The role of Plus Energy Buildings in decarbonizing the building stock

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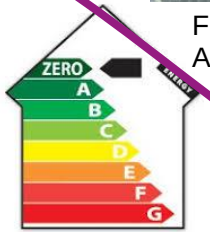
Path to market valuable Plus Energy Buildings

CONSTRUCTION COSTS

First PEH:
Heliotrope

First Plus Energy neighborhood: Solarsiedlung



EPBD
Nearly Zero
Energy Buildings

First multifamily PEH
Activ-Stadhaus, Frankfurt

wohnbau Studio

PEB demonstration cases

Multi-storey PEB as power plant for the neighborhood

1994 2005 2010 2015 2024 2026

PEB contribution to EU building stock decarbonization

PEB shall contribute to **reduce the greenhouse gas emissions** in the surrounding energy system

PEBs shall **support e.g., older buildings**, where the transition to zero energy state would not be cost-efficient

PEBs shall contribute to reduce the stress on energy grids by providing a **flexible energy asset** that allows buildings and energy communities to act as integrated part of the energy system and exchange energy between among them or with the grid

The Gardens Elderly Center / Örebro, Sweden / Designed by: Marge Architects / Photo by: Johan Fowelin

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**.

*The definition applies to all-electric buildings and the energy balance is based on measured or predicted final energy between load and generation. In case of new buildings electrification is an inevitable process. In case other renewable energy vectors are used in the building (i.e. biomass, biogas...), final energy balance shall be zero.

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.

It can be extended to adjacent lots as long as there is a physical connection and direct control of renewable **energy generation system**.

Ownership of the buildings or lots, neighborhood grid infrastructure and building management is a must.

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**.

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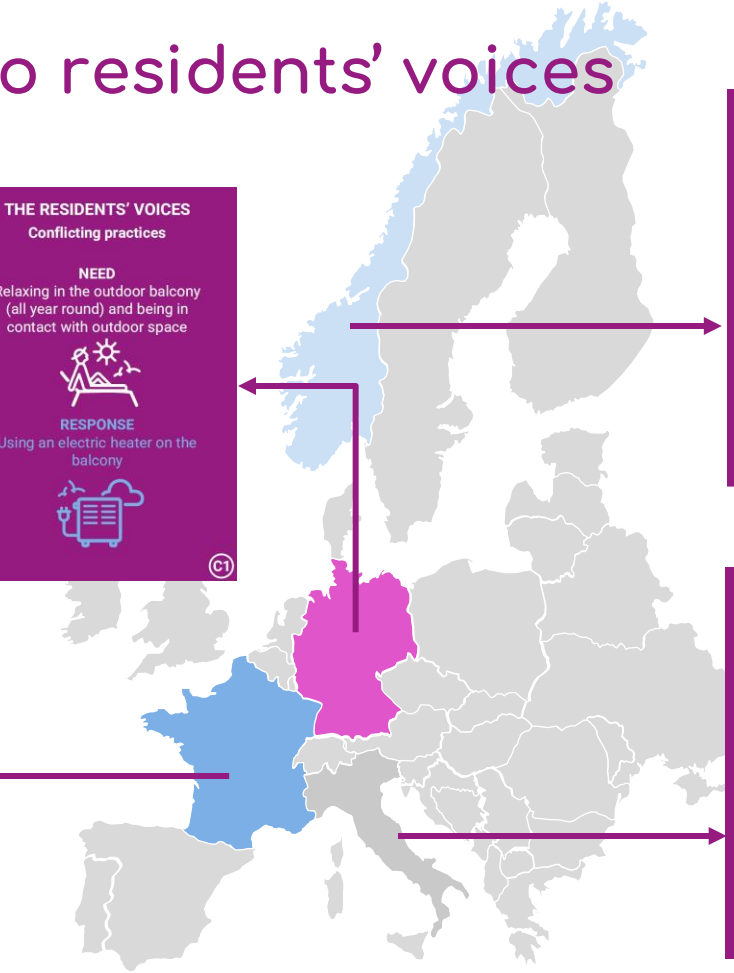
www.cultural-e.eu

How can PEB become the new building standard?

- 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

Listening to residents' voices



THE RESIDENTS' VOICES
Conflicting practices

NEED
Getting rid of cooking smells

RESPONSE
Using both mechanical ventilation and natural ventilation (creating a draught)

C4

THE RESIDENTS' VOICES
Conflicting practices

NEED
Relaxing in the outdoor balcony (all year round) and being in contact with outdoor space

RESPONSE
Using an electric heater on the balcony

C1

THE RESIDENTS' VOICES
Conflicting practices

NEED
Pleasing visitors when hosting at home

RESPONSE
Adjusting temperature to the visitors' thermal comfort expectations

C3

THE RESIDENTS' VOICES
Conflicting practices

NEED
Sleeping comfortably with an adequate temperature

RESPONSE
Opening windows (having "cracked open" windows) & having appropriate duvets

D4

THE RESIDENTS' VOICES
Conflicting practices

NEED
Getting rid of cleaning odours

RESPONSE
Opening windows instead of using mechanical ventilation

A4

THE RESIDENTS' VOICES
Conflicting practices

NEED
Ventilating and being in contact with the outdoor space

RESPONSE
Opening windows. Very little use of the ventilation system

A1

cultural E+

RMIT UNIVERSITY

Thermal comfort expectations are driven by cultural factors

		Operative temperature values [°C] for Thermal Feeling (TF) in summer				
		France	Greece	Portugal	Sweden	UK
Mechanical ventilation	<0.1 m s^{-1}	24.6	27.1	24.9	23.5	23.8
	0.6 m s^{-1}	26.4	28.9	26.7	25.3	25.6
	0.9 m s^{-1}	27.4	29.9	27.7	26.3	26.6
	1.2 m s^{-1}	28.4	30.9	28.7	27.3	27.6
Natural ventilation	<0.1 m s^{-1}	25.1	27.6	25.4	24	24.3
	0.6 m s^{-1}	26.9	29.4	27.3	25.9	26.1
	0.9 m s^{-1}	27.9	30.4	28.3	26.9	27.1
	1.2 m s^{-1}	28.9	31.4	29.3	27.9	28.1

	Operative temperature values [°C] for Thermal Feeling (TF) in winter				
	France	Greece	Portugal	Sweden	UK
Mechanical ventilation	22.3	28.2	22.5	24.1	20.5
Natural ventilation	22.5	28.4	22.7	24.3	20.7

cultural E+

Ca' Foscari University of Venice

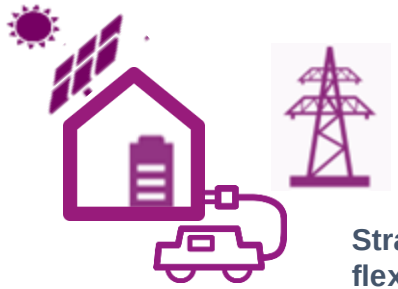
Indoor operative temperatures that optimize thermal feeling (neutral sensation)

Users in different countries respond differently to standardized (EN 16798) indoor environmental quality scenarios.

L. Pistore, C. Varin, W. Pasut, Development of climate-based thermal comfort ranges from existing data: Analysis of the Smart Controls and thermal comfort (SCATS) database, Energy and Buildings, Volume 298, 2023, 113509, ISSN 0378-7788, https://doi.org/10.1016/j.enbuild.2023.113509

Key technology concepts of Cultural-E project

Cloud-based House Management System



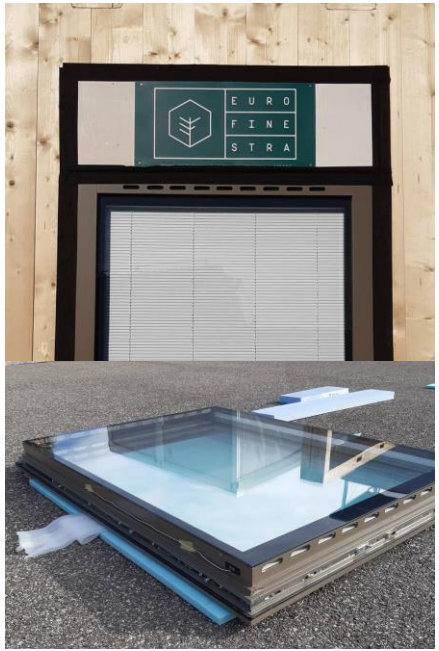
Strategies for building flexibility

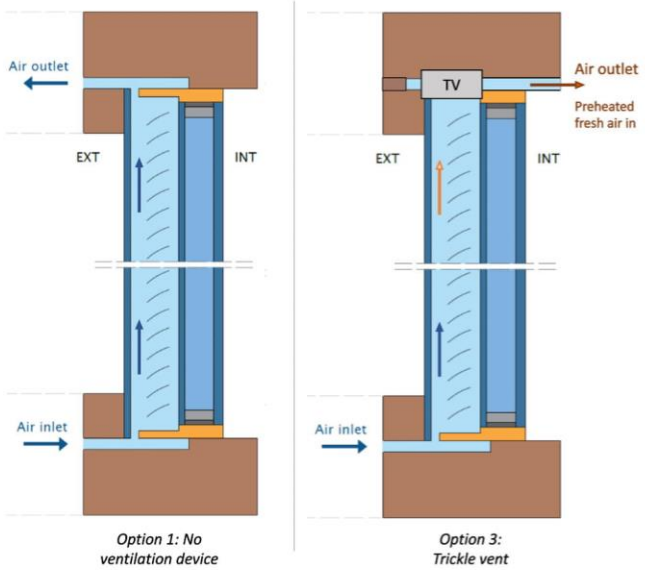
Active window system

Smart air movement

Decentralized packed Heat Pump system

Active Window System





- Easy and quick installation
- protected but accessible semi-ventilated cavity.
- interaction between the ventilation of the shading cavity and the ventilation of the indoor space
- shading control strategies optimised

EURO FINE STRA

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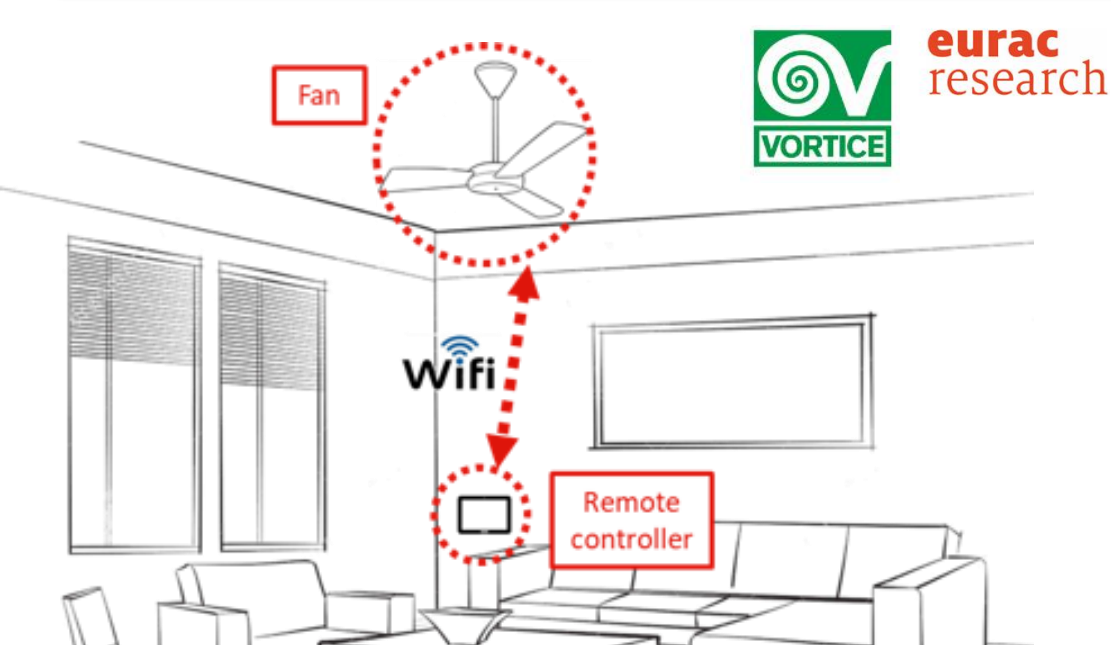
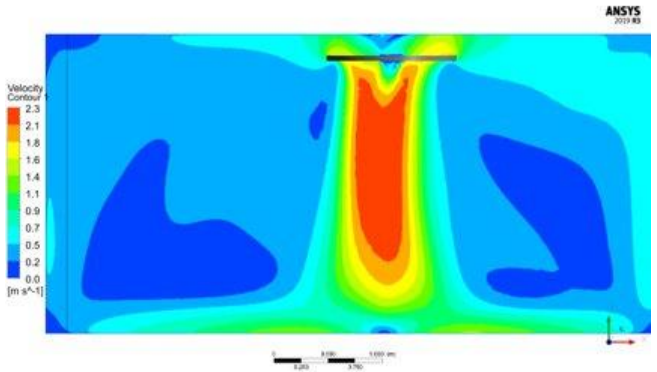
Increased air movement through smart ceiling fans

up to 60% energy saving were estimated without jeopardizing thermal comfort.



VORTICE

eurac research

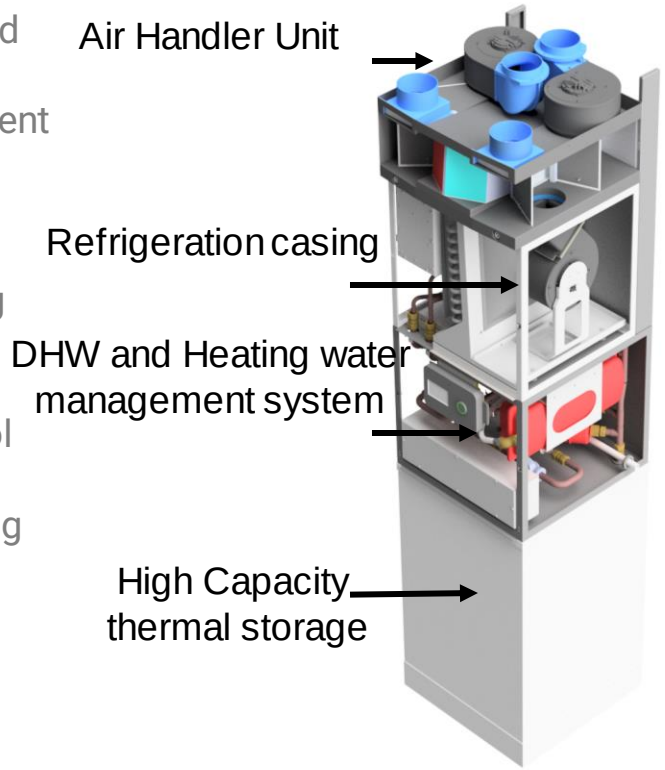


Laboratory tests with human participants showed no significant difference in terms of user satisfaction with indoor environment between automated and manual control

Packed heat pump system

all-in-one system for **heating, domestic hot water and ventilation** with demand driven and learning controls for an optimal demand/response management

- Compact system
- Higher efficiency, load shifting capacity and free summer cooling thanks to the bigger thermal capacity
- Data driven optimization of control
- Full off-site assembly
- Attractive concept also for building retrofit
- Maximises self-consumption

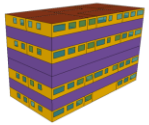


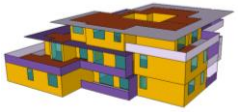
Cloud-based House Management System

- **Leverage data** from indoor and outdoor sensors, renewable energy systems, storages, web services, grid signals, and other buildings.
- **Enable user-centred services** that informs and guides the users on how to interact with the systems and adopt energy-efficient behaviour.
- **cost-effective solution** that requires no maintenance and can be easily integrated with existing equipment.

Factsheets

HIGH-RISE BUILDING LOW-RISE BUILDING





2x Building archetypes

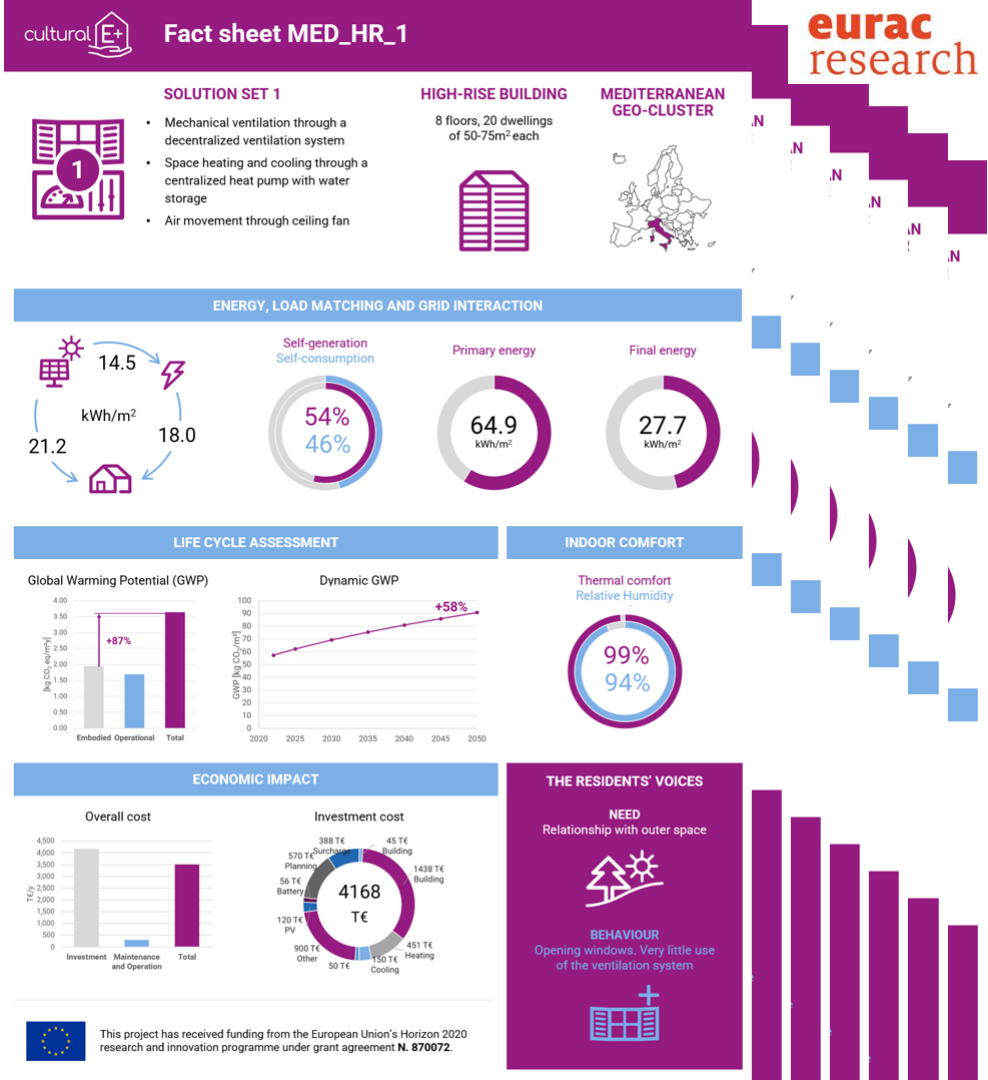
SOLUTION SETS

2x Solution Sets

MEDITERRANEAN GEO-CLUSTER OCEANIC GEO-CLUSTER CONTINENTAL GEO-CLUSTER SUB ARCTIC GEO-CLUSTER

4x Geoclusters

16 factsheets



Francesco Isaia, Francesco Turrin, Hermann Leis, Roberta Di Bari, & Beatriz Pineda. (2023). Factsheets reporting solution set description and metrics for each climate-cultural geo-cluster. Zenodo. https://doi.org/10.5281/zenodo.8273531

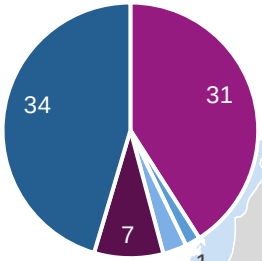
SOLUTION SET 2

- Mechanical ventilation through a decentralized system
- Space heating, cooling and DHW through a decentralized PHP
- Air movement through ceiling fan

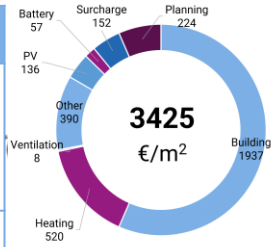
HIGH-RISE BUILDING

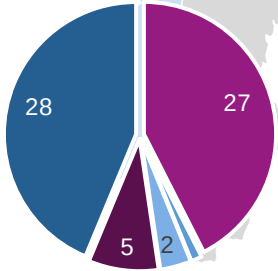
8 floors, 20 dwellings of 50-75m² each

- Appliances [kWh/m2]
- Lighting [kWh/m2]
- Smart ventilation [kWh/m2]
- Auxiliaries [kWh/m2]
- Heat pump [kWh/m2]

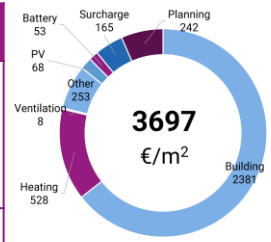


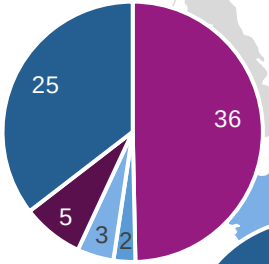
Sub-artic climate	
Tot final energy consumption [kWh/m²]	Energy balance* [MWh]
75	5



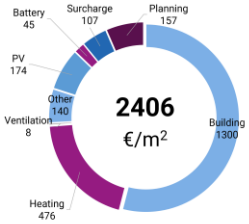


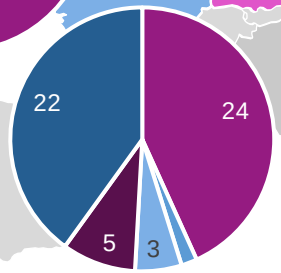
Continental climate	
Tot final energy consumption [kWh/m²]	Energy balance* [MWh]
63	13



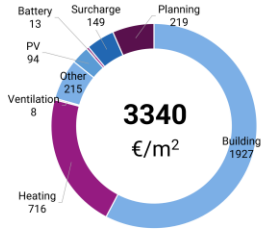


Oceanic climate	
Tot final energy consumption [kWh/m²]	Energy balance* [MWh]
72	26



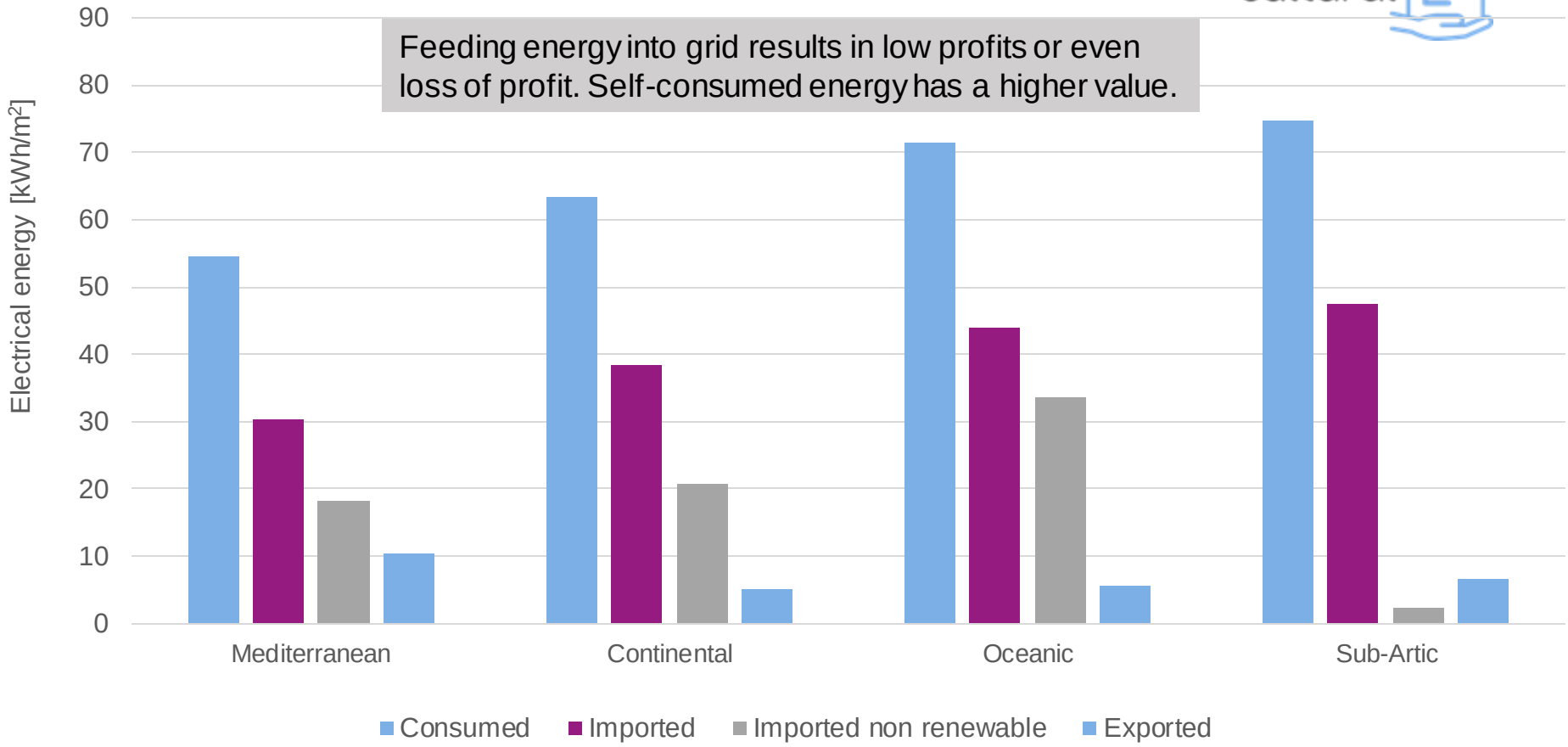


Mediterranean climate	
Tot final energy consumption [kWh/m²]	Energy balance* [MWh]
54	45

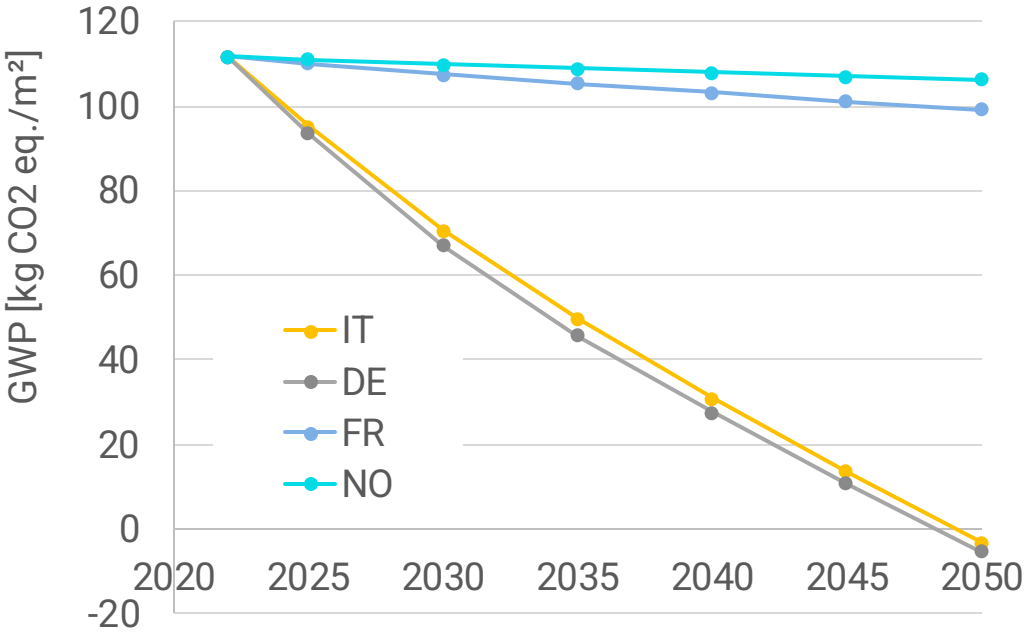


*generation-load energy balance excl. appliances

Exchange with the energy grid



Environmental payback of technology solutions



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.

Roberta Di Bari, Olivia Jorgji, Francesco Turrin, Riccardo Pinotti, & Cristian Pozza. (2022). Environmental lifecycle impact assessment for CULTURAL-E climate and cultural based solution sets. https://doi.org/10.1088/1755-1315/1085/1/012061

Lesson learned and key messages

- Most of the total electrical consumption is due to plug loads, which are difficult to reduce or to shift in time. **Empowering users** in reducing energy consumption is fundamental
- **Understanding social and cultural practices** can lead to more efficient buildings
- Multi-residential PEBs in continental and sub-artic climates have very low space cooling demand, which can be covered by implementing a device for smart air movement.
- PEBs can play a significant role in reducing the stress on the energy grid infrastructure (with **up to 70% self-consumption rates**)
- Even though **decentralized HVAC systems** have several other advantages, they impact significantly the overall investment costs (up to 10% more compared to centralized systems)
- **LCA analysis** shall be applied in the decision-making process to have an impact on construction material choices and PV-battery system size.

Thank you for you attention!

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More info on our project website:
https://www.cultural-e.eu/

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