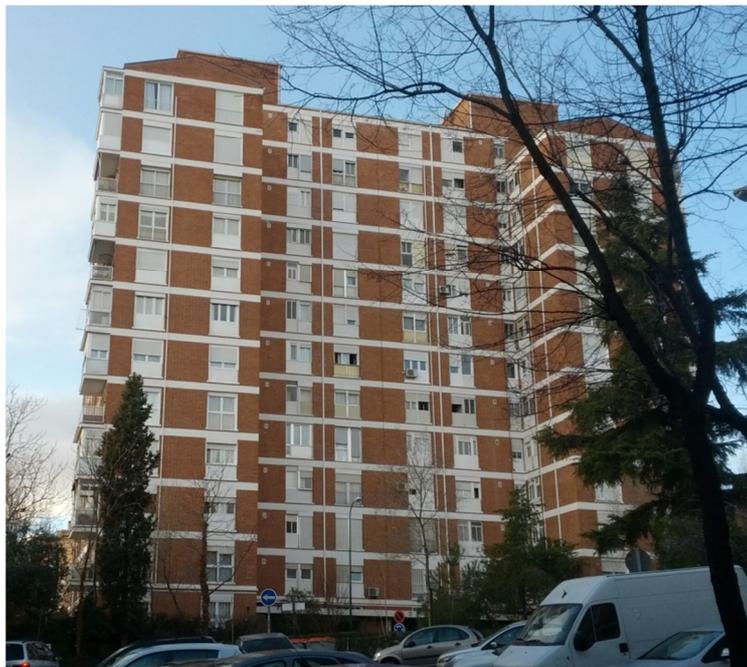


# Project Documentation

Step-by-step retrofitting building

Treviana Social Housing\_Madrid



Co-funded by the Intelligent Energy Europe  
Programme of the European Union

**EuroPHit**

## Table of Contents

Abstract	4
1 General Project Description	5
1.1 Responsible project participants	5
1.2 Motivation	6
1.3 Existing Building	6
1.4 Refurbishment steps	6
1.4.1 Retrofit steps within EuroPHit	6
1.4.2 Further retrofit steps	6
1.5 EnerPHit standard	6
1.6 Pictures	7
2 Existing Building	8
2.1 General description	8
2.1.1 Building data	11
2.1.2 Client	11
2.2 Envelope of the existing building	11
2.2.1 Floor slab	11
2.2.2 External walls	11
2.2.3 External walls to ground	11
2.2.4 Windows	12
2.2.5 Roof / Top floor ceiling	12
2.3 Technical equipment of the existing building	12
2.3.1 Heating	12
2.3.2 Domestic hot water	12
2.3.3 Ventilation	13
2.4 Energy efficiency of the existing building	13
2.4.1 Modelled efficiency parameters	13
2.4.2 Available consumption parameters	13
2.5 Pictures / Drawings	15
3 Planning Progress	18
3.1 Project preparation and design period	18
3.1.1 Involved design / consultancy teams	18
3.1.2 Planning/design periods	18
3.2 Overall refurbishment Plan	19
3.2.1 Retrofit steps:	19
3.2.2 Efficiency Improvements	20
3.3 Retrofit steps within EuroPHit	20
3.3.1 Retrofit step 1:	20

3.4	Pictures / Drawings	23
3.5	Future retrofit steps	27
3.5.1	Retrofit step 2:	27
3.5.2	Retrofit step 3:	27
3.5.3	Retrofit step 4:	28
3.6	Drawings	29
4	RES Strategy / PV Potential Evaluation	30
4.1	Multifunctional behaviour of the BIPV systems: active and passive properties	31
4.2	Inhabitant's comfort and location concept	32
4.3	Evaluation of potential PV systems	33
4.3.1	PV ventilated facade	33
4.3.2	PV Roof superposition	35
4.4	Production estimation	38
4.4.1	Option 1.	39
4.4.2	Option 2	39
4.4.3	Total	39
4.5	Financial evaluation & taxes and incentives assessment	39
4.5.1	Specific Assumptions	39
4.5.2	Results	40
5	Completion of step-by-step refurbishment to EnerPHit standard including RES	41
5.1	General description	41
5.2	Retrofit steps carried out	41
5.3	Envelope of the refurbished Building	42
5.3.1	Basement ceiling	42
5.3.2	External walls	42
5.3.3	Windows	42
5.3.4	Roof / Top floor ceiling	42
5.4	Technical equipment of the refurbished building	43
5.4.1	Domestic hot water	43
5.4.2	Ventilation	43
5.5	Energy efficiency of the refurbished building	43
5.5.1	Modelled efficiency parameters	43
6	Estimated Construction Costs	45
6.1	Retrofit step 1:	45
6.2	Retrofit step 2:	45
6.3	Retrofit step 3 and 4:	45
7	Conclusions	45
8	Appendix I: Project information	46

## Abstract

This report provides an overview of the retrofit actions carried out for the step-by-step refurbishment project OP23.

First, the existing building will shortly be described, including building component and component conditions. In addition, the existing energy efficiency performance of the building will be described.

Further on, an overall refurbishment plan will describe the retrofit steps to be undertaken until the refurbishment will finally be completed in EnerPHit standard including RES.

This report documents the general situation at the beginning of the project, the design period and the measures carried out in the period of the EuroPHit project as well as considerations regarding PV potentials, construction costs or comparison of the measures to national retrofit building regulations



Figure 1: Aerial view of the building [Google earth]

# 1 General Project Description

## 1.1 Responsible project participants

Architect/  
Entwurfsverfasser Anne Vogt and Nuria Diaz, VAND Arquitectura

Implementation planning/  
Ausführungsplanung

Building systems/  
Haustechnik Altertechnica

Structural engineering/  
Baustatik

Building physics/  
Bauphysik Anne Vogt and Nuria Diaz, VAND Arquitectura

Passive House project  
planning/  
Passivhaus-Projektierung Nuria Díaz, VAND Arquitectura

Construction  
management/  
Bauleitung

Author of project documentation /  
Verfasser der Gebäude-Dokumentation Nuria Díaz, VAND Arquitectura

Date, Signature/  
Datum, Unterschrift

Madrid, 27 de octubre de 2017

A handwritten signature in black ink, consisting of several loops and a vertical stroke, positioned below the date.

## **1.2 Motivation**

The new flat owners want to create a more comfortable and efficient dwelling before moving on the apartment. They decide to retrofit only the apartment before the community take the decision to realize other interventions.

## **1.3 Existing Building**

Treviana Social Housing is a large building with 14 floors and 72 apartments. External walls are made of two layers of bricks with a 50 cm air chamber between them and the building structure is made of reinforce concrete. The thermal envelope has no insulation. Ventilation is natural, using opening window sections. Windows have single glazing and aluminium frame without thermal break. Fuel boiler is used to community heating generation and gas boiler to individual hot water generation.

## **1.4 Refurbishment steps**

### **1.4.1 Retrofit steps within EuroPHit**

The retrofit works that have been undertaken within EuroPHit include the first step of the refurbishment plan. This step 1 affects to one apartment.

- Step 1: Exterior wall inner insulation
- High-quality windows installation and connexions with walls
- Airtightness improvement
- Ventilation system with heat recovery installation

### **1.4.2 Further retrofit steps**

The next steps of the refurbishment plan will affects to the entire building.

- Step 2: ETICS installation
- Step 3: Roof insulation
- Step 4: Basement ceiling insulation

Future works will be undertaken on an individual way by apartment owners if they decide to improve their dwellings.

## **1.5 EnerPHit standard**

The project intends to achieve the EnerPHit standard at the end of the works, not only the apartment but the building.

**1.6 Pictures**



**Figure 2: Building - north façade**

## 2 Existing Building

### 2.1 General description

The following drawings show the building geometry. The building use is residential so it is not a temporary use.

Since it is a social housing the building has no monument protection. At the time of the building construction there was no building regulation in Spain.

The first step apartment is marked in red.

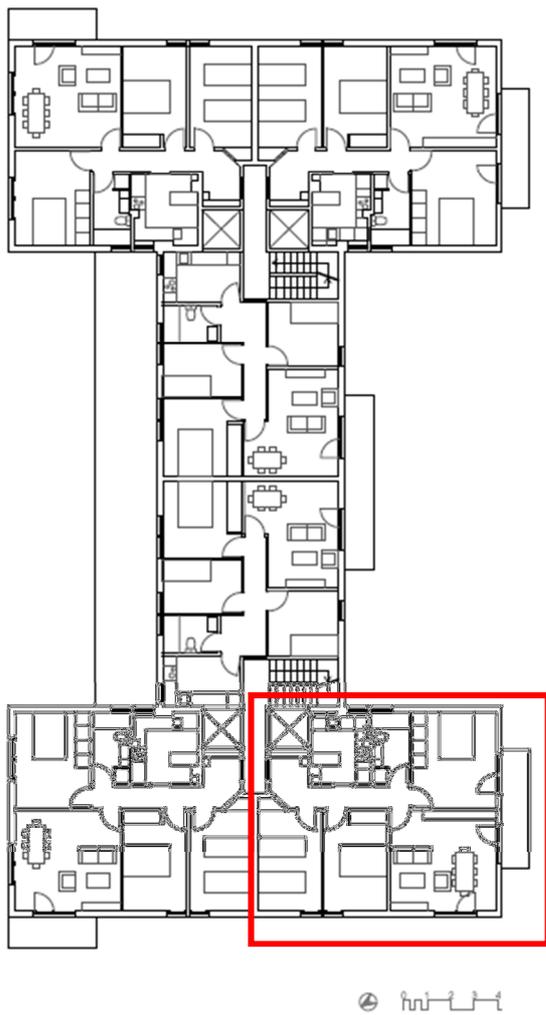


Figure 3: Type floor plan

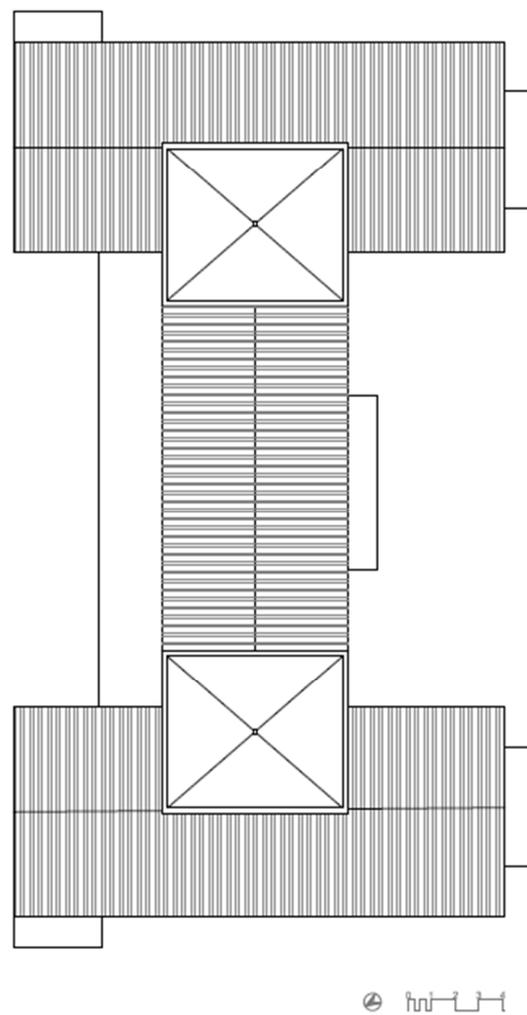
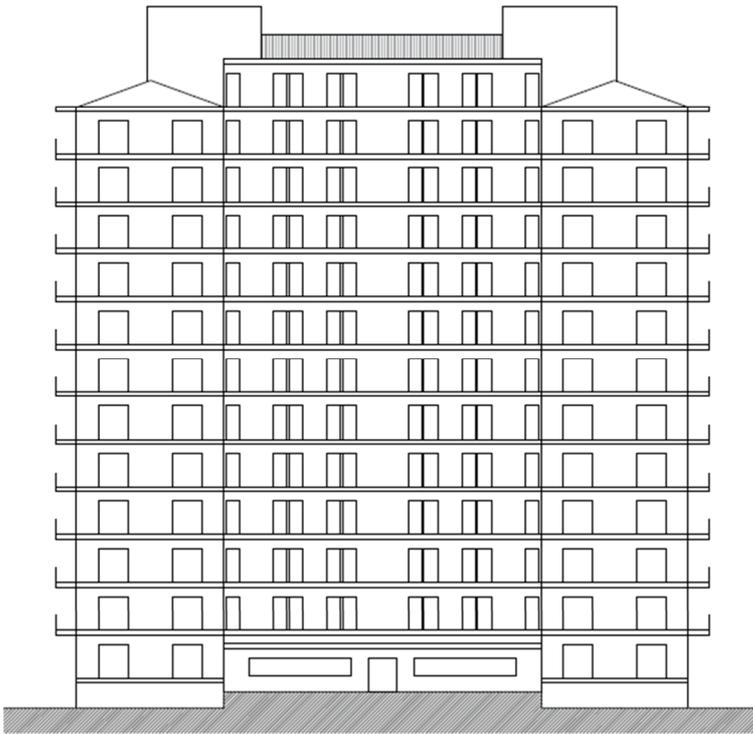
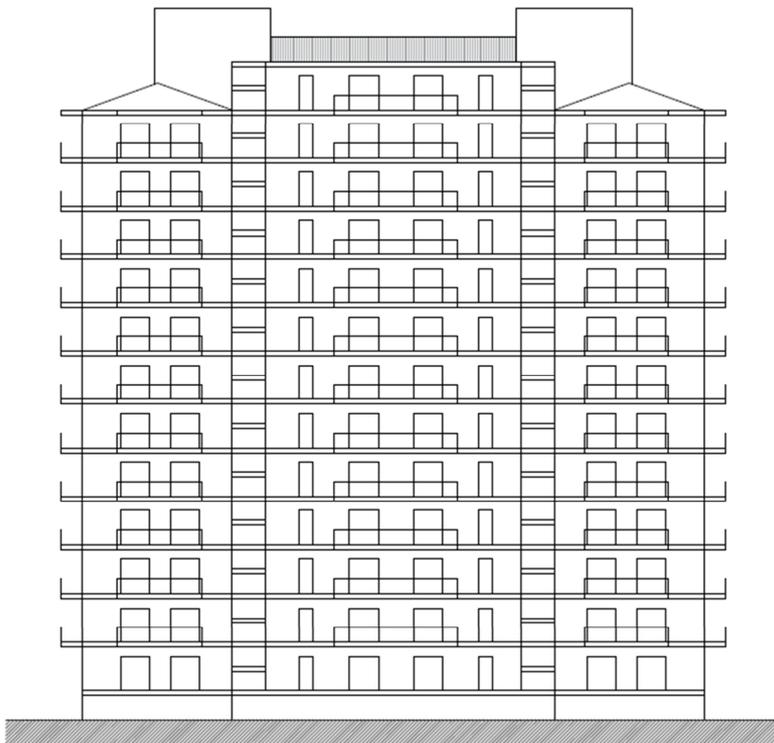


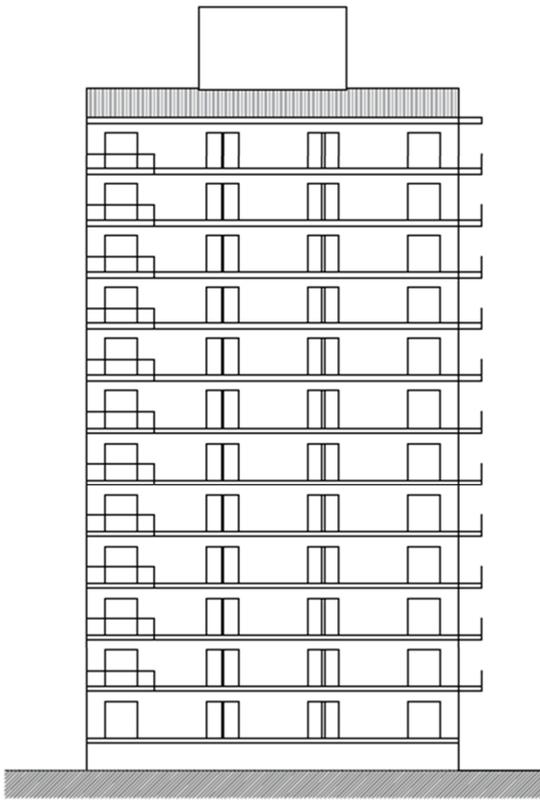
Figure 4: Roof plant



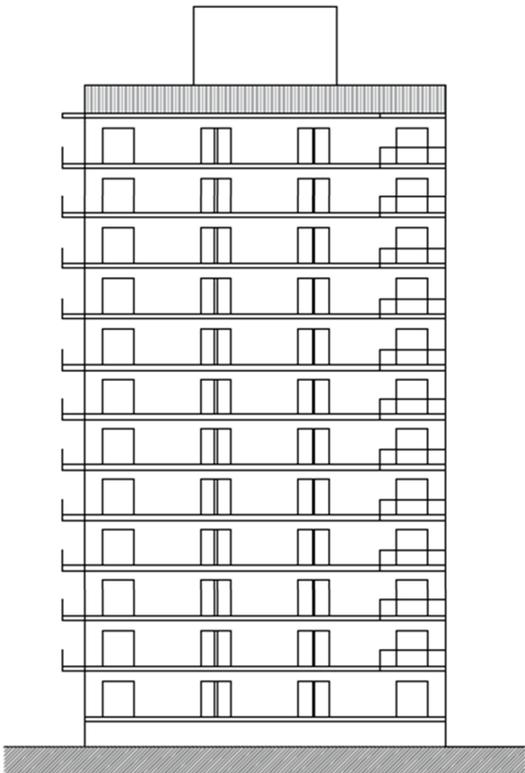
**Figure 5: Principal elevation**



**Figure 6: Rear elevation**



**Figure 7: Right elevation**



**Figure 8: Left elevation**

### **2.1.1 Building data**

Construction Time : 1963  
Last retrofit : Individual apartment retrofits  
Building use : Residential  
General condition : Acceptable  
Occupancy : Yes  
Treated floor Area : 5580 m<sup>2</sup>  
Other :

### **2.1.2 Client**

Name / Company : Marcos García Caravantes  
Address : C/Trevina, 3  
Email : garciacaravantes@hotmail.com  
Other :

## **2.2 Envelope of the existing building**

### **2.2.1 Floor slab**

Description : Concrete slab  
U-Value [W/(m<sup>2</sup>K)] : 1.51 W/(m<sup>2</sup>K)  
Installation date : 1963  
Condition : Good  
Next replacement : Step 4 (Date has not been determined yet)  
Other :

### **2.2.2 External walls**

Description : Two layers of bricks and air chamber  
U-Value [W/(m<sup>2</sup>K)] : 1.57 W/(m<sup>2</sup>K)  
Installation date : 1963  
Condition : Acceptable  
Next replacement : Step 1 (2015)  
Other :

### **2.2.3 External walls to ground**

Description : Reinforce concrete wall  
U-Value [W/(m<sup>2</sup>K)] : 3.73 W/(m<sup>2</sup>K)  
Installation date : 1963

Condition : Acceptable  
Next replacement : Step 2 (Date has not been determined yet)  
Other : -

#### **2.2.4 Windows**

Description : Single glazing and aluminium frame without thermal break  
U-Value [W/(m<sup>2</sup>K)] : 5.7 W/(m<sup>2</sup>K) (standard value)  
Installation date : 1963  
Condition : Poor  
Next replacement : Step 1 (2015, apartment)  
Other : -

#### **2.2.5 Roof / Top floor ceiling**

Description : Reinforced concrete floor structure, brick works to form the slope and air chamber, compression layer and ceramic tiles  
U-Value [W/(m<sup>2</sup>K)] : 1.05 W/(m<sup>2</sup>K)  
Installation date : 1963  
Condition : Acceptable  
Next replacement : Step 3 (Date has not been determined yet)  
Other : -

### **2.3 Technical equipment of the existing building**

#### **2.3.1 Heating**

Description : Central heating – fuel boiler  
Performance ratio of heat generation [%] : No information  
Installation date : 1963  
Condition : Good  
Next replacement : -  
Other : -

#### **2.3.2 Domestic hot water**

Description : Individual gas boiler  
Performance ratio of heat generation [%] : No information  
Installation date : 1963  
Condition : Bad  
Next replacement : Step 1 (2015, apartment)

### 2.3.3 Ventilation

Description	:	Natural ventilation
HR Efficiency[%]	:	-
El.Efficiency [Wh/m <sup>3</sup> ]	:	-
Installation date	:	-
Condition	:	-
Next replacement	:	Step 1 (2015, apartment)
Other	:	

## 2.4 Energy efficiency of the existing building

The energy efficiency properties of the building were calculated with PHPP 9. The results show that the energy performance of the building is very poor due mainly to the lack of insulation, low quality windows and leakages in the thermal envelope and the low efficiency technical systems.

### 2.4.1 Modelled efficiency parameters

PHPP: specific heating demand [kWh/(m <sup>2</sup> K)]	:	150
PHPP: specific cooling demand   Overheating frequency [kWh/(m <sup>2</sup> K)   %]	:	6
PHPP: specific primary energy demand [kWh/(m <sup>2</sup> K)]	:	168

### 2.4.2 Available consumption parameters

Annual Gas/Oil consumption   bills [kWh/a   €]	:	-
Annual Electricity consumption   bills [kWh/a   €]	:	-
Other	:	-

For an overview of the energy efficiency of the existing building, see the verification spreadsheet of the PHPP 9 beta version [PHI 2013] on the next page.

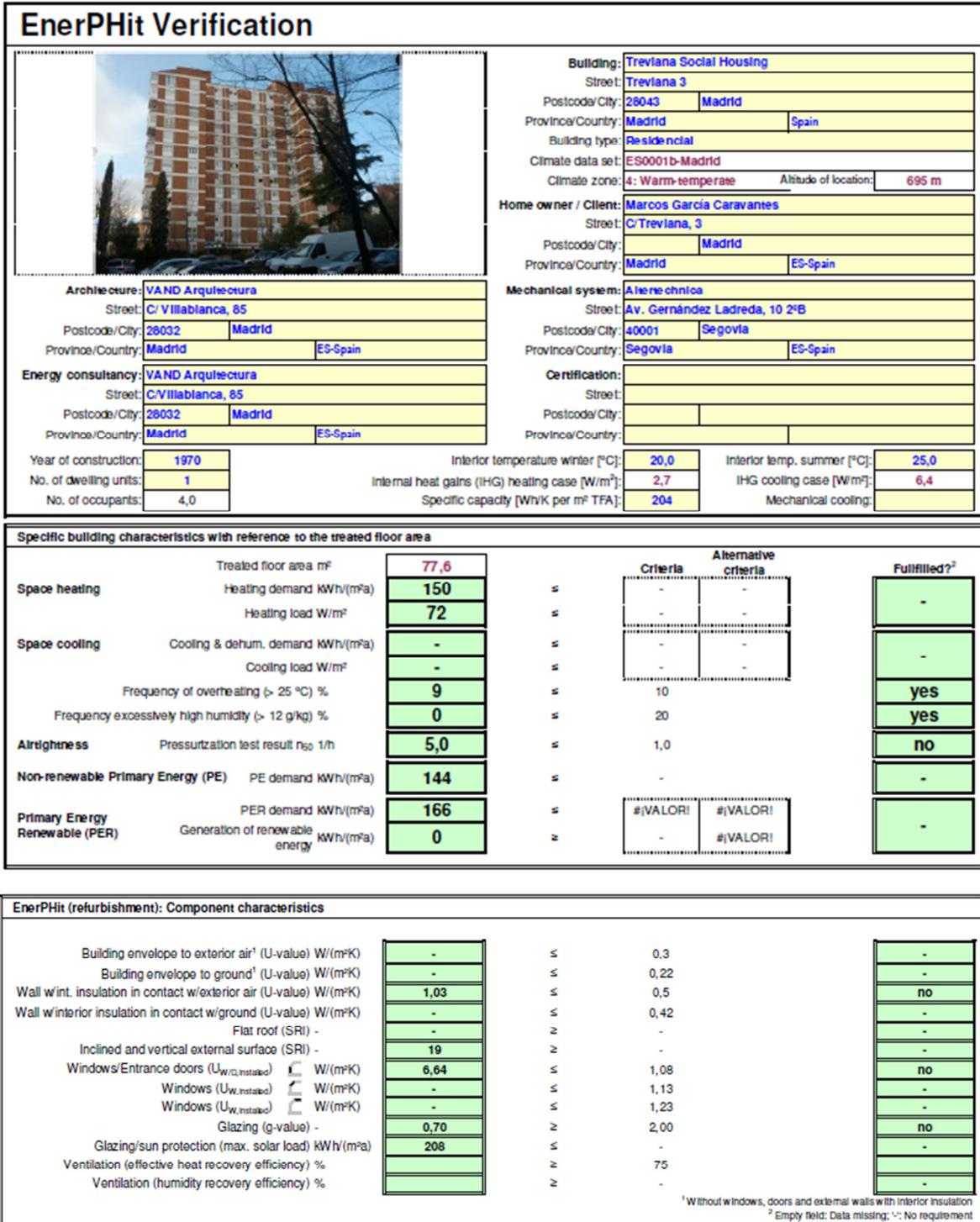


Figure 9: Specific energy efficiency values of the existing building modelled with PHPP 9.3

## 2.5 Pictures / Drawings

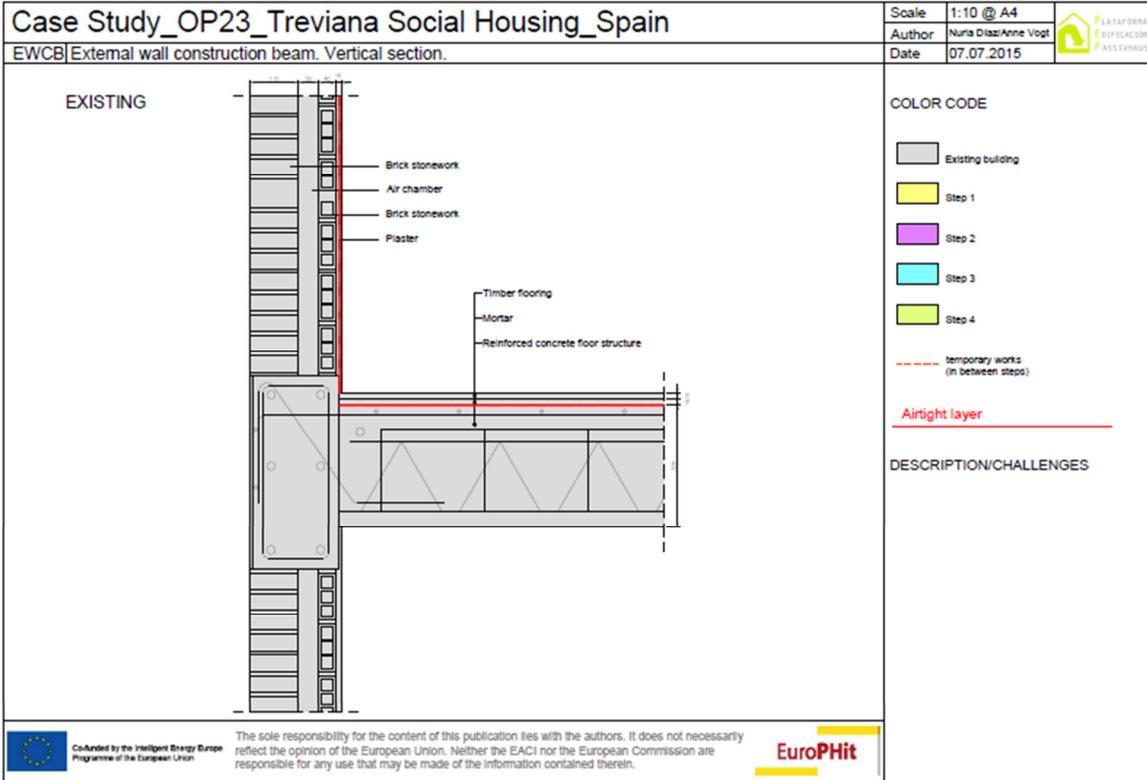
These pictures or drawings illustrate the existing building and apartment.



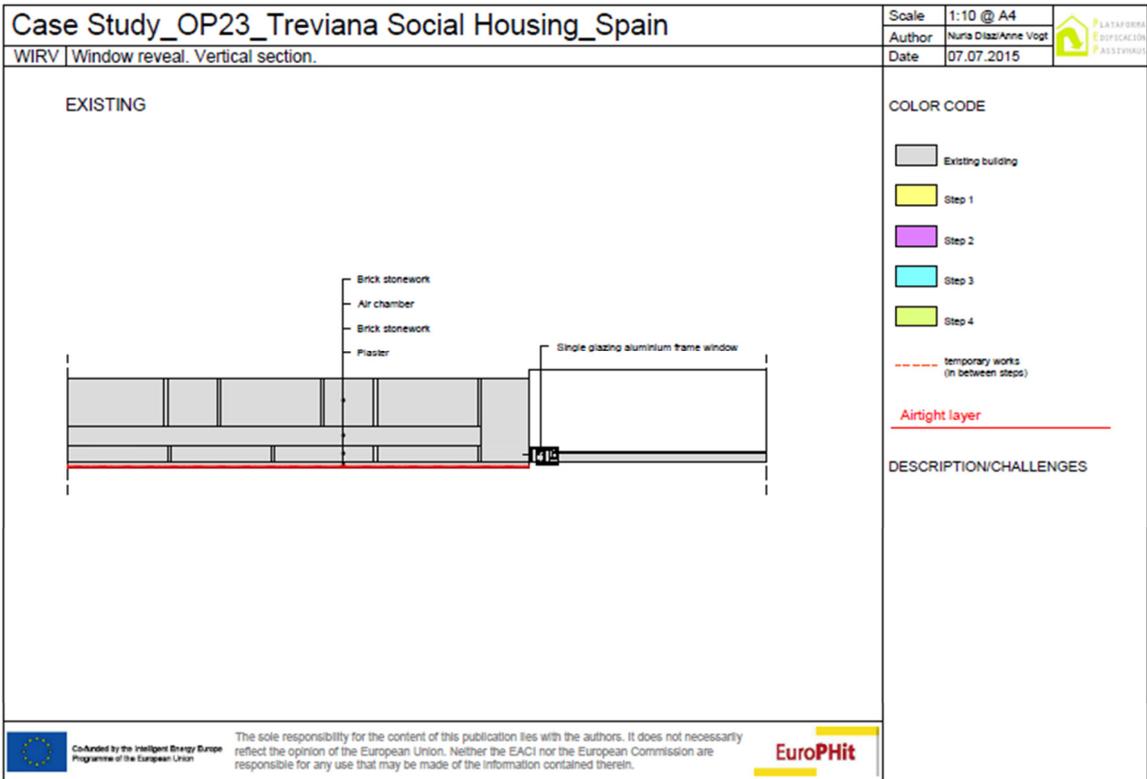
**Figure 10: Existing window**



**Figure 11: Balcony windows**



**Figure 12: Existing external wall construction beam**



**Figure 13: Existing window installation**

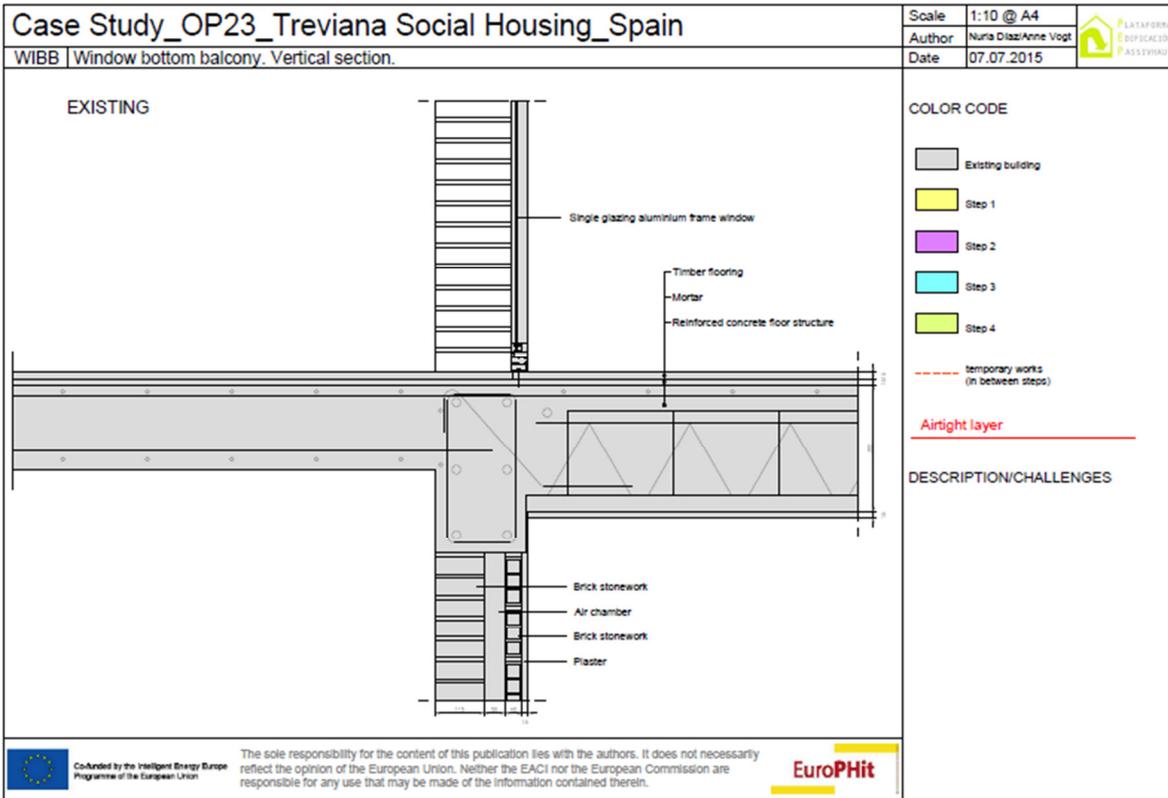


Figure 14: Existing window installation and balcony

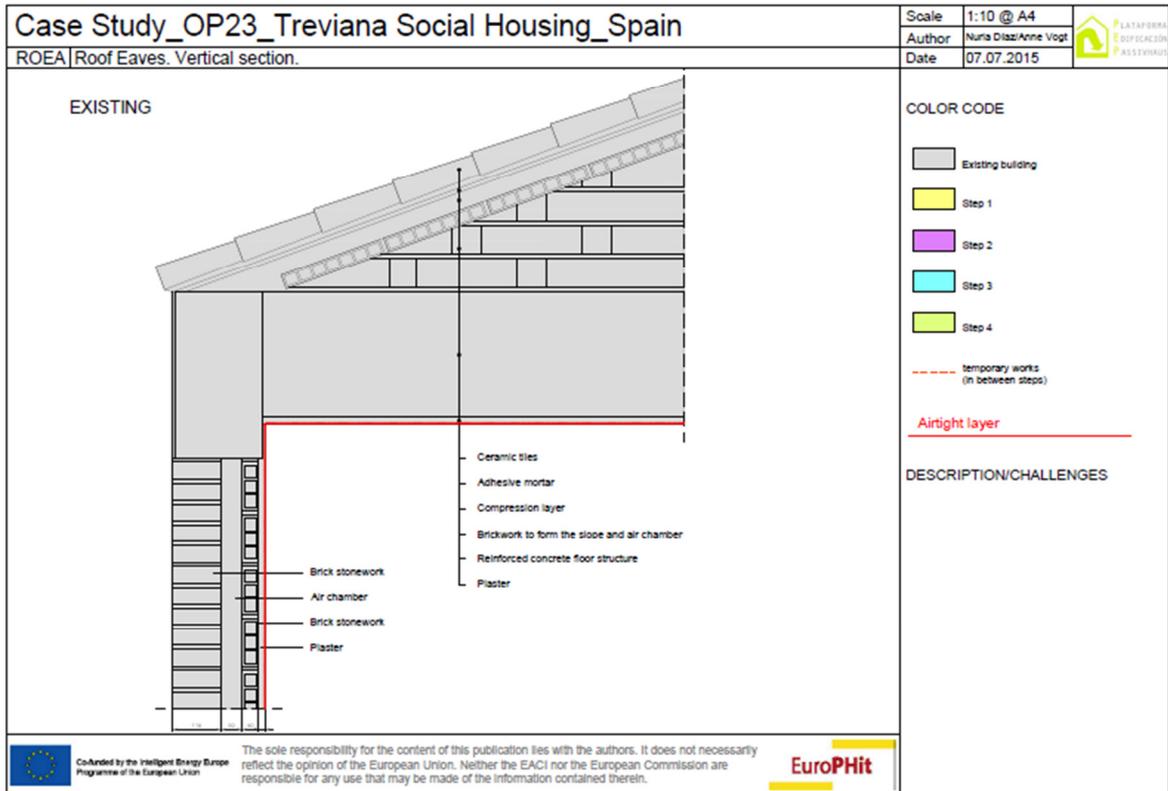


Figure 15: Existing external wall and roof connection

## 3 Planning Progress

### 3.1 Project preparation and design period

The first step retrofit was proposed by the new owner of an apartment in the building. They wanted to improve the efficiency and comfort condition of the apartment. The first challenge in a design stage is the thermal bridges elimination as far as possible.

The original façade line is restored, recovering the original terrace. This means an interior comfort reduction in both winter and summer season and a thermal energy cost increment due to the poor quality of the components and also the new uninsulated floor and ceiling areas that have been created.

Construction details were designed focus on not only reducing the heating demand but avoiding the risk of condensation since the insulation is collocated on the inside and is not possible to eliminate all the thermal bridges.

Further steps have been taking into account during this first design period. Those will be development more in deep when the community decide to improve any of the envelope components.

A methodology has been created for this kind of project where a single apartment can be retrofitted first and years later the whole building or vice versa. The energy balance is calculated by the component method for the building, and later in order to avoid overheating an apartment for each orientation is analysed too. In this way, every owner who wants to retrofit his dwelling could take as reference the energy balance of the building and the single apartment with the same orientation.

#### 3.1.1 Involved design / consultancy teams

<b>Main Tasks</b>	<b>: Team</b>	<b>City</b>
Architecture	: VAND Arquitectura	Madrid
Structural engineering	:	
HVAC	: Altertechnica	Segovia
Electrical	:	
Efficiency Consultant	: VAND Arquitectura	Madrid
Overall refurbishment plan	: VAND Arquitectura	Madrid
Other	:	

#### 3.1.2 Planning/design periods

<b>Planning period</b>	<b>: From</b>	<b>Until</b>
Discussions and negotiation period	:	
Design concept	: January2015	February 2015
Overall refurbishment plan	: January2015	February 2015
Building permission	:	
Excecution planning	:	
Tender release	: April 2015	May 2015

Start of construction works	: March 2015
Completion of 1 <sup>st</sup> retrofit step	: May 2015
Other (monitoring)	: October 2015

## 3.2 Overall refurbishment Plan

### 3.2.1 Retrofit steps:

The first step includes the next works on the apartment: continuous interior wall insulation, airtightness improvement, high quality window installation and connection with the walls, mechanical ventilation with heat recovery installation and boiler substitution. It is to be carried out within EuroPhit project.

Further steps have to be ratified by the majority of these owners since they affects to community part of the building.

The next schedule shows the first two steps (apartment). Steps 3 and 4 have not been analysed at this point since have no specific effects on the apartment. The step 2, 3 and 4 dates are not representatives since those steps will be implemented when the lifespan of the components are ending.

Step No.	Year	Measures	Specific Heating Demand	Specific Primary Energy	Additional Specific PV Gains
0	1963	Existing Building	150 (apartment)	166 (apartment)	
1	2015	Step 1 (apartment)	47(apartment)	143 (apartment)	
2	2025	Exterior wall insulation - ETICS (entire building)	6 (apartment)	143 (apartment)	
3	No date	Roof insulation			
4	No date	Basement ceiling insulation			

**Figure 16: Overview refurbishment steps**

### 3.2.2 Efficiency Improvements

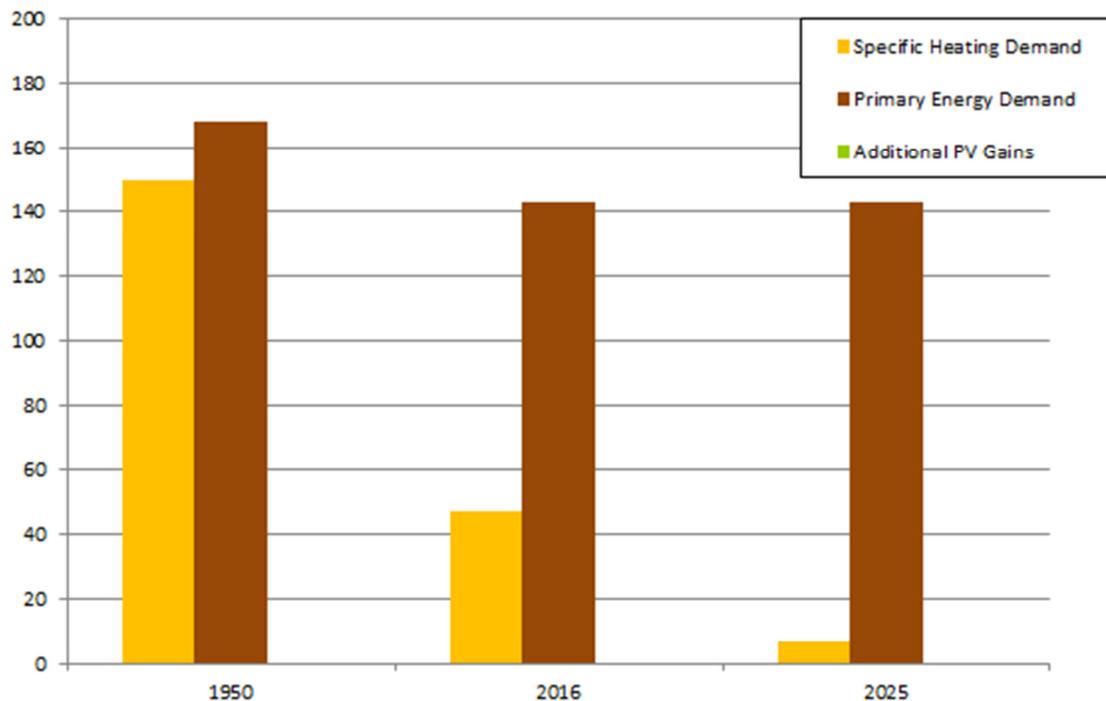


Figure 17: Overview energy efficiency improvement according to the overall refurbishment plan

## 3.3 Retrofit steps within EuroPHit

### 3.3.1 Retrofit step 1:

The works included in this first step are the followings:

- Exterior wall inner insulation: Improvement of heating and cooling demand using 4, 6 and 8 cm of mineral wool inner insulation have been calculated with PHPP software. Taking into account the exterior wall and floor structure connection thermal bridge, the huge demand increment makes not interesting thinking about high thicknesses that remove interior area of the flat. The mineral wool thickness chosen is 4 cm to reduce the demand as far as possible but above all to increase the surface temperature, raise the comfort, and reduce surface condensation risk
- High-quality windows installation and connexions with walls: High quality windows installation adequated to Madrid climate and flat orientation, mostly south-west with high overheating risk in summer. Besides, solar control glass and roll shutters with electrical mechanism as protection against overheating. This element affects badly to the flat airtightness but it is installed by aesthetic reasons of integration with the building. Other solutions require the approval of the owner association.

- Airtightness improvement: Airtightness improvement through PP membrane and adequate tapes in windows connexions and systems conducts passages. The pressurization test result n50 is estimated in 6,0 1/h in the original state of the flat and the measured test result after finishing the first step works is 1.67 1/h.
- Ventilation system with heat recovery installation: The machine is located in the bathroom false ceiling and the distribution ducts runs though the corridor ceiling. Madrid City regulations do not allow the placement of outside elements on the façade, as grids. In this case an exception has been made since the building is located outside the historical city centre, but this can be an extra difficulty for other cases.

Start date	:	2015
Completion date	:	2015
Budget	:	13726
PHPP: specific heating demand [kWh/(m <sup>2</sup> K)]	:	47
PHPP: specific cooling demand   Overheating frequency [kWh/(m <sup>2</sup> K)   %]	:	6.5%
PHPP: specific primary energy demand [kWh/(m <sup>2</sup> K)]	:	143

#### 3.3.1.1 New envelope component (external wall)

Description	:	40 mm mineral wool insulation, air chamber and plasterboard. The inner brick layer will be kept.
U-Value [W/(m <sup>2</sup> K)]	:	0.531 W/(m <sup>2</sup> K)
Installation date	:	2015
Condition	:	
Next replacement	:	
Other	:	

#### 3.3.1.1 New envelope component (windows)

Description	:	Deceunink, neo@zendow premium U <sub>f</sub> = 1.03 W/(m <sup>2</sup> K), Glazing: 4Guardian Sun/16arg/4/16arg/premium4 U <sub>g</sub> -value =0.50W/(m <sup>2</sup> K), g -value = 35%
U-Value [W/(m <sup>2</sup> K)]	:	1.11 (average)
Installation date	:	2015
Condition	:	
Next replacement	:	
Other	:	

### 3.3.1.2 New ventilation component

Description : Ventilation system with heat recovery. Product name: ComfoAir 200 (Zehnder)

HR Efficiency[%] : 95%

EI.Efficiency [Wh/m³]

Installation date : 2015

Condition :

Next replacement : -

Other : -

EnerPHit Verification						
			<b>Building:</b> Treviana Social Housing Street: Treviana 3 Postcode/City: 28043 Madrid Province/Country: Madrid Spain Building type: Residencial Climate data set: ES0001b-Madrid Climate zone: 4: Warm-temperate Altitude of location: 695 m			
			<b>Home owner / Client:</b> Marcos Garcia Carvantes Street: C/Treviana, 3 Postcode/City: Madrid Province/Country: Madrid ES-Spain			
<b>Architecture:</b> VAND Arquitectura Street: C/ Villablanca, 85 Postcode/City: 28032 Madrid Province/Country: Madrid ES-Spain			<b>Mechanical system:</b> Alternativa Street: Av. Gernández Ladreda, 10 2ºB Postcode/City: 40001 Segovia Province/Country: Segovia ES-Spain			
<b>Energy consultancy:</b> VAND Arquitectura Street: C/Villablanca, 85 Postcode/City: 28032 Madrid Province/Country: Madrid ES-Spain			<b>Certification:</b> Street: Postcode/City: Province/Country:			
Year of construction:	1970	Interior temperature winter [°C]:	20,0	Interior temp. summer [°C]:	25,0	
No. of dwelling units:	1	Internal heat gains (IHG) heating case [W/m²]:	2,7	IHG cooling case [W/m²]:	6,9	
No. of occupants:	4,0	Specific capacity [Wh/K per m² TFA]:	204	Mechanical cooling:		
Specific building characteristics with reference to the treated floor area						
	Treated floor area m²					
Space heating	Heating demand kWh/(m²a)	77,6	≤	Criteria	Alternative criteria	Fulfilled?²
	Heating load W/m²	47	≤	-	-	
Space cooling	Cooling & dehum. demand kWh/(m²a)	33	≤	-	-	-
	Cooling load W/m²	-	≤	-	-	-
	Frequency of overheating (> 25 °C) %	-	≤	10	-	yes
	Frequency excessively high humidity (> 12 g/kg) %	7	≤	20	-	yes
Airtightness	Pressurization test result n50 1/h	0	≤	1,0	-	no
Non-renewable Primary Energy (PE)	PE demand kWh/(m²a)	1,7	≤	-	-	-
Primary Energy Renewable (PER)	PER demand kWh/(m²a)	155	≤	96	111	no
	Generation of renewable energy kWh/(m²a)	143	≥	-	13	
		0				

EnerPHit (refurbishment): Component characteristics					
Building envelope to exterior air <sup>1</sup> (U-value) W/(m <sup>2</sup> K)	-	≤	0,3	-	-
Building envelope to ground <sup>1</sup> (U-value) W/(m <sup>2</sup> K)	-	≤	0,23	-	-
Wall w/int. insulation in contact w/external air (U-value) W/(m <sup>2</sup> K)	0,53	≤	0,5	-	no
Wall w/interior insulation in contact w/ground (U-value) W/(m <sup>2</sup> K)	-	≤	0,43	-	-
Flat roof (SRI) -	-	≥	-	-	-
Inclined and vertical external surface (SRI) -	19	≥	-	-	-
Windows/Entrance doors (U <sub>W,D,installed</sub> ) W/(m <sup>2</sup> K)	1,11	≤	1,08	-	no
Windows (U <sub>W,installed</sub> ) W/(m <sup>2</sup> K)	-	≤	1,13	-	-
Windows (U <sub>W,installed</sub> ) W/(m <sup>2</sup> K)	-	≤	1,23	-	-
Glazing (g-value) -	0,35	≥	0,18	-	yes
Glazing/sun protection (max. solar load) kWh/(m <sup>2</sup> a)	64	≤	-	-	-
Ventilation (effective heat recovery efficiency) %	90	≥	75	-	yes
Ventilation (humidity recovery efficiency) %	0	≥	-	-	-

<sup>1</sup> Without windows, doors and external walls with interior insulation  
<sup>2</sup> Empty field: Data missing; -: No requirement

Figure 18: Specific energy efficiency values after measures within EuroPHit

### 3.4 Pictures / Drawings

These pictures or drawings illustrate the retrofit process.



Figure 19: Window-wall airtickness



**Figure 20: Continuous inner insulation layer**



**Figure 21: Inner insulation [VAND architectura]**



Figure 22: Inner insulation [VAND arquitectura]

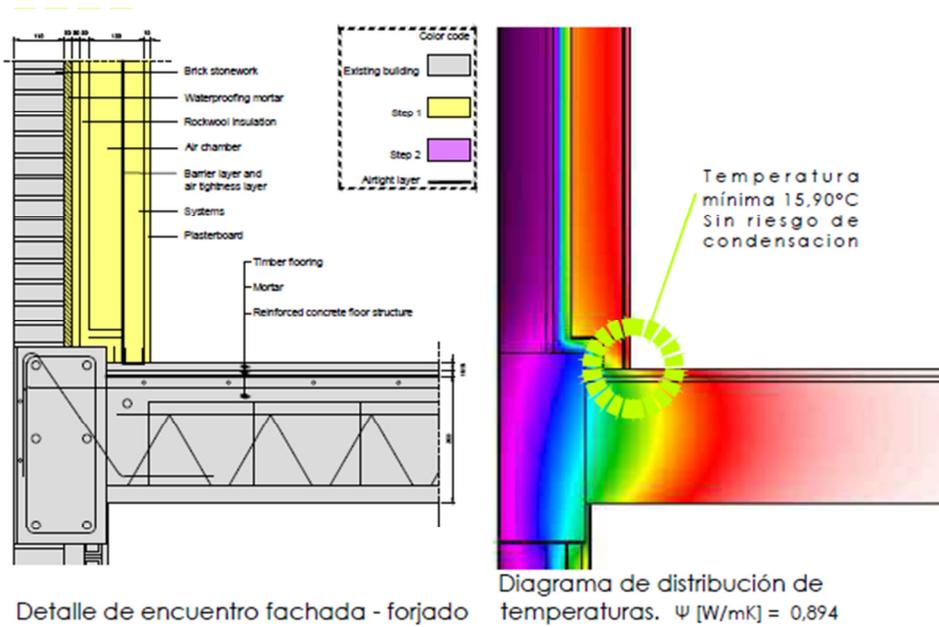


Figure 23: Hygrothermal study - exterior wall and floor structure connection detail, step 1



Figure 24: Airtightness layer - PP membrane [VAND arquitectura]

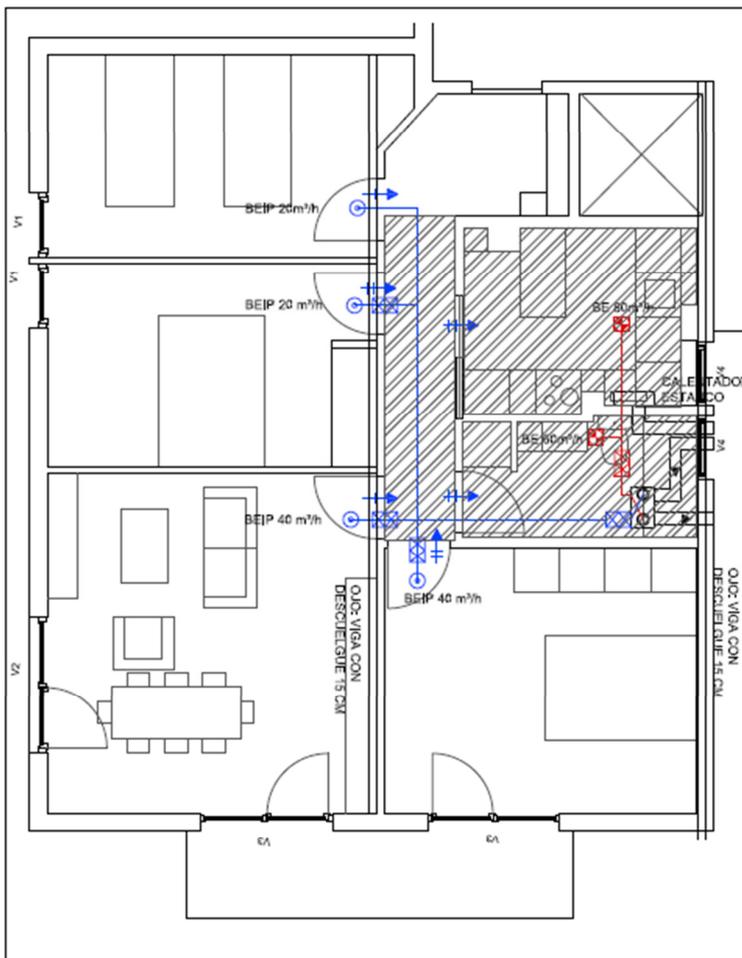


Figure 25: Ventilation distribution plan [VAND arquitectura]

## 3.5 Future retrofit steps

### 3.5.1 Retrofit step 2:

The entire external wall of the building will be insulated through ETICS installation. There will be two types of external wall: with external insulation (step 2) and with external and inner insulation (step 1 + 2).

Start date	:	2025 (approximately)
Completion date	:	2025 (approximately)
Budget	:	-
PHPP: specific heating demand [kWh/(m <sup>2</sup> K)]	:	6 (apartment)
PHPP: specific cooling demand   Overheating frequency [kWh/(m <sup>2</sup> K)   %]	:	1 (apartment)
PHPP: specific primary energy demand [kWh/(m <sup>2</sup> K)]	:	143 (apartment)

#### 3.5.1.1 New Envelope component (External wall - Step 2)

Description	:	ETICS 100 mm
U-Value [W/(m <sup>2</sup> K)]	:	0.30 W/(m <sup>2</sup> K) (approximated value)
Installation date	:	Step 2 (2025 approximately)
Condition	:	
Next replacement	:	
Other	:	

#### 3.5.1.1 New Envelope component (External wall - Step 1 + 2)

Description	:	Step 2: 100 mm ETICS (the system and material will be decided in the future). Step 1: 40 mm mineral wool insulation, air chamber and plasterboard. The inner brick layer will be kept.
U-Value [W/(m <sup>2</sup> K)]	:	0.22 W/(m <sup>2</sup> K) (approximated value)
Installation date	:	Step 2 (2025 approximately)
Condition	:	
Next replacement	:	
Other	:	

### 3.5.2 Retrofit step 3:

When the roof needs to be repaired, insulation will be added.

Start date : No date  
 Completion date : No date  
 Budget : -  
 PHPP: specific heating demand [kWh/(m<sup>2</sup>K)] : -  
 PHPP: specific cooling demand | :  
 Overheating frequency [kWh/(m<sup>2</sup>K) | %]  
 PHPP: specific primary energy demand [kWh/(m<sup>2</sup>K)] :

### 3.5.2.1 New Envelope component (Pitched roof)

Description : 100 XPS insulation, timber battens and ceramic tiles. The slope surface below the initial ceramic tiles will be kept.  
 U-Value [W/(m<sup>2</sup>K)] : 0.27 W/(m<sup>2</sup>K) (approximated value)  
 Installation date :  
 Condition :  
 Next replacement :  
 Other :

### 3.5.3 Retrofit step 4:

When the systems need to be replaced by a new and more efficient one, basement ceiling insulation will be done.

Start date : No date  
 Completion date : No date  
 Budget : -  
 PHPP: specific heating demand [kWh/(m<sup>2</sup>K)] :  
 PHPP: specific cooling demand | :  
 Overheating frequency [kWh/(m<sup>2</sup>K) | %]  
 PHPP: specific primary energy demand [kWh/(m<sup>2</sup>K)] :

#### 3.5.3.1 New Envelope component (basement ceiling)

Description : 100 mm mineral wool insulation and plasterboard below the existing floor structure.  
 U-Value [W/(m<sup>2</sup>K)] : 0.29 W/(m<sup>2</sup>K) (approximated value)  
 Installation date :  
 Condition :  
 Next replacement :  
 Other :

### 3.6 Drawings

These pictures or drawings illustrate the future retrofit process.

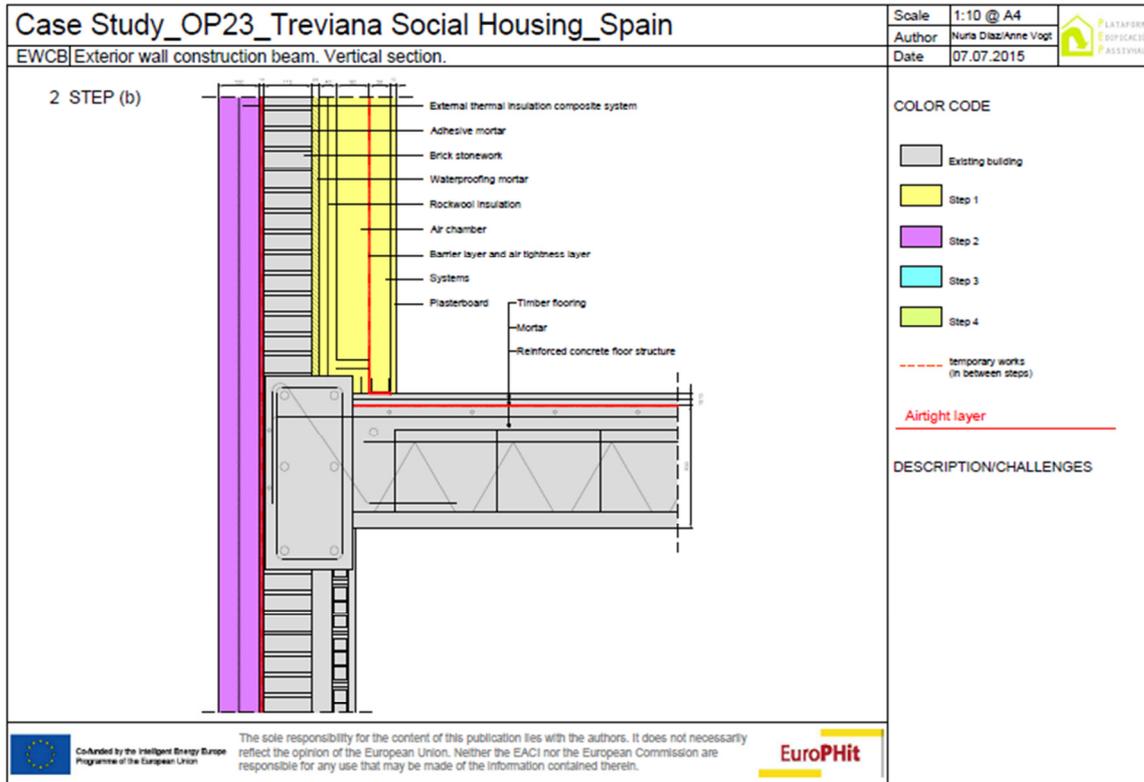


Figure 26: Future retrofit steps – Step 2 (ETICS)

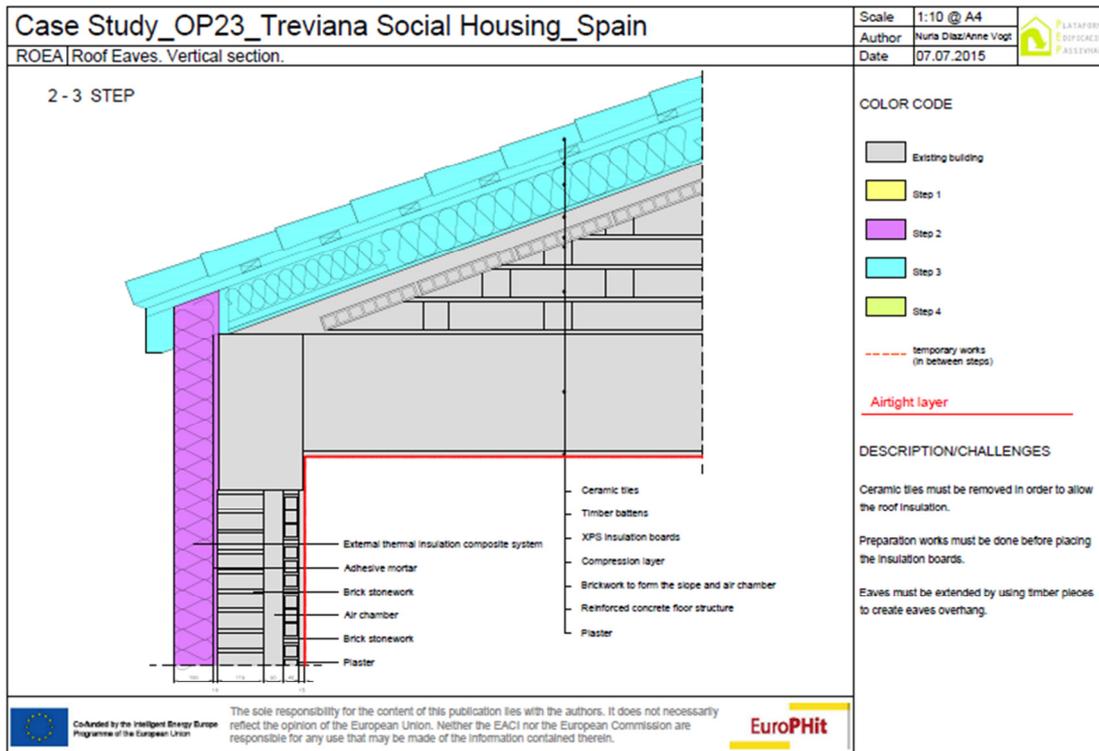


Figure 27: Future retrofit steps – Step 2 (ETICS) and step 3 (roof insulation)

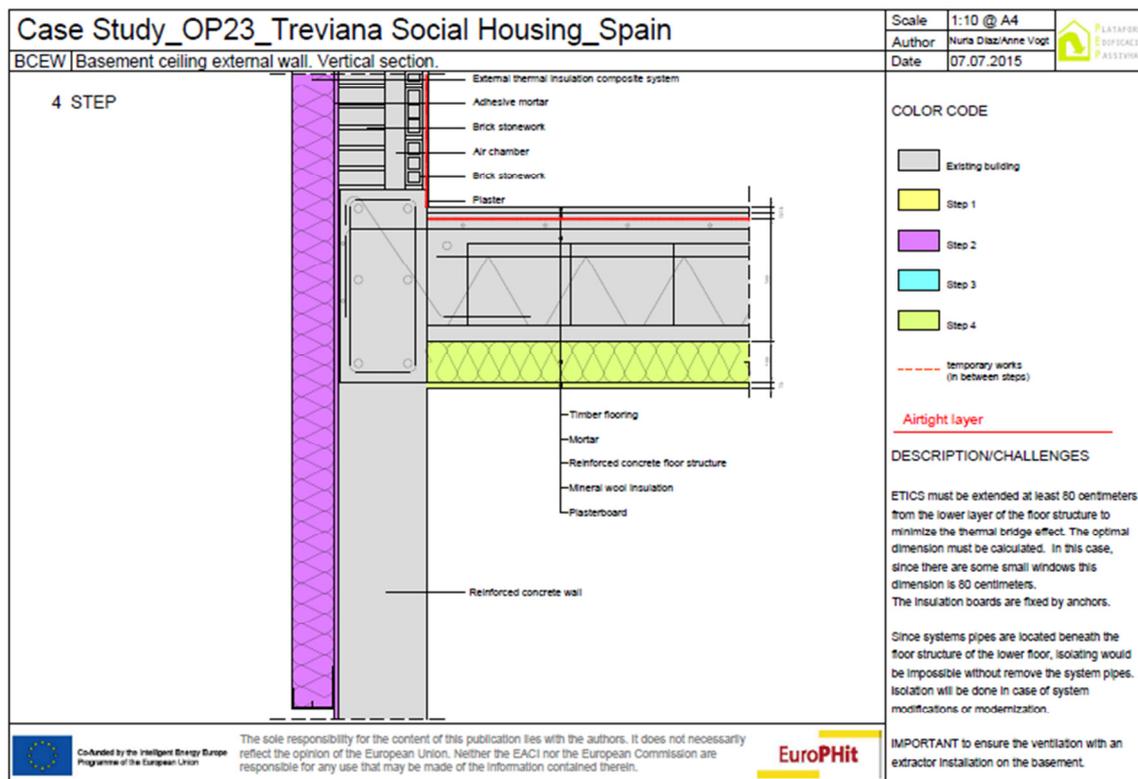


Figure 2821: Future retrofit steps – Step 4 (basement ceiling insulation)

## 4 RES Strategy / PV Potential Evaluation

Photovoltaic systems use sun radiation to produce electrical energy. As buildings envelopes are exposed to the sun radiation, the installation of photovoltaic technology on facades, roofs, floors, canopies... is a good solution to save energy generating clean electricity where it is consumed. This solution provides immediate energetic savings in the actual net electric consumption and economic feasibility on medium-long term basis; it should be taken into account that photovoltaic systems suppose an additional saving cost in transportation and energy distribution, one of the main limitations of effective energetic sources access.

Photovoltaic modules integration can be included in buildings in several ways. Depending on the level of integration and the functionalities that can be developed, they can be classified as:

- BAPV (Building Applied Photovoltaic) systems are regular photovoltaic solar systems that are generally installed on top of the roofs.
- BIPV (Building Integrated Photovoltaics) concept refers to photovoltaic products that are used as replacements for traditional building materials. BIPV solutions are being designed to completely replace building components including parts of building envelopes such as skylights, curtain walls, ventilated facades, balconies, floors...

The use of components with photovoltaic materials on retrofitting projects is highly recommended because it improves the energy efficiency of the obsolete buildings that did not follow the modernized patterns of sustainability. On the other hand, governments where

solar radiation conditions are optimal and the energetic net cost is considerably high are analysing the possibility of promoting the photovoltaic energy integration in buildings.

Then, in the following sections, different options of photovoltaic systems for this building are presented.

#### 4.1 Multifunctional behaviour of the BIPV systems: active and passive properties

Building integrated photovoltaic solutions (BIPV) are capable of fully replacing conventional construction materials for the building envelope such as skylights, façades, windows, curtain walls, roofs, balcony railings and floors. These multifunctional bioclimatic solutions combine both active and passive properties, providing greater acoustic and thermal insulation and at the same time producing clean energy on site. Furthermore, different colours, technologies and see-through degrees are possible allowing customizing the solution.

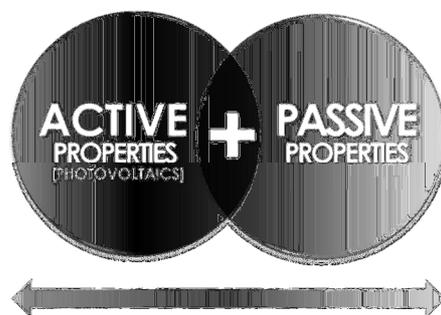


Figure 2922: Multifunctional concept of BIPV

Façade insulation solutions for external walls can be implemented to reduce thermal exchanges between exterior and interior and to avoid thermal bridges. Photovoltaic ventilated facades, thanks to the ventilated air chamber and to the application of insulating material, increases the acoustic absorption and can reduce the amount of heat that buildings absorb in hot weather conditions. In the air gap, the density difference between a hot and cold air creates a natural flow removing the air through a chimney effect. That is a natural ventilation system that helps to eliminate heat and moisture increasing inner comfort and in addition, the façade produces energy. In cold seasons, the warm air of the air chamber can be used to reduce the heat demand of the building (HVAC or DHW systems) enhancing the energy efficiency of the buildings.

Photovoltaic semi-transparent glass can be used on glazing systems refurbishment. Not only clean and free energy is being generated in-situ, but also natural illumination is being provided implementing solar control by filtering effect, avoiding infrared and UV irradiation to the interior (enhancing thermal comfort and avoiding interior aging). Double or triple glazed photovoltaic insulating units can be incorporated into the project improving thermal insulation properties, and the large variety in form, structure and colour of transparent photovoltaic glass, provides a free reign of creativity enhancing the attractiveness of the project.

Canopies and pergolas can be made also with photovoltaic materials, combining power generation with solar protection properties against adverse weather conditions. In these sense, the photovoltaic integration on the deck of a parking structure can produce on-site power generation to supply the batteries of an electric car, promoting sustainable mobility.

Photovoltaic walkable roof, photovoltaic balcony railings and photovoltaic spandrels are other innovative BIPV solutions that can be applied in new and retrofit projects

BIPV integration will be analyzed as a multifunctional added value where, in addition to the electrical generation, the system could provide passive bioclimatic properties as thermal inner comfort -since most of the UV and infrared radiation from the sun will be harvested by the silicon-based material (solar filter effect)-, natural sunscreen and the highly modern appearance.

## 4.2 Inhabitant's comfort and location concept

The location is a key issue in order to consider the best solutions for this intervention. Into these parameters, there are critical factors that must be taken into account to move ahead. These critical factors include climate and microclimate features, geographical conditions (latitude, longitude, altitude above sea level, orientation) and building orientation.

Location	Madrid
Country	Spain
Region	Europe
Latitude	40.4°N
Longitude	-3.7°E
Altitude	695 m
Time Zone	UTC/GMT +1

Figure 30: Location parameters

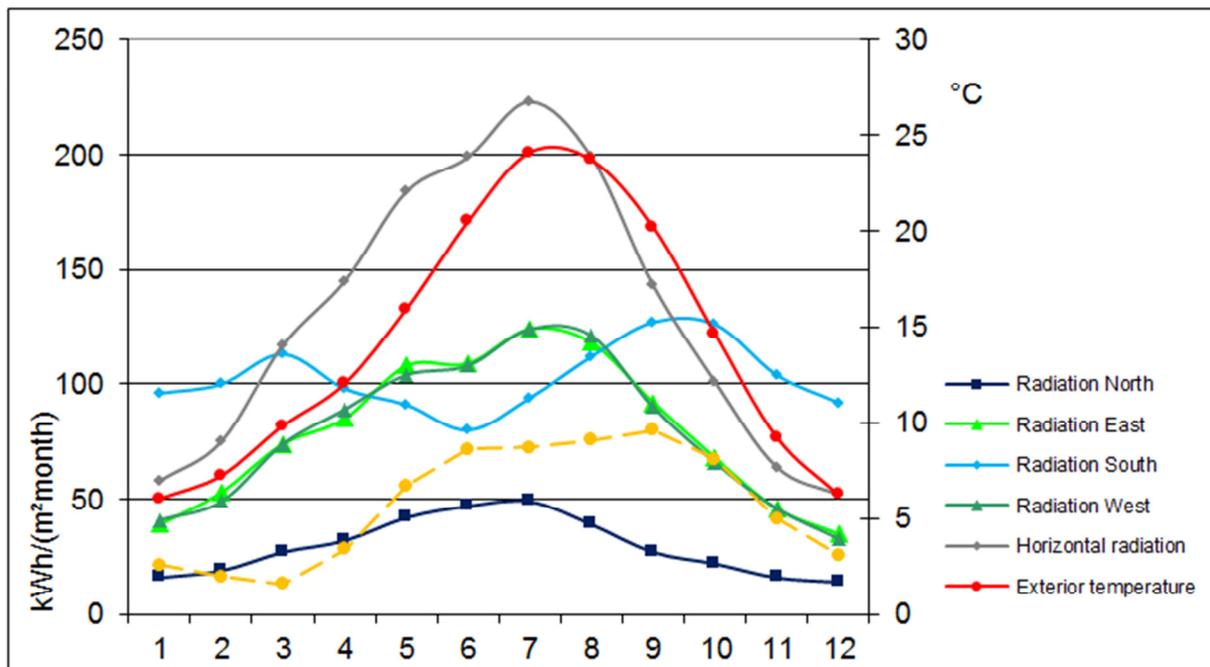


Figure 3123: Microclimate conditions. Source PHPP

These climatic and geographic parameters, and the specific location of the building –latitude, longitude, altitude above sea level, orientation- were critical facts when selecting the technology to be implemented.

It is mandatory to point out that it has not been considered the effects of shadows or components of diffuse radiation and albedo in this approach. Therefore, a detailed analysis of production taking into account these critical factors should be done in subsequent stages of the analysis.

### 4.3 Evaluation of potential PV systems

#### 4.3.1 PV ventilated facade

The ventilated façade would be located in the south oriented elevation, covering the opaque walls.. The scheme of the PV integration is shown below:

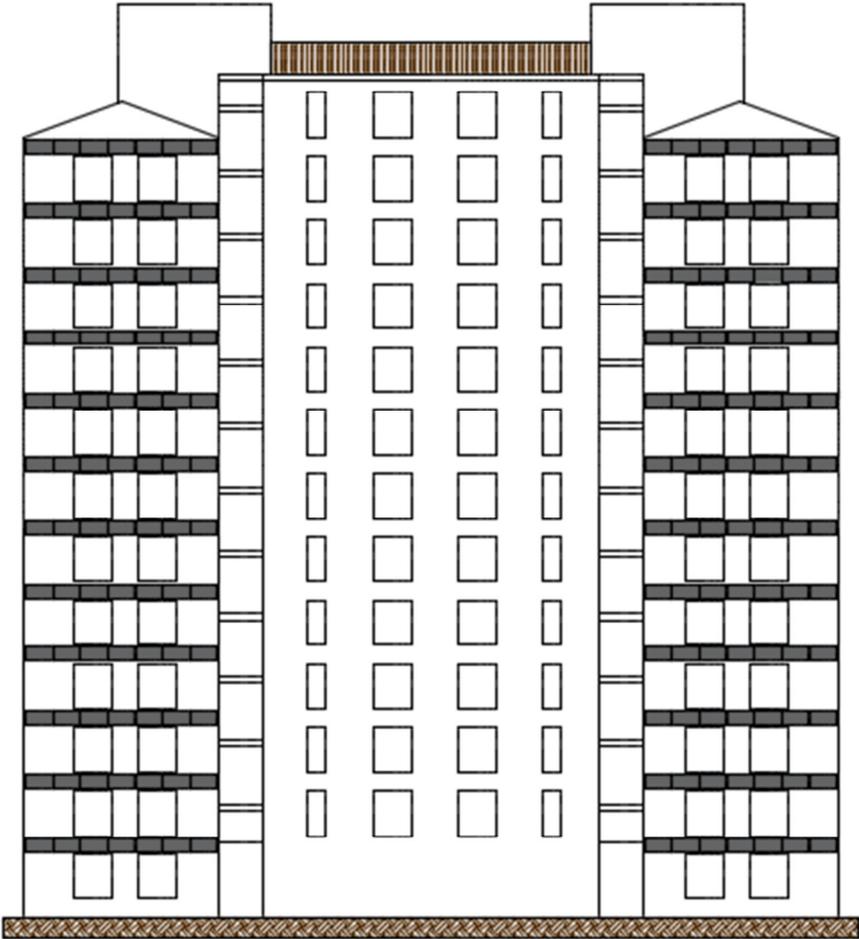


Figure 32: PV ventilated façade (West elevation)

**4.3.1.1 PV glass**

**Amorphous silicon technology**

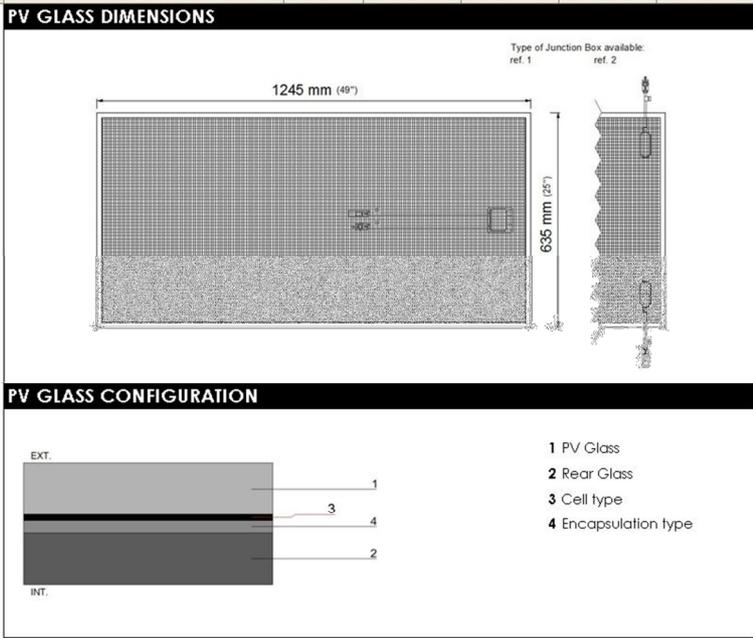
The technology selected for this proposal will be amorphous silicon technology (a-Si) due to the following reasons:

- Due to the location, orientation and surroundings, direct exposure of glass to solar radiation rarely would be achieved in an optimal way, being mandatory the harvesting of diffuse radiation. Then, amorphous silicon technology is the one that offers the best result in terms of kWh/kWp installed under these irradiation conditions.
- Furthermore, this technology offers the best aesthetic solutions when combining with other claddings/construction materials due to its plain characteristics and opaque color.

**Glass dimensions and configuration**

The glass selected for the integration is an opaque glass with a nominal power of 49 Wp/unit. The initial dimensions proposed for the PV glass are 1245x635 mm.

The installation consists of 91 glasses, with an active surface of 71.89 sqm and a total power installed of 4.45 kWp.



**Figure 33: PV opaque a-Si glass. Dimensions and configuration. Source ONYX**

A-SI OPAQUE		
Electrical data		
Nominal peak power	49,00	$P_{mpp}$ (Wp)
Open-circuit voltage	64,50	$V_{oc}$ (V)
Short-circuit current	1,05	$I_{sc}$ (A)
Voltage at nominal power	51,70	$V_{mpp}$ (V)
Current at nominal power	0,95	$I_{mpp}$ (A)
Power tolerance not to exceed	±5	%
STC: 1000 w/m <sup>2</sup> , AM 1.5 and a cell temperature of 25°C, stabilized module state.		
Mechanical description		
Length	1245	mm
Width	660	mm
Thickness	3,65	mm
Weight	0,75	kg
Temperature degree	1200	°C
Cell type	e-Si thin film, multi cells	
Temperature degree	Dark	
Back sheet	0,2 mm Fluor. Glass	
Accessories	0,2 mm Fluor. Glass	
Front sheet	0,2 mm EVA	
Wiring section	2,5 mm	
Limits		
Maximum system voltage	1000	$V_{sys}$ (V)
Operating module temperature	-40...+85	°C
Temperature Coefficients		
Temperature Coefficient of $P_{mpp}$	-0,19	%/°C
Temperature Coefficient of $V_{oc}$	-0,28	%/°C
Temperature Coefficient of $I_{sc}$	+0,09	%/°C

Figure 34: PV opaque a-Si glass Technical data sheet. Source ONYX

### 4.3.2 PV Roof superposition

Another option is the integration on the roof, taking advantage of this area directly exposed to the sun.

#### 4.3.2.1 PV glass

##### Crystalline technology

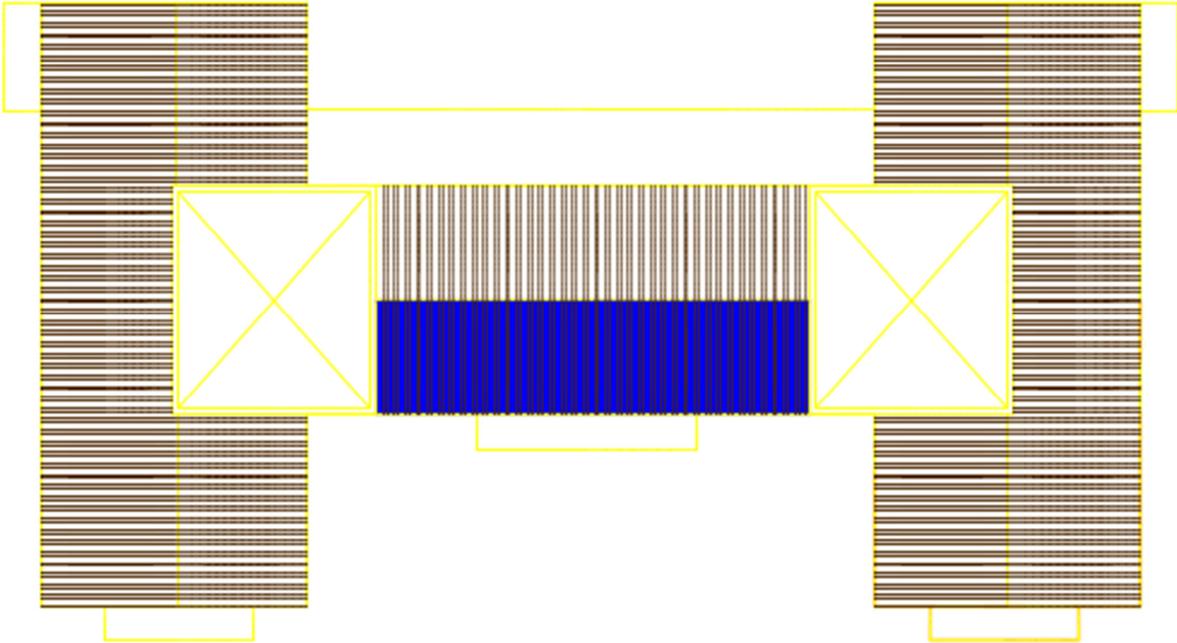
The technology selected is the mono-crystalline (m-c) silicon, with a black back sheet, for the following reason:

Due to the location, orientation and planned placement, photovoltaic traditional panels can provide the best exposure to solar radiation (understood as such direct solar radiation in optimum angle) so it becomes critical exploit the available area to install most power as possible. Technology of mono-crystalline silicon is which provides the best results in terms of kWp/m<sup>2</sup> radiation for these conditions.

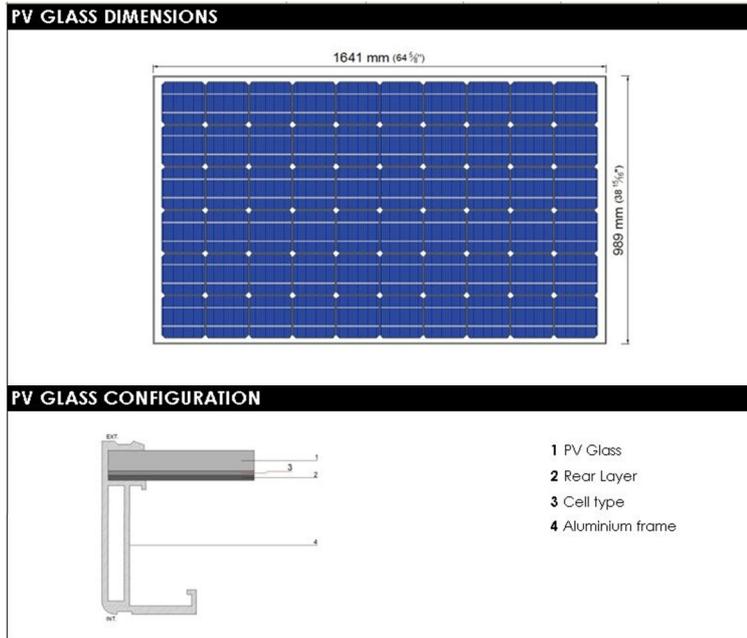
**Glass dimensions and configuration**

The glass selected for the integration is an opaque glass with a nominal power of 274 Wp/unit. The initial dimensions proposed for the PV glass are 1641x989 mm.

There is one roof area where PV units superposition is proposed. The installation consists of 30 units, with an active surface of 48.60 sqm and a total power installed of 8.22 kWp.



**Figure 35: PV roof area in blue**



**Figure 36: PV m-c glass Dimensions and configuration. Source ONYX**

<b>PHOTOVOLTAIC GLASS</b>		<b>1641 x 989</b>	
		<b>6" Mono</b>	<b>Crystalline</b>
<b>Electrical data test conditions (STC)</b>			
Nominal peak power	274	P <sub>mpp</sub> (Wp)	
Open-circuit voltage	38	V <sub>oc</sub> (V)	
Short-circuit current	9.09	I <sub>sc</sub> (A)	
Voltage at nominal power	32	V <sub>mpp</sub> (V)	
Current at nominal power	8.55	I <sub>mpp</sub> (A)	
Power tolerance not to exceed	±3	%	
STC: 1000 w/m <sup>2</sup> , AM 1.5 and a cell temperature of 25°C, stabilized module state.			
<b>Mechanical description</b>			
Length	1641	mm	
Width	989	mm	
Thickness	5.9	mm	
Surface area	1.62	sqm	
Weight	23.50	Kgs	
Cell type	6" Mono	Crystalline	
No PV cells / Transparency degree	60 cells	Dark	
Front Glass	4 mm	Tempered Glass	
Rear Glass	1 mm	TEDLAR/PYE	
Thickness encapsulation	0.90 mm	EVA Foils	
Category / Color code			
<b>Junction Box</b>			
Protection	IP65		
Wiring Section	2.5 mm <sup>2</sup> or 4.0 mm <sup>2</sup>		
<b>Limits</b>			
Maximum system voltage	1000	V <sub>sys</sub> (V)	
Operating module temperature	-40...+85	°C	
<b>Temperature Coefficients</b>			
Temperature Coefficient of P <sub>mpp</sub>	-0.451	%/°C	
Temperature Coefficient of V <sub>oc</sub>	-0.361	%/°C	
Temperature Coefficient of I <sub>sc</sub>	+0.08	%/°C	

**Figure 37: PV m-c glass Technical data sheet. Source ONYX**

## 4.4 Production estimation

A preliminary estimation of PV energy generation can be determined for the proposed solutions by means of implementing simulation tools, where key site location factors as climatic parameters (latitude, longitude, altitude above sea level, orientation) and BIPV system characteristics (tilted angle, azimuth etc.) are considered to establish the final solution energy performance.

#### **4.4.1 Option 1.**

PV type : a-Si  
Location : South façade  
Installed PV area [m<sup>2</sup>] : 71.89  
Installed peak power [Wp] : 4459  
Annual RES gains [kWh] : 4097

#### **4.4.2 Option 2**

PV type : Mono-Si  
Location : Roof superposition  
Installed PV area [m<sup>2</sup>] : 48.60  
Installed peak power [Wp] : 8220  
Annual RES gains [kWh] : 11203

#### **4.4.3 Total**

Installed PV area [m<sup>2</sup>] : 120.49  
Installed peak power [Wp] : 12,679  
Annual RES gains [kWh] : 15,300

### **4.5 Financial evaluation & taxes and incentives assessment**

#### **4.5.1 Specific Assumptions**

Installed PV area [m<sup>2</sup>] : 120.49  
Annual RES gains [kWh] : 15,300  
Total Estimated Cost [€] : 54,100  
Local Electricity Cost [€] : 0.24  
Variation in Electricity Cost until 2020 [%] : 8.18  
Variation in Electricity Cost from 2020 [%] : 1.00

Feed in Tariff [€] : 0

- Estimated cost includes: modules and supports cost, inverters and wiring, transports and mounting. These values should only be considered as an order of magnitude.
- IPC: The electricity price increase was calculated with data obtained from Eurostat. Up to year 2020, the average price increase is at 8.18% for the buildings with annual consumption under 500 MWh, during the last 10 years in SPAIN (electricity price in 2004S1: 10.79 cents EUR/Kwh; electricity price in 2014S1: 21.65 cents EUR/Kwh) (<http://ec.europa.eu/eurostat/web/energy/data/database>). From year 2020 onwards, the price increase used is at 1% which considers the energy price forecast included in the European Commission report “EU Energy, Transport, and Greenhouse Gas Emissions Trends to 2050”.

(<http://ec.europa.eu/transport/media/publications/doc/trends-to-2050-update-2013.pdf>).

#### 4.5.2 Results

Photovoltaic Energy Production [€/m <sup>2</sup> ]	: 601.13
Costs [€/m <sup>2</sup> ]	: 449.00
Investment after Incentives [€/m <sup>2</sup> ]	: 449.00
ROI [%]	: 34
Payback Period [years]	: <10
IRR [%]	: 6
Times the investment [times]	: 1

- Photovoltaic Energy Production: average reduction of energy demand per square meter of photovoltaic glass from energy generation
- Costs: estimated investment (modules, supports, inverters, wirings, transports and mounting).
- Investments after incentives: investments after applying federal incentives for solar photovoltaics).
- Return on investment in 20 years (profit-investment/investment)
- Payback period: time required for the return on the investment.
- IRR (Internal Rate of Return): average annual return during the first 20 years of the investment.
- Times the investment: number of times that the amount invested is received during the investment period of 20 years (Average Reduction of Energy Demand /Investment).

## 5 Completion of step-by-step refurbishment to EnerPHit standard including RES

### 5.1 General description

The retrofit works that have been undertaken within EuroPHit include the first step of the refurbishment plan. This step 1 affects to one apartment.

- Step 1:
- Exterior wall inner insulation
  - High-quality windows installation and connexions with walls
  - Airtightness improvement
  - Ventilation system with heat recovery installation

The next steps of the refurbishment plan will affects to the entire building.

- Step 2: ETICS installation
- Step 3: Roof insulation
- Step 4: Basement ceiling insulation

Future works will be undertaken on an individual way by apartment owners if they decide to improve their dwellings.

PV panel installation will be the last step of the refurbishment. The Spanish regulation will be analysed at that time to check the installation viability.

### 5.2 Retrofit steps carried out

The following figure presents the chosen efficiency improvement steps expected to be carried out after completion of the overall refurbishment plan (only apartment calculation, so no steps 3 and 4):

		Active			
		1-Existing apartment	Existing apartment	Step 1	Step 2
		1	1	2	3
<b>Results</b>	<b>Units</b>				
Heating demand	kWh/(m <sup>2</sup> a)	149,7	149,7	47,0	5,9
Heating load	W/m <sup>2</sup>	71,9	71,9	33,0	18,1
Cooling & dehum. demand	kWh/(m <sup>2</sup> a)				
Cooling load	W/m <sup>2</sup>				
Frequency of overheating (> 25 °C)	%	8,5	8,5	6,5	5,8
PER demand	kWh/(m <sup>2</sup> a)	166,1	166,1	142,8	142,8
EnerPHit Classic?	yes / no			no	no

Figure 38: PHPP9.3 [PHI 2015] Variant sheet with the retrofit steps carried out

## 5.3 Envelope of the refurbished Building

### 5.3.1 Basement ceiling

Description	:	EXTERIOR – Timber floor, mortar, reinforced concrete floor structure, 100 mm insulation, plasterboard - INTERIOR
U-Value [W/(m <sup>2</sup> K)]	:	0.302
Installation date	:	No date – Step 4
Condition	:	
Next replacement	:	
Other	:	

### 5.3.2 External walls

Description	:	EXTERIOR - 100 mm ETICS, existing wall or wall step 1 - INTERIOR
U-Value [W/(m <sup>2</sup> K)]	:	0.217 (interior insulation – step 1) – 0.347 (no interior insulation)
Installation date	:	Step 2 (2025 approximately)
Condition	:	
Next replacement	:	
Other	:	

### 5.3.3 Windows

Description	:	PVC frame and triple glazing
U-Value [W/(m <sup>2</sup> K)]	:	1.11 (average)
Installation date	:	Step 1 (2015) and 2 (2025)
Condition	:	
Next replacement	:	
Other	:	

### 5.3.4 Roof / Top floor ceiling

Description	:	EXTERIOR – Tiles, 100mm XPS insulation, existing roof structure - INTERIOR
U-Value [W/(m <sup>2</sup> K)]	:	0.229
Installation date	:	No date - Step 3
Condition	:	
Next replacement	:	

## 5.4 Technical equipment of the refurbished building

### 5.4.1 Domestic hot water

Description	:	Condensation boiler – natural gas
Performance ratio of heat generation [%]	:	
Installation date	:	2015 (only apartment)
Condition	:	
Next replacement	:	
Other	:	

### 5.4.2 Ventilation

Description	:	Mechanical ventilation with HR
HR Efficiency[%]	:	90%
EI.Efficiency [Wh/m <sup>3</sup> ]	:	
Installation date	:	2015 (only apartment)
Condition	:	
Next replacement	:	
Other	:	

## 5.5 Energy efficiency of the refurbished building

### 5.5.1 Modelled efficiency parameters

PHPP: specific heating demand [kWh/(m <sup>2</sup> K)]	:	
PHPP: specific cooling demand   Overheating frequency [kWh/(m <sup>2</sup> K)   %]	:	
PHPP: specific primary energy demand [kWh/(m <sup>2</sup> K)]	:	

For an overview of the energy efficiency of the completed step-by-step refurbishment, see the verification spreadsheet of the PHPP 9.3 version [PHI 2015] on the next page.

# EnerPHit Nachweis



Objekt:	Passivhaus-Endhaus Kranichstein				
Straße:					
PLZ/Ort:	D-64289 Darmstadt				
Land:	Deutschland/Hessen				
Objekt-Typ:	Reihenhaus/Wohnungen				
Klima:	Deutschland: PHPP-Standard				
Höhe Gebäudetendert (m ü. NN):	-				
Bauherrschaft:	Bauherrengemeinschaft Passivhaus				
Straße:					
PLZ/Ort:	D-64289 Darmstadt				
Haustechnik:	Geb Dipl.-Ing. Norbert Storz				
Straße:	Bahnhofstr. 49				
PLZ/Ort:	D-64319 Pfungstadt				
Zertifizierung:					
Straße:					
PLZ/Ort:					
Baujahr:	2035	Innentemperatur Winter [°C]	20,0	Innentemp. Sommer [°C]	25,0
Zahl WE:	1	Interne Wärmequellen Winter [W/m²]:	2,1	IvQ Sommer [W/m²]	2,1
Personenzahl:	4,5			spez. Kapazität [Wh/K pro m² EBF]:	204
Umbautes Vol. V.:	665,0 m³			Mechanische Kühlung:	

Gebäudekennwerte mit Bezug auf Energiebezugsfläche und Jahr				
	Energiebezugsfläche		Anforderungen	Erfüllt?*
<b>Heizen</b>	Heizwärmebedarf	14 kWh/(m²a)	25 kWh/(m²a)	ja
	Heizlast	10 W/m²	-	-
<b>Kühlen</b>	Kühlbedarf gesamt	kWh/(m²a)	-	-
	Kühllast	W/m²	-	-
	Übertemperaturhäufigkeit (> 25 °C)	1,5 %	-	-
<b>Primärenergie</b>	Heizen, Kühlen, Entfeuchten, WW, Hilfsstrom, Licht, elektr. Geräte	60 kWh/(m²a)	120 kWh/(m²a)	ja
	Ww, Heizung und Hilfsstrom	33 kWh/(m²a)	-	-
	PE-Einsparung durch solar erzeugten Strom	25 kWh/(m²a)	-	-
<b>Luftdichtheit</b>	Drucktest-Luftwechsel n <sub>50</sub>	0,2 1/h	1 1/h	ja

EnerPHit (Modernisierung): Bauteilkennwerte				
<b>Gebäudehülle</b>	Außendämmung zu Außenluft	0,13 W/(m²K)	-	-
<b>mittlere U-Werte</b>	Außendämmung zu Erdreich	0,13 W/(m²K)	-	-
	Innendämmung zu Außenluft	W/(m²K)	-	-
	Innendämmung zu Erdreich	W/(m²K)	-	-
	Wärmebrücken ΔU	-0,01 W/(m²K)	-	-
	Fenster	0,78 W/(m²K)	-	-
	Außentüren	W/(m²K)	-	-
<b>Lüftungsanlage</b>	eff. Wärmebereitstellungsgrad	82 %	-	-

\* leeres Feld: Daten fehlen; -: keine Anforderung

Figure 39: Specific energy efficiency values of the completed project modelled with PHPP 9.3

## 6 Estimated Construction Costs

No financial strategy has been considered for step 1. Performing the following steps will require the ratification by the majority of owners. At that point will be critical a financial strategy.

### 6.1 Retrofit step 1:

Estimated construction costs	:	13726 (energy efficiency measures)
Estimated Energy savings per year	:	7989 kWh (only apartment)

### 6.2 Retrofit step 2:

Estimated construction costs	:	-
Estimated Energy savings per year	:	11093 (only apartment)

### 6.3 Retrofit step 3 and 4:

Estimated construction costs	:	
Estimated Energy savings per year	:	

	Step 1	Step 2	Step 3	Step 4	Total
Estimated Cost	13726 €	5119 €	-	-	
Energy Savings per year	7989 kWh	11093 kWh			

**Figure 24: Estimated costs and energy savings for each retrofit step**

## 7 Conclusions

Single apartment retrofitting is very common in Spain. Nowadays most of these retrofits are performed by small companies where no qualified technicians are involved. It makes that, in most cases, the implemented solutions are not appropriated and the execution quality is deficient. It is necessary to set a methodology of actuation for these cases, since another way the final quality is no guaranteed. The retrofits should take place when the lifespan of a component is ending, other ways is quite complicate to persuade owners to improve the energy efficiency of the apartment or house.

Performing in the building is complicated since the low purchasing power of social housing owners, who cannot afford the cost of the retrofit works, makes worse the social housing refurbishment problems. Most of these social houses are not rented but owned. The fact each condo has a different owner makes it difficult to perform community retrofits in common areas because every change or intervention has to be ratified by the majority of these owners.

## **8 Appendix I: Project information**

[http://www.passivhausprojekte.de/index.php?lang=en#d\\_4549](http://www.passivhausprojekte.de/index.php?lang=en#d_4549)

<http://euophit.eu/op23-treviana-social-housing-madrid>

[https://www.passipedia.org/planning/refurbishment\\_with\\_passive\\_house\\_components/step-by-step\\_retrofits\\_towards\\_enerphit\\_standard\\_in\\_social\\_housing\\_in\\_spain](https://www.passipedia.org/planning/refurbishment_with_passive_house_components/step-by-step_retrofits_towards_enerphit_standard_in_social_housing_in_spain)