GOING BEYOND

INNOVATIVE INTEGRATION OF SUSTAINABLE AND ENERGY-EFFICIENT SOLUTIONS IN BUILDING DESIGN

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Innovative prefabricated envelop solutions for Zero Energy and Zero Emission Buildings: The PLURAL and GreeNest projects.

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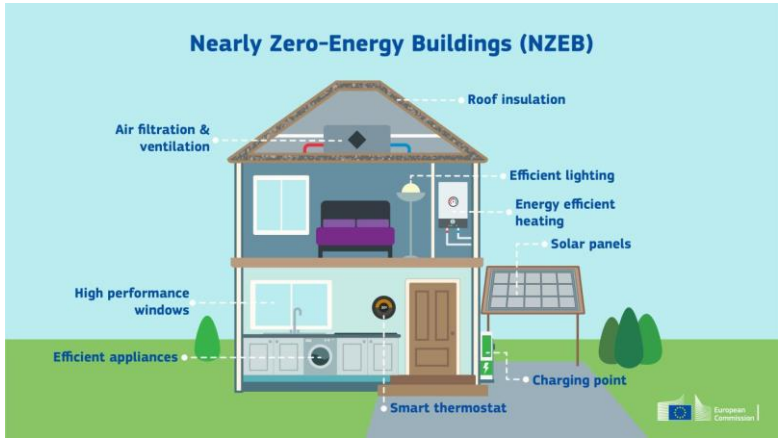
Why is renovation towards NZEB and ZeB important?

- FIT FOR 55 PACKAGE UNDER THE EUROPEAN GREEN DEAL;
- *March 2024*: European Parliament adopts the revision of the Energy Performance of Buildings Directive (EPBD) aiming to **progressively reduce greenhouse gas (GHG) emissions and energy consumption in the EU building sector and make it climate neutral by 2050.**
  - Buildings account for 36% of EU greenhouse-gas emissions
  - Measures to help lower energy bills, fight climate change: Deep –energy renovation towards NZEB; For residential buildings, member states will have to put in place measures to ensure a reduction in the average primary energy used of at least 16% by 2030 and at least 20 to 22% by 2035
  - **New buildings to be zero-emission from 2030 ;**
  - New buildings occupied or owned by public authorities should be zero-emission as of 2028.
  - In the emission calculations, member states will take into account the **life-cycle global warming potential of a building**, including the production and disposal of the construction products used to build it.
  - Agricultural buildings and historic buildings can be excluded



What is the offering of off-site prefabrication?

- Adaptable/tunable solutions for NZEB and ZeB
- Improves both *production and resource efficiency* in new constructions and deep-energy renovations.
- Provides higher performance and resource efficiency, both in energy and material
- Speeds up the renovation time, reducing disturbance for occupants, i.e. supports *user-centric deep renovation* approaches
- Makes renovation *more cost-effective*
- Potential of re-use of building materials and urban mining
- Compatible with construction 4.0 principles, such as point clouds, Building Information Models (BIMs) Digital Twins, material passports etc

Our solutions: Two projects that address these targets

PLURAL: Plug-and-use Renovation with adaptable lightweight Systems

Funding: H2020 - LC-EEB-04-2020:- Industrialisation of building envelope kits
Duration: 01/10/2020 – 30/09/2024
Project Website: https://www.plural-renovation.eu/

GreeNest: NEST InGrained ecosystem foR zEro EmissioN buildings

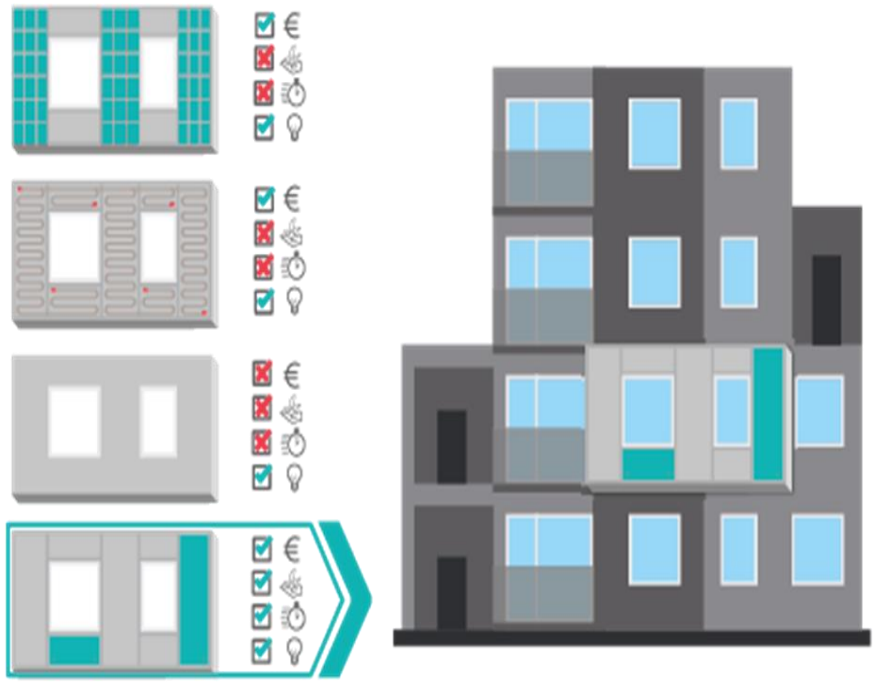
Funding: HORIZON-CL5-2023-D4-01-01: Innovative cost-efficient solutions for zero-emission buildings
Duration: 01/01/2024 – 31/12/2027
Project Website: https://www.greenest-ecosystem.eu/

PLURAL key objectives

PLURAL aims to design, validate and demonstrate a palette of versatile, adaptable, scalable, **off-site prefabricated Plug-and-Use (PnU) kits**.

The key is to understand how to select and integrate various renewable energy technologies, incorporate them in **prefabricated façade components** and optimize their performance for different building types, climates and socio-economic conditions.

PLURAL demonstrates the integration of **hybrid passive and active façade systems into one kit** and their ability to work together in **synergy** for façade retrofitting, reaching NZEB.



Key Objectives

1) Near zero energy consumption of buildings renovated with PnU kits
2) Fast-tra ck renovation
3) Cost-effective renovation
4) Environmentally-friendlier deep renovation
5) Flexibility – Adaptability

PLURAL key results

- **Three PnU kits:** the **SmartWall, the ConExWall with eWHC** (external Wall Heating and Cooling kit) and the **DEN comfort with eAHC** (external Advanced Heat and Cool recovery kit)
- Six demonstration sites implementing the PnU kits (3 real and 3 virtual)
- Enhancement of occupant satisfaction via a **user centric approach** that implements learning based control methods and strategies.
- **LYSiS-MODEST tools**: A **Building Information Modelling** (BIM) based **data handling platform** and a **Decision Support Tool** (DST) are developed to enable the optimal component selection, and integration, best PnU kit design, faster and low-cost manufacturing and installation.
- Regulated manufacturing of the PnU kits minimizing energy use and material waste (implementing **lean manufacturing principles-F.Q.Ps**).
- **Training tools** for main stakeholders (planners, installers, building owners and end users);
- **Life cycle based (LCA, LCC) performance standards** applied in the building sector.

The three PLURAL PnU kits

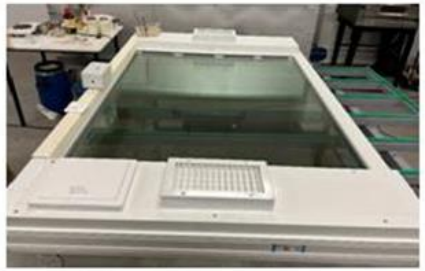
The SmartWall




The DEN Comfort



The Heat Harvesting Window




The ConExWall


The three real demonstration Sites

- The **PLURAL** PnU kits will be integrated at **three different real demo building sites**, located in **Greece, Spain** and the **Czech Republic**, featuring different climate conditions, heating/cooling needs and user requirements.

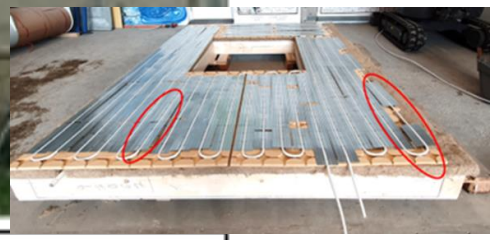
Mediterranean climate (hot summer)
2 of 10 flats - SmartWall

Greek demonstrator in Vari-Voula-Vouliagmeni (VVV)

Mediterranean climate (mild summer)
1 block of 2 – DEN Comfort.

Spanish demonstrator in Terrassa

Continental climate (warm, humid)
Whole building-ConExWall



Czech demonstrator in Kasava

The replication sites : Virtual demos

- **PLURAL** also includes **three virtual building demos** in **Switzerland**, **Germany** and **Sweden** for simulating and validating the performance and operation of the solutions.

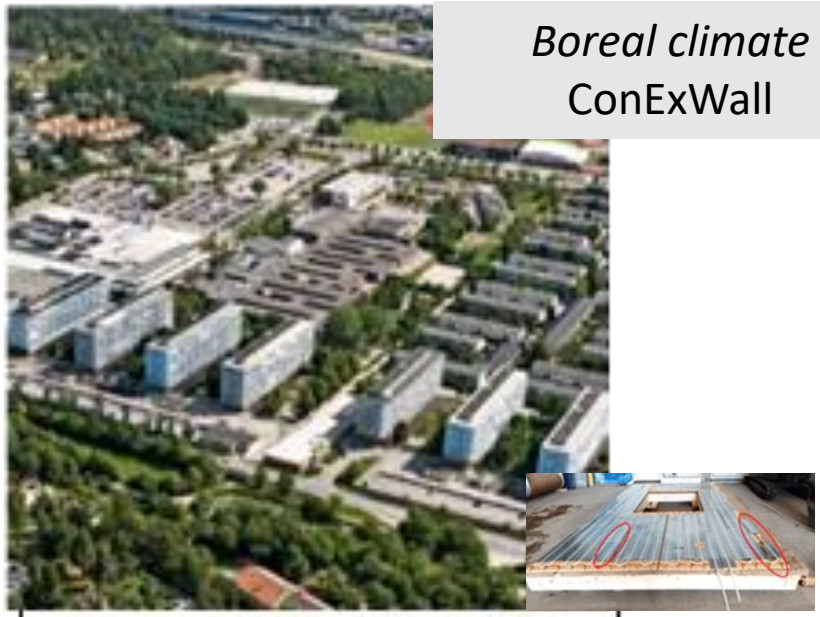
Alpine climate
ConExWall

Virtual demonstrator in Bern

Continental climate
SmartWall

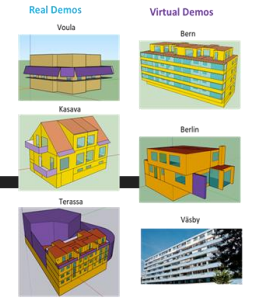
Virtual demonstrator in Berlin

Boreal climate
ConExWall



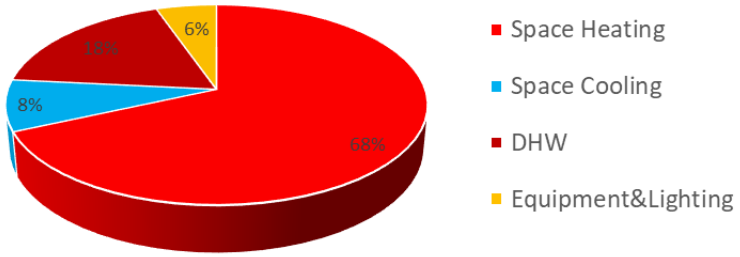
Virtual demonstrator in Väsby

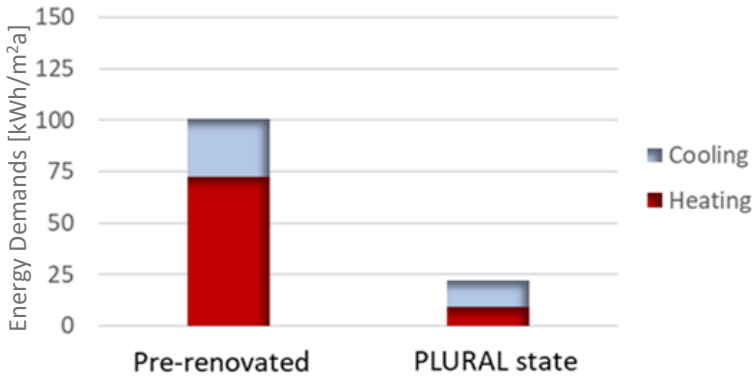
Energy Performance modelling for all six demos



Pre-renovated state

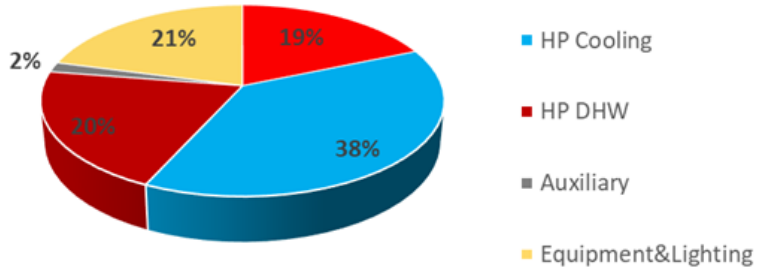
Energy Breakdown

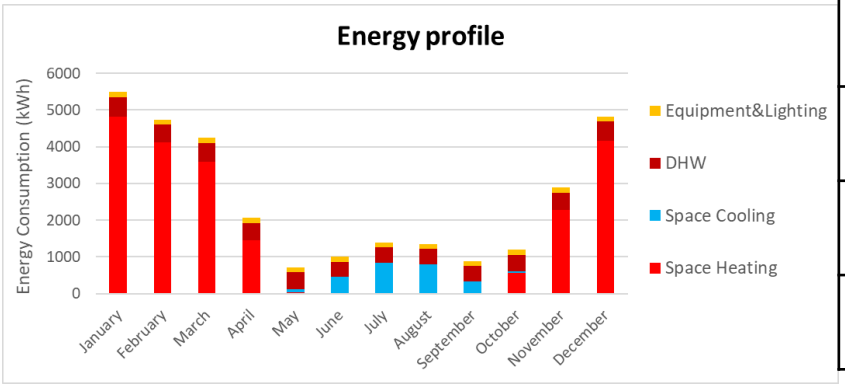




PLURAL - renovated state

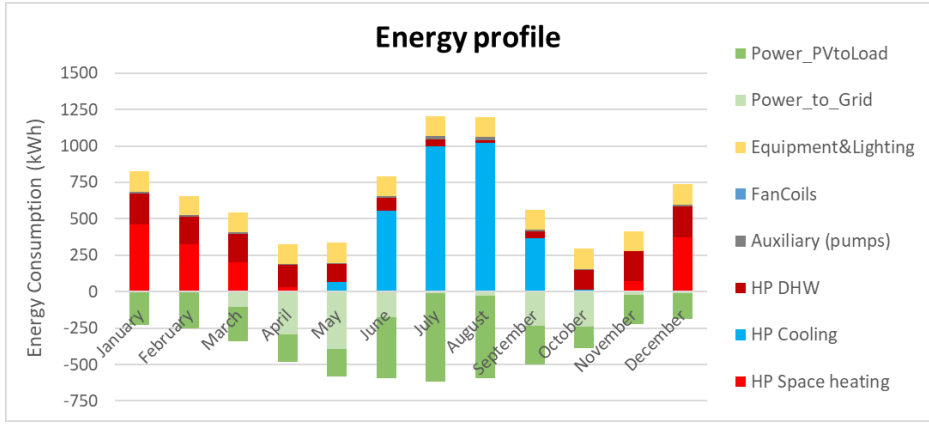
Energy Breakdown





Energy Totals	Pre-renovated	Plural state
Demands[1] [kWh/(m²·a)]	129.7	47.4
Energy consumption [kWh/(m²·a)]	129.7	27.55
Power generation [kWh/·a]	-	4,978
Non-renewable Primary energy [kWh/(m²·a)]	376	48.1[2]

[1] Demands for heating, cooling and DHW
[2] Taking into account the total potential PV production



PLURAL Key Performance Indicators

KPI	Performance Value	Target Value	Results achieved
Near zero energy consumption of buildings renovated with PnU kits	U-value (W/m²K) of PnU kit	0.23 W/m²K	PnU designed with U-value matching nZEB; U-value including the R-value of existing walls: Voula/SmartWall: 0.23 W/(m²K), Terrassa/ Denvelops Comfort: 0.20 W/(m²K), Kasava/ConExWall: 0.18 W/m²K²
	Primary Energy consumption per building	<90 kWh/m²a (depends on country)	**Voula/SmartWall:** Non-Renewable Primary Energy: 48.1 kWh/ m²a Total Primary Energy (without the contribution of PVs & solar): 80 kWh/ m²a (fulfils NZEB) **Terrassa/ Denvelops Comfort:** Non-Renewable Primary Energy: 38 kWh/ m²a Total Primary Energy (without the contribution of PVs & solar): 76 kWh/m² a (fulfils NZEB) **Kasava/ConExWall**: Non-Renewable Primary Energy: 3.9 kWh/ m²a Total Primary Energy (without the contribution of PVs & solar): 93 kWh/m²a (fulfils NZEB)
Environmental impact	CO2eq/m² per PnU kit	0.5 tCO_2eq/m^2	SmartWall: 0.116 tCO_2eq/m^2 Denvelops Comfort: 0.0815 tCO_2eq/m^2 ConExWall: 0.079 tCO_2eq/m^2
	Recyclability per PnU kit	70% material recyclability	SmartWall: 90% Denvelops Comfort: 70% ConExWall: 78%
Flexibility – Adaptability	per PnU kit	System combinations	SmartWall: 8 variants defined Denvelops Comfort: 3 variants defined ConExWall: 2 variants defined

PnU application – expected improvements

PnU	Climate	Construction year	Constraints	U-value (existing) [W/(m²K)]	U-value (final) [W/(m²K)]
ConExWall	Especially cold	Before 1994	Only external wall surface	0.87 – 1.36	0.16 – 0.18
SmartWall	All except extreme cold	Before 2006	Up to 4 storeys	0.70 – 2.20	0.19 – 0.24
Denvelops Comfort	All except extreme cold	Before 2010	Only external wall surface & up to 7 storeys	0.48 – 2.56	0.20 – 0.30

PLURAL experiences - outcomes

Advantages of prefabrication and integration of RES in the component/system design for heating and cooling:

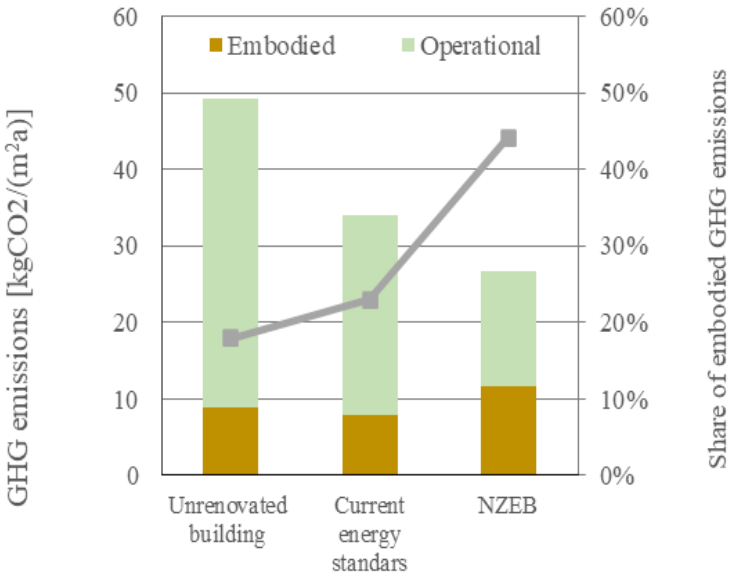
- PnU kits can successfully integrate RES (PVs, OPVs, solar thermal systems, various types of heat pumps, ventilation, air-handling, hydronic systems) and achieve efficient operation.
- Storage (thermal, electrical) and low carbon footprint materials and components could be part of the PnU design
- Flexible solution for retrofitting including EV-charging
- Effective “ integrated” solution for decarbonised, adaptative and regenerative Built Environment

Challenges:

- PnU kit design and RES need to be adapted to building characteristics
- Industrialization, component integration as part of the manufacturing: new business models
- Lack of regulatory framework for active building façade components
- Acceptance (industrial, end-user and social): Restricted due to lack of large-scale demonstrations, long-term performance evaluation, harmonized standards, economies of scale to reduce costs

The GreeNest scope

Contribute to the zero-emission building (ZeB) EU future by demonstrating keyways to reduce building emissions



- **ZeB definition:** A building with a very high energy performance, with a very low amount of energy still required fully covered by energy from renewable sources and without on-site carbon emissions from fossil fuels. It includes the calculation of life-cycle Global Warming Potential (GWP) and its disclosure through the Energy Performance Building Certificate (EPBC).
- ZeB definition to be applied from 1 January 2027 for all new buildings with a useful floor area larger than 2000 m^2 and as of 1 January 2030 for all new buildings.

The GreeNest objectives/targets

- **100% carbon free construction** through the application of biogenic materials that store carbon, (timber, extension of the carbon storage via reused timber, application of nearly CO2 neutral materials such as earth that can be reused endless times). Reduction of embodied emissions by 50% with respect to NZEB standard.
- **NZEB status** minimizing the energy need and covering it via renewable energy sources with remaining primary energy consumption less than 30-40 kWh/m2 (ZEB or even positive energy standards). RES installed (220 W per m2 of floor area). Reduction of GHG emissions by 60%.
- **Increased productivity by >30% based on local value chains** using digitized, time efficient, prefabricated design, manufacturing, construction methods for timber, reused timber and prefabricated earthen components.
- **Flexibility – Adaptability**: Material - component and system combinations creating a matrix of increased number of solutions allowing easy adaptation to various building typologies in all EU climatic zones.
- Support to the **circular economy** through the development of circular construction elements based on waste wood with reversible connections that can be reused or recycled at the end of life. Targets: Use of recycled components (55%), improved recyclability (85%).

The GreeNest **S**tandardized **P**ackages (SPs)

Embodied & End of life carbon				Upfront carbon				Operational & Use stage carbon	
Material		IoT & Digital Design Tools		Design / Construction /Productivity Schemes		Envelope Systems		Technical Systems	
SP#	Name	SP#	Name	SP#	Name	SP#	Name	SP#	Name
1	KARZ	4	GreeNPLUGIN	7	DesignByInventory	9	SmartWall	14	Eco-BIPV/PV
2	Waste-wood processing	5	ZeBIM			10	GreenWall	15	CASCADE
3	Earth screed for WDLT-Slab	6	ASSESS-DST	8	DeltaSmart	11	EcoTechWal	16	NestControl
						12	Heat-Harvest Window (HHW)		
						13	Rotating Window		

SP1: Insulation panel based on coffee bean wastes

SP2: Waste-wood material processing

SP3: Waste Dowel Laminated Timber (WDLT-slab with waste-wood and earth-based screed

SP4: GreeNest BIM objects and database.

SP5: Digital design-monitoring tool

SP6: Digital platform including Decision Support tool.

SP7: Design scheme with limited material access

SP8: Modular building construction method

SP9: Multifunctional wall incorporating HVAC components

SP10: Vertical Garden integrated into a prefab façade

SP11: Prefab, circular wall from waste wood, natural fibres

SP12: Window with ventilation system with heat recovery

SP13: Window that rotates with low-E glass.

SP14: PVs with low carbon footprint

SP15: Heating/cooling energy production system with eco-friendly refrigerants.

SP16: BMS tool for IAQ sensors and centralized control.

Demo Case #1 – New building: Museum Pavilion

1 Museum "Pavilion and Knowledge Paths"

Demo responsible: TUB

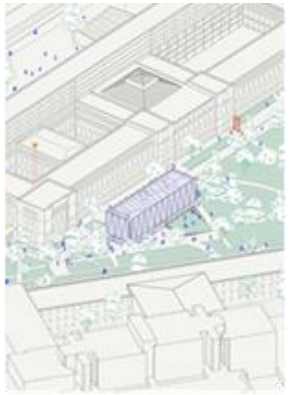
Location: Berlin (Germany)
Type: Public, knowledge hub
Size (area): 1,250 m^2
Number of floors: 3
Owner: TU Berlin

Climatic zone:
Dfb – Humid continental climate
Demonstrated SPs:
SP1, SP2, SP3, SP4, SP5, SP6, SP7, SP14, SP15, SP16

Baseline values:
1. Primary energy: 40-55 kWh/(m^2y)
2. Baseline $CO_{2\text{-eq}}$ emissions (OP): 9 $kgCO_2$/(m^2y)
3. EPBC: mandatory (A class)

Partners involved: ***TUB***, *ZRS, INEB, KMAEL, DAIK, THOLZ, AMS, METSOL*

Photos



Demo Case #2 – New building: Berlin Lodge

2 Berlin lodge

Location: Berlin (Germany)
Type: Residential
Size (area): 2,705 m^2
Number of floors: 5
Number of apartments: 54
Owner: HoWoGe

Climatic zone:
Dfb – Humid continental climate
Demonstrated SPs: SP2, SP3, SP4, SP5, SP6, SP7, SP11, SP16

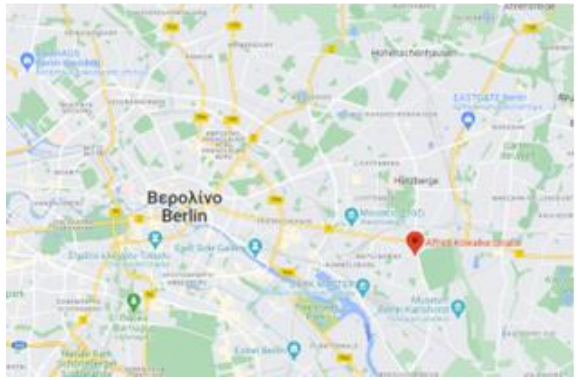
Demo responsible: HoWoGe

Baseline energy values:

1. Primary energy: 15-30 kWh/(m^2yr)
2. Baseline $CO_{2\text{-eq}}$ emissions (OP): 6-12 $kgCO_2/(m^2y)$
3. EPBC: mandatory (A class)

Partners involved: ***HoWoGe****, ZRS, DAIK, THOLZ, HAMS, METSOL, INEB*

Photos



Demo Case #3 – New building: Delta info center

3 Delta info-center

Demo responsible: MPV

Location: Porto Viro (Italy)
Type: Public, office – info center
Size (area): 52.5 m^2
Number of floors: 1
Owner: MPV

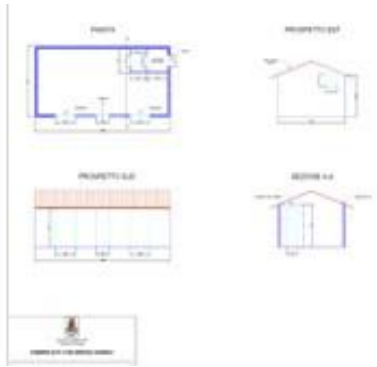
Climatic zone:
Csc – Cool - summer Mediterranean climate

Demonstrated SPs:
SP4, SP5, SP6, SP8, SP10, SP12, SP13, SP14, SP15, SP16

Baseline values:
1. Primary energy: 40-55 kWh/(m^2yr)
2. Baseline $CO_{2\text{-eq}}$ emissions (OP): 10-14 $kgCO_2/(m^2y)$
3. EPBC: mandatory (A class)

*Partners involved: **MPV**, AMS, BGTeC, DAIK, HAMS, METSOL*

Photos



Demo Case #4 – New building: Recreational Center

North Aegean youth recreational center

Demo responsible: AMS

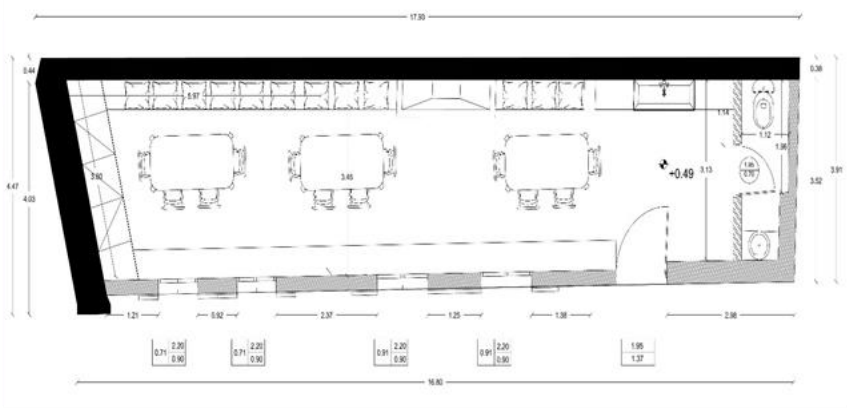
Location: Stypsi, Lesvos (Greece)
Type: Public, youth recreational center
Size: 57.6 m^2
Number of floors: 1
Owner: MoS

Climatic zone:
Csc - Cool-summer Mediterranean climate
Demonstrated SPs: SP4, SP5, SP6, SP8, SP9, SP13, SP14, SP15, SP16

Baseline values:
1. Primary energy: 20-30 kWh/(m^2yr)
2. Baseline $CO_{2\text{-eq}}$ emissions (OP): 12-18 $kgCO_2/(m^2y)$
3. EPBC: mandatory (A class)

Partners involved: ***AMS,*** *MoS, BGTeC, DAIK, HAMS, METSOL*

Photos



Expected outcomes

Materials
1. KMÄLEON: Demonstration of eco-friendly, high-performance **coffee-ground based thermal insulation panels and blow-in insulation**
2. THOLZ: Processing of **waste wood to dowel laminated timber slabs for facades**
IoT & Design Tools
3. INTRA: **ASSESS platform** to facilitate information flows between designers, builders, local authorities, regulators and accessors in a BIM based approach
4. BIMETICA: **ZeBIM;** first digital twin platform for ZeB using circular materials
Standardized Packages Cluster 3 – Design, Construction and Productivity Schemes
5. ZRS: Expertise in Circular Construction and use of **waste wood and earthen materials for construction**
Technical Systems
6. METSOL: Seamless custom **photovoltaic modules** fur building integration (BIPV) aesthetically adapted to the target building
7. DAIKIN: Validation of **new generation of heat pumps** with eco-friendly refrigerants
Building Envelope Systems
8. AMS: **SmartWall** – pre-fabricated adaptable multifunctional wall system incl. insulation, HVAC, smart windows, energy harvesting]
9. BGTeC: Inclusion of **Smart/Green wall solutions** to the BGTeC portfolio of wall and façade systems
Demonstration Level
10. HOWOGE: **Zero-carbon 4-floor residential building**
11. TUB, MPV, CoS: Demonstration of **construction methodology** for ZeBs. Validation of ZeB construction using local value chains
12. Non-profit organizations: **PILLI, LIG:** 1. BIM library of components: **alternative construction systems** in different possible applications. 2. BIM library of materials and products.

GreeNest long-term impacts

- ✓Use of nature-bio-earth-based materials. Potential emissions reduction by 2050: >20%;
- ✓Reuse building materials, components (e.g. reused and wood). Potential emissions reduction by 2050: >10%
- ✓Reduce material consumption and need for building services through innovative design by 2050: >10%
- ✓Implement digital tools in material design (avoid waste). Potential emissions reduction by 2050: >18%
- ✓Use local RES. Potential reduction of operational emissions: 90%, whole life cycle >25%
- ✓Enhance existing building utilization and user comfort. Potential emissions reduction by 2050: >11%

These projects have received funding from the European Union's Horizon 2020 and HORIZON research and innovation programmes

THANK YOU

FOR THE ATTENTION!

SPECIAL THANKS TO ALL THE PLURAL AND GREENEST PARTNERS

FOR CONSTRUCTIVE WORK and OUR COLABORATION!