningful information, guide him/her **toward better practices** and enable and assist in **the control of the technologies**

Acts as **a central brain** for the control of IEQ taking into account **user practices** and by **coordinating the set of technologies** to ensure best indoor conditions and minmize energy consumption and CO_2eq emissions

Active poll

0

Do you think our solution complies with data security and GDPR? Any comments?

Anonymous
Yes

Anonymous
Yes!

Anonymous
I place my confidence in your competence 😉

Anonymous
Yes

Anonymous
Yes it is

Join at
slido.com
#CulturalE

2 participants typing

6

Join at
slido.com
#CulturalE

Which benefit do you see in moving to a cloud system instead of having a typical control solution?

Anonymous
Access from everywhere

Anonymous
More compact control and easy access

Anonymous
Easier to manage

Anonymous
Gathering data for future follow-up analysis of data should be easier in this way

Anonymous
Additional information as weather data or energy prices

Anonymous
Remote maintenance and upgrading. Scalability

Thank you for you attention!

José J. de las Heras

Advanticsys

jheras@advanticsys.com

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 870072

User-centered technologies for Plus Energy Buildings

Active window system

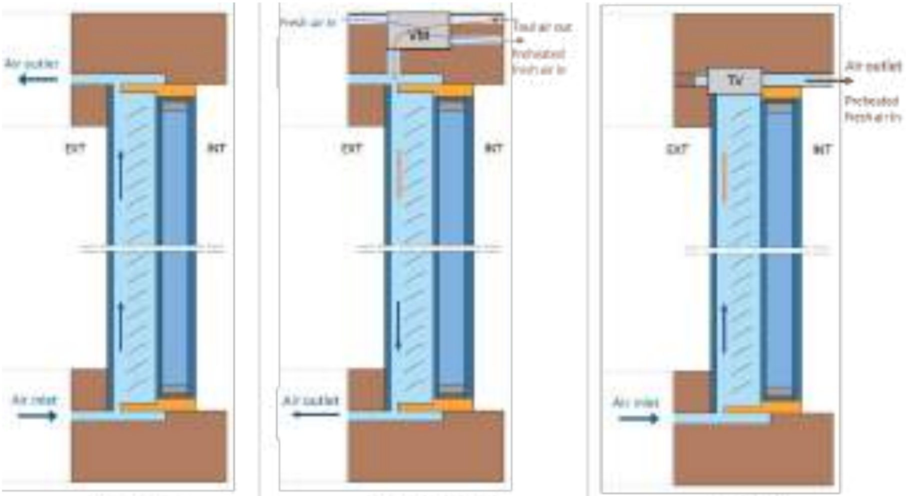
Giovanni Toniato, Eurofinestra

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 870072

Concept

Main features

1. **Modular wood frame** system
2. Movable **adaptive shading** system
3. Integrated **decentralized ventilation** device
4. **Interaction** between **shading** semi ventilated cavity and decentralized **ventilation** device



Option 1: No ventilation device

Option 2: Mechanical ventilation machine

Option 3: Trickle vent

Objectives

- Build a catalog of solutions
- Overall design and specific focus on an adaptable modular frame to be easily adapted to different climates or configurations.
- Then, design of the integration of the ventilation devices (trickle vents, ventilation machine) within the window system."

Progress

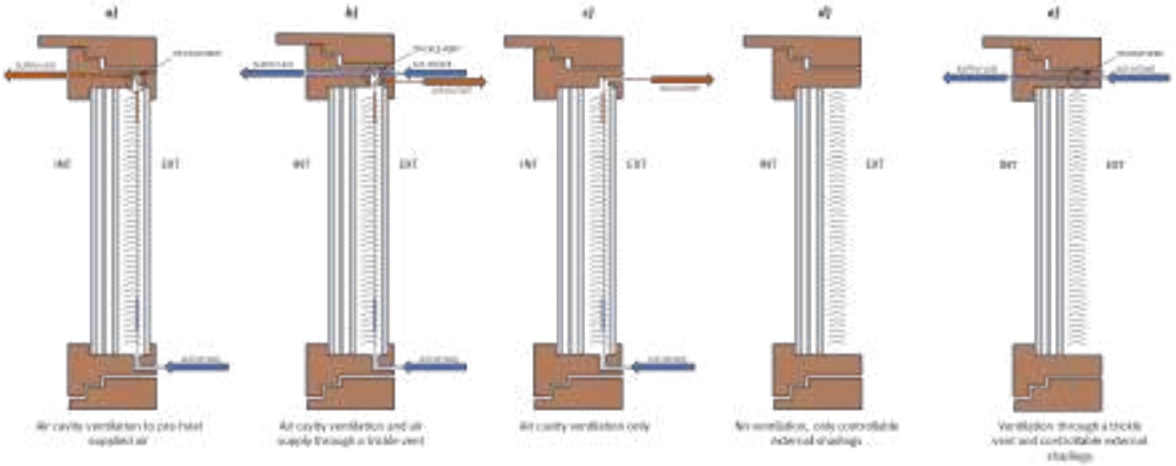
Completion of the **Active Window Configurator Tool (D3.3)**

Published in Zenodo (Scientific Open Repository) and presented in a IBPSA Italy conference[1]

Configurations considered

AWS different solutions		
Window type (3): frame + IGU	**Shading (3)**	**Ventilation (5)**
Mediterranean: frame1+IGU1	External	No Ventilation device
Continental: frame2+IGU2	Integrated - ventilated*	VM independent
Nordic: frame3+IGU3	Electrochromic	TV independent
		VM coupled with ventilated shading cavity*
		TV Coupled with ventilated shading cavity*
Total: 33 possible AWS configurations		

Schematic representation of some of the considered configurations



[1]Demanega I., Gennaro G., De Michele G., Isaia F., Favoino F., Avesani S., *Implementation and calibration of a model to treat naturally ventilated Complex Fenestration Systems in TRNSYS*, Building Simulation Applications (BSA2022), 29/06-01/07/2022 Bozen-Bolzano (Italy)

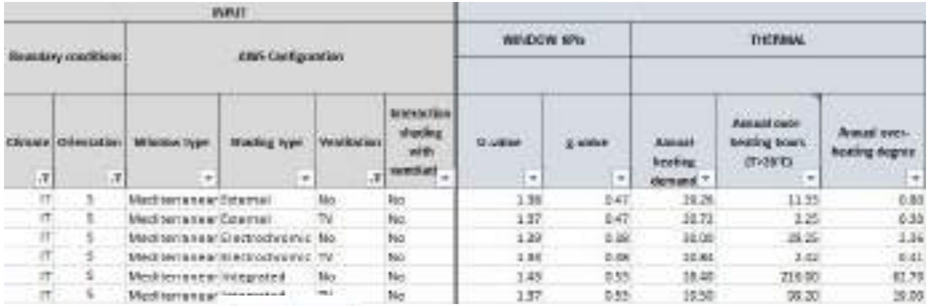
Methodology

Key Performance Indicators assessed (KPIs)

WINDOW		THERMAL			DAYLIGHT			
U-value	g-value	Annual heating demand	Annual over-heating hours (T>26°C)	Annual over-heatin g degree	Daylight autonomy	UDI-s	UDI-a	UDI-x
[W/m^{2}K]	[-]	[kWh/m^2]	[h]	[°C]	[%]	[%]	[%]	[%]

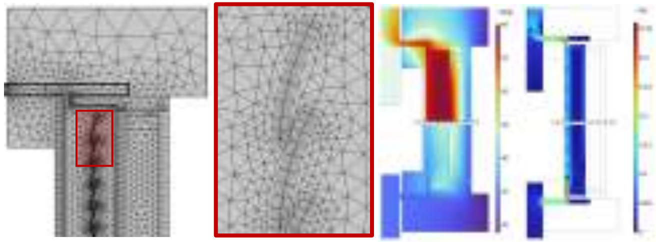
INDOOR AIR QUALITY				VENTILATION		
CO_2 CAT1	CO_2 CAT2	CO_2 CAT3	CO_2 CAT4	Air change rate	Hours natural ventilation	Mechanical ventilation consumption
[%]	[%]	[%]	[%]	[1/h]	[h]	[kWh/m^2]

Example use of the tool

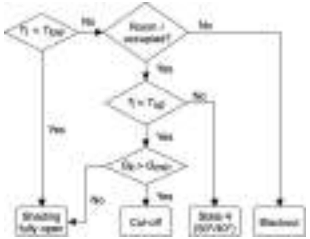


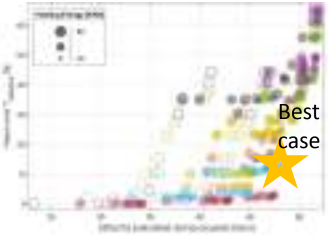
INPUT						WINDOW KPIs		THERMAL		
Boundary conditions		EWS Configuration								
Climate	Orientation	Window type	Shading type	Ventilation	Interaction shading with ventilation	U-value	g-value	Annual heating demand	Annual over-heating hours (T>26°C)	Annual over-heating degree
IT	S	Mediterranean	External	No	No	1.38	0.47	19.26	11.55	0.83
IT	S	Mediterranean	External	TV	No	1.37	0.47	18.73	2.25	0.33
IT	S	Mediterranean	Electrochromic	No	No	1.29	[illegible]	18.08	28.25	1.36
IT	S	Mediterranean	Electrochromic	TV	No	[illegible]	[illegible]	18.84	3.02	0.41
IT	S	Mediterranean	Integrated	No	No	1.45	0.55	18.48	216.90	81.79
IT	S	Mediterranean	[illegible]	TV	No	1.37	0.55	19.58	98.20	39.00

Methodologies and tools used for performance evaluation process

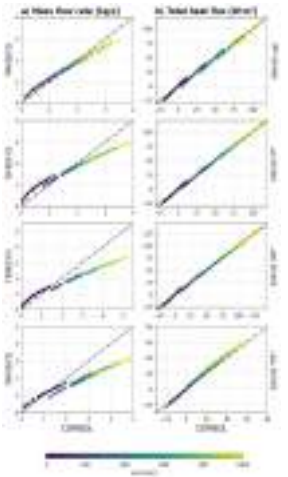


CFD analysis





Shading control algorithm optimization



Building simulation models validation through CFD results

Next actions

Prototypes for testing at Eurac outdoor laboratories

- Results will allow to **verify** the assumptions made during the simulation activity, **calibrate** the build models and get more insight on how this complex widow systems behave under **real conditions**

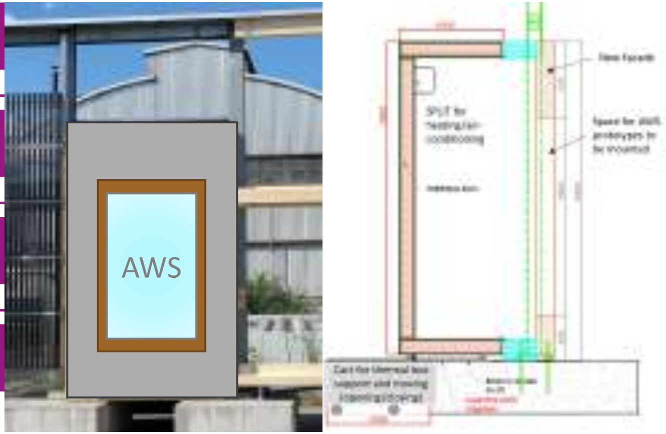
Finalization of the design for the Demo buildings

Completion of the CE marking

Installation in the Demo buildings

Connection to the HMS

- Implementation of the defined control strategies in real time



Eurac "Flexi" Lab

Thank you for you attention!

Giovanni Toniato (eurofinestra)

giovanni@eurofinestra.it

+39 3466137235

Leire Minguez (Eurac)

leire.minguez@eurac.edu

+39 0471 055 719

Francesco Isaia (Eurac)

francesco.isaia@eurac.edu

+39 0471 055 758

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 870072

User-centered technologies for Plus Energy Buildings

Packed heat pump system and hybrid storage capacity

Tom Lipinski, VENTIVE

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 870072

naturally intelligent buildings

Packed Heat Pump

One box integrated Heating, Hot Water, Cooling & Load-Levelling solution

Challenge:

Positive Energy Housing & Energy Transition: A Complex Problem

How do we transition to low Carbon heating in a sustainable and manageable way?

Solution:

A self-optimizing energy platform for modern buildings:

Intelligent, data-enabled comfort system

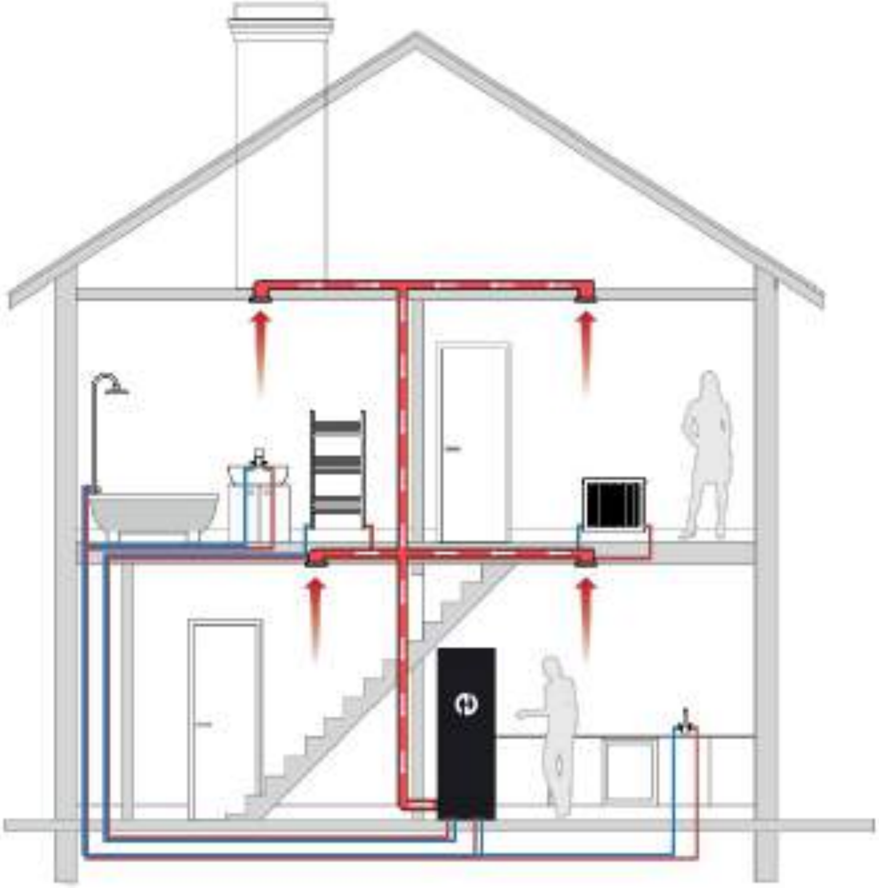
In one box

Home E

Exhaust air heat pump comfort system

- Renewable heating
- Exhaust ventilation
- Hot water
- Energy Storage

- Remote monitoring
- Performance optimisation
- Grid Load Levelling

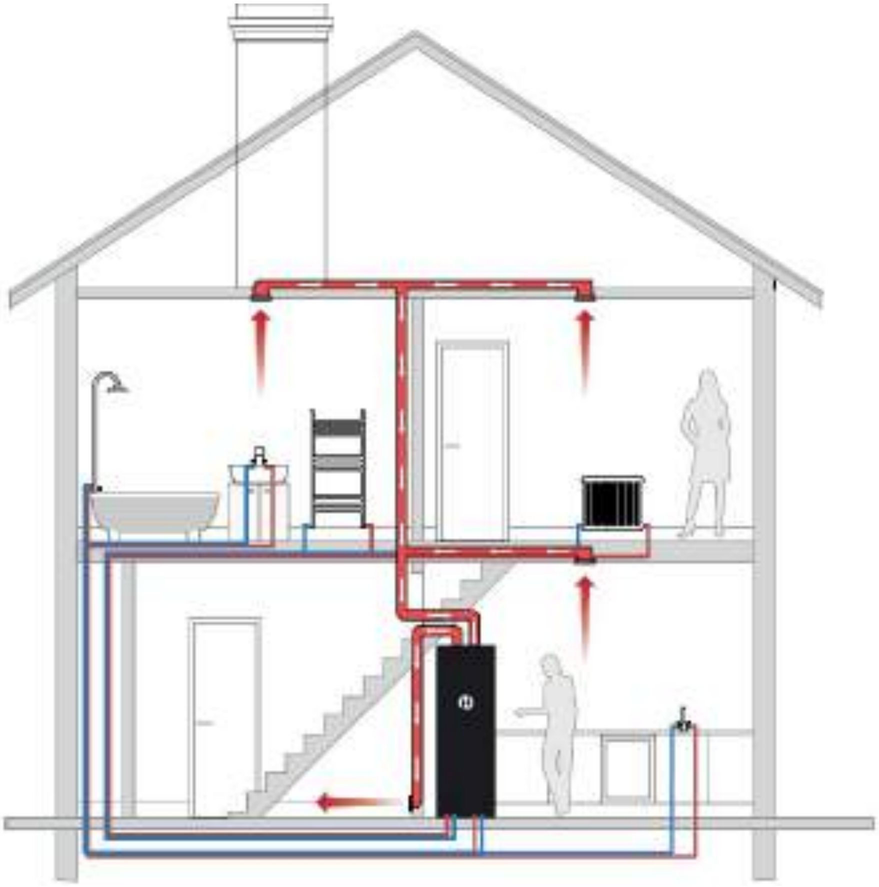


Home B

Heat pump-based comfort management system

- Renewable heating
- Balanced ventilation
- Hot water
- Free Cooling
- Energy Storage

- Remote monitoring
- Performance optimisation
- Grid Load Levelling



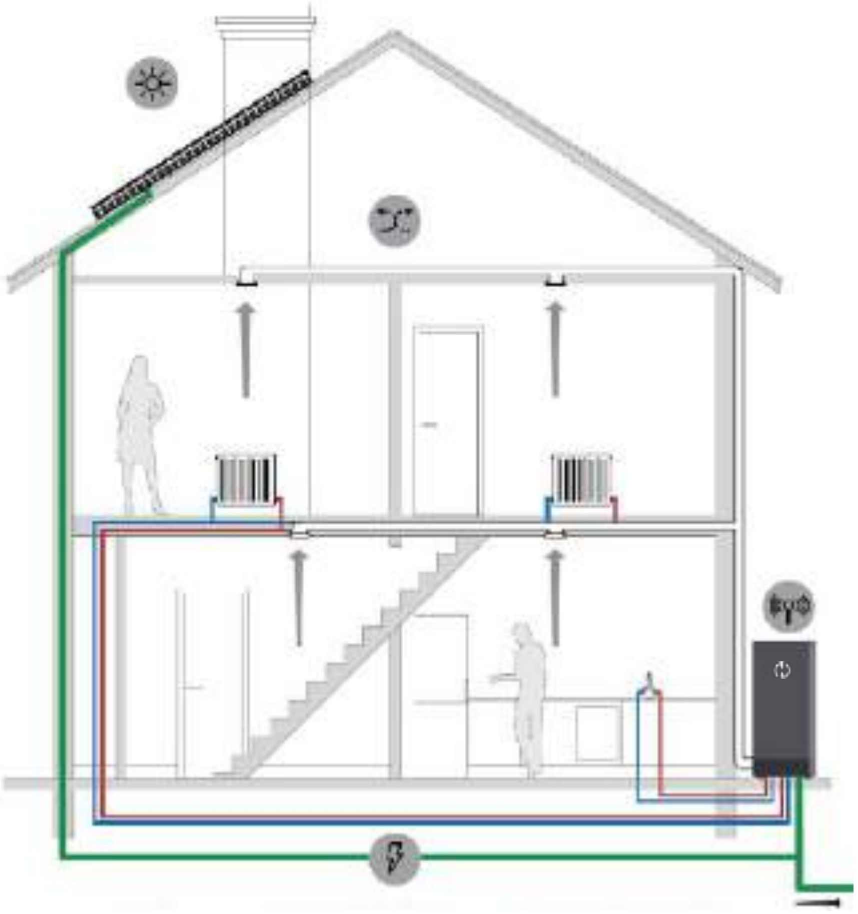
ventive

Home+

The complete home comfort & energy management system

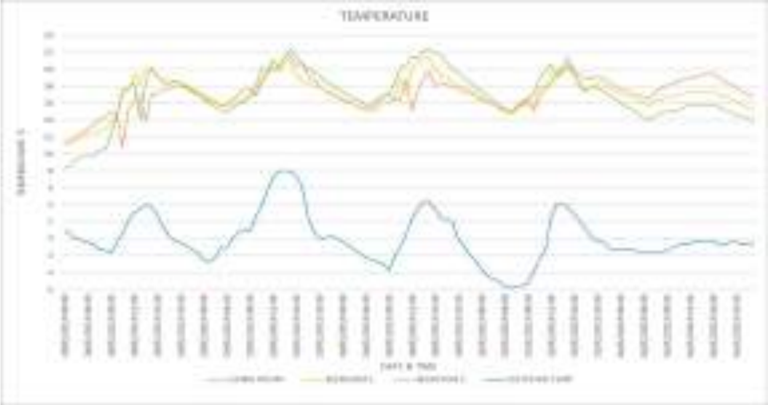
- Renewable heating
- Ventilation
- Hot water
- Free cooling
- Thermal storage
- Electrical storage

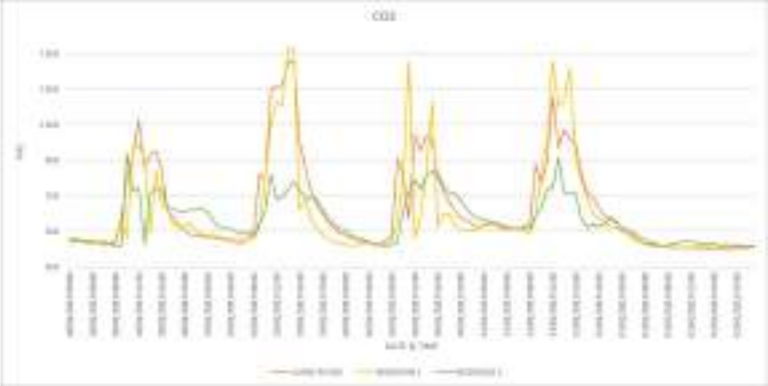
- Remote monitoring
- Performance optimisation
- Grid balancing



Performance Monitoring

- Monitor system performance in real time.
- Able to see if the building is running the way it was designed.
- Build up a profile for the house to learn from occupant behaviour.
- Tweak system parameters to get the exact performance for the occupant.
- Able to monitor how much energy is saved.
- Reports provided quarterly to client & design team demonstrating efficacy.





User Interface (FM/Landlord)

- Real time monitoring
- Performance data
- Historical reporting
- System optimisation
- Predictive maintenance

User Interface (resident)

- Simple user comfort set-point control
- Comfort management communication
- Basic operational data
- Interface for behavioural change nudges

Zero Carbon

Ventilation

Heating

Hot Water

Free Cooling

Energy Storage

Made in Europe

“If we are to meet our bold commitments on tackling climate change, finding low-carbon solutions to how we warm and cool our homes and workplaces is going to be vital.”

“Ventive is supporting the move away from using fossil fuels to heat buildings and demonstrates how UK innovators continue to lead the fight against climate change whilst creating new job opportunities along the way.”

Lord Callanan, Energy Minister at the Department for Business, Energy & Industrial Strategy (BEIS)

Thank you for you attention!

Contacts:

Tom Lipinski

tom@ventive.co.uk

Sam Whitfield

Sam@ventive.co.uk

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 870072

User-centered technologies for Plus Energy Buildings

Smart ventilation through ceiling fan

Giulia Torriani, EURAC

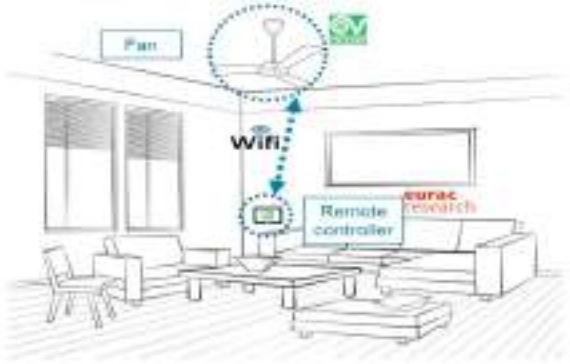
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 870072

Background and context

Air movement through ceiling fans can be an ENERGY-EFFICIENT way to provide COMFORTABLE cooling in warm and hot environments.

- Recent studies proved that the ceiling fans **reduce the space cooling need** in the Mediterranean climate by 49%, in the Continental climate by 91%, in the Oceanic climate by 45% and in the Sub-Artic region by 88%.
- In addition to the impact on thermal comfort, elevated airspeed is proven to positively impact **perceived air quality**.

It was developed* a **SMART CEILING FAN** with different control modes able of automatically adapting its rotational speed based on the temperature and relative humidity values measured in the room.



Proper **TESTING AND VALIDATION** in real scenarios still needed to be conducted.

*H2020 4RinEU (grant agreement No 723829)

What should we ask ourselves?

Does **AIR MOVEMENT** improve thermal environment and IAQ acceptability in the **residential buildings**?

Does **AUTOMATIC ALGORITHMS** work in terms of resulting comfort?

Is there any significant difference in people answers between **MANUAL AND AUTOMATIC** control?

Climatic chamber experimental study

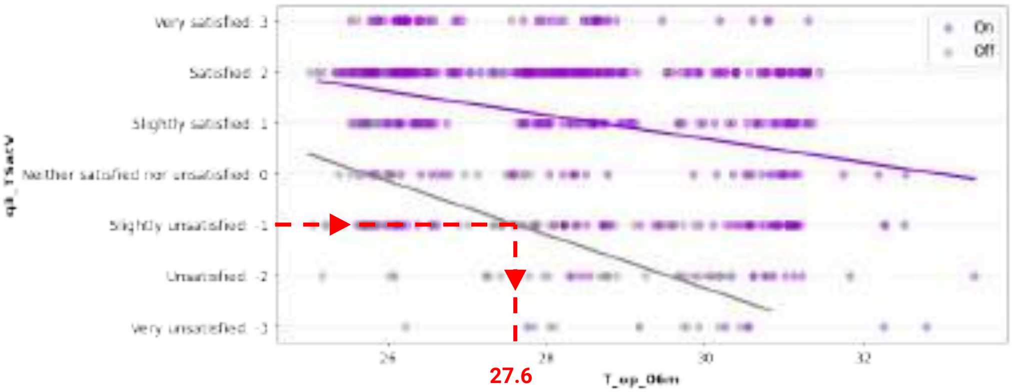
- Eurac Research **Façade System Interactions Lab** (Bolzano, Italy)
- Two climatic chambers set up as **residential environments** (i.e., living rooms)
- Three temperatures (**27 °C, 29 °C, 31 °C**)
- Three types of **surveys** (729 questionnaires collected) + monitoring of **environmental parameters**
- **30** participants

Does air movement improve thermal environment in residential buildings?

Yes!

- There can be **real benefits** until T_{op} = 31.5 °C.
- After T_{op} = 31.5 °C, the air movement provided by the ceiling fan does **not** seem to be **enough** to guarantee thermal satisfaction.
- At T_{op} = 27.6 °C, the ceiling fan needs to be **switched on**.

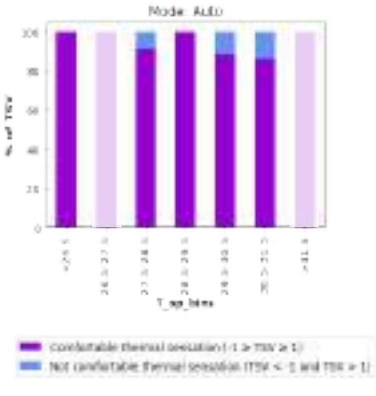
	Regression equation	R^2	p-value	T_{op} (q3_TSatV = -1)
Off	q3_TSatV = -0.5231 · T_{op} + 13.4573	0.45	0.00	27.64



Does automatic algorithm work in terms of resulting comfort?

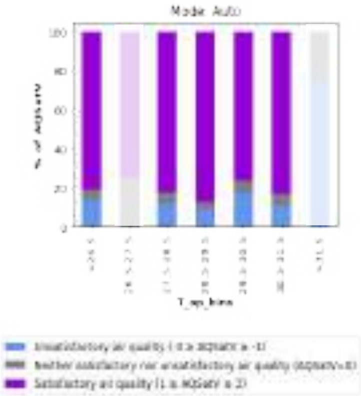
Thermal comfort

% Satisfaction ≥ 85%



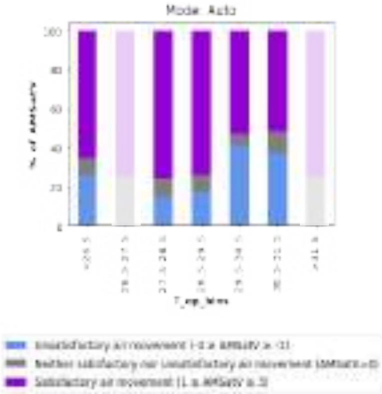
Perceived IAQ

% Satisfaction ≥ 82%



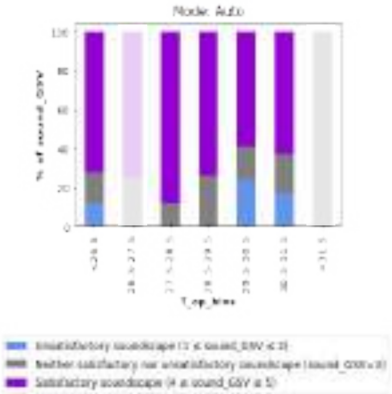
Perceived air movement

% Satisfaction ≥ 58%



Perceived soundscape

% Satisfaction ≥ 77%



The algorithm works really well especially in terms of **thermal comfort, indoor air quality** and **soundscape**. There are some minor issues connected to **air movement**.

Is there any difference according to the ceiling fan mode?

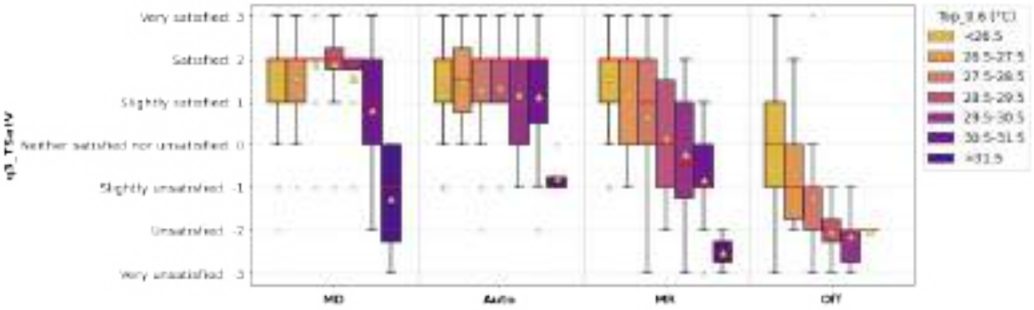
CONTROL MODES:

- Automatic (Auto)
- Manual (M)

FLOW DIRECTIONS:

- Direct (D)
- Reverse (R)

- The **automatic** mode seems to differ very little from the **manual** mode.
- The **direct** flow mode seems to work better.
- The automatic mode is able to **increase the neutral temperature** of 2.3 °C.



Conclusions

- Ceiling fans are an effective way to provide both **COMFORT** and **ENERGY SAVING** in warm and hot indoor environments.
- They can complement or replace the use of more energy-intensive cooling systems such as **AIR CONDITIONING**.
- It was developed a **COMFORT ALGORITHM** to automatically control the fan speed.
- The comfort level achieved with the automatic control is the same people experienced when they had manual control, but without requiring them to do **ANY ACTIONS**.

Active poll

12

How will the changing climate change the energy demand?

Increase in summer decrease in winter

More energy requirements for cooling systems.

Overall increase cooling demand

The Energy demand will increase especially due to population growth

Increase demand dramatically

Increase the cooling demand

increase

More cooling

Increase in cooling

It will increase

Increase the need for cooling in summer

Join at

slido.com

#CulturalE

Thank you for you attention!

Giulia Torriani

Eurac Research

giulia.torriani@eurac.edu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 870072

User-centered technologies for Plus Energy Buildings

Enabling building flexibility

Enrico Dalla Maria, EURAC

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 870072

“Energy Flexibility”. A definition.

cultural E+

(GRID)

(DISTRICT LEVEL)

BUILDING LEVEL

COMPONENT SYSTEM

Flexibility can be defined as the capability of a system to **ADAPT** its **<u>behavior</u>** to **external requirements.**

Definition from IEA EBC Annex 67: “*The energy flexibility of a building is the ability to <u>manage its demand and generation according to local climate conditions, user needs and grid requirements</u>*”.

Intersection with Plus Energy Building PEB paradigm.

Flexibility within the PEB paradigm

cultural E+

PEB means:

- Different underlying objectives, mindset, design target
- Additional resource and systems:
  - Local Renewable Production (PV).
  - Storage (Thermal and Electrical).

OBJECTIVEs:

- Environment
- Local energy resource exploitation
- Costs reduction

ACTIONS

Consume Less (Energy Efficiency)	Onsite renewable generation (PV, BIPV)	Consume Differently		
		Move consumption according to a target objective (MODULATE).	Reduce peak power during short periods (LOAD SHED).	Move energy use away from peak hours (LOAD SHIFT).

Focus on the operation of controllers onboard the system's components

Devices and flexibility potential

PRODUCTION. No active control (~~curtailment~~).

Photovoltaic or BIPV

Energy storage system (electric, thermal)

LOADS. Act on operation parameters of the **onboard controllers**.

Heat pump

Electric vehicles

Energy storage system (electric, thermal)

APPLIANCES.* "Aware" consumers. "Aware" inhabitants

We believe the *simplest* practice is to demand this care to a **properly educated and sensitized user**, that may be helped in the operation of its daily activity according to its needs and possible inputs from the building smart system.

* Their contribution to energy flexibility is not explored in the simulation framework.

Geo-clusters variations and potentials

cultural E+

Factors:

- Cultural, habits, behaviours
- Climatic (Weather) □ PV production + Cooling/Heating
- Structural (Energy system, Building Stocks characteristics , EV share)

Different system components (e.g. presence of EV charging point). Setpoints (Cooling/Heating needs)

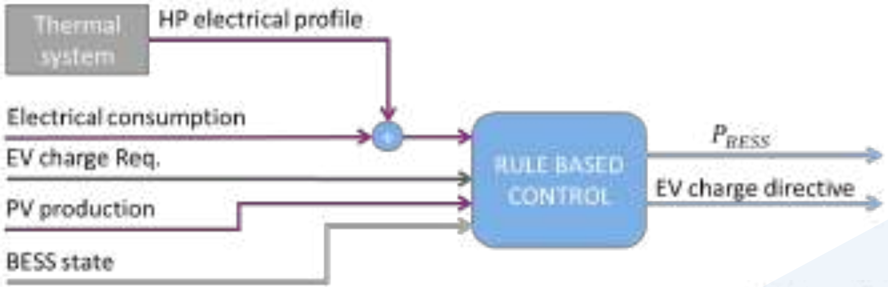
Electrical load profiles.

Geo-clusters	PV/BIPV	Electric storage	EV	Heat Pump
Subarctic (Norway)		X	X	H*
Oceanic (France)		X	X	H/C*
Continental (Germany)	X	X	X	H/C*
Mediterranean (Italy)	X	X		H/C*

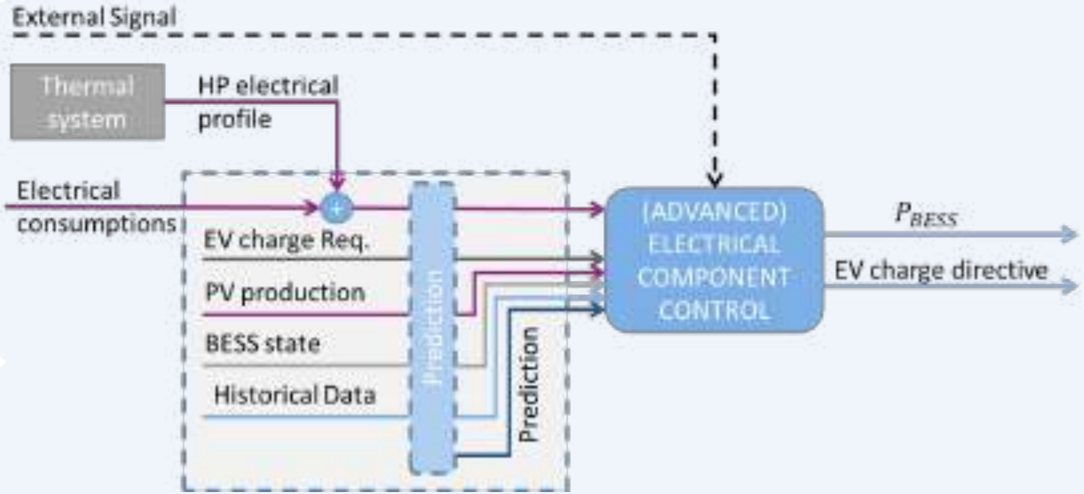
Qualitative identification of the relevant component according to the current diffusion/use/effectiveness in different geo-climate

* (H)eating / (C)ooling

Advanced Control Rules & Model Predictive Controls (MPC)



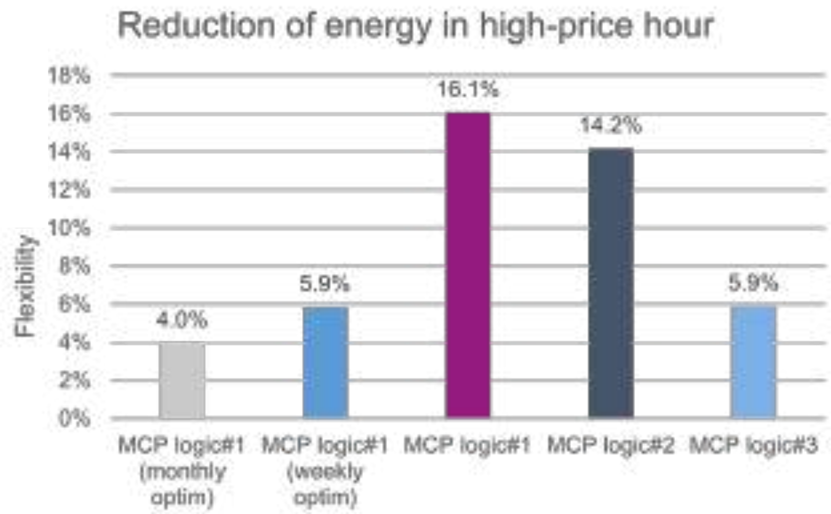
Electrical domains.
Control paradigms.



Simulation Phase. Preliminary outcomes

- **Target Objective**:
  - Maximise RES exploitation
  - Grid signal (price or other grid support)
- **Flexible Components**:
  - PV/BIPV + Battery, EV, HP
- **KPIs** (1 year simulation):
  - Self-Consumption (SC), Self-production (SP)
  - daily € savings, daily CO2 reduction
  - **Flexibility KPIs**
- **Control Strategies**:
  - Rule-Based (available load/production)
  - Rule-based control + Prediction
  - Model Predictive controls

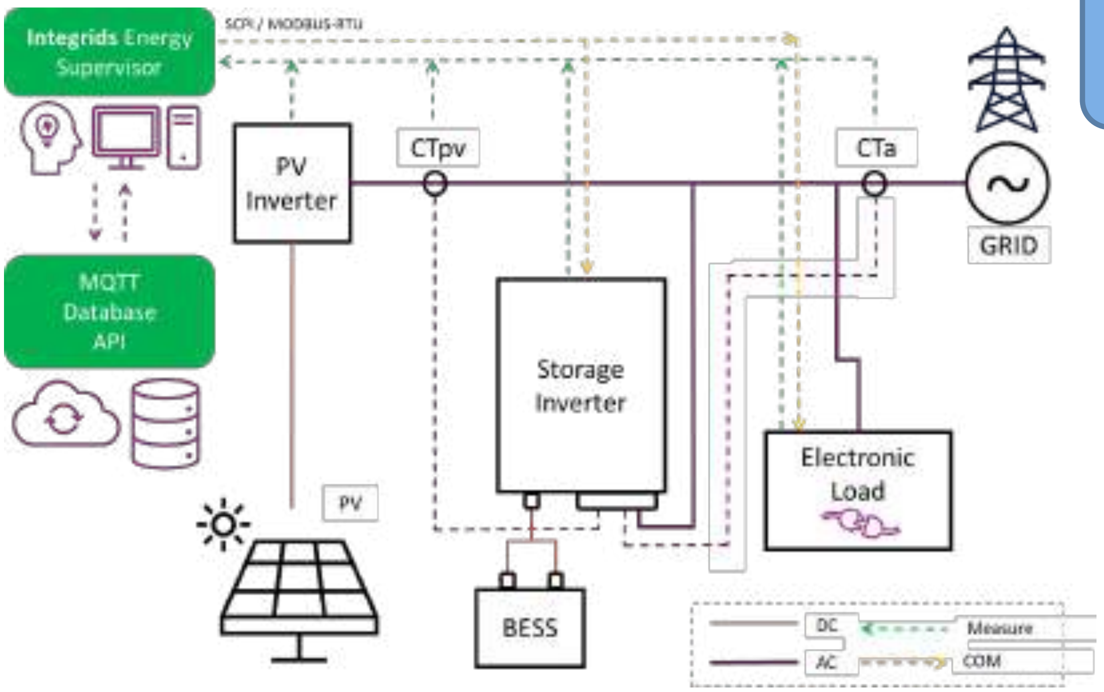
Simulation target



Reduction of the energy consumption from grid during high price hours. Perfect prediction (Best case scenario).

Preliminary qualitative results

(Upcoming*) Experimental setup.
Eurac Research (Bolzano, IT) outdoor exp. facilities



PV production.
Electrical Storage.
Arbitrary consumption profiles.

PENDING ACTIVITIES

Experimental system setup and integration within the "Integrids" MICRO-GRID

MODEL VALIDATION

CONTROL ALGORITHM VALIDATION

** Currently being deployed and installed*

Thank you for you attention!

Grazia Barchi
Eurac Research
grazia.barchi@eurac.edu

Enrico Dalla Maria
Eurac Research
enrico.dallamaria@eurac.edu

Kari Thunshelle
SINTEF
kari.thunshelle@sintef.no

Harald Taxt Walnum
SINTEF
harald.walnum@sintef.no

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 870072

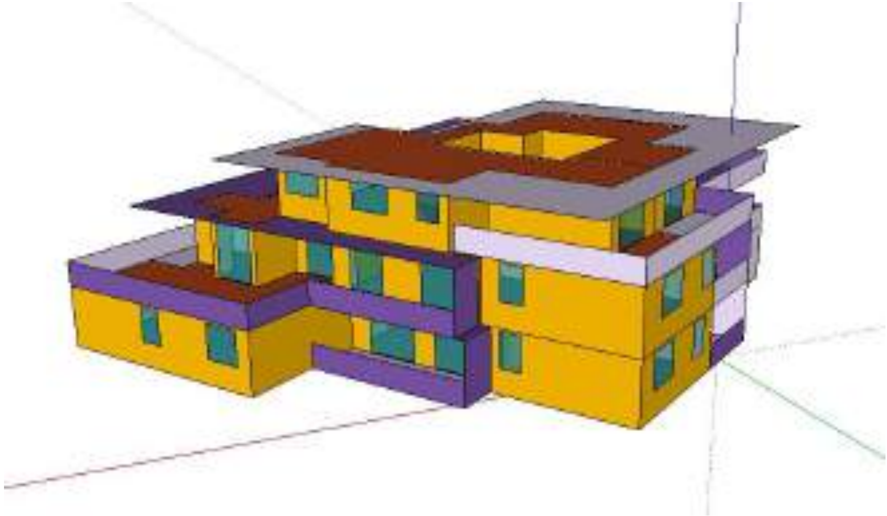
Cultural-E solution sets for Plus Energy Buildings: performance analysis and harmonized control strategies

Francesco Isaia, EURAC

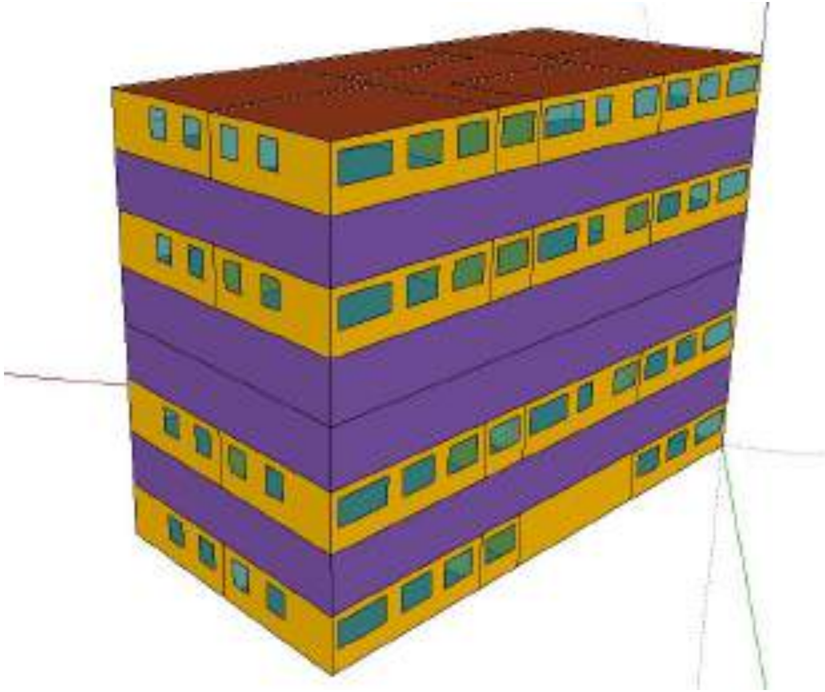
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 870072

Performance analysis

Two building archetypes

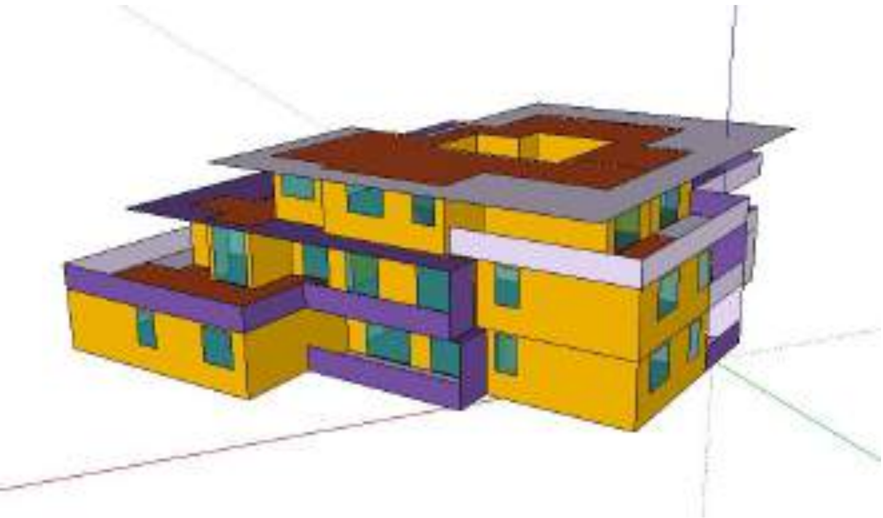


Low-rise building



High-rise building

Performance analysis



Low-rise building

Simulation **inputs** take into account different geo-clusters and cultural habits:

- Opaque envelope **U-value** according to the geo-cluster
- Heating/cooling **setpoint temperatures** different for each climate

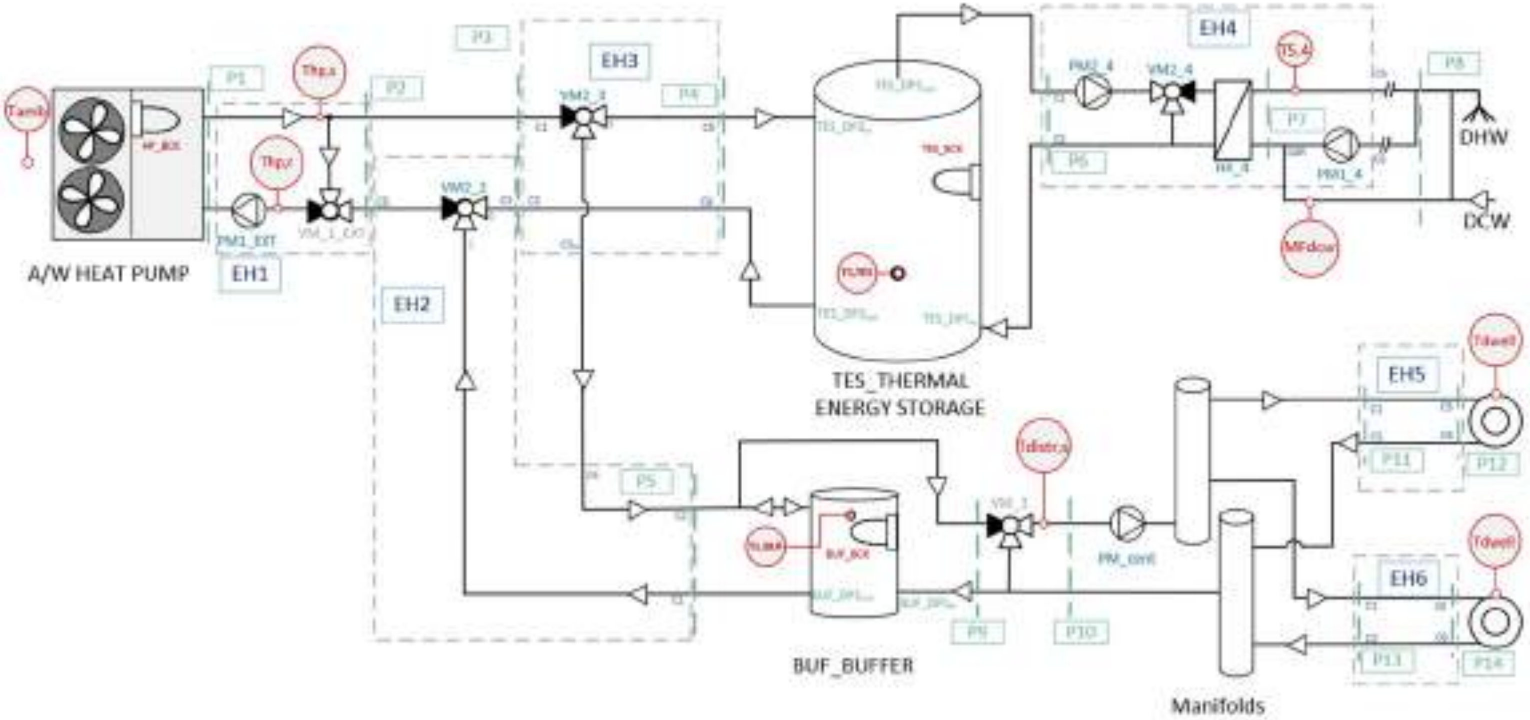
Geo-cluster	U-value [W/m²K]	Setpoint temperature Heating/Cooling
Mediterranean (Italy)	0.18	20/26
Continental (Germany)	0.13	21/26
Oceanic (France)	0.18	20/24
Sub Artic (Norway)	0.10	22/-

- **Internal gains** different in each geocluster, depending on statistically defined use of the building and occupants' habits

- Cultural-E technologies are considered: **air movement** (ceiling fan), **ventilation machine** with HR, advanced **shading system** and **Heat Pump** and distribution system

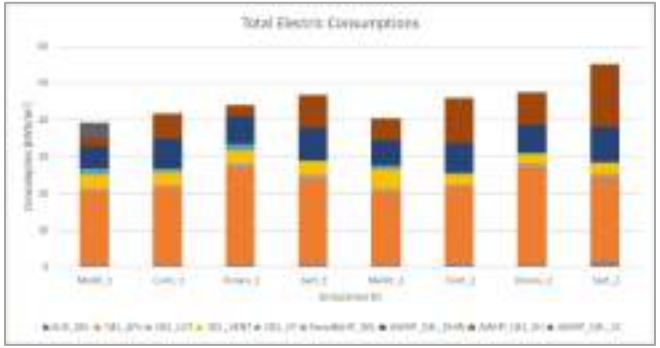
Performance analysis

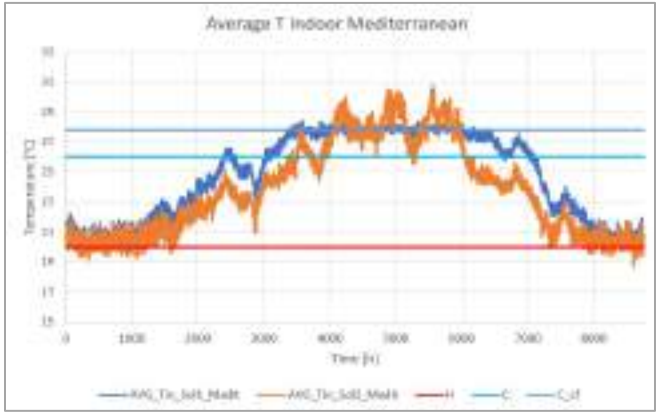
HVAC system



Performance analysis

Preliminary results





Low-rise building

		Low-rise building				High-rise building			
		IT	DE	FR	NO	IT	DE	FR	NO
Primary energy conversion factor	[-]	2.42	1.37	2.3	2.28	2.42	1.37	2.3	2.28
national %renewable in grid	[-]	0.398	0.457	0.236	0.95	0.398	0.457	0.236	0.95
Primary energy	[kWh/m^2]	72.3	61.4	98.5	112.4	63.6	49	84.5	81.3
Final energy	[kWh/m^2]	32.8	31.4	27.7	38	24.7	24.4	24.3	29.5
Annual heating demand	[kWh/m^2]	8.7	16.4	8.3	22.9	4.8	10.8	4	16.1
Annual cooling demand	[kWh/m^2]	-9.2	-0.1	-4.5	-0.1	-6.5	-0.2	-7	-0.1
Annual DHW demand	[kWh/m^2]	15	14.9	14.9	15	13.4	13.4	13.4	13.4
Heating Peak power	[kW]	12.8	13.2	8.8	24.7	23.5	25.5	13.6	50.8
Cooling Peak power	[kW]	-14.3	-3.4	-12.2	-4.5	-35.6	-13.1	-38.8	-11.5
DHW Peak power	[kW]	19.3	19.3	20.5	19.6	77.3	73.8	77.3	74.7
Annual electric energy per net area	[kWh/m^2]	50.2	52.2	58.6	60.4	38.9	42.2	52.1	50.8
Electric energy for lighting	[kWh/m^2]	0.9	0.7	1.2	1.1	1.1	0.8	1.9	1.4
Electric energy for appliances	[kWh/m^2]	29.7	31.3	39.6	34.8	23.6	26.9	35.6	30.6
Renewable energy installed capacity	[kW]	32.6	32.2	32.6	31.7	136.2	139.7	209.1	207
Renewable energy generation	[kWh/m^2]	61.8	48.1	40.2	41.7	46.3	41	45	46
Imported renewable energy	[kWh/m^2]	6.2	11.4	7.2	38.6	6.9	8.5	5.9	22.6
Exported renewable energy	[kWh/m^2]	10.2	7.7	1	11.4	14.9	7.8	8.1	10
PV self-sufficiency	[-]	68.90	52.20	47.70	32.80	55.10	56.10	52.10	53.10
PV self-consumption	[-]	55.90	56.70	69.50	47.60	46.20	57.70	60.20	58.70
IAQ- CO2	[ppm]	730	667	731	720	744	670	881	738
Thermal - % Yearly hours within indoor temperature ranges	[%]	100.00	100.00	100.00	99.80	99.90	100.00	99.60	99.70
Thermal - % Yearly hours within indoor relative humidity ranges	[%]	93.30	97.40	88.40	93.60	93.70	97.90	91.70	94.00

Solution sets

Low-rise building

LOW-RISE BUILDING (i.e. 3 floors - 6 dwellings - 80-110 m2 each)							
SOLUTION SET 1				SOLUTION SET 2			
Mediterranean	**Continental**	**Oceanic**	**Sub Arctic**	**Mediterranean**	**Continental**	**Oceanic**	**Sub Arctic**
VMC + **dehumidifier**	Mechanical ventilation and heat recovery by active window system + **exhaust fan** in bathroom	Mechanical ventilation and heat recovery by active window system+ **exhaust fan** in bathroom	Mech ventilation (dwelling) + HR	PHP (mech.ventilation, storage, h&C,DHW)	PHP (mech.ventilation, storage, Heating, DHW. Cooling by storing into DHW)	PHP (mech.ventilation, storage, Heating, DHW. Cooling by storing into DHW)	PHP (mech.ventilation, storage, Heating, DHW. Cooling by storing into DHW)
Ceiling fan	Air movement	Air movement	Air movement	Ceiling fan			
Standard heat pump with water storage (H&C, DHW)	Centralized standard outdoor-air heat pump with water storage - heating and DHW	Standard heat pump with water storage - heating and DHW	Standard heat pump with water storage - heating and DHW	Space heating: Underfloor heating	Space heating: Underfloor heating	Space heating: Underfloor heating	Space heating: Underfloor heating
Space heating: Underfloor heating	Space heating: Underfloor heating	Space heating: Underfloor heating	Space heating: Wall panel (electric / water radiant). UFH for bath. UFH water heating.	Space cooling: air cooling	Space cooling: air cooling (up to DHW is full)	Space cooling: air cooling (up to DHW is full)	Space cooling: air cooling (up to DHW is full)
Space Cooling: Underfloor cooling	Freecooling + natural ventilation (cooling)	Freecooling	Freecooling	Suitable windows, shading and envelope	Suitable windows, shading and envelope	Suitable windows, shading and envelope	Suitable windows, shading and envelope
Suitable windows, shading, envelope	Suitable shading, envelope	Suitable shading, envelope	Suitable shading, envelope, BIPV on facades	PHP (mech.ventilation, storage, h&C,DHW)	PHP (mech.ventilation, storage, Heating, DHW. Cooling by storing into DHW)	PHP (mech.ventilation, storage, Heating, DHW. Cooling by storing into DHW)	PHP (mech.ventilation, storage, Heating, DHW. Cooling by storing into DHW)

Solution sets

High-rise building

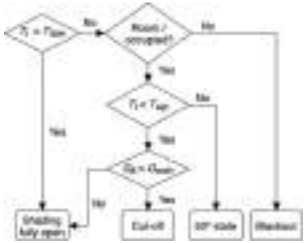
HIGH-RISE (i.e. 8 floors - >20 dwellings, 50-75 m2 each)							
SOLUTION SET 1				SOLUTION SET 2			
Mediterranean	**Continental**	**Oceanic**	**Sub Arctic**	**Mediterranean**	**Continental**	**Oceanic**	**Sub Arctic**
Mechanical ventilation and heat recovery by active window system + exhaust fan in bathroom	Mechanical ventilation and heat recovery by active window system + exhaust fan in bathroom	Centralized mechanical ventilation and heat recovery -- centralized at building level	Centralized mechanical ventilation and heat recovery -- centralized at building level	PHP (mech.ventilation, storage, h&C,DHW)	PHP (mech.ventilation, storage, Heating, DHW. Cooling by storing into DHW)	PHP (mech.ventilation, storage, Heating, DHW. Cooling by storing into DHW)	PHP (mech.ventilation, storage, Heating, DHW. Cooling by storing into DHW)
Ceiling fan	Ceiling fan/wall	Air movement	Air movement	Ceiling fan			
Centralized heating - heat pump with water storage (H&C, DHW)	Centralized heating - outdoor air heat pump with water storage - heating, DHW by fresh water stations	Centralized heating - heat pump with water storage - heating and DHW	Centralized heating - heat pump with water storage - heating and DHW	Space heating: Underfloor heating	Space heating: Underfloor heating	Space heating: Fan coils	Space heating: Underfloor heating
Space heating: fan coils	Space heating: underfloor heating system	Space heating: fan coils	Space heating: low temp radiator	Space cooling: air cooling	Space cooling: air cooling (up to DHW is full)	Space cooling: air cooling (up to DHW is full)	Space cooling: air cooling (up to DHW is full)
Space Cooling: fan coils	Freecooling + natural ventilation	Freecooling	Freecooling	Suitable windows, shading and envelope	Suitable windows, shading and envelope	Suitable windows, shading and envelope	Suitable windows, shading and envelope
Suitable shading, envelope	Suitable shading, envelope	Suitable shading, envelope	Suitable shading, envelope	PHP (mech.ventilation, storage, h&C,DHW)	PHP (mech.ventilation, storage, Heating, DHW. Cooling by storing into DHW)	PHP (mech.ventilation, storage, Heating, DHW. Cooling by storing into DHW)	PHP (mech.ventilation, storage, Heating, DHW. Cooling by storing into DHW)

Control strategies

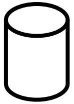
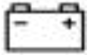
Each technological solution has its own **control logic**

Ceiling fan control

Shading system control

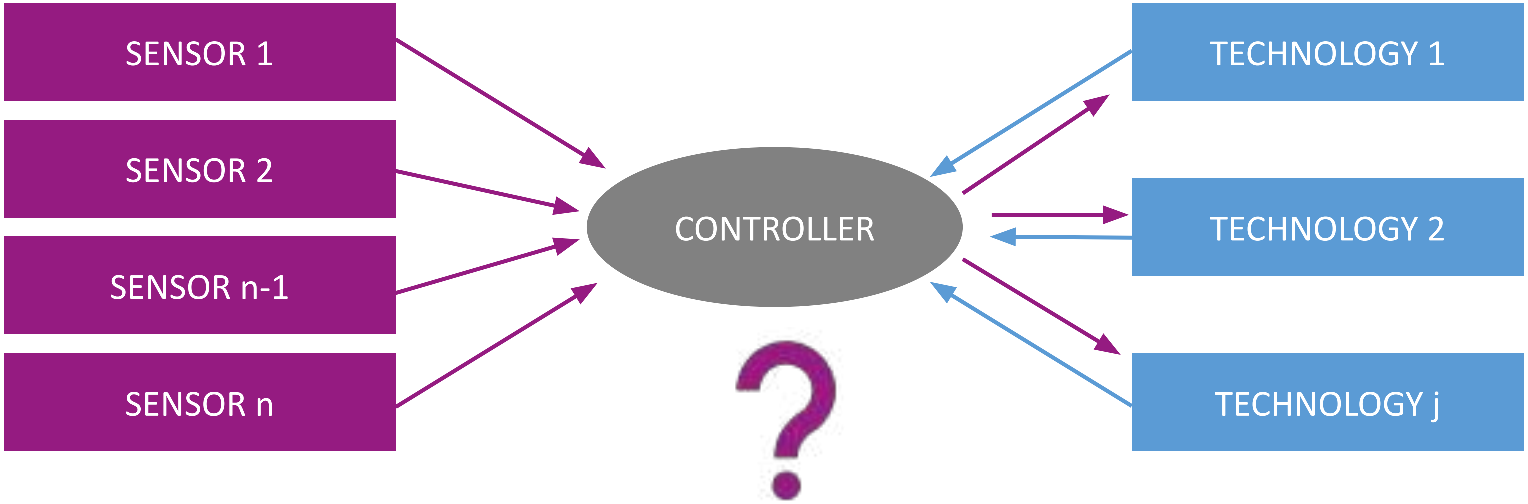


Other control logics related to:

- PV production 
- Thermal Energy Storage (TES) 
- HVAC system 
- Battery Energy Storage System (BESS)
- Mechanical ventilation

Control strategies

- The different technologies should work in harmony
- There should be a controller that manages different inputs and decide how to run the different components

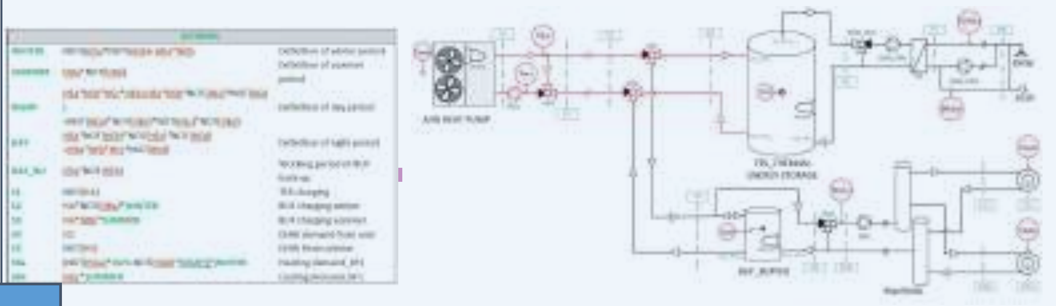


Control strategies

Need to **harmonize** all the control strategies

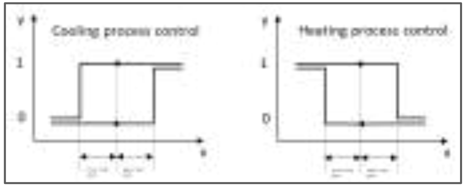
Objectives:

- Maximization of **thermal comfort**
- Maximization of **indoor air quality**
- Minimization of **energy consumptions**



Scheme 1 (S1): running the HP unit for DHW production

HYSTERESIS → SCHEMES



SCHEMES + MODULATIONS → CONTROL SIGNAL

The control signals delivered to the components are the combination of schemes and modulations

$$M\_PM1a = \frac{MIN\left(MAX\left(\left|\frac{AWHP\_LOA\_QTH * 3.6}{AWHP\_DT\_WM * CP\_WATER}\right|, PM1\_MF\_MIN\right), PM1\_MF\_MAX\right)}{PM1\_MF\_MAX}$$

☰ Active poll

12

As a user, would you prefer a control system that:

Only suggests you the best actions to take
58%

Operates independently only when you are not home
33%

Directly implements the control actions
8%

Others
0%

Thank you for you attention!

Francesco Isaia (Eurac)

francesco.isaia@eurac.edu

+39 0471 055 758

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 870072

Understanding cultural and climate drivers for plus energy building design

Ralph Horne and Ivan Luque Segura, RMIT

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 870072

Domain of Research: Climate and Cultural Drivers of Energy Demand in Domestic Buildings

Signifyingly, Cultural-E focuses on cultural and climatic related aspects of domestic energy demand, which are the basis for an **understanding of household practices in the context of the development of user-involved smart energy technologies and building design criteria**.

The research intends to address the **gap between building design expectations and the reality of household energy performance**.

Energy is often considered to be a transacted product, where a conscious decision is made to consume it, then **Energy Efficiency comes to be about providing information to inform this choice**. **In reality, many other social, economic, and cultural factors are in play, beyond individual choice**.

Comfort, for example, is not simply a personal choice, it is also a matter of convention, looking after others' presumed comfort needs, or maintaining standards of comfort that are socially rather than individually maintained.

Source: Changing energy demand - Concepts, metaphors and implications for policy - Insights across DEMAND, Noel Cass and Elizabeth Shove (2017)

2CAP-Energy Atlas – Design Concept

cultural E+

- **Sharing the knowledge and results developed in the project with building designers, policy makers and researchers.**
- **Focusing the development efforts on appropriate technologies** throughout the context analysis.
- **Addressing the existing energy efficiency 'gap'** which is complex and multidimensional.
- **Accounting for culture and climate,** the 2CAP-Energy Atlas aims to have an impact on future PEB design.
- **Dedicated online tool that can be constantly updated by the building science community** –it aims to make results from Cultural-E project becoming complementary to stakeholders and science community's contributions and available to target audiences-.

energyatlas.eurac.edu/

2CAP-Energy Atlas – Design Concept

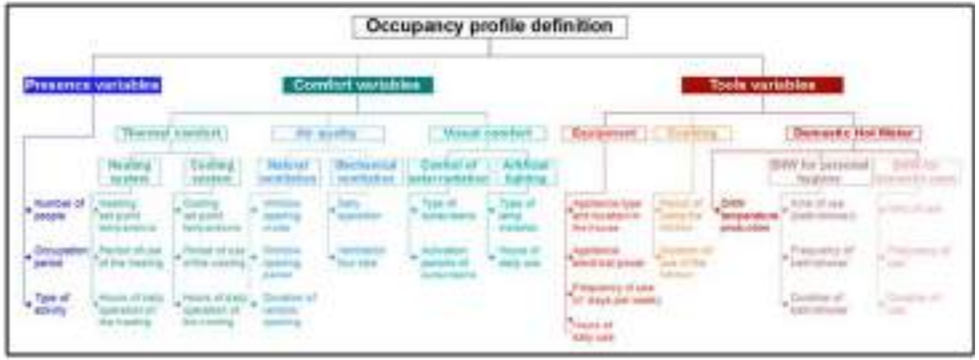
cultural E+

- **How to tackle user energy demand by means of integrating its complexity into PEB design?**

User behaviour prediction models and simulation-aided building design could conflict with the energy demand concept from a social sciences perspective, instead both approaches become complementary and will drive some light on how integrating user energy-related practices into the design process.

- **How should the existing energy performance 'gap' -which is uncertain and multidimensional- be addressed by the Atlas?**

In addition to user-centric design approaches, modelling the scope and effects of user behaviour (window, shading, lighting operation, thermostat adjustment, appliance use, clothing adjustment, etc) enables to mitigate the EPG for a successful PEB design.



Source: *Reference procedures for obtaining occupancy profiles in residential buildings. Marilena De Simone M. et al. (2018) IEA EBC Annex 66 – Subtask A Deliverable*

'Currently, the scope of the metrics used **OB Modelling is limited to energy and comfort aspects**, which are normalised by building features **instead of occupant related factors'.**

Ref: Mahecha Zambrano, Juan & Filippi Oberegger, Ulrich & Salvalai, Graziano. (2021). Towards integrating occupant behaviour modelling in simulation-aided building design: Reasons, challenges and solutions. Energy and Buildings. 253. 111498. 10.1016/j.enbuild.2021.111498.

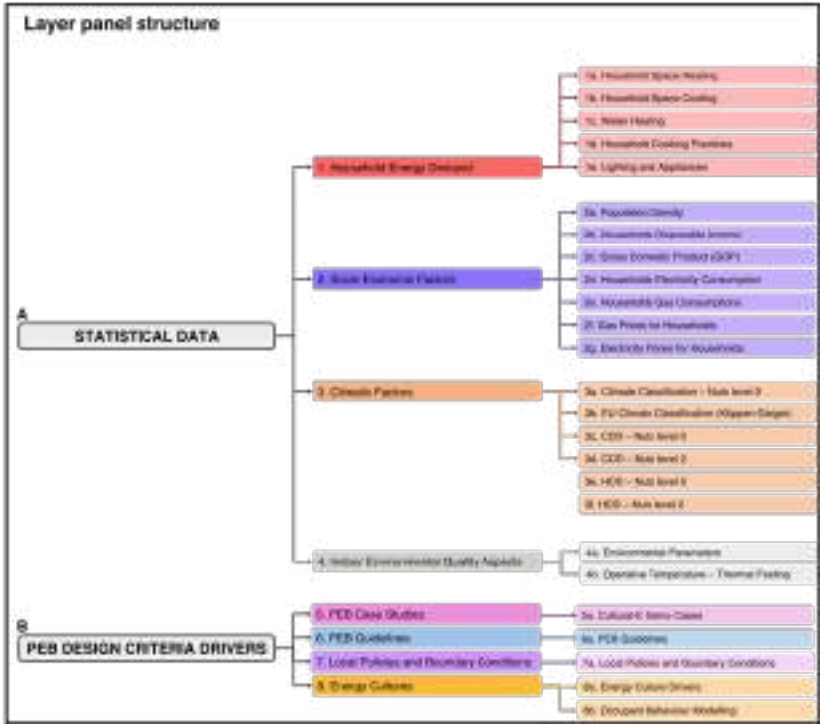
2CAP-Energy Atlas – Main Features

The 2CAP-Energy Atlas, a data visualization library, **intends to be perceived as a comprehensive set of information sources which add questions and provide key inputs to building designers' daily practices.**

The tool is backed up on a **GIS online interface** which aims to make **results from the Cultural-E project complementary to stakeholders and the building science community**, as well as to enable constant updating. The Atlas' main group of layers are:

A. Cultural and Climatic statistical data.

B. PEB design criteria drivers.



2CAP-Energy Atlas – continues update

The Atlas is a singular design tool with a specific focus on occupant behaviour profiling, household energy demand and relevant IEQ aspects at different EU climatic areas. It is a continues evolving tool and will integrate forthcoming project results into dedicated map layers, such as:

- Building technologies for PEB;
- **Simulations-aided design approaches (on going);**
- PEB solution-sets;
- **IEQ and user comfort aspects (on going),**
- Co-impacts for PEBs;
- Demo building outcomes, monitoring process and POE campaigns

With the aim to enhance the knowledge transfer between WP3, WP4, WP5 and WP6, socio-cultural factors that directly affect building energy performance are integrated into the EU 2CAP-Energy Atlas, where specific user-focused-content layers have been designed, such as:

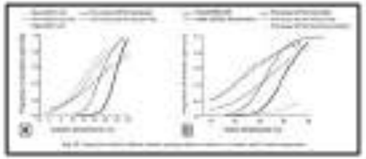
- **the 'Energy Culture Drivers' layer**
- **the 'Occupant Behaviour Modelling' layer**
- **The 'Indoor Environmental Quality aspects' layers group**

'Introducing **human behaviour to BPS is fundamental for achieving accurate simulation results** and their resulting predictions for energy consumption and comfort assessment.'
Ref: Experimental study on occupants' interaction with windows and lights in Mediterranean offices during the non-heating season. Naspi, F. et al. (2017). Building and Environment. 127. 10.1016/j.buildenv.2017.11.009.

'...**not assign the occupants a priori as the main culprits responsible for the Energy Performance-Gap**, but as partners in a collective endeavour to enhance the energy performance of the built environment.'
Ref: The Role of Occupants in Buildings' Energy Performance Gap: Myth or Reality? Mahdavi, A et al. Sustainability 2021, 13, 3146. https://doi.org/10.3390/su13063146

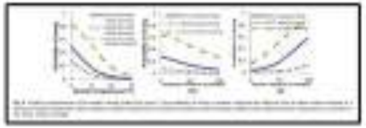
NUTS2 | NUTS 0 | Climatic Areas | Geo-referred locations

ITALY



Ref: Experimental study on occupants' interaction with windows and lights in Mediterranean offices during the non-heating season. Naspi, F. et al. (2017). Building and Environment. 127. 10.1016/j.buildenv.2017.11.009.

DENMARK



Ref: Window opening behaviour modelled from measurements in Danish dwellings. Andersen, Rune et al. (2013). Building and Environment. 69. 101-113. 10.1016/j.buildenv.2013.07.005.

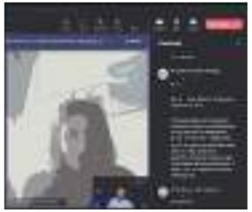
Validation and evaluation of the role of cultural and climate factors

- **Coordination of 4 series of interviews with building occupants** at different climatic areas across identified buildings as part of the Demo owners' portfolio. It will **provide valuable criteria and recommendations within the design and performance strategies of PEB demos** from the specific socio-cultural and occupants' context-related perspective.

- All involved partners (RMIT, UNIVE, EURAC, NBK, SIZ EGS, SINTEF, VILOGIA, ABITCOOP, BAERUM and WOHNBAU) are collaborating to implement **first CULTURAL-E actions aiming at engaging users from high-energy efficient buildings.**

- At the current reporting period, the **French and Italian series have been mostly completed** by addressing different high-efficient building communities; instead, the **German series has recently started** and the **Norwegian series are about to kick-off** -building case is already identified, the data protection plans are validated and first communications with residents are planned-.





Thank you for you attention!

Contacts:

Iván Luque Segura

ivan.luque.segura@rmit.edu.au

Ralph Horne

ralph.horne@rmit.edu.au

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 870072

Environmental life cycle assessment of Plus Energy Houses

Roberta Di Bari, University of Stuttgart

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 870072

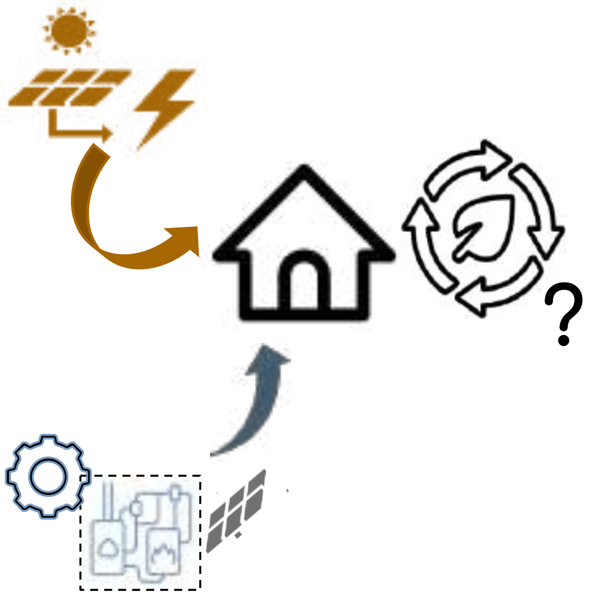
Introduction

- *Global Status Report 2021: urgent application of measures for decreasing emissions and energy consumption in buildings*
- *Passive and zero-energy building offer new perspectives aiming also to carbon neutrality by 2050*

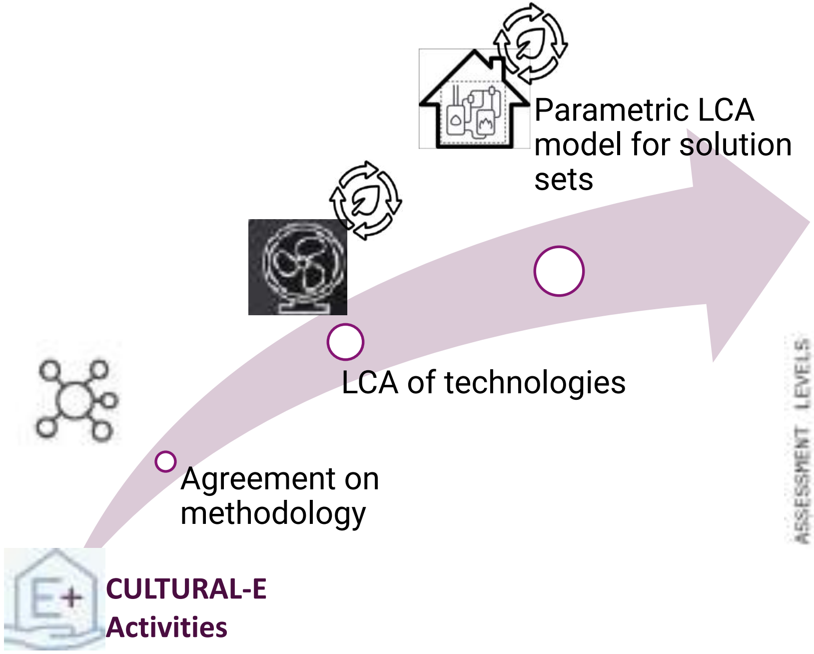
Introduction

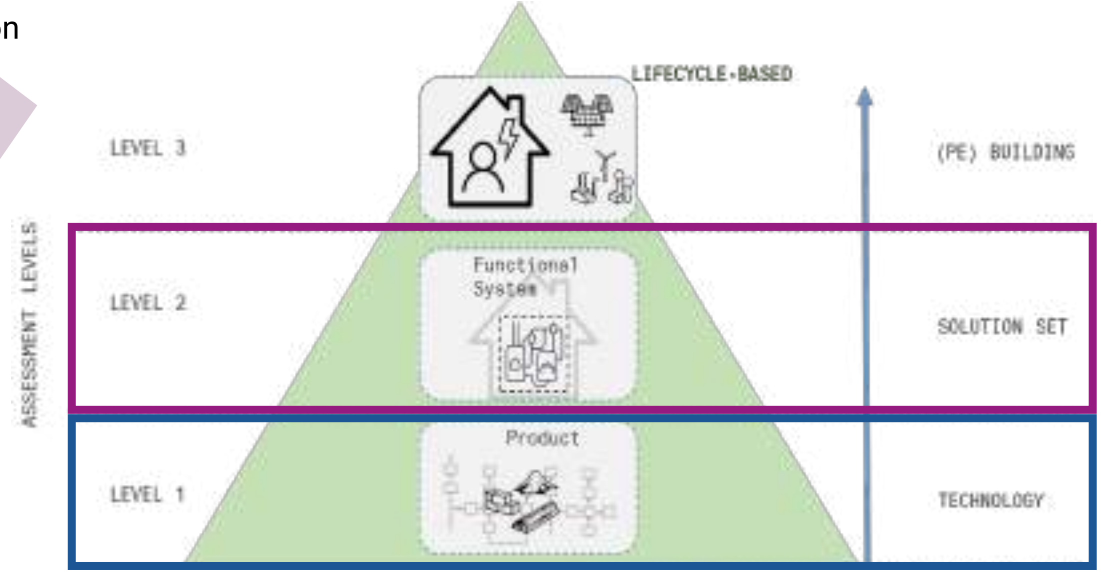
Increasing interest in Plus Energy Buildings (PEBs)

- *Decrease operational energy consumption*
- *Increasing amount of materials and installation components*
- *Life Cycle Assessment (LCA) for quantifying life cycle environmental impacts*



Life Cycle Assessment of PEHs in CULTURAL-E





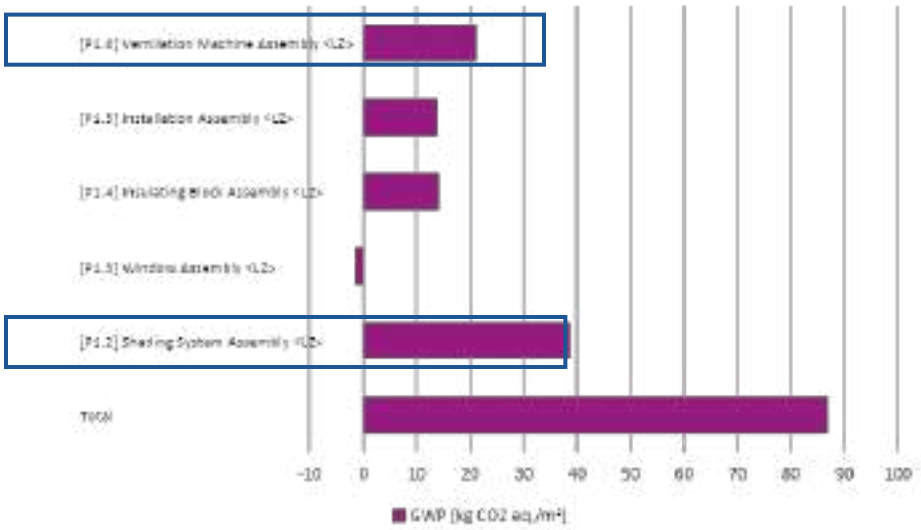
LCA of CULTURAL–E technologies

cultural E+

Opportunities

- Comparing innovative technologies with traditional ones
- Identify improvements potential
- Provide feedbacks to developers

EUROFINESTRA Active window (AWS)



LCA of CULTURAL-E solution sets

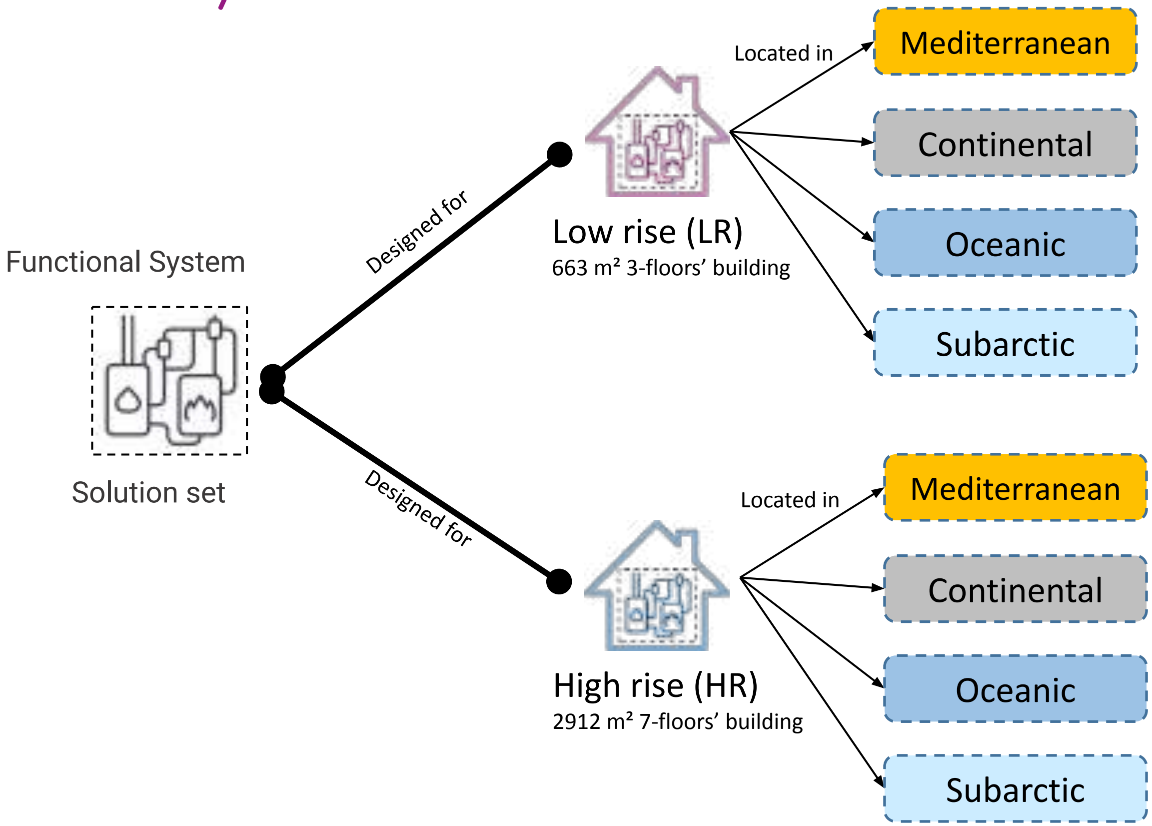
Goal of the analysis

Parametric modelling for LCA

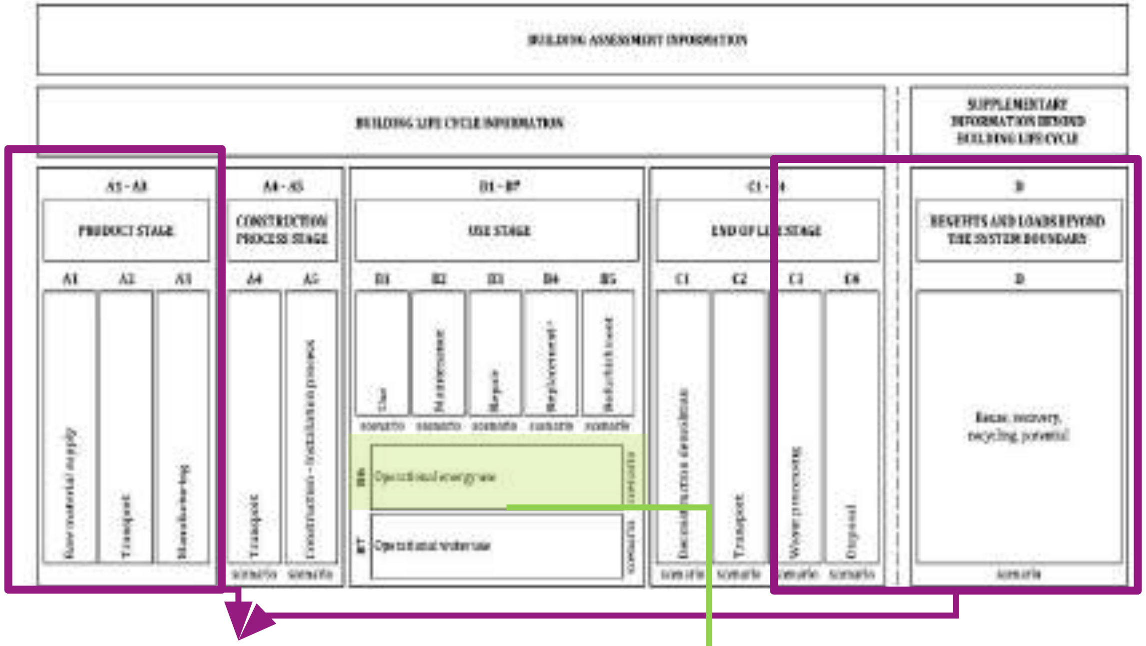
Assess their environmental potential

Explore benefits in different climate- cultural contexts

Case study and results



Case study and results



From building and installations planning

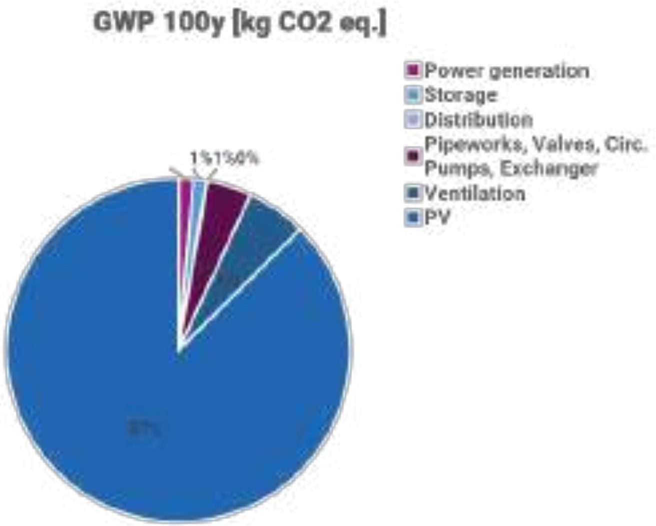
From building energy simulations

LCA specifications (based on ISO 14044)	
FU (functional unit)	1 m²*y
Lifespan duration	30 years
Impact categories	Global Warming Potential - GWP in kg. CO_2 eq.
Environmental database	Ökobau.dat[11] , Environmental Product Declaration (EPDs)

Case study and results

Component type	Specifications	LR	HR
PWG	Air-Water heat pump - heating, cooling, DHW by fresh water stations	50 kW	150 kW
TES	Water Storage+ Heating/Cooling buffer in stainless steel units – XPS insulation	1000 l + 500 l Buffer	3000 l + 1500 l Buffer
DISTR	Low temperature fan coil, free cooling	950 W	950 W
VEN	Ventilation and air treatment		
PIP	Copper pipes with XPS insulation. Stainless steel elements (Valves, Circulation pumps and Heat exchanger)	ø52cm x 3m ø38mm x 10m ø38mm x 10m	ø52cm x 3m ø38mm x 22m ø38mm x 22m
PV	Average technology with battery, sized to provide a positive balance	240 m² (estimated)	528 m² (estimated)

Component	**LR** GWP [kg CO_2 eq.]	**HR** GWP [kg CO_2 eq.]
Tot. embodied [impact/m²]	**111.8**	**57.36**
Tot. embodied [impact/m²*y]	**3.762**	**1.948**

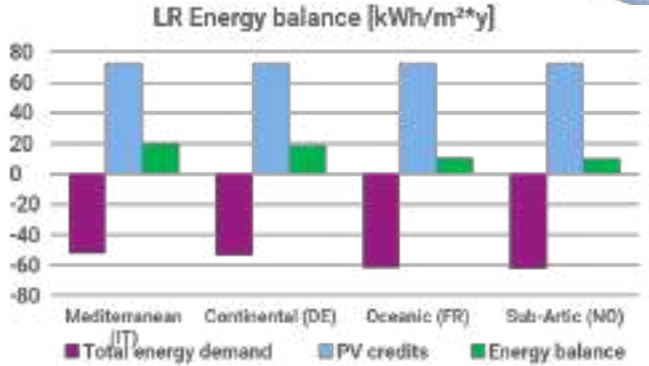


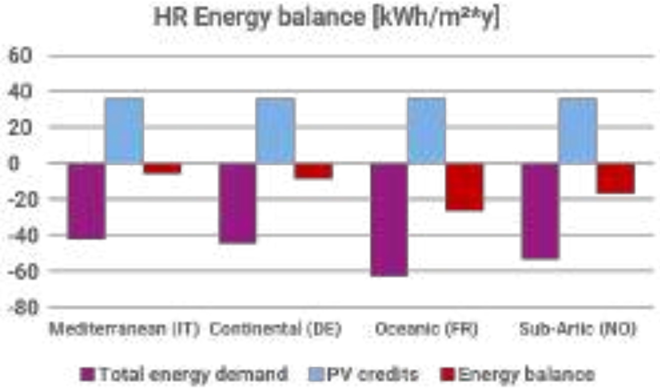
Case study and results

Electricity mix	(IT)	(DE)	(FR)	(NO)
[kg CO_2 eq./kWh]	0.285	0.337	0.057	0.027

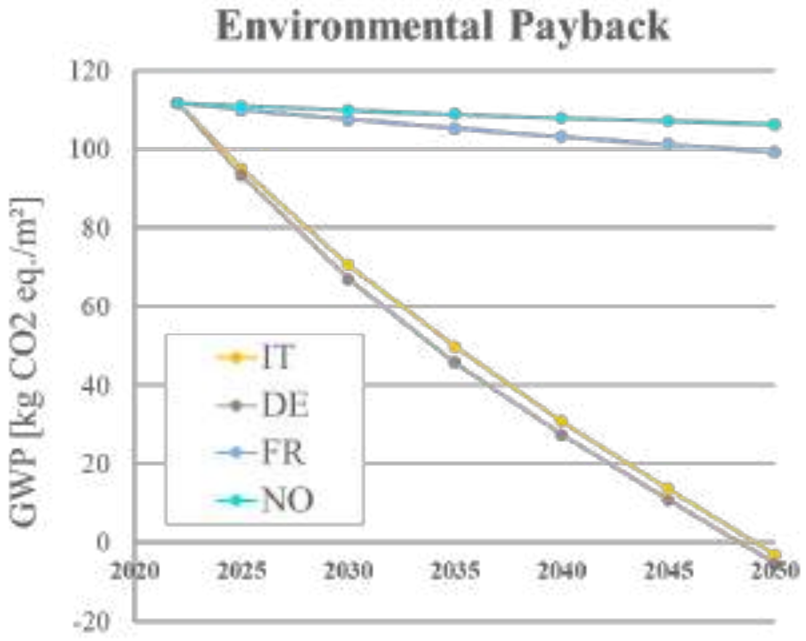
LOW RISE	Mediterranean (IT)	Continental (DE)	Oceanic (FR)	Sub-Artic (NO)
Energy balance [kWh/m²*y]	+20,4	+18.8	+10.6	+10.0
[kg CO_2 eq./m²*y]	-5.80	-6.34	-0.6	-0.31

HIGH RISE	Mediterranean (IT)	Continental (DE)	Oceanic (FR)	Sub-Artic (NO)
Energy balance [kWh/m²*y]	-5.9	-8.3	-26.5	-16.8
[kg CO_2 eq./m²*y]	1.69	2.81	1.51	0.52





Case study and results



- **Payback (PB) periods** calculated by assuming a variable (*dynamic*) electricity mix (EU scenario 2020).

- Italian and German examples reach environmental payback periods by 2050.
- In the French and Norwegian cases, slower trend
- Payback periods affected by the carbon intensities of current national electricity generation.

Conclusion

- Performance level differences

- Effects related to
    - design choices,
    - cultural-climate context and
    - national energy generation.

Conclusion

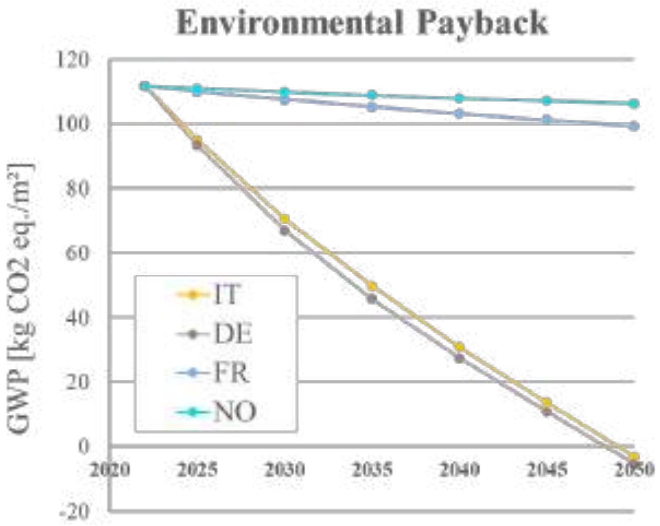
- **Design choices**
  - PV modules are main responsible of total embodied impacts.
  - Building type may dictate also the operational energy. Within high rise buildings, other surfaces besides roofs need to be spotted aiming at a positive energy balance.

- **Climate context**
  - Due to lower temperatures and annual solar yields, Continental and subarctic area reached less energy credits.
  - Continental and subarctic area present also higher user-related energy consumption

Conclusion

- **National energy generation**
  - higher effectiveness in Italian and German contexts.

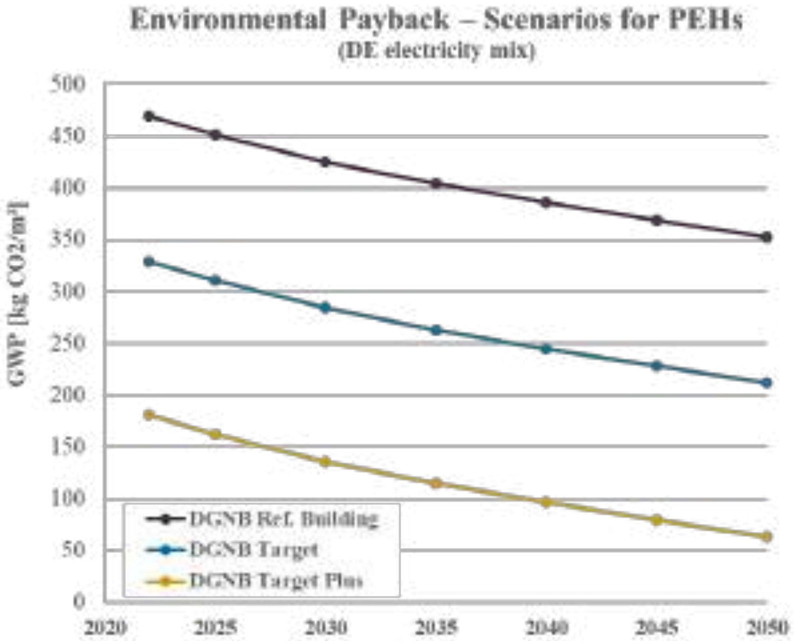
All analyses and observations to be addressed also *on the whole building level*



Outlooks for LCA of PEHs

- **3 Scenarios for Germany according to DGNB reference and target values**

- **PB Periods**
  - Reference Building: year 2159
  - Target Building: year 2116
  - Target Plus building: year 2070



Active poll

8

As designers /architects, are you aware of the consequences related to the design choices and embodied impacts?

yes

75%

no

13%

no, I will study more about it.

13%

Join at

slido.com

#CulturalE

Active poll

6

Join at
slido.com
#CulturalE

Do you think the information about environmental impacts of construction materials and photovoltaics is well presented and with a sufficient level of transparency?

no, it could be better.
100%

yes, it is well presented.
0%

Thank you for you attention!

Roberta Di Bari

University of Stuttgart
Institute for Acoustics and Building Physics
Department of Life Cycle Engineering

Email: roberta.di-bari@iabp.uni-stuttgart.de

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 870072

Any questions?

If you are connected online, please use the Sli.do chat box

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 870072

Thank you for joining us today

More information can be found at
https://www.cultural-e.eu/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 870072

Lunch break

See you back at **14:00 CET** for the Open Workshop co-organised with sister projects syn.ikia and EXCESS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 870072