4RinEU

Reliable models for deep renovation

D5.5

WP5

Potential renovation rate of a building typology in a specific area

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Foreword

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

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

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

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

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

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

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

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

Principal Authors

Roberta Pernetti (EURAC)
Riccardo Pinotti (EURAC)

Contributors

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Executive Summary

The potential renovation rate analysis aims at evaluating the energy and environmental effects of deep renovation, taking results from the replication potential studied in 4RinEU deliverable D4.4. Here, the performances of the renovation packages are combined to the replication potential in specific contexts, namely Agència de l'Habitatge de Catalunya (AHC) and WOONZORG building stocks.
The analysis provides an estimation of the potential savings in energy consumptions and CO_2 emissions occurring in case of deep renovation. Moreover, a potential monetary saving due to reduced energy consumption is presented. The deep renovation approach has been compared to non-renovation scenario looking at a 50-years-long period.

Concerning AHC's building stock, information from the most general and extended pool of buildings available from AHC have been considered and a selection of 688 buildings have been taken into account. This selection consists of Social apartments in Public Residential building blocks, whose construction years is from 1930 up to 2010. Therefore, the replication potential evaluation will focus on **688 buildings (~69% of AHC total building stock**); considering the *80% (550 buildings)* of them as isolated multifamily houses, and the remaining *20% (138 buildings)* as adjacent to other constructions.
Concerning to Woonzorg building stock, it consists of approximately 641 buildings (corresponding to 28,705 apartments) almost totally identifiable with the multifamily house archetype defined in 4RinEU. **67% of the buildings (427)** are categorized with energy label B or lower, following the national regulation. Therefore, the renovation potential will be analysed, specifically on these buildings.
For both building stocks, the effect of two main renovation packages have been investigated (those maximizing energy and CO_2 emissions performances).

Remarkable results have been noticed concerning energy consumptions and CO_2 emissions reductions, especially considering the outcomes of renovation packages where heat pump is used for both heating and cooling.
In particular, in AHC buildings stock, energy consumption reduction compared to non-renovation scenario after 50 years is in the range of 80-90%, with a reduction in CO_2 emissions of almost 75%.
For Woonzoorg building stock, energy reduction is between 90-95% with an emissions reduction of about 90% respect to non-renovation scenario.

1 Introduction

This document presents the results of the evaluation of the impact of 4RinEU deep renovation packages on the existing building stocks in specific regions.

In particular, such an evaluation focuses on the two building stocks managed by the owners of the demo cases (i.e., AHC and WOONZORG), which will be considered as representative for Spain and The Netherlands (representative of two of the six geoclusters defined within 4RinEU).

It is linked to the results included in the 4RinEU D4.4 where it is reported the analysis of the replication potential of the 4RinEU renovation packages in the two abovementioned countries. Following the constraints as identified in deliverable 4.4 and their impact on the performances of the renovation packages, D5.5 will provide deep renovation scenarios and potential energy savings in these reference countries.

2 Features of the existing building stock and widespread of constraints

The European residential building stock has been analyzed starting from the data available from existing studies and available databases (e.g. FP7 project INSPIRE, BPIE Report European building stock under the microscope, EU Building Observatory) and according to the 4RinEU geo-clusters (Figure 1).

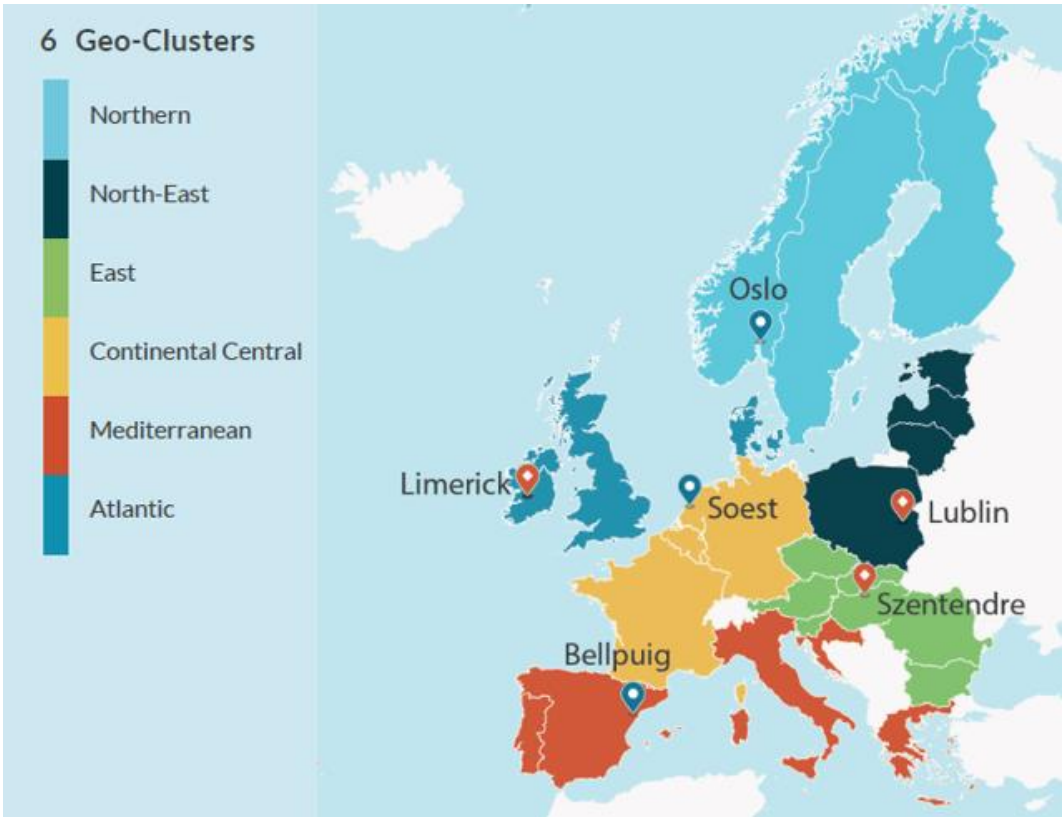

Figure 1. 4RinEU geo-clusters

In particular, the data about the share of single-family houses and multi-family houses and the distribution in different construction periods has been collected.
For a preliminary evaluation on the potential replication, we considered that the 4RinEU renovation packages would be theoretically applicable to buildings in the construction period from 1961 and 1991 that usually do not present constraints with regard to the cultural heritage protection for the renovation and have poor thermal performances.
Table 1 reports the main information collected about the EU building stock and an initial estimation of the potential floor area to be renovated with 4RinEU.

Geo-cluster	Country	Total residential stock in the EU countries			Residential buildings for each construction period			Potential floor are to be renovated with 4RinEU renovation packages (initial estimation)	
		Tot [Mm²]	SHF [%]	MFH [%]	pre 1961 [%]	1961 – 1991 [%]	>1991 [%]	SHF [Mm²]	MFH [Mm²]
Northern	Finland	199	66,3	33,7	23,4	51,1	25,5	0,8	0,4
	Norway	**333**	**84,3**	**15,7**	**44,2**	**49,7**	**6,1**	**1,7**	**0,3**
	Sweden	381	57,0	43,0	…	…	…	…	…
North-East	Estonia	33	71,5	28,5	9,4	82,2	8,4	0,2	0,1
	Latvia	60	26,0	74,0	22,7	65,9	11,4	0,1	0,4
	Lithuania	104	51,2	48,8	10,9	59,8	29,3	0,4	0,4
	Poland	934	56,0	44,0	38,8	35,9	25,4	2,3	1,8
Continental	France	1616	68,0	32,0	42,9	37,7	19,4	5,0	2,3
	Netherlands	**624**	**80,0**	**20,0**	**35,7**	**44,9**	**19,4**	**2,7**	**0,7**
	Germany	3198	61,0	39,0	36,4	40,6	23,0	9,5	6,1
	Luxemb.	16	64,0	36,0	…	…	…	…	…
	Belgium	376	64,1	35,9	43,5	47,3	9,2	1,4	0,8

Geo-cluster	Country	Total residential stock in the EU countries			Residential buildings for each construction period			Potential floor are to be renovated with 4RinEU renovation packages (initial estimation)	
		Tot [Mm²]	SHF [%]	MFH [%]	pre 1961 [%]	1961 – 1991 [%]	>1991 [%]	SHF [Mm²]	MFH [Mm²]
East	Slovenia	55	77,0	23,0	37,4	43,2	19,4	0,2	0,1
	Czech	308	53,9	46,1	41,5	40,8	17,7	0,8	0,7
	Austria	338	57,7	42,3	33,4	43,7	22,9	1,0	0,7
	Slovakia	132	68,0	32,0	36,8	51,7	11,5	0,6	0,3
	Romania	452	64,2	35,8	33,0	59,0	8,0	2,1	1,1
	Hungary	300	66,3	33,7	25,4	58,1	16,5	1,4	0,7
	Bulgaria	195	54,9	45,1				0,0	0,0
Mediterranean	Italy	1642	30,0	70,0	39,6	53,5	6,9	3,2	7,4
	Spain	**1263**	**33,0**	**67,0**	**30,0**	**41,3**	**28,7**	**2,1**	**4,2**
	Greece	312	51,6	48,4	28,0	56,4	15,6	1,1	1,0
	Portugal	240	56,3	43,8				0,0	0,0
Atlantic	Denmark	296	73,0	27,0	48,1	35,6	16,3	0,9	0,3
	United	1824	89,0	11,0	55,4	32,1	12,5	6,3	0,8

Geo-cluster	Country	Total residential stock in the EU countries			Residential buildings for each construction period			Potential floor are to be renovated with 4RinEU renovation packages (initial estimation)	
		Tot [Mm²]	SHF [%]	MFH [%]	pre 1961 [%]	1961 – 1991 [%]	>1991 [%]	SHF [Mm²]	MFH [Mm²]
	Ireland	182	90,1	9,9	27,1	33,0	39,9	0,6	0,1

Table 1 Single Family houses (SFH) and Multi Family houses (MFH) shares in main European Countries, divided in 4RinEU geo-clusters

3 Definition of deep renovation scenarios

This chapter will include the evaluation of deep renovation scenarios in specific contexts of reference countries within 4RinEU, exploiting the outcomes from the analysis of the building stock owned by 4RinEU demo case partners.
In particular, these data will be integrated with results coming from simulations performed on specific solution sets, as described in Deliverable 4.4, in order to assess a quantitative evaluation of the renovation potential in demo owners' building stocks.
Each section will resume the features and the current consumption of the buildings owned by the social housing agency ACH and by Woonzorg Netherland.
A set of renovation scenarios will be investigated, considering different yearly renovation rates, in order to understand the potential energy savings towards 50 years in the ACH and Woonzorg building stocks.
The energy consumption curves, related CO_2 emissions and energy costs in the existing scenario will be compared to results coming from renovated scenarios.

3.1 Spain

3.1.1 AHC Building stock analysis

Concerning AHC's building stock, information from the most general and extended pool of buildings available from AHC have been considered. In particular, from the 20,365 total apartments managed by the Agència (grouped approximately in 1,000 buildings), a selection of 688 buildings have been taken into account. This selection consists of Social apartments in Public Residential building blocks, whose construction years is from 1930 up to 2010. Hence, being these buildings completely managed by AHC, they represent the most appropriate typology to undergo deep renovation. This building stock is further described below.

Therefore, the replication potential evaluation will focus on **688 buildings (~69% of AHC total building stock**); taking into account building stock differentiations described in Chapter 6.1 of Project Deliverable 4.4, related to AHC total building stock context:

- *80% (550 buildings)* of them will be considered as isolated multifamily houses. These buildings have all the orientations exposed to the outdoor environment, therefore the timber prefabricated façade can be applied on 4 sides

- the remaining *20% (138 buildings)* will be considered as adjacent to other constructions, with prefabricated timber façade applied only on two (main) sides. In this case, only two orientations are exposed to the outdoor environment, while the other sides are adjacent to other constructions.

Since no specific diffused obstacles for the use of **active technologies within prefabricated façade** have been identified in AHC building stock, their application will be investigated without particular limitations, as well as the **use of smart ceiling fan** (as defined in Project Deliverable 3.3) inside apartments. In fact, although in the demo building of the 4RinEU Project the use of ceiling fan was not possible due to low floor-to-ceiling height, it is plausible that the smart ceiling fans will be adapted to similar indoor spaces heights after future technology developments (having a floor-to-ceiling distance <2.6m is a very common situation around Europe).

3.1.2 Best performing packages in AHC specific context

In Deliverable 4.4, the best renovation packages in different geo-clusters have been identified, maximizing performances in each main thematic area of KPI.
Table 3 reports the best performing packages for the Mediterranean geo-cluster, including AHC building stock area. Identification number for renovation package are presented in Table 2.

IDENTIFICATION n.	RENOVATION PACKAGE
1	Prefabricated façade
2 (or 3)	Prefabricated façade + Decentralized ventilation (+ BiPV panels)
4	Prefabricated façade + Centralized ventilation + BiPV panels
5	Prefabricated façade + Decentralized ventilation + BiPV panels + Smart Ceiling Fan
6	Prefabricated façade + Smart Ceiling Fan

Table 2 Identification number for the renovation package

<table>
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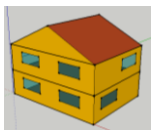
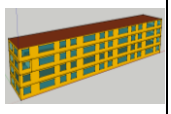
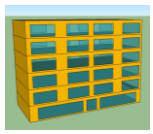
<tr><td></td><td>  </td><td>  </td><td>  </td><td>  </td></tr>
<tr><td>Tot Area</td><td>88 m2</td><td>228 m2</td><td>3456 m2</td><td>1330 m2</td></tr>
</table>

Thematic Area	KPI considered	Best renovation package for the specific KPI			
ENERGY	Energy demand (H+C) saving respect to non-renovated	5 (-81%)	4 (-92%)	5 (-99%)	5 (-87%)
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more explanation on these KPIs)	CAT_I_Adpt (evaluated in cooling period)	6 (90.7%)	4 (99.37%)	6 (99.8%)	6 (79.8%)
ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	6 (0.27)	4 (0.32)	4 (~0)	2 (0.13)
ECONOMIC ISSUES	Net Present Value (50 years) [€]	1 (55,727)	1 (72,153)	1 (712,630)	1 (343,166)
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	6 (44)	6 (55)	6 (562)	6 (272)

Table 3 Best performing packages in Mediterranean Geo-cluster and resulting value between brackets

In order to focus on different energy consumptions, energy costs and CO_2 emissions scenarios, results related to two main thematic areas have been taken into account, namely ENERGY and ENVIROMENT. Furthermore, stated that AHC's building stock to be potentially renovated consist of multi-apartments buildings (80% isolated and 20% with adjacent constructions), the multifamily archetype has been considered to perform the evaluation on renovation potential.

Since the analysis on AHC building stock highlighted the presence of non-isolated buildings (i.e. multi-family houses where two lateral sides are adjacent to other constructions), outcomes from Project Deliverable 4.4 (Chapter 4.2) have been integrated to assess the renovation potential evaluation of that specific typology of buildings.

3.1.3 Renovation potential scenarios

Therefore, the best performing renovation packages for Energy and Environment thematic areas applied to multifamily archetype, as shown in Table 3, are package n°5 (Prefabricated façade + Decentralized ventilation + BiPV panels + Smart Ceiling

Fan) and package n°4 (Prefabricated façade + Centralized ventilation + BiPV panels).
The performances provided by these above-mentioned renovation packages have been evaluated using energy consumption and environment KPIs; then, extending these outcomes at building stock level, the renovation potential evaluation has been defined.
Table 4 reports, referring to the reference multi-family house building (horizontal surface 3456 m^2) the energy demand both for heating and cooling, the energy consumption (delivered energy) for heating and cooling (for simplifying the analysis, consumptions related to the use of a heat pump both for heating and cooling are shown) and CO_2 emissions due to energy systems.
Results are given in ranges since minor renovation options are included in the considered renovation packages.

		Energy Demand (Heating + Cooling)	Energy Consumption (Heating & Cooling - Heat Pump)	CO_2 Emissions (Heating + Cooling)
		kWh_{th}/m^2 per year	kWh/m^2 per year	$kgCO_2/m^2$ per year
Isolated Multi-Family House	Existing Case (BASELINE	60.34	88.47 (only for heating, from traditional source)	17.87
	Renovation Package 4 (Prefabricated façade + Centralized ventilation + BiPV panels)	1.51÷15.13	0.0053÷19.08	2÷8
	Renovation Package 5 (Prefabricated façade + Decentralized ventilation + BiPV panels + Smart Ceiling Fan)	0.39÷7.06	0.027÷9.68	0.12÷3.9
Multi-Family House with adjacent buildings on lateral sides	Existing Case (BASELINE	58	85.4 (only for heating, from traditional source)	17.25
	Renovation Package 4 (Prefabricated façade + Centralized ventilation + BiPV panels)	1.55÷12.49	0.001÷15.7	0.001÷6.66
	Renovation Package 5 (Prefabricated façade + Decentralized ventilation + BiPV panels + Smart Ceiling Fan)	0.35÷5.40	0.017÷7.41	0.13÷2.93

Table 4 Energy and environmental performances for analyzed retrofit packages, AHC building stock (the symbol "÷" is used for "between")

In the following graphs, the results presented in Table 4, given per square meters of horizontal surface and per year, are applied to the AHC building stock in an extended evaluation up to 50 years, in order to have a long-term vision of the renovation potential. Results have been applied to 550 isolated multi-family

buildings and 138 multi-family buildings with adjacent constructions on lateral sides. Reference floor area for multi-family house archetype has been estimated at 3,456 m^2.

The evaluation of the renovation scenarios in the specific AHC building stock context has been analyzed in terms of energy consumptions and CO_2 emissions, considering a 50-years-long time frame. Both renovation package 4 and 5 have been evaluated in ISOLATED and NON-ISOLATED building typology.
For facilitating the analysis, only the configuration where the heat pump is used for both heating and cooling system is reported in graphs. Therefore, energy consumption is referring to electricity need.
Moreover, in the graphs, it is possible to see the worst and best scenario trends both for energy consumption and CO_2 emissions. The emission factor is depending on the used fuel: if fuel is Natural Gas it is 0.202 tCO_2/MWh, in case of electricity the emission factor depends on the National value (NL=0.483, NO=0.532, HG=0.566, SP=0.44, PL=1.191, IR=0.436) (source: technical annex Covenant of Mayors). Different scenarios are given by the presence, within the pool of results related to a specific renovation package, of several "secondary" parameters which have not been distinguished in these graphs. These parameters are, for instance, the presence of shading system or the different type of insulation material and windows' properties.

In the following graphs (Figure 1 and Figure 2), the cumulative energy consumption for ISOLATED BUILDING configuration is reported, respectively for renovation package 4 and 5 application.
It is possible to notice that, in both best scenarios, energy consumption for heating and cooling is extremely low. This means that in this context, thanks to the deep renovation, heating and cooling demands are almost satisfied thanks to the new characteristics of the envelope and active technologies.

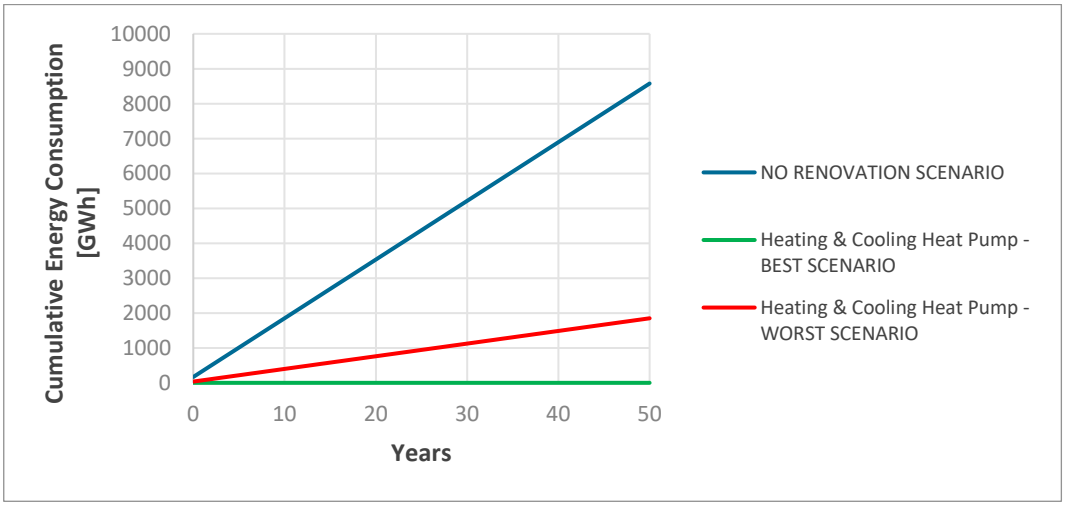


Figure 1 Energy Consumption ISOLATED BUILDING - Renovation Package 4

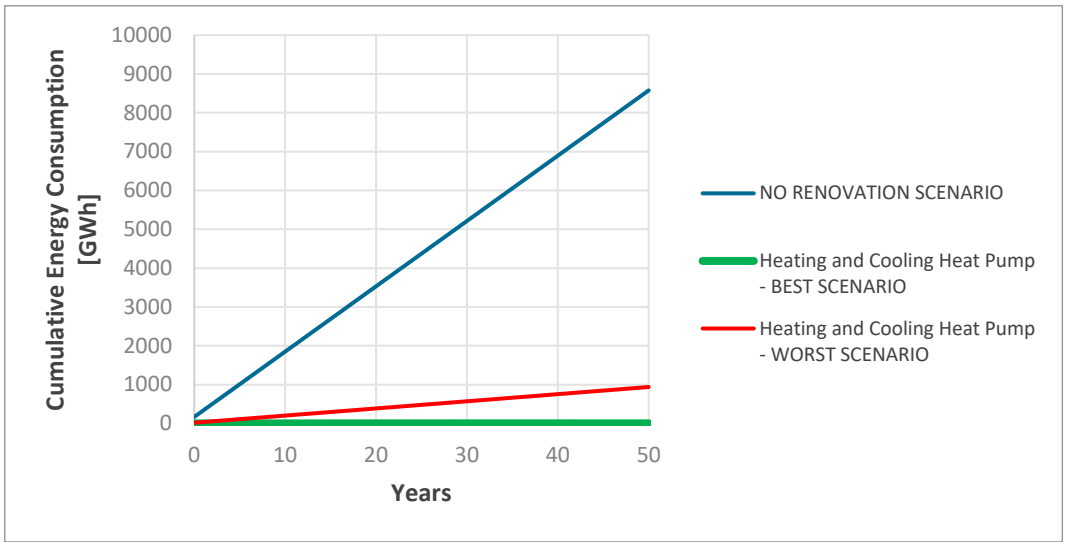


Figure 2 Energy Consumption ISOLATED BUILDING - Renovation Package 5

In the following graphs (Figure 1 and Figure 2), the cumulative CO_2 emissions for ISOLATED BUILDING configuration is reported, respectively for renovation package 4 and 5 application.

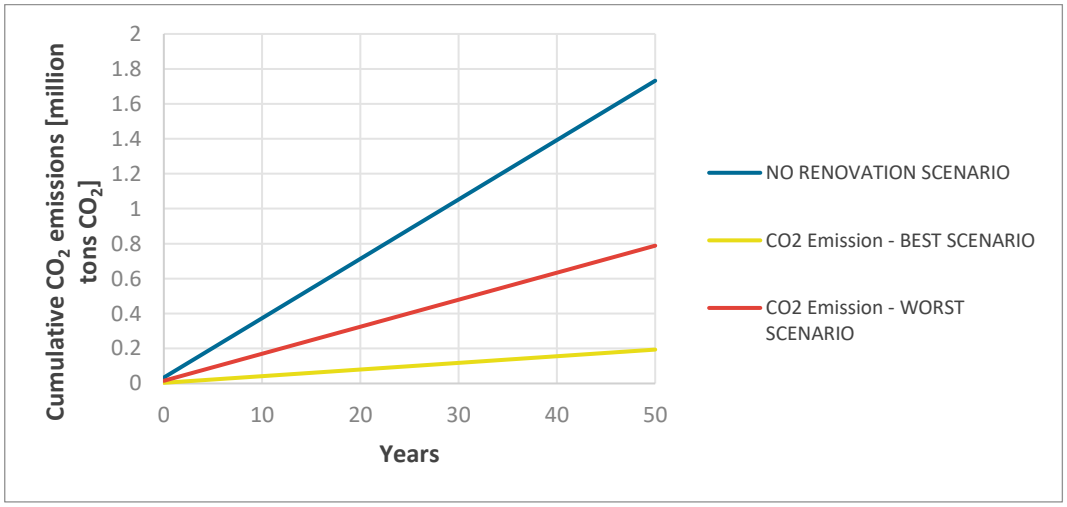


Figure 3 CO_2 Emission ISOLATED BUILDING - Renovation Package 4

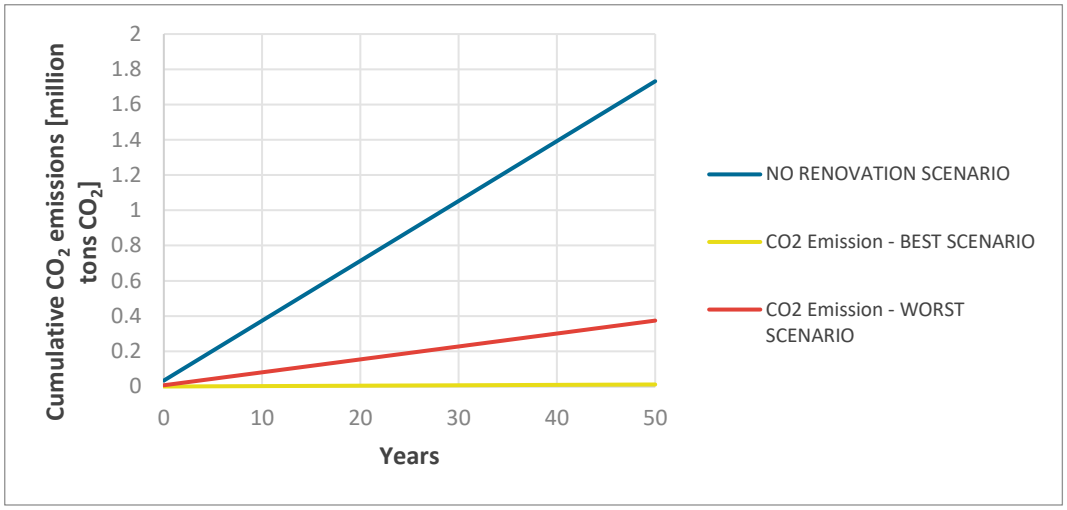


Figure 4 CO_2 Emission ISOLATED BUILDING - Renovation Package 5

In the following graphs (Figure 1 and Figure 2), the cumulative energy consumption for NON-ISOLATED BUILDING configuration is reported, respectively for renovation package 4 and 5 application.
Also, in the NON-ISOLATED building Spanish contexts, heating and cooling energy consumption in the best scenario can be very low.

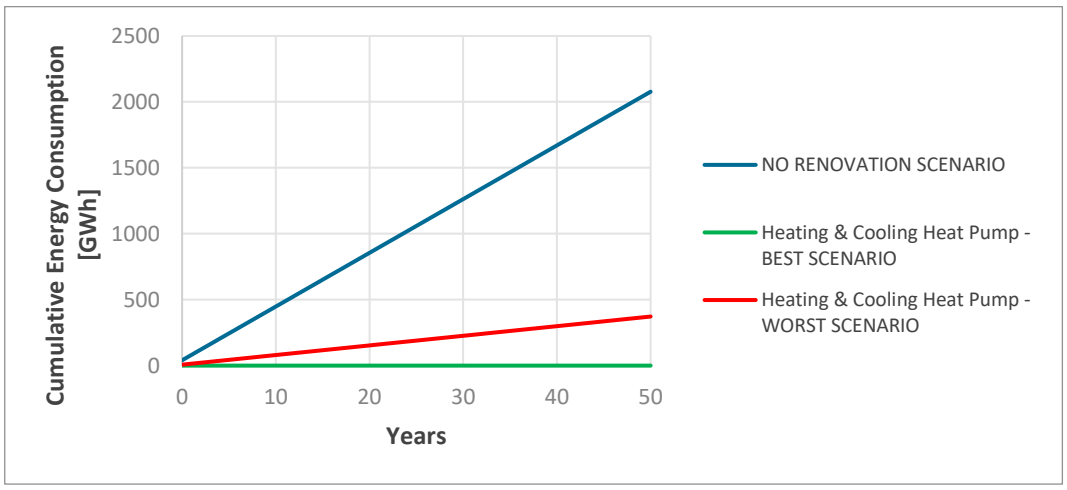


Figure 5 Energy Consumption NON-ISOLATED BUILDING - Renovation Package 4

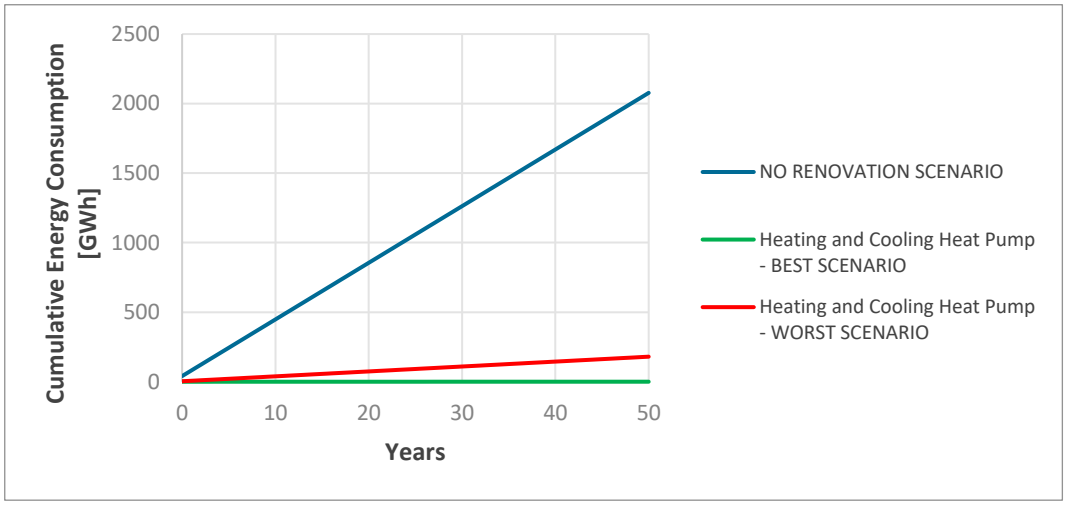


Figure 6 Energy Consumption NON-ISOLATED BUILDING - Renovation Package 5

In the following graphs (Figure 1 and Figure 2), the cumulative CO_2 emissions for NON-ISOLATED BUILDING configuration is reported, respectively for renovation package 4 and 5 application.

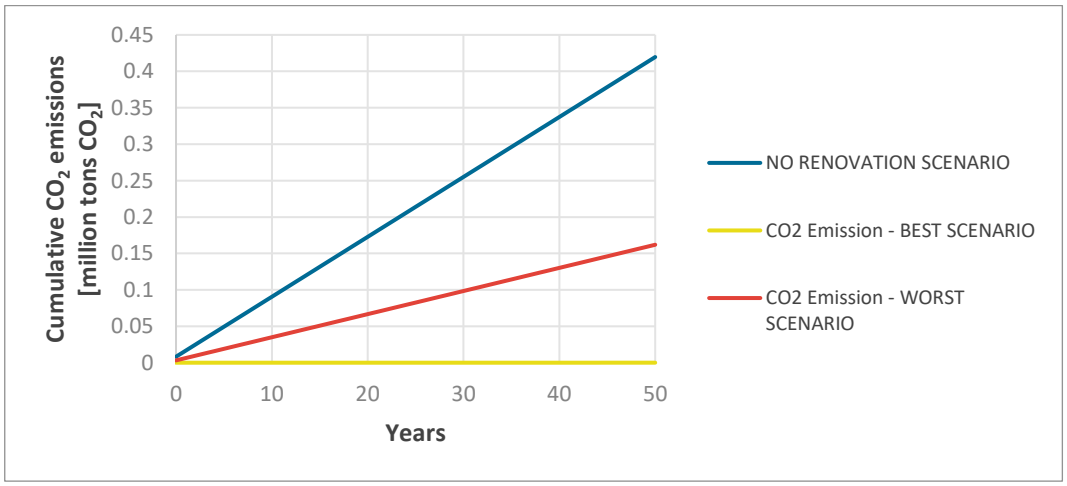


Figure 7 CO_2 Emission NON-ISOLATED BUILDING - Renovation Package 4

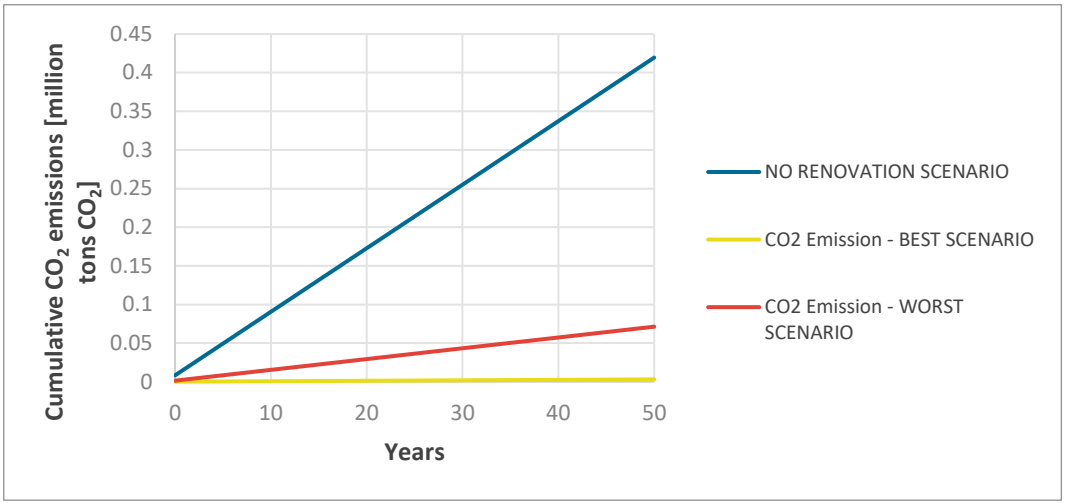


Figure 8 CO_2 Emission NON-ISOLATED BUILDING - Renovation Package 5

Considering the cost for buying electricity from the grid of approximately 0,21 euro/kWh for the Spanish market*, in case a heat pump is used for both heating and cooling, it is easy to estimate the expenses after the 50-years, the considered period in different configurations (Table 5) for 550 isolated buildings and 138 non-isolated buildings, both having a horizontal surface of 3,456m^2.
As for the very low energy consumptions, the best scenarios expenses calculation in the 50 years, is extremely low. This may be unrealistic, nevertheless, it shows that with a proper deep renovation, heating and cooling demands in such contexts can be reduced to the very minimum.

	No renovation	Renovation Package 4		Renovation Package 5	
		Best scenario	Worst Scenario	Best scenario	Worst Scenario
ISOLATED BUILDING	~1,800mln€	~108000€	~388mln€	~565,000€	~197mln€
NON-ISOLATED BUILDING	~436mln€	~5000€	~78mln€	~86,500€	~38mln€

Table 5 Estimate cumulative energy costs in different scenarios after 50 years for 550 Isolated Buildings and 138 Non-Isolated Buildings

*source https://www.statista.com/statistics/418085/electricity-prices-for-households-in-spain/

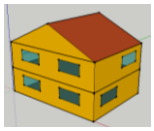
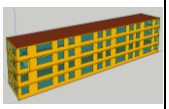
3.2 The Netherlands

3.2.1 WOONZORG Building stock analysis

Woonzorg building stock consists of approximately 641 buildings (corresponding to 28,705 apartments) almost totally identifiable with the multifamily house archetype defined in 4RinEU. **67% of the buildings (427)** are categorized with energy label b or less, following the National regulation. Therefore, the renovation potential will be analysed, specifically on these buildings.
As for the AHC building stock, since no specific obstacles for the application of certain 4RinEU renovation packages have been identified, the application of the main renovation packages will be considered without further distinctions.
Hence, different renovation potential scenarios will be analysed.

3.2.2 Best performing packages in Woonzorg specific context

In Deliverable 4.4, the best renovation packages in different geo-clusters have been identified, maximizing performances in each main thematic area of KPI.
Table 3 reports the best performing packages for the Mediterranean geo-cluster, including AHC building stock area. Identification number for renovation package are presented in Table 2.

	**GEOCLUSTER CONTINENTAL - CENTRAL**				
					
	Tot Area	**88 m2**	**228 m2**	**3456 m2**	**1330 m2**
Thematic Area	**KPI considered**	**Best renovation package for the specific KPI**			
ENERGY	Energy demand (H+C) saving respect to non-renovated	6 (-73.1%)	4 (-90.86%)	4 (-95.36%)	5 (-76.3%3)
COMFORT AND IAQ (check Table 3 of Deliverable 3.3 for more explanation on these KPIs)	CAT_I_Adpt (evaluated in cooling period)	2 (97%)	6 (92%)	2 (96.6%)	1 (94.39%)

ENVIRONMENT	Yearly CO_2 emissions due to Heating + Cooling [tCO_2 year]	6 (0.4)	4 (0.66)	4 (2.47)	2 (2.08)
ECONOMIC ISSUES	Net Present Value (50 years) [€]	1 (66786)	1 (86328)	1 (853375)	1 (411275)
BUILDING SITE MANAGEMENT	Duration of the building site [n. of hours]	6 (44)	6 (55)	6 (562)	6 (272)

Table 6 Best performing packages in Continental Central Geo-cluster

In order to focus on different energy consumptions, energy costs and CO_2 emissions scenarios, results related to two main thematic areas have been taken into account, namely ENERGY and ENVIRONMENT. Furthermore, stated that WOONZORG's building stock to be potentially renovated consist almost totally of multi-apartments buildings, the multifamily archetype has been considered to perform the evaluation on renovation potential.

3.2.3 Renovation potential scenarios

Therefore, the best performing renovation packages for Energy and Environment thematic areas applied to multifamily archetype, as shown in Table 3, are package n°5 (Prefabricated façade + Decentralized ventilation + PV panels + Smart Ceiling Fan) and package n°4 (Prefabricated façade + Centralized ventilation + BiPV panels).
The performances provided by these above-mentioned renovation packages have been evaluated using energy consumption and environment KPIs; then, extending these outcomes at building stock level, the renovation potential evaluation has been defined.
Table 4 reports, referring to the reference multi-family house building (horizontal surface 3456 m^2) the energy demand both for heating and cooling, the energy consumption for heating and cooling (for simplifying the analysis, consumptions related to the use of a heat pump both for heating and cooling are shown) and CO_2 emissions due to energy systems.
Results are given in ranges since minor renovation options are included in the considered renovation packages.

	Energy Demand (Heating + Cooling)	Energy Consumption (Heating & Cooling - Heat Pump)	CO_2 Emissions (Heating + Cooling)

		kWh_{th}/m^2 per year	kWh/m^2 per year	$kgCO_2/m^2$ per year
Isolated Multi-Family House	Existing Case (BASELINE	108.39	159 (only for heating, from traditional source)	32.12
	Renovation Package 4 (Prefabricated façade + Centralized ventilation + BiPV panels)	5 ÷13.58	1.48÷10.81	0.71÷5.6
	Renovation Package 5 (Prefabricated façade + Decentralized ventilation + BiPV panels + Smart Ceiling Fan)	8.8÷12.8	2.94÷5.74	1.4÷3.47

Table 7 Energy and environmental performances for analyzed retrofit packages, WOONZORG building stock (the symbol "÷" is used for "between")

In the following graphs, the results presented in Table 4, given per square meters of horizontal surface and per year, are applied to the WOONZORG building stock in an extended evaluation up to 50 years, in order to have a long-term vision of the renovation potential. Results have been applied to 427 isolated multi-family buildings. Reference floor area for multi-family house archetype has been estimated at 3,456 m^2.

The evaluation of the renovation scenarios in the specific WOONZORG building stock context has been analyzed in terms energy consumptions and CO_2 emissions, considering a 50-years-long time frame. Both renovation package 4 and 5 effects have been evaluated.
For facilitating the analysis, only the configuration where the heat pump is used for both heating and cooling system is reported in graphs. Therefore, energy consumption is referring to electricity need.
Moreover, in the graphs it is possible to see the worst and best scenario trends both for energy consumption and CO_2 emissions. Different scenarios are given by the presence, within the pool of results related to a specific renovation package, of several "secondary" parameters which have not been distinguished in these graphs. These parameters are, for instance, the presence of a shading system or the different type of insulation material and windows' properties.

In the following graphs (Figure 1 and Figure 2), the cumulative energy consumption for ISOLATED BUILDING configuration is reported, respectively for renovation package 4 and 5 application.

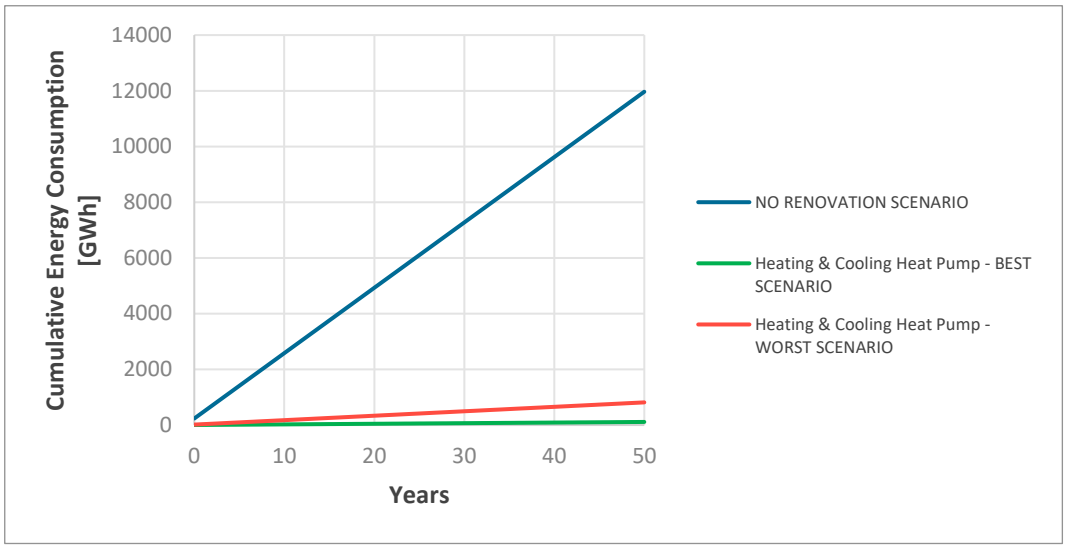


Figure 9 Energy Consumption ISOLATED BUILDING - Renovation Package 4

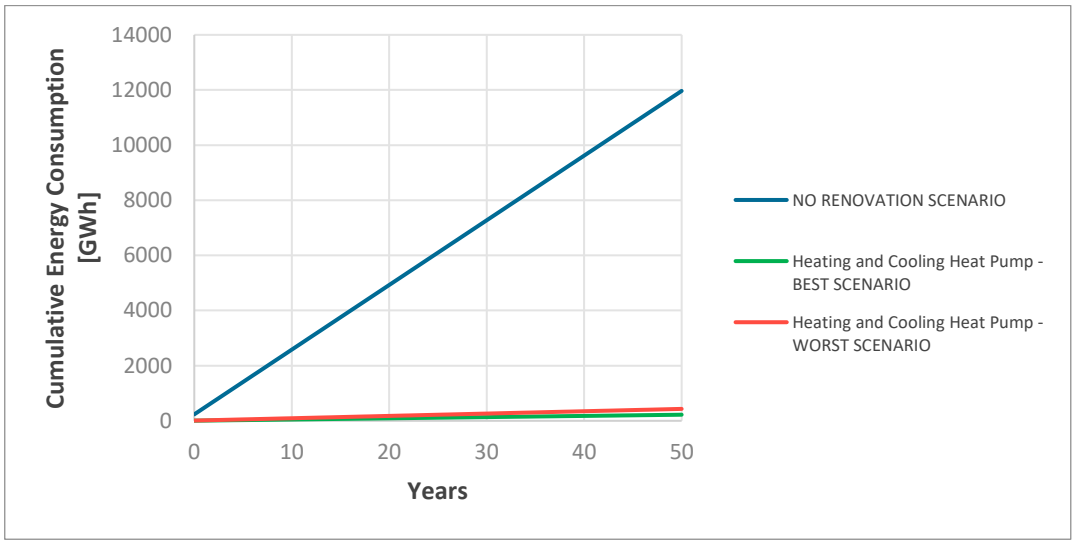


Figure 10 Energy Consumption ISOLATED BUILDING - Renovation Package 5

In the following graphs (Figure 1 and Figure 2), the cumulative CO_2 emissions for ISOLATED BUILDING configuration is reported, respectively for renovation package 4 and 5 application.

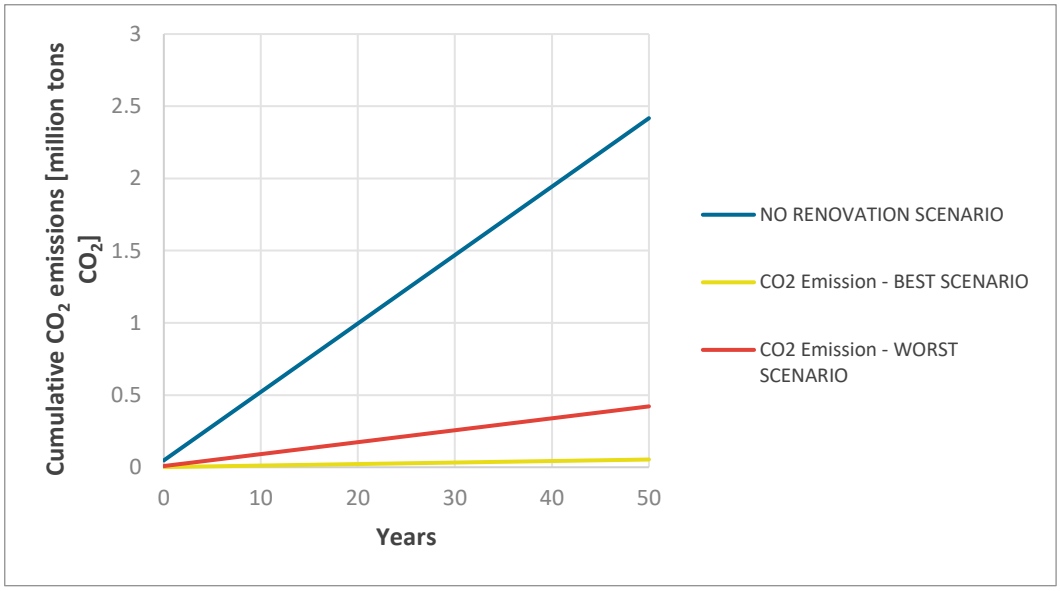


Figure 11 CO_2 Emission ISOLATED BUILDING - Renovation Package 4

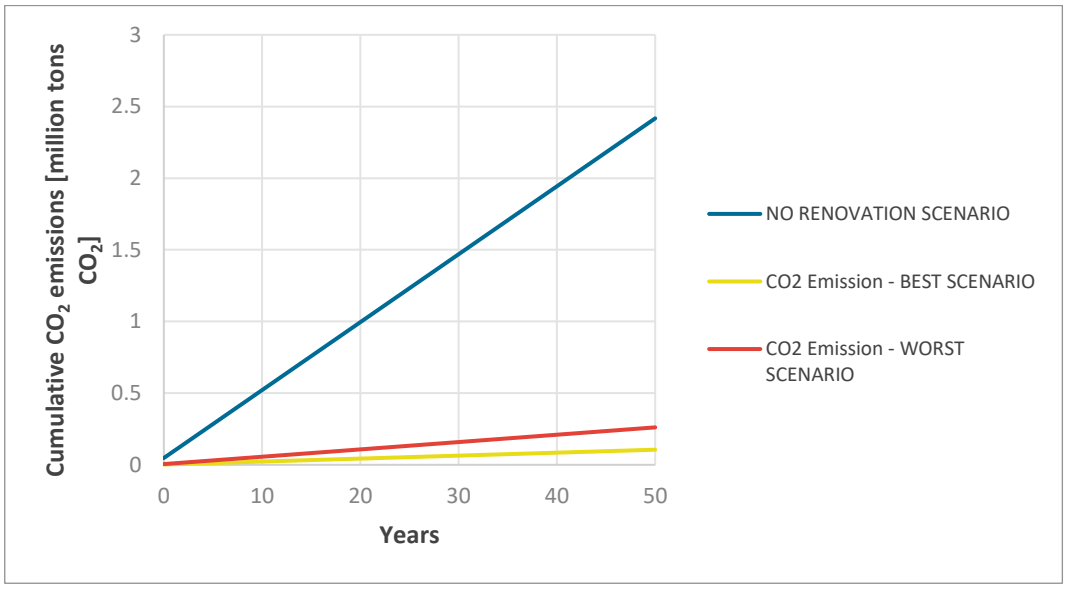


Figure 12 CO_2 Emission ISOLATED BUILDING - Renovation Package 5

Considering the cost for buying electricity from the grid of approximately 0.16 euro/kWh for the Dutch market*, in case a heat pump is used for both heating and cooling, it is easy to estimate the expenses after the 50-years, the considered period in different configurations (Table 5) for 427 isolated buildings having a horizontal surface of 3,456m^2.

	No renovation	Renovation Package 4		Renovation Package 5	
		Best scenario	Worst Scenario	Best scenario	Worst Scenario

ISOLATED BUILDING	~2,500mln€	~24mln€	˜170mln€	~46mln€	~90mln€

Table 8 Estimate cumulative energy costs in different scenarios after 50 years for 427 Isolated Buildings

*source https://www.globalpetrolprices.com/Netherlands/electricity_prices/

Conclusions

This document presents the results of the evaluation of the impact of 4RinEU deep renovation packages on the existing building stocks in specific contexts, namely AHC and WOONZORG buildings stocks, where data were easily available.

After evaluating the replication potential of the deep retrofit intervention and the performances in the analyzed contexts (Deliverable 4.4), information has been used to provide an estimation of the potential energy consumption, emissions and costs reduction in AHC and Woonzorg building stocks, looking at a 50-years-long period.

For both building stocks, the effect of two main renovation packages have been investigated (those maximizing energy and CO_2 emissions performances).

Remarkable results have been noticed concerning energy consumptions and CO_2 emissions reductions, especially considering the outcomes of renovation packages where a heat pump is used for both heating and cooling.

In particular, in AHC buildings stock, energy consumption reduction compared to non-renovation scenario after 50 years is in the range of 80-90%, with a reduction in CO_2 emissions of almost 75%.

For Woonzoorg building stock, energy reduction is between 90-95% with a CO_2 emissions reduction of about 90% with respect to the non-renovation scenario.

Although the best scenario reports a utopic condition of very low heating and cooling demand, it gives the idea of the huge results achievable performing a deep renovation in the analysed contexts.