RINNO

RINNO PROJECT *Report*

Transforming energy efficiency in European building stock through technology-enabled deep energy renovation

Deliverable 1.4: RINNO Pilot Analysis and Deployment Plan

Work Package 1: RINNO Augmented Intelligence Renovation Framework

Enrico Scoditti
Eva Raggi

April 2021

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 892071

Document Information

Title	RINNO Pilot Analysis and Deployment Plan
Author(s)	Enrico Scoditti (Rina-C)
Editor(s)	Paola Robello (Rina-C)
Reviewed by	CERTH, EKOLAB
Document Nature	Report
Date	07/04/2021 05/05/2021 (Actual date)
Dissemination Level	Public
Status	Open Deliverable
Copyright	All rights reserved by the authors and the RINNO consortium
Grant Agreement Number	892071

Revision History

Version	Editor(s)	Date	Change Log
0.1	Enrico Scoditti	15/12/2020	Preliminary draft
0.2	Eva Raggi	15/01/2021	Common methodology
0.3	Enrico Scoditti	10/02/2021	Greek pilot contribution
0.4	Enrico Scoditti	20/02/2021	Polish pilot contribution
0.5	Enrico Scoditti	09/03/2021	Danish pilot contribution

0.6	Enrico Scoditti	12/03/2021	French pilot contribution
1.1	Arianna Amati	18/03/2021	Review
1.2	Enrico Scoditti	26/03/2021	Updated content
1.3	Paola Robello	29/03/2021	Review
1.4	Enrico Scoditti	06/04/2021	Updated content
1.5	Vasileios Sougkakis, Stelios Krinidis	13/04/2021	Review
1.6	Elsebeth Terkelsen	14/04/2021	Peer review
1.7	Diane Olsen, Jørgen Lange	21/04/2021	Peer Review
1.8	Enrico Scoditti	05/05/2021	Updated content
1.9	Enrico Scoditti	15/07/2021	Redaction of a new version
2.0	Enrico Scoditti	24/08/2021	Submission of new version

Executive Summary

This report presents the preliminary renovation scenarios identified for each pilot included in the project. It focuses mainly on the expected impact of the implementation of each technology in the pilot buildings, and thus on their adequacy to meet occupants' needs and pursue RINNO project goals

The main objective of RINNO is to help drastically accelerate the rate of deep renovation of energy inefficient buildings and thereby contribute to Europe's medium-term ambition of a 3,5% yearly renovation rate of its building stock. To this end, Task 1.3 "Pilot Sites Surveys & Definition of Use Case Renovation Scenarios" aims to draft the preliminary deep renovation scenarios related to the demonstrators, based on the results of the pre-surveys and occupant needs analysis. Scenarios that, when finalized, will be evaluated to verify the adequacy of the RINNO solutions with respect to the project objectives.

Among the activities conducted to draft the preliminary renovation scenarios, the most relevant have included:

- Definition of a questionnaire aimed at framing the occupants' needs, desires, and objectives, from whose answers it has been then possible to extract the drivers for the design of the renovation scenarios
- Analysis of the information provided by the preliminary surveys, which enabled the identification of structural, architectural and technological constraints.
- Analysis of the RINNO technological solutions to qualitatively assess their applicability to the different pilot buildings and their effect in relation to occupants' needs and project objectives

The present document is organised as follows:

In **Section 2**, the approach adopted for the pilot analysis is reported.

Section 3 is, instead, dedicated to the analysis of the categories by which the RINNO technologies have been classified. The aim of this analysis is to identify their limits, benefits and fields of application.

Finally, **Section 4, 5, 6 and 7** are devoted to the different pilots. In each chapter, after an overall brief description of the building, all the steps identified in the methodology described in Chapter 2 are addressed, culminating in the description of the selected deep renovation scenarios.

Table of Contents

TABLE OF FIGURES

List of acronyms

Acronym	Description
BM	Business Model
BRPs	Building Renovation Passports
DoA	Description of Action
EC	European Commission
EE	Energy Efficiency
EM	Exploitation Manager
EU	European Union
GA	Grant Agreement
IPR	Intellectual Property Right
KPI	Key Performance Indicators
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
PB	Plenary Board
PC	Project Coordinator
PM	Pilot Manager
RES	Renewable Energy Sources
RPDA	RINNO Planning & Design Assistant
RRM	RINNO Retrofitting Manager
RRR	RINNO Renovation Repository
WP	Work Package

1. Introduction

This report describes the results of the work undertaken so far in the context of task T1.3 – "Pilot Sites Surveys & Definition of Use Case Renovation Scenarios". Final purpose of the task is precisely to define, for each demonstrator involved in the project, the deep renovation scenarios that will then be processed and analyzed in the framework of WP3, through the "RINNO Renovation Optimizer & Planner" module. In particular, the scenarios qualitatively defined in this task represent the starting point for the scenarios that will be thoroughly and quantitatively defined in task T3.2.

The results of this activity will also enable technical description of the overall RINNO Suite (Task 1.5), by supporting the definition of the connection between the renovation scenarios and the platform modules.
It is worth to mention also that the proposed renovation scenarios are compliant with the national regulations and standards as identified in D1.3 (Task 1.2 outcome).

During the first phase of the task, to which this report refers, the first preliminary surveys of the buildings have been carried out, with the aim of identifying structural, architectural and technological constraints. Moreover, a questionnaire aimed at framing the needs, desires and objectives to be pursued through the renovation process has been prepared and circulated among the residents of the buildings (the questionnaires are reported in Annex). On the basis of (1) the framework provided by this preliminary analytical activity and through (2) the qualitative assessment of the impacts that the individual technologies involved in RINNO have in pursuing the specific objectives of each demonstrator, it has been possible to define preliminary renovation scenarios, which will however be reviewed and further developed in the light of more in-depth investigations that will take place in the course of the activity (and included in the second release of this report).

The methodological approach, common to all the demos analyzed, is described in depth in Chapter 2. Chapter 3 is, instead, dedicated to the analysis of the categories by which the RINNO technologies have been classified. The aim of this analysis is to define their limits, benefits and fields of application. Finally, the remaining chapters are devoted to the different demonstrators. In each chapter, after an overall brief description of the building, the following contents are reported:

1. the description of the preliminary survey and questionnaire results
2. analysis of the expected impacts for each technology
3. the description of the preliminary rehabilitation scenarios

according to the scheme indicated in the methodological approach described in Chapter 2.

2. Common methodology

This section describes the methodology adopted to qualitatively define the most promising renovation scenarios for each demonstrator, which will be considered during the following project phases, when the scenarios to be analyzed will be precisely defined and modelled. The process consists of four steps, some of which are iterated during both the phases of which this task is composed. The four steps are:

- Assessment of the existing condition
- Definition of objectives
- Analysis of the most appropriate solutions
- Definition of the Renovation Scenarios

Figure 1 represents the schematic overview of the methodological approach to the task, while a description of the various steps mentioned is provided below.

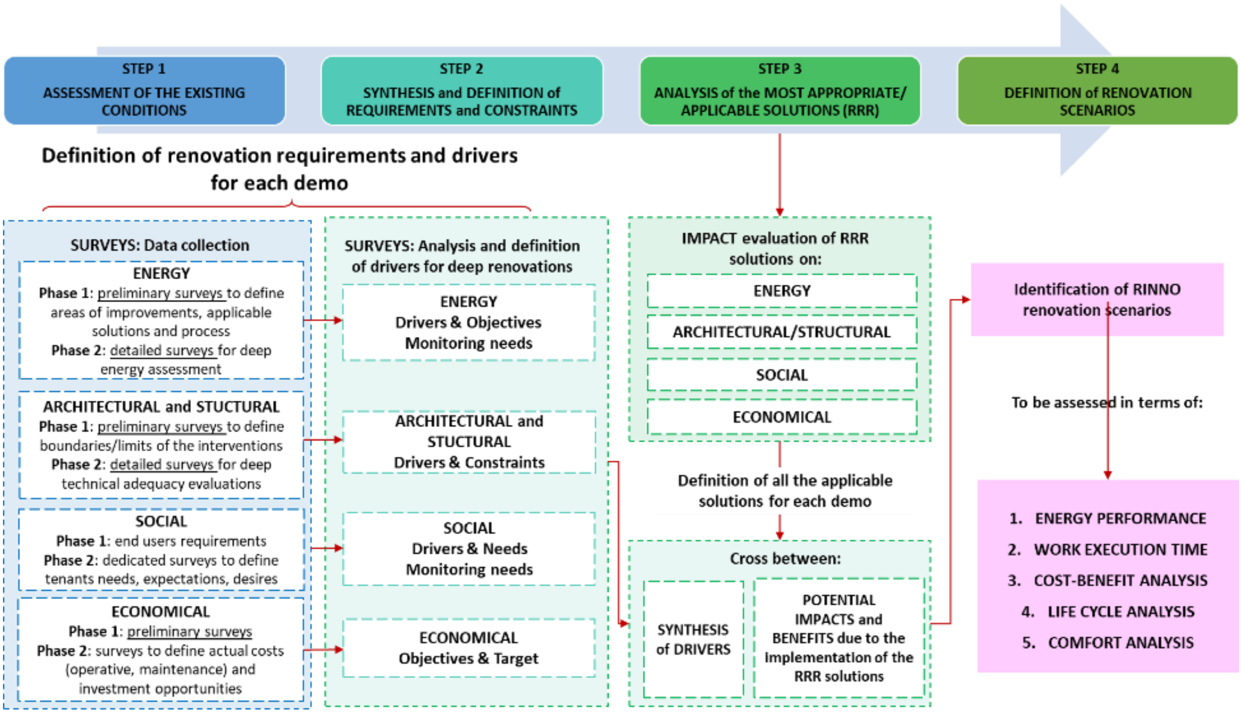

Figure 1 - Methodological approach adopted. Overview

- **Step 1 - Assessment of the existing conditions:**

The objective of this phase is to get a picture of the existing condition of the building, with a level of detail consistent with the state of progress of the project. Thus, for the more technical aspects, two investigation and survey phases are scheduled, each one corresponding to a level of detail appropriate to the two phases of the task: a first preliminary level and a more detailed level are planned for the second part of the task.

For energy, structural and architectural aspects, the goal at this stage is to define:

- Rough identification of the materials and construction systems
- Identification of all relevant structural and architectural constraints
- Preliminary analysis of the main degradation factors

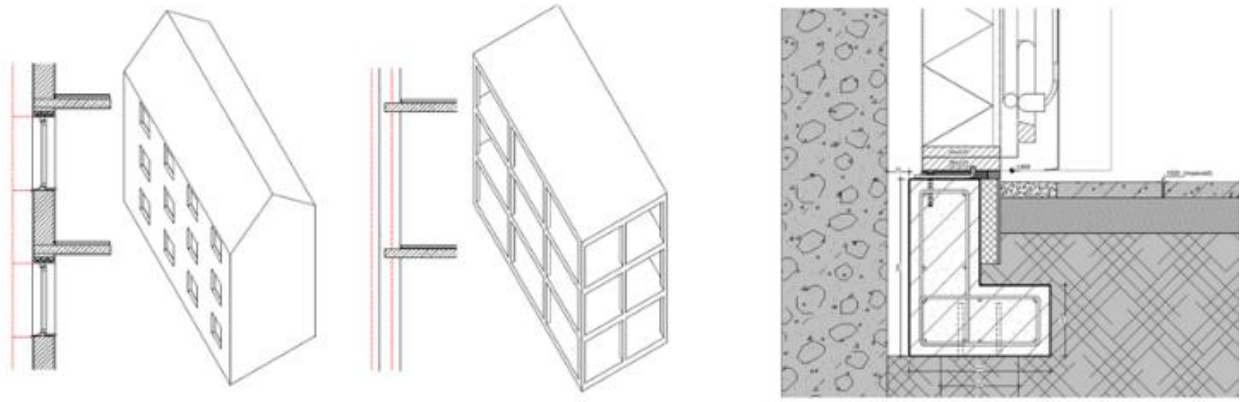

Figure 2 - Structural typologies and constraints for facade systems

Another objective of this preliminary phase is to identify the demo users, to interpret and understand their needs from a social, environmental and economic point of view. To this end, a questionnaire, slightly customized for each demo, was distributed to take into account the individual peculiarities of each building under investigation.

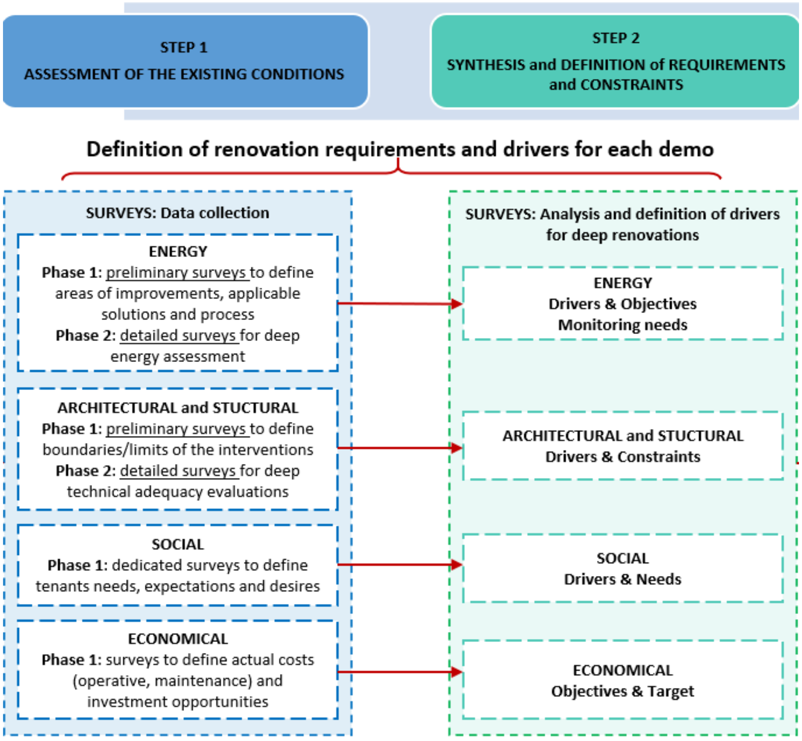

Figure 3 - Analysis and synthesis. From surveys to target definition

- **Step 2 – Definition of drivers and objectives:**

After the completion of the analysis carried out during phase 1, this step aims to define the objectives and to set priorities to be pursued through the possible renovation projects.
For the sake of clarity, the objectives recall those already selected in the questionnaires proposed and distributed among the users but, with respect to the outcomes, it will be adjusted and retuned taking into account the specificities of each demo, based also on previous project experiences gained by the partners involved in RINNO in the field of energy renovations in buildings.
Therefore, the 15 possible objectives to be pursued, listed in the table below, will be given a priority level that will also take into account the answers of the questionnaire.

		Objectives that can be achieved through a renovation process	Priority degree
ENERGY-RELATED	1	Heating cost savings	
	2	Cooling cost savings	
	3	Lighting cost savings	
ECONOMICAL	4	Minimization of renovation time	
	5	Minimization of renovation costs	
	6	Maintenance cost reduction	
SOCIAL	7	Eco-Labelling	
	8	Residents' Comfort	
	9	Better air quality	
	10	Building life extension	
	11	Building aesthetics enhancement	
	12	Lower noise level	
ENVIRON-MENTAL	13	Minimization of waste production	
	14	Carbon footprint	
	15	Eco-friendliness	

Figure 4 - Objectives and priority levels

- **Step 3 – Impact of renovation solutions:**

In this third step, the technologies related to energy renovations are first divided into 3 macro-categories.

The impact that each macro-category is expected to have in pursuing the identified objectives during the previous steps, is then analyzed to evaluate, by analogy, also the effect of each single technology present in the RRR. To this end, Chapter 3 addresses the arbitrary definition of the categories of interventions, providing a description and a brief analysis of their limitations, benefits, and areas of application, as well as the classification of the technologies in the RRR into such categories.

This work will be useful for the choice of the solutions to be implemented in each demonstrator.

- **Step 4 – Use-case definition:**

Finally, on the basis of the considerations made in the previous steps, after having analyzed impacts and design implications related to the adoption of each technology, it will be possible to select a limited and preliminary set of scenarios, to be subsequently checked and reviewed during the second phase of the task, when more detailed information will be available.

In chapter 4,5, 6 and 7 the above described steps are applied to each demo sites, and articulated into the following subsections:

- Step 1 and 2– Preliminary survey and questionnaire
- Step 3 – Impact of renovation solutions
- Step 4 – Preliminary renovation scenarios

3. Objectives-technologies matrix

This chapter is dedicated to the description of the renovation technologies considered by RINNO, in order to facilitate the subsequent identification of potential benefits, limits and applications fields.

This activity will enable a preliminary framing of all the considered technologies, supporting the impact assessment of the RINNO solutions (step 3), carried out in detail in the following chapters on demonstrators.

As already mentioned in the previous chapters, in order to not widen excessively the field of investigation, the considered solutions have been classified into categories, broken down into the following 3 macro families:

- Interventions on the envelope
- Interventions on systems
- Implementation of renewable energy systems

As a result of this activity, a matrix that includes objectives and possible interventions has been defined. The matrix allows therefore to select, among the applicable categories of technologies, the most suitable ones to satisfy the specific needs of each demonstrator. Below, the template of the matrix is shown. It will be reported/compiled later in the chapters specifically related to each demonstrator.

Drivers | Matrix types of interventions-objectives

	ENVELOPE					SYSTEMS				RES TECHNOLOGIES			
Objectives that can be achieved through a renovation process	Systems to renovate external facades	Systems to insulate from the inside	Plug and play system (for both ventilated and unventilated roof and facades)	Windows replacement (considering also coating)	Insufflation of organic insulation materials	Cooling systems (generation and distribution)	Heating Sistems (generation and distribution)	Ventilation systems (with air filtering)	Pipe/duct insulation	BIPV	Photovoltaic systems on roof	Solar collectors	Energy and heat storages
Heating cost* savings													
Cooling cost savings													
Lighting cost savings													
Minimization of renovation time													
Minimization of renovation costs													
Maintenance cost reduction													
Eco-Labelling													
Residents' Comfort													
Better air quality													
Building life extension													
Building aesthetics enhancement													
Lower noise level													
Minimization of waste production													
Carbon footprint													
Eco-friendliness													

*Includes costs for DHW production

Figure 5 - Objectives-technologies matrix. Template

In the following sections a brief description of the types of interventions taken into consideration is provided, including each of RINNO specific solutions

3.1 Interventions on the envelope

Possible interventions on the envelope include the following measures:

- **Facade insulation from the outside**

  As a general rule, this is always recommended, in the absence of external constraints. In wintertime it allows the storage of heat in the walls during the warm hours, and the subsequent re-emission to the interior during the cold hours. On the other hand, during the summer, the possibility of transferring heat to the wall mass is a typical passive cooling strategy for buildings.

  Among the technologies presented in RINNO, the **Bio-based double layer panels (K-FLEX)** can be applied in this mode. In fact, it can be applied both for internal and external use.

- **Facade insulation from the inside**

  It is generally not advisable, unless it is possible to isolate from the outside. The only situations where internal insulation may be preferable are when heating and cooling systems are supposed to operate intermittently or when room occupancy is occasional.

  As abovementioned, **Bio-based double layer panels (K-FLEX)** can be applied also in this way.

- **Plug-and-play systems for external facade renovation**

  This category of interventions includes plug-and-play solutions that also allow the implementation of ventilated and non-ventilated cavities. Since it is compatible with the implementation of insulating layers on the outer side of the walls, it is recommended in all contexts. Other advantages include the possibility of shielding possible air vents, the reduction of maintenance costs and the reduction of costs for future facade renovations.

  Among the technologies presented in RINNO, the **Zappa PV -Roof and -Facade solutions (EKOLAB)** belongs to this intervention category. The solution consists of a fast and cheap mounting system for natural slate with zero maintenance. Some of the slate area can be substituted with 100% integrated solar cells, saving materials compared to a PV add-on solution.

  In addition, in cases where an air cavity is not required, it is also possible to consider blowing the cavity with insulation material (i.e.: **Isocell Cellulose Insulation**).

Figure 6 - Zappa PV -Roof and -Facade solutions (EKOLAB)

- **Windows replacement**

  Window replacement can have multiple benefits. It can be aimed at:

  ✓ reducing heating consumption,

  ✓ improving thermal comfort by reducing the temperature gap between air and window surfaces,

  ✓ Improving the level of sound insulation,

  ✓ limiting air infiltration

  ✓ In warm climates, reducing unwanted heat gains through the use of thermochromic, reflective or selective glazing. In this case, avoiding the need to close shutters and thus allowing a higher level of natural lighting, can also lead to the reduction of lighting costs

  Associated with this category of interventions is the **thermochromic glass**, available from **GREENSTRUCT**, that utilizes a thermochromic layer inside a triplex glass which reacts when the temperature on the surface rises and its transmissivity is reduced resulting in a tinted glass while keeping the visibility at all times.

- **Insufflation**

  Insufflation of insulating material is usually applied in hollow walls or in the attic spaces

  It has the advantage of being very affordable but does not adequately solve the problem of thermal bridges. Associated with this category of interventions is the **ISOCELL Cellulose Insulation**, available from **CBI Danmark**, that is a 90% bio-based material made of newspapers surplus upcycling.

Figure 7 - ISOCELL Cellulose Insulation (CBI Danmark) and insufflation

As already mentioned, in addition to the traditional use described above, ISOCELL insulation material can also be blown into the cavities of the ZAPPA plug and play system.

3.2 Interventions on systems

Possible interventions on the system include the following measures:

- **Installation/replacement of cooling systems**

  Given the type of buildings, it is necessary to consider here only systems with air-water or water-water heat pumps, both centralized and decentralized, with limited air treatment capacity and emission through mini splits, fan coils or water coils installed on walls, ceilings or floors (the latter case should be avoided in order to prevent heat stratification phenomena.). Should there be a need for both cooling and heating, heat pumps can be used in both modes, as well as for domestic hot water production. Given the dependence of COP and ERP with the temperature of the exchanging source, the use of hybrid solutions with buffer connected to solar collectors, installed downstream or upstream of the heat pump, can be evaluated case by case.

The effects of replacing the cooling system are:

- ✓ improvement of thermal comfort
- ✓ reduction of cooling costs

- **Installation/replacement of heating systems**

  This measure should be considered in any situation in which the existing heating system is inefficient. Both condensing boiler and heat pump systems are investigated and based on the climate, the preferable solution will be selected. However, replacing the generation system also implies the need to implement low-temperature emission systems, which may be radiant panels or split units. The heat generator can generally also be used for the production of domestic hot water.

  The effects of replacing the heating system are:

  - ✓ improvement of thermal comfort
  - ✓ reduction of heating costs
  - ✓ Air quality improvement (in cases where the existing generator is a coal or oil-fired stove)

- **Installation ventilation systems**

  This intervention type has the following advantages:

  - ✓ Air quality improvement, keeping humidity, particulate matter and carbon dioxide levels under control.
  - ✓ Reduction of energy consumption, both for cooling and heating. Especially if equipped with heat recovery, it avoids dispersions due to air changes through the continuous opening of the windows.
  - ✓ Reduction of sound impact from external sources. In warm climates it allows free cooling by natural ventilation without the need to open the windows during the night.

On the other hand, ventilation systems have an aesthetic impact both on the interior and on the facade and it increases electrical consumption.

Associated with this category of interventions is the **MicroVent sustainable Ventilation system**, a facade integrated ventilation system characterized by low power consumption and an 85-92% heat recovery. It is demand-controlled with variable air volume (VAV) based on CO2, temperature and humidity, and can be combined with window replacement.

Figure 8 - MicroVent sustainable Ventilation system (InVentilate). Concept of the system (upper left) and examples of interior (upper right) and exterior architectural integration (below)

- **Pipe/duct insulation**

  Pipe/duct insulation has the advantage of reducing the heating, domestic hot water and cooling costs. Associated with this category of interventions are:

  - the **K-BOX bio-based insulating system for parts of energy systems (K-FLEX),** which consists of a FEF (flexible elastomeric foam) insulation material mechanically preformed allowing tailor made solutions
  - **Bio-based pipes and sheets (K-FLEX)**, which consists of pipes and sheets based on EPDM with a high percentage of bio-based content (45-60%) and increased fire resistance.

3.3 Implementation of renewable energy systems

Possible interventions include the following measures:

- **PV panels**

  Traditional photovoltaic panels can be installed almost exclusively on roofs and terraces. They aim to reduce electrical bills and are highly convenient, not to say necessary, when combined with heat pumps, especially when used for summer cooling. In this case, in fact, the peak load of the heat pumps matches the peak production of electricity from PV panels.

  The main disadvantage is that, since they can only be installed on the roof, their use is alternative to solar collectors, which are usually too heavy to be applied on facades. It is necessary to evaluate which solution brings the greatest benefits.

- **Building Integrated Photovoltaic Systems**

  BIPV have the advantages mentioned for the traditional PV panels but have greater flexibility of utilization. They are easily integrated with plug-and-play façade systems and can also be applied on roofs, skylights, verandas or to replace windowpanes. Consequently, their use does not prevent the installation of solar collectors and does not force to choose between the two technologies. For example, in the case of heat pump installation in cold climates, solar collectors could provide hot water at low temperature to be used to exchange heat with the evaporator, thus enabling to obtain better COP, while PV panels could be used to produce part of the electricity absorbed by the heat pump compressor.

Associated with this category of interventions is the **BIPV glass,** available from **GREENSTRUCT**, that is an integrated structural-insulation-energy production element that can be used in different applications such as roofs, facades and canopies and can be installed the same way as conventional glasses.

Figure 9 - BIPV glass (GREENSTRUCT). Application examples

- **Solar collectors**

Only the traditional glazed flat place collectors, that are the most diffused in the EU and typically used for DHW production and space heating, are considered here. Systems integrated in the facade are not considered because the glazed collectors are generally too heavy while unglazed flat plate collectors have low efficiencies.

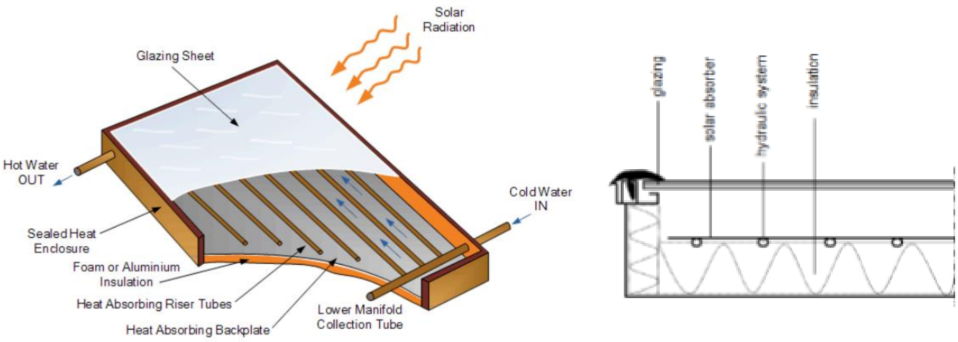

Figure 10 - Traditional glazed flat place collectors

As anticipated, these elements are used to produce DHW or in support of hybrid heating systems, especially in combination with heat pumps. They should always be paired with storage tanks and, in the case of domestic hot water production, with a backup generator in case of not suitable weather conditions, thus implying significant installation costs.

- **Heat storages**

  Associated with this category of interventions are the **de-centralized DHW-solutions of in- and on-wall storage tanks** provided by **PINK**. They can be a) combined to the heating system and solar thermal via a heat exchanger within the tank, or b) separated from the heating system via a tank with a special electrical heating element

Figure 11 - De-centralized DHW-solutions of on- and in-wall storage tanks

4. Greek Demo

4.1 Building overview

The pilot building is a flat block of 4 floors and 2 flats per floor of 75sqm, with a concrete frame structure and hollow brick infill, built in 1970 in the context of a large social housing complex. It was built without any measures to reduce energy consumption, neither for heating nor for cooling, it has a shell with low thermal resistance and low inertia, thus inadequate to guarantee the necessary thermal phase shifting and attenuation during the summer season. The windows are provided with aluminum frames, without thermal break, and single glazing, while the external shutters are sliding blinds or rolling shutters, which do not allow the light to be adjusted according to the sunlight at different times of the day.

Figure 12 - Greek demo. Degradation factors

4.2 Preliminary survey and questionnaire (step 1 and 2)

The preliminary investigation revealed the presence of several external degradation factors linked to the uneven appearance of elements on the facades, such as:

- Different shutters in different maintenance states, some in very bad condition
- Presence of air conditioners and cables, with their associated occurrence of significant holes, disposed without any visual order
- Disordered distribution of solar collectors on the roof

Other degradation signs are the deterioration of the plaster around the windows and the detachment of the plaster from the balconies. There are also traces of stains due to rainwater runoff, caused by the lack of proper gutters.

It is worth mentioning the presence of a mural on the facade on the north side, made by students of Athens Fine Arts University, which will not be preserved but will be renewed with a new mural dedicated to the energy efficiency and environmental sustainability issues.

Critical elements linked to the context where the building is located are the closeness on the north side of a very trafficked road which leads to high noise levels for the flats on that side. Indeed, the questionnaire shows that, together with air infiltration, noise is the most important cause of discomfort.

Again, the questionnaire reveals that, in the users opinion, there are no important architectural elements to be preserved.

Finally, although currently the building has independent heating systems, given the presence of suitable common areas on the basement floor, it is also possible to consider the switch from independent to centralized cooling and heating systems.

The following is a summary of the objectives to be met by the renovation of the building, according to the level of importance perceived by the occupant.

		Objectives that can be achieved through a renovation process	Priority degree
ENERGY-RELATED	1	Heating cost savings	5
	2	Cooling cost savings	5
	3	Lighting cost savings	3
ECONOMICAL	4	Minimization of renovation time	5
	5	Minimization of renovation costs	4
	6	Maintenance cost reduction	4
SOCIAL	7	Eco-Labelling	4
	8	Residents' Comfort	5
	9	Better air quality	5
	10	Building life extension	5
	11	Building aesthetics enhancement	3
	12	Lower noise level	4
ENVIRON-MENTAL	13	Minimization of waste production	4
	14	Carbon footprint	5
	15	Eco-friendliness	4

Figure 13 - Greek demo. Questionnaire

The objective already stated in the Grant Agreement is confirmed: the building at the end of the deep renovation will have to meet the requirements to be Passive House Premium certified. This implies, on the one hand, the need to minimize demand and, on the other hand, the need to emphasize as much as possible the on-site production of energy from renewable sources.

4.3 Impact of renovation solutions (step 3)

The combination of the objectives with the groups of interventions taken into account, for this specific building and climatic context, showed that:

- with regard to the **envelope**, ventilated facades are probably the most effective type of intervention, at least on the surfaces directly exposed to the solar radiation. The outer skin prevents the absorption and the consequent accumulation of heat in the walls. Another recommended intervention is the conventional insulation from the outside, which is effective in both summer and winter. In addition, window replacement can have a significant impact on both heating and cooling cost savings. In addition, the use of thermochromic glazing can allow shutters to remain open even during the warmest hours in summer, minimizing unwanted solar gains. Thus, reducing the use of artificial light.
- with reference to the **systems**, given the need to have both the heating and cooling systems, the optimal solution could be provided by water-to-air heat pumps with emission through fan coils, ideal for mild and mid-season contexts. In addition, the installation of ventilation systems with heat recovery can be essential to ensure high levels of air quality while limiting heat losses that would occur by continuously opening the windows.
- with regard to **Renewable Energy Systems**, given the need to install electrically powered systems such as heat pumps, fan coils and ventilation systems, PV panels are likely to be the solution that provides the most benefits

Hereafter, the summary of the expected impacts of each cluster of interventions on the targets to be met by the energy renovation is reported.

		ENVELOPE					SYSTEMS				RES TECHNOLOGIES			
Objectives that can be achieved through a renovation process	level of importance	Systems to renovate external facades	Systems to insulate from the inside	Plug and play system (for both ventilated and unventilated roof and facades)	Windows replacement (considering also coating)	Insufflation of organic insulation materials	Cooling systems (generation and distribution)	Heating Sistems (generation and distribution)	Ventilation systems (with air filtering)	Pipe/duct insulation	BIPV	Photovoltaic systems on roof	Solar collectors	Energy and heat storages
Heating cost savings	4	*****	****	****	***	**		****		***			*****	*****
Cooling cost savings	5	****	*****	*****	****	**	****		***	***	*****	*****		***
Lighting cost savings	5			**	***						*****	*****		***
Minimization of renovation time	5	***		*****										
Minimization of renovation costs	4		****											
Maintenance cost reduction	4	**									**			
Eco-Labelling	4					****				**	**	**	***	
Residents' Comfort	5				****		****	****	****					
Better air quality	5				****		***		*****					
Building life extension	5	****		**			**	**	**					
Building aesthetics enhancement	3	***		*****							***			
Lower noise level	5	*****	***	*****	*****				**					
Minimization of waste production	4													
Carbon footprint	5	***	***			**			***	**	***	***	**	
Eco-friendliness	4	**				***								
Other specific objectives for the demo														
Expectetions to meet Passive House Premium reqirements		*****		****	****		****	****	***	***	*****	*****	*****	****

Figure 14 - Greek demo. Impacts of technologies

4.4 Preliminary renovation scenarios (step 4)

Three redevelopment scenarios were defined on the basis of the objectives set by the occupants and the suitability of each type of intervention to meet such goals. Starting from a baseline scenario defined by considering only the minimum measures necessary in order to achieve the Passive house premium standard and the objectives identified by the questionnaire, the other two scenarios have been identified by implementing additional solutions that, although more expensive, might allow for further substantial benefits. The scenarios are presented and described below

4.4.1 Renovation scenario 1 – Base case

In the base scenario the facades, as well as the roof, are isolated from the outside (Insulated External Façade System). Regarding the roof, it is also planned to replace the waterproof membrane and lay a gravel layer to reduce the heat absorption of the concrete slab through radiation. In the sunniest areas, not shaded by neighboring buildings, photovoltaic panels are installed.

Regarding the systems, the existing burners are to be replaced by air-water heat pumps located on the East and North facades. The heat pumps are expected to be used both for cooling and heating, as well as for DHW production. In addition, an inertia storage tank is to be installed for DHW production.

Windows are replaced with double or triple pane units.

USE CASE SCENARIO 1	
ENVELOPE External insulation **WINDOWS** Replacement with double/triple-glazed windows **ROOF** External insulation combined with gravel layer to reduce solar absorption. Installation of PV panels **SYSTEMS** Heat pumps (with mini split units) for heating, cooling and DHW production. Buffer storage is required for the DHW system	

4.4.2 Renovation scenario 2 - Base case + Ventilated facades on exposed sides

As regards the facades on the south and west sides, which are more exposed to sunlight, it is proposed to use a plug-and-play system where the external insulation is combined with a ventilated façade and photovoltaic cladding while, on north and east sides, always in shadow, it is proposed the adoption of an Insulated External Façade System. Given the presence of PV in the facades exposed to the sun, in this scenario the roof is equipped with solar collectors to produce domestic hot water. Consequently, DHW storage tanks have double coils to exchange heat with both the heat pump and the solar collector circuit. As in scenario 1, windows are replaced with double or triple pane units, with the exception of one window per floor where the use of BIPV glass (from Greenstruct) will be tested

Figure 15 - Greek demo. Scenario 2. Facade solutions

USE CASE SCENARIO 2	
ENVELOPE South and West façade: Plug-and-play façade integrated with solar cells North and East façade: Insulated External Façade System **WINDOWS** Replacement with double/triple-glazed windows. Installation of one BIPV glass window (from Greenstruct) for each floor on the west side. **ROOF** External insulation combined with gravel layer to reduce solar absorption. Installation of solar collectors for hot water production **SYSTEMS** Heat pumps (with mini split units) for heating, cooling and DHW production. Buffer storage is required for the DHW system	

4.4.3 Renovation scenario 3 - Base case + Ventilated facades and thermocromic glasses

In this scenario the roof is modified to a greater extent. A second membrane with a reflective treatment is to be installed, providing both external insulation and a ventilated cavity. In addition to the insulation layer, this time placed on top of the concrete slab, a ventilation gap, usually 50mm, should be provided between the top of the insulation and underside of the roof covering to allow the air to flow across.

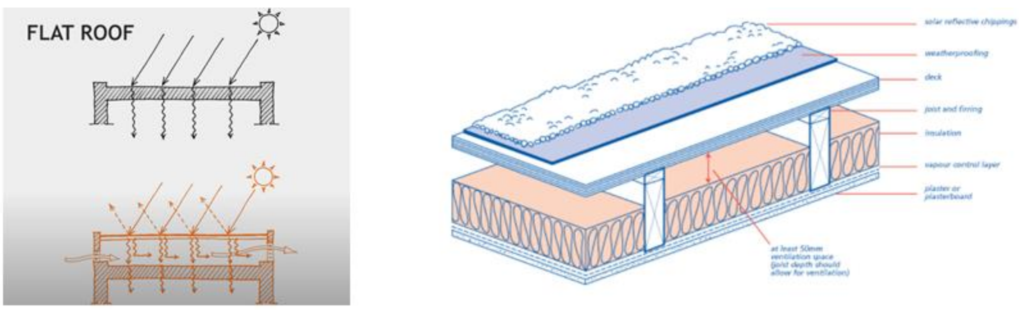

Figure 16 - Greek demo. Scenario 3. Ventilated roof

As regards the façades, this time the use of a plug-and-play system is extended also to north and east sides but combined with combined with insulation blown into the cavities (ISOCELL).

This time heating, cooling and hot water systems are centralized, with heat pumps and storage located in the basement.

A further difference with scenario 2, windows of the west facade have thermochromic glass.

USE CASE SCENARIO 3	
ENVELOPE South and West façade: Plug-and-play façade integrated with solar cells North and East façade: Plug-and-play façade integrated with other finishing **WINDOWS** Compared to scenario 2, the windows on the west side are thermochromic glass. **ROOF** External insulation combined with gravel layer to reduce solar absorption. Installation of solar collectors for hot water production **SYSTEMS** Heat pumps (with mini split units) for heating, cooling and DHW production (Centralized System). Inertial storages are required both for the DHW and cooling and heatin system.	

5. Polish Demo

5.1 Building overview

The Polish demonstrator is a detached building of traditional load-bearing masonry, built in 1949, with three floors above ground and a semi-basement level on the north side. It is 12 metres high and consists of 5 flats accessible through a central unheated staircase.

Figure 17 - Polish demo. South (left) and North (right) façades

The building has a wide rectangular base which tapers to a square plan on subsequent floors. Accordingly, 3 of the 5 flats are located on the ground floor, one on the second floor and one on the third floor.

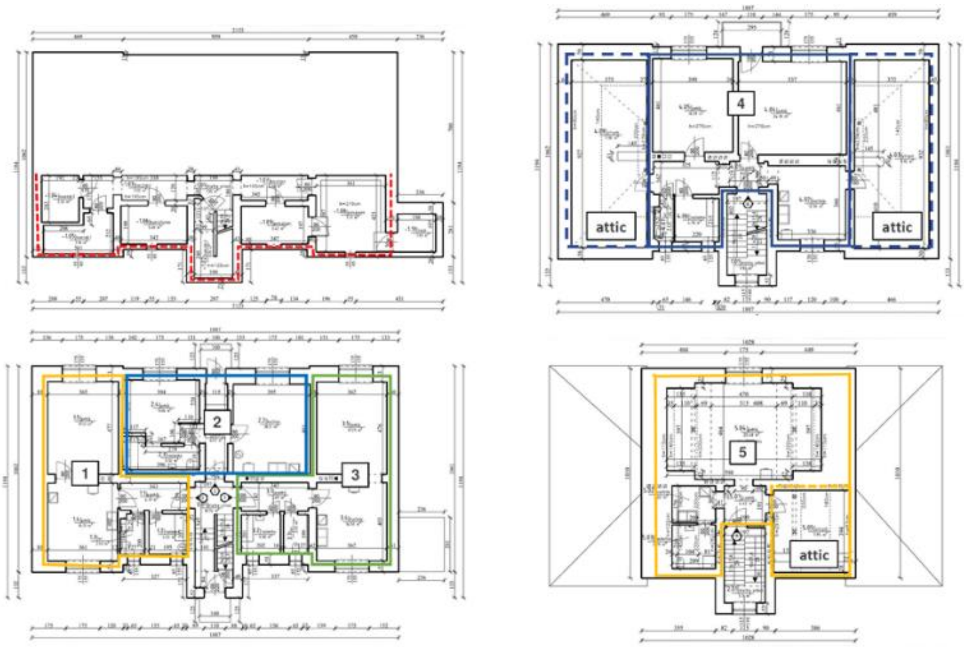

Figure 18 - Polish demo. Plants. Semi-basement and Ground Floor on the left side. First and second floor on the right side

Each flat is heated by stoves that are manually fed with coal, in pieces and powder, pellets and wood.

The natural ventilation system is ineffective, as certified by technical inspection.

Both the envelope walls and the partitions with attic, staircase and other unheated rooms have no insulating layers.

5.2 Preliminary survey and questionnaire (step 1 and step 2)

Preliminary investigation showed that the plasterwork, especially on the north side, has humidity patches due to water infiltration and interstitial condensation caused by thermal bridges. The walls, made of solid masonry of variable thickness of one, two and three blocks, have high transmittance values, ranging from 0.82 W/m²K to 1.84 W/m²K, and are therefore not suitable to provide an adequate level of thermal insulation. Windows were replaced in quite recently but have nevertheless relatively high U-values (1.7 W/m²K), as the entrance door (U-value = 2.6 W/m²K).

The roof, which has been recently renovated and is in an excellent state of maintenance, has adequate transmittances with estimated U-values of about 0.7 W/m²K.

On the other hand, weak elements are the ceiling of the basement, consisting of a concrete slab with no insulating layers, and the floor of the remaining part of the ground floor, made of concrete slabs on brick rubble acting as under-floor cavity.

The following is a summary of the objectives to be met by the renovation of the building, according to the level of importance perceived by the occupants, consisting of low-income residents (retired, unemployed or unable to work).

		Objectives that can be achieved through a renovation process	Priority degree
ENERGY	1	Heating cost savings	5
	2	Cooling cost savings	2
	3	Lighting cost savings	5
ECONOMICAL	4	Minimization of renovation time	4
	5	Minimization of renovation costs	4
	6	Maintenance cost reduction	4
SOCIAL	7	Eco-Labelling	3
	8	Residents' Comfort	4
	9	Better air quality	5
	10	Building life extension	3
	11	Building aesthetics enhancement	3
	12	Lower noise level	2
ENVIRON-MENTAL	13	Minimization of waste production	2
	14	Carbon footprint	3
	15	Eco-friendliness	4

Figure 19 - Polish demo. Questionnaire

According to the questionnaire, the primary objectives to be achieved by the renovation are the reduction of heating costs and lighting costs as well as the improvement of air quality, which is currently affected by the presence of coal-fired stoves and the lack of adequate ventilation. Other important objectives are the comfort improvement, the reduction of maintenance and renovation costs and the eco-compatibility of renovation measures. Consistent with the location and the climatic context of the building, which is isolated and surrounded by woods in a cold continental climate zone, the reduction of cooling consumption and the improvement of sound insulation are of secondary importance.

Other useful information for the definition of the renovation scenarios:

- Some trees cast shadows on the facade from the south-west, which partially limits the use of photovoltaics in the lower areas of the façade.
- There is no risk of radon gas from the soil
- There is a gas network close to the building and the Commune Jablonna (owner) plans to connect the building to the gas network by the end of 2021.

5.3 Impact of renovation solutions (step 3)

The combination of the objectives with the groups of interventions taken into account, for this specific building and climatic context, showed that:

- with regard to the **envelope**, the type of intervention that should allow the greatest benefits in terms of heating cost savings is the external insulation of the façade, while the use of the plug and play system can be useful to minimize the installation time, conceal the vents in case of installation of mechanical ventilation and allow the use of photovoltaic panels on the facades.
- with reference to the **systems**, in order to reduce thermal discomfort and improve air quality, it would be advisable to replace the heat generation system, which would also be useful for reducing heating costs. Given the need to improve air quality, it may be advisable to also install a mechanical ventilation system.
- with regard to **Renewable Energy Systems**, the installation of solar panels or solar collectors can be useful for reducing heating costs, although their exploitation may be limited by the presence of shadow zones that need to be evaluated more in detail.

Hereafter, the summary of the expected impacts of each cluster of interventions on the targets to be met by the energy renovation is reported.

		ENVELOPE					SYSTEMS				RES TECHNOLOGIES			
Objectives that can be achieved through a renovation process	level of importance	Systems to renovate external facades	Systems to insulate from the inside	Plug and play system (for both ventilated and unventilated roof and facades)	Windows replacement (considering also coating)	Insufflation of organic insulation materials	Cooling systems (generation and distribution)	Heating Sistems (generation and distribution)	Ventilation systems (with air filtering)	Pipe/duct insulation	BIPV	Photovoltaic systems on roof	Solar collectors	Energy and heat storages
Heating cost savings	5	*****	****	*****	*****			****	**	***	**	**	****	*****
Cooling cost savings	2	*	*	*	*				*	***	**	**		**
Lighting cost savings	5										****	*****		***
Minimization of renovation time	4	***		****										
Minimization of renovation costs	4		****											
Maintenance cost reduction	4	**		*****										
Eco-Labelling	3									**	**	**	***	
Residents' Comfort	4	***	***	****	*			****	***					
Better air quality	5	***		****	*				*****					
Building life extension	3	****		****				**						
Building aesthetics enhancement	3	*****		*****	*						***			
Lower noise level	2	*****	***	*****	**				*					
Minimization of waste production	2													
Carbon footprint	3	***	***						**	**	***	***	**	
Eco-friendliness	4	**												

Figure 20 - Polish demo. Impacts of technologies

5.4 Preliminary renovation scenarios (step 4)

On the basis of the above considerations, three possible preliminary renovation scenarios have been drafted, characterized by different cost levels and expected performance.

After the identification of some necessary interventions common to all scenarios (i.e. insulation of walls surrounding the stairwell, insulation of cellar ceilings.....) the different scenarios were defined by selecting different solutions for heat generation (gas boilers or heat pumps) and, consistently, different solutions for the energy production from renewable sources, opting for photovoltaics in the case of the installation of heat pumps and for solar collectors in the case of gas-fired generators, since in this latter case there is no need for additional electrical power supply. In addition, window replacement is considered in scenarios 2 and 3.

The scenarios are presented and described below.

5.4.1 Renovation scenario 1 – Base case

The first scenario involves the replacement of coal-fired stoves with an independent gas heating system (condensing boilers) integrated with rooftop solar collectors for the production of domestic hot water.

The condensing boiler operates at best efficiency when the temperature of the fluid sent back to the boiler is around 40-45° C, or in any case below 50°. It should therefore be combined with low-temperature emission systems such as radiant floors or walls. Considering the need to insulate the floors from the ground and unheated basement rooms, the installation of radiant floor coils seems more convincing, also to minimize the thermal phase shift due to the high thermal capacity of the walls.

In addition to the solar collectors, it is proposed to install decentralised wall-mounted heat storage tanks (proposed by PINK), combined with the heating system.

Concerning the building envelope, an external insulation is to be applied, made with the Bio-based double layer panels produced by K-FLEX. On the other hand, windows are not expected to be replaced in this scenario, as they have been replaced quite recently.

The following table summarizes the measures contained in scenario 1.

USE CASE SCENARIO 1	
ENVELOPE Facade treatment: External insulation (Bio-based double layer panels by K-FLEX or others) applied to all the walls **WINDOWS** No replacement of windows **ROOF** Installation of solar collectors for hot water production **SYSTEMS** Condensing gas boilers for heating and in support of solar collectors for the production of domestic hot water. The solar collectors are only for de-centrilized domestic hot water production. Solar collectors are integrated with the on-wall storage tanks provided by PINK. Heating system emission system - radiant floor panels	

5.4.2 Renovation scenario 2 – Base case + PV panels

The second scenario is built on the first one but it also aims to maximize the production from renewable energy sources through the installation of photovoltaic panels on the facade. Like the first scenario, the coal-fired stoves are replaced by a gas heating system (condensing boilers) integrated with rooftop solar collectors for DHW production. The heat emission system is underfloor and again in this scenario, decentralized wall-mounted heat storage tanks from PINK are to be installed combined with the solar collectors.

In addition, with respect to scenario 1, a plug-and-play facade system (Zappa solution by EKOLAB) is planned on the southern side, with the implementation of photovoltaic panels along the vertical strips not occupied by windows and balconies, and an opaque finish on the other parts, while still maintaining the application of the external insulation.

Figure 21 - Polish demo. Scenario 2. South facade. Positioning of vents (green) and PV panels (yellow)

Moreover, taking advantage of the second skin allowing to conceal the installation of wall-mounted equipment, it is proposed to install, again on the southern side, micro-ventilation units with heat recovery to limit the need for air changes by opening the windows and thus limiting the related dispersion as well as ensuring a controlled air quality. Considering the structural typology, it seems advisable to locate the ventilation units under the windows, in areas barely affected by vertical loads.

The following table summarizes the measures contained in scenario 2.

USE CASE SCENARIO 2	
ENVELOPE SUD façade: Plug-and-play facade solution with external insulation (Bio-based double layer panels by K-FLEX or others). Solution with integrated and hidden ventilation, incorporating solar cells Other facades: External insulation (Bio-based double layer panels by K-FLEX or others) applied to all the walls **WINDOWS** Replacement with double/triple-glazed windows **ROOF** Installation of solar collectors for hot water production **SYSTEMS** Condensing gas boilers for heating and in support of solar collectors for the production of domestic hot water. The solar collectors are only for de-centrilized domestic hot water production. Solar collectors are integrated with the on-wall storage tanks provided by PINK. Heating system emission system - radiant floor panels. Installation of ventilation system integrated in the south facade	

5.4.3 Renovation scenario 3 - Base case + Heat pump and PV panels

The third scenario is a further evolution of the second one and it involves an heat pump as generation system in place of the condensing gas boiler. In order to satisfy the consequent additional power demand, it is assumed to use the roof for the installation of PV panels. Concerning the building envelope, similarly to scenario 1, an external insulation is to be applied, made with the Bio-based double layer panels produced by K-FLEX.

The following table summarizes the measures contained in scenario 3.

USE CASE SCENARIO 3	
ENVELOPE Facade treatment: External insulation (Bio-based double layer panels by K-FLEX or others) applied to all the walls **WINDOWS** Replacement with double/triple-glazed windows **ROOF** Installation of PV panel to cover heat pum demand **SYSTEMS** Heat pump for heating and for the production of domestic hot water. Heating system emission system - radiant floor panels. Installation of ventilation system in the north and south facades	

6. French Demo

6.1 Building overview

The French demonstrator is a 5-storey multi-family building (4 floors plus the ground floor) built in 1976, subdivided into 6 small flats (less than 40 sqm) per floor, each one with a single large window on the east or west side. The flats are accessed via a corridor running along the central axis of the building. The north and south fronts are completely blind. The heating system is centralized with heat generation provided by a natural gas boiler located in the boiler room. Concerning the envelope, both the walls and the roof are characterized by a low level of insulation.


Figure 22 - French demo. Views

6.2 Preliminary survey and questionnaire (step 1 and step 2)

Awaiting more detailed surveys, the questionnaire revealed the need to improve both the insulation of the building envelope and the efficiency of the heating system, which emits heat at excessively low temperatures. Moreover, occupants complain of poor natural light and ventilation, supposedly caused by the presence of only one window per flat, which makes the air exchange through the sole natural ventilation very difficult. Lastly, windows are ineffective not only in terms of thermal insulation but also with regard to acoustic performance.

No critical issues seem to arise from the context. The nearest roads are far enough from the building to not be a source of pollution affecting air quality, and there aren't any neighboring elements that may cast shadows on the envelope surfaces potentially interested by the presence of photovoltaic panels and/or solar collectors.

The following is a summary of the objectives to be met by the renovation of the building, according to the level of importance perceived by the occupants, consisting mainly of low-income residents.

		Objectives that can be achieved through a renovation process	Priority degree
ENERGY	1	Heating cost savings	5
	2	Cooling cost savings	2
	3	Lighting cost savings	2
ECONOMICAL	4	Minimization of renovation time	4
	5	Minimization of renovation costs	5
	6	Maintenance cost reduction	5
SOCIAL	7	Eco-Labelling	3
	8	Residents' Comfort	5
	9	Better air quality	3
	10	Building life extension	5
	11	Building aesthetics enhancement	4
	12	Lower noise level	3
ENVIRON-MENTAL	13	Minimization of waste production	4
	14	Carbon footprint	5
	15	Eco-friendliness	5

Figure 23 - French demo. Questionnaire

As shown by the questionnaire, the priority objectives to be achieved by the renovation are the reduction of heating and maintenance costs as well as the improvement of residents comfort, which is now affected by the inefficiencies of the heating system and the inherent layout of the flats. Other important objectives to be pursued are the eco-sustainability of the interventions, the minimization of renovation time, and the aesthetic improvement of the facades.

6.3 Impact of renovation solutions (step 3)

The combination of the objectives with the groups of interventions taken into account, for this specific building and climatic context, showed that:

- with regard to the **envelope**, the type of intervention that should allows the greatest benefits is the external insulation of the facade, especially in the case of integration with plug-and-play systems that would allow more flexibility in the choice of finishing surfaces, thus improving the aesthetic quality of the building. Coherently, the two solutions that could be analyzed are the adoption of an Insulated External Façade System and the plug-and-play system with insulation blown into the cavity. Moreover, according to the thermal transmittance of the existing windows, their replacement will also be considered.
- with reference to the **systems**, in order to reduce thermal discomfort, it would be advisable to replace the heat generation system and insulate the distribution pipes, which would also be useful for reducing heating costs. As it is difficult to ensure air renewal with a single window, the installation of mechanized ventilation systems can be important to improve air quality.
- with regard to **Renewable Energy Systems**, the installation of solar panels or solar collectors can be useful for reducing heating costs, taking advantage of the absence of elements that can cast shadows on the building and the pitched roof.

Hereafter, the summary of the expected impacts of each cluster of interventions on the targets to be met by the energy renovation is reported.

		ENVELOPE					SYSTEMS				RES TECHNOLOGIES			
Objectives that can be achieved through a renovation process	level of importance	Systems to renovate external facades	Systems to insulate from the inside	Plug and play system (for both ventilated and unventilated roof and facades)	Windows replacement (considering also coating)	Insufflation of organic insulation materials	Cooling systems (generation and distribution)	Heating Sistems (generation and distribution)	Ventilation systems (with air filtering and heat recovery)	Pipe/duct insulation	BIPV	Photovoltaic systems on roof	Solar collectors	Energy and heat storages
Heating cost savings	5	*****	***	*****	*****	****		****	**	***	**	**	****	*****
Cooling cost savings	2	*	*	*	*	*			***	***	**	**		**
Lighting cost savings	2										****	*****		***
Minimization of renovation time	4	***		****										
Minimization of renovation costs	5		****											
Maintenance cost reduction	5	**		*****										
Eco-Labelling	3									**	**	**	***	
Residents' Comfort	5	***	***	****	****	***		****	***					
Better air quality	3	***		****	****	***			*****					
Building life extension	5	****		****				**						
Building aesthetics enhancement	4	*****		*****	***						***			
Lower noise level	3	*****	***	*****	*****				*					
Minimization of waste production	4													
Carbon footprint	5	***	***			***			**	**	***	***	**	
Eco-friendliness	5	**				*****								

Figure 24 - French demo. Impacts of technologies

6.4 Preliminary renovation scenarios (step 4)

As for the other demonstrators, 3 possible preliminary redevelopment scenarios have been drafted. Again, after the identification of a baseline scenario that included the essential measures required to achieve the desired results, it was decided to investigate possible alternatives that, although more costly, could lead to significant improvements. The scenarios are presented and described below.

6.4.1 Renovation scenario 1 – Base case

The first scenario involves the replacement of the existing boiler with a centralized condensing gas boiler, integrated with roof-mounted solar collectors for domestic hot water production. It is accordingly planned to install, in the boiler room, a double coil heat storage tank for domestic hot water. The storage tank should be heated, according on weather conditions and consumption, either by the solar collector circuit or by the condensing boiler.

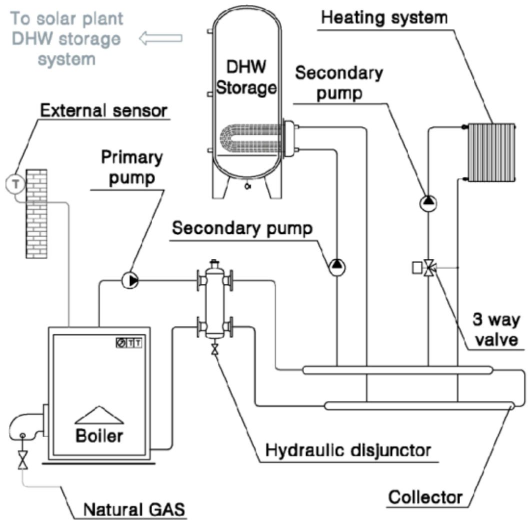

Figure 25 - French demo. Scenario 1. Hybrid system for DHW production

As far as the building envelope is concerned, an external coat is to be applied, made with the Bio-based double layer panels produced by K-FLEX. The replacement of windows is only considered in cases of poor thermal performance levels of existing windows, resulting in a significant impact not only on energy consumption but also on thermal comfort.
The following table summarizes the measures contained in scenario 1.

USE CASE SCENARIO 1	
ENVELOPE Facade treatment: External insulation (Bio-based double layer panels by K-FLEX or others) applied to all the walls. **WINDOWS** Replacement of windows only only in case of very high U-Value of existing windows **ROOF** Installation of solar collectors for hot water production **SYSTEMS** Centralized condensing gas boilers for heating and in support of solar collectors for the production of domestic hot water. Centralized double coil heat storage tank for domestic hot water heated by both condensing boiler and solar collectors.	

In case of a hollow space in the walls, insulation of organic material (ISOCELL) will be also considered.

6.4.2 Renovation scenario 2 + Heat pump and PV panels

Compared to the baseline scenario, the second scenario involves the heat pump as generation system in place of the condensing gas boiler. In order to cover the consequent additional electrical power demand, it has been decided to mount photovoltaic panels on the roof, thus excluding the use of solar collectors for hot water production. Hot water production is no longer hybrid, therefore a single coil storage tank, heated by the heat pump, is to be installed.

As for the envelope, this time it is planned to renovate the façades by means of a Plug-and-Play facade system, in any case combined with insulation blown into the cavities (ISOCELL). Windows are replaced, unless the existing windows already have very low U-values.

The following table summarizes the measures contained in scenario 2.

USE CASE SCENARIO 2	
ENVELOPE Façade: Plug-and-play facade solution with insulation blown into the cavities (ISOCELL), incorporating natural slate or other finishing. **WINDOWS** Replacement of windows, unless the existing windows already have very low U-values **ROOF** Installation of a photovoltaic modules **SYSTEMS** Centralized Heat Pump for heating and domestic hot water production. Centralized single coil heat storage tank for domestic hot water heated by heat pump. Centralized extraction fan with heat recovery	

In case of a hollow space in the walls, insulation of organic material (ISOCELL) will be also considered.

6.4.3 Renovation scenario 3 + Heat pump, PV panels and solar collectors

Compared to the previous scenario, it has been decided to maintain the solar collectors on the roof, thus keeping a hybrid hot water production system. In this case, the two-coil storage tank is heated by both the heat pump and the solar collectors. In order to cover the additional power demand, the plug and play facades, blown again with insulation (ISOCELL), on the south, east and west sides are integrated with photovoltaic panels, taking advantage of the fact that the east and west facades are completely without windows. Windows are replaced, unless the existing windows already have very low U-values.
The following table summarizes the measures contained in scenario 3.

USE CASE SCENARIO 3	
ENVELOPE South, East and West facades: Plug-and-play facade solution with external insulation (Bio-based double layer panels by K-FLEX or others), incorporating solar cells along the bands not occupied by windows. North facade: Plug-and-play ventilated facade solution with insulation blown into the cavities (ISOCELL), incorporating natural slate or other finishing. **WINDOWS** Replacement of windows, unless the existing windows already have very low U-values **ROOF** Installation of solar collectors for hot water production **SYSTEMS** Centralized Heat pump for heating and in support of solar collectors for the production of domestic hot water. Centralized double coil heat storage tank for domestic hot water heated by both heat pump and solar collectors. Centralized extraction fan with heat recovery	

7. Danish Demo

7.1 Building overview

The Danish demonstrator is a linear building of over 200 meters in length and over 10 floors in height that includes about 464 apartments ranging in size from 56 to 121 sqm. The building is oriented along the North-South axis, consequently the apartments face alternatively east or west. Built in 1978, in the original conception, it was provided with balconies on both east and west sides, which have been closed by glazed facade modules during a refurbishment carried out in 1988, which has completely spoiled the Rationalistic layout.

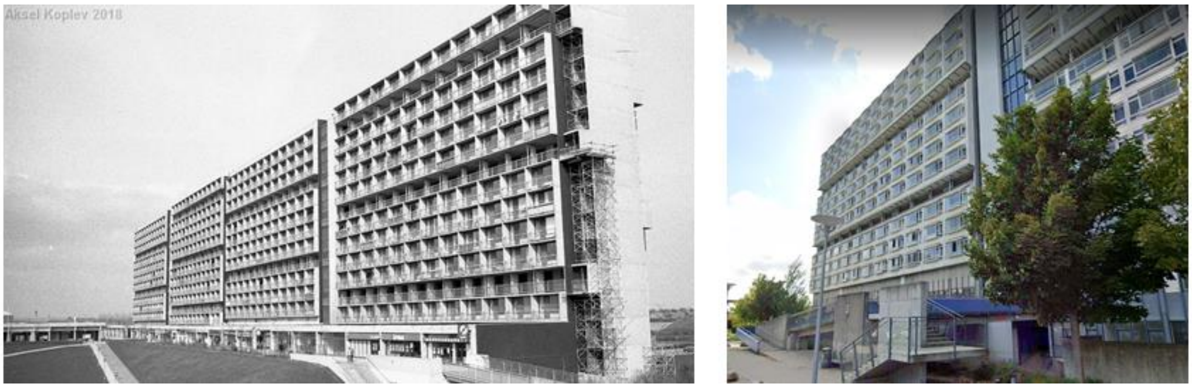

Figure 26 - Avedöre City. The Store Hus. Original configuration (on the left) and after the intervention of 1988 (on the right)

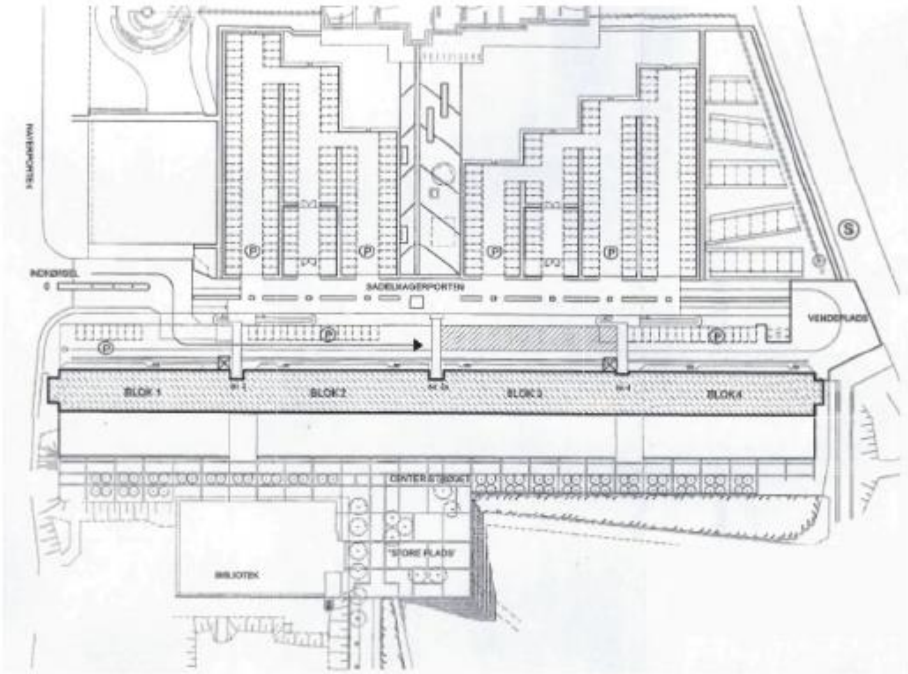

Figure 27 - Avedöre City. The Store Hus. Situation plan: the four blocks into which the linear building is divided and the parking lot.

Another characterizing element of the original project, typical of the modern movement, concerns the distribution of the single apartments. Each apartment is distributed on two floors, which are accessed by long walkways on the facades, connected to the stairwells that divide vertically the building in four parts (Figure 28).

Starting from the entrance level, each apartment goes up or down through two mezzanine floors and is exposed to both the main fronts of the building. Feature made possible by the half-story offset of the west facade from the east façade (Figure 29).

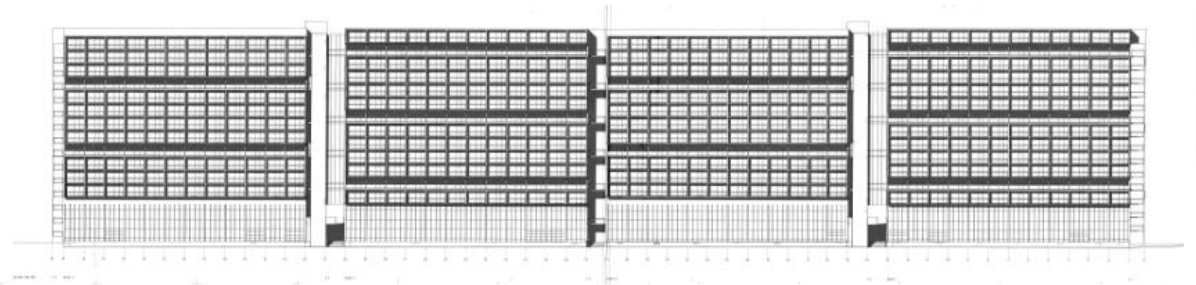

Figure 28 - Avedöre City. The Store Hus. Façade towards the East – block 1-4

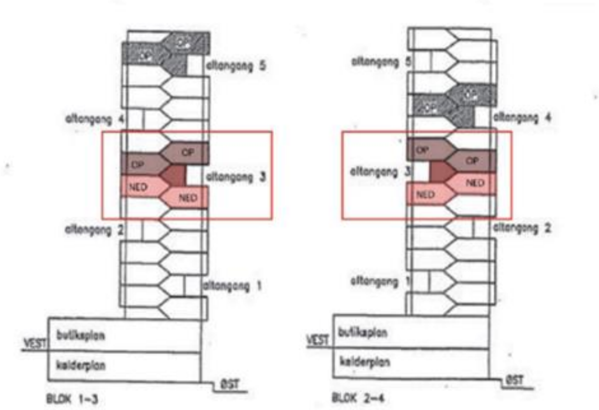

Figure 29 - Avedöre City. The Store Hus. Section showing the typological scheme of the apartments. All flats are in two levels – up-up ("op") or down-down ("ned")

The 1988 intervention also involved the installation of a solar thermal system on the roof integrated to the District Heating Network.

7.2 Preliminary survey and questionnaire (step 1 and step 2)

Awaiting more in-depth survey, what stands out from the questionnaire is the need to reduce energy consumption. Other important goals are the minimization of renovation costs, the improvement of both thermal comfort and air quality, and the improvement of the aesthetic quality of the building, damaged by the 1988 renovation that completely altered the original design of the facades (Figure 26).

	Objectives that can be achieved through a renovation process	Priority degree
1	Heating cost savings	5
2	Cooling cost savings	1
3	Lighting cost savings	3
4	Minimization of renovation time	3
5	Minimization of renovation costs	4
6	Maintenance cost reduction	3
7	Eco-Labelling	4
8	Residents' Comfort	4
9	Better air quality	4
10	Building life extension	4
11	Building aesthetics enhancement	4
12	Lower noise level	4
13	Minimization of waste production	2
14	Carbon footprint	4
15	Eco-friendliness	4

Figure 30 - Danish demo. Questionnaire

In addition, it is reported the need to improve the acoustic insulation between neighboring apartments, given that from the surrounding context there are no noise sources close to the building.

As easily predictable, there is no need for summer cooling, while the minimization of renovation time and maintenance costs are not priorities.

The following part includes a summary of the objectives to be met by the renovation of the building, according to the level of importance perceived by the occupants, consisting mainly of low-income residents.

7.3 Impact of renovation solutions (step 3)

Compared to other demonstrators, the presence of the high-temperature (95°C) district heating network for heating and domestic hot water production along with the need to reduce renovation costs limits considerably the range of options as both the interventions on the systems and the implementation of renewable energy systems appear to be less effective. However, for this specific building and climatic context, the combination of the objectives, with the groups of interventions taken into account, showed that:

- with regard to the **envelope**, the type of interventions that should allow the greatest benefits are the external insulation of the facade, especially in the case of integration with plug-and-play systems that would allow an aesthetic enhancement of the building, and the replacement of the windows, that allow the reduction of energy consumption and the improvement of the thermal comfort for the occupants. Interior insulation is considered because it minimizes installation costs, although it does not solve the problem of thermal bridges.
- with reference to the **systems**, the interventions that can bring significant improvements and keep optimal humidity levels (after the envelope interventions) are (1) the installation of a ventilation system with heat recovery, more efficient than the one already installed, and (2) the insulation of the heating pipes.

- with regard to Renewable Energy Systems, the interventions that may be useful to reduce energy consumption are (1) the replacement of the solar collectors on the roof with more efficient ones e.g. with PVT, and (2) the implementation of photovoltaic panels on the facades, integrated in a plug-and-play system.

Hereafter, the summary of the expected impacts of each cluster of interventions on the targets to be met by the energy renovation is reported.

		ENVELOPE					SYSTEMS				RES TECHNOLOGIES			
Objectives that can be achieved through a renovation process	level of importance	Systems to renovate external facades	Systems to insulate from the inside	Plug and play system (for both ventilated and unventilated roof and facades)	Windows replacement (considering also coating)	Insufflation of organic insulation materials	Cooling systems (generation and distribution)	Heating Sistems (generation and distribution)	Ventilation systems (with air filtering)	Pipe/duct insulation	BIPV	Photovoltaic systems on roof	Solar collectors	Energy and heat storages
Heating cost savings	5	*****	***	*****	*****			**	**	***	*	*	****	*
Cooling cost savings	1	*	*	*	*				*					
Lighting cost savings	3										****	****		
Minimization of renovation time	3	***		****	**									
Minimization of renovation costs	4		****											
Maintenance cost reduction	3	**		*****										
Eco-Labelling	4									**	**	**	**	
Residents' Comfort	4	***	***	****	*****			**	****					
Better air quality	4	***		****	****				***					
Building life extension	4	****		****										
Building aesthetics enhancement	4	*****		*****	**						***			
Lower noise level	4	*****	***	*****	*****				*					
Minimization of waste production	2													
Carbon footprint	4	***	***						**	**	***	***	***	
Eco-friendliness	4	**												

Figure 31 - Danish demo. Impacts of technologies

7.4 Preliminary renovation scenarios (step 4)

Given the reduced room for action, due to the presence of an already efficient district heating system, only two scenarios are proposed for this demonstrator at this preliminary stage. The first one, the baseline scenario, only includes the measures required to improve the existing conditions, according to the indications provided in the questionnaire. Furthermore, the second scenario also involves the replacement of the facades. The two scenarios are presented and described below.

7.4.1 Renovation scenario 1 – Base case

The first scenario aims at minimizing renovation costs. It involves the replacement of the windows and the implementation of the insulation of the facade modules from the inside with the Bio-based double layer panels produced by K-FLEX, avoiding scaffolding costs. Regarding the systems, the intervention considered is the replacement of the existing mechanical ventilation system with a more efficient with heat recovery and the insulation of the heating pipes

USE CASE SCENARIO 1	
ENVELOPE Facade treatment: Insulation from the inside of the façade modules **WINDOWS** Replacement of double glazing windows with triple glazing in the façade modules. **ROOF** Insulation from the outside wherever possible **SYSTEMS** Replacement of the existing mechanical ventilation system with a more efficient one with heat recovery. Insulation of the heating pipes	

7.4.2 Renovation scenario 2 - Base case + Integrated photovoltaic facade

The second scenario involves a replacement of the facade modules from the outside with a new, pre-fabricated plug-and-play façade modules, that combines Zappa PV facade solution with ISOCELL insulation and InVentilate ventilation system. The facades are therefore to be integrated with photovoltaic panels.

USE CASE SCENARIO 2	
ENVELOPE Facade treatment: Replacement of external modules with a Plug-and-play system provided by insulation blown inside the module, integrated with PV panels and ventilation system. **WINDOWS** Replacement of double glazing windows with triple glazing in the façade modules. **ROOF** Insulation from the outside wherever possible **SYSTEMS** Replacement of the existing mechanical ventilation system with a more efficient one with heat recovery. Insulation of the heating pipes	

8. Conclusions

This report provides an initial hypothesis of the deep renovation scenarios related to each demo, which will be evaluated and optimized throughout the project. As mentioned, the scenarios are qualitatively defined here, and they represent the starting point for the analysis and the general scenarios that will be thoroughly and quantitatively defined in task T3.2. This is therefore an intermediate step, propaedeutic to a further development that will be carried out when the surveys and investigations will reach a more detailed level.

Nevertheless, the preliminary analysis, including the clarification of the occupants' needs and the identification of the most suitable technologies to pursue the established targets, have allowed to identify at least the proper selection of the mix of measures of interest for each demonstrator. The following table summarizes the types of intervention under consideration for each scenario.

		ENVELOPE				SYSTEMS				RES TECHNOLOGIES			
		Systems to renovate external facades	Plug and play system (for both ventilated and unventilated roof and facades)	Windows replacement (considering also coating)	Insufflation of organic insulation materials	Cooling systems (generation and distribution)	Heating Sistems (generation and distribution)	Ventilation systems (with air filtering and heat recovery)	Pipe/duct insulation	BIPV	Photovoltaic systems on roof	Solar collectors	Energy and heat storages
GREEK DEMO	Scenario 1	x		(x)		x	x		x		x		
	Scenario 2	x	x	x		x	x		x	x		x	x
	Scenario 3	x	x	x	x	x	x	x	x	x		x	x
POLISH DEMO	Scenario 1	x					x					x	x
	Scenario 2	x	x	x			x	x		x		x	x
	Scenario 3	x		x			x			x		x	x
FRENCH DEMO	Scenario 1	x		(x)			x		x			x	x
	Scenario 2	x	x	x	x		x	x	x		x		
	Scenario 3	x	x	x	x		x	x	x	x		x	x
DANISH DEMO	Scenario 1	x		x				x	x				
	Scenario 2		x	x				x	x	x			

9. Annexes

Questionnaire for the definition of the objectives to be addressed through the renovation scenarios of the Demonstrators

GREEK DEMO

Technical aspects

1 The objectives in terms of reduction of consumption reported in the Grant Agreement are confirmed? i.e. Deep Energy Renovation of the whole building according to the Passive House Premium standard. After completion the building will be certified as the first EnerPHit Premium in SE Europe. **-YES**

2 Are there any architectural elements considered to be preserved (e.g. murals, features on the facade...)? - If yes, please specify which ones - **NO**

3 Are there any regulatory architectural constraints? (maintaining the size of exterior openings...) - If yes, please specify which ones **- NO**

4 Are there any elements of discomfort in addition to those related to energy aspects (e.g. noise, poor natural lighting, air infiltration, etc.)? - Please specify which ones - **Noise, Air Infiltration**

5 Are there any deterioration signs inside or outside the building? - If yes, please specify which ones - **YES , there is a big Graffity , which has to be replaced.**

6 Are there any critical issues arising from the external environment where the building is located (proximity to high-traffic streets, tall buildings/trees casting shade on the building....)? - if yes, please specify which ones - **YES, proximity to high-traffic streets**

7 Are there gas or district heating networks close to the building? **- YES**

Objective framing

For the purpose of targeting the renovation scenarios in accordance with the needs of the Users, could you assign a score according to the level of priority (from 1, low priority, to 5 highest priority) to be assigned to each of the following potential objectives, achievable through the requalification of the building?

		Objectives that can be achieved through a renovation process	Priority degree
ENERGY-RELATED	1	Heating cost savings	5
	2	Cooling cost savings	5
	3	Lighting cost savings	3
ECONOMICAL	4	Minimization of renovation time	5
	5	Minimization of renovation costs	4
	6	Maintenance cost reduction	4
SOCIAL	7	Eco-Labelling	4
	8	Residents' Comfort	5
	9	Better air quality	5
	10	Building life extension	5
	11	Building aesthetics enhancement	3
	12	Lower noise level	4
ENVIRON-MENTAL	13	Minimization of waste production	4
	14	Carbon footprint	5
	15	Eco-friendliness	4

Questionnaire for the definition of the objectives to be addressed through the renovation scenarios of the Demonstrators

POLISH DEMO

Technical aspects

1 Are the objectives in terms of reduction of consumption reported in the Grant Agreement are confirmed? (i.e. Improve thermal comfort and reduce energy use/costs. Complex modernisation of the building envelope, ventilation system as well as the heating system is foreseen)
Yes, they are confirmed

2 Are there any architectural elements considered to be preserved (e.g. murals, features on the facade...)? - if yes, please specify which ones
The building is not historic. There are no architectural features that need to be preserved.

3 Are there any regulatory architectural constraints? (e.g. maintaining the size of exterior openings...)- if yes, please specify which ones
No.

4 Are there any elements of discomfort in addition to those related to energy aspects (e.g. noise, poor natural lighting, air infiltration, etc.)? - Please specify which ones
There are no specific comments from residents and the owner

5 Are there any deterioration signs inside or outside the building? - if yes, please specify which ones and, if possible, provide some evidence
The table below shows the technical condition of the building elements created for the needs of the technical condition assessment in December 2019 performed by an authorized unit.

6 Are there any critical issues arising from the external environment where the building is located (proximity to high-traffic streets, tall buildings/trees casting shade on the building....)? - if yes, please specify which ones
The building is surrounded by trees. Shading mainly from the south and south-west. Additionally, the low ground near the Vistula River causes periodic flooding of some of the unused cellars.

7 Have radon gas measurements been carried out? Is there a risk of possible infiltration of radon gas?
No risk of radon occurrence in this area.

8 Is there a gas network close to the building?
There is a gas network near the building. The Commune Jablonna (owner) plans to connect the building to the network in the second quarter of 2021.

Objective framing

For the purpose of targeting the renovation scenarios in accordance with the needs of the Users, could you assign a score according to the level of priority (from 1, low priority, to 5 highest priority) to be assigned to each of the following potential objectives, achievable through the requalification of the building?

		Objectives that can be achieved through a renovation process	Priority degree
ENERGY	1	Heating cost savings	5
	2	Cooling cost savings	2
	3	Lighting cost savings	5
ECONOMICAL	4	Minimization of renovation time	4
	5	Minimization of renovation costs	4
	6	Maintenance cost reduction	4
SOCIAL	7	Eco-Labelling	3
	8	Residents' Comfort	4
	9	Better air quality	5
	10	Building life extension	3
	11	Building aesthetics enhancement	3
	12	Lower noise level	2
ENVIRON-MENTAL	13	Minimization of waste production	2
	14	Carbon footprint	3
	15	Eco-friendliness	4

Questionnaire for the definition of the objectives to be addressed through the renovation scenarios of the Demonstrators

FRENCH DEMO

Technical aspects

1 Which are the objectives in terms of reduction of consumption? **321 kWhep/m².year according to the official energy audit --> 104 kWh/m².year (so 68% energy reduction)**

2 Are there architectural elements considered to be preserved (murals, features on the facade...)? - Please specify which ones:
Facade insulation
Facade cladding or equivalenet finishing
Replace the exisitng windows by an efficient model.

3 Are there any regulatory architectural constraints? (maintaining the size of exterior openings...) - Please specify which ones
ATEX (installation of a new innovation or a non traditional technology instalaltion onsite)
Fire regulations: all elements installed on the facade should have a A2S3D0 firerating (for buildings with more than 3 floors)
Window blocks: - Endurance to repeated opening / closing: Tests EN 1191 - Mechanical resistance: Tests EN 14608 and EN 14609 - Operating force: Tests EN 12046-1 - Dynamic wind forces: NFP 20 501

4 Are there elements of discomfort in addition to those related to energy aspects (noise, poor natural lighting, air infiltration, etc.)? - Please specify which ones
Noise
Poor natural lighting
Air infiltration
Low heating temperature
Automation of stores ...

5 Are there any deterioration signs inside or outside the building? - Please specify which ones and, if possible, provide some evidence **(no idea for now, an audit shoud be done to the existing site), we have to wait until the Partner is completely involved in the project**

6 Are there any critical issues arising from the external context where the building is located (proximity to high-traffic areas), tall buildings casting shade on the building....)? - Please specify which ones **No critical issues**

8 Are there gas or district heating networks close to the building? **Gas network already exisitng in the building. I don't have the plans of the district heating networks.**

Objective framing

For the purpose of targeting the renovation scenarios in accordance with the needs of the Users, could you assign a score according to the level of priority (from 1, low priority, to 5 highest priority) to be assigned to each of the following potential objectives, achievable through the requalification of the building?

		Objectives that can be achieved through a renovation process	Priority degree
ENERGY	1	Heating cost savings	5
	2	Cooling cost savings	2
	3	Lighting cost savings	2
ECONOMICAL	4	Minimization of renovation time	4
	5	Minimization of renovation costs	5
	6	Maintenance cost reduction	5
SOCIAL	7	Eco-Labelling	3
	8	Residents' Comfort	5
	9	Better air quality	3
	10	Building life extension	5
	11	Building aesthetics enhancement	4
	12	Lower noise level	3
ENVIRON-MENTAL	13	Minimization of waste production	4
	14	Carbon footprint	5
	15	Eco-friendliness	5

Questionnaire for the definition of the objectives to be addressed through the renovation scenarios of the Demonstrators

DANISH DEMO

Technical aspects

1 Which are the objectives in terms of reduction of consumption? **Low energy - a reduction of at least 30 %, but we hope for much more!**

2 Are there architectural elements considered to be preserved (murals, features on the facade...)? - Please specify which ones **Yes, the architects have projected a very fine facade with respect to the original architecture**

3 Are there any regulatory architectural constraints? (maintaining the size of exterior openings...) - Please specify which ones **The building has been spoiled by the latest renovation (1988). Goal is to restore the original impression of the building - and make it energy efficient at the same time.**

4 Are there elements of discomfort in addition to those related to energy aspects (noise, poor natural lighting, air infiltration, etc.)? - **Please specify which ones Loads! Cold bridges, untight windows, noise from the neighbours (due to the plan of the bulding, each flat has at least six neighbours!).**

5 Are there any deterioration signs inside or outside the building? - **Please specify which ones and, if possible, provide some evidence Yes, the concrete is demolished especially at the entrances and the out door accesses.**

6 Are there any critical issues arising from the external context where the building is located (proximity to high-traffic areas), tall buildings casting shade on the building....)? - Please specify which ones **No - it is - in itself - a very large building. It lies next to a train station - but only with the gable facing the train station. We have not registered complaints from the tenants on that issue.**

8 Are there gas or district heating networks close to the building? **Yes, district heating.**

Objective framing

For the purpose of targeting the renovation scenarios in accordance with the needs of the Users, could you assign a score according to the level of priority (from 1, low priority, to 5 highest priority) to be assigned to each of the following potential objectives, achievable through the requalification of the building?

		Objectives that can be achieved through a renovation process	Priority degree
ENERGY-RELATED	1	Heating cost savings	5
	2	Cooling cost savings	1
	3	Lighting cost savings	3
ECONOMICAL	4	Minimization of renovation time	3
	5	Minimization of renovation costs	4
	6	Maintenance cost reduction	3
SOCIAL	7	Eco-Labelling	4
	8	Residents' Comfort	4
	9	Better air quality	4
	10	Building life extension	4
	11	Building aesthetics enhancement	4
	12	Lower noise level	4
ENVIRON-MENTAL	13	Minimization of waste production	2
	14	Carbon footprint	4
	15	Eco-friendliness	4

ABOUT RINNO

RINNO is a four-year EU-funded research project that aspires to deliver greener, bio-based, less energy-intensive from a life cycle perspective and easily applicable building renovation elements and energy systems that will reduce the time and cost required for deep energy renovation, while improving the building energy performance. Its ultimate goal is to develop, validate and demonstrate an operational interface with augmented intelligence and an occupant-centered approach that will streamline and facilitate the whole lifecycle of building renovation.

For more information, please visit **https://rinno-h2020.eu/**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 892071