4RinEU

Reliable models for deep renovation

D3.3

WP3

Deep renovation packages and parametric models in different geo-clusters

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Foreword

Despite the low energy performances of the European building stock, the yearly renovation rate and the choice to perform a building deep renovation is strongly affected by uncertainties in terms of costs and benefits in the life cycle.

The project 4RinEU faces these challenges, offering technology solutions and strategies to encourage the existing building stock transformation, fostering the use of renewable energies, and providing reliable business models to support a deep renovation.

4RinEU project minimizes failures in design and implementation, manages different stages of the deep renovation process - from the preliminary audit up to the end-of-life - and provides information on energy, comfort, users' impact, and investment performance.

The 4RinEU deep renovation strategy is based on 3 pillars:

- *technologies* - driven by robustness - to decrease net primary energy use (60 to 70% compared to pre-renovation), allowing a reduction of life cycle costs over 30 years (15% compared to a typical renovation);
- *methodologies* - driven by usability - to support the design and implementation of the technologies, encouraging all stakeholders' involvement and ensuring the reduction of the renovation time;
- *business models* - driven by reliability - to enhance the level of confidence of deep renovation investors, increasing the EU building stock transformation rate.

4RinEU technologies, tools and procedures are expected to generate significant impacts: energy savings, reduction of renovation time, improvement of occupants IEQ conditions, optimization of RES use, acceleration of EU residential building renovation rate. This will bring a revitalization of the EU construction sectors, making renovation easier, quicker and more sustainable.

4RinEU is a project funded by the European Commission under the Horizon 2020 Programme and runs for four years from 2016 to 2020.

The 4RinEU consortium is pleased to present this report which is one of the public deliverables from the project work.

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Disclaimer

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Executive Summary

This deliverable provides designers and specialists the framework to perform analyses in the pre-design phase of a renovation, accessing information on the possible results brought by a deep renovation based on the 4RinEU approach.
In the first chapters, important information used by this deliverable is recalled from other 4RinEU deliverables. In particular, from the D2.1, the simulation activity performed to assess the renovation potential around Europe is reported. Six geoclusters have been defined, identifying different zones according to the features of the residential building stock, the average building performances provided by the law and climatic conditions.
Four building typologies have been defined too, in order to perform a comprehensive analysis of the European building stock.
Based on this information, all the renovation packages, composed by different combinations of the 4RinEU related technologies, have been studied in a parametric analysis. The result of this simulation campaign has been 41470 variants of solution sets per each geocluster, where KPIs have been used to assess indication of the performances of a certain renovation package applied in a specific context. Investigated thematic areas for KPIs are energy, comfort, environment, economic issues and building site management.
Using all these available results, renovation package sheets have been prepared in a dedicated ANNEX. Using these sheets, a professional designer working on a deep building renovation can have a preliminary evaluation of the effects of the application of different technologies and interventions.
In the ANNEX, 42 sheets can be found. They are divided in 6 geocluster groups, each of them containing 7 sheets, one per each renovation package studied.
These seven packages have been chosen for being presented in the sheets since they represent the most relevant combinations of renovation technologies. The first part of the sheets indicates the input for the KPIs reported below.
An example of these sheet is presented here below. The geocluster shown is the one referring to continental – central Europe, while the renovation package is the one considering the application of the prefabricated façade with a decentralized mechanical ventilation system integrated.

The renovation package sheets, providing a preliminary analysis looking at a summarized set of results, can be further detailed using the cost effectiveness rating tool structured in the Deliverable 4.2.

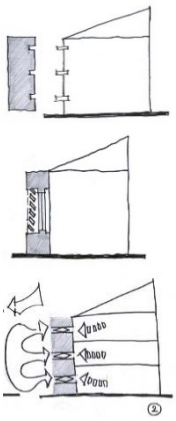
2

RENOVATION PACKAGE

GEOCLUSTER CONTINENTAL - CENTRAL

PREFABRICATED FACADE + DECENTRALIZED VENTILATION




		Tot Area	88 m2	228 m2	3456 m2	1330 m2
REQUIREMENTS OF THE COMPONENTS		Opaque part	Prefabricated facade thickness [cm]	~20 ÷ ~35		
			Final U-value wall [W/m²K]	~0.2 ÷ ~0.1		
		Window	Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
			Frame U-value [W/m²K]	1.4 ÷ 1		
			g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
		Shading system	Presence	May be applicable		
			Control strategy	If present, the shading system control is depending on external temperature, incident radiation and internal temperature		
		Mechanical ventilation system	Type	Decentralized ventilation system providing punctual inlet and outlet of air. Decentralized machine also provides heat recovery. The mechanical ventilation system is considered to be switched off during summer period (from June to August).		
Key Performance Indicators						
ENERGY			Heating demand [kWh/m²]	72.49 ÷ 80.27	24.6 ÷ 33.2	8.7 ÷ 11.4	27.8 ÷ 30.96
			Cooling demand [kWh/m²]	0 ÷ 3.31	0 ÷ 0.24	0.16 ÷ 4.9	0.14 ÷ 4.13
			Ventilation consumption [kWh]	1224.61 ÷ 1224.61	2400 ÷ 2400	31900 ÷ 31900	31674.64 ÷ 31674.64
			Ceiling fan consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
			Estimate PV power production [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0

	PEF (H+C) saving respect to non-renovated	-87.2% ÷ -75.76%	-93.15% ÷ -88.04%	-95.33% ÷ -83.24%	-89.47% ÷ -77.84%
	Energy demand (H+C) saving respect to non-renovated	-71.44% ÷ -68.19%	-87.94% ÷ -83.88%	-91.71% ÷ -85.49%	-76.01% ÷ -72.08%
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more explanation on these KPIs)	CAT_1_PPM	100% ÷ 100%	93.28% ÷ 95.13%	86.87% ÷ 91.02%	88.93% ÷ 88.93%
	CAT_2_PPM	0% ÷ 0%	2.06% ÷ 2.58%	5.62% ÷ 6.87%	11.04% ÷ 11.04%
	CAT_I_Adpt (evaluated in cooling period)	47.73% ÷ 97.1%	19.52% ÷ 92.31%	23.32% ÷ 96.61%	1.02% ÷ 81.69%
	CAT_II_Adpt (evaluated in cooling period)	2.01% ÷ 20.65%	6.92% ÷ 37.4%	3.72% ÷ 35.88%	7.3% ÷ 24.52%
	pmv _CatI (evaluated in heating period)	1.99% ÷ 4.72%	2.4% ÷ 10.79%	7.74% ÷ 18.3%	8.13% ÷ 15.42%
	pmv _CatII (evaluated in heating period)	1.79% ÷ 7.82%	14.7% ÷ 24.43%	15.91% ÷ 20.95%	11.48% ÷ 19.39%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.42 ÷ 1.61	0.89 ÷ 1.67	4.84 ÷ 17.96	2.08 ÷ 8.54
ECONOMIC ISSUES	Investment cost [€]	64859 ÷ 243406	83420 ÷ 264713	826767 ÷ 1396960	399415 ÷ 619965
	Net Present Value (50 years) [€]	73485 ÷ 275778	94514 ÷ 299919	936727 ÷ 1582755	452537 ÷ 702420
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	47 ÷ 98	58 ÷ 122	596 ÷ 1240	288 ÷ 586

1 Links with other activities in the project

Interrelation between D2.1 – D3.3 – D4.2:

- D2.1: general performance assessment for the building archetypes and defined renovation packages – structure and population of the repository of buildings and renovation packages – all performance evaluations
- D3.3: technical description of the renovation packages. Starting from an overview of the renovation needs, the packages are defined as a combination of the single technologies and according to the local specificities of each geocluster. Technological overview and main performance results
- D4.2: decision-support tool and definition of the criteria for defining the optimal renovation package according to the needs and priority of the stakeholders and the context of the geoclusters.

Overview of the main contents and organization of the information:

- General part with main renovation needs and description of the technologies
- Specific technical sheets with the detailed description of the renovation packages according to the technical features, the main constraints and the performances in each geocluster.

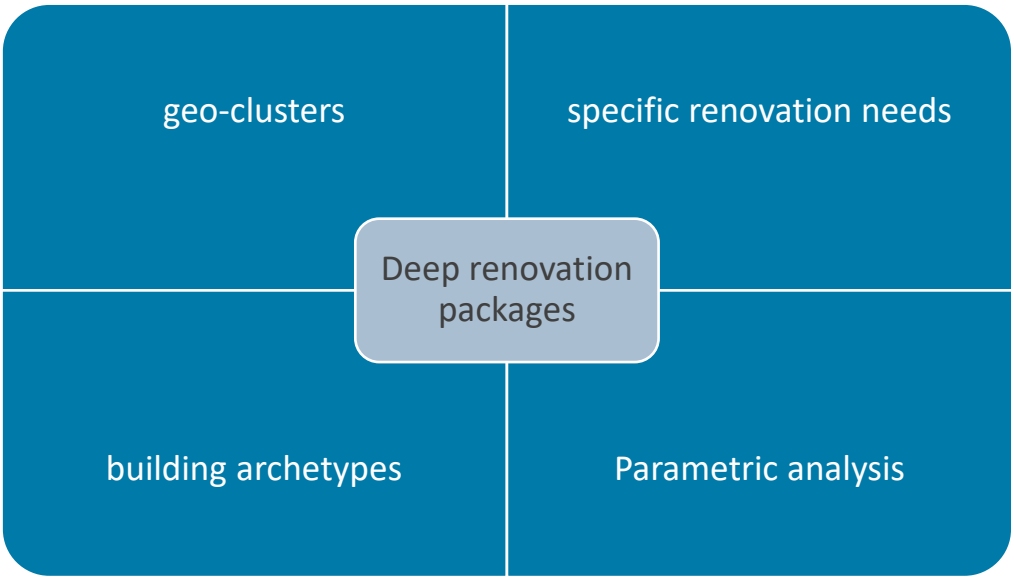


Table 1 Overview of main contents

2 Introduction

2.1 Why: how buildings can reduce emissions

The world suffers from potential climate change, caused by human activities in almost all economic sectors. The building sector is one of the major sectors, contributing to around 40% of the CO2 emissions of EU member states.
(source https://ec.europa.eu/energy/en/topics/energy-efficiency/building)

The Paris agreement calls for significant CO2 emission reductions in order to limit the global temperature increase to 1,5 to 2 degrees Celsius. The European Commission aims at reducing emissions up to 90% by 2050, with intermediate emission reductions by 2030 and 2040. Short term European objectives are the 20-20-20 objectives by 2020 (20% GHG emission reduction, 20% increased energy efficiency, 20% share of renewable energy)

The EU has set itself a long-term goal of reducing greenhouse gas emissions by 80-95%, when compared to 1990 levels, by 2050. The Energy Roadmap 2050 explores the transition of the energy system in ways that would be compatible with this greenhouse gas reductions target while also increasing competitiveness and security of supply.

To achieve these goals, significant investments need to be made in new low-carbon technologies, renewable energy, energy efficiency, and grid infrastructure. Because investments are made for a period of 20 to 60 years, policies that promote a stable business climate which encourages low-carbon investments must start being made today.

2.1.1 Energy Roadmap

The European Commission's 2011 Energy Roadmap set out four main routes to a more sustainable, competitive and secure energy system in 2050: energy efficiency, renewable energy, nuclear energy, and carbon capture and storage. It combined these routes in different ways to create and analyse seven possible scenarios for 2050.

Conclusions of the analysis:

- De-carbonising the energy system is technically and economically feasible. In the long run, all scenarios that achieve the emissions reduction target are cheaper than the continuation of current policies.

- Increasing the share of renewable energy and using energy more efficiently is crucial, irrespective of the particular energy mix chosen.
- Early infrastructure investments cost less, and much of the infrastructure in the EU built 30 to 40 years ago needs to be replaced anyway. Immediately replacing it with low-carbon alternatives can avoid more costly changes in the future. According to the International Energy Agency, investments in the power sector made after 2020 would cost 4.3 times as much as those made before 2020.
- A European approach is expected to result in lower costs and more secure energy supplies when compared to individual national schemes. With a common energy market, energy can be produced where it is cheapest and delivered to where it is needed.

Source: https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/2050-energy-strategy; consulted on 10 January 2019

2.1.2 Buildings in Europe

Buildings are responsible for approximately 40% of energy consumption and 36% of CO2 emissions in the EU. Currently, about 35% of the EU's buildings are over 50 years old and almost 75% of the building stock is energy *in*efficient, while only 0.4-1.2% (depending on the country) of the building stock is renovated each year. Therefore, more renovation of existing buildings has the potential to lead to significant energy savings – potentially reducing the EU's total energy consumption by 5-6% and lowering CO_2 emissions by about 5%.

Improving the energy efficiency of buildings can also generate other economic, social and environmental benefits. Better performing buildings provide higher levels of comfort and wellbeing for their occupants and improve health by reducing illnesses caused by a poor indoor climate. It also has a major impact on the affordability of housing and on the concept of energy poverty. Improvement of the energy performance of the housing stock and the energy savings it brings would enable many households to escape energy poverty. Investments in energy efficiency also stimulate the economy, in particular the construction industry, which generates about 9% of Europe's GDP and directly accounts for 18 million direct jobs. SMEs would particularly benefit from a boosted renovation market, as they contribute more than 70% of the value-added in the EU building sector.

Source: https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings, consulted on 10 January 2019

2.2 What: How Deep Renovation Concepts help

What if you own or manage a building which has an average or poor energy performance, in which tenants experience some sort of discomfort, in which heating systems are hard to manage, in which indoor air quality is mainly maintained by coincidental air leakages and ad hoc solutions for the ventilation of bathrooms, WC's and kitchens? But the building itself is not at the end of its technical lifetime, its structure is robust and sound, and the inhabitants like to live there, and have created a coherent social community.

In such case, it may help to consider a deep renovation, instead of just maintaining a building at its current quality. Deep renovation offers you a superb energy performance and good and healthy living conditions. Indoor air quality is guaranteed by active ventilation, providing the right amounts of fresh air without losing heat in winter. It includes control mechanisms such as shading, operable windows and ceiling fans for improved solar comfort. Heating can be provided from an optimized communal plant, which distributes heat to individual apartments or houses. A so-called energy hub gives the tenants full control over its own energy consumption.

The Deep Renovation Packages have been developed to assist building owners and designers in selecting possible solutions for existing buildings.
There are many reasons why deep renovation provides answers to problems of existing buildings; if a building is to have an extended lifetime, integrated solutions help solving multiple issues at the same time. Deep Renovation itself is a necessary pathway for the building sector to meet the needs of the society in moving towards a low carbon society.
Buildings have a long lifetime, and when renovation works are needed, deep renovation is the option to achieve a significant step in reductions, and improve the performance of buildings. Therefore, a number of relevant Key Performance Indicators are reported.
Instead of replacing or renovating individual components of a building, deep renovation with prefabricated facades offers the opportunity to integrate multiple technologies in the same elements.

4RinEU boosts Deep Renovation
The Deep Renovation Packages result in new insights in achieving environmental and project objectives in demonstration projects and feasibility studies in six geoclusters in Europe.

Energy
The objective is to reduce the energy demand for space heating and hot water by at least 60% and to increase the share of renewable energy

Comfort
To increase comfort levels in terms of indoor air quality and indoor temperatures in all seasons within acceptable ranges compared with outdoor temperatures

Environment
To reduce the CO2 emissions of the building, to pay attention to the environmental impact of building materials

Risks
To integrate multiple components in façade elements, thereby optimizing the deep renovation approach and quality of the intervention.

Time
To reduce the time of the physical renovation, in order to generate broad tenant's acceptance for deep renovation approaches.

Costs
To reduce the investment costs for Deep Renovation by prefabrication of integrated façade renovation elements, to achieve affordable building exploitation costs, and affordable costs of living for inhabitants, thus avoiding energy poverty.

2.3 How to use the Catalogue of Deep Renovation Packages

The Deep Renovation Packages sheets are a catalogue of integrated solutions which become feasible once one embraces the idea of a prefabricated façade. The energy-saving potential for example increases when integrated solutions are used.

- The energy demand saving of prefabricated facades in comparison the non-renovated situation ranges from 63 to 73% for different building types in Central Continental Europe.
- Adding decentralized ventilation with heat recovery results in ranges from 72 to 88% saving.
- Adding BIPV results in additional power generation, depending on the type of PV panels and orientations.
- Using centralized ventilation with heat recovery results in savings from 70 to 90%

- Adding smart ceiling fans for summer comfort conditions results in savings from 64 to 80% and better

In the same way other KPI's are influenced. Indoor climate conditions are improved in summer and winter conditions.

The simulation work behind the Deep Renovation Packages offers an insight in the range of combinations. To get a first idea one should follow a step by step procedure:

1. Choosing the geo-cluster, see section 3
2. Choosing the building typology, see section 3
3. Reviewing needs in section 4 with the help of technologies in section 5,
4. Choosing the packages in section 6

Selecting solutions for your project could also be done by using the tool developed under WP4.2 of 4RinEU. In this tool one can start from project priorities and needs, and ask the tool to select those packages which best meet personal project needs.

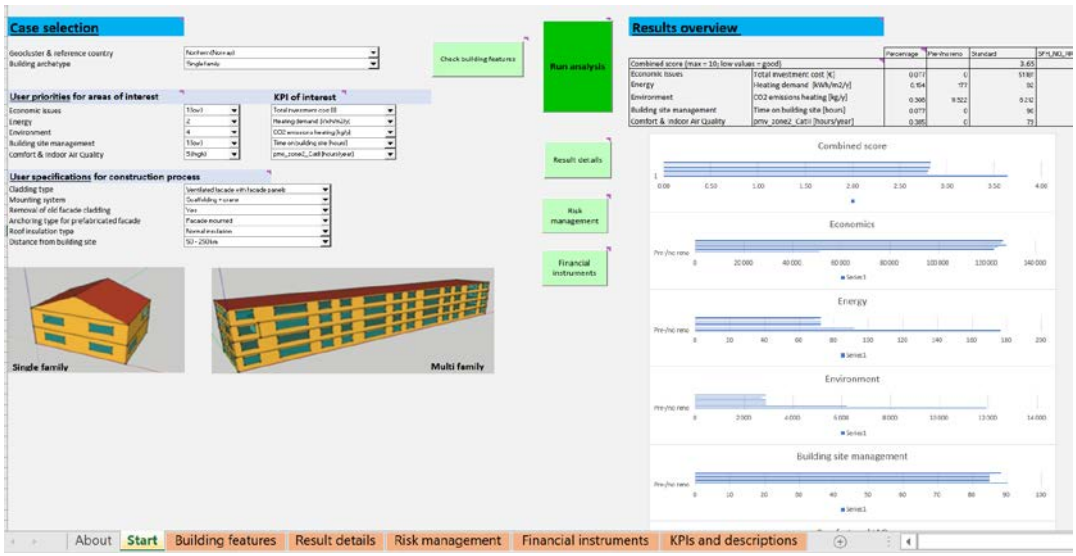


Figure 1 D4.2 Cost Effective Rating Tool user's interface

3 How to define and assess the renovation packages:geoclusters, building archetypes and KIPs

In this chapter, a summary of the main steps which brought to the definition of the repository and simulation outputs is reported. For more details on these activities, see Deliverable 2.1.

3.1 Definition of geoclusters

In order to provide a European framework for the parametric analysis of the renovation package performances, Europe has been divided in six homogeneous geo-clusters, according to the features of the residential building stock (share of single and multi-family houses), the average building performances provided by the law (in terms of U-value for the envelope) and climatic conditions. National boundaries have been used since they influence technical constraints and legislative requirements in case of renovation (Figure 2). Each geo-cluster includes either a demo case or an early adopter (EA) building where the 4RinEU renovation packages will be integrated respectively with a real implementation (demos) or a feasibility study:

- Geo-cluster 1: Northern Europe countries with cold climate and prevalence of single-family houses – reference country: Norway
- Geo-cluster 2: Northern East Europe countries with cold climate and large amount of multi-family houses built between 1960 and 1990, with prefabricated concrete panel – reference country: Poland
- Geo-cluster 3: Continental West and central with continental climate. The building stock is mainly composed by single-family houses, although also terraced houses and apartment block are often present, and there is no prevailing construction period, thus the stock presents different construction features (masonry, concrete or prefabricated structure) – reference country: The Netherlands
- Geo-cluster 4: Continental East, main building typology is single-family with a significant amount of multi-family houses built after the 2nd World War with prefabricated concrete structure – reference country: Hungary
- Geo-cluster 5: Mediterranean countries with warmer climate, where the building stock is split almost equally in single and multi-family houses built in different construction periods mainly with masonry or concrete structures – reference country: Spain
- Geo-cluster 6: Atlantic zone with cold oceanic climate and single-family houses as main building type - reference country: the UK

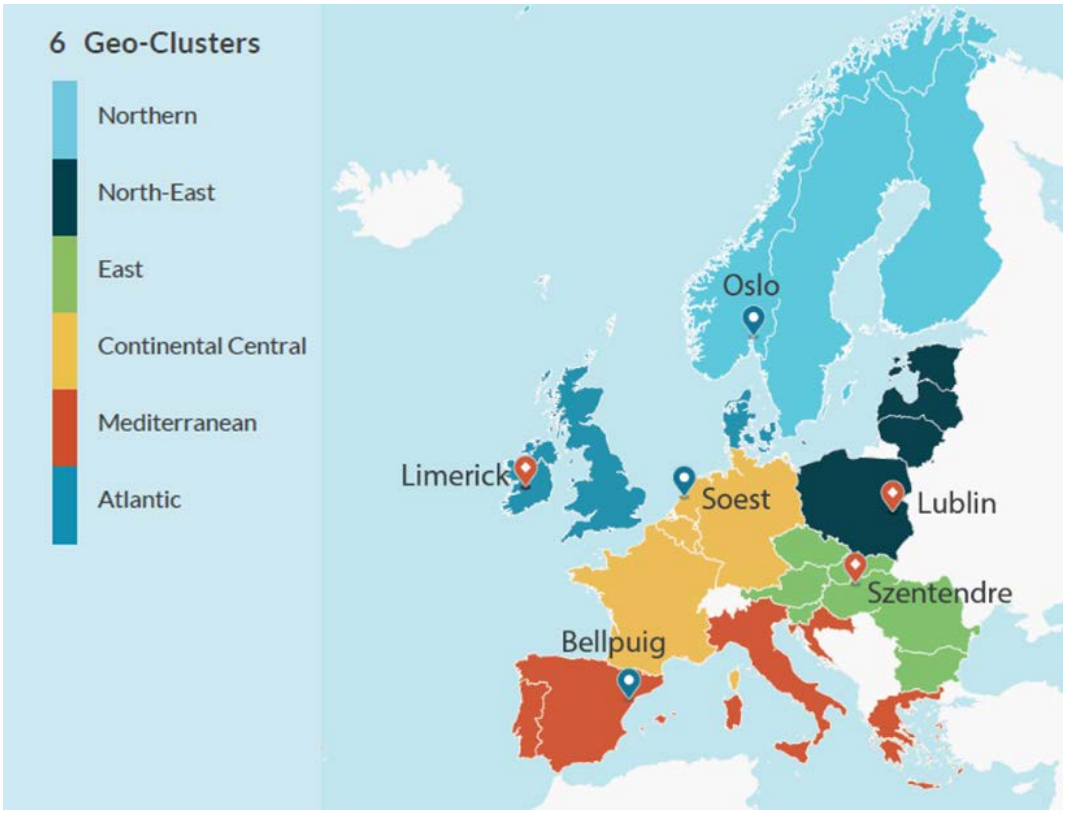


Figure 2. Geo-cluster division

3.2 Definition of Building Archetypes

For each geo-cluster, four representative building archetypes in the respective reference country have been selected. The source for this selection was the national building typologies developed as part of the TABULA project (Institut Wohnen und Umwelt GmbH, 2018). All 4RinEU archetypes are selected among these example buildings. However, in order to keep the number of models manageable, four main geometries have been identified and used for the simulation in each geo-cluster (Table 2).

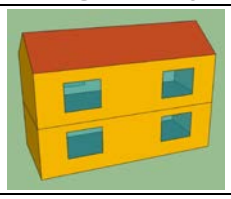
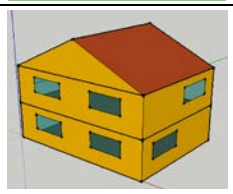
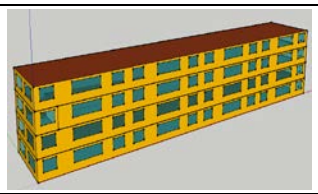
Building archetypes	Building characteristics
	Archetype: TERRACED HOUSE (TH) Lateral sides are set as ADIABATIC Reference floor area: 88 m^2 Floor Height: 2.8 m
	Archetype: SINGLE FAMILIY HOUSE (SFH) Reference Floor Area: 228 m^2 Floor Height: 2.5 m
	Archetype: APARTMENT BLOCK (AB) Reference Floor Area: 1330 m^2 Floor Height: 2.6 m
	Archetype: MULTIFAMILY HOUSE (MFH) Reference Floor Area: 3456 m^2 Floor Height: 2.8 m

Table 2. Simulated geo-cluster geometries

Although the geometries were identical in each geo-cluster (e.g. windows number and dimensions), the envelope's characteristics (i.e. materials and thermal properties) have been varied according to the typical features of each geo-cluster. Technical data for the archetypes has been extracted from the TABULA data tool. Therefore, existing building's envelope characteristics (i.e. wall, roof, window glazing and window frame) have been defined for each geo-cluster.

3.3 Job list & simulations KPIs

The different combinations between renovation packages have been studied performing a parametric analysis per each of the four building geometries in the six climatic areas. The software used has been TRNSYS in combination with JEplus, that is able to launch a huge number of simulations using TRNSYS executable files. The differences between all the simulation must be listed in a "job list" file made by the user.
In fact, each raw of this file corresponds to a simulation and it contains the values of each of the parameters to be specified.

3.3.1 Description of selected KPIs

The performances of the 4RinEU deep renovation packages are evaluated using a set of Key Performance Indicators (KPIs), set as the outputs of the parametric study. The evaluated thematic areas considered within the project are:

- **Energy**: indicators dealing with the energy consumptions of the building and with the energy produced with Renewable Energy Sources (RES). In particular, both energy demand, energy consumption and primary energy consumption have been considered for all the energy-consuming technologies within the building or integrated in the renovation packages.
- **Comfort** and Indoor Air Quality (IAQ): indicators dealing with users' comfort and indoor air quality.
- **Environment**: evaluation of the environmental impact of the building after the renovation
- **Economic issues**: evaluation of the NPV of the renovation calculated along 25 years from the intervention; moreover, the investment cost and energy cost for the renovation.
- **Building site management**: indications on the renovation time due on building site.

In the following Table 3, the detailed list of evaluated KPIs are listed.

Topic and KPI name	Explanation
Energy	
Total heating demand	Yearly net energy demand for heating as calculated considering the boundaries set in Annex A of Deliverable 2.1 "Geo-clusters and Building Archetypes"
Total cooling demand	Yearly net energy demand for cooling as calculated considering the boundaries set in Annex A of Deliverable 2.1 "Geo-clusters and Building Archetypes"
Heating demand per m^2	Yearly net energy demand for heating as calculated considering the boundaries set in Annex A of Deliverable 2.1 "Geo-clusters and Building Archetypes" and normalised according to the heated building surface
Cooling demand per m^2	Yearly net energy demand for cooling as calculated considering the boundaries set in Annex A of Deliverable

Topic and KPI name	Explanation
	2.1 "Geo-clusters and Building Archetypes" and normalised according to the heated building surface
Heating consumption [kWh/y]	Yearly final energy consumption for heating as calculated considering the boundaries set in Annex A of Deliverable 2.1 "Geo-clusters and Building Archetypes" and normalised according to the heated building surface
Heating consumption [kWh/m2/y]	Yearly final energy consumption for heating as calculated considering the boundaries set in Annex A of Deliverable 2.1 "Geo-clusters and Building Archetypes" and normalised according to the heated building surface
Primary energy heating [kWh/y]	Yearly final energy consumption for cooling as calculated considering the boundaries set in Annex A of Deliverable 2.1 "Geo-clusters and Building Archetypes"
Primary energy heating [kWh/m2/y]	Yearly primary energy consumption for heating as calculated considering the boundaries set in Annex A of Deliverable 2.1 "Geo-clusters and Building Archetypes" and normalised according to the heated building surface
Cooling consumption [kWh/y]	Yearly final energy consumption for cooling as calculated considering the boundaries set in Annex A of Deliverable 2.1 "Geo-clusters and Building Archetypes"
Cooling consumption [kWh/m²/y]	Yearly final energy consumption for cooling as calculated considering the boundaries set in Annex A of Deliverable 2.1 "Geo-clusters and Building Archetypes" and normalised according to the heated building surface
DHW demand kWh/year	Yearly energy demand for Domestic Hot Water production
Ventilation consumption [kWh/y]	Final Energy consumption for mechanical ventilation
Ceiling fan consumption [kWh/y]	Final energy consumption for the operation of the comfort ceiling fans
PV power produced [kW/y]	Yearly energy produced by the photovoltaic system (if installed during renovation)
Environment	
CO_2 emissions heating [kg/y]	Yearly CO2 emissions for heating
CO_2 emissions cooling [kg/y]	Yearly CO2 emissions for cooling
Comfort & IAQ	
CAT_1_PPM [hours/year] (OPTIMAL)	Number of hours in comfort category I (EN ISO 15251) according to the CO_2 concentration calculated in a sample room - number of hours in optimal indoor air quality conditions
CAT_2_PPM [hours/year] (ACCEPTABLE)	Number of hours in comfort category II (EN ISO 15251) according to the CO_2 concentration calculated in a sample room - number of hours in acceptable indoor air quality conditions
CAT_I_Adpt [hours/year] (OPTIMAL)	Number of hours in comfort category I (EN ISO 15251) according to the indoor temperature and relative humidity conditions in summer period calculated in a

Topic and KPI name	Explanation
	sample room - number of hours in optimal thermal comfort conditions (evaluated in cooling period)
CAT_II_Adpt [hours/year] (ACCEPTABLE)	Number of hours in comfort category II (EN ISO 15251) according to the indoor temperature and relative humidity conditions in summer period calculated in a sample room – number of hours in acceptable thermal comfort conditions (evaluated in cooling period)
pmv_zone2_CatI [hours/year] (OPTIMAL)	Number of hours in comfort category I (EN ISO 15251) according to the Predicted Mean Vote of the occupants during winter period calculated in a sample room – number of hours in optimal thermal comfort conditions (evaluated in heating period)
pmv_zone2_CatII [hours/year] (ACCEPTABLE)	Number of hours in comfort category II (EN ISO 15251) according to the Predicted Mean Vote of the occupants during winter period calculated in a sample room – number of hours in acceptable thermal comfort conditions (evaluated in heating period)
Economic issues	
Total investment cost [€] related to technology and/or installation works and materials on building site	
Approximated LCC 50 years [€]	Life Cycle Cost of the building calculated for 50 years after renovation considering investment cost for the interventions, energy supply during operation and maintenance
Building site management	
Time on building site due to installation/mounting works [hours]	Number of Hours needed for the installation of 4RinEU renovation packages

Table 3 Evaluated KPIs

A special remark should be done concerning the time reduction on building site due to the prefabricated renovation approach.
In fact, the use of prefabrication allows to manufacture off-site the modules, reducing possible mistakes and failure, while increasing productivity and safety during construction.
Remaining works to be performed on-site will consist in the installation of modules and the wires connection to electricity, depending on the technologies installed during prefabrication.
Moreover, the prefabrication approach allows for a lean construction management methodology, where different actors have clear responsibilities, avoiding delays and mistakes throughout the process.
Time on building site can be further reduced if BIM approach is implemented during the construction. In the Table 4, some of the most important actions along the prefabrication process which may foster on-site time reduction are listed:

Actions shifted during the industrial process
Fixing, positioning and levelling of the insulation panel, mechanical fixing of the insulation panel, Installation of new windows and new windowsills, Installation of the decentralized ventilation machines, Installation of the new boiler for heating and DHW, Installation of the heating distribution system, installation of PV system and solar thermal collectors
Actions not necessary with 4RinEU
Installation of corner pieces, Application of the primer coat, a base mortar over the insulation panel and reinforcing mesh, application of the finishing coat
Actions improved through Lean Management of the building site
Preparation of the building site; removal of the facade cladding, removal of existing windows, removal of existing windows sills
Further actions needed for the installation of 4RinEU packages
Preparation of the façade, anchoring system installation, crane installation of the façade; Connection of integrated systems (HVAC + PV + ST)

Table 4 Actions possibly fostering on-site time reduction

3.4 Requirements for prefabrication module to insert in public tenders

Public tenders are strategic instruments used to support the public investment achieving the fixed targets and projects objectives.
At European level there are some directives that rule and identified the national laws:

- Directive 2014/24/EU on public procurement
- Directive 2014/25/EU on procurement by entities operating in the water, energy, transport and postal services sectors
- Directive 2014/23/EU on the award of concession contracts

These directives aim to harmonize rules for tenders in order to enlarge the cross-border interest of possible investors at EU level.
Following these regulations, each public tender will be composed by several articles and laws requirements. The experience gained from the implementation of 4RinEU renovation packages in the demo cases highlight the importance of an effective design and planning when using prefabrication.
Within the 4RinEU project, we have summarized and reported in Table 5 some necessary points that should have a positive influence the building sector of the prefabrication module.

Requirements identification	Specification
Prefabrication module requirements to insert in the public tenders	Identification of the objectives of prefabrication façade

Minimum requirements of prefabrication façade (presentation)	Identification of the completed list of minimum requirements as: - architectonic, - structural - aesthetics - energy efficiency - functional - economic - design teams: list of experts or company requirements (designers, manufacturers and installers)
Awards criteria identification	Identification of the valuation points criteria - (min.-max. value) for each predefined criteria (preidentified above).
Composition of the jury	Experts able to assign and valuate the results Suggestions: to use an IDP (or Integrated Project Delivery) process to plan a multidisciplinary team who works on the project development
Guidelines developed within 4RinEU project, for supporting public/private partners in the elaboration of the prefabrication tender	• 4RinEU - D3.6 Management to implement deep renovation • 4RinEU - D4.1 Risk Assessment

Table 5. Prefabrication requirements for public procedures

4 Renovation needs and targets for geoclusters

The starting point of the renovation in the three demo cases was to identify the main drivers and needs of the building owners and users. In particular, during the Local Demo Case Working Group, we collected a series of inputs that have been also applied for the definition of the renovation packages in the geoclusters. In the following, we report an overview of the main findings from the discussion.

Geocluster 1 - Reference country: Norway

The discussion involved: Boligbygg, the owner of the Norwegian demo case, and in particular the section dealing with the management of the public residential buildings owned by the Municipality of Oslo and SINTEF, a Norwegian research centre with a comprehensive overview of the needs of the Norwegian stock.

Drivers and targets for the renovation

- ✓ Specific target for Oslo city – reducing CO_2 emissions and increasing energy efficiency and since Boligbygg is a public institution it has to contribute actively and to have an exemplary role.
- ✓ Boligbygg would try to reach higher performances than a common renovation. In fact, Boligbygg has a social responsibility and it has not to consider in the decision process only the simple cost-effectiveness, but also the co-benefits for the users.
- ✓ Many buildings have poor indoor air quality due to use and age of the construction, and currently, only natural ventilation is installed and not properly used by the tenants. One of the need is to install controlled ventilation and heat recovery for an improved indoor air quality while keeping energy efficiency.
- ✓ Consistency of the envelope: insufficient insulation and thermal bridges and, for the wooden buildings, damages on the external facade layers.
- ✓ Reduction of maintenance cost

Key issues to be reached for a successful renovation

- ✓ To find a renovation approach with high replication potential.
- ✓ To Adopt robust technologies, also easy to be maintained by the building owners.
- ✓ To reach passive house standards.
- ✓ Organization to perform the renovation works during summer season, with the tenants living inside. Reduce disturbance to minimum possible.

Geocluster 4 – Reference country: The Netherlands

The following considerations were mad during the discussion with WOONZORG, an entity managing a huge amount of residential buildings for elderly people, and TRECODOME, a Dutch consultant in the field of energy efficiency.

Drivers and targets for the renovation

- ✓ To adapt the building according to the needs of the users that, in many cases, are getting older and require more functional building.
- ✓ To renovate the building setting a flexible configuration to possible change spaces functions.
- ✓ To improve the building aesthetic.
- ✓ To improve indoor comfort of the occupants.

Key issues to be reached for a successful renovation

- ✓ Woonzorg is the owner of several buildings in the same area. High replication potential
- ✓ To identify an approach for retrofitting works with the tenants living inside. Reduce disturbance to minimum possible.
- ✓ To work for involving the end-users in order to increase the awareness and responsibility for the billing (as highlighted by the Municipality of Soest)

Geocluster 5 – Reference country: Spain

The reference partners in Spain are AHC, that is the social housing institute of Catalogna and the demo owner, and Aiguasol, a Spanish consultancy company in the field of energy efficiency and renewable integration in buildings.

Drivers and targets for the renovation

- ✓ In Spain, there is a huge amount of buildings with low-quality construction features, although built in recent years (also after 2000). These buildings present a lot of construction problems due to the poor quality of materials and because of the technical solutions applied since the design was based on the energy law of 1987.
- ✓ The social status of the social housing tenants (lots of them in fuel poverty) is a clear conditioning of the possible actions and solutions to be implemented. The principal goal is to improve the comfort conditions of the users, but at the same time the kind of people who lives in, can't allow themselves to pay more for new services.

- ✓ To focus on the evaluation of the consumption reduction on the theoretical energy use, because of fuel poverty, the actual consumption is lower than the average consumption per type of building and climatic zone.
- ✓ There is the need to provide solutions also coping the conditions of continental climate, that presents a significant heating need from October to May and two months of severe summer conditions.
- ✓ To reduce the maintenance cost during the operation.

Key issues to be reached for a successful renovation

- ✓ High replication potential with similar buildings in Spain (+ application of the technologies to other buildings of the building stock AHC manages)
- ✓ To include and motivate the tenants in the process by providing them visible benefits.
- ✓ To demonstrate the objective of the project – also consider comfort issues (benefit for the users also in this term) and also to calculate the theoretical consumption before and after renovation.
- ✓ Retrofitting works with the tenants living inside. Reduce disturbance to minimum possible.
- ✓ Maximize the passive retrofitting actions (by acting in the overall building skin, which includes both facades and the roof), and see what it fits related to the HVAC and RES solutions.

5 Overview 4RinEU technologies: main features and design aspects

In the following chapter, an overview of the main technologies used within 4RinEU is presented.
Technical details are described as well as critical issues related to their integration in the renovation process dealing with prefabrication.
The 4RinEU renovation packages are a combination of the following technologies.
For more details on the specific technologies, the reader can go to the dedicated deliverables from WP2.

5.1 Overview of the affected quality-energy performance parameters

In the following Table 6, an overview of the parameters affected by different technologies is presented. In each geocluster, the combinations between these parameters have been implemented to assess all the possible performances due to the different technologies.

PARAMETER	Involved controls/technologies
INFILTRATIONS	Infiltrations air flow rate is influenced by the presence of the retrofit façade envelope. In fact, due to the presence of the Prefabricated Multifunctional Façade and new windows in the renovation package, a tighter envelope occurs as far as infiltrations are concerned.
SHADING	An advanced shading system control is taken into account in case the Prefabricated Multifunctional Façade (PMF) is used in the renovation package. The added value in this smart shading system is that its operability is depending on external incident radiation on the façade, as well as on indoor and outdoor temperatures. The shading system is automatically activated and integrated within the prefabricated façade module.
VENTILATION	A new mechanical ventilation may be included in the renovation package. Two types of ventilation have been analysed for being integrated as well within the prefabricated façade module. On the one hand, decentralized machines with heat recovery can be placed beneath the windows, to exploit the existing window holes on the existing envelope. These machines usually can provide ventilation rate for one room. The analysed renovation packages consider a decentralized machine with 42m^3/h air flow rate and 70% efficiency for heat recovery.

PARAMETER	Involved controls/technologies
	On the other hand, centralized air handling units can be used to ventilate entire floors or apartments, exploiting the heat recovery as well. In this case, it is more feasible to integrate only the ventilation ducts within the prefabricated façade. The analysed renovation packages consider centralized AHU with 600m^3/h air flow rate and 81% efficiency for heat recovery.
PHOTOVOLTAIC	PV panels presence within the building is almost essential to provide energy gains by renewables. The solution developed within 4RinEU renovation packages foresees PV panels integration in the prefabricated façade modules.
COOLING	In order to avoid overheating or to reduce the cooling load within renovated buildings, smart ceiling fan can be considered in the renovation package. These fans, hanging on the ceiling, can communicate with temperature and relative humidity sensor, and hence can adjust automatically the fan speed.
ENVELOPE THERMAL TRANSMITTANCE	The opaque envelope is expected to undergo renovation using timber-based prefabricated module. These modules behave as new thermal and airtight layers and can vary their thicknesses and insulation material depending on the required performances. Along with other technologies, new windows are already integrated in the modules. The analysed renovation packages are expected to ensure a final envelope thermal transmittance of either 0.2 W/m^{2}K or 0.1 W/m^{2}K for all the geocluster except for Spain, where 0.2 W/m^{2}K and 0.7 W/m^{2}K possibilities have been investigated. Different new integrated windows performances have been analysed in all geocluster: 1.24 W/m^{2}K or 0.61 W/m^{2}K are the possible values used in different renovation packages.

Table 6 Parameters and technologies within renovation packages

5.2 Overview of the technical and design features

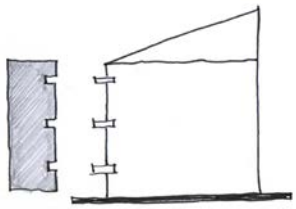
In this chapter, information of each **technology** is provided in 8 sheets where information regarding features and data are reported.

(6.4) Technical sheet for the technology

PREFABRICATED FAÇADE SYSTEM

1

Timber prefabricated façade systems are modules used for the renovation of existing buildings.Thus, they do not replace the existing façade, but they are added externally. In these modules, active systems may be integrated, in order to increase energy performance and comfort of the building.



	PROPERTIES	DESCRIPTION	NOTES TO DESIGNERS
DATA & FEATURES	**Dimension of prefabricated module**	Thickness, length, height, weight. Prefabricated façade modules can be either horizontally or vertically designed. In the first case, prefabricated modules have the same high of floor-to-floor, and cover part of the walls. Otherwise, they can also be mounted as "columns", covering different floors. Modules can cover a surface up to ~12m * ~3m. Modules thickness depends on different factors, such as aimed final thermal performances of the whole wall and presence of integrated components.	Horizontal mounting is usually preferred dealing with a high multi-story building. On the other hand, in case, of low-rise buildings, may be quicker to install modules vertically. Bigger dimensions for modules are mainly avoided due to transportation issues.
	Overall U-value of prefabricated module	Depending on the existing wall of the building and on the aimed thermal performances, modules insulation can be varied, easily reaching an overall thermal transmittance of the opaque envelope < 0.2 W/m^{2}K	The use of the prefabricated timber façade for retrofit implies a very good final value for thermal transmittance. In fact, modules, due to structural issues, cannot be too thin. On the other hand, modules thickness may also be limited due to public land occupation issues.
	Insulation material	Insulation material choice depends mainly on the thermal and structural characteristics of the modules to be achieved. Usually, soft insulation material is used as a main insulation and it is located inside the module. Another soft insulation material is used as adaption layer for other technical elements (as pipes) or between the module and the existing wall.	Along with insulation layers, vapor open or retarder membranes should be considered in order to avoid condensation issues Recyclable materials can be used, to the effect of reducing the embodied carbon of materials, making the renovation more environmental friendly, as little or no CO2 emissions are emitted by material production.
	Windows	New windows can be easily integrated in the prefabricated façade module. Their performances only depend on National regulation and no specific constraints.	In case new windows are integrated in the prefabricated façade, existing windows may be kept or removed. In this case, it is necessary to put more attention in the air tightness in the installation phase of the existing windows.
	Shading system	New shading system can be directly integrated in the prefabricated timber modules.	Suggested: -Vertical shading system: east and west orientation

	(see technology 4 – shading system integrated)		-Horizontal shading system: south orientation
	Anchoring structure to existing wall	Different systems for anchoring the prefabricated modules to the existing building are present. The modules' anchoring can rely on timber beams attached to the concrete slabs or on steel beams. In case the existing structure is not good enough from the structural point of view, a new foundation can be built on the ground.	The choice of the proper anchoring system is mainly depending on how the existing structure can bear additional loads.
	Fire protection	Fire resistance class EI /REI minimum	To be verified with national law
	Costs/added values	Performing a deep renovation using a prefabricated timber façade requires a relevant initial investment, usually higher of a traditional isolation of the existing wall, but with some benefits in the installation phase, short timing with low costs connected to the construction site and low inconveniences for the tenants. To have a complete and clear vision of the costs of such an intervention, it is useful to evaluate not only the costs at the initial stage but also on a wider time span. In fact, this is a very long-lasting kind of intervention. Therefore, if the evaluation is based on building lifetime, costs may become lower respect to other interventions.	It must be considered that, if the prefabricated timber façade is only used to integrate a new insulation, the costs of a standard external insulation process would be lower. Anyway, the real added value of this approach is the possibility of integrating in the prefabricated façade different technologies, in order to reach deep renovation standards, reducing time on building site and occupants' disturbance. The comparison with other intervention's approaches should be done keeping the final performances at the same level and extending the analysis on building lifetime span. In this way timber prefabricated approach usually comes out to be more advantageous.
	Maintenance	External layer	Like in a traditional system
		Shading system	Like in a traditional system
	Property Real estate value	Added value for the property	People can stay inside during the building works with reduced inconvenient for the tenants. Reduced timing (usually no scaffolding structure and relative costs)
		Aesthetic	
		Long-lasting durable	
DESIGN AND CONSTRUCTION ISSUES			
	Critical points for: - Investors, designers and installers	More efforts during the design phase. It is suggested to develop the design project in a deeply and active collaboration between design team, manufactures and installers. Sometimes this participation process is reduced by the typology of procurement process used ➢ Example: the final objective of design tender it is the project definition as developed from design teams. In this case it is difficult to include the manufactures or the installers. Changes in the construction phase are not allowed	Positive results are achieved using: -BIM technology - Integrated design process /Participative design process
		Multidisciplinary teams	

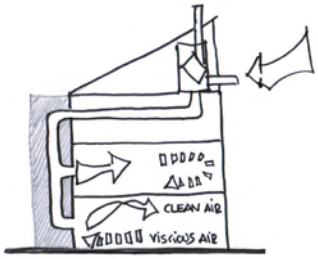
	Integrated design process (IDP) **Participative design process**	Decision process through feedbacks loop mechanism	Further information, explanation and reference on how to use other4RinEU relevant results: D3.5 - Participative design approach D3.2 - Collaborative design platform) - Identification of needs (inclusive process with the tenants)
		Identification of the project phases, objective, KPIs, tools and verification process.	
	Verification of internal condensation	Verification during the design phase – identification of the minimum requirements (specification) and calculation method (tools).	EN ISO 13788:2012
	Procurement process	To identify the objectives, the KPI, the tools and verification phase (responsible people and process to use during the verification phase)	
		To require a multidisciplinary team, as a minimum participation requirement of public tender or identify specific score points for a multidisciplinary team composed of a certain number of experts on specific knowledge or experiences. Suggested experts to involve in the design process: of the technological element: - architects - structural engineer - energy designer - manufacturers - installers - other experts (in relation to the specific features case by case)	Important to define the detailed design with the manufacturer Another possibility is to review the design after the assignment of the contract
	Prefabricated façade (including insulation, new windows and new shadings system)		Timber prefabricated façade systems are modules used for the renovation of existing buildings. Thus, they do not replace the existing façade, but they are added externally. In these modules, active systems may be integrated, in order to increase energy performance and comfort of the building.

(6.4) Technical sheet for the technology

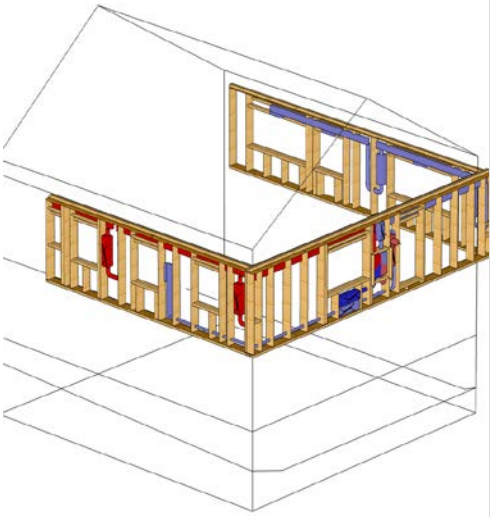
BALANCED AHU/HR

2

Centralized ventilation machines aim to guarantee the proper ventilation rate within the building.
These machines are typically equipped with a heat exchanger and can serve more than one apartment. If they are used in combination with the prefabricated façade, ventilation ducts can be integrated within the modules, while the machine is usually placed in a dedicated technical room.



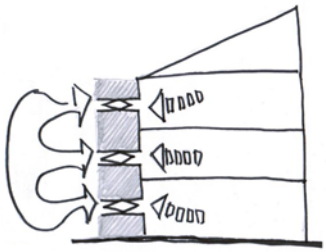
	PROPERTIES	DESCRIPTION	NOTES TO DESIGNERS
DATA & FEATURES	**Location of air heat recovery unit**	Balanced AHUs with heat recovery are usually used to provide proper ventilation rate to entire apartments, at floor level or at building level. Units can quite bulky, therefore they are placed in dedicated technical rooms. Anyway, ventilation ducts integration within the prefabricated façade is possible and advantageous.	In case ventilation ducts are integrated within the prefabricated façade, a proper ducts insulation must be carried out in order to avoid any possible condensation issue. Moreover, sound absorber should be used to avoid noise issues, in particular in some ambient, like bedrooms.
	Air volume	AHUs air flow rate considered for residential application can be between 250 m^3/h and 600 m^3/h or even more.	Balanced AHU with heat recovery system should be carefully designed depending on the building needs and following National regulations in order to ensure the right ventilation rate.
	Heat recovery	Air from indoor rooms is extracted and, thanks to a heat exchanger within the AHU, part of its heat is recovered and used to heat up the inlet fresh air. Generally, centralized units have quite a high potential for heat recovery efficiencies (around 90%). Summer bypass technology is suggested.	Having pre-heated air entering indoor environments is very important to ensure good quality for tenants' comfort. Moreover, heat recovery is fundamental for decreasing the heating load of a building.
	Energy consumption	Centralized ventilation units usually require power in the range of some kWs, depending on the machine size.	The energy consumption is one of the parameters that can influence the AHU choice.
	Building structure	Due to AHU dimensions, one or more dedicated technical rooms are needed in order to place the machine/s.	
	Integration of conducts in the prefab module	Ventilation ducts can both pass inside building rooms and corridors or being integrated in the prefabricated façade modules.	If this option is chosen, attention must be paid in properly insulating the ducts. This is necessary to overcome possible condensation issues due to cold air flow and also to avoid heat recovery efficiency's loss.
		Connection between central unit and pipes in the prefabricated façade	
	Costs and added values	When the ventilation ducts are integrated in the prefabricated façade, less indoor volume is used to technical system installation with more available space within the building. This gives an increase in saleable space and potentially an increase of the income for the building owner.	

	Maintenance: costs and specification	When technical system of AHU is installed in the prefab. façade a specific maintenance program completed of series of processes and guidelines, that help the whole system to being efficient.	
DESIGN AND CONSTRUCTION ISSUES			
	Critical points for the designers	Acoustic	An important issue to consider when opting for centralized ventilation systems used at apartment level or between different apartments is the presence of unpleasant odors. This problem can be prevented only through a proper balancing of air flow of the system. The proper balancing must guarantee bathrooms and kitchens to be slightly underpressurized respect to living rooms and bedrooms. This will avoid odors and exhaust air to reach tenants. • Supply air in the living room and bedrooms. • Extract air in the kitchen and bathrooms.
		Location of the unit	
		Conduct	
	Participative design process	Integrated design process (IDP) or Integrated Project Delivery (IPD)	
	Best practice considerations		
	Tender process	Definition of needs and the minimum requirements, as ventilation rate and efficiency.	
	Experts to involve in the design process of the technological element	Architects	
		Air flow engineers	
Centralized ventilation			Centralized ventilation machines aim to guarantee the proper ACH within the building. These machines are typically equipped with a heat exchanger and can serve more than one apartment. If they are used in combination with the prefabricated façade, ventilation ducts can be integrated within the modules, while the machine is usually placed in a dedicated technical room.

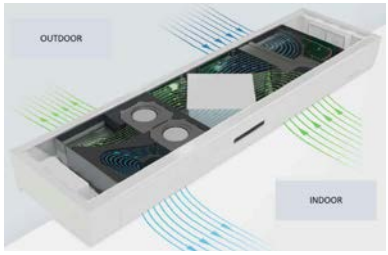
(6.4) Technical sheet for the technology

3 FACADE INTEGRATED VENTILATION/HR

Decentralized ventilation machines are used in order to guarantee the right ACH within rooms or apartments. These devices may be equipped with a heat exchanger in order to recover heat from the exhaust air and to heat up the inlet air. Usually, one or two machines properly located can serve an entire apartment. If they are used in combination with the prefabricated façade for retrofit, the whole machine can be integrated in the modules.



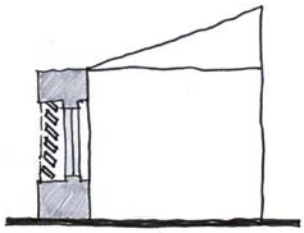
	PROPERTIES	DESCRIPTION	NOTES TO DESIGNERS
DATA & FEATURES	**Location**	Decentralized ventilation systems can usually ensure the proper ventilation rate for single rooms or small apartments. In case this technology is used in a deep renovation process including the use of the prefabricated façade, ventilation devices can be integrated in the new envelope. In particular, the devices can be integrated beneath new windows. Therefore, the existing windows' hole will be exploited, avoiding additional works on building site (e.g. drilling new holes in the existing wall)	Integrating ventilation devices within the prefabricated façade, near new integrated windows, allows for the exploitation of the existing windows' hole and can avoid additional works on building site. Nevertheless, this operation is only possible if windows area is large enough. Machine can be placed both horizontally or vertically, but windows' area shouldn't be reduced too much, both for lighting and ventilation issues.
	Design principles air volume	Decentralized ventilation units can usually provide air flow rates between 15 m^3/h and 80 m^3/h.	Decentralized ventilation units with heat recovery system should be carefully designed depending on the building needs and following National regulations in order to ensure the right ventilation rate.
	Heat recovery	Air from indoor rooms is extracted and, thanks to a heat exchanger within the device, part of the heat is recovered and used to heat up the inlet fresh air. Generally, decentralized units have good potential for heat recovery efficiencies (around 70%), depending on the operative conditions.	Having pre-heated air entering indoor environments is very important to ensure good quality for tenants' comfort. Moreover, heat recovery is fundamental for decreasing the heating load of a building.
	Energy requirements	Decentralized ventilation units generally require from some tens up to some hundreds of Watts.	Designers must be aware that electricity is available for connecting the machine after they are installed. Ventilation device could exploit façade integrated PV power production with an in-loco exchange.
DESIGN AND CONSTRUCTION ISSUES			
	Critical points for the designers	Acoustic Location of the unit Conduct	To consider the acoustic design (noise protection) + take care about odours
	Critical points for the installers		Installation position of decentralized ventilation machines must allow for an easy inspection of the machine itself, in case of malfunctioning.

			Moreover, air filter within the device should be easily accessible to allow cleaning procedure.
	Tender process	Definition of needs and the minimum requirements, as ventilation rate, efficiency, etc.	
	Experts to involve in the design process of the technological element	Architects	
		Air flow engineers	
	Decentralized ventilation		Decentralized ventilation machines are used in order to guarantee the right ACH within apartments. These devices may be equipped with a heat exchanger in order to recover heat from the exhaust air and to heat up the inlet air. Usually, one or two machines properly located can serve an entire apartment. If they are used in combination with the prefabricated façade for retrofit, the whole machine can be integrated in the modules.

(6.4) Technical sheet for the technology

4 INTEGRATED SHADING

Automatic shading system can be integrated within prefabricated façade in order to reduce solar gains and overheating. Usually, shading lamellas are placed outside, in front of the window. Control strategy can be based on external incident radiation, indoor or/and outdoor temperatures.



	PROPERTIES	DESCRIPTION	NOTES TO DESIGNERS
DATA & FEATURES	**Location**	Solar shadings may be integrated within the prefabricated façade. Usually, they are placed outside windows.	Shadings should always be present in South, West and East oriented façades, while on the North exposed one, they can be avoided. Their orientation may be horizontal or vertical, with a variable or fixed tilt angle. These choices should be performed after a detailed solar exposure and shades analyses.
	Design principles	Shading system, integrated within the prefabricated façade, is automatically controlled. The control strategy, exploiting the communication with different ambient sensors, can be based on the incident solar radiation on the façade and indoor or/and outdoor temperature.	A manual control of the shading device should always be available for the occupants.
	Energy requirements	If the shading system requires electrical supply, few tens of Watts are required for the automation.	Designers must be aware that electricity is available for connecting the shading device after they are installed.

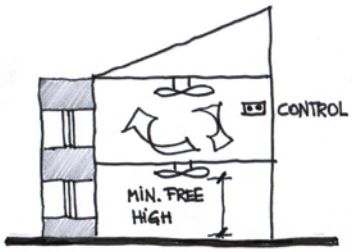
			Shading device could exploit façade integrated PV power production with an in-loco exchange.
	Shading brie soleil elements orientation	Vertical– eat- west orientation	
		Horizontal – south orientation	
DESIGN AND CONSTRUCTION ISSUES			
	Experts to involve in the design process of the technological element	Interior Light designers	Study the best solution in terms of daylight, avoiding glare effects
		Energy engineers	Evaluate the performances of the building in terms of energy balance, considering solar gains. Shadings can be used to adjust the balance and strongly improve energy performances
	Automated sun shadings integrated in prefabricated façade		Automatic shading system can be integrated within prefabricated façade in order to reduce solar gains and overheating. Usually, shading lamellas are placed outside, in front of the window. Control strategy can be based on external incident radiation, indoor or/and outdoor temperatures.

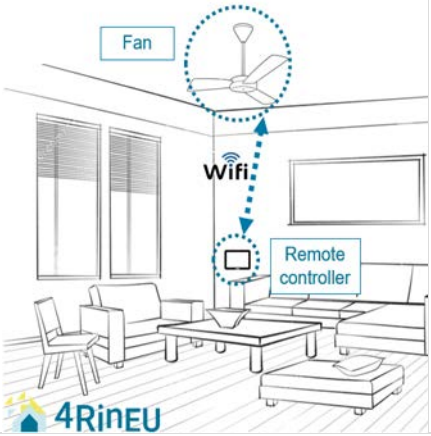
(6.4) Technical sheet for the technology

5

SMART CEILING FAN

Smart ceiling fan has been developed to ensure a well-defined level of comfort considering the environmental and personal conditions at a specific point in time. The system is made by a common ceiling fan that can be controlled remotely, and a remote-control unit that includes the temperature and relative humidity sensors, and the control algorithm.
Smart ceiling fans are intended for summer cooling.



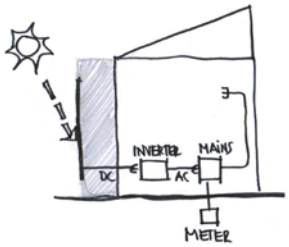
	PROPERTIES	DESCRIPTION	NOTES TO DESIGNERS
DATA & FEATURES	**Location**	Smart ceiling fans should be placed in mostly occupied rooms of apartments.	Temperature and relative humidity sensors, which communicate with the ceiling fan to adjust fan speed, should be placed in a representative point for the room's indoor conditions. In this way, cooling potential of the ceiling fan is really coupled with users' comfort and needs.
	Design considerations	Ceiling fan technology requires the room to be high enough. This is to avoid dangerous conditions and to generate the right air movement within the room.	For safety reasons, ceiling fan can be used only if distance between floor and fan blades is more than 2.3 meters. For residential use, the measure from blades until ceiling varies, according to products, from 30 cm until 60 cm. Reference standard: IEC 60335-2-80:2015 Household and similar electrical appliances -Safety - Part 2-80: Particular requirements for fans.
	Average air movement speed	Depends on the ceiling fan model, high of blades and radius of the blades.	
	Health considerations	Prolonged exposure may incur into dehydration of occupants. For this reason, and in order to provide a beneficial cooling effect, it is suggested to use the ceiling fan when air temperature is lower than the skin temperature.	
DESIGN AND CONSTRUCTION ISSUES			
	Critical points for the designers	Internal high. Position, right location for tenants/users	
	Critical points for the installers	Position, right location for tenants/users	
			Smart ceiling fan has been developed to ensure a well-defined level of comfort considering the environmental and personal conditions at a specific point in time. The system is made by a common ceiling fan that can be controlled remotely, and a remote-control unit that includes the temperature and relative humidity sensors, and the control algorithm.

(6.4) Technical sheet for the technology

BUILDING INTEGRATED PV

6

Photovoltaic modules are used in order to exploit renewable energy in order to produce electricity. PV can be integrated both on the roof and within the timber prefabricated façade. The power produced can be both stored, sent to the grid or directly delivered to the active components integrate in the façade (e.g. ventilation machine, shading systems etc.)



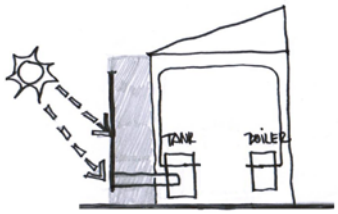
	PROPERTIES	DESCRIPTION	NOTES TO DESIGNERS
DATA & FEATURES	**Location**	Photovoltaic modules can be integrated in the prefabricated structure. They can be both placed on the prefabricated roof or façade. The optimal orientation should be optimized to exploit in the best way the sun irradiation. The optimization should also be done considering the load profile of the building/users.	PV system may be designed to provide electricity to other building-integrated technologies (e.g. sun shadings, ventilation machines, etc) Stan-alone façade modules solutions may be taken into account from the energy point of view.
	Design considerations	Modules thickness is usually within few centimeters (<5cm) and depends on the chosen technology.	The designer should consider that integrating the PV modules, the coplanarity of the main structure (especially if PV are façade-integrated) should be maintained, almost for aesthetical reasons. To avoid overheating of the PV modules and a consequent loss of efficiency, a retro-ventilation of the modules should be kept. Therefore a few-centimeters-deep cavity between PV modules and façade should be designed.
	Type of Photovoltaic cell	Most known PV technologies are monocrystalline, polycrystalline and thin-film. Usually, thin-film technology is slightly less efficient respect the other two.	Mono- and poli- crystalline consist of rigid modules, therefore, they are not indicated if the substructure is a free-form one. On the other hand, thin-film technology can adapt more easily to curved shapes. While thin-film can usually assume different colours, mono- and poli-crystalline PV panels are usually dark. In general, darker PV modules have higher efficiencies.
	Safety issues	PV panels substructure must be carefully designed for safety reasons, especially when facade integration occurs. Specific caution must be paid to avoid panels drop.	National regulations may forbid or limit the use of PV modules façade integrated for safety reasons.
	Average energy production/energy harvest	PV modules energy production depends on the technology of the modules themselves and the sun irradiation. Generally, peak power production is about 150-200W per square meter.	

DESIGN AND CONSTRUCTION ISSUES			
	Critical points for the designers	Aesthetical issues due to BiPV integration	Nowadays, PV modules are provided with various colours and in different shapes (e.g. thin films), so that they can easily be integrated in buildings
	Experts to involve in the design process of the technological element	Energy engineer	In order to properly estimate the amount of PV to be installed, taking into account the electrical loads due to users, appliances and heating/cooling loads.
		Electricians	
	PV integration		Photovoltaic modules are used in order to exploit renewable energy in order to produce electricity. PV can be integrated both on the roof and within the timber prefabricated façade. The power produced can be both stored, sent to the grid or directly delivered to the active components integrate in the façade (e.g. ventilation machine, shading systems etc.)

(6.4) Technical sheet for the technology

7 BUILDING INTEGRATED ST

Solar-thermal modules are needed in order to exploit sun power in order to produce heated water. These ST modules can be placed both on the roof and within the façade. Using ST panels, a water storage or a heat pump is needed in order to produce hot water for DHW or heating system.



	PROPERTIES	DESCRIPTION	NOTES TO DESIGNERS
DATA & FEATURES	**location**	Solar thermal modules can be integrated in the prefabricated structure. They can be both placed on the prefabricated roof or façade. The optimal orientation should be optimized to exploit in the best way the sun irradiation.	
	design considerations	Modules thickness is usually within few centimeters (<10cm) and depends on the chosen technology.	The designer should consider that integrating the ST modules, the coplanarity of the main structure (especially if ST are façade-integrated) should be maintained, almost for aesthetical reasons. To avoid thermal losses of the ST modules and a consequent loss of efficiency, a retro-ventilation of the modules should be kept at a very low level, although few-centimetres-deep cavity between ST modules and façade can be kept, to avoid moisture coming from indoor environments to be blocked.

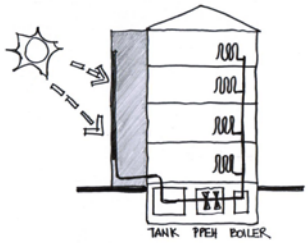
	average energy production/energy harvest	ST modules energy production depends on the technology of the modules themselves and the sun irradiation.	
	Safety issue	ST panels substructure must be carefully designed for safety reasons, especially when facade integration occurs. Specific caution must be paid to avoid panels drop.	National regulations may forbid or limit the use of ST modules façade integrated for safety reasons.
DESIGN AND CONSTRUCTION ISSUES			
	Critical points for the designers	Aesthetical issues due to BiST integration and placement of the water storage and related circuits	
	Experts to involve in the design process of the technological element	Energy engineer	In order to properly estimate the amount of ST panels to be installed, taking into account the building geometry and production potential in a specific area.
		Electricians	
	ST integration		Solar-thermal modules are needed in order to exploit sun power in order to produce heated water. These ST modules can be placed both on the roof and within the façade. Using ST panels, a water storage or an heat pump is needed in order to produce hot water for DHW or heating system.

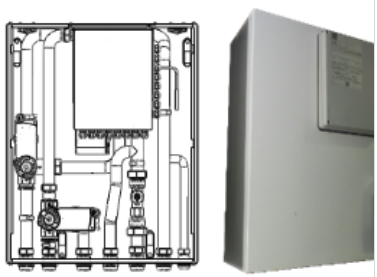
(6.4) Technical sheet for the technology

ENERGY HUB

8

The Energy Hub is a hydronic system able to manage complex heating and cooling system.
It can be used in combination with a solar-thermal system, as well as with a heat pump and it can properly control the heat fluxes depending on the required needs.
Energy hub can also be integrated in the prefabricated façade, provided that it is placed in a compartment easy to inspect.



	PROPERTIES	DESCRIPTION	NOTES TO DESIGNERS
DATA & FEATURES	Location	The hydronic unit can be integrated in a dedicated technical room, inside the apartments as a normal heating boiler, or also being integrated in the prefabricated façade. Its dimension are 648.5 x 502 x 189 mm	In case the hub is integrated in the prefabricated façade, it must be given the possibility to assess the component easily for any maintenance issue.
	Design considerations	The use of the hydronic unit is mostly indicated if the complexity of the water distribution plant is relevant. And if the system has to supply water to different users.	The energy hub allows for an estimated reduction of 20% on heating, cooling and domestic hot water consumption, corresponding to a 2-classes-step in the BACS categories in the EN ISO 15232 for building automation system.
		The energy hub can be coupled with a solar thermal plant, a heat pump or/and a water storage to manage in an efficient way the water flows.	
		This unit can come in the 2-pipes or 4-pipes version. The 4-pipe version allows to manage separately the domestic hot water circuit and the space heating and cooling circuit, allowing a very effective production of hot water during the warm season because the heat rejected by the heat pump thermodynamic cycle is used to heat up the water instead of being released in the environment. The 2-pipes version can be operated in inverse mode which allows the machine to work as a chiller instead of a heater.	
		The system can work with temperature between 2°C and 95°C. The maximum water flow allowed is 3 m^3/h	
	Energy hub		The Energy Hub is a hydronic system able to manage complex heating and cooling system. It can be used in combination with a solar-thermal system, as well as with a heat pump and it can properly control the heat fluxes depending on the required needs. Energy hub can also be integrated in the prefabricated façade, provided that it is placed in a compartment easy to inspect.

6 4RinEU renovation packages

This chapter reports a comprehensive overview of achievable results, in terms of the selected KPIs, for the 4RinEU renovation packages. In fact, as a result of the huge parametric analysis performed (see Deliverable 2.1 for more information) combining all the different technologies in the geoclusters and building archetypes, a significant number of possibilities were available. For each of the modelled conditions, consisting of a variant of a renovation package, the set of KPIs was indicating the performances. However, in order to let the results be accessible in the design phase, it has been decided to resume them in a series of renovation package sheets. Between the huge amount of combination available, only the most relevant renovation packages have been selected for the inclusion in these sheets.
The sheets are mainly grouped depending on the geocluster; in each group, the seven renovation packages are presented in different tables including the results for the four building typologies.
The presented results for each KPI are sometimes given as a range. Indeed, each presented renovation package can be assessed in different variants by a set of simulations, where some of the technology features may vary between different values. As an example, the energy-related KPIs are given in a range since the results come from simulations considering different thermal transmittance for opaque and transparent envelope.
Moreover, although some renovation activities are not specifically mentioned in the sheets, all the renovation conditions are considering the improvement of the ground floor and roof, better airtightness and higher efficiency for the heating system.

6.1 How to use the packages sheets

Here below, a summary of all the sheets is presented, in order to guide the reader through the tables.
Renovation package sheets are reported in the ANNEX "Renovation Packages" tables.

Sheets are divided in 6 groups, one per each geocluster (reference colours' per geocluster are shown in Table 7). In each group, the 7 renovation packages are presented:

1. Prefabricated Façade
2. Prefabricated Façade + Decentralized Ventilation
3. Prefabricated Façade + Decentralized Ventilation + PV modules
4. Prefabricated Façade + Centralized Ventilation + PV modules
5. Prefabricated Façade + Decentralized Ventilation + PV modules + Smart Ceiling Fan
6. Prefabricated Façade + Smart Ceiling Fan

7. Prefabricated Façade + Energy Hub + ST modules

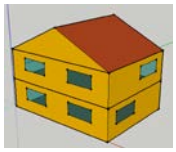
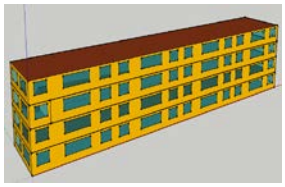
Table 7 Geocluster identification color

Geocluster	Color	
Continental - central		
Mediterranean		
Northern		
Noth-east		
East		

Geocluster	Color	
Atlantic		

In each sheet, the results for the four building archetypes (Table 8) are reported:

Table 8 Building archetypes

Terraced House	Single-Family House	Multi-Family House	Apartment Block
			

7 Conclusions

This deliverable reports the technical overview of the more comprehensive work, performed within the project 4RinEU, for the definition of renovation packages in the EU. Coupled with deliverables D2.1, including the approach for the definition of the geoclusters and reference archetypes, and D4.2 with the cost-effective rating tool, it represents one of the key results of the project.

The geoclusterization process was the starting point for the definition of the renovation packages, since it allowed to identify homogeneous renovation needs, climatic conditions and building stock consistency for identifying the most-suitable technologies and variants to be included in the packages. Concerning the technologies, following the detailed characterization as reported in deliverable from WP2, D3.3 describes the main technical aspects considering the information needed by a designer when approaching a renovation intervention.

Therefore, the technical sheets for the technologies reports the features, performances and design issues to be considered when planning a renovation with 4RinEU technologies, representing an important support for the implementation of the approach across Europe.

Moreover, the detailed performance analysis in the EU geocluster provide also a preliminary estimation of the potential benefits from 4RinEU renovation packages in different contexts and for the different building archetypes, and allow for a quick and comprehensive estimation of the impact on existing buildings.

In Indeed, the Annex report the series of KPIs in different thematic areas (i.e. energy, comfort, environment, economic issues and building site management) for the archetypes in the geoclusters. summarizing the results of 41470 simulations per each geocluster.

This huge amount of information is available for designers and professionals approaching to building renovation. It can give an overview of the performances of the building to be renovated as well as assessing information on the works in terms of economic affordability.

To conclude, this document can represent an important support for the preliminary design phase, on the one hand as a structured source of information for the technologies to be implemented in a renovation and, on the other hand, providing an estimation of the impact on the building performances.

4RinEU

Reliable models for deep renovation

ANNEX D3.3

WP3

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 723829

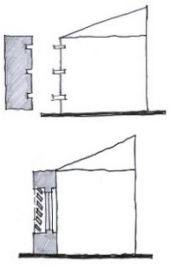
1

RENOVATION PACKAGE

GEOCLUSTER CONTINENTAL - CENTRAL

PREFABRICATED FACADE




	Tot Area	**88 m2**	**228 m2**	**3456 m2**	**1330 m2**
REQUIREMENTS OF THE COMPONENTS		Opaque part	Prefabricated facade thickness [cm]	~20 ÷ ~35			
			Final U-value wall [W/m²K]	~0.2 ÷ ~0.1			
		Window	Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
			Frame U-value [W/m²K]	1.4 ÷ 1			
			g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
		Shading	Presence	May be applicable			
			Control strategy	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			
Key Performance Indicators							
ENERGY			Heating demand [kWh/m²]	68 ÷ 76	42.1 ÷ 50.7	32 ÷ 34.8	39.24 ÷ 43.14
			Cooling demand [kWh/m²]	0 ÷ 4	~0	0.138 ÷ 3.44	0 ÷ 2.61
			Ventilation consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
			Ceiling fan consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
			Estimate PV power production [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
			PEF (H+C) saving respect to non-renovated	-97.9% ÷ -76.6%	-88.3% ÷ -81.7	-82.8% ÷ -69.9%	-85.1% ÷ -71.9%
			Energy demand (H+C) saving respect to non-renovated	-73.1% ÷ -69.5%	-79.45% ÷ -75.38%	-69.7% ÷ -65.71%	-66.6% ÷ -62.9%
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more explanation on these KPIs)			CAT_1_PPM	100%	79.45% ÷ 82.22%	16.03% ÷ 20.39%	100%
			CAT_2_PPM	0%	8.28% ÷ 9.14%	23.22% ÷ 24.92%	0%

	CAT_I_Adpt (evaluated in cooling period)	47.6 95.7	19.54% ÷ 92.18%	23.80% ÷ 96.61%	28.8% ÷ 94.39%
	CAT_II_Adpt (evaluated in cooling period)	3.6% ÷ 19.77%	7.18% ÷ 37.32%	3.72% ÷ 35.05%	5.6% ÷ 21.51%
	pmv _CatI (evaluated in heating period)	1.2% ÷ 3.54%	0.48% ÷ 7.66%	2.23% ÷ 11.80%	8.2% ÷ 14.16%
	pmv _CatII (evaluated in heating period)	3.34% ÷ 7.82%	5.54% ÷ 16.25%	7.61% ÷ 16.01%	11.12% ÷ 14.58%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.404 ÷ 1.55	1.53 ÷ 2.55	17.9 ÷ 32.9	2.93 ÷ 11.03
ECONOMIC ISSUES	Investment cost [€]	58947 ÷ 237495	76195 ÷ 257488	753200 ÷ 1323392	362997 ÷ 583546
	Net Present Value (50 years) [€]	66786 ÷ 269081	86328 ÷ 291733	853375 ÷ 1499403	411275 ÷ 661157
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	44 ÷ 95	55 ÷ 118	562 ÷ 1206	272 ÷ 569

2

RENOVATION PACKAGE

GEOCLUSTER CONTINENTAL - CENTRAL

PREFABRICATED FACADE + DECENTRALIZED VENTILATION




	Tot Area	**88 m2**	**228 m2**	**3456 m2**	**1330 m2**
REQUIREMENTS OF THE COMPONENTS	Opaque part – Prefabricated facade thickness [cm]	~20 ÷ ~35			
	Opaque part – Final U-value wall [W/m²K]	~0.2 ÷ ~0.1			
	Window – Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
	Window – Frame U-value [W/m²K]	1.4 ÷ 1			
	Window – g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
	Shading system – Presence	May be applicable			
	Shading system – Control strategy	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			
	Mechanical ventilation system – Type	Decentralized ventilation system providing punctual inlet and outlet of air. Decentralized machine also provides heat recovery. The mechanical ventilation system is considered to be switched off during summer period (from June to August).			
Key Performance Indicators					
ENERGY	Heating demand [kWh/m²]	72.49 ÷ 80.27	24.6 ÷ 33.2	8.7 ÷ 11.4	27.8 ÷ 30.96
	Cooling demand [kWh/m²]	0 ÷ 3.31	0 ÷ 0.24	0.16 ÷ 4.9	0.14 ÷ 4.13
	Ventilation consumption [kWh]	1224.61 ÷ 1224.61	2400 ÷ 2400	31900 ÷ 31900	31674.64 ÷ 31674.64
	Ceiling fan consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Estimate PV power production [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	PEF (H+C) saving respect to non-renovated	-87.2% ÷ -75.76%	-93.15% ÷ -88.04%	-95.33% ÷ -83.24%	-89.47% ÷ -77.84%

	Energy demand (H+C) saving respect to non-renovated	-71.44% ÷ -68.19%	-87.94% ÷ -83.88%	-91.71% ÷ -85.49%	-76.01% ÷ -72.08%
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more explanation on these KPIs)	CAT_1_PPM	100% ÷ 100%	93.28% ÷ 95.13%	86.87% ÷ 91.02%	88.93% ÷ 88.93%
	CAT_2_PPM	0% ÷ 0%	2.06% ÷ 2.58%	5.62% ÷ 6.87%	11.04% ÷ 11.04%
	CAT_I_Adpt (evaluated in cooling period)	47.73% ÷ 97.1%	19.52% ÷ 92.31%	23.32% ÷ 96.61%	1.02% ÷ 81.69%
	CAT_II_Adpt (evaluated in cooling period)	2.01% ÷ 20.65%	6.92% ÷ 37.4%	3.72% ÷ 35.88%	7.3% ÷ 24.52%
	pmv _CatI (evaluated in heating period)	1.99% ÷ 4.72%	2.4% ÷ 10.79%	7.74% ÷ 18.3%	8.13% ÷ 15.42%
	pmv _CatII (evaluated in heating period)	1.79% ÷ 7.82%	14.7% ÷ 24.43%	15.91% ÷ 20.95%	11.48% ÷ 19.39%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.42 ÷ 1.61	0.89 ÷ 1.67	4.84 ÷ 17.96	2.08 ÷ 8.54
ECONOMIC ISSUES	Investment cost [€]	64859 ÷ 243406	83420 ÷ 264713	826767 ÷ 1396960	399415 ÷ 619965
	Net Present Value (50 years) [€]	73485 ÷ 275778	94514 ÷ 299919	936727 ÷ 1582755	452537 ÷ 702420
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	47 ÷ 98	58 ÷ 122	596 ÷ 1240	288 ÷ 586

3

RENOVATION PACKAGE

GEOCLUSTER CONTINENTAL - CENTRAL

PREFABRICATED FACADE + DECENTRALIZED VENTILATION + BIPV




	Tot Area	**88 m2**	**228 m2**	**3456 m2**	**1330 m2**
REQUIREMENTS OF THE COMPONENTS	Opaque part – Prefabricated facade thickness [cm]	~20 ÷ ~35			
	Opaque part – Final U-value wall [W/m²K]	~0.2 ÷ ~0.1			
	Window – Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
	Window – Frame U-value [W/m²K]	1.4 ÷ 1			
	Window – g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
	Shading system – Presence	May be applicable			
	Shading system – Control strategy	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			
	Mechanical ventilation system – Type	Decentralized ventilation system providing punctual inlet and outlet of air. Decentralized machine also provides heat recovery. The mechanical ventilation system is considered to be switched off during summer period (from June to August).			
Key Performance Indicators					
ENERGY	Heating demand [kWh/m²]	72.49 ÷ 80.27	24.6 ÷ 33.2	8.7 ÷ 11.4	27.8 ÷ 30.96
	Cooling demand [kWh/m²]	0 ÷ 3.31	0 ÷ 0.24	0.16 ÷ 4.9	0.14 ÷ 4.13
	Ventilation consumption [kWh]	1224.61 ÷ 1224.61	2400 ÷ 2400	31900 ÷ 31900	31674.64 ÷ 31674.64
	Ceiling fan consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Estimate PV power production [kWh]	967.81 ÷ 967.81	12800 ÷ 12800	18200 ÷ 18200	4664.62 ÷ 4664.62
	PEF (H+C) saving respect to non-renovated	-87.2% ÷ -75.76%	-93.15% ÷ -88.04%	-95.33% ÷ -83.24%	-89.47% ÷ -77.84%

	Energy demand (H+C) saving respect to non-renovated	-71.44% ÷ -68.19%	-87.94% ÷ -83.88%	-91.71% ÷ -85.49%	-76.01% ÷ -72.08%
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more explanation on these KPIs)	CAT_1_PPM	100% ÷ 100%	93.28% ÷ 95.13%	86.87% ÷ 91.02%	88.93% ÷ 88.93%
	CAT_2_PPM	0% ÷ 0%	2.06% ÷ 2.58%	5.62% ÷ 6.87%	11.04% ÷ 11.04%
	CAT_I_Adpt (evaluated in cooling period)	47.73% ÷ 97.1%	19.52% ÷ 92.31%	23.32% ÷ 96.61%	1.02% ÷ 81.69%
	CAT_II_Adpt (evaluated in cooling period)	2.01% ÷ 20.65%	6.92% ÷ 37.4%	3.72% ÷ 35.88%	7.3% ÷ 24.52%
	pmv _CatI (evaluated in heating period)	1.99% ÷ 4.72%	2.4% ÷ 10.79%	7.74% ÷ 18.3%	8.13% ÷ 15.42%
	pmv _CatII (evaluated in heating period)	1.79% ÷ 7.82%	14.7% ÷ 24.43%	15.91% ÷ 20.95%	11.48% ÷ 19.39%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.42 ÷ 1.61	0.89 ÷ 1.67	4.84 ÷ 17.96	2.08 ÷ 8.54
ECONOMIC ISSUES	Investment cost [€]	67302 ÷ 245850	86406 ÷ 267699	857171 ÷ 1427363	414466 ÷ 635016
	Net Present Value (50 years) [€]	76253 ÷ 278548	97897 ÷ 303302	971174 ÷ 1617202	469589 ÷ 719473
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	50 ÷ 100	62 ÷ 125	630 ÷ 1275	305 ÷ 603

4

RENOVATION PACKAGE

GEOCLUSTER CONTINENTAL - CENTRAL

PREFABRICATED FACADE + CENTRALIZED VENTILATION + BIPV




	Tot Area	**88 m2**	**228 m2**	**3456 m2**	**1330 m2**
REQUIREMENTS OF THE COMPONENTS	Opaque part	Prefabricated facade thickness [cm]	~20 ÷ ~35			
		Final U-value wall [W/m²K]	~0.2 ÷ ~0.1			
	Window	Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
		Frame U-value [W/m²K]	1.4 ÷ 1			
		g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
	Shading system	Presence	May be applicable			
		Control strategy	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			
	Mechanical ventilation system	Type	Balanced Air Handling Unit for centralized ventilation system. Centralized machine also provides heat recovery. The mechanical ventilation system is considered to be switched off during summer period (from June to August).			
Key Performance Indicators						
ENERGY		Heating demand [kWh/m²]	77.23 ÷ 85.27	18.5 ÷ 26.8	4.45 ÷ 7.13	31.07 ÷ 34.55
		Cooling demand [kWh/m²]	0 ÷ 2.78	0 ÷ 0.31	0.43 ÷ 7.15	0.1 ÷ 3.45
		Ventilation consumption [kWh]	605.42 ÷ 605.42	1410 ÷ 1410	15200 ÷ 15200	15659.44 ÷ 15659.44
		Ceiling fan consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
		Estimate PV power production [kWh]	967.81 ÷ 967.81	12800 ÷ 12800	18200 ÷ 18200	4664.62 ÷ 4664.62
		PEF (H+C) saving respect to non-renovated	-86.36% ÷ -74.54%	-94.85% ÷ -90.32%	-97.6% ÷ -81.62%	-88.24% ÷ -76.36%

	Energy demand (H+C) saving respect to non-renovated	-69.58% ÷ -66.3%	-90.86% ÷ -86.99%	-95.36% ÷ -87.47%	-73.36% ÷ -69.81%
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more explanation on these KPIs)	CAT_1_PPM	100% ÷ 100%	93.28% ÷ 95.13%	86.87% ÷ 91.02%	93.05% ÷ 93.05%
	CAT_2_PPM	0% ÷ 0%	2.09% ÷ 2.58%	5.66% ÷ 6.85%	6.92% ÷ 6.92%
	CAT_I_Adpt (evaluated in cooling period)	57.3% ÷ 95.96%	19.64% ÷ 92.31%	23.32% ÷ 95.92%	4.23% ÷ 88.86%
	CAT_II_Adpt (evaluated in cooling period)	3.14% ÷ 20.78%	6.92% ÷ 37.9%	4% ÷ 36.09%	9.9% ÷ 26.16%
	pmv _CatI (evaluated in heating period)	1.75% ÷ 4.07%	5.29% ÷ 18.65%	7.46% ÷ 21.65%	7.27% ÷ 15.85%
	pmv _CatII (evaluated in heating period)	1.75% ÷ 8.02%	23.58% ÷ 36.21%	16.53% ÷ 25.24%	11.06% ÷ 18.86%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.45 ÷ 1.69	0.66 ÷ 1.35	2.47 ÷ 19.35	2.32 ÷ 9.17
ECONOMIC ISSUES	Investment cost [€]	68787 ÷ 247335	88222 ÷ 269514	875653 ÷ 1445845	423616 ÷ 644165
	Net Present Value (50 years) [€]	77935 ÷ 280230	99955 ÷ 305359	992114 ÷ 1638142	479956 ÷ 729838
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	110 ÷ 161	135 ÷ 199	1382 ÷ 2027	678 ÷ 976

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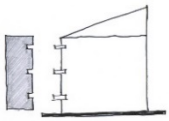
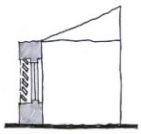
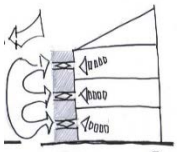
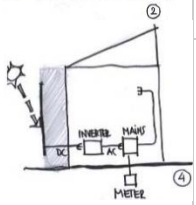
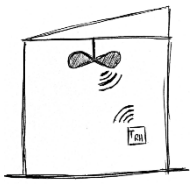
RENOVATION PACKAGE

GEOCLUSTER CONTINENTAL - CENTRAL

PREFABRICATED FACADE + DECENTRALIZED VENTILATION + BIPV + SMART CEILING FAN




		Tot Area	88 m2	228 m2	3456 m2	1330 m2
REQUIREMENTS OF THE COMPONENTS		Opaque part	Prefabricated facade thickness [cm]	~20 ÷ ~35		
			Final U-value wall [W/m²K]	~0.2 ÷ ~0.1		
		Window	Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
			Frame U-value [W/m²K]	1.4 ÷ 1		
			g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
		Shading system	Presence	May be applicable		
			Control strategy	If present, the shading system control is depending on external temperature, incident radiation and internal temperature		
		Mechanical ventilation system	Type	Decentralized ventilation system providing punctual inlet and outlet of air. Decentralized machine also provides heat recovery. The mechanical ventilation system is considered to be switched off during summer period (from June to August).		
		Smart ceiling fan	Control strategy	Temperature and relative humidity sensor communicate with the smart ceiling fan to automatically adjust its fan speed		
Key Performance Indicators						
ENERGY			Heating demand [kWh/m²]	72.48 ÷ 80.27	24.6 ÷ 33.2	8.7 ÷ 11.4	27.8 ÷ 30.96
			Cooling demand [kWh/m²]	0 ÷ 1.18	0 ÷ 0.04	0 ÷ 1.78	0 ÷ 1.68
			Ventilation consumption [kWh]	1224.61 ÷ 1224.61	2400 ÷ 2400	31900 ÷ 31900	31674.64 ÷ 31674.64
			Ceiling fan consumption [kWh]	0 ÷ 33.29	0 ÷ 7.04	80.1 ÷ 1460	3.59 ÷ 199.6
			Estimate PV power production [kWh]	967.81 ÷ 967.81	12800 ÷ 12800	18200 ÷ 18200	4664.62 ÷ 4664.62

	PEF (H+C) saving respect to non-renovated	-87.18% ÷ -76.37%	-93.11% ÷ -88.04%	-95.26% ÷ -88.98%	-89.37% ÷ -80.07%
	Energy demand (H+C) saving respect to non-renovated	-71.45% ÷ -68.43%	-88.03% ÷ -83.88%	-91.88% ÷ -88.19%	-76.33% ÷ -73.63%
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more explanation on these KPIs)	CAT_1_PPM	100% ÷ 100%	93.28% ÷ 94.82%	86.87% ÷ 90.65%	88.93% ÷ 88.93%
	CAT_2_PPM	0% ÷ 0%	2.12% ÷ 2.58%	5.7% ÷ 6.77%	11.04% ÷ 11.04%
	CAT_I_Adpt (evaluated in cooling period)	47.73% ÷ 97.1%	19.52% ÷ 92.31%	22.36% ÷ 95.92%	1.02% ÷ 81.69%
	CAT_II_Adpt (evaluated in cooling period)	2.01% ÷ 20.65%	6.92% ÷ 37.4%	4.07% ÷ 36.3%	7.3% ÷ 24.52%
	pmv _CatI (evaluated in heating period)	1.99% ÷ 4.72%	2.4% ÷ 10.75%	7.8% ÷ 16.87%	8.13% ÷ 15.42%
	pmv _CatII (evaluated in heating period)	1.79% ÷ 7.82%	14.7% ÷ 24.43%	16.66% ÷ 20.87%	11.48% ÷ 19.39%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.43 ÷ 1.58	0.89 ÷ 1.67	4.9 ÷ 12.01	2.1 ÷ 7.82
ECONOMIC ISSUES	Investment cost [€]	68867 ÷ 246970	90407 ÷ 270563	918618 ÷ 1471359	438185 ÷ 651998
	Net Present Value (50 years) [€]	78026 ÷ 279817	102431 ÷ 306547	1040794 ÷ 1667049	496463 ÷ 738713
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	50 ÷ 100	62 ÷ 125	630 ÷ 1275	305 ÷ 603

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RENOVATION PACKAGE

GEOCLUSTER CONTINENTAL - CENTRAL

PREFABRICATED FACADE + SMART CEILING FAN




	Tot Area	**88 m2**	**228 m2**	**3456 m2**	**1330 m2**
REQUIREMENTS OF THE COMPONENTS	Opaque part – Prefabricated facade thickness [cm]	~20 ÷ ~35			
	Opaque part – Final U-value wall [W/m²K]	~0.2 ÷ ~0.1			
	Window – Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
	Window – Frame U-value [W/m²K]	1.4 ÷ 1			
	Window – g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
	Shading system – Presence	May be applicable			
	Shading system – Control strategy	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			
	Smart ceiling fan – Control strategy	Temperature and relative humidity sensor communicate with the smart ceiling fan to automatically adjust its fan speed			
Key Performance Indicators					
ENERGY	Heating demand [kWh/m²]	68.33 ÷ 75.71	42.1 ÷ 50.7	32 ÷ 34.8	39.24 ÷ 43.13
	Cooling demand [kWh/m²]	0 ÷ 1.66	0 ÷ 0.04	0 ÷ 1	0 ÷ 0.9
	Ventilation consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Ceiling fan consumption [kWh]	0 ÷ 44.99	0 ÷ 6.5	41.9 ÷ 982	0 ÷ 100.4
	Estimate PV power production [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	PEF (H+C) saving respect to non-renovated	-87.91% ÷ -77.67%	-88.26% ÷ -81.72%	-82.43% ÷ -74.51%	-85.1% ÷ -72.66%

	Energy demand (H+C) saving respect to non-renovated	-73.08% ÷ -70.19%	-79.54% ÷ -75.38%	-70.23% ÷ -67.86%	-66.78% ÷ -63.5%
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more explanation on these KPIs)	CAT_1_PPM	100% ÷ 100%	79.43% ÷ 81.89%	16.05% ÷ 20.2%	99.98% ÷ 99.98%
	CAT_2_PPM	0% ÷ 0%	8.31% ÷ 9.14%	23.22% ÷ 25.11%	0% ÷ 0%
	CAT_I_Adpt (evaluated in cooling period)	47.6% ÷ 95.71%	19.52% ÷ 92.06%	22.56% ÷ 95.92%	28.82% ÷ 94.39%
	CAT_II_Adpt (evaluated in cooling period)	3.65% ÷ 19.77%	7.17% ÷ 37.27%	4.07% ÷ 35.26%	5.6% ÷ 21.51%
	pmv _CatI (evaluated in heating period)	1.26% ÷ 3.54%	0.48% ÷ 7.33%	2.23% ÷ 11.49%	8.22% ÷ 14.16%
	pmv _CatII (evaluated in heating period)	3.34% ÷ 7.82%	5.53% ÷ 16.25%	7.64% ÷ 15.73%	11.12% ÷ 14.58%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.4 ÷ 1.49	1.53 ÷ 2.55	18.22 ÷ 28.1	2.94 ÷ 10.8
ECONOMIC ISSUES	Investment cost [€]	60512 ÷ 238615	80196 ÷ 260352	814648 ÷ 1367388	386715 ÷ 600528
	Net Present Value (50 years) [€]	68560 ÷ 270350	90862 ÷ 294978	922996 ÷ 1549250	438148 ÷ 680398
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	44 ÷ 95	55 ÷ 118	562 ÷ 1206	272 ÷ 569

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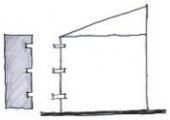
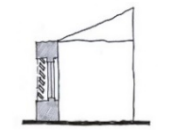
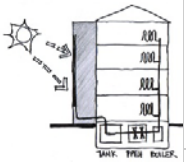
RENOVATION PACKAGE

GEOCLUSTER CONTINENTAL - CENTRAL

PREFABRICATED FACADE + PLUG&PLAY ENERGY HUB + SOLAR THERMAL




		Tot Area	88 m2	228 m2	3456 m2	1330 m2
REQUIREMENTS OF THE COMPONENTS		Opaque part	Prefabricated facade thickness [cm]	~20 ÷ ~35		
			Final U-value wall [W/m²K]	~0.2 ÷ ~0.1		
		Window	Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
			Frame U-value [W/m²K]	1.4 ÷ 1		
			g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
		Shading system	Presence	May be applicable		
			Control strategy	If present, the shading system control is depending on external temperature, incident radiation and internal temperature		
		Plug&Play Energy Hub	Presence	Used in order to improve efficiency of heating, cooling and DHW systems. Approximately, a decrease of 20% in consumptions of these systems is expected.		
Key Performance Indicators						
ENERGY			Heating demand [kWh/m²]	68 ÷ 76	42.1 ÷ 50.7	32 ÷ 34.8	39.24 ÷ 43.14
			Cooling demand [kWh/m²]	0 ÷ 4	~0	0.138 ÷ 3.44	0 ÷ 2.61
			Ventilation consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
			Ceiling fan consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
			Estimated ST production (roof placement) [MWh]	1.39	1.45	12.39	12.36
			Energy Consumption (H + C) savings due to EnergyHub	-20%	-20%	-20%	-20%

	DHW consumption savings due to Energy Hub	-20%	-20%	-20%	-20%
	Energy demand (H+C) saving respect to non-renovated	-73.1% ÷ -69.5%	-79.45% ÷ -75.38%	-69.7% ÷ -65.71%	-66.6% ÷ -62.9%
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more explanation on these KPIs)	CAT_1_PPM	100%	79.45% ÷ 82.22%	16.03% ÷ 20.39%	100%
	CAT_2_PPM	0%	8.28% ÷ 9.14%	23.22% ÷ 24.92%	0%
	CAT_I_Adpt (evaluated in cooling period)	47.6 95.7	19.54% ÷ 92.18%	23.80% ÷ 96.61%	28.8% ÷ 94.39%
	CAT_II_Adpt (evaluated in cooling period)	3.6% ÷ 19.77%	7.18% ÷ 37.32%	3.72% ÷ 35.05%	5.6% ÷ 21.51%
	pmv _CatI (evaluated in heating period)	1.2% ÷ 3.54%	0.48% ÷ 7.66%	2.23% ÷ 11.80%	8.2% ÷ 14.16%
	pmv _CatII (evaluated in heating period)	3.34% ÷ 7.82%	5.54% ÷ 16.25%	7.61% ÷ 16.01%	11.12% ÷ 14.58%
ENVIRONMENT	Yearly CO2 emissions due to Heating + Cooling [tCO2 year]	0.3232÷1.24	1.224÷2.04	14.32÷26.32	2.344÷8.824
ECONOMIC ISSUES	Investment cost [€] **(Not considering Energy Hub Technology)**	58947 ÷ 237495	76195 ÷ 257488	753200 ÷ 1323392	362997 ÷ 583546
	Net Present Value (50 years) [€] **(Not considering Energy Hub Technology)**	66786 ÷ 269081	86328 ÷ 291733	853375 ÷ 1499403	411275 ÷ 661157
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours] **(Not considering Energy Hub Technology)**	44 ÷ 95	55 ÷ 118	562 ÷ 1206	272 ÷ 569

1 GEOCLUSTER MEDITERRANEAN

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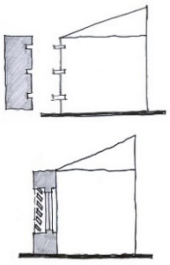
RENOVATION PACKAGE

GEOCLUSTER MEDITERRANEAN

PREFABRICATED FACADE




		88 m2	228 m2	3456 m2	1330 m2
Tot Area					
REQUIREMENTS OF THE ENVELOPE					
Opaque part	Prefabricated facade thickness [cm]	~15 ÷ ~25			
	Final U-value wall [W/m²K]	~0.75 ÷ ~0.29			
Window	Glazing U-value [W/m²K]	2.93 ÷ 1.8	1.1 ÷ 0.62	1.24 ÷ 0.61	2.93 ÷ 1.8
	Frame U-value [W/m²K]	1.4 ÷ 1			
	g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
Shading system	Presence	May be applicable			
	Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			

Key Performance Indicators					
ENERGY	Heating demand [kWh/m²]	35.9 ÷ 66.2	23.74 ÷ 39.53	9.51 ÷ 17.69	4.84 ÷ 13.17
	Cooling demand [kWh/m²]	5.85 ÷ 26.88	0 ÷ 0.04	0.05 ÷ 5.87	4.43 ÷ 18.64
	Ventilation consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Ceiling fan consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Estimate PV power production [kWh]	0 ÷0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	PEF (H+C) saving respect to non-renovated	-91.15% ÷ -58.05%	-89.38% ÷ -77.42%	-90.68% ÷ -66.92%	-94.34% ÷ -28.09%
	Energy demand (H+C) saving respect to non-renovated	-79.57% ÷ -56.94%	-82.24% ÷ -70.48%	-80.86% ÷ -70.58%	-80.08% ÷ -45.46%
COMFORT AND IAQ	CAT_1_PPM	100% ÷ 100%	61.11% ÷ 67.82%	24.94% ÷ 28.53%	99.98% ÷ 99.98%

(check Table 3 of Deliverable 3.3 for more explanation on these KPIs)	CAT_2_PPM	0% ÷0%	10.83% ÷ 11.79%	7.3% ÷ 8.12%	0% ÷ 0%
	CAT_I_Adpt (evaluated in cooling period)	1.63% ÷ 90.6%	58.94% ÷ 99.37%	23.18% ÷ 99.86%	0% ÷ 79.84%
	CAT_II_Adpt (evaluated in cooling period)	3.77% ÷ 20.90%	0.5% ÷ 32.24%	0.13% ÷ 43.89%	1.02% ÷ 35.17%
	pmv _CatI (evaluated in heating period)	2.52% ÷ 10.30%	2.4% ÷ 11.2%	4.73% ÷ 17.26%	10.9% ÷ 32.83%
	pmv _CatII (evaluated in heating period)	7.90% ÷ 13.44%	5.37% ÷ 17.55%	8.6% ÷ 28.88%	18.86% ÷ 27.73%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.21÷1.90	0.78 ÷ 1.98	4.82 ÷ 18.3	0.36 ÷ 8.25
ECONOMIC ISSUES	Investment cost [€]	49186 ÷ 201603	63684 ÷ 218209	628977 ÷ 1105231	302883 ÷ 485569
	Net Present Value (50 years) [€]	55727 ÷ 228416	72153 ÷ 247230	712630 ÷ 1252226	343166 ÷ 550149
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	44 ÷ 95	55 ÷ 118	562 ÷ 1206	272 ÷ 569

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RENOVATION PACKAGE

GEOCLUSTER MEDITERRANEAN

PREFABRICATED FACADE + DECENTRALIZED VENTILATION




	Tot Area	**88 m2**	**228 m2**	**3456 m2**	**1330 m2**
REQUIREMENTS OF THE COMPONENTS					
Opaque part	Prefabricated facade thickness [cm]	~15 ÷ ~25			
	Final U-value wall [W/m²K]	~0.75 ÷ ~0.29			
Window	Glazing U-value [W/m²K]	2.93 ÷ 1.8	1.1 ÷ 0.62	1.24 ÷ 0.61	2.93 ÷ 1.8
	Frame U-value [W/m²K]	1.4 ÷ 1			
	g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
Shading	Presence	May be applicable			
	Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			
Mechanical	Type	Decentralized ventilation system providing punctual inlet and outlet of air. Decentralized machine also provides heat recovery. The mechanical ventilation system is considered to be switched off during summer period (from June to August).			

Key Performance Indicators

ENERGY	Heating demand [kWh/m²]	35.07 ÷ 65.25	11.3 ÷ 26.91	0.07 ÷ 2.79	1.83 ÷ 8.62
	Cooling demand [kWh/m²]	6.39 ÷ 28.91	0 ÷ 0.08	0.32 ÷ 12.93	6.07 ÷ 25.91
	Ventilation consumption [kWh]	552.27 ÷ 552.27	1111.04 ÷ 1111.04	14767.58 ÷ 14767.58	14284.64 ÷ 14284.64
	Ceiling fan consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Estimate PV power production [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	PEF (H+C) saving respect to non-renovated	-91.38% ÷ -57.67%	-94.94% ÷ -84.63%	-99.93% ÷ -53.44%	-97.85% ÷ -17.77%
	Energy demand (H+C) saving respect to non-renovated	-79.69% ÷ -56.82%	-91.49% ÷ -79.9%	-97.98% ÷ -78.45%	-80.07% ÷ -46.28%
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more	CAT_1_PPM	60.46% ÷ 60.46%	88.94% ÷ 93.81%	22.49% ÷ 25.4%	7.56% ÷ 7.56%
	CAT_2_PPM	35.56% ÷ 35.56%	5.08% ÷ 5.84%	38.45% ÷ 39.62%	6.66% ÷ 6.66%

explanation on these KPIs)	CAT_I_Adpt (evaluated in cooling period)	0% ÷ 65.74%	58.94% ÷ 99.37%	23.05% ÷ 99.86%	0% ÷ 29.5%
	CAT_II_Adpt (evaluated in cooling period)	0% ÷ 24.81%	0.5% ÷ 33.37%	0.13% ÷ 43.47%	0% ÷ 21.44%
	pmv _CatI (evaluated in heating period)	3.21% ÷ 11.28%	1.71% ÷ 17.18%	11.51% ÷ 27.63%	11.7% ÷ 35.8%
	pmv _CatII (evaluated in heating period)	9.2% ÷ 15.15%	11.32% ÷ 31.36%	20.04% ÷ 43.31%	17.64% ÷ 35.97%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.2 ÷ 1.91	0.37 ÷ 1.35	0.03 ÷ 24.09	0.13 ÷ 8.91
ECONOMIC ISSUES	Investment cost [€]	54270 ÷ 206687	69897 ÷ 224423	692244 ÷ 1168499	334203 ÷ 516889
	Net Present Value (50 years) [€]	61487 ÷ 234176	79193 ÷ 254271	784312 ÷ 1323909	378651 ÷ 585635
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	47 ÷ 98	58 ÷ 122	596 ÷ 1240	288 ÷ 586

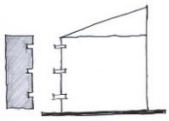
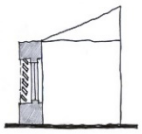
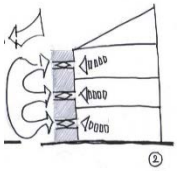
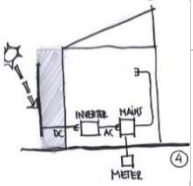
3

RENOVATION PACKAGE

GEOCLUSTER MEDITERRANEAN

PREFABRICATED FACADE + DECENTRALIZED VENTILATION + BIPV




		Tot Area	88 m2	228 m2	3456 m2	1330 m2
REQUIREMENTS OF THE COMPONENTS		Opaque part	Prefabricated facade thickness [cm]	~15 ÷ ~25		
			Final U-value wall [W/m²K]	~0.75 ÷ ~0.29		
		Window	Glazing U-value [W/m²K]	2.93 ÷ 1.8	1.1 ÷ 0.62	1.24 ÷ 0.61	2.93 ÷ 1.8
			Frame U-value [W/m²K]	1.4 ÷ 1		
			g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
		Shading	Presence	May be applicable		
			Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature		
		Mechanical	Type	Decentralized ventilation system providing punctual inlet and outlet of air. Decentralized machine also provides heat recovery. The mechanical ventilation system is considered to be switched off during summer period (from June to August).		

Key Performance Indicators

ENERGY	Heating demand [kWh/m²]	35.07 ÷ 65.25	11.3 ÷ 26.91	0.07 ÷ 2.79	1.83 ÷ 8.62
	Cooling demand [kWh/m²]	6.39 ÷ 28.91	0 ÷ 0.08	0.32 ÷ 12.93	6.07 ÷ 25.91
	Ventilation consumption [kWh]	552.27 ÷ 552.27	1111.04 ÷ 1111.04	14767.58 ÷ 14767.58	14284.64 ÷ 14284.64
	Ceiling fan consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Estimate PV power production [kWh]	1487.19 ÷ 1487.19	20091.13 ÷ 20091.13	35732.18 ÷ 35732.18	9220.13 ÷ 9220.13
	PEF (H+C) saving respect to non-renovated	-91.38% ÷ -57.67%	-94.94% ÷ -84.63%	-99.93% ÷ -53.44%	-97.85% ÷ -17.77%
	Energy demand (H+C) saving respect to non-renovated	-79.69% ÷ -56.82%	-91.49% ÷ -79.9%	-97.98% ÷ -78.45%	-80.07% ÷ -46.28%
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more	CAT_1_PPM	60.46% ÷ 60.46%	88.94% ÷ 93.81%	22.49% ÷ 25.4%	7.56% ÷ 7.56%
	CAT_2_PPM	35.56% ÷ 35.56%	5.08% ÷ 5.84%	38.45% ÷ 39.62%	6.66% ÷ 6.66%

explanation on these KPIs)	CAT_I_Adpt (evaluated in cooling period)	0% ÷ 65.74%	58.94% ÷ 99.37%	23.05% ÷ 99.86%	0% ÷ 29.5%
	CAT_II_Adpt (evaluated in cooling period)	0% ÷ 24.81%	0.5% ÷ 33.37%	0.13% ÷ 43.47%	0% ÷ 21.44%
	pmv _CatI (evaluated in heating period)	3.21% ÷ 11.28%	1.71% ÷ 17.18%	11.51% ÷ 27.63%	11.7% ÷ 35.8%
	pmv _CatII (evaluated in heating period)	9.2% ÷ 15.15%	11.32% ÷ 31.36%	20.04% ÷ 43.31%	17.64% ÷ 35.97%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.2 ÷ 1.91	0.37 ÷ 1.35	0.03 ÷ 24.09	0.13 ÷ 8.91
ECONOMIC ISSUES	Investment cost [€]	56371 ÷ 208788	72465 ÷ 226991	718392 ÷ 1194646	347146 ÷ 529833
	Net Present Value (50 years) [€]	63868 ÷ 236556	82102 ÷ 257180	813938 ÷ 1353533	393316 ÷ 600300
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	50 ÷ 100	62 ÷ 125	630 ÷ 1275	305 ÷ 603

4

RENOVATION PACKAGE

GEOCLUSTER MEDITERRANEAN

PREFABRICATED FACADE + CENTRALIZED VENTILATION + BIPV




	Tot Area	**88 m2**	**228 m2**	**3456 m2**	**1330 m2**
REQUIREMENTS OF THE COMPONENTS	Opaque part – Prefabricated facade thickness [cm]	~15 ÷ ~25			
	Opaque part – Final U-value wall [W/m²K]	~0.75 ÷ ~0.29			
	Window – Glazing U-value [W/m²K]	2.93 ÷ 1.8	1.1 ÷ 0.62	1.24 ÷ 0.61	2.93 ÷ 1.8
	Window – Frame U-value [W/m²K]	1.4 ÷ 1			
	Window – g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
	Shading – Presence	May be applicable			
	Shading – Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			
	Mechanical – Type	Balanced Air Handling Unit for centralized ventilation system. Centralized machine also provides heat recovery. The mechanical ventilation system is considered to be switched off during summer period (from June to August).			

Key Performance Indicators

ENERGY	Heating demand [kWh/m²]	36.54 ÷ 66.85	9.74 ÷ 25.15	0.01 ÷ 1.82	2.31 ÷ 9.47
	Cooling demand [kWh/m²]	6.29 ÷ 28.35	0 ÷ 0.12	0.51 ÷ 15.11	5.92 ÷ 24.86
	Ventilation consumption [kWh]	285.57 ÷ 285.57	654.54 ÷ 654.54	7025.35 ÷ 7025.35	7386.53 ÷ 7386.53
	Ceiling fan consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Estimate PV power production [kWh]	1487.19 ÷ 1487.19	20091.13 ÷ 20091.13	35732.18 ÷ 35732.18	9220.13 ÷ 9220.13
	PEF (H+C) saving respect to non-renovated	-91.02% ÷ -57.22%	-95.64% ÷ -85.63%	-99.98% ÷ -45.67%	-97.3% ÷ -20.03%
	Energy demand (H+C) saving respect to non-renovated	-79.05% ÷ -56.21%	-92.63% ÷ -81.21%	-97.49% ÷ -74.93%	-79.88% ÷ -45.63%
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more	CAT_1_PPM	67.61% ÷ 67.61%	88.94% ÷ 93.81%	22.58% ÷ 25.4%	9.8% ÷ 9.8%
	CAT_2_PPM	32.38% ÷ 32.38%	5.04% ÷ 5.84%	38.45% ÷ 39.62%	8.82% ÷ 8.82%

explanation on these KPIs)	CAT_I_Adpt (evaluated in cooling period)	0% ÷ 67.12%	58.94% ÷ 99.37%	22.91% ÷ 99.86%	0% ÷ 32.1%
	CAT_II_Adpt (evaluated in cooling period)	0% ÷ 22.79%	0.5% ÷ 34.38%	0.13% ÷ 43.34%	0% ÷ 21.85%
	pmv _CatI (evaluated in heating period)	2.76% ÷ 10.34%	1.5% ÷ 16.13%	13.62% ÷ 32.86%	11.28% ÷ 35.86%
	pmv _CatII (evaluated in heating period)	8.92% ÷ 14.37%	14.05% ÷ 37.43%	19.42% ÷ 48.82%	19.46% ÷ 35.53%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.21 ÷ 1.94	0.32 ÷ 1.26	0 ÷ 28.1	0.17 ÷ 8.68
ECONOMIC ISSUES	Investment cost [€]	57648 ÷ 210065	74027 ÷ 228552	734286 ÷ 1210541	355015 ÷ 537702
	Net Present Value (50 years) [€]	65315 ÷ 238003	83872 ÷ 258949	831946 ÷ 1371542	402231 ÷ 609216
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	110 ÷ 161	135 ÷ 199	1382 ÷ 2027	678 ÷ 976

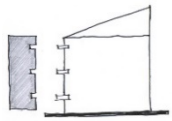
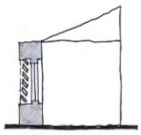
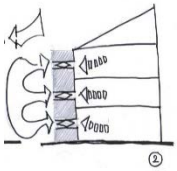
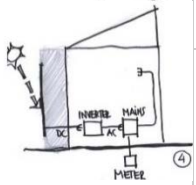
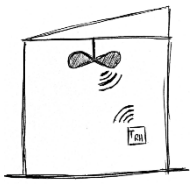
5

RENOVATION PACKAGE

GEOCLUSTER MEDITERRANEAN

PREFABRICATED FACADE + DECENTRALIZED VENTILATION + BIPV + SMART CEILING FAN




		Tot Area	88 m2	228 m2	3456 m2	1330 m2
REQUIREMENTS OF THE COMPONENTS		Opaque part	Prefabricated facade thickness [cm]	~15 ÷ ~25		
			Final U-value wall [W/m^{2}K]	~0.75 ÷ ~0.29		
		Window	Glazing U-value [W/m^{2}K]	2.93 ÷ 1.8	1.1 ÷ 0.62	1.24 ÷ 0.61	2.93 ÷ 1.8
			Frame U-value [W/m^{2}K]	1.4 ÷ 1		
			g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
		Shading	Presence	May be applicable		
			Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature		
		Mechanical	Type	Decentralized ventilation system providing punctual inlet and outlet of air. Decentralized machine also provides heat recovery. The mechanical ventilation system is considered to be switched off during summer period (from June to August).		
		Smart ceiling fan	Control strategy	Temperature and relative humidity sensor communicate with the smart ceiling fan to automatically adjust its fan speed		

Key Performance Indicators

ENERGY	Heating demand [kWh/m^2]	35.07 ÷ 65.25	11.3 ÷ 26.91	0.06 ÷ 2.79	1.82 ÷ 8.61
	Cooling demand [kWh/m^2]	2.65 ÷ 21.42	0 ÷ 0	0 ÷ 6.99	2.82 ÷ 19.27
	Ventilation consumption [kWh]	552.27 ÷ 552.27	1111.04 ÷ 1111.04	14767.58 ÷ 14767.58	14284.64 ÷ 14284.64
	Ceiling fan consumption [kWh]	65.87 ÷ 176.4	0 ÷ 4.56	287.81 ÷ 3044.57	215.6 ÷ 616.79
	Estimate PV power production [kWh]	1487.19 ÷ 1487.19	20091.13 ÷ 20091.13	35732.18 ÷ 35732.18	9220.13 ÷ 9220.13
	PEF (H+C) saving respect to non-renovated	-89.28% ÷ -62.83%	-94.94% ÷ -84.63%	-99.18% ÷ -74.21%	-84.89% ÷ -37.97%

	Energy demand (H+C) saving respect to non-renovated	-81.51% ÷ -60.71%	-91.56% ÷ -79.9%	-99.35% ÷ -88.29%	-87.44% ÷ -58.35%
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more explanation on these KPIs)	CAT_1_PPM	60.46% ÷ 60.46%	88.94% ÷ 93.81%	22.51% ÷ 25.36%	7.56% ÷ 7.56%
	CAT_2_PPM	35.56% ÷ 35.56%	5.08% ÷ 5.84%	38.45% ÷ 39.54%	6.66% ÷ 6.66%
	CAT_I_Adpt (evaluated in cooling period)	0% ÷ 65.74%	58.94% ÷ 99.37%	21.87% ÷ 99.79%	0% ÷ 29.5%
	CAT_II_Adpt (evaluated in cooling period)	0% ÷ 24.81%	0.5% ÷ 33.37%	0.2% ÷ 40.51%	0% ÷ 21.44%
	pmv _CatI (evaluated in heating period)	3.21% ÷ 11.28%	1.71% ÷ 17.18%	12.01% ÷ 22.51%	11.7% ÷ 35.8%
	pmv _CatII (evaluated in heating period)	9.2% ÷ 15.15%	11.32% ÷ 31.2%	19.76% ÷ 44.3%	17.64% ÷ 35.97%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.29 ÷ 1.71	0.37 ÷ 1.35	0.42 ÷ 13.35	1.38 ÷ 6.73
ECONOMIC ISSUES	Investment cost [€]	57716 ÷ 209751	75906 ÷ 229454	771236 ÷ 1232482	367544 ÷ 544438
	Net Present Value (50 years) [€]	65392 ÷ 237647	86001 ÷ 259971	873810 ÷ 1396402	416427 ÷ 616848
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	50 ÷ 100	62 ÷ 125	630 ÷ 1275	305 ÷ 603

6

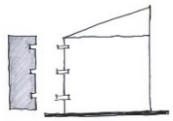
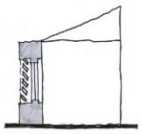
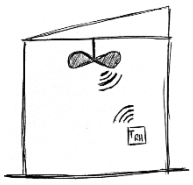
RENOVATION PACKAGE

GEOCLUSTER MEDITERRANEAN

PREFABRICATED FACADE + SMART CEILING FAN




	Tot Area	88 m2	228 m2	3456 m2	1330 m2
REQUIREMENTS OF THE COMPONENTS	Opaque part	Prefabricated facade thickness [cm]	~15 ÷ ~25			
		Final U-value wall [W/m²K]	~0.75 ÷ ~0.29			
	Window	Glazing U-value [W/m²K]	2.93 ÷ 1.8	1.1 ÷ 0.62	1.24 ÷ 0.61	2.93 ÷ 1.8
		Frame U-value [W/m²K]	1.4 ÷ 1			
		g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
	Shading	Presence	May be applicable			
		Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			
	Smart ceiling fan	Control strategy	Temperature and relative humidity sensor communicate with the smart ceiling fan to automatically adjust its fan speed			

Key Performance Indicators

ENERGY	Heating demand [kWh/m²]	35.99 ÷ 66.2	23.74 ÷ 39.53	9.47 ÷ 17.69	4.84 ÷ 13.17
	Cooling demand [kWh/m²]	2 ÷ 19.28	0 ÷ 0	0 ÷ 1.71	1.19 ÷ 12.02
	Ventilation consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Ceiling fan consumption [kWh]	64.07 ÷ 172.26	0 ÷ 2.38	38.11 ÷ 1718.98	166.8 ÷ 477.59
	Estimate PV power production [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	PEF (H+C) saving respect to non-renovated	-89.61% ÷ -63.17%	-89.38% ÷ -77.42%	-88.96% ÷ -77.84%	-88.97% ÷ -47.8%
	Energy demand (H+C) saving respect to non-renovated	-81.49% ÷ -60.8%	-82.27% ÷ -70.48%	-81.46% ÷ -70.66%	-87.17% ÷ -57.94%
COMFORT AND IAQ	CAT_1_PPM	100% ÷ 100%	61.11% ÷ 67.82%	24.94% ÷ 28.46%	99.98% ÷ 99.98%

(check Table 3 of Deliverable 3.3 for more explanation on these KPIs)	CAT_2_PPM	0% ÷ 0%	10.83% ÷ 11.79%	7.32% ÷ 8.12%	0% ÷ 0%
	CAT_I_Adpt (evaluated in cooling period)	1.63% ÷ 90.68%	58.94% ÷ 99.37%	22.29% ÷ 99.79%	0% ÷ 79.84%
	CAT_II_Adpt (evaluated in cooling period)	3.77% ÷ 20.9%	0.5% ÷ 32.24%	0.2% ÷ 40.92%	1.02% ÷ 35.17%
	pmv _CatI (evaluated in heating period)	2.52% ÷ 10.3%	2.4% ÷ 11.2%	4.68% ÷ 15.39%	10.9% ÷ 32.83%
	pmv _CatII (evaluated in heating period)	7.9% ÷ 13.44%	5.37% ÷ 17.51%	8.65% ÷ 26.36%	18.86% ÷ 27.73%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.27 ÷ 1.7	0.78 ÷ 1.98	5.7 ÷ 13.68	0.93 ÷ 6.13
ECONOMIC ISSUES	Investment cost [€]	50531 ÷ 202566	67124 ÷ 220673	681822 ÷ 1143068	323280 ÷ 500174
	Net Present Value (50 years) [€]	57251 ÷ 229507	76051 ÷ 250022	772504 ÷ 1295096	366276 ÷ 566697
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	44 ÷ 95	55 ÷ 118	562 ÷ 1206	272 ÷ 569

7

RENOVATION PACKAGE

GEOCLUSTER MEDITERRANEAN

PREFABRICATED FACADE + PLUG&PLAY ENERGY HUB (+ SOLAR THERMAL)




	Tot Area	**88 m2**	**228 m2**	**3456 m2**	**1330 m2**
REQUIREMENTS OF THE COMPONENTS	Opaque part	Prefabricated facade thickness [cm]	~15 ÷ ~25			
		Final U-value wall [W/m²K]	~0.75 ÷ ~0.29			
	Window	Glazing U-value [W/m²K]	2.93 ÷ 1.8	1.1 ÷ 0.62	1.24 ÷ 0.61	2.93 ÷ 1.8
		Frame U-value [W/m²K]	1.4 ÷ 1			
		g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
	Shading system	Presence	May be applicable			
		Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			
	Plug&Play Energy Hub	Presence	Used in order to improve efficiency of heating, cooling and DHW systems. Approximately, a decrease of 20% in consumptions of these systems is expected.			

Key Performance Indicators					
ENERGY	Heating demand [kWh/m²]	35.9 ÷ 66.2	23.74 ÷ 39.53	9.51 ÷ 17.69	4.84 ÷ 13.17
	Cooling demand [kWh/m²]	5.85 ÷ 26.88	0 ÷ 0.04	0.05 ÷ 5.87	4.43 ÷ 18.64
	Ventilation consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Ceiling fan consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Estimated ST production (roof placement) [MWh]	1.62	1.37	32.87	12.40
	Energy Consumption (H + C) savings due to EnergyHub	-20%	-20%	-20%	-20%
	DHW consumption savings due to Energy Hub	-20%	-20%	-20%	-20%
	Energy demand (H+C) saving respect to non-renovated	-79.57% ÷ -56.94%	-82.24% ÷ -70.48%	-80.86% ÷ -70.58%	-80.08% ÷ -45.46%

COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more explanation on these KPIs)	CAT_1_PPM	100% ÷ 100%	61.11% ÷ 67.82%	24.94% ÷ 28.53%	99.98% ÷ 99.98%
	CAT_2_PPM	0% ÷0%	10.83% ÷ 11.79%	7.3% ÷ 8.12%	0% ÷ 0%
	CAT_I_Adpt (evaluated in cooling period)	1.63% ÷ 90.6%	58.94% ÷ 99.37%	23.18% ÷ 99.86%	0% ÷ 79.84%
	CAT_II_Adpt (evaluated in cooling period)	3.77% ÷ 20.90%	0.5% ÷ 32.24%	0.13% ÷ 43.89%	1.02% ÷ 35.17%
	pmv _CatI (evaluated in heating period)	2.52% ÷ 10.30%	2.4% ÷ 11.2%	4.73% ÷ 17.26%	10.9% ÷ 32.83%
	pmv _CatII (evaluated in heating period)	7.90% ÷ 13.44%	5.37% ÷ 17.55%	8.6% ÷ 28.88%	18.86% ÷ 27.73%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.168÷1.52	0.624÷1.584	3.856÷14.64	0.288÷6.6
ECONOMIC ISSUES	Investment cost [€] **(Not considering Energy Hub Technology)**	49186 ÷ 201603	63684 ÷ 218209	628977 ÷ 1105231	302883 ÷ 485569
	Net Present Value (50 years) [€] **(Not considering Energy Hub Technology)**	55727 ÷ 228416	72153 ÷ 247230	712630 ÷ 1252226	343166 ÷ 550149
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours] **(Not considering Energy Hub Technology)**	44 ÷ 95	55 ÷ 118	562 ÷ 1206	272 ÷ 569

2 GEOCLUSTER NORTHERN

1

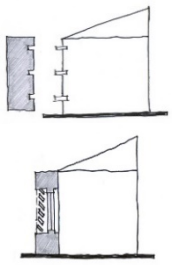
RENOVATION PACKAGE

GEOCLUSTER NORTHERN

PREFABRICATED FACADE




		88 m2	228 m2	3456 m2	1330 m2
Tot Area					
REQUIREMENTS OF THE	Opaque part	Prefabricated facade thickness [cm]	~20 ÷ ~35		
		Final U-value wall [W/m²K]	~0.2 ÷ ~0.1		
	Window	Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
		Frame U-value [W/m²K]	1.4 ÷ 1		
		g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
	Shading	Presence	May be applicable		
		Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature		



Key Performance Indicators					
ENERGY	Heating demand [kWh/m²]	103.21 ÷ 114.97	63.54 ÷ 72.26	55.15 ÷ 61.38	58.11 ÷ 63.33
	Cooling demand [kWh/m²]	0.07 ÷ 7.39	0 ÷ 0.17	0.36 ÷ 4.56	0.3 ÷ 5.55
	Ventilation consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Ceiling fan consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Estimate PV power production [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	PEF (H+C) saving respect to non-renovated	-70.72% ÷ -41.99%	-89.38% ÷ -77.42%	-79.31% ÷ -56.06%	-72.31% ÷ -44.76%
	Energy demand (H+C) saving respect to non-renovated	-36.48% ÷ -25.37%	-82.24% ÷ -70.48%	-53.6% ÷ -46.01%	-39.49% ÷ -29.13%
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more	CAT_1_PPM	100% ÷ 100%	69.39% ÷ 72.84%	13.69% ÷ 17.39%	99.98% ÷ 99.98%
	CAT_2_PPM	0% ÷ 0%	10.34% ÷ 10.86%	11.76% ÷ 12.1%	0% ÷ 0%

explanation on these KPIs)	CAT_I_Adpt (evaluated in cooling period)	41.93% ÷ 91.81%	15.49% ÷ 89.67%	4.14% ÷ 87.16%	0% ÷ 37.77%
	CAT_II_Adpt (evaluated in cooling period)	7.8% ÷ 15.86%	10.2% ÷ 32.36%	11.38% ÷ 34.5%	2.25% ÷ 25.47%
	pmv _CatI (evaluated in heating period)	1.62% ÷ 3.46%	0% ÷ 4.27%	4% ÷ 8.32%	3.74% ÷ 8.4%
	pmv _CatII (evaluated in heating period)	3.17% ÷ 5.01%	2.24% ÷ 6.19%	7.87% ÷ 10.66%	8.73% ÷ 11.15%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.61 ÷ 2.43	2.53 ÷ 3.63	33.8 ÷ 56.93	4.35 ÷ 17.49
ECONOMIC ISSUES	Investment cost [€]	115551 ÷ 465548	149361 ÷ 504739	1476456 ÷ 2594173	711563 ÷ 1143893
	Net Present Value (50 years) [€]	130919 ÷ 527465	169226 ÷ 571869	1672824 ÷ 2939198	806200 ÷ 1296030
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	44 ÷ 95	55 ÷ 118	562 ÷ 1206	272 ÷ 569

2

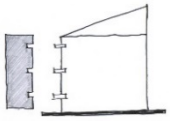
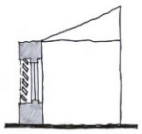
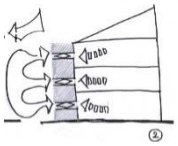
RENOVATION PACKAGE

GEOCLUSTER NORTHERN

PREFABRICATED FACADE + DECENTRALIZED VENTILATION




		Tot Area	88 m2	228 m2	3456 m2	1330 m2
REQUIREMENTS OF THE COMPONENTS	Opaque part	Prefabricated facade thickness [cm]	~20 ÷ ~35			
		Final U-value wall [W/m²K]	~0.2 ÷ ~0.1			
	Window	Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
		Frame U-value [W/m²K]	1.4 ÷ 1			
		g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
	Shading	Presence	May be applicable			
		Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			
	Mechanical	Type	Decentralized ventilation system providing punctual inlet and outlet of air. Decentralized machine also provides heat recovery. The mechanical ventilation system is considered to be switched off during summer period (from June to August).			

Key Performance Indicators

ENERGY	Heating demand [kWh/m²]	90.07 ÷ 101.91	25.11 ÷ 33.18	9.48 ÷ 16.24	29.85 ÷ 35.91
	Cooling demand [kWh/m²]	0.13 ÷ 8.8	0 ÷ 0.23	0.98 ÷ 8.21	1.83 ÷ 10.86
	Ventilation consumption [kWh]	384.19 ÷ 384.19	740.69 ÷ 740.69	9845.05 ÷ 9845.05	9937.14 ÷ 9937.14
	Ceiling fan consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Estimate PV power production [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	PEF (H+C) saving respect to non-renovated	-74.45% ÷ -47.49%	-93.61% ÷ -85.99%	-96.44% ÷ -79.27%	-85.77% ÷ -61.77%
	Energy demand (H+C) saving respect to non-renovated	-44.49% ÷ -32.66%	-85.64% ÷ -81.19%	-91.03% ÷ -80.28%	-66.84% ÷ -52.33%
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more	CAT_1_PPM	41.16% ÷ 41.16%	75.89% ÷ 78.91%	6.49% ÷ 9.89%	2.42% ÷ 2.42%
	CAT_2_PPM	14.25% ÷ 14.25%	9.42% ÷ 10.06%	7.13% ÷ 7.64%	2.3% ÷ 2.3%

explanation on these KPIs)	CAT_I_Adpt (evaluated in cooling period)	22.54% ÷ 85.64%	15.86% ÷ 90.3%	4.14% ÷ 77.91%	0% ÷ 0.47%
	CAT_II_Adpt (evaluated in cooling period)	5.66% ÷ 14.6%	9.57% ÷ 32.36%	11.04% ÷ 29.12%	0% ÷ 4.84%
	pmv _CatI (evaluated in heating period)	2.81% ÷ 6.55%	3.46% ÷ 8.87%	7.74% ÷ 13.96%	6.47% ÷ 11.12%
	pmv _CatII (evaluated in heating period)	3.42% ÷ 5.58%	11.16% ÷ 17.31%	8.32% ÷ 28.86%	9.79% ÷ 12.03%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.53 ÷ 2.21	1 ÷ 1.66	5.81 ÷ 29.94	2.23 ÷ 12.28
ECONOMIC ISSUES	Investment cost [€]	127140 ÷ 477136	163525 ÷ 518902	1620666 ÷ 2738382	782952 ÷ 1215282
	Net Present Value (50 years) [€]	144049 ÷ 540595	185273 ÷ 587915	1836214 ÷ 3102586	887084 ÷ 1376914
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	47 ÷ 98	58 ÷ 122	596 ÷ 1240	288 ÷ 586

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RENOVATION PACKAGE

GEOCLUSTER NORTHERN

PREFABRICATED FACADE + DECENTRALIZED VENTILATION + BIPV




	Tot Area	**88 m2**	**228 m2**	**3456 m2**	**1330 m2**
REQUIREMENTS OF THE COMPONENTS	Opaque part	Prefabricated facade thickness [cm]	~20 ÷ ~35			
		Final U-value wall [W/m²K]	~0.2 ÷ ~0.1			
	Window	Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
		Frame U-value [W/m²K]	1.4 ÷ 1			
		g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
	Shading	Presence	May be applicable			
		Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			
	Mechanical	Type	Decentralized ventilation system providing punctual inlet and outlet of air. Decentralized machine also provides heat recovery. The mechanical ventilation system is considered to be switched off during summer period (from June to August).			

Key Performance Indicators

ENERGY	Heating demand [kWh/m²]	90.07 ÷ 101.91	25.11 ÷ 33.18	9.48 ÷ 16.24	29.85 ÷ 35.91
	Cooling demand [kWh/m²]	0.13 ÷ 8.8	0 ÷ 0.23	0.98 ÷ 8.21	1.83 ÷ 10.86
	Ventilation consumption [kWh]	384.19 ÷ 384.19	740.69 ÷ 740.69	9845.05 ÷ 9845.05	9937.14 ÷ 9937.14
	Ceiling fan consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Estimate PV power production [kWh]	981.69 ÷ 981.69	13758.92 ÷ 13758.92	18361.34 ÷ 18361.34	4706.38 ÷ 4706.38
	PEF (H+C) saving respect to non-renovated	-74.45% ÷ -47.49%	-93.61% ÷ -85.99%	-96.44% ÷ -79.27%	-85.77% ÷ -61.77%
	Energy demand (H+C) saving respect to non-renovated	-44.49% ÷ -32.66%	-85.64% ÷ -81.19%	-91.03% ÷ -80.28%	-66.84% ÷ -52.33%
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more	CAT_1_PPM	41.16% ÷ 41.16%	75.89% ÷ 78.91%	6.49% ÷ 9.89%	2.42% ÷ 2.42%
	CAT_2_PPM	14.25% ÷ 14.25%	9.42% ÷ 10.06%	7.13% ÷ 7.64%	2.3% ÷ 2.3%

explanation on these KPIs)	CAT_I_Adpt (evaluated in cooling period)	22.54% ÷ 85.64%	15.86% ÷ 90.3%	4.14% ÷ 77.91%	0% ÷ 0.47%
	CAT_II_Adpt (evaluated in cooling period)	5.66% ÷ 14.6%	9.57% ÷ 32.36%	11.04% ÷ 29.12%	0% ÷ 4.84%
	pmv _CatI (evaluated in heating period)	2.81% ÷ 6.55%	3.46% ÷ 8.87%	7.74% ÷ 13.96%	6.47% ÷ 11.12%
	pmv _CatII (evaluated in heating period)	3.42% ÷ 5.58%	11.16% ÷ 17.31%	8.32% ÷ 28.86%	9.79% ÷ 12.03%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.53 ÷ 2.21	1 ÷ 1.66	5.81 ÷ 29.94	2.23 ÷ 12.28
ECONOMIC ISSUES	Investment cost [€]	131929 ÷ 481926	169378 ÷ 524756	1680264 ÷ 2797980	812456 ÷ 1244786
	Net Present Value (50 years) [€]	149475 ÷ 546022	191905 ÷ 594548	1903739 ÷ 3170111	920512 ÷ 1410342
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	50 ÷ 100	62 ÷ 125	630 ÷ 1275	305 ÷ 603

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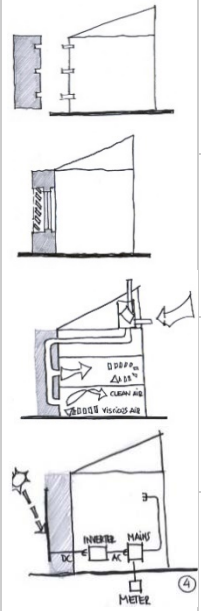
RENOVATION PACKAGE

GEOCLUSTER NORTHERN

PREFABRICATED FACADE + CENTRALIZED VENTILATION + BIPV




	Tot Area	**88 m2**	**228 m2**	**3456 m2**	**1330 m2**
REQUIREMENTS OF THE COMPONENTS	Opaque part: Prefabricated facade thickness [cm]	~20 ÷ ~35			
	Opaque part: Final U-value wall [W/m²K]	~0.2 ÷ ~0.1			
	Window: Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
	Window: Frame U-value [W/m²K]	1.4 ÷ 1			
	Window: g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
	Shading: Presence	May be applicable			
	Shading: Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			
	Mechanical ventilation: Type	Balanced Air Handling Unit for centralized ventilation system. Centralized machine also provides heat recovery. The mechanical ventilation system is considered to be switched off during summer period (from June to August).			



Key Performance Indicators

ENERGY	Heating demand [kWh/m²]	93.46 ÷ 105.25	22.36 ÷ 30.29	7.48 ÷ 14.18	32.19 ÷ 38.21
	Cooling demand [kWh/m²]	0.11 ÷ 8.29	0 ÷ 0.3	1.26 ÷ 9.13	1.51 ÷ 10.17
	Ventilation consumption [kWh]	205.61 ÷ 205.61	436.36 ÷ 436.36	4683.57 ÷ 4683.57	5318.3 ÷ 5318.3
	Ceiling fan consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Estimate PV power production [kWh]	981.69 ÷ 981.69	13758.92 ÷ 13758.92	18361.34 ÷ 18361.34	4706.38 ÷ 4706.38
	PEF (H+C) saving respect to non-renovated	-73.49% ÷ -46.16%	-94.31% ÷ -87.21%	-97.19% ÷ -79.38%	-84.66% ÷ -60.56%
	Energy demand (H+C) saving respect to non-renovated	-42.43% ÷ -30.89%	-87.17% ÷ -82.83%	-92.41% ÷ -81.28%	-64.81% ÷ -50.62%
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more explanation on these KPIs)	CAT_1_PPM	43.87% ÷ 43.87%	75.89% ÷ 78.91%	6.53% ÷ 9.89%	3.81% ÷ 3.81%
	CAT_2_PPM	22.13% ÷ 22.13%	9.42% ÷ 10.06%	7.15% ÷ 7.7%	3.17% ÷ 3.17%
	CAT_I_Adpt (evaluated in cooling period)	26.57% ÷ 86.64%	17.12% ÷ 90.3%	4.14% ÷ 76.53%	0% ÷ 2.59%

	CAT_II_Adpt (evaluated in cooling period)	7.68% ÷ 13.6%	9.57% ÷ 32.36%	11.04% ÷ 30.29%	0% ÷ 9.63%
	pmv _CatI (evaluated in heating period)	3.01% ÷ 5.98%	3.21% ÷ 9.69%	4.73% ÷ 18.22%	7.86% ÷ 11.59%
	pmv _CatII (evaluated in heating period)	3.38% ÷ 5.33%	15.8% ÷ 22.15%	7.77% ÷ 28.05%	8.97% ÷ 11.21%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.55 ÷ 2.26	0.89 ÷ 1.52	4.58 ÷ 30.46	2.41 ÷ 12.64
ECONOMIC ISSUES	Investment cost [€]	134840 ÷ 484837	172936 ÷ 528314	1716494 ÷ 2834210	830390 ÷ 1262721
	Net Present Value (50 years) [€]	152773 ÷ 549320	195936 ÷ 598579	1944787 ÷ 3211159	940831 ÷ 1430662
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	110 ÷ 161	135 ÷ 199	1382 ÷ 2027	678 ÷ 976

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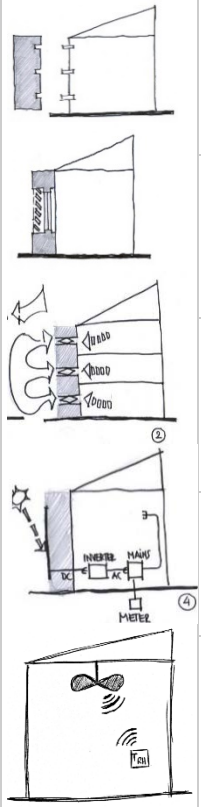
RENOVATION PACKAGE

GEOCLUSTER NORTHERN

PREFABRICATED FACADE + DECENTRALIZED VENTILATION + BIPV + SMART CEILING FAN




	Tot Area	**88 m2**	**228 m2**	**3456 m2**	**1330 m2**
REQUIREMENTS OF THE COMPONENTS					
Opaque part	Prefabricated facade thickness [cm]	~20 ÷ ~35			
	Final U-value wall [W/m^{2}K]	~0.2 ÷ ~0.1			
Window	Glazing U-value [W/m^{2}K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
	Frame U-value [W/m^{2}K]	1.4 ÷ 1			
	g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
Shading	Presence	May be applicable			
	Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			
Mechanical	Type	Decentralized ventilation system providing punctual inlet and outlet of air. Decentralized machine also provides heat recovery. The mechanical ventilation system is considered to be switched off during summer period (from June to August).			
Smart ceiling fan	Control strategy	Temperature and relative humidity sensor communicate with the smart ceiling fan to automatically adjust its fan speed			



Key Performance Indicators

ENERGY	Heating demand [kWh/m^2]	90.07 ÷ 101.91	25.11 ÷ 33.18	9.39 ÷ 16.22	29.84 ÷ 35.9
	Cooling demand [kWh/m^2]	0 ÷ 5.55	0 ÷ 0.01	0.2 ÷ 4.35	0.39 ÷ 7.49
	Ventilation consumption [kWh]	384.19 ÷ 384.19	740.69 ÷ 740.69	9845.05 ÷ 9845.05	9937.14 ÷ 9937.14
	Ceiling fan consumption [kWh]	1.07 ÷ 89.64	0 ÷ 11.83	504.51 ÷ 1989.74	137.2 ÷ 366.79
	Estimate PV power production [kWh]	981.69 ÷ 981.69	13758.92 ÷ 13758.92	18361.34 ÷ 18361.34	4706.38 ÷ 4706.38
	PEF (H+C) saving respect to non-renovated	-74.43% ÷ -49.21%	-93.6% ÷ -85.99%	-96.01% ÷ -84.37%	-85.24% ÷ -64.94%
	Energy demand (H+C) saving respect to non-renovated	-44.6% ÷ -34.53%	-85.76% ÷ -81.19%	-91.75% ÷ -83.42%	-68.55% ÷ -55.76%

COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more explanation on these KPIs)	CAT_1_PPM	41.16% ÷ 41.16%	75.89% ÷ 78.91%	6.64% ÷ 9.36%	2.42% ÷ 2.42%
	CAT_2_PPM	14.25% ÷ 14.25%	9.42% ÷ 10.06%	7.25% ÷ 7.66%	2.3% ÷ 2.3%
	CAT_I_Adpt (evaluated in cooling period)	22.54% ÷ 85.64%	15.86% ÷ 89.29%	9.1% ÷ 72.73%	0% ÷ 0.47%
	CAT_II_Adpt (evaluated in cooling period)	5.66% ÷ 14.6%	10.57% ÷ 32.36%	17.94% ÷ 30.15%	0% ÷ 4.84%
	pmv _CatI (evaluated in heating period)	2.81% ÷ 6.55%	3.46% ÷ 8.87%	9.36% ÷ 13.78%	6.47% ÷ 11.12%
	pmv _CatII (evaluated in heating period)	3.42% ÷ 5.58%	11.16% ÷ 17.18%	11.02% ÷ 29.14%	9.79% ÷ 12.03%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.53 ÷ 2.13	1 ÷ 1.66	6.51 ÷ 21.62	2.41 ÷ 11.19
ECONOMIC ISSUES	Investment cost [€]	134996 ÷ 484122	177220 ÷ 530370	1800716 ÷ 2884223	858949 ÷ 1278075
	Net Present Value (50 years) [€]	152950 ÷ 548510	200790 ÷ 600909	2040211 ÷ 3267824	973189 ÷ 1448058
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	50 ÷ 100	62 ÷ 125	630 ÷ 1275	305 ÷ 603

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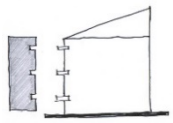
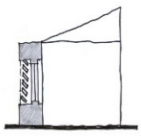
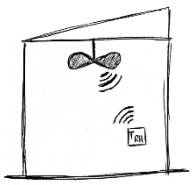
RENOVATION PACKAGE

GEOCLUSTER NORTHERN

PREFABRICATED FACADE + SMART CEILING FAN




	Tot Area	88 m2	228 m2	3456 m2	1330 m2
REQUIREMENTS OF THE COMPONENTS	Opaque part: Prefabricated facade thickness [cm]	~20 ÷ ~35			
	Opaque part: Final U-value wall [W/m²K]	~0.2 ÷ ~0.1			
	Window: Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
	Window: Frame U-value [W/m²K]	1.4 ÷ 1			
	Window: g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
	Shading: Presence	May be applicable			
	Shading: Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			
	Smart ceiling fan: Control strategy	Temperature and relative humidity sensor communicate with the smart ceiling fan to automatically adjust its fan speed			

Key Performance Indicators					
ENERGY	Heating demand [kWh/m²]	103.21 ÷ 114.97	63.54 ÷ 72.26	55.1 ÷ 61.35	58.11 ÷ 63.33
	Cooling demand [kWh/m²]	0 ÷ 4.39	0 ÷ 0.01	0.05 ÷ 1.74	0 ÷ 2.88
	Ventilation consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Ceiling fan consumption [kWh]	0 ÷ 70.02	0 ÷ 8.67	132.29 ÷ 1166.44	8.4 ÷ 205.2
	Estimate PV power production [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	PEF (H+C) saving respect to non-renovated	-70.71% ÷ -43.55%	-83.83% ÷ -69.49%	-79.07% ÷ -59.88%	-72.28% ÷ -47.18%
	Energy demand (H+C) saving respect to non-renovated	-36.53% ÷ -27.06%	-63.98% ÷ -59.05%	-53.89% ÷ -48.34%	-39.85% ÷ -31.77%
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more	CAT_1_PPM	100% ÷ 100%	69.39% ÷ 72.84%	13.82% ÷ 16.84%	99.98% ÷ 99.98%
	CAT_2_PPM	0% ÷ 0%	10.34% ÷ 10.86%	11.72% ÷ 12.06%	0% ÷ 0%

explanation on these KPIs)	CAT_I_Adpt (evaluated in cooling period)	41.93% ÷ 91.81%	15.49% ÷ 88.66%	9.1% ÷ 86.4%	0% ÷ 37.77%
	CAT_II_Adpt (evaluated in cooling period)	7.8% ÷ 15.86%	10.83% ÷ 32.36%	13.31% ÷ 31.33%	2.25% ÷ 25.47%
	pmv _CatI (evaluated in heating period)	1.62% ÷ 3.46%	0% ÷ 4.27%	4.1% ÷ 8.21%	3.74% ÷ 8.4%
	pmv _CatII (evaluated in heating period)	3.17% ÷ 5.01%	2.24% ÷ 6.19%	8.99% ÷ 10.63%	8.73% ÷ 11.15%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.61 ÷ 2.36	2.53 ÷ 3.63	34.21 ÷ 50.7	4.35 ÷ 16.66
ECONOMIC ISSUES	Investment cost [€]	118618 ÷ 467744	157203 ÷ 510354	1596909 ÷ 2680415	758057 ÷ 1177182
	Net Present Value (50 years) [€]	134394 ÷ 529953	178110 ÷ 578231	1809297 ÷ 3036910	858878 ÷ 1333747
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	44 ÷ 95	55 ÷ 118	562 ÷ 1206	272 ÷ 569

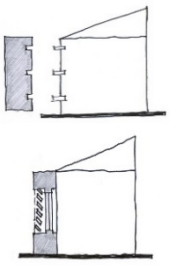
7

RENOVATION PACKAGE

GEOCLUSTER NORTHERN

PREFABRICATED FACADE + PLUG&PLAY ENERGY HUB (+ SOLAR THERMAL)




	Tot Area	**88 m2**	**228 m2**	**3456 m2**	**1330 m2**
REQUIREMENTS OF THE		Opaque part	Prefabricated facade thickness [cm]	~20 ÷ ~35			
			Final U-value wall [W/m²K]	~0.2 ÷ ~0.1			
		Window	Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
			Frame U-value [W/m²K]	1.4 ÷ 1			
			g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
		Shading system	Presence	May be applicable			
			Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			
		Plug&Play Energy Hub	Presence	Used in order to improve efficiency of heating, cooling and DHW systems. Approximately, a decrease of 20% in consumptions of these systems is expected.			

Key Performance Indicators

ENERGY	Heating demand [kWh/m²]	103.21 ÷ 114.97	63.54 ÷ 72.26	55.15 ÷ 61.38	58.11 ÷ 63.33
	Cooling demand [kWh/m²]	0.07 ÷ 7.39	0 ÷ 0.17	0.36 ÷ 4.56	0.3 ÷ 5.55
	Ventilation consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Ceiling fan consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Estimated ST production (roof placement) [MWh]	1.43	1.52	32.82	12.41
	Energy Consumption (H + C) savings due to EnergyHub	-20%	-20%	-20%	-20%
	DHW consumption savings due to Energy Hub	-20%	-20%	-20%	-20%
	Energy demand (H+C) saving respect to non-renovated	-36.48% ÷ -25.37%	-82.24% ÷ -70.48%	-53.6% ÷ -46.01%	-39.49% ÷ -29.13%
COMFORT AND IAQ	CAT_1_PPM	100% ÷ 100%	69.39% ÷ 72.84%	13.69% ÷ 17.39%	99.98% ÷ 99.98%

(check Table 3 of Deliverable 3.3 for more explanation on these KPIs)	CAT_2_PPM	0% ÷ 0%	10.34% ÷ 10.86%	11.76% ÷ 12.1%	0% ÷ 0%
	CAT_I_Adpt (evaluated in cooling period)	41.93% ÷ 91.81%	15.49% ÷ 89.67%	4.14% ÷ 87.16%	0% ÷ 37.77%
	CAT_II_Adpt (evaluated in cooling period)	7.8% ÷ 15.86%	10.2% ÷ 32.36%	11.38% ÷ 34.5%	2.25% ÷ 25.47%
	pmv _CatI (evaluated in heating period)	1.62% ÷ 3.46%	0% ÷ 4.27%	4% ÷ 8.32%	3.74% ÷ 8.4%
	pmv _CatII (evaluated in heating period)	3.17% ÷ 5.01%	2.24% ÷ 6.19%	7.87% ÷ 10.66%	8.73% ÷ 11.15%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.488÷1.944	2.024÷2.904	27.04÷45.544	3.48÷13.992
ECONOMIC ISSUES	Investment cost [€] **(Not considering Energy Hub Technology)**	115551 ÷ 465548	149361 ÷ 504739	1476456 ÷ 2594173	711563 ÷ 1143893
	Net Present Value (50 years) [€] **(Not considering Energy Hub Technology)**	130919 ÷ 527465	169226 ÷ 571869	1672824 ÷ 2939198	806200 ÷ 1296030
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours] **(Not considering Energy Hub Technology)**	44 ÷ 95	55 ÷ 118	562 ÷ 1206	272 ÷ 569

3 GEOCLUSTER NORTH-EAST

1 RENOVATION PACKAGE

GEOCLUSTER NORTH-EAST

PREFABRICATED FACADE




	Tot Area	**88 m2**	**228 m2**	**3456 m2**	**1330 m2**
REQUIREMENTS OF THE	Opaque part	Prefabricated facade thickness [cm]	~20 ÷ ~35			
		Final U-value wall [W/m²K]	~0.2 ÷ ~0.1			
	Window	Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
		Frame U-value [W/m²K]	1.4 ÷ 1			
		g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
	Shading system	Presence	May be applicable			
		Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			

Key Performance Indicators					
ENERGY	Heating demand [kWh/m²]	96.05 ÷ 104.61	57.03 ÷ 67.95	46.39 ÷ 52.6	53.57 ÷ 56.73
	Cooling demand [kWh/m²]	0.51 ÷ 12.35	0 ÷ 0.06	0.12 ÷ 4.49	1 ÷ 7.62
	Ventilation consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Ceiling fan consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Estimate PV power production [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	PEF (H+C) saving respect to non-renovated	-85.96% ÷ -69.6%	-89.38% ÷ -77.42%	-80.57% ÷ -69.72%	-75.99% ÷ -47.92%
	Energy demand (H+C) saving respect to non-renovated	-68.9% ÷ -62.73%	-82.24% ÷ -70.48%	-70.73% ÷ -65.19%	-47.15% ÷ -38.29%
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more	CAT_1_PPM	100% ÷ 100%	72.41% ÷ 77.49%	17.11% ÷ 21.69%	99.98% ÷ 99.98%
	CAT_2_PPM	0% ÷ 0%	9.14% ÷ 10%	17.07% ÷ 17.54%	0% ÷ 0%

explanation on these KPIs)	CAT_I_Adpt (evaluated in cooling period)	10.45% ÷ 91.68%	18.01% ÷ 90.3%	7.66% ÷ 99.86%	1.98% ÷ 41.8%
	CAT_II_Adpt (evaluated in cooling period)	7.3% ÷ 15.99%	7.43% ÷ 36.77%	0.13% ÷ 55.27%	7.78% ÷ 20.49%
	pmv _CatI (evaluated in heating period)	4.03% ÷ 6.88%	0.12% ÷ 5.82%	2.31% ÷ 9.75%	6.31% ÷ 13.05%
	pmv _CatII (evaluated in heating period)	4.07% ÷ 8.3%	3.13% ÷ 11.12%	9.56% ÷ 16.32%	7.98% ÷ 15.2%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.56 ÷ 2.35	2.87 ÷ 6.07	35.86 ÷ 91.56	4.01 ÷ 16.5
ECONOMIC ISSUES	Investment cost [€]	47165 ÷ 190025	60965 ÷ 206021	602652 ÷ 1058875	290442 ÷ 466908
	Net Present Value (50 years) [€]	53437 ÷ 215298	69073 ÷ 233421	682804 ÷ 1199705	329070 ÷ 529006
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	44 ÷ 95	55 ÷ 118	562 ÷ 1206	272 ÷ 569

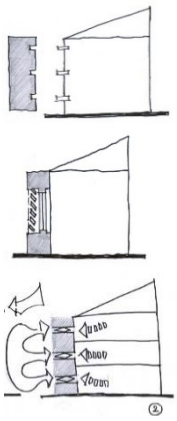
2 RENOVATION PACKAGE

GEOCLUSTER NORTH-EAST

PREFABRICATED FACADE + DECENTRALIZED VENTILATION




	Tot Area	**88 m2**	**228 m2**	**3456 m2**	**1330 m2**
REQUIREMENTS OF THE COMPONENTS	Opaque part: Prefabricated facade thickness [cm]	~20 ÷ ~35			
	Opaque part: Final U-value wall [W/m²K]	~0.2 ÷ ~0.1			
	Window: Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
	Window: Frame U-value [W/m²K]	1.4 ÷ 1			
	Window: g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
	Shading system: Presence	May be applicable			
	Shading system: Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			
	Mechanical ventilation: Type	Decentralized ventilation system providing punctual inlet and outlet of air. Decentralized machine also provides heat recovery. The mechanical ventilation system is considered to be switched off during summer period (from June to August).			



Key Performance Indicators

ENERGY	Heating demand [kWh/m²]	84.85 ÷ 93.48	24.5 ÷ 34.65	5.99 ÷ 12.25	26.07 ÷ 29.93
	Cooling demand [kWh/m²]	0.64 ÷ 13.63	0 ÷ 0.06	0.31 ÷ 8.97	2.5 ÷ 12.92
	Ventilation consumption [kWh]	528.26 ÷ 528.26	1029.56 ÷ 1029.56	13684.63 ÷ 13684.63	13663.57 ÷ 13663.57
	Ceiling fan consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Estimate PV power production [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	PEF (H+C) saving respect to non-renovated	-87.6% ÷ -71.83%	-92.83% ÷ -88.77%	-97.48% ÷ -81.71%	-88.31% ÷ -61.24%
	Energy demand (H+C) saving respect to non-renovated	-72.46% ÷ -65.97%	-89.31% ÷ -84.93%	-95.85% ÷ -87.59%	-72.03% ÷ -59.36%
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more	CAT_1_PPM	55.72% ÷ 55.72%	83.74% ÷ 88.02%	11.57% ÷ 15.92%	6.61% ÷ 6.61%
	CAT_2_PPM	33.31% ÷ 33.31%	7.94% ÷ 8.77%	35.08% ÷ 35.52%	5.99% ÷ 5.99%

explanation on these KPIs)	CAT_I_Adpt (evaluated in cooling period)	3.4% ÷ 84.38%	18.38% ÷ 97.6%	5.86% ÷ 99.44%	0% ÷ 7.1%
	CAT_II_Adpt (evaluated in cooling period)	5.03% ÷ 14.23%	2.26% ÷ 36.77%	0.55% ÷ 55.14%	0% ÷ 9.35%
	pmv _CatI (evaluated in heating period)	3.99% ÷ 10.5%	0.65% ÷ 13.19%	6.86% ÷ 19.7%	2.79% ÷ 5.43%
	pmv _CatII (evaluated in heating period)	5.33% ÷ 9.61%	15.84% ÷ 23.34%	14.17% ÷ 23.94%	5.27% ÷ 10.3%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.5 ÷ 2.16	1.23 ÷ 3.09	4.63 ÷ 58.5	1.95 ÷ 11.44
ECONOMIC ISSUES	Investment cost [€]	51895 ÷ 194755	66746 ÷ 211802	661514 ÷ 1117738	319581 ÷ 496047
	Net Present Value (50 years) [€]	58797 ÷ 220657	75623 ÷ 239971	749495 ÷ 1266397	362085 ÷ 562021
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	47 ÷ 98	58 ÷ 122	596 ÷ 1240	288 ÷ 586

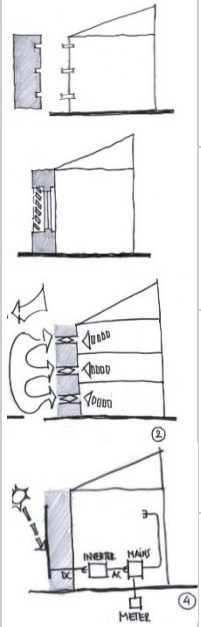
3 RENOVATION PACKAGE

GEOCLUSTER NORTH-EAST

PREFABRICATED FACADE + DECENTRALIZED VENTILATION + BIPV




	Tot Area	**88 m2**	**228 m2**	**3456 m2**	**1330 m2**
REQUIREMENTS OF THE COMPONENTS	Opaque part	Prefabricated facade thickness [cm]	~20 ÷ ~35			
		Final U-value wall [W/m^{2}K]	~0.2 ÷ ~0.1			
	Window	Glazing U-value [W/m^{2}K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
		Frame U-value [W/m^{2}K]	1.4 ÷ 1			
		g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
	Shading system	Presence	May be applicable			
		Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			
	Mechanical ventilation	Type	Decentralized ventilation system providing punctual inlet and outlet of air. Decentralized machine also provides heat recovery. The mechanical ventilation system is considered to be switched off during summer period (from June to August).			



Key Performance Indicators

ENERGY	Heating demand [kWh/m^2]	84.85 ÷ 93.48	24.5 ÷ 34.65	5.99 ÷ 12.25	26.07 ÷ 29.93
	Cooling demand [kWh/m^2]	0.64 ÷ 13.63	0 ÷ 0.06	0.31 ÷ 8.97	2.5 ÷ 12.92
	Ventilation consumption [kWh]	528.26 ÷ 528.26	1029.56 ÷ 1029.56	13684.63 ÷ 13684.63	13663.57 ÷ 13663.57
	Ceiling fan consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Estimate PV power production [kWh]	1072.57 ÷ 1072.57	7039.39 ÷ 7039.39	23587.15 ÷ 23587.15	5161.56 ÷ 5161.56
	PEF (H+C) saving respect to non-renovated	-87.6% ÷ -71.83%	-92.83% ÷ -88.77%	-97.48% ÷ -81.71%	-88.31% ÷ -61.24%
	Energy demand (H+C) saving respect to non-renovated	-72.46% ÷ -65.97%	-89.31% ÷ -84.93%	-95.85% ÷ -87.59%	-72.03% ÷ -59.36%
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more	CAT_1_PPM	55.72% ÷ 55.72%	83.74% ÷ 88.02%	11.57% ÷ 15.92%	6.61% ÷ 6.61%
	CAT_2_PPM	33.31% ÷ 33.31%	7.94% ÷ 8.77%	35.08% ÷ 35.52%	5.99% ÷ 5.99%

explanation on these KPIs)	CAT_I_Adpt (evaluated in cooling period)	3.4% ÷ 84.38%	18.38% ÷ 97.6%	5.86% ÷ 99.44%	0% ÷ 7.1%
	CAT_II_Adpt (evaluated in cooling period)	5.03% ÷ 14.23%	2.26% ÷ 36.77%	0.55% ÷ 55.14%	0% ÷ 9.35%
	pmv _CatI (evaluated in heating period)	3.99% ÷ 10.5%	0.65% ÷ 13.19%	6.86% ÷ 19.7%	2.79% ÷ 5.43%
	pmv _CatII (evaluated in heating period)	5.33% ÷ 9.61%	15.84% ÷ 23.34%	14.17% ÷ 23.94%	5.27% ÷ 10.3%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.5 ÷ 2.16	1.23 ÷ 3.09	4.63 ÷ 58.5	1.95 ÷ 11.44
ECONOMIC ISSUES	Investment cost [€]	53850 ÷ 196710	69136 ÷ 214192	685841 ÷ 1142064	331623 ÷ 508090
	Net Present Value (50 years) [€]	61012 ÷ 222872	78331 ÷ 242679	777057 ÷ 1293958	375728 ÷ 575665
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	50 ÷ 100	62 ÷ 125	630 ÷ 1275	305 ÷ 603

4

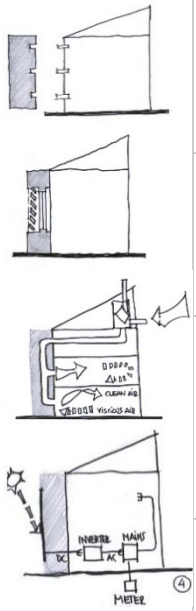
RENOVATION PACKAGE

GEOCLUSTER NORTH-EAST

PREFABRICATED FACADE + CENTRALIZED VENTILATION + BIPV




	Tot Area	**88 m2**	**228 m2**	**3456 m2**	**1330 m2**
REQUIREMENTS OF THE COMPONENTS	Opaque part	Prefabricated facade thickness [cm]	~20 ÷ ~35			
		Final U-value wall [W/m²K]	~0.2 ÷ ~0.1			
	Window	Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
		Frame U-value [W/m²K]	1.4 ÷ 1			
		g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
	Shading system	Presence	May be applicable			
		Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			
	Mechanical ...	Type	Balanced Air Handling Unit for centralized ventilation system. Centralized machine also provides heat recovery. The mechanical ventilation system is considered to be switched off during summer period (from June to August).			



Key Performance Indicators

ENERGY	Heating demand [kWh/m²]	88.36 ÷ 96.94	21.16 ÷ 31.02	3.81 ÷ 9.82	28.55 ÷ 32.34
	Cooling demand [kWh/m²]	0.58 ÷ 12.97	0 ÷ 0.06	0.68 ÷ 10.26	2.19 ÷ 12.13
	Ventilation consumption [kWh]	274.15 ÷ 274.15	606.54 ÷ 606.54	6510.16 ÷ 6510.16	7091.06 ÷ 7091.06
	Ceiling fan consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Estimate PV power production [kWh]	1072.57 ÷ 1072.57	7039.39 ÷ 7039.39	23587.15 ÷ 23587.15	5161.56 ÷ 5161.56
	PEF (H+C) saving respect to non-renovated	-87.09% ÷ -71.25%	-93.8% ÷ -89.95%	-98.4% ÷ -80.79%	-87.2% ÷ -60.46%
	Energy demand (H+C) saving respect to non-renovated	-71.34% ÷ -65.04%	-90.77% ÷ -86.51%	-96.85% ÷ -88.42%	-69.97% ÷ -57.77%
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more	CAT_1_PPM	66.68% ÷ 66.68%	83.74% ÷ 88.08%	11.55% ÷ 15.92%	8.73% ÷ 8.73%
	CAT_2_PPM	32.05% ÷ 32.05%	7.91% ÷ 8.77%	35.12% ÷ 35.59%	7.46% ÷ 7.46%

explanation on these KPIs)	CAT_I_Adpt (evaluated in cooling period)	4.53% ÷ 85.89%	18.51% ÷ 99.11%	5.86% ÷ 98.27%	0% ÷ 11.88%
	CAT_II_Adpt (evaluated in cooling period)	7.93% ÷ 12.97%	0.75% ÷ 36.77%	1.72% ÷ 55.55%	0% ÷ 14.34%
	pmv _CatI (evaluated in heating period)	4.19% ÷ 10.02%	1.22% ÷ 10.14%	7.38% ÷ 19.16%	2.5% ÷ 4.07%
	pmv _CatII (evaluated in heating period)	5.7% ÷ 9.24%	20.97% ÷ 26.88%	14.74% ÷ 32.73%	4.61% ÷ 10.64%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.52 ÷ 2.21	1.06 ÷ 2.77	2.94 ÷ 61.86	2.13 ÷ 11.79
ECONOMIC ISSUES	Investment cost [€]	55038 ÷ 197898	70588 ÷ 215644	700629 ÷ 1156852	338944 ÷ 515410
	Net Present Value (50 years) [€]	62358 ÷ 224218	79976 ÷ 244324	793812 ÷ 1310713	384023 ÷ 583959
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	110 ÷ 161	135 ÷ 199	1382 ÷ 2027	678 ÷ 976

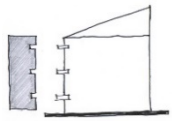
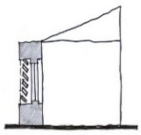
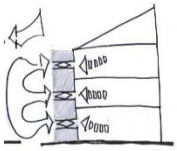
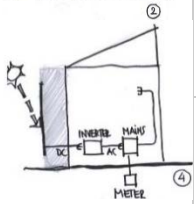
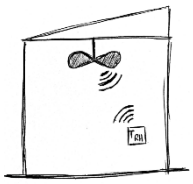
5

RENOVATION PACKAGE

GEOCLUSTER NORTH-EAST

PREFABRICATED FACADE + DECENTRALIZED VENTILATION + BIPV + SMART CEILING FAN




		Tot Area	88 m2	228 m2	3456 m2	1330 m2
REQUIREMENTS OF THE COMPONENTS		Opaque part	Prefabricated facade thickness [cm]	~20 ÷ ~35		
			Final U-value wall [W/m^{2}K]	~0.2 ÷ ~0.1		
		Window	Glazing U-value [W/m^{2}K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
			Frame U-value [W/m^{2}K]	1.4 ÷ 1		
			g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
		Shading system	Presence	May be applicable		
			Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature		
		Mechanical ...	Type	Decentralized ventilation system providing punctual inlet and outlet of air. Decentralized machine also provides heat recovery. The mechanical ventilation system is considered to be switched off during summer period (from June to August).		
		Smart ceiling ...	Control strategy	Temperature and relative humidity sensor communicate with the smart ceiling fan to automatically adjust its fan speed		

Key Performance Indicators

ENERGY	Heating demand [kWh/m^2]	84.83 ÷ 93.48	24.5 ÷ 34.65	5.95 ÷ 12.25	26.06 ÷ 29.92
	Cooling demand [kWh/m^2]	0.03 ÷ 8.99	0 ÷ 0	0 ÷ 4.37	0.85 ÷ 8.85
	Ventilation consumption [kWh]	528.26 ÷ 528.26	1029.56 ÷ 1029.56	13684.63 ÷ 13684.63	13663.57 ÷ 13663.57
	Ceiling fan consumption [kWh]	3.6 ÷ 108.9	0 ÷ 1.4	194.35 ÷ 2236.92	142.8 ÷ 423.99
	Estimate PV power production [kWh]	1072.57 ÷ 1072.57	7039.39 ÷ 7039.39	23587.15 ÷ 23587.15	5161.56 ÷ 5161.56
	PEF (H+C) saving respect to non-renovated	-87.58% ÷ -73.77%	-92.82% ÷ -88.77%	-97.41% ÷ -88.67%	-86.94% ÷ -66.67%
	Energy demand (H+C) saving respect to non-renovated	-72.67% ÷ -67.39%	-89.34% ÷ -84.93%	-96.21% ÷ -90.31%	-73.77% ÷ -63.26%

COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more explanation on these KPIs)	CAT_1_PPM	55.72% ÷ 55.72%	83.74% ÷ 88.02%	11.65% ÷ 15.82%	6.61% ÷ 6.61%
	CAT_2_PPM	33.31% ÷ 33.31%	7.94% ÷ 8.77%	35.1% ÷ 35.63%	5.99% ÷ 5.99%
	CAT_I_Adpt (evaluated in cooling period)	3.4% ÷ 84.38%	18.38% ÷ 97.6%	5.38% ÷ 99.3%	0% ÷ 7.1%
	CAT_II_Adpt (evaluated in cooling period)	5.03% ÷ 14.23%	2.26% ÷ 36.77%	0.69% ÷ 57.07%	0% ÷ 9.35%
	pmv _CatI (evaluated in heating period)	3.99% ÷ 10.5%	0.65% ÷ 13.19%	5.09% ÷ 17.1%	2.79% ÷ 5.43%
	pmv _CatII (evaluated in heating period)	5.33% ÷ 9.61%	15.84% ÷ 23.34%	12.97% ÷ 25.97%	5.27% ÷ 10.3%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.5 ÷ 2.05	1.23 ÷ 3.09	4.82 ÷ 35.68	2.28 ÷ 10.12
ECONOMIC ISSUES	Investment cost [€]	55102 ÷ 197606	72336 ÷ 216483	735007 ÷ 1177267	350601 ÷ 521678
	Net Present Value (50 years) [€]	62430 ÷ 223887	81956 ÷ 245275	832762 ÷ 1333843	397230 ÷ 591061
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	50 ÷ 100	62 ÷ 125	630 ÷ 1275	305 ÷ 603

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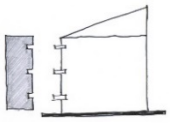
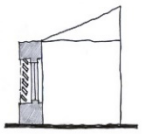
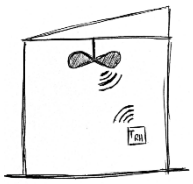
RENOVATION PACKAGE

GEOCLUSTER NORTH-EAST

PREFABRICATED FACADE + SMART CEILING FAN




	Tot Area	88 m2	228 m2	3456 m2	1330 m2
REQUIREMENTS OF THE COMPONENTS	Opaque part	Prefabricated facade thickness [cm]	~20 ÷ ~35			
		Final U-value wall [W/m²K]	~0.2 ÷ ~0.1			
	Window	Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
		Frame U-value [W/m²K]	1.4 ÷ 1			
		g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
	Shading system	Presence	May be applicable			
		Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			
	Smart ceiling fan	Control strategy	Temperature and relative humidity sensor communicate with the smart ceiling fan to automatically adjust its fan speed			

Key Performance Indicators

ENERGY	Heating demand [kWh/m²]	96.04 ÷ 104.61	57.03 ÷ 67.95	46.37 ÷ 52.6	53.57 ÷ 56.73
	Cooling demand [kWh/m²]	0.01 ÷ 7.95	0 ÷ 0	0 ÷ 1.16	0.11 ÷ 4.41
	Ventilation consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Ceiling fan consumption [kWh]	2.33 ÷ 97.38	0 ÷ 1.32	14.12 ÷ 1233.32	46.79 ÷ 252
	Estimate PV power production [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	PEF (H+C) saving respect to non-renovated	-85.95% ÷ -71.43%	-83.31% ÷ -77.99%	-80.33% ÷ -74.42%	-75.77% ÷ -52.12%
	Energy demand (H+C) saving respect to non-renovated	-69.07% ÷ -64.08%	-75.2% ÷ -70.45%	-71% ÷ -67.1%	-48.06% ÷ -41.31%
COMFORT AND IAQ	CAT_1_PPM	100% ÷ 100%	72.41% ÷ 77.49%	17.16% ÷ 21.51%	99.98% ÷ 99.98%

(check Table 3 of Deliverable 3.3 for more explanation on these KPIs)	CAT_2_PPM	0% ÷ 0%	9.14% ÷ 10%	17.09% ÷ 17.62%	0% ÷ 0%
	CAT_I_Adpt (evaluated in cooling period)	10.45% ÷ 91.68%	18.01% ÷ 90.3%	6.69% ÷ 99.86%	1.98% ÷ 41.8%
	CAT_II_Adpt (evaluated in cooling period)	7.3% ÷ 15.99%	7.43% ÷ 36.77%	0.13% ÷ 57.34%	7.78% ÷ 20.49%
	pmv _CatI (evaluated in heating period)	4.03% ÷ 6.88%	0.12% ÷ 5.82%	2.31% ÷ 8.84%	6.31% ÷ 13.05%
	pmv _CatII (evaluated in heating period)	4.07% ÷ 8.3%	3.13% ÷ 11.12%	9.59% ÷ 16.19%	7.98% ÷ 15.2%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.56 ÷ 2.24	2.87 ÷ 6.07	36.32 ÷ 76.17	4.06 ÷ 15.48
ECONOMIC ISSUES	Investment cost [€]	48417 ÷ 190921	64166 ÷ 208313	651817 ÷ 1094077	309419 ÷ 480496
	Net Present Value (50 years) [€]	54856 ÷ 216313	72700 ÷ 236018	738508 ÷ 1239589	350571 ÷ 544401
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	44 ÷ 95	55 ÷ 118	562 ÷ 1206	272 ÷ 569

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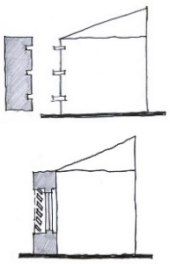
RENOVATION PACKAGE

GEOCLUSTER NORTH-EAST

PREFABRICATED FACADE + PLUG&PLAY ENERGY HUB (+ SOLAR THERMAL)




	Tot Area	**88 m2**	**228 m2**	**3456 m2**	**1330 m2**
REQUIREMENTS OF THE COMPONENTS		Opaque part	Prefabricated facade thickness [cm]	~20 ÷ ~35			
			Final U-value wall [W/m²K]	~0.2 ÷ ~0.1			
		Window	Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
			Frame U-value [W/m²K]	1.4 ÷ 1			
			g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
		Shading system	Presence	May be applicable			
			Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			
		Plug&Play Energy Hub	Presence	Used in order to improve efficiency of heating, cooling and DHW systems. Approximately, a decrease of 20% in consumptions of these systems is expected.			

Key Performance Indicators					
ENERGY	Heating demand [kWh/m²]	96.05 ÷ 104.61	57.03 ÷ 67.95	46.39 ÷ 52.6	53.57 ÷ 56.73
	Cooling demand [kWh/m²]	0.51 ÷ 12.35	0 ÷ 0.06	0.12 ÷ 4.49	1 ÷ 7.62
	Ventilation consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Ceiling fan consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Estimated ST production (roof placement) [MWh]	1.52	1.42	32.87	12.30
	Energy Consumption (H + C) savings due to EnergyHub	-20%	-20%	-20%	-20%
	DHW consumption savings due to Energy Hub	-20%	-20%	-20%	-20%
	Energy demand (H+C) saving respect to non-renovated	-68.9% ÷ -62.73%	-82.24% ÷ -70.48%	-70.73% ÷ -65.19%	-47.15% ÷ -38.29%
COMFORT AND IAQ	CAT_1_PPM	100% ÷ 100%	72.41% ÷ 77.49%	17.11% ÷ 21.69%	99.98% ÷ 99.98%

(check Table 3 of Deliverable 3.3 for more explanation on these KPIs)	CAT_2_PPM	0% ÷ 0%	9.14% ÷ 10%	17.07% ÷ 17.54%	0% ÷ 0%
	CAT_I_Adpt (evaluated in cooling period)	10.45% ÷ 91.68%	18.01% ÷ 90.3%	7.66% ÷ 99.86%	1.98% ÷ 41.8%
	CAT_II_Adpt (evaluated in cooling period)	7.3% ÷ 15.99%	7.43% ÷ 36.77%	0.13% ÷ 55.27%	7.78% ÷ 20.49%
	pmv _CatI (evaluated in heating period)	4.03% ÷ 6.88%	0.12% ÷ 5.82%	2.31% ÷ 9.75%	6.31% ÷ 13.05%
	pmv _CatII (evaluated in heating period)	4.07% ÷ 8.3%	3.13% ÷ 11.12%	9.56% ÷ 16.32%	7.98% ÷ 15.2%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.448÷1.88	2.296÷4.856	28.688÷73.248	3.208÷13.2
ECONOMIC ISSUES	Investment cost [€] **(Not considering Energy Hub Technology)**	47165 ÷ 190025	60965 ÷ 206021	602652 ÷ 1058875	290442 ÷ 466908
	Net Present Value (50 years) [€] **(Not considering Energy Hub Technology)**	53437 ÷ 215298	69073 ÷ 233421	682804 ÷ 1199705	329070 ÷ 529006
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours] **(Not considering Energy Hub Technology)**	44 ÷ 95	55 ÷ 118	562 ÷ 1206	272 ÷ 569

4 GEOCLUSTER EAST

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RENOVATION PACKAGE

GEOCLUSTER EAST

PREFABRICATED FACADE




	Tot Area	**88 m2**	**228 m2**	**3456 m2**	**1330 m2**
REQUIREMENTS OF THE	Opaque part	Prefabricated facade thickness [cm]	~20 ÷ ~35			
		Final U-value wall [W/m^{2}K]	~0.2 ÷ ~0.1			
	Window	Glazing U-value [W/m^{2}K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
		Frame U-value [W/m^{2}K]	1.4 ÷ 1			
		g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
	Shading	Presence	May be applicable			
		Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			

Key Performance Indicators					
ENERGY	Heating demand [kWh/m^2]	66.82 ÷ 73.7	40.9 ÷ 49.38	29.51 ÷ 33.57	31.07 ÷ 32.95
	Cooling demand [kWh/m^2]	2.06 ÷ 21.54	0 ÷ 0.32	1.1 ÷ 9.83	3.36 ÷ 13.58
	Ventilation consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Ceiling fan consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Estimate PV power production [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	PEF (H+C) saving respect to non-renovated	-86.79% ÷ -65.84%	-89.38% ÷ -77.42%	-81.54% ÷ -51.18%	-80.89% ÷ -46.29%
	Energy demand (H+C) saving respect to non-renovated	-70.97% ÷ -60.94%	-82.24% ÷ -70.48%	-67.45% ÷ -56.78%	-57.24% ÷ -43.59%
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more explanation on these KPIs)	CAT_1_PPM	100% ÷ 100%	65.57% ÷ 72.75%	21.71% ÷ 24.91%	99.98% ÷ 99.98%
	CAT_2_PPM	0% ÷ 0%	9.94% ÷ 11.66%	10.38% ÷ 10.99%	0% ÷ 0%
	CAT_I_Adpt (evaluated in cooling period)	0% ÷ 81.1%	57.43% ÷ 98.99%	12.14% ÷ 85.09%	0% ÷ 11.74%

	CAT_II_Adpt (evaluated in cooling period)	0.25% ÷ 22.41%	0.88% ÷ 28.46%	12.69% ÷ 31.46%	0% ÷ 19.8%
	pmv _CatI (evaluated in heating period)	3.34% ÷ 8.47%	2.52% ÷ 3.99%	10.42% ÷ 15%	4.43% ÷ 13.45%
	pmv _CatII (evaluated in heating period)	8.43% ÷ 16.17%	4.96% ÷ 20.73%	13.98% ÷ 20.28%	8.84% ÷ 16.73%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.39 ÷ 1.96	1.73 ÷ 2.48	51.81 ÷ 69.88	2.32 ÷ 12.44
ECONOMIC ISSUES	Investment cost [€]	38272 ÷ 154198	49471 ÷ 167178	489029 ÷ 859237	235682 ÷ 378878
	Net Present Value (50 years) [€]	43362 ÷ 174706	56050 ÷ 189412	554069 ÷ 973515	267027 ÷ 429268
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	44 ÷ 95	55 ÷ 118	562 ÷ 1206	272 ÷ 569

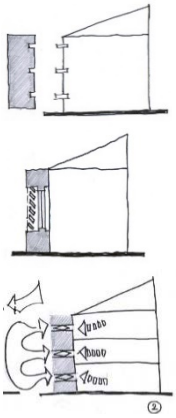
2

RENOVATION PACKAGE

GEOCLUSTER EAST

PREFABRICATED FACADE + DECENTRALIZED VENTILATION




		Tot Area	88 m2	228 m2	3456 m2	1330 m2
REQUIREMENTS OF THE COMPONENTS		Opaque part	Prefabricated facade thickness [cm]	~20 ÷ ~35		
			Final U-value wall [W/m²K]	~0.2 ÷ ~0.1		
		Window	Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
			Frame U-value [W/m²K]	1.4 ÷ 1		
			g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
		Shading	Presence	May be applicable		
			Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature		
		Mechanical	Type	Decentralized ventilation system providing punctual inlet and outlet of air. Decentralized machine also provides heat recovery. The mechanical ventilation system is considered to be switched off during summer period (from June to August).		

Key Performance Indicators

ENERGY	Heating demand [kWh/m²]	62.49 ÷ 69.26	17.8 ÷ 25.62	2.51 ÷ 6.01	15.72 ÷ 17.92
	Cooling demand [kWh/m²]	2.38 ÷ 23.03	0 ÷ 0.59	2.74 ÷ 16	5.6 ÷ 19.45
	Ventilation consumption [kWh]	576.28 ÷ 576.28	1119.93 ÷ 1119.93	14885.72 ÷ 14885.72	14905.71 ÷ 14905.71
	Ceiling fan consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Estimate PV power production [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	PEF (H+C) saving respect to non-renovated	-87.64% ÷ -66.6%	-94.79% ÷ -90.04%	-98.42% ÷ -59.28%	-90.33% ÷ -52.93%
	Energy demand (H+C) saving respect to non-renovated	-72.68% ÷ -62.19%	-90.4% ÷ -86.64%	-93.97% ÷ -78.55%	-73.26% ÷ -54.98%
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more	CAT_1_PPM	66.68% ÷ 66.68%	86.2% ÷ 91.93%	18.6% ÷ 21.28%	8.73% ÷ 8.73%
	CAT_2_PPM	32.05% ÷ 32.05%	5.48% ÷ 6.83%	39.86% ÷ 40.77%	7.46% ÷ 7.46%

explanation on these KPIs)	CAT_I_Adpt (evaluated in cooling period)	0% ÷ 63.6%	57.3% ÷ 99.24%	11.93% ÷ 83.36%	0% ÷ 0.06%
	CAT_II_Adpt (evaluated in cooling period)	0% ÷ 24.93%	0.62% ÷ 28.33%	14.28% ÷ 30.77%	0% ÷ 0.68%
	pmv _CatI (evaluated in heating period)	6.02% ÷ 17.31%	5.53% ÷ 16.74%	5.64% ÷ 19.34%	5% ÷ 7.55%
	pmv _CatII (evaluated in heating period)	10.02% ÷ 15.23%	13.84% ÷ 22.56%	10.63% ÷ 28.18%	7.62% ÷ 13.47%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.37 ÷ 1.91	0.75 ÷ 1.28	4.42 ÷ 12.51	1.17 ÷ 10.55
ECONOMIC ISSUES	Investment cost [€]	42111 ÷ 158036	54162 ÷ 171869	536794 ÷ 907001	259328 ÷ 402523
	Net Present Value (50 years) [€]	47711 ÷ 179054	61365 ÷ 194727	608187 ÷ 1027632	293818 ÷ 456058
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	47 ÷ 98	58 ÷ 122	596 ÷ 1240	288 ÷ 586

3

RENOVATION PACKAGE

GEOCLUSTER EAST

PREFABRICATED FACADE + DECENTRALIZED VENTILATION + BIPV




	Tot Area	88 m2	228 m2	3456 m2	1330 m2
REQUIREMENTS OF THE COMPONENTS	Opaque part	Prefabricated facade thickness [cm]	~20 ÷ ~35			
		Final U-value wall [W/m²K]	~0.2 ÷ ~0.1			
	Window	Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
		Frame U-value [W/m²K]	1.4 ÷ 1			
		g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
	Shading	Presence	May be applicable			
		Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			
	Mechanical	Type	Decentralized ventilation system providing punctual inlet and outlet of air. Decentralized machine also provides heat recovery. The mechanical ventilation system is considered to be switched off during summer period (from June to August).			

Key Performance Indicators

ENERGY	Heating demand [kWh/m²]	62.49 ÷ 69.26	17.8 ÷ 25.62	2.51 ÷ 6.01	15.72 ÷ 17.92
	Cooling demand [kWh/m²]	2.38 ÷ 23.03	0 ÷ 0.59	2.74 ÷ 16	5.6 ÷ 19.45
	Ventilation consumption [kWh]	576.28 ÷ 576.28	1119.93 ÷ 1119.93	14885.72 ÷ 14885.72	14905.71 ÷ 14905.71
	Ceiling fan consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Estimate PV power production [kWh]	634.74 ÷ 634.74	15716.36 ÷ 15716.36	22202.65 ÷ 22202.65	6805.78 ÷ 6805.78
	PEF (H+C) saving respect to non-renovated	-87.64% ÷ -66.6%	-94.79% ÷ -90.04%	-98.42% ÷ -59.28%	-90.33% ÷ -52.93%
	Energy demand (H+C) saving respect to non-renovated	-72.68% ÷ -62.19%	-90.4% ÷ -86.64%	-93.97% ÷ -78.55%	-73.26% ÷ -54.98%
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more	CAT_1_PPM	66.68% ÷ 66.68%	86.2% ÷ 91.93%	18.6% ÷ 21.28%	8.73% ÷ 8.73%
	CAT_2_PPM	32.05% ÷ 32.05%	5.48% ÷ 6.83%	39.86% ÷ 40.77%	7.46% ÷ 7.46%

explanation on these KPIs)	CAT_I_Adpt (evaluated in cooling period)	0% ÷ 63.6%	57.3% ÷ 99.24%	11.93% ÷ 83.36%	0% ÷ 0.06%
	CAT_II_Adpt (evaluated in cooling period)	0% ÷ 24.93%	0.62% ÷ 28.33%	14.28% ÷ 30.77%	0% ÷ 0.68%
	pmv _CatI (evaluated in heating period)	6.02% ÷ 17.31%	5.53% ÷ 16.74%	5.64% ÷ 19.34%	5% ÷ 7.55%
	pmv _CatII (evaluated in heating period)	10.02% ÷ 15.23%	13.84% ÷ 22.56%	10.63% ÷ 28.18%	7.62% ÷ 13.47%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.37 ÷ 1.91	0.75 ÷ 1.28	4.42 ÷ 12.51	1.17 ÷ 10.55
ECONOMIC ISSUES	Investment cost [€]	43697 ÷ 159622	56101 ÷ 173808	556534 ÷ 926741	269100 ÷ 412295
	Net Present Value (50 years) [€]	49508 ÷ 180851	63562 ÷ 196924	630553 ÷ 1049997	304890 ÷ 467130
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	50 ÷ 100	62 ÷ 125	630 ÷ 1275	305 ÷ 603

4

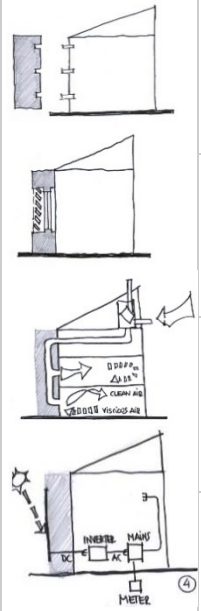
RENOVATION PACKAGE

GEOCLUSTER EAST

PREFABRICATED FACADE + CENTRALIZED VENTILATION + BIPV




	Tot Area	**88 m2**	**228 m2**	**3456 m2**	**1330 m2**
REQUIREMENTS OF THE COMPONENTS	Opaque part: Prefabricated facade thickness [cm]	~20 ÷ ~35			
	Opaque part: Final U-value wall [W/m²K]	~0.2 ÷ ~0.1			
	Window: Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
	Window: Frame U-value [W/m²K]	1.4 ÷ 1			
	Window: g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
	Shading: Presence	May be applicable			
	Shading: Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			
	Mechanical ventilation: Type	Balanced Air Handling Unit for centralized ventilation system. Centralized machine also provides heat recovery. The mechanical ventilation system is considered to be switched off during summer period (from June to August).			



Key Performance Indicators

ENERGY	Heating demand [kWh/m²]	65.36 ÷ 72.32	14.92 ÷ 22.38	1.09 ÷ 4.31	17.69 ÷ 19.84
	Cooling demand [kWh/m²]	2.25 ÷ 22.4	0 ÷ 0.72	3.66 ÷ 17.84	5.24 ÷ 18.58
	Ventilation consumption [kWh]	297 ÷ 297	659.78 ÷ 659.78	7081.55 ÷ 7081.55	7681.99 ÷ 7681.99
	Ceiling fan consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Estimate PV power production [kWh]	634.74 ÷ 634.74	15716.36 ÷ 15716.36	22202.65 ÷ 22202.65	6805.78 ÷ 6805.78
	PEF (H+C) saving respect to non-renovated	-87.08% ÷ -65.92%	-95.63% ÷ -91.3%	-99.31% ÷ -56.26%	-89.12% ÷ -52.25%
	Energy demand (H+C) saving respect to non-renovated	-71.48% ÷ -61.21%	-91.84% ÷ -88.33%	-94.37% ÷ -78.44%	-71.33% ÷ -53.66%
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more explanation on these KPIs)	CAT_1_PPM	77.21% ÷ 77.21%	86.23% ÷ 92.14%	18.64% ÷ 21.28%	10.77% ÷ 10.77%
	CAT_2_PPM	22.78% ÷ 22.78%	5.48% ÷ 6.83%	39.86% ÷ 40.71%	11.53% ÷ 11.53%
	CAT_I_Adpt (evaluated in cooling period)	0% ÷ 68.01%	57.43% ÷ 99.24%	11.87% ÷ 82.88%	0% ÷ 0.27%

	CAT_II_Adpt (evaluated in cooling period)	0% ÷ 24.3%	0.62% ÷ 28.84%	14.49% ÷ 30.64%	0% ÷ 1.91%
	pmv _CatI (evaluated in heating period)	5.21% ÷ 14.98%	5.13% ÷ 16.7%	6.26% ÷ 18.79%	4.36% ÷ 8.68%
	pmv _CatII (evaluated in heating period)	10.14% ÷ 15.31%	17.39% ÷ 31.2%	10.63% ÷ 33.72%	7.73% ÷ 14.23%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.38 ÷ 1.96	0.63 ÷ 1.12	1.92 ÷ 8.98	1.32 ÷ 10.76
ECONOMIC ISSUES	Investment cost [€]	44661 ÷ 160586	57279 ÷ 174987	568533 ÷ 938741	275040 ÷ 418236
	Net Present Value (50 years) [€]	50600 ÷ 181943	64897 ÷ 198260	644147 ÷ 1063593	311620 ÷ 473861
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	110 ÷ 161	135 ÷ 199	1382 ÷ 2027	678 ÷ 976

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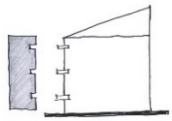
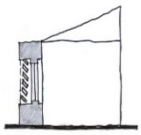
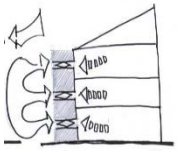
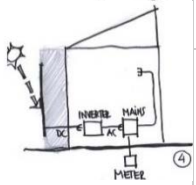
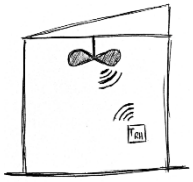
RENOVATION PACKAGE

GEOCLUSTER EAST

PREFABRICATED FACADE + DECENTRALIZED VENTILATION + BIPV + SMART CEILING FAN




		Tot Area	88 m2	228 m2	3456 m2	1330 m2
REQUIREMENTS OF THE COMPONENTS		Opaque part	Prefabricated facade thickness [cm]	~20 ÷ ~35		
			Final U-value wall [W/m²K]	~0.2 ÷ ~0.1		
		Window	Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
			Frame U-value [W/m²K]	1.4 ÷ 1		
			g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
		Shading	Presence	May be applicable		
			Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature		
		Mechanical	Type	Decentralized ventilation system providing punctual inlet and outlet of air. Decentralized machine also provides heat recovery. The mechanical ventilation system is considered to be switched off during summer period (from June to August).		
		Smart ceiling fan	Control strategy	Temperature and relative humidity sensor communicate with the smart ceiling fan to automatically adjust its fan speed		

Key Performance Indicators

ENERGY	Heating demand [kWh/m²]	62.49 ÷ 69.26	17.79 ÷ 25.62	2.44 ÷ 5.96	15.7 ÷ 17.92
	Cooling demand [kWh/m²]	0.33 ÷ 17.63	0 ÷ 0.04	0.97 ÷ 10.52	2.96 ÷ 14.63
	Ventilation consumption [kWh]	576.28 ÷ 576.28	1119.93 ÷ 1119.93	14885.72 ÷ 14885.72	14905.71 ÷ 14905.71
	Ceiling fan consumption [kWh]	28.97 ÷ 151.92	0 ÷ 30.09	1227.66 ÷ 2669.23	282.8 ÷ 523.99
	Estimate PV power production [kWh]	634.74 ÷ 634.74	15716.36 ÷ 15716.36	22202.65 ÷ 22202.65	6805.78 ÷ 6805.78
	PEF (H+C) saving respect to non-renovated	-87.37% ÷ -69.3%	-94.74% ÷ -90.04%	-95.56% ÷ -71.66%	-85.37% ÷ -60.3%
	Energy demand (H+C) saving respect to non-renovated	-73.55% ÷ -64.48%	-90.7% ÷ -86.64%	-95.97% ÷ -84.24%	-76.63% ÷ -60.9%

COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more explanation on these KPIs)	CAT_1_PPM	66.68% ÷ 66.68%	86.2% ÷ 91.93%	18.71% ÷ 20.75%	8.73% ÷ 8.73%
	CAT_2_PPM	32.05% ÷ 32.05%	5.51% ÷ 6.83%	39.9% ÷ 40.67%	7.46% ÷ 7.46%
	CAT_I_Adpt (evaluated in cooling period)	0% ÷ 63.6%	57.3% ÷ 99.11%	28.22% ÷ 80.95%	0% ÷ 0.06%
	CAT_II_Adpt (evaluated in cooling period)	0% ÷ 24.93%	0.75% ÷ 28.33%	16.01% ÷ 32.02%	0% ÷ 0.68%
	pmv _CatI (evaluated in heating period)	6.02% ÷ 17.31%	5.53% ÷ 16.25%	8.06% ÷ 17.7%	5% ÷ 7.55%
	pmv _CatII (evaluated in heating period)	10.02% ÷ 15.23%	13.84% ÷ 22.56%	17.42% ÷ 28.26%	7.62% ÷ 13.47%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.38 ÷ 1.77	0.76 ÷ 1.28	4.29 ÷ 12.42	2.22 ÷ 8.99
ECONOMIC ISSUES	Investment cost [€]	44713 ÷ 160349	58698 ÷ 175668	596430 ÷ 955307	284499 ÷ 423321
	Net Present Value (50 years) [€]	50659 ÷ 181675	66504 ÷ 199031	675755 ÷ 1082362	322337 ÷ 479622
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	50 ÷ 100	62 ÷ 125	630 ÷ 1275	305 ÷ 603

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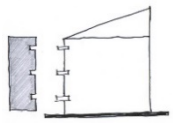
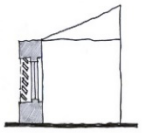
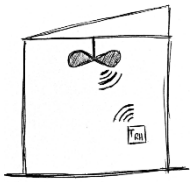
RENOVATION PACKAGE

GEOCLUSTER EAST

PREFABRICATED FACADE + SMART CEILING FAN




	Tot Area	**88 m2**	**228 m2**	**3456 m2**	**1330 m2**
REQUIREMENTS OF THE COMPONENTS	Opaque part – Prefabricated facade thickness [cm]	~20 ÷ ~35			
	Opaque part – Final U-value wall [W/m²K]	~0.2 ÷ ~0.1			
	Window – Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
	Window – Frame U-value [W/m²K]	1.4 ÷ 1			
	Window – g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
	Shading – Presence	May be applicable			
	Shading – Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			
	Smart ceiling fan – Control strategy	Temperature and relative humidity sensor communicate with the smart ceiling fan to automatically adjust its fan speed			

Key Performance Indicators

ENERGY	Heating demand [kWh/m²]	66.81 ÷ 73.7	40.89 ÷ 49.38	29.43 ÷ 33.51	31.07 ÷ 32.95
	Cooling demand [kWh/m²]	0.18 ÷ 16.09	0 ÷ 0.01	0.19 ÷ 5.1	1 ÷ 9.01
	Ventilation consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Ceiling fan consumption [kWh]	20.33 ÷ 147.42	0 ÷ 13.51	407.21 ÷ 1718.64	184.8 ÷ 404.79
	Estimate PV power production [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	PEF (H+C) saving respect to non-renovated	-86.59% ÷ -68.56%	-88.03% ÷ -80.82%	-80.58% ÷ -61.93%	-79.11% ÷ -53.2%
	Energy demand (H+C) saving respect to non-renovated	-71.78% ÷ -63.25%	-78.67% ÷ -74.25%	-68.49% ÷ -61.7%	-60.21% ÷ -49.12%
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more	CAT_1_PPM	100% ÷ 100%	65.57% ÷ 72.75%	21.79% ÷ 24.13%	99.98% ÷ 99.98%
	CAT_2_PPM	0% ÷ 0%	9.94% ÷ 11.66%	10.46% ÷ 10.93%	0% ÷ 0%

explanation on these KPIs)	CAT_I_Adpt (evaluated in cooling period)	0% ÷ 81.1%	57.43% ÷ 98.99%	28.36% ÷ 83.91%	0% ÷ 11.74%
	CAT_II_Adpt (evaluated in cooling period)	0.25% ÷ 22.41%	0.88% ÷ 28.46%	13.66% ÷ 34.02%	0% ÷ 19.8%
	pmv _CatI (evaluated in heating period)	3.34% ÷ 8.47%	2.52% ÷ 3.99%	11.18% ÷ 14.56%	4.43% ÷ 13.45%
	pmv _CatII (evaluated in heating period)	8.43% ÷ 16.17%	4.96% ÷ 20.52%	17.18% ÷ 19.7%	8.84% ÷ 16.73%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.4 ÷ 1.82	1.73 ÷ 2.48	51.68 ÷ 69.75	2.69 ÷ 10.97
ECONOMIC ISSUES	Investment cost [€]	39288 ÷ 154925	52068 ÷ 169038	528925 ÷ 887802	251082 ÷ 389904
	Net Present Value (50 years) [€]	44513 ÷ 175530	58993 ÷ 191520	599272 ÷ 1005879	284475 ÷ 441761
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	44 ÷ 95	55 ÷ 118	562 ÷ 1206	272 ÷ 569

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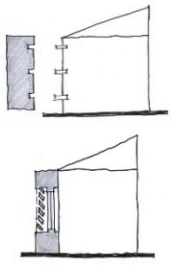
RENOVATION PACKAGE

GEOCLUSTER EAST

PREFABRICATED FACADE + PLUG&PLAY ENERGY HUB (+ SOLAR THERMAL)




	Tot Area	**88 m2**	**228 m2**	**3456 m2**	**1330 m2**
REQUIREMENTS OF THE ENVELOPE 	Opaque part — Prefabricated facade thickness [cm]	~20 ÷ ~35			
	Opaque part — Final U-value wall [W/m²K]	~0.2 ÷ ~0.1			
	Window — Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
	Window — Frame U-value [W/m²K]	1.4 ÷ 1			
	Window — g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
	Shading system — Presence	May be applicable			
	Shading system — Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			
	Plug&Play Energy Hub — Presence	Used in order to improve efficiency of heating, cooling and DHW systems. Approximately, a decrease of 20% in consumptions of these systems is expected.			

Key Performance Indicators

ENERGY	Heating demand [kWh/m²]	66.82 ÷ 73.7	40.9 ÷ 49.38	29.51 ÷ 33.57	31.07 ÷ 32.95
	Cooling demand [kWh/m²]	2.06 ÷ 21.54	0 ÷ 0.32	1.1 ÷ 9.83	3.36 ÷ 13.58
	Ventilation consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Ceiling fan consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Estimated ST production (roof placement) [MWh]	1.52	1.46	32.85	12.31
	Energy Consumption (H + C) savings due to EnergyHub	-20%	-20%	-20%	-20%
	DHW consumption savings due to Energy Hub	-20%	-20%	-20%	-20%
	Energy demand (H+C) saving respect to non-renovated	-70.97% ÷ -60.94%	-82.24% ÷ -70.48%	-67.45% ÷ -56.78%	-57.24% ÷ -43.59%
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more	CAT_1_PPM	100% ÷ 100%	65.57% ÷ 72.75%	21.71% ÷ 24.91%	99.98% ÷ 99.98%
	CAT_2_PPM	0% ÷ 0%	9.94% ÷ 11.66%	10.38% ÷ 10.99%	0% ÷ 0%

explanation on these KPIs)	CAT_I_Adpt (evaluated in cooling period)	0% ÷ 81.1%	57.43% ÷ 98.99%	12.14% ÷ 85.09%	0% ÷ 11.74%
	CAT_II_Adpt (evaluated in cooling period)	0.25% ÷ 22.41%	0.88% ÷ 28.46%	12.69% ÷ 31.46%	0% ÷ 19.8%
	pmv _CatI (evaluated in heating period)	3.34% ÷ 8.47%	2.52% ÷ 3.99%	10.42% ÷ 15%	4.43% ÷ 13.45%
	pmv _CatII (evaluated in heating period)	8.43% ÷ 16.17%	4.96% ÷ 20.73%	13.98% ÷ 20.28%	8.84% ÷ 16.73%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.312÷1.568	1.384÷1.984	41.448÷55.904	1.856÷9.952
ECONOMIC ISSUES	Investment cost [€] **(Not considering Energy Hub Technology)**	38272 ÷ 154198	49471 ÷ 167178	489029 ÷ 859237	235682 ÷ 378878
	Net Present Value (50 years) [€] **(Not considering Energy Hub Technology)**	43362 ÷ 174706	56050 ÷ 189412	554069 ÷ 973515	267027 ÷ 429268
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours] **(Not considering Energy Hub Technology)**	44 ÷ 95	55 ÷ 118	562 ÷ 1206	272 ÷ 569

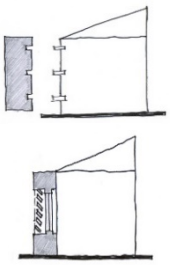
5 GEOCLUSTER ATLANTIC

1 RENOVATION PACKAGE

GEOCLUSTER ATLANTIC

PREFABRICATED FACADE




		Tot Area	88 m2	228 m2	3456 m2	1330 m2
REQUIREMENTS OF THE ENVELOPE		Opaque part	Prefabricated facade thickness [cm]	~20 ÷ ~35			
			Final U-value wall [W/m²K]	~0.2 ÷ ~0.1			
		Window	Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
			Frame U-value [W/m²K]	1.4 ÷ 1			
			g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
		Shading system	Presence	May be applicable			
			Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			

Key Performance Indicators					
ENERGY	Heating demand [kWh/m²]	40.7 ÷ 46.26	48.47 ÷ 59.19	32.25 ÷ 35.68	14.09 ÷ 15.95
	Cooling demand [kWh/m²]	0.37 ÷ 12.61	0 ÷ 0	0 ÷ 2.17	1.22 ÷ 8.9
	Ventilation consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Ceiling fan consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Estimate PV power production [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	PEF (H+C) saving respect to non-renovated	-90.43% ÷ -75.13%	-89.38% ÷ -77.42%	-86.42% ÷ -79.36%	-88.83% ÷ -61.9%
	Energy demand (H+C) saving respect to non-renovated	-78.39% ÷ -70.73%	-82.24% ÷ -70.48%	-77.14% ÷ -74.59%	-72.71% ÷ -59.91%
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more	CAT_1_PPM	100% ÷ 100%	75.33% ÷ 76.32%	10.67% ÷ 13.31%	99.98% ÷ 99.98%
	CAT_2_PPM	0% ÷ 0%	9.88% ÷ 10.25%	13.72% ÷ 15.44%	0% ÷ 0%

explanation on these KPIs)	CAT_I_Adpt (evaluated in cooling period)	4.28% ÷ 96.22%	0.37% ÷ 63.09%	7.59% ÷ 100%	0% ÷ 35.1%
	CAT_II_Adpt (evaluated in cooling period)	3.77% ÷ 35.76%	0% ÷ 23.8%	0% ÷ 57.34%	0.68% ÷ 23.56%
	pmv _CatI (evaluated in heating period)	4.8% ÷ 10.14%	0% ÷ 0%	0.02% ÷ 6.03%	7.93% ÷ 16.47%
	pmv _CatII (evaluated in heating period)	9.53% ÷ 11.85%	0.77% ÷ 4.56%	1.5% ÷ 13.31%	13.18% ÷ 21.08%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.24 ÷ 1.18	1.58 ÷ 2.97	16.22 ÷ 30.03	1.05 ÷ 6.53
ECONOMIC ISSUES	Investment cost [€]	56920 ÷ 229327	73575 ÷ 248632	727297 ÷ 1277881	350513 ÷ 563478
	Net Present Value (50 years) [€]	64490 ÷ 259827	83360 ÷ 281700	824027 ÷ 1447839	397131 ÷ 638420
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	44 ÷ 95	55 ÷ 118	562 ÷ 1206	272 ÷ 569

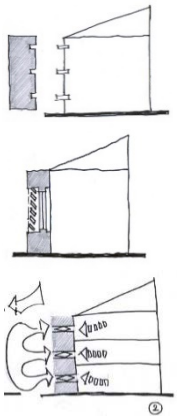
2

RENOVATION PACKAGE

GEOCLUSTER ATLANTIC

PREFABRICATED FACADE + DECENTRALIZED VENTILATION




		Tot Area	88 m2	228 m2	3456 m2	1330 m2
REQUIREMENTS OF THE COMPONENTS		Opaque part	Prefabricated facade thickness [cm]	~20 ÷ ~35			
			Final U-value wall [W/m²K]	~0.2 ÷ ~0.1			
		Window	Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
			Frame U-value [W/m²K]	1.4 ÷ 1			
			g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
		Shading system	Presence	May be applicable			
			Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			
		Mechanical ...	Type	Decentralized ventilation system providing punctual inlet and outlet of air. Decentralized machine also provides heat recovery. The mechanical ventilation system is considered to be switched off during summer period (from June to August).			

Key Performance Indicators

ENERGY	Heating demand [kWh/m²]	37.5 ÷ 42.89	20.05 ÷ 30.82	1.95 ÷ 5.06	6.63 ÷ 7.58
	Cooling demand [kWh/m²]	0.44 ÷ 13.84	0 ÷ 0	0 ÷ 5.36	2.9 ÷ 13.88
	Ventilation consumption [kWh]	408.2 ÷ 408.2	799.95 ÷ 799.95	10632.66 ÷ 10632.66	10558.21 ÷ 10558.21
	Ceiling fan consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Estimate PV power production [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	PEF (H+C) saving respect to non-renovated	-91.18% ÷ -75.71%	-94.46% ÷ -89.52%	-99.17% ÷ -89.98%	-94.73% ÷ -61.47%
	Energy demand (H+C) saving respect to non-renovated	-79.97% ÷ -71.86%	-90.85% ÷ -85.94%	-98.56% ÷ -93.85%	-83.17% ÷ -64.9%
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more	CAT_1_PPM	43.16% ÷ 43.16%	79.95% ÷ 80.66%	3.36% ÷ 5.79%	3.09% ÷ 3.09%
	CAT_2_PPM	19.98% ÷ 19.98%	9.35% ÷ 9.69%	6.06% ÷ 7.38%	2.82% ÷ 2.82%

explanation on these KPIs)	CAT_I_Adpt (evaluated in cooling period)	1.51% ÷ 93.82%	0.37% ÷ 64.86%	5.93% ÷ 100%	0% ÷ 1.63%
	CAT_II_Adpt (evaluated in cooling period)	1.76% ÷ 17.75%	0% ÷ 23.8%	0% ÷ 61%	0% ÷ 8.6%
	pmv _CatI (evaluated in heating period)	6.06% ÷ 16.08%	0% ÷ 2.36%	10.19% ÷ 24.72%	11.19% ÷ 17.95%
	pmv _CatII (evaluated in heating period)	8.47% ÷ 12.09%	14.94% ÷ 28.63%	20.25% ÷ 34.39%	14.96% ÷ 24.91%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.22 ÷ 1.14	0.65 ÷ 1.55	0.98 ÷ 12.48	0.49 ÷ 6.19
ECONOMIC ISSUES	Investment cost [€]	62628 ÷ 235036	80551 ÷ 255609	798334 ÷ 1348918	385679 ÷ 598644
	Net Present Value (50 years) [€]	70957 ÷ 266295	91264 ÷ 289604	904512 ÷ 1528324	436974 ÷ 678263
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	47 ÷ 98	58 ÷ 122	596 ÷ 1240	288 ÷ 586

3

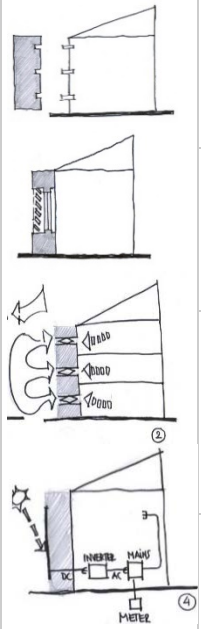
RENOVATION PACKAGE

GEOCLUSTER ATLANTIC

PREFABRICATED FACADE + DECENTRALIZED VENTILATION + BIPV




	Tot Area	**88 m2**	**228 m2**	**3456 m2**	**1330 m2**
REQUIREMENTS OF THE COMPONENTS	Opaque part	Prefabricated facade thickness [cm]	~20 ÷ ~35			
		Final U-value wall [W/m²K]	~0.2 ÷ ~0.1			
	Window	Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
		Frame U-value [W/m²K]	1.4 ÷ 1			
		g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
	Shading system	Presence	May be applicable			
		Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			
	Mechanical ventilation	Type	Decentralized ventilation system providing punctual inlet and outlet of air. Decentralized machine also provides heat recovery. The mechanical ventilation system is considered to be switched off during summer period (from June to August).			



Key Performance Indicators

ENERGY	Heating demand [kWh/m²]	37.5 ÷ 42.89	20.05 ÷ 30.82	1.95 ÷ 5.06	6.63 ÷ 7.58
	Cooling demand [kWh/m²]	0.44 ÷ 13.84	0 ÷ 0	0 ÷ 5.36	2.9 ÷ 13.88
	Ventilation consumption [kWh]	408.2 ÷ 408.2	799.95 ÷ 799.95	10632.66 ÷ 10632.66	10558.21 ÷ 10558.21
	Ceiling fan consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Estimate PV power production [kWh]	940.03 ÷ 940.03	12483.25 ÷ 12483.25	20091.65 ÷ 20091.65	5205.22 ÷ 5205.22
	PEF (H+C) saving respect to non-renovated	-91.18% ÷ -75.71%	-94.46% ÷ -89.52%	-99.17% ÷ -89.98%	-94.73% ÷ -61.47%
	Energy demand (H+C) saving respect to non-renovated	-79.97% ÷ -71.86%	-90.85% ÷ -85.94%	-98.56% ÷ -93.85%	-83.17% ÷ -64.9%
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more	CAT_1_PPM	43.16% ÷ 43.16%	79.95% ÷ 80.66%	3.36% ÷ 5.79%	3.09% ÷ 3.09%
	CAT_2_PPM	19.98% ÷ 19.98%	9.35% ÷ 9.69%	6.06% ÷ 7.38%	2.82% ÷ 2.82%

explanation on these KPIs)	CAT_I_Adpt (evaluated in cooling period)	1.51% ÷ 93.82%	0.37% ÷ 64.86%	5.93% ÷ 100%	0% ÷ 1.63%
	CAT_II_Adpt (evaluated in cooling period)	1.76% ÷ 17.75%	0% ÷ 23.8%	0% ÷ 61%	0% ÷ 8.6%
	pmv _CatI (evaluated in heating period)	6.06% ÷ 16.08%	0% ÷ 2.36%	10.19% ÷ 24.72%	11.19% ÷ 17.95%
	pmv _CatII (evaluated in heating period)	8.47% ÷ 12.09%	14.94% ÷ 28.63%	20.25% ÷ 34.39%	14.96% ÷ 24.91%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.22 ÷ 1.14	0.65 ÷ 1.55	0.98 ÷ 12.48	0.49 ÷ 6.19
ECONOMIC ISSUES	Investment cost [€]	64987 ÷ 237395	83435 ÷ 258493	827692 ÷ 1378276	400213 ÷ 613177
	Net Present Value (50 years) [€]	73630 ÷ 268968	94531 ÷ 292872	937775 ÷ 1561586	453441 ÷ 694729
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	50 ÷ 100	62 ÷ 125	630 ÷ 1275	305 ÷ 603

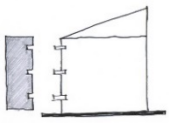
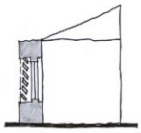
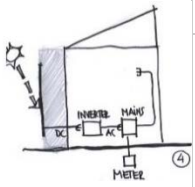
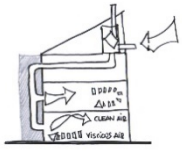
4

RENOVATION PACKAGE

GEOCLUSTER ATLANTIC

PREFABRICATED FACADE + CENTRALIZED VENTILATION + BIPV




		Tot Area	88 m2	228 m2	3456 m2	1330 m2
REQUIREMENTS OF THE COMPONENTS		Opaque part	Prefabricated facade thickness [cm]	~20 ÷ ~35			
			Final U-value wall [W/m²K]	~0.2 ÷ ~0.1			
		Window	Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
			Frame U-value [W/m²K]	1.4 ÷ 1			
			g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
		Shading system	Presence	May be applicable			
			Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			
		Mechanical ...	Type	Balanced Air Handling Unit for centralized ventilation system. Centralized machine also provides heat recovery. The mechanical ventilation system is considered to be switched off during summer period (from June to August).			

Key Performance Indicators					
ENERGY	Heating demand [kWh/m²]	39.16 ÷ 44.68	17.78 ÷ 28.51	0.98 ÷ 3.86	7.53 ÷ 8.57
	Cooling demand [kWh/m²]	0.39 ÷ 13.26	0 ÷ 0	0.07 ÷ 6.55	2.59 ÷ 13.12
	Ventilation consumption [kWh]	217.04 ÷ 217.04	471.27 ÷ 471.27	5058.25 ÷ 5058.25	5613.76 ÷ 5613.76
	Ceiling fan consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Estimate PV power production [kWh]	940.03 ÷ 940.03	12483.25 ÷ 12483.25	20091.65 ÷ 20091.65	5205.22 ÷ 5205.22
	PEF (H+C) saving respect to non-renovated	-90.79% ÷ -75.38%	-95.08% ÷ -90.31%	-99.58% ÷ -88.67%	-94.02% ÷ -61.95%
	Energy demand (H+C) saving respect to non-renovated	-79.16% ÷ -71.25%	-91.88% ÷ -86.99%	-99.02% ÷ -93.8%	-82.15% ÷ -64.57%
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more	CAT_1_PPM	45.22% ÷ 45.22%	79.95% ÷ 80.66%	3.36% ÷ 5.81%	4.46% ÷ 4.46%
	CAT_2_PPM	26.75% ÷ 26.75%	9.35% ÷ 9.69%	6.06% ÷ 7.38%	3.63% ÷ 3.63%

explanation on these KPIs)	CAT_I_Adpt (evaluated in cooling period)	1.76% ÷ 94.08%	0.37% ÷ 65.49%	5.93% ÷ 100%	0% ÷ 4.09%
	CAT_II_Adpt (evaluated in cooling period)	2.26% ÷ 24.81%	0% ÷ 23.92%	0% ÷ 61.35%	0% ÷ 14.13%
	pmv _CatI (evaluated in heating period)	5.66% ÷ 15.23%	0% ÷ 4.19%	8.47% ÷ 25.76%	10.77% ÷ 18.39%
	pmv _CatII (evaluated in heating period)	9.08% ÷ 10.83%	25.13% ÷ 41.71%	20.04% ÷ 38.76%	15.34% ÷ 24.54%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.23 ÷ 1.16	0.58 ÷ 1.43	0.49 ÷ 13.89	0.56 ÷ 6.16
ECONOMIC ISSUES	Investment cost [€]	66422 ÷ 238829	85188 ÷ 260245	845539 ÷ 1396122	409047 ÷ 622012
	Net Present Value (50 years) [€]	75256 ÷ 270593	96518 ÷ 294857	957995 ÷ 1581806	463450 ÷ 704739
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	110 ÷ 161	135 ÷ 199	1382 ÷ 2027	678 ÷ 976

5

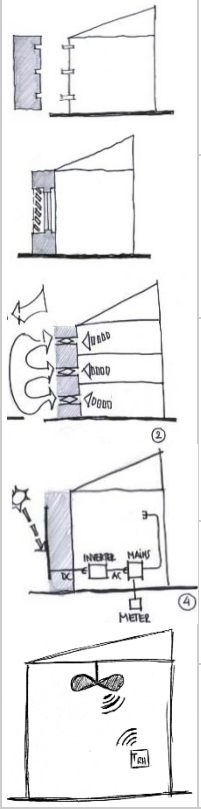
RENOVATION PACKAGE

GEOCLUSTER ATLANTIC

PREFABRICATED FACADE + DECENTRALIZED VENTILATION + BIPV + SMART CEILING FAN




		Tot Area	88 m2	228 m2	3456 m2	1330 m2
REQUIREMENTS OF THE COMPONENTS	Opaque part	Prefabricated facade thickness [cm]	~20 ÷ ~35			
		Final U-value wall [W/m²K]	~0.2 ÷ ~0.1			
	Window	Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
		Frame U-value [W/m²K]	1.4 ÷ 1			
		g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
	Shading system	Presence	May be applicable			
		Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			
	Mechanical ...	Type	Decentralized ventilation system providing punctual inlet and outlet of air. Decentralized machine also provides heat recovery. The mechanical ventilation system is considered to be switched off during summer period (from June to August).			
	Smart ceiling ...	Control strategy	Temperature and relative humidity sensor communicate with the smart ceiling fan to automatically adjust its fan speed			



Key Performance Indicators

ENERGY	Heating demand [kWh/m²]	37.5 ÷ 42.89	20.05 ÷ 30.82	1.95 ÷ 5.06	6.63 ÷ 7.58
	Cooling demand [kWh/m²]	0 ÷ 9.22	0 ÷ 0	0 ÷ 1.94	0.94 ÷ 9.6
	Ventilation consumption [kWh]	408.2 ÷ 408.2	799.95 ÷ 799.95	10632.66 ÷ 10632.66	10558.21 ÷ 10558.21
	Ceiling fan consumption [kWh]	1.79 ÷ 131.76	0 ÷ 0	3.38 ÷ 2258.36	187.2 ÷ 460.39
	Estimate PV power production [kWh]	940.03 ÷ 940.03	12483.25 ÷ 12483.25	20091.65 ÷ 20091.65	5205.22 ÷ 5205.22
	PEF (H+C) saving respect to non-renovated	-91.09% ÷ -78.63%	-94.46% ÷ -89.52%	-99.16% ÷ -95.18%	-92.3% ÷ -70.64%
	Energy demand (H+C) saving respect to non-renovated	-80.45% ÷ -74.25%	-90.85% ÷ -85.94%	-98.62% ÷ -95.77%	-86.74% ÷ -72.04%

COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more explanation on these KPIs)	CAT_1_PPM	43.16% ÷ 43.16%	79.95% ÷ 80.66%	3.36% ÷ 5.7%	3.09% ÷ 3.09%
	CAT_2_PPM	19.98% ÷ 19.98%	9.35% ÷ 9.69%	6.06% ÷ 7.4%	2.82% ÷ 2.82%
	CAT_I_Adpt (evaluated in cooling period)	1.51% ÷ 93.82%	0.37% ÷ 64.86%	3.58% ÷ 100%	0% ÷ 1.63%
	CAT_II_Adpt (evaluated in cooling period)	1.76% ÷ 17.75%	0% ÷ 23.8%	0% ÷ 55.9%	0% ÷ 8.6%
	pmv _CatI (evaluated in heating period)	6.06% ÷ 16.08%	0% ÷ 2.36%	8.21% ÷ 24.33%	11.19% ÷ 17.95%
	pmv _CatII (evaluated in heating period)	8.47% ÷ 12.09%	14.94% ÷ 28.63%	16.82% ÷ 29.19%	14.96% ÷ 24.91%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.22 ÷ 1.02	0.65 ÷ 1.55	0.99 ÷ 6.27	0.86 ÷ 4.79
ECONOMIC ISSUES	Investment cost [€]	66498 ÷ 238476	87298 ÷ 261258	887027 ÷ 1420759	423115 ÷ 629575
	Net Present Value (50 years) [€]	75342 ÷ 270193	98908 ÷ 296005	1005001 ÷ 1609719	479389 ÷ 713308
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	50 ÷ 100	62 ÷ 125	630 ÷ 1275	305 ÷ 603

6

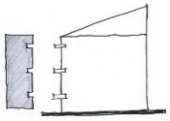
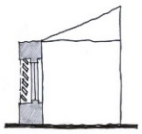
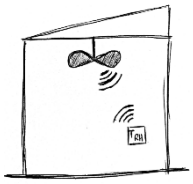
RENOVATION PACKAGE

GEOCLUSTER ATLANTIC

PREFABRICATED FACADE + SMART CEILING FAN




		Tot Area	88 m2	228 m2	3456 m2	1330 m2
REQUIREMENTS OF THE COMPONENTS	Opaque part	Prefabricated facade thickness [cm]	~20 ÷ ~35			
		Final U-value wall [W/m²K]	~0.2 ÷ ~0.1			
	Window	Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
		Frame U-value [W/m²K]	1.4 ÷ 1			
		g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
	Shading system	Presence	May be applicable			
		Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			
	Smart ceiling fan	Control strategy	Temperature and relative humidity sensor communicate with the smart ceiling fan to automatically adjust its fan speed			

Key Performance Indicators

ENERGY	Heating demand [kWh/m²]	40.7 ÷ 46.26	63.54 ÷ 72.26	32.25 ÷ 35.68	14.09 ÷ 15.95
	Cooling demand [kWh/m²]	0 ÷ 7.96	0 ÷ 0.01	0 ÷ 0.49	0.11 ÷ 5
	Ventilation consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Ceiling fan consumption [kWh]	1.07 ÷ 126	0 ÷ 8.67	0 ÷ 918.45	55.59 ÷ 334.39
	Estimate PV power production [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	PEF (H+C) saving respect to non-renovated	-90.38% ÷ -78.06%	-83.83% ÷ -69.49%	-86.25% ÷ -81.43%	-88.04% ÷ -70.06%
	Energy demand (H+C) saving respect to non-renovated	-78.82% ÷ -73.13%	-63.98% ÷ -59.05%	-77.5% ÷ -75.19%	-75.38% ÷ -66.4%
COMFORT AND IAQ	CAT_1_PPM	100% ÷ 100%	69.39% ÷ 72.84%	10.67% ÷ 13.22%	99.98% ÷ 99.98%

(check Table 3 of Deliverable 3.3 for more explanation on these KPIs)	CAT_2_PPM	0% ÷ 0%	10.34% ÷ 10.86%	13.72% ÷ 15.46%	0% ÷ 0%
	CAT_I_Adpt (evaluated in cooling period)	4.28% ÷ 96.22%	15.49% ÷ 88.66%	5.93% ÷ 100%	0% ÷ 35.1%
	CAT_II_Adpt (evaluated in cooling period)	3.77% ÷ 35.76%	10.83% ÷ 32.36%	0% ÷ 52.79%	0.68% ÷ 23.56%
	pmv _CatI (evaluated in heating period)	4.8% ÷ 10.14%	0% ÷ 4.27%	0.02% ÷ 6.03%	7.93% ÷ 16.47%
	pmv _CatII (evaluated in heating period)	9.53% ÷ 11.85%	2.24% ÷ 6.19%	1.5% ÷ 13.23%	13.18% ÷ 21.08%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.24 ÷ 1.06	2.53 ÷ 3.63	16.42 ÷ 27.58	1.15 ÷ 5.29
ECONOMIC ISSUES	Investment cost [€]	58431 ÷ 230409	77438 ÷ 251398	786632 ÷ 1320364	373416 ÷ 579876
	Net Present Value (50 years) [€]	66202 ÷ 261053	87737 ÷ 284833	891254 ÷ 1495972	423080 ÷ 656999
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	44 ÷ 95	55 ÷ 118	562 ÷ 1206	272 ÷ 569

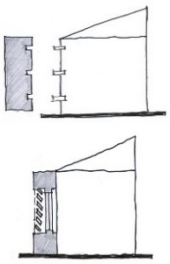
7

RENOVATION PACKAGE

GEOCLUSTER ATLANTIC

PREFABRICATED FACADE + PLUG&PLAY ENERGY HUB (+ SOLAR THERMAL)




	Tot Area	**88 m2**	**228 m2**	**3456 m2**	**1330 m2**
REQUIREMENTS OF THE COMPONENTS		Opaque part	Prefabricated facade thickness [cm]	~20 ÷ ~35			
			Final U-value wall [W/m²K]	~0.2 ÷ ~0.1			
		Window	Glazing U-value [W/m²K]	1.24 ÷ 0.61	1.1 ÷ 0.62	1.24 ÷ 0.61	1.24 ÷ 0.61
			Frame U-value [W/m²K]	1.4 ÷ 1			
			g-value [%]	58 ÷ 40	62 ÷ 60	58 ÷ 40	58 ÷ 40
		Shading system	Presence	May be applicable			
			Logic	If present, the shading system control is depending on external temperature, incident radiation and internal temperature			
		Plug&Play Energy Hub	Presence	Used in order to improve efficiency of heating, cooling and DHW systems. Approximately, a decrease of 20% in consumptions of these systems is expected.			

Key Performance Indicators					
ENERGY	Heating demand [kWh/m²]	40.7 ÷ 46.26	48.47 ÷ 59.19	32.25 ÷ 35.68	14.09 ÷ 15.95
	Cooling demand [kWh/m²]	0.37 ÷ 12.61	0 ÷ 0	0 ÷ 2.17	1.22 ÷ 8.9
	Ventilation consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Ceiling fan consumption [kWh]	0 ÷ 0	0 ÷ 0	0 ÷ 0	0 ÷ 0
	Estimated ST production (roof placement) [MWh]	1.47	1.42	32.91	12.35
	Energy Consumption (H + C) savings due to EnergyHub	-20%	-20%	-20%	-20%
	DHW consumption savings due to Energy Hub	-20%	-20%	-20%	-20%
	Energy demand (H+C) saving respect to non-renovated	-78.39% ÷ -70.73%	-82.24% ÷ -70.48%	-77.14% ÷ -74.59%	-72.71% ÷ -59.91%
COMFORT AND IAQ	CAT_1_PPM	100% ÷ 100%	75.33% ÷ 76.32%	10.67% ÷ 13.31%	99.98% ÷ 99.98%

(check Table 3 of Deliverable 3.3 for more explanation on these KPIs)	CAT_2_PPM	0% ÷ 0%	9.88% ÷ 10.25%	13.72% ÷ 15.44%	0% ÷ 0%
	CAT_I_Adpt (evaluated in cooling period)	4.28% ÷ 96.22%	0.37% ÷ 63.09%	7.59% ÷ 100%	0% ÷ 35.1%
	CAT_II_Adpt (evaluated in cooling period)	3.77% ÷ 35.76%	0% ÷ 23.8%	0% ÷ 57.34%	0.68% ÷ 23.56%
	pmv _CatI (evaluated in heating period)	4.8% ÷ 10.14%	0% ÷ 0%	0.02% ÷ 6.03%	7.93% ÷ 16.47%
	pmv _CatII (evaluated in heating period)	9.53% ÷ 11.85%	0.77% ÷ 4.56%	1.5% ÷ 13.31%	13.18% ÷ 21.08%
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	0.192÷0.944	1.264÷2.376	12.976÷24.024	0.84÷5.224
ECONOMIC ISSUES	Investment cost [€] **(Not considering Energy Hub Technology)**	56920 ÷ 229327	73575 ÷ 248632	727297 ÷ 1277881	350513 ÷ 563478
	Net Present Value (50 years) [€] **(Not considering Energy Hub Technology)**	64490 ÷ 259827	83360 ÷ 281700	824027 ÷ 1447839	397131 ÷ 638420
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours] **(Not considering Energy Hub Technology)**	44 ÷ 95	55 ÷ 118	562 ÷ 1206	272 ÷ 569