



Sustainable solutions for affordable **REtroFIT** of domestic buildings

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Contents

Table of figures	5
Table of tables	8
Abbreviations	10
Publishable summary	11
Introduction	12
1.1 SUREFIT Technologies	13
1.1.1 Aerogel Insulation	13
1.1.2 PV vacuum glazing windows (PV-VG)	15
1.1.3 Phase Changing Materials (PCM)	16
1.1.4 Insulating breather membrane – WINCO Skytech	16
1.1.5 Windows Heat Recovery (WHR) system	17
1.1.6 Photovoltaic Thermal system (PV/T)	18
1.1.7 Direct Expansion Solar Assisted Heat Pump (DX SAHP)	18
1.1.8 Ground Source Heat Pump (TP GSHP)	20
1.1.9 Light Technology-Blinds/Louvers	20
2 Economic impact of SUREFIT technologies and combined solutions	21
2.1 Methodology	22
2.1.1 General Approach	24
2.1.2 Inflation Rate	24
2.1.3 Avoided Annual Cost (AaC) & Total Cost of Energy (TCE)	26
2.1.4 Initial Capital Cost (C_i) & Cumulative Savings (CS)	27
2.1.5 Balance (Ba)	27
2.1.6 Payback Period (PBP)	28
2.2 Assumptions	28
2.2.1 Inflation Scenarios Assumptions	28
2.2.2 Heating Operation Schedules (Intermittent & Continuous)	29
2.2.3 Retrofitting Parameters	30
2.2.4 Commercial Price Case	31
2.3 Results	31
2.3.1 United Kingdom (UK)	31
2.3.2 Spain (SP)	34
2.3.3 Portugal (PT)	36
2.3.4 Greece (GR)	39
2.3.5 Finland (FI)	42
2.4 Conclusions	43
3 Environmental impact of SUREFIT technologies and combined solutions	45
3.1 Methodology	45
3.2 Assumptions	45
3.3 Results	46
3.3.1 United Kingdom (UK)	46
3.3.2 Spain (SP)	46
3.3.3 Portugal (PT)	47
3.3.4 Greece (GR)	47
3.3.5 Finland (FI)	48
3.4 Conclusions	48



4	<i>Social assessment</i>	50
4.1	Methodology	50
4.2	Results	51
4.2.1	Pre- and post-occupancy surveys	51
4.2.1.1	Pre-occupancy survey	51
4.2.1.1.1	Portugal	51
4.2.1.1.2	Greece	55
4.2.1.1.3	UK	60
4.2.1.1.4	Spain	66
4.2.1.1.5	Finland	71
4.2.1.2	Post-occupancy survey	78
4.2.2	Pre-occupancy on-site inspections and interviews	78
4.2.2.1	Portugal	78
4.2.2.1	Greece	79
4.2.2.2	UK	80
4.2.2.3	Spain	81
4.2.2.4	Finland	82
4.2.3	Post-occupancy on-site inspections and interviews	83
4.3	Conclusions	83
	<i>Conclusions</i>	84



Table of figures

FIGURE 1: SUSTAINABILITY INTERCONNECTED DOMAINS.....	12
FIGURE 2: BIO-AEROGELS.....	14
FIGURE 3: PV-VG THREE-LAYER CONFIGURATION	15
FIGURE 4: PCM PANELS.....	16
FIGURE 5: WINCO SKYTECH BREATHABLE MEMBRANE	16
FIGURE 6: WINDOW HEAT RECOVERY UNIT.....	17
FIGURE 7: SOLAR ASSISTED HEAT PUMP LAYOUT	19
FIGURE 8: THERMAL PIPE HEAT PUMP SYSTEM.....	20
FIGURE 9: LIGHT LOUVERS BY KOST.....	20
FIGURE 10: CONCEPT MAP OF ECONOMIC ASPECT	21
FIGURE 11: RELATION OF ECONOMIC PARAMETERS	21
FIGURE 12: ECONOMIC ASSESSMENT COMPARISON SCENARIOS.....	22
FIGURE 13: RETROFIT PACKAGES CONNECTION DIAGRAM (RECEIVED FROM D2.2).....	23
FIGURE 14: EU AVERAGE INFLATION RATE INDEX FOR THE LAST TWO DECADES	25
FIGURE 15: EU INFLATION RATE VALUES BY COMPONENTS.....	26
FIGURE 16: SEALANT APPLICATION	31
FIGURE 17: SIMULATION OF ENERGY CONSUMPTION-FINAL SCENARIO-UK.....	33
FIGURE 18: SIMULATION OF ENERGY CONSUMPTION - FINAL SCENARIO – SP	36
FIGURE 19: SIMULATION OF ENERGY CONSUMPTION - FINAL SCENARIO – PT	38
FIGURE 20: SIMULATION OF PURCHASED ENERGY - FINAL SCENARIO – GR	41
FIGURE 21: SIMULATION OF PURCHASED ENERGY - FINAL SCENARIO – FI	43
FIGURE 22: ENVIRONMENTAL COMPARISON SCENARIOS	45
FIGURE 23: CO ₂ EMISSIONS - FINAL CASE – UK.....	46
FIGURE 24: CO ₂ EMISSIONS – FINAL CASE – SP.....	47
FIGURE 25: CO ₂ EMISSIONS - FINAL CASE – PT	47
FIGURE 26: CO ₂ EMISSIONS – FINAL CASE – GR.....	48
FIGURE 27: CO ₂ EMISSIONS - FINAL CASE – FI	48
FIGURE 28: SUREFIT INFLUENCE ON CO ₂ EMISSIONS.....	49
FIGURE 29 – TEMPERATURE INSIDE THE PORTUGUESE HOUSE AS CHARACTERISED BY THE RESIDENT.....	52
FIGURE 30 – CHARACTERIZATION OF IAQ BY THE RESIDENT OF THE PORTUGUESE HOUSE.	52
FIGURE 31 – ADJUSTMENT OF AIR RELATED ISSUES BY OPENING/CLOSING WINDOWS IN THE PORTUGUESE HOUSE.....	52
FIGURE 32 – OPERATION OF THE VENTILATION GRID IN THE PORTUGUESE HOUSE.	53
FIGURE 33 – OPEN WINDOWS IN SPECIFIC ROOMS IN THE PORTUGUESE HOUSE.....	53
FIGURE 34 – MAIN NOISE SOURCES AS REPORTED BY THE RESIDENT OF THE PORTUGUESE HOUSE.....	53
FIGURE 35 – LIGHTING ADJUSTMENT IN THE PORTUGUESE HOUSE.	54
FIGURE 36 – INDOOR CONDITIONS REGARDING THE ARTIFICIAL AND NATURAL LIGHT IN THE PORTUGUESE HOUSE.	54
FIGURE 37 – SUN EXPOSURE, OVERHEATING AND GLARE THROUGH WINDOWS IN THE PORTUGUESE HOUSE.....	55
FIGURE 38 – THE MOST IMPORTANT NEEDS THAT THE RESIDENT WOULD LIKE TO IMPROVE IN THE HOUSE.....	55
FIGURE 39 – THE RENT INCREASE THAT THE RESIDENT IS WILLING TO PAY.	55
FIGURE 40 – TEMPERATURE INSIDE THE GREEK APARTMENT AS CHARACTERISED BY AN RESIDENT.	56
FIGURE 41 – ADJUSTMENT OF INDOOR TEMPERATURE BY USING THE COOLING SYSTEM CONTROL IN THE GREEK APARTMENT.	56
FIGURE 42 – ADJUSTMENT OF INDOOR TEMPERATURE BY USING THE HEATING SYSTEM CONTROL IN THE GREEK APARTMENT.	56
FIGURE 43 – CHARACTERIZATION OF IAQ BY AN RESIDENT OF THE GREEK APARTMENT.....	56
FIGURE 44 – ADJUSTMENT OF AIR RELATED ISSUES BY OPENING/CLOSING WINDOWS IN THE GREEK APARTMENT.	57
FIGURE 45 – OPERATION OF THE VENTILATION GRID IN THE GREEK APARTMENT.....	57
FIGURE 46 – OPEN WINDOWS IN SPECIFIC ROOMS IN THE GREEK APARTMENT.	57
FIGURE 47 – MAIN NOISE SOURCES AS REPORTED BY AN RESIDENT OF THE GREEK APARTMENT.	58
FIGURE 48 – LIGHTING ADJUSTMENT IN THE GREEK APARTMENT.....	58
FIGURE 49 – INDOOR CONDITIONS REGARDING THE ARTIFICIAL AND NATURAL LIGHT IN THE GREEK APARTMENT.	59
FIGURE 50 – SUN EXPOSURE, OVERHEATING AND GLARE THROUGH WINDOWS IN THE GREEK APARTMENT.	59
FIGURE 51 – THE MOST IMPORTANT NEEDS THAT THE RESIDENT (ALSO OWNER) WOULD LIKE TO IMPROVE IN THE HOUSE	60
FIGURE 52 – THE AMOUNT OF MONEY THAT THE RESIDENT (ALSO OWNER) IS WILLING TO PAY.	60
FIGURE 53 – THE 3 MOST IMPORTANT NEEDS THAT THE RESIDENT (ALSO OWNER) WOULD LIKE TO IMPROVE IN THE HOUSE	60
FIGURE 54 – THE AMOUNT OF MONEY THAT THE RESIDENT (ALSO OWNER) IS WILLING TO PAY.	60



FIGURE 55 – THE RENT INCREASE THAT THE RESIDENT (ALSO OWNER) WOULD ASK FOR AFTER THE RENOVATION.....	60
FIGURE 56 – TEMPERATURE INSIDE THE UK HOUSE AS CHARACTERISED BY THE RESIDENTS.	61
FIGURE 57 – ADJUSTMENT OF INDOOR TEMPERATURE BY USING THE HEATING SYSTEM CONTROL IN THE UK HOUSE.	61
FIGURE 58 – CHARACTERIZATION OF IAQ BY THE RESIDENTS OF THE UK HOUSE.....	62
FIGURE 59 – ADJUSTMENT OF AIR RELATED ISSUES BY OPENING/CLOSING WINDOWS IN THE UK APARTMENT.....	62
FIGURE 60 – OPERATION OF THE VENTILATION GRID IN THE UK HOUSE.	63
FIGURE 61 – OPEN WINDOWS IN SPECIFIC ROOMS IN THE UK HOUSE.	63
FIGURE 62 – MAIN NOISE SOURCES AS REPORTED BY THE RESIDENTS OF THE UK HOUSE.	63
FIGURE 63 – LIGHTING ADJUSTMENT IN THE UK HOUSE.	64
FIGURE 64 – INDOOR CONDITIONS REGARDING THE ARTIFICIAL AND NATURAL LIGHT IN THE UK HOUSE.....	64
FIGURE 65 – SUN EXPOSURE, OVERHEATING AND GLARE THROUGH WINDOWS IN THE UK HOUSE.	65
FIGURE 66 – THE MOST IMPORTANT NEEDS THAT THE RESIDENT #1 (ALSO OWNER) WOULD LIKE TO IMPROVE IN THE HOUSE	65
FIGURE 67 – THE AMOUNT OF MONEY THAT THE RESIDENT #1 (ALSO OWNER) WILL BE WILLING TO PAY FOR THE RENOVATION.....	65
FIGURE 68 – THE 3 MOST IMPORTANT NEEDS THAT THE RESIDENT #1 (ALSO OWNER) WOULD LIKE TO IMPROVE IN THE HOUSE.....	65
FIGURE 69 – THE AMOUNT OF MONEY THAT THE RESIDENT #1 (ALSO OWNER) WILL BE WILLING TO PAY FOR THE RENOVATION.....	65
FIGURE 70 – THE OWNER WOULD ASK FOR A 25% RENT INCREASE AFTER THE RENOVATION.....	66
FIGURE 71 – THE MOST IMPORTANT NEED THAT THE RESIDENT #2 WOULD LIKE TO IMPROVE IN THE HOUSE.....	66
FIGURE 72 – THE RENT INCREASE THAT THE RESIDENT #2 IS WILLING TO PAY.	66
FIGURE 73 – THE 3 MOST IMPORTANT NEEDS THAT THE RESIDENT #2 WOULD LIKE TO IMPROVE IN THE HOUSE	66
FIGURE 74 – THE RENT INCREASE THAT THE RESIDENT #2 IS WILLING TO PAY.	66
FIGURE 75 – TEMPERATURE INSIDE THE SPANISH HOUSE AS CHARACTERISED BY A RESIDENT.	67
FIGURE 76 – ADJUSTMENT OF INDOOR TEMPERATURE BY USING THE HEATING SYSTEM CONTROL IN A SPANISH HOUSE.	67
FIGURE 77 – CHARACTERIZATION OF IAQ BY A RESIDENT OF THE SPANISH HOUSE.....	67
FIGURE 78 – ADJUSTMENT OF AIR RELATED ISSUES BY OPENING/CLOSING WINDOWS IN A SPANISH HOUSE.	68
FIGURE 79 – OPERATION OF THE VENTILATION GRID IN A SPANISH HOUSE.	68
FIGURE 80 – OPEN WINDOWS IN SPECIFIC ROOMS IN A SPANISH HOUSE.	68
FIGURE 81 – MAIN NOISE SOURCES AS REPORTED BY A RESIDENT OF A SPANISH HOUSE.	69
FIGURE 82 – LIGHTING ADJUSTMENT IN A SPANISH HOUSE.....	69
FIGURE 83 – INDOOR CONDITIONS REGARDING THE ARTIFICIAL AND NATURAL LIGHT IN A SPANISH HOUSE.	70
FIGURE 84 – SUN EXPOSURE, OVERHEATING AND GLARE THROUGH WINDOWS IN A SPANISH HOUSE.	70
FIGURE 85 – THE MOST IMPORTANT NEEDS THAT THE RESIDENT (ALSO, OWNER) WOULD LIKE TO IMPROVE IN THE HOUSE	71
FIGURE 86 – THE AMOUNT OF MONEY THAT THE RESIDENT (ALSO, OWNER) WILL BE WILLING TO PAY FOR THE RENOVATION.	71
FIGURE 87 – THE 3 MOST IMPORTANT NEEDS THAT THE RESIDENT (ALSO, OWNER) WOULD LIKE TO IMPROVE IN THE HOUSE	71
FIGURE 88 – THE AMOUNT OF MONEY THAT THE RESIDENT (ALSO, OWNER) WILL BE WILLING TO PAY FOR THE RENOVATION.	71
FIGURE 89 – THE RENT INCREASE THAT THE RESIDENT (ALSO OWNER) WOULD ASK FOR AFTER THE RENOVATION.....	71
FIGURE 90 – TEMPERATURE INSIDE THE FINISH APARTMENTS AS CHARACTERISED BY THE RESIDENTS.	72
FIGURE 91 – ADJUSTMENT OF INDOOR TEMPERATURE BY USING THE HEATING SYSTEM CONTROL IN THE FINISH APARTMENTS.	72
FIGURE 92 – CHARACTERIZATION OF IAQ BY THE RESIDENTS OF THE FINISH APARTMENTS.....	72
FIGURE 93 – ADJUSTMENT OF AIR RELATED ISSUES BY OPENING/CLOSING WINDOWS IN THE FINISH APARTMENTS.....	73
FIGURE 94 – OPERATION OF THE VENTILATION GRID IN THE FINISH APARTMENTS.....	74
FIGURE 95 – OPEN WINDOWS IN SPECIFIC ROOMS IN THE FINISH APARTMENTS.....	74
FIGURE 96 – MAIN NOISE SOURCES AS REPORTED BY THE RESIDENTS OF THE FINISH APARTMENTS.	74
FIGURE 97 – LIGHTING ADJUSTMENT IN THE FINISH APARTMENTS.	75
FIGURE 98 – INDOOR CONDITIONS REGARDING THE ARTIFICIAL AND NATURAL LIGHT IN THE FINISH APARTMENTS.....	75
FIGURE 99 – SUN EXPOSURE, OVERHEATING AND GLARE THROUGH WINDOWS IN THE FINISH APARTMENTS.....	76
FIGURE 100 – THE MOST IMPORTANT NEEDS THAT THE RESIDENT #1 WOULD LIKE TO IMPROVE IN THE HOUSE	76
FIGURE 101 – THE RENT INCREASE THAT THE RESIDENT #1 IS WILLING TO PAY.	76
FIGURE 102 – THE 3 MOST IMPORTANT NEEDS THAT THE RESIDENT #1 WOULD LIKE TO IMPROVE IN THE HOUSE	76
FIGURE 103 – THE RENT INCREASE THAT THE RESIDENT #1 IS WILLING TO PAY.	76
FIGURE 104 – THE MOST IMPORTANT NEEDS THAT THE RESIDENT #2 WOULD LIKE TO IMPROVE IN THE HOUSE	77
FIGURE 105 – THE RENT INCREASE THAT THE RESIDENT #2 IS WILLING TO PAY.	77
FIGURE 106 – THE 3 MOST IMPORTANT NEEDS THAT THE RESIDENT #2 WOULD LIKE TO IMPROVE IN THE HOUSE	77
FIGURE 107 – THE RENT INCREASE THAT THE RESIDENT #2 IS WILLING TO PAY.	77
FIGURE 108 – THE 3 MOST IMPORTANT NEEDS THAT THE RESIDENT #3 WOULD LIKE TO IMPROVE IN THE HOUSE	77
FIGURE 109 – THE RENT INCREASE THAT THE RESIDENT #3 IS WILLING TO PAY.	77
FIGURE 110 – THE 3 MOST IMPORTANT NEEDS THAT THE RESIDENT #3 WOULD LIKE TO IMPROVE IN THE HOUSE	77
FIGURE 111 – THE RENT INCREASE THAT THE RESIDENT #3 IS WILLING TO PAY.	77
FIGURE 112 – THE HOUSE IN PORTUGAL.....	79



<i>FIGURE 113 – THE APARTMENT IN GREECE.....</i>	<i>79</i>
<i>FIGURE 114 – THE HOUSE IN THE UK.</i>	<i>80</i>
<i>FIGURE 115 – UK BUILDING PLAN LAYOUT.</i>	<i>81</i>
<i>FIGURE 116 – THE HOUSES IN SPAIN.</i>	<i>82</i>
<i>FIGURE 117 – THE APARTMENTS IN FINLAND.</i>	<i>83</i>



Table of tables

TABLE 1: BIO-AEROGEL DATA	14
TABLE 2: SILICA-AEROGEL DATA.....	15
TABLE 3: PV-VG DATA	15
TABLE 4: PCM DATA.....	16
TABLE 5: WINCO SKYTECH BREATHABLE MEMBRANE DATA.....	17
TABLE 6: WHR SYSTEM PROPERTIES.....	17
TABLE 7: PV/T DATA.....	18
TABLE 8: SAHP DATA.....	19
TABLE 9: SUREFIT TECHNOLOGIES & SCENARIOS.....	23
TABLE 10: ELECTRICITY PRICES PER KWH.....	24
TABLE 11: ENERGY FUEL PRICES PER KWH.....	24
TABLE 12: BUILDING-DATA OF THE DEMO BUILDINGS.....	24
TABLE 13: ECONOMIC ASSESSMENT PARAMETERS FOR LIFETIME “N” YEARS	28
TABLE 14: LATEST INFLATION RATE VALUES.....	29
TABLE 15: SOLAR ENERGY PRICES.....	30
TABLE 16: PBP - CONTINUOUS HEATING - UK	32
TABLE 17: PBP - CONTINUOUS HEATING - COMMERCIAL PRICE - UK	32
TABLE 18: PBP - CONTINUOUS HEATING - ALTERNATIVE INPUT - UK.....	32
TABLE 19: PBP - INTERMITTENT HEATING - SP.....	34
TABLE 20: PBP - CONTINUOUS SUPPLY - COMBINED SCENARIOS - COMMERCIAL PRICE - SP	34
TABLE 21: PBP - INTERMITTENT HEATING - ALTERNATIVE INPUT - SP	35
TABLE 22: PBP – INTERMITTENT HEATING – FINAL CASE SP.....	36
TABLE 23: PBP - INTERMITTENT HEATING - PT.....	37
TABLE 24: PBP - CONTINUOUS HEATING - COMBINED SCENARIOS - COMMERCIAL PRICE – PT.....	37
TABLE 25: PBP - CONTINUOUS HEATING - PT	37
TABLE 26: PBP – INTERMITTENT HEATING – FINAL CASE PT.....	38
TABLE 27: PBP - INTERMITTENT HEATING - GR	39
TABLE 28: PBP - INTERMITTENT HEATING - COMMERCIAL PRICE - GR	39
TABLE 29: PBP - CONTINUOUS HEATING - GR	40
TABLE 30: PBP - INTERMITTENT HEATING - ALTERNATIVE INPUT - GR	40
TABLE 31: PBP – INTERMITTENT HEATING – FINAL CASE GR	41
TABLE 32: PBP - CONTINUOUS HEATING – FI	42
TABLE 33: PBP – INTERMITTENT HEATING – FINAL CASE FI.....	42
TABLE 34: CO ₂ EMISSIONS - CONTINUOUS SUPPLY - UK	46
TABLE 35: CO ₂ EMISSIONS - CONTINUOUS SUPPLY - ALTERNATIVE INPUT – UK	46
TABLE 36: CO ₂ EMISSIONS - INTERMITTENT SUPPLY - SP	46
TABLE 37: CO ₂ EMISSIONS - INTERMITTENT SUPPLY - ALTERNATIVE COMBINED – SP	46
TABLE 38: CO ₂ EMISSIONS - INTERMITTENT SUPPLY - PT	47
TABLE 39: CO ₂ EMISSIONS - CONTINUOUS SUPPLY – PT.....	47
TABLE 40: CO ₂ EMISSIONS - INTERMITTENT SUPPLY – GR.....	47
TABLE 41: CO ₂ EMISSIONS - CONTINUOUS SUPPLY - GR	48
TABLE 42: CO ₂ EMISSIONS - INTERMITTENT SUPPLY - ALTERNATIVE COMBINED – GR	48
TABLE 43: CO ₂ EMISSIONS - CONTINUOUS SUPPLY – FI	48
TABLE 44: SIMULATION - CONTINUOUS - UK.....	85
TABLE 45: SIMULATION - ALTERNATIVE SCENARIOS CONTINUOUS - UK.....	86
TABLE 46: SIMULATION – FINAL CASE - UK.....	87
TABLE 47: SIMULATION – INTERMITTENT - SP.....	88
TABLE 48: SIMULATION – ALTERNATIVE INTERMITTENT - SP	89
TABLE 49: SIMULATION – FINAL CASE – SP.....	90
TABLE 50: SIMULATION – INTERMITTENT - PT.....	91
TABLE 51: SIMULATION - CONTINUOUS - PT	92
TABLE 52: SIMULATION – FINAL CASE – PT.....	93
TABLE 53: SIMULATION – INTERMITTENT - GR.....	94



TABLE 54: SIMULATION – CONTINUOUS - GR	95
TABLE 55: SIMULATION – ALTERNATIVE COMBINED - GR.....	96
TABLE 56: SIMULATION – FINAL CASE – GR.....	97
TABLE 57: SIMULATION - CONTINUOUS - FI.....	98
TABLE 58: SIMULATION – FINAL CASE - FI.....	99
TABLE 59: ESTIMATION OF TCE_o AND TCE_R FOR WINCO'S BREATHABLE MEMBRANE DURING THE CASE OF 100% INFILTRATION IMPACT FOR INTERMITTENTLY HEATED PT DEMO	100
TABLE 60: ESTIMATION OF TCE_o AND TCE_R FOR PV/T IMPACT FOR INTERMITTENTLY HEATED PT DEMO.....	100
TABLE 61: BIO - AEROGEL COST.....	101
TABLE 62: SILICA - AEROGEL COST.....	102
TABLE 63: PCM COST.....	102
TABLE 64: BLINDS – LOUVERS COST	102
TABLE 65: PV VACUUM GLAZING WINDOWS COST	103
TABLE 66: WINCO'S BREATHABLE SKYTECH MEMBRANE COST.....	103
TABLE 67: WINDOW HEAT RECOVERY SYSTEM COST	104
TABLE 68: PV/T PANELS COST.....	104
TABLE 69: PV PANELS FOR FI DEMO COST.....	105
TABLE 70: SAHP COST.....	105
TABLE 71: GSHP COST.....	106
TABLE 72: CI OF BIO AEROGEL PT.....	107
TABLE 73: PBP CALCULATION OF BIO-AEROGEL (CONTINUOUS) PT.....	108
TABLE 74: PBP CALCULATION OF BIO-AEROGEL (INTERMITTENT) PT	108
TABLE 75: CI OF SILICA AEROGEL FOR PT	109
TABLE 76: PBP CALCULATION OF SILICA-AEROGEL (CONTINUOUS) PT	109
TABLE 77: PBP CALCULATION OF SILICA-AEROGEL (INTERMITTENT) PT.....	110
TABLE 78: CI OF VACUUM WINDOWS FOR PT.....	110
TABLE 79: PBP CALCULATION OF BIO-AEROGEL & PV VACUUM WINDOWS (CONTINUOUS) PT	111
TABLE 80: PBP CALCULATION OF BIO-AEROGEL & PV VACUUM WINDOWS (INTERMITTENT) PT.....	111
TABLE 81: CI OF PCMs FOR PT.....	112
TABLE 82: PBP CALCULATION OF BIO-AEROGEL & PV VACUUM WINDOWS & PCMs (CONTINUOUS) PT.....	112
TABLE 83: PBP CALCULATION OF BIO-AEROGEL & PV VACUUM WINDOWS & PCMs (INTERMITTENT) PT.....	113
TABLE 84: CI OF SKYTECH MEMBRANE FOR 50% AND 100% INFILTRATION FOR PT.....	113
TABLE 85: PBP CALCULATION OF 50% INFILTRATION (CONTINUOUS) PT.....	114
TABLE 86: PBP CALCULATION OF 50% INFILTRATION (INTERMITTENT) PT	114
TABLE 87: PBP CALCULATION OF 100% INFILTRATION (CONTINUOUS) PT.....	115
TABLE 88: PBP CALCULATION OF 100% INFILTRATION (INTERMITTENT) PT	116
TABLE 89: CI OF 100% INFILTRATION & WHR FOR PT	116
TABLE 90: PBP CALCULATION OF 100% INFILTRATION & WHR (CONTINUOUS) PT.....	117
TABLE 91: PBP CALCULATION OF 100% INFILTRATION & WHR (INTERMITTENT) PT	117
TABLE 92: CI OF PVT FOR PT	117
TABLE 93: PBP CALCULATION OF PVT (CONTINUOUS) PT.....	118
TABLE 94: PBP CALCULATION OF PVT (INTERMITTENT) PT	119
TABLE 95: CI OF SAHP FOR PT	119
TABLE 96: PBP CALCULATION OF SAHP (CONTINUOUS) PT.....	119
TABLE 97: PBP CALCULATION OF SAHP (INTERMITTENT) PT	120
TABLE 98: PBP CALCULATION OF COMBINED SCENARIO 1 (CONTINUOUS) PT.....	120
TABLE 99: PBP CALCULATION OF COMBINED SCENARIO 1 (INTERMITTENT) PT	121
TABLE 100: PBP CALCULATION OF COMBINED SCENARIO 2 (CONTINUOUS) PT.....	121



Abbreviations

AaC	Avoided annual cost
AALTO	AALTO University (partner)
ACH	Air changes per hour
AMS	Advanced Management Solutions (partner)
Ba	Balance
CF	Cash flow
CS	Cumulative savings
DHW	Domestic Hot Water
DoA	Description of Action
DX SAHP	Direct expansion Solar assisted heat pump
ECB	European Central Bank
EEA	European Environment Agency
EIA	Economic impact assessment
EPS	Expanded polystyrene
EU	European Union
GHG	Green House Gas
ISQ	Instituto de Soldadura e Qualidade (partner)
KGM	Konjac glucomannan
KOST	Helmut Koester (partner)
PBP	Payback period
PCM	Phase changing materials
PV	Photovoltaic
PV/T	Photovoltaic thermal system
PV-VG	Photovoltaic vacuum glazing window
PVC	Polyvinyl chloride
SAHP	Solar assisted heat pump
SHGC	Solar heat gain coefficient
TCE	Total cost of energy
TP GSHP	Ground source heat pump
UNNOT	University of Nottingham (partner)
WHR	Windows heat recovery
WINCO	WINCO Technologies (partner)



Publishable summary

The present deliverable aims to report the activities performed during the first stage of the SUREFIT project regarding the assessment of the economic, environmental and social impact of the SUREFIT renovations in domestic buildings. In order the aforementioned targets to be achieved the following actions took place (based also on the Description of Action (DoA)):

- i) a methodology was developed by AALTO in order to analyse the environmental impact, i.e. the carbon dioxide emissions before and after the renovation;
- ii) a methodology was developed by AMS in order to analyse the economic benefits of the renovation. This included the calculation of the financial cost of the renovations (purchase, installation, maintenance cost), as well as the energy cost before and after the renovations that was based on the analysis of the energy consumption performed by AALTO. Finally, the payback period for each one of the new technologies and their combinations was calculated taking into account forecasted inflation and energy prices;
- iii) assessment of the social aspects of the renovations was performed through interactive surveys, questionnaires and interviews to gather feedback of the end users prior to renovation, to involve them in monitoring activities, and to assess fast-track renovation attractiveness and acceptability. This is realised through a dedicated platform created for this purpose, where users can participate interactively and will be accessible through the project website and social networks.

Introduction

During the past years, the European Environment Agency (EEA)¹ has recorded a significant increase in urbanization trend. City centres are constantly expanding in terms of number of population, occupied areas, energy consumption and pollution levels. Urban buildings constitute 30% to 40% of the global final energy use, while in Europe, domestic houses consume approximately 40% of the total energy generated in the continent. In addition, they are responsible for almost 36% of European greenhouse gas emissions. Reduction in energy demand, and decrease of consumption levels are essential in order to challenge the already existing, and forthcoming energy poverty issues; and achieve desired and viable sustainability levels as enacted by the Paris Agreement in 2015².

The SUREFIT project introduces effective existing and innovative building-technologies to be implemented, for enhancing the sustainability asset of dwellings. Sustainability is defined via the interconnected parameters of four dimensions, environment, economy and society (Figure 1)³.

SUREFIT-retrofitting bears significant influence to the three domains constituting sustainability concept in the boundaries of a building-system. Particularly, the retrofitting will introduce exploitation of renewable sources, lower environmental impacts and costs, reliability, less and low-cost maintenance and ameliorated performance.

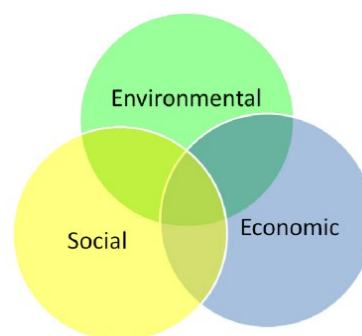


Figure 1: Sustainability Interconnected Domains

This study constitutes a first approach of the influence of SUREFIT-retrofitting regarding the sustainability factor. Therefore, each one of the sustainability domains has to be assessed. The Deliverable 2.4 purpose is to provide an initial indication of results that will be brought when the potential SUREFIT-technologies-combinations are introduced. The latter is assessed toward the economic benefit, environmental impact and social influence and acceptance. Concluding, this study will propose which SUREFIT technology/technologies and/or technology-combinations, should be applied in each demonstration-building, taking into account the most suitable solution in terms of sizing and of heating/cooling operation schedule. This deliverable is also a reference for WP8 “Economic, social and environmental assessments” for the evaluation of practical retrofitting results in comparison with theoretical ones.

Deliverable 2.4:

This deliverable widely aims at broadening societal acceptance and promoting wide-scale commercial application of the SUREFIT technologies within the EU and worldwide. The retrofitting concepts will estimate capacity levels of integrating technologies and demonstrate the sustainability-related results acquired. Through D2.4 the final technologies to be implemented in each demonstration-building will be considered for WP5 “Installation of technologies in real buildings”.

¹ <https://www.eea.europa.eu/el>

² https://www.researchgate.net/publication/353682547_Energy_emissions_and_economic_impact_of_the_new_nZEB_regulatory_framework_on_residential_buildings_renovation_Case_study_in_southern_Spain

³ <https://en.unesco.org/themes/education-sustainable-development/what-is-esd/sd>



Chapters' Description:

Chapter 2 focuses on economic impact brought by retrofitting. The effectiveness of economic impact is presented through “period required/intervene for recapping the initial investment”. This period-value is investigated towards the most profitable-for-the-building-owner outcome as per project's favourable impact. Chapter 2 shows the relation of cost and economic benefit produced by retrofitting and concludes to the economically-best scenario for each demo site building.

Chapter 3 presents the environmental impact of retrofitting and the degree of influence on GHG emissions reduction and energy streams. An assessment of CO₂ emissions is conducted by comparing the pre- and after-retrofitting values. Additionally, the energy streams of pre- and after- retrofitting will be monitored too. Chapter 3 concludes to the most environmental-friendly oriented technologies of the project.

The final domain of sustainability framework is investigated in *Chapter 4* where social effect is interpreted. A survey through questionnaires was administered for the appraisal of social impact assessment.

The progress of the document is in accordance, and links directly, with D2.2 “Results of dynamic simulation of building energy demand”. The results presented in the current study follow and connect with the simulations-development conducted via the IDA-ICE 4.8⁴ software and received during D2.2 progression.

1.1 SUREFIT Technologies

1.1.1 Aerogel Insulation

Aerogels are a synthetic, porous, extremely ultralight material. They are a type of gel where the liquid part has been replaced by gas. Aerogels are introduced in blankets which incorporate particles in ultra-thin, flexible nonwovens. They can be attached internally and externally to the building walls and roof, guided by wooden rafters/frames. The aerogel technologies to be exploited in the boundaries of SUREFIT are the innovative bio-aerogels and the commercial silica-aerogels.

Bio-aerogel:

The technology of Bio-aerogel that will be used in the SUREFIT project has been developed by UNOTT. It is made of konjac glucomannan⁵ (KGM)/starch-based aerogels. In the boundaries of sustainable-product, bio-aerogels are consisted of natural raw materials from agriculture-derived waste, such as wheat straw. Their formation process is attributed very low environmental impact/footprint. The method of freeze-drying administers good thermal insulation and favourable mechanical properties to the final product. Bio-aerogels present high

⁴ <https://www.equa.se/en/ida-ice>

⁵ <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5713220/>

surface area, excellent thermal and acoustic properties, low density and thermal conductivity, high porosity, flame and humidity resistance, low refractive index and dielectric constant. However, this type of aerogels associates with high manufacturing costs, impending to potential low market growth. High production price can be explained by the low product maturity level. Though, with market maturity increase, cost of purchase is reduced. The aerogel market is expected to exhibit growth at a compound of annual-growth-rate between 30.8% and 31% during period 2017-2023⁶.

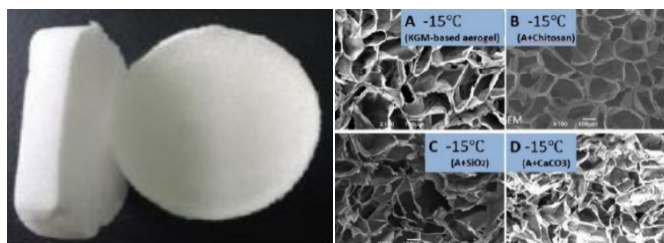


Figure 2: Bio-aerogels

Further analysis of the bio-aerogel technology in “WP4 D4.1 – “Bio aerogel panel”.

Bio-aerogels Properties		
	Value	Unit
Materials	konjac glucomannan (KGM)/starch	-
Density	43	kg/m ³
Thermal conductivity	0.037	W/(mK)
Specific heat capacity	2260	J/(kgK)
Moisture permeability	65	GNs/kgm
Overall product thermal	0.024	W/(mK)
Safety	Non-toxicity and biodegradable	-
Lifespan	20	years
Cost - purchase	69.8	€/m ²

Table 1: Bio-aerogel data

Silica-aerogel:

Silica aerogel is the first type of aerogel made, and the most common type in the market. Silica is indicated as the oxide of silicon (SiO₂) and is a glassy insulating material. They are highly porous solids with specific surfaces up to 1000 m²/g. Their density is about 70-150 kg/m³ but they are an extremely light material (up to 95% if their volume is air).

They are produced from molecular precursors by sol-gel processing, through supercritical drying of cluster assembled gels. The absence of capillary forces during the supercritical drying process permits the porosity to be preserved.

Silica is deemed as a sufficient insulator due to the poor heat conduction. It solidifies in three-dimensional clusters. The latter occupies only 3% of the total volume, while the rest 97% are covered by air in nano-pores. Silica-aerogels bear a non-sustainable footprint when taking into account their production process. Furthermore, during their use/incorporation-phase they generate and emit hydrophobic dust.

⁶ <https://www.mdpi.com/1999-4923/12/5/449/pdf>

Silica-aerogels Properties		
	Value	Unit
Materials	synthetic amorphous silica dioxide impregnated with fibers	-
Density	150	kg/m ³
Thermal conductivity	0.015	W/(mK)
Specific heat capacity	1000	J/(kgK)
Moisture permeability	25	GNs/kgm
Overall product thermal	0.019	W/(mK)
Safety	100% recyclable and reusable	-
Lifespan	60	years
Cost - purchase	20	€/m ²

Table 2: Silica-aerogel data

1.1.2 PV vacuum glazing windows (PV-VG)

The structure of vacuum glazing window is commercially mature, and it is similar to the double-glazed unit, however the cavity indicates no gas, but vacuum. Vacuum acquires significantly more

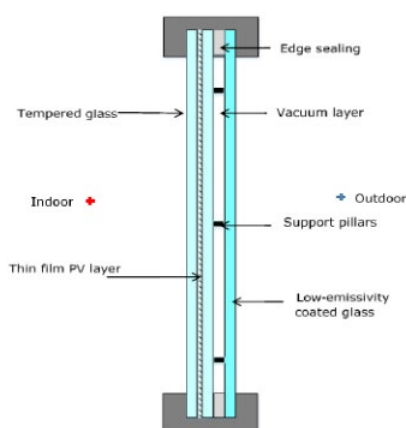


Figure 3: PV-VG three-layer configuration

effective insulation levels compared to any gas. In addition, greater performance in terms of acoustics and sound reduction accompany the VG windows. The PV component on the window is integrated in the form of thin-elastic-films. PV-VG exhibits three different components:

- The self-cleaning coated glass,
- the vacuum-filled layer and finally,
- a thin film PV glass with additional grass cover.

The system is thinner than 30 mm and presents lower U-value than 2.5 W/m²K. The thin film will bear solar shading coefficient of 0.45 and solar heat gain coefficient of 0.39, while light transmittance is 70%.

Further analysis of the PV vacuum glazing window technology in “WP4 D4.2 – “PV vacuum glazing unit”.

PV vacuum glazing window Properties		
	Value	Unit
U-value	0.45	W/(m ² K)
Density	241	kg/m ³
Thickness	8.3	mm
Light transmittance	70	%
Solar heat gain coefficient (SHGC)	0.39	-
Solar shading coefficient	0.45	-
Lifespan	20	years
Cost - purchase	432	€/unit

Table 3: PV-VG data

1.1.3 Phase Changing Materials (PCM)

The working principle of Phase Change Materials is connected to their heat capacity and latent heat characteristic. They constantly release and absorb sufficient energy at phase transition to provide useful heat/cooling. Their constant change of physical state from solid to liquid and vice versa occurs in fixed temperatures and the released/absorbed energy during the transition process is greater than the sensible heat (body exchange heat-thermodynamically) of the medium.



Figure 4: PCM panels

Introducing PCMs into a building block or panel can increase the energy storage density of material. Additionally, if integrated into the insulation, the transfer of heat to, and from, indoor environment is decreased. Thereof, PCMs are characterised by smooth temperature variations about a set value. UNNOT together with PCMproducts⁷ have developed PCM in form of panels (Figure 4).

Further investigation of PCMs will take place in “WP4 D4.2 – “PCM panel””.

PCM Properties		
	Value	Unit
Thermal conductivity	0.21 – 0.23	W/(mK)
Density	765 - 1500	Kg/m ³
Specific thermal capacity	2.2 – 2.42	kJ/kg K
PCM solidification point	2	°C
PCM melting point	164	°C
Lifespan	25	years
Cost - purchase	93.60	€/m ²

Table 4: PCM data

1.1.4 Insulating breather membrane – WINCO Skytech



Figure 5: WINCO Skytech breathable membrane

The breathable membrane developed by WINCO achieves a closed envelope when implemented. It increases the tightness against wind (air-tightness), promotes prevention of thermal bridges and reflects up to 95% of the radiation, resulting to better indoor comfort levels during summer period.

The incorporation of the insulating membrane will bring also better control of internal conditions since active heating or cooling requirements will be reduced. A 16 dB noise reduction will be also achieved. Installing the breathable membrane requires rafters and wood sheathing. The air tightness capacity in each partner-country’s demonstration building will be tested via the pulse technique developed by UNNOT.

⁷ <https://www.pcmproducts.net/>

WINCO Skytech breathable membrane Properties		
	Value	Unit
Thermal conductivity	0.029	W/(mK)
Density	96.15	Kg/m ³
Sound reduction	-16	dB
Available thickness	6, 13, 26	mm
Airtightness	0.16 – 0.18	m ³ /hm ²
Thermal resistance	1.50, 1.70, 2.20	m ² K/W
Water vapor resistance	0.022, 0.041, 0.080	m
Vapor resistance	0.11, 0.20, 0.40	MNs/g
Life span	30	years
Cost - purchase	10.80	€/m ²

Table 5: WINCO Skytech Breathable Membrane data

1.1.5 Windows Heat Recovery (WHR) system

Ventilation of the living space is often achieved via opening of windows. As a result, significant indoor heat levels are lost, causing increase in heating fuel usage.

The WHR system developed by UNNOT can reduce the annual energy bill by 20%. The units constituting WHR systems are small and can be installed/mounted on window frames. WHR operates via exploiting the room's lost heat to preheat the fresh air and save energy. It is presented that it bears the capacity to recover 70% of heat required to achieve indoor temperature/thermal comfort.

A broader analysis of WHR system will be presented in *WP4 D4.6 – "Heat recovery unit"*.

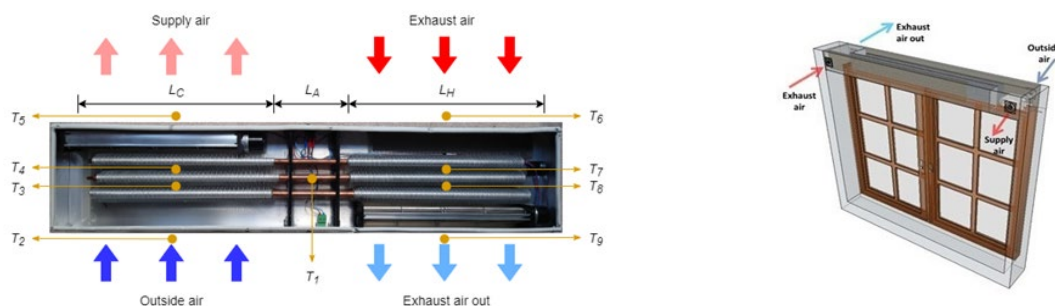


Figure 6: Window Heat Recovery Unit

WHR system Properties		
	Value	Unit
Heat recovery efficiency	>70	%
Ventilation rate	10-60	m ³ /h
Max fan power	34	W
Lifespan	20	Years
Cost - purchase	432	€/unit

Table 6: WHR system properties

1.1.6 Photovoltaic Thermal system (PV/T)

PV/T is a hybrid technology combining Photovoltaics (PV) and thermal energy production (T). This system addresses the paradox regarding the operation principle of PVs. They require sunlight to generate power but suffer a degradation in performance as they get heated. The average efficiency of standard commercial PVs ranges from 10% to 15% conversion of solar radiation to electricity. The rest is depleted as waste heat.

SOLIMPEKS has developed the PV/T system which takes advantage of waste heat and exploits it for thermal heat production. Therefore, only a single panel is required to generate both electricity and usable thermal energy. The PV module's heat is absorbed to produce hot water; this way, PV efficiency is optimised as heat is transferred into water for DHW production⁸. Moreover, a percentage of the produced thermal energy can be used for space heating.

PV/T system will be further investigated in *WP4 D4.7 – “Solar Thermal/PV unit”*.

PV/T system Properties		
	Value	Unit
Dimensions	1670x1005x60	mm
Gross area	1.68	m ²
Weight	28.4	kg
Nominal power (W_p)	325	W
Short circuit current (I_{sc})	9.94	A
Open circuit voltage (V_{oc})	39.25	V
Max power voltage (V_{pm})	32.18	V
Liquid content	0.85	L
Max operating pressure	8.6	bar
Lifetime	20	Years
Cost - purchase	350	€/unit
Cost - maintenance	70	€/hour of work

Table 7: PV/T data

1.1.7 Direct Expansion Solar Assisted Heat Pump (DX SAHP)

The solar assisted heat pump displays a combination of solar-air collector with heat pump technology. UNNOT has developed a heat pump including direct expansion to provide heating and/or cooling and hot water for buildings. The operation principle of this technology as per heating implements utilization of ambient air as heat source, and could be combined with PV panels in order to extract solar energy from the back of the panels. Thus, cooling of PV panels will enhance their efficiency.

The technology of solar assisted heat pump developed by UNNOT will be analyzed further in *WP4 D4.4 – “Heat Pumps”*.

⁸ <https://solimpeks.com/en/product/volther-excell/>

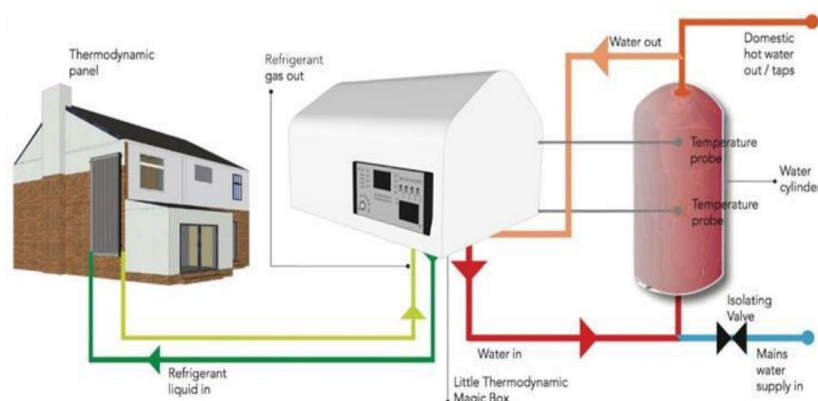
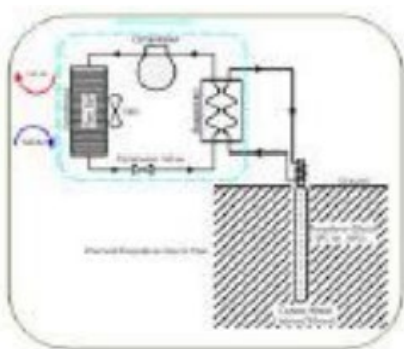


Figure 7: Solar Assisted Heat Pump layout

SAHP system Properties		
	Value	Unit
General System capacity Developed	2.8	kW
	5	
	7	
	11	
Heated water output	52	L/h
	80	
	143	
	180	
Suggested water tank capacity	60-150	L
	150-260	
	200-320	
	200-420	
Delivery efficiency	98	%
Solar thermodynamic panels required (for system capacity)	1(2.8)	Panels per kW
	2(5)	
	3(7)	
	4(13)	
Cost - purchase	2.8 – 1,323	kW-€/unit
	5 – 1,701	
	7 – 2,205	
	11 – 3,647	
Cost - maintenance	180	€/year/unit

Table 8: SAHP data

1.1.8 Ground Source Heat Pump (TP GSHP)



The GSHP has been developed by UNOTT. The innovative GSHP exploits hand-held piler for heat source. It brings low cost and easy installation compared with a conventional Ground Source Heat Pump. It is considered optimal for geographies with demonstrating unreachability to drilling. The system consists of thermal pipes which can be sold rods or tubes containing liquid such as propylene glycol/water. The heating of the pump is achieved by circuiting glycol.

Figure 8: Thermal Pipe Heat Pump system

1.1.9 Light Technology-Blinds/Louvers

Electricity consumed by lighting systems occupies a significant percentage of the overall electricity consumption. To make full use of daylight a layout incorporated in the window is introduced by KOST⁹. By the use of such systems the electricity consumption can be reduced, whereas glare issues can be prevented. This configuration facilitates the daylight to be redirected up to 6m into the depth of the room, while the direct sun rays are retro-reflected.

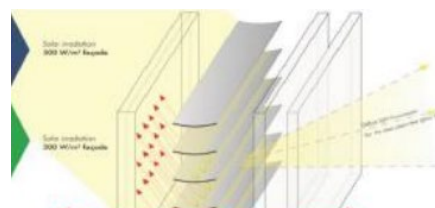


Figure 9: Light Louvers by KOST

⁹ http://www.koester-lichtplanung.de/pages_gb/news_01.html

2 Economic impact of SUREFIT technologies and combined solutions

The Economic goals are determined through the *Economic Impact*, or *Economic Impact Analysis (EIA)*. This method investigates the economic influence of an action, a decision or an event. The Cambridge Dictionary defines the term of economic impact as “the financial effect that something, especially something new, has on a situation or a person”¹⁰. It is therefore considered, as an evaluation tool of implemented actions. EIA bears a great variety of applicability regarding the implementation areas, ranging from single households and individuals to the entire globe. Additionally, via EIA one can acquire meaningful levels of convenience, regarding measures of strategic goal achievement that complements efficiency in the boundaries of benefit “versus” cost, and financial feasibility.

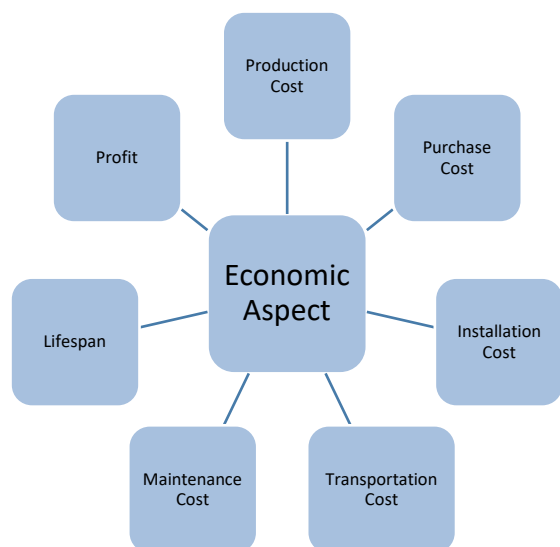


Figure 10: Concept map of economic aspect

The aspects linked to the economic parameter of a project have always been in the centre of sustainability evaluation together with the environmental and social influence.

A building-renovation project exploits the economic assessment as an asset for the planning to be followed toward desired/favorable results. Contemplated economic parameters concerning the energy-reduction subject, encompass retrofitting technologies’ production, or purchase, cost (with margin percentage), incorporation/installation cost, auxiliary cost required for the installation, transportation and maintenance cost, social carbon cost¹¹. On the other hand, streams of reduced energy consumption; and profit revenues will be introduced to form the cost-benefit ratio. The variety of parameters determining EIA from the installation time to the technologies’ end-of-life are illustrated at the radial cluster diagram of Figure 10.

In the boundaries of savings, the EIA developed in the current deliverable observes the extent of time/period to acquire economic profit. The indicators contemplated for the representation of the inducing parameters of economic evaluation, and demonstration of the long-term project-impact are acknowledged by the literature. In addition, other indexes are enhanced to a concise and applicable way to exhibit quantitative and qualitative impacts. The main indicators proposed for this model; and their interconnection and interaction, are illustrated in the Figure 11.

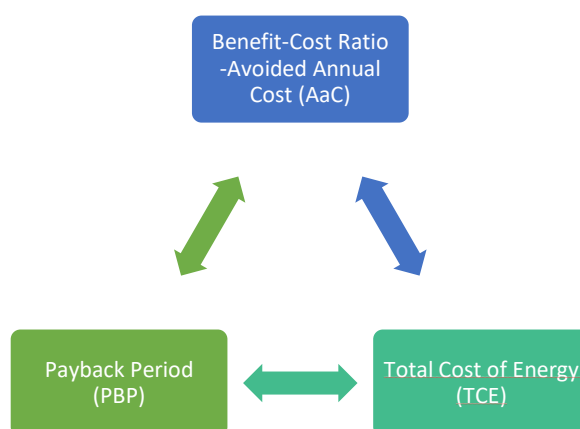


Figure 11: Relation of economic parameters

¹⁰ <https://dictionary.cambridge.org/dictionary/english/economic-impact>

¹¹ https://www.researchgate.net/publication/45267139_Building_Sustainability_Assessment

2.1 Methodology

In the boundaries of economic assessment, the monitoring and the multifaceted investigation of scenarios is achieved via energy performance *simulations* which incorporate the proposed retrofitting technologies. During these simulations, different retrofitting scenarios had been tested, while calculating the values of purchased and primary energy consumption and comparing them with those of original case-scenario (Figure 12).

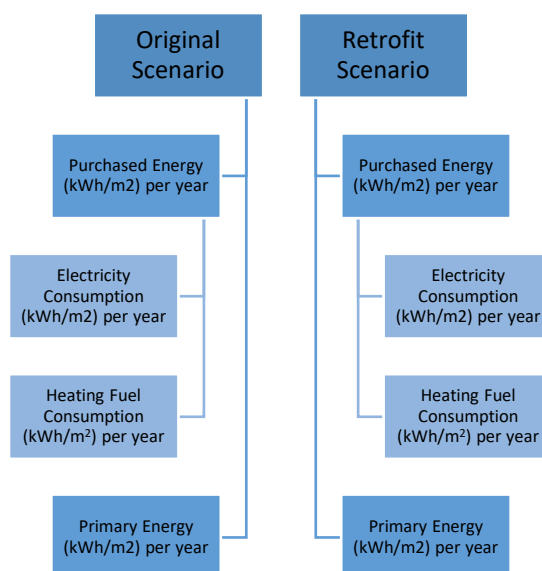


Figure 12: Economic Assessment Comparison Scenarios

The simulation results produced by deliverables D2.2 “Results of dynamic simulation of building energy demand” and D2.3 “Results of indoor environment modelling”, are acknowledged and perform as a guideline for the current assessment.

The results received by D2.2, together with Figure 12 exhibit the progress that drives the progress of the current study.

The simulations are categorized based on their type of service and nature of operation/function to:

- *Passive*, where the U-values of walls and windows are influenced by simply incorporating different insulating solutions, on/onto the walls, floor and roof, and by using innovative window technologies. These technologies do not exploit any mechanical system when servicing.
- *Infiltration*, where the infiltration rates in the demo buildings are calculated (in Air Changes per Hour – ACH, before and after the installation of the insulating breather membrane. This scenario, notably effects the U-value of walls together with the air tightness of the building. WHR units operate via electricity supply.
- *Active*, due to which the technologies are actively influencing the energy mixture, the indoor temperature, while they require energy to operate or produce it while operating.
- Finally, a *Combination* of the above scenarios is assumed.

SUREFIT Technology Product	
Category	Product
Passive	Bio-aerogel
	Silica-aerogel
	Bio-aerogel & PV vacuum glazing windows (PV-VG)
	Bio-aerogel & PV-VG & PCMs
Infiltration	Breathable membrane with 50% infiltration capacity
	Breathable membrane with 100% infiltration capacity
	Breathable membrane with 100% infiltration capacity & WHR system
Active	Photovoltaic/Thermal system (PV/T)
	Solar Assisted Heat Pump (SAHP)
Combination	Combined Scenario 1: (Bio-aerogel & PV-VG & PCMs) + (Breathable membrane 100% & WHR system) + (PV/T)
	Combined Scenario 2: (Bio-aerogel & PV-VG & PCMs) + (Breathable membrane 100% & WHR system) + (SAHP)

Table 9: SUREFIT technologies & scenarios

A resemblance of SUREFIT technologies and scenarios' interconnections is demonstrated in Figure 13 as received from deliverable D2.2. The commercial products referred, "Mineral Wool and borehole

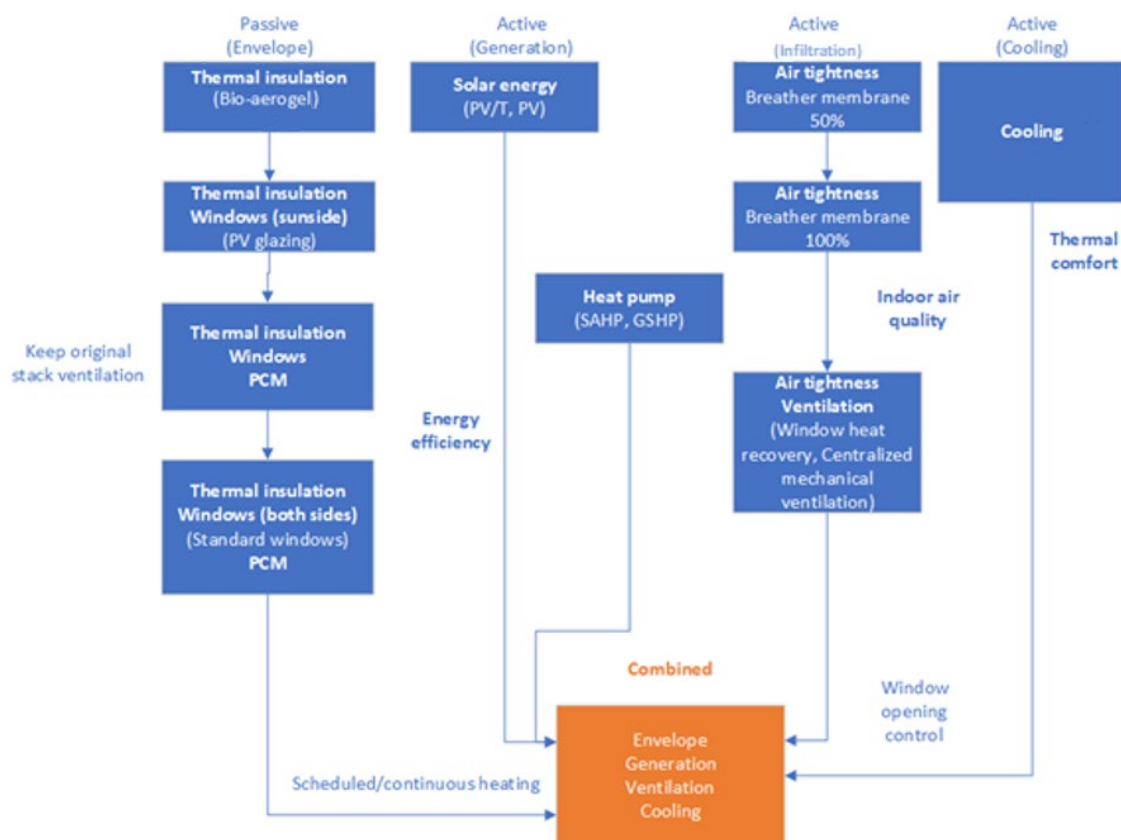


Figure 13: Retrofit Packages connection diagram (received from D2.2)

2.1.1 General Approach

The economic influence of the retrofitted case can be interpreted as time mediated to reap benefits. The lesser the “benefit-cost” difference, the lower the recap time is. On the contrary, if the system’s recap time is long, it means that the “benefit-cost” ratio is resulted quite big.

This particular ratio is directly connected with the energy price values, which is then affected by a variety of external and internal factors/parameters. To calculate the Energy Price (electricity plus main heating fuel - Figure 12), the addressed approach implies a multiplication of the demo building-utilized/simulated floor area (Table 12) times the energy consumption values in kWh/m² (purchased and primary energy). The latter traits are linked to original or retrofit scenario and the local energy prices which are provided by the project partners and presented below:

Partner-Country	Electricity Price (€/kWh)
United Kingdom (UK)	0.346
Spain (SP)	0.210
Portugal (PT)	0.240
Greece (GR)	0.190
Finland (FI)	0.160

Table 10: Electricity Prices per kWh

Partner-Country	Type of Fuel	Heating Fuel Price (€/kWh)
United Kingdom (UK)	Natural Gas	0.083
Spain (SP)	Natural Gas	0.070
Portugal (PT)	Natural Gas	0.070
Greece (GR)	Oil	0.115
Finland (FI)	District Heating	0.069

Table 11: Energy Fuel prices per kWh

An analytic example of estimating the energy consumption values is provided in the following chapter 2.1.3 and **APPENDIX B**.

Site	Floor area (m ²)	No. Rooms	Wall area (m ²)	Roof area (m ²)	Window area (m ²)	Sun-side Window area (m ²)	Shady-side Window area (m ²)
United Kingdom (UK)	115.7	4	80.9	72.7	35.7	12.8	22.9
Spain (SP)	290	8	281.8	111.7	29.5	19.8	9.7
Portugal (PT)	77	2	133.3	55.0	4.6	1.6	3
Greece (GR)	268.9	7	288.6	108.4	26.0	11.2	14.8
Finland (FI)	5260	N/A	2294.1	988.3	380.4	238.1	142.3

Table 12: Building-data of the demo buildings

The energy price calculation implies both for electricity and heat fuel consumption:

$$E = \text{consumption (kWh/m}^2\text{/year)} \times \text{Floor area (m}^2\text{)} \times \text{local energy price (€/kWh)}$$

2.1.2 Inflation Rate

For market-realistic and close-to-reality results, the study takes into consideration the influence of inflation rate.

The decrease in average purchasing value of currency is referred to as inflation. This value is directly affected by the increasing demand for oil and gas, resulting to global energy prices pushed up. In addition, as pandemic hampers the operations, and induces obstacle to the global shipping, several economies have been disturbed by shortages regarding variety of goods. Moreover, shortages caused by the long-term exploitation of raw materials are retrograding the condition of supply chain of goods; including mainly building materials, vital car components, lumber, computer chips¹² and many other products.

The inflation rate comprises a highly weighted parameter for sustainability studies and can radically alter their outcome. When inflation rate is used in economic evaluations¹³, all items except interest on a loan and depreciation are expected to increase in value at the same rate as inflation¹⁴.



Figure 14: EU Average Inflation rate Index for the last two decades

By term, inflation rate induces the cost of capital and nominal cost values¹⁵:

$$(1 + i) = (1 + C_i)(1 + h)$$

Where:

- i: nominal cost of capital
- C_i : initial capital cost
- h: inflation rate

In this study the inflation rate has been considered unto inducing the energy source prices. The prices are affected and defined by the corresponding inflation rate value (e.g. electricity, gas, oil, district heating). In addition, the price value of solar energy sold-to-the-grid (in case of photovoltaic implementation) is similarly influenced.

Principal method to estimate future prices after inflation:

$$B = A \left(1 + \frac{h}{100} \right)$$

Where:

¹² <https://www.cnbc.com/2021/11/30/inflation-euro-zone-november-2021.html>

¹³ <https://ec.europa.eu/eurostat/web/covid-19/economy>

¹⁴ [https://books.google.gr/books?hl=el&lr=&id=d2GrbBCOIoQC&oi=fnd&pg=PP1&dq=Coker,+A.+K.+\(2007\).+COST+ESTIMATION+AND+ECONOMIC+EVALUATION.+Ludwig+E2%80%99s+Applied+Process+Design+for+Chemical+and+Petrochemical+Plants&ots=f7KLY1k2Gu&sig=P8aYDh0A1b3IUzvDR67rWYWkaI0&redir_esc=y#v=onepage&q&f=false](https://books.google.gr/books?hl=el&lr=&id=d2GrbBCOIoQC&oi=fnd&pg=PP1&dq=Coker,+A.+K.+(2007).+COST+ESTIMATION+AND+ECONOMIC+EVALUATION.+Ludwig+E2%80%99s+Applied+Process+Design+for+Chemical+and+Petrochemical+Plants&ots=f7KLY1k2Gu&sig=P8aYDh0A1b3IUzvDR67rWYWkaI0&redir_esc=y#v=onepage&q&f=false)

¹⁵ <https://www.accaglobal.com/uk/en/student/exam-support-resources/fundamentals-exams-study-resources/f9/technical-articles/inflation-investment-appraisal.html>

- A: the starting price value (non-inflated)
- B: the ending price value (inflated)
- h: inflation rate

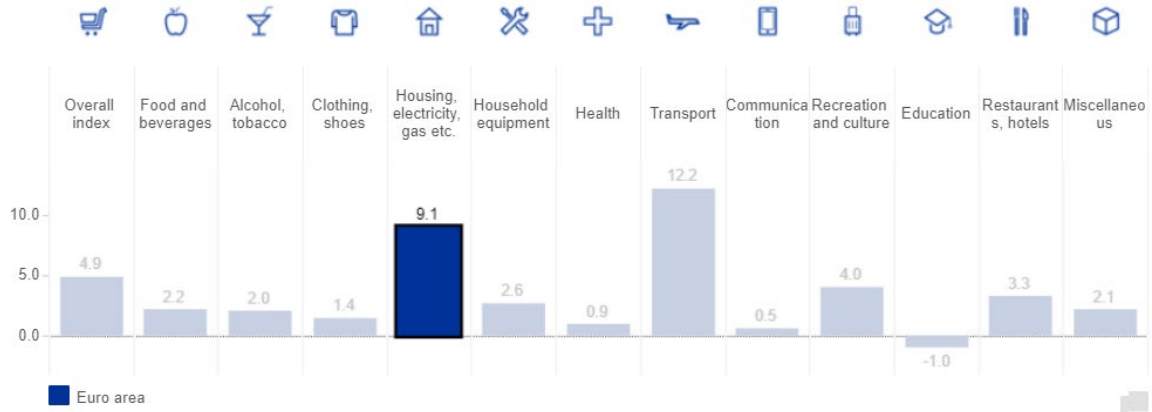


Figure 15: EU Inflation Rate values by Components

A broader image of inflation rate influence on this SUREFIT EIA is demonstrated in the current study in chapter 2.2.1.

2.1.3 Avoided Annual Cost (AaC) & Total Cost of Energy (TCE)

The Net Annual Cash Flow (CF) stands for the difference in consumption-expenses equilibrium caused by retrofitting. It demonstrates the result of year's cash outflows subtracted by inflows due to SUREFIT installations. CF value can be positive or negative, linked to cash net increase or decrease. Since Cash Flow is connected with domestic installation and affects the annual household expenses, the CF value will be referred as Avoided annual Cost (AaC) in this study.

In order to acquire the AaC values of each demo, one needs to calculate the Total Cost of *purchased* Energy (TCE) both for original and retrofit scenarios.

TCE values for both, derive from the sum of annual inflated electricity consumption of year "n"; plus, the annual inflated fuel consumption of the same year "n":

- For Original Scenario: $TCE_{o_n} = electricity\ cost_{o_n} + fuel\ cost_{o_n}$
- For Retrofit Scenario: $TCE_{r_n} = electricity\ cost_{r_n} + fuel\ cost_{r_n}$

The AaC of year "n" is calculated as the difference between TCE of the original and retrofit scenario in year "n":

$$AaC_n = TCE_{o_n} - TCE_{r_n}$$

Where:

- AaC: Avoided annual Cost in €
- TCE_{o_n} : Total Cost of *purchased* Energy at year n for the original in €
- TCE_{r_n} : Total Cost of *purchased* Energy at year n for the retrofit in €
- n: The year of investigation

When the retrofit scenario requires maintenance cost, the maintenance-related expenses are introduced to the AaC after year one of operation. Therefore:

$$AaC_n \xrightarrow{n \geq 1} TCE_{o_n} - TCE_{r_n} - m$$

Where:

- m: maintenance cost in €

In case of PV/T implementation, when profit occurs from selling the excess produced solar energy to the grid, and annual maintenance is required, the AaC value is estimated by the following equation:

$$AaC_n = TCE_{o_n} - TCE_{r_n} - m + p_n$$

- p: the annual income from energy sold back to the grid in € and is derived from the following equation:

$$p = \text{local current solar energy price (€/kWh)} \times \text{gross of energy sold to the grid (kWh)}$$

The profit value is affected by inflation rates (ANNEX)

2.1.4 Initial Capital Cost (C_i) & Cumulative Savings (CS)

The reference values of C_i regarding each SUREFIT technology are provided by the manufacturers and the installation professionals/workshops (**APPENDIX C**). It is constituted by the following values of costs:

$$C_i = \text{Manufactoring} + \text{Auxiliary equipment} + \text{Installation} + \text{Transportation}$$

The building parameters (Table 12) are exploited to acquire the final C_i values connected to each technology.

Further analysis of the building-parameters at the following chapter 2.3 'Results'.

The C_i values vary based on building type, region and its corresponding economy, and operation principles.

Each year's AaC value is summed in order to monitor the total benefit achieved from the year of introducing the assessed technology. The sum of annual revenue achieved by incorporating the SUREFIT technologies can be attributed as the Cumulative Savings (CS):

$$CS_n = \sum_{t=0}^{t=n} AaC$$

Where:

- n: year of investigation

2.1.5 Balance (Ba)

The Ba parameter presents the economic status from the year of installation to the end of product's lifetime. It represents the initial capital investment (C_i) value deducted from the particular year's cumulative savings (CS_n) and presents an adequate idea of the project's impact.

$$Ba_n = CS_n - C_i$$

2.1.6 Payback Period (PBP)

The recap period from investment is indicated via the term of Payback Period (PBP) and illustrates how long does it take for the project to recoup an investment. The time spot when C_i is recapped, is named breakeven point. The shorter the PBP an investment bears, the more attractive it becomes.

Simply, the PBP is the time taken for the AaC from the start-up year of the project to match the initial capital investment, while subtracting the revenue achieved through retrofitting.

The PBP is the value of “t” that satisfies the equation:

$$\sum_{t=0}^{t=(PBP)} AaC = (CS - C_i)$$

Where:

- AaC: Avoided annual Cost
- C_i : Initial capital cost
- CS_t : Cumulative savings/salvage value/sum of revenue from retrofitting the year t

Economic Assessment - <i>product X</i>					
Year	TCE_o	TCE_r	Avoided Annual Cost (AaC)	Cumulative Savings (CS)	Balance (Ba)
0	$TCE_{o_{n=0}}$	$TCE_{r_{n=0}}$	$AaC_{n=0}$	$CS_{n=0}$	$Ba_{n=0}$
...	...	...	...	...	...
n	TCE_{o_n}	TCE_{r_n}	AaC_n	CS_n	Ba_n

Table 13: Economic assessment parameters for lifetime “n” years

APPENDIX D presents the principle method of calculating PBP indexes, following the methodology explained above and the format of Table 13. It is presented only an example of PBP estimation associated with the Portuguese case under the European average inflation rate.

2.2 Assumptions

2.2.1 Inflation Scenarios Assumptions

The study of EIA broadens the results by taking into consideration three different case-scenarios for each retrofitted building. According to the Grant Agreement, the retrofitting has to be assessed through a variety of inflation rates. By monitoring the results under diverse inflation values one can acquire a wider perspective of the project’s impact; thereof, the inflation rates assumptions taken are:

1. Latest inflation rate

This inflation rate shows the current market condition of each partner-country. This scenario illustrates and carries out the assumption that the retrofitting actions occur at present; and reveals what is the effect of SUREFIT at the close future. The latest inflation scenarios taken into account:

Partner-Country	Indication	Latest Inflation Rate value (%)
United Kingdom (UK)	h_{UK}	5.1
Spain (SP)	h_{SP}	6.7
Portugal (PT)	h_{PT}	2.7
Greece (GR)	h_{GR}	5.1
Finland (FI)	h_{FI}	3.7

Table 14: Latest Inflation Rate Values

The inflation rate values correspond to December of 2021.

2. Zero inflation rate

A zero-inflation rate gives an adequate image of the retrofit results, demonstrating directly and clearly the product/technology influence towards energy consumption, CO₂ emissions (without taking into account the time value of money).

3. EU average inflation rate

Since the SUREFIT project is developed under the scope of EU, the European average inflation rate should be investigated as well as a case.

The above values of inflation rates have been collected by the European Central Bank¹⁶. According to ECB, the EU average inflation rate:

$$h_{EU} = 5.00\%$$

2.2.2 Heating Operation Schedules (Intermittent & Continuous)

The simulations for monitoring the impact of SUREFIT technologies should demonstrate realistic characteristics. Assumptions have to be taken in order to achieve scenarios and cases as close as possible to reality. For each demo case, two separate heating operation schedules were considered:

- **The Intermittent:** During the intermittent schedule, the heating system does not operate 24h/day but only for two (2) hours in the morning (07.00 – 09.00) and three (3) hours in the evening (19:00 – 22:00). Furthermore, the heating is on from the 1st of November till the 31st of March. in a variety of countries and is directly connected with their climate, culture and economy condition. The intermittent heating occurs in a variety of countries and is directly connected with their climate, culture and economy condition. Portugal and Greece have this type of heat supply.
- **The Continuous:** The operating principle of this case is to constantly provide heat from the 1st of September till the 1st of May and for 24h/day. The continuous heating aims at keeping a constant indoor temperature, which is usually around 18 - 20 °C. The UK and Finnish demos serve continuous heating delivery. In case of Spanish demo, the heating is considered continuous too, with high full operation between 14:00 and 23:00; and lower set points the rest hours.

¹⁶ <https://www.ecb.europa.eu/stats/html/index.en.html>

Both types of heating supply will be observed in simulations.

2.2.3 Retrofitting Parameters

PV/T:

The Photovoltaic Thermal panels are exploited to the roof of the demo-houses. The number of panels used vary between the countries and relate with the roof area of each demo-building. The maintenance cost of PV/Ts has been considered for two hours work for every demo site. The surplus of produced energy is sold back to the grid for the solar energy prices linked to each partner-country:

Partner-Country	Solar Energy Price (€/kWh)
United Kingdom (UK)	0.030
Spain (SP)	0.050
Portugal (PT)	0.013
Greece (GR)	0.087
Finland (FI)	0.040

Table 15: Solar Energy Prices

The values were provided by SUREFIT partners.

Aerogels:

The aerogel insulation has been considered to be installed to the overall envelope of the demo buildings (walls, roof and floor where applicable). A separate calculation has been conducted for the bio and the silica aerogel blanket.

PV-VG windows:

The area of vacuum glazing windows and PV-VG windows have been regarded according to D2.2 *"Results of dynamic simulation of building energy demand"*.

PCMs:

The innovative technology of PCM is exploited for particular number of rooms in the demo-buildings. The associated data and the area of PCM implementation are provided by D2.2 *"Results of dynamic simulation of building energy demand"*.

WINCO Breathable Membranes:

The same WINCO product is exploited for the three different infiltration scenarios. The actual infiltration of the particular demo-sites after the membrane incorporation is unidentified. Thereof, the retrofit simulations observe two potential scenarios, the 50% and 100% infiltration when the membrane is implemented. According to D2.2, the 50% airtightness corresponds to a more realistic assumption, while the 100% represents the ideal case of airtightness. For both cases a one-layer membrane blanket is considered.

WHR:

The number of WHR units installed is equal to the number of rooms of each demo-buildings. However, there are particular cases where the WHR units' number exploited is provided by D2.2 "Results of dynamic simulation of building energy demand". For the installation of WHR unit, has been assumed the use of sealant across every edge of the product which is in contact with the wall (Green contour of Figure 16)

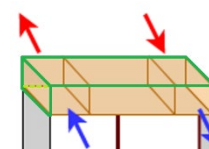


Figure 16:
Sealant
Application

2.2.4 Commercial Price Case

In order to cover the long-term market impact of the project, the current deliverable observes also PBP indexes correlated with greater market-maturity levels of the innovative SUREFIT product/technologies particularly; meaning that D2.4 implicates also a resemblance of product-prices that according to the technology providers will value the product at the time it is commercially produced. This particular price-case information is received by the manufacturers, specifically for bio-aerogel and PCM panel inputs.

- Bio-aerogel commercial price assumption: $16\text{€/m}^2 + \text{margin cost (20\%)} = 19.2\text{€/m}^2$
- PCM panels commercial price assumption: 50€/m^2

PBP estimations for commercial price cases will be determined only for each demo's applicable heating supply occasion.

2.3 Results

The process for acquiring results, follows the above analysed steps. The PBP (**APPENDIX D** example) is estimated by calculating TEC indexes (**APPENDIX B** examples) linked to the simulations conducted for every demo case. The C_i values for the PBP calculations are given in **APPENDIX C**. The current study does not contemplate the expenses associated with transportation service. Transportation cost parameter will be included in the analysis of WP8. When the PBP outcome value is considerably large (in particular >50 years), or there is no PBP resulted from the fact of constant negative annual AaC values, the result is represented by a **dash symbol (-)**

2.3.1 United Kingdom (UK)

Key aspects taken into account for the PBP calculation regarding continuous supply and due to Table 44, are also harmonized with Table 12:

- Insulation Thickness: 5.0 cm
- Area of Insulation and Infiltration blankets: Total wall area and roof area
- Windows: PV Vacuum Glazing Windows in the sun-side area of the building
- PCM: To the overall roof area
- SAHP of 11 kW capacity
- 8 PV/T panels are exploited for the 14.0 m^2

PBP – Continuous UK					
			PBP (years) with Inflation Rate Values		
Category	No.	Scenario Description	PBP when h_{UK}	PBP when h_0	PBP when h_{EU}
Insulation	1	Bio-aerogel	27.60	-	27.87
	2	Silica-aerogel	16.72	28.06	16.84
	3	Bio aerogel & PV Windows	34.49	-	34.92
	4	Bio aerogel & PV Windows & PCM	31.89	-	32.27
Infiltration	5	50%	2.91	3.16	2.92
	6	100%	2.30	2.49	2.30
	7	Windows HR & 100%	5.38	6.31	5.40
Active	8	PV/T	-	-	-
	9	SAHP	-	-	-
Combined Scenario 1	10	PV/T & Bio-aerogel & PV Windows & PCM & Windows HR & 100%	-	-	-
Combined Scenario 2	11	SAHP & Bio-aerogel & PV Windows & PCM & Windows HR & 100%	45.11	-	45.68

Table 16: PBP - Continuous heating - UK

PBP Commercial Price Case – Continuous UK					
			PBP (years) with Inflation Rate Values		
Category	No.	Scenario Description	PBP when h_{UK}	PBP when h_0	PBP when h_{EU}
Combined Scenario 2	11	SAHP & Bio-aerogel & PV Windows & PCM & Windows HR & 100%	30.33	-	30.33

Table 17: PBP - Continuous heating - commercial Price - UK

Inspecting the different impact of variable parameters/assumptions on PBP, the simulation of Table 45 introduces different inputs regarding retrofitting:

- Insulation thickness reduction from 5.0 cm to 2.0 cm;
- Replacement of PV windows with conventional vacuum glazing windows (area of installation: 12.8 m²);
- Installation of PCM only in one bedroom (area of installation: 12.3m²);
- WHR installation only in two living rooms;
- Utilization of the original (existing) boiler as backup heater for the active packages instead of electric backup heater;
- Reduction of SAHP capacity from 11kW to 2.8kW;
- Simulation for both types of aerogels

PBP – Continuous Alternative UK					
			PBP (years) with Inflation Rate Values		
Category	No.	Scenario Description	PBP when h_{UK}	PBP when h_0	PBP when h_{EU}
Combined Scenario 1 (Bio)	1	PV/T & Bio-aerogel & VG & PCM & Windows HR & 100%	18.22	31.47	18.36
Combined Scenario 2 (Bio)	2	SAHP & Bio-aerogel & VG Windows & PCM & Windows HR & 100%	29.03	-	29.35
Combined Scenario 1 (Silica)	3	PV/T & Silica-aerogel & VG & PCM & Windows HR & 100%	15.18	23.94	15.28
Combined Scenario 2 (Silica)	4	SAHP & Silica-aerogel & VG & PCM & Windows HR & 100%	23.33	43.90	23.56

Table 18: PBP - Continuous heating - Alternative Input - UK

The active scenarios of Table 16 return no PBP since the active technologies bring negative AaC from their installation year and after. *Table 44* indicates that the primary energy consumption values have been slightly decreased, however the new energy mixture is entirely consisted of electricity meaning a quite costly annual consumption bill. Therefore, the investment cost is never recapped.

The shortest PBP occurred when breathable membrane technology is installed (Table 16 *No.5 & No.6*), and in infiltration group scenarios in general. Recap time is estimated to less than 3 years for 100% infiltration approach, while almost 3 years are required assuming 50% airtightness during local latest inflation rate. When WHR system accompanies the 100% airtightness case, return of investment occurs in 5.5 years.

Table 18, presents that the silica-aerogel-envelope bears better results for both combined scenarios (*No.3 & No.4*), while scenario no.3 leads to the best PBP score, as heat pump capacity has been considerably decreased, ensuing less energy consumption.

The final “to-be-implemented” scenario, is assessed, where the occupant, the demo-building supervisors and the simulations results indicated the following inputs:

- Bio-aerogel insulation panel covering the west party wall (internally) of 46.9 m². The exploited blanket thickness will be 2.0 cm.
- The eastern and southern external walls occupying 58.1 m² will be insulated with 2.0 cm thickness silica-aerogel panels.
- PV vacuum windows will be exploited in the south façade only.
- Three units of WHR system will be introduced.
- PV panels of 3.6 kW peak power located on roof.
- SAHP of 2.8 kW primarily for DHW.
- GSHP of 4 kW capacity primarily for space heating purposes.
- A 800 L volume hot water storage tank will be placed in the garden.

PBP FINAL – Intermittent UK					
			PBP (years) with Inflation Rate Values		
Category	No.	Scenario Description	PBP when h_{UK}	PBP when h_0	PBP when h_{EU}
Final Scenario		Silica & Bio-aerogel & PV-VG & WHR & SAHP & PV & GSHP	43.22	-	45.28

There is no PBP values since the retrofitted energy mixture is quite expensive. The AaC values achieved are of the magnitude of 200 to 300€ per annum. However, the target of consumption decrease is achieved.

	Original	Passive + Infiltration + PV/T
Purchased energy (kWh/m ²)	206.8	60.8
Reduction (%)	-	71%
Primary energy (kWh/m ²)	242.7	91.2
Reduction (%)	-	62%

Figure 17: Simulation of energy consumption-final scenario-UK

2.3.2 Spain (SP)

The Retrofit scenario inputs of Spanish demo implements the following sizing parameters and recons with Table 12:

- Insulation Thickness: 5.0 cm
- Area of Insulation and Infiltration blankets: Total wall area and roof area
- Windows: PV Vacuum Glazing Windows in the sun-side area of the building
- PCM: To the overall roof area
- SAHP of 11kW capacity
- 12 PV/T panels are exploited for the 20m²

The PBP resulted by following the principle of **APPENDIX D** and while the TEC values are influenced by the three referred inflation assumption scenarios:

PBP – Intermittent SP					
			PBP (years) with Inflation Rate Values		
Category	No.	Scenario Description	PBP when h_{SP}	PBP when h_0	PBP when h_{EU}
Insulation	1	Bio-aerogel	31.74	-	38.78
	2	Silica-aerogel	17.14	32.45	19.15
	3	Bio aerogel & PV Windows	30.71	-	37.11
	4	Bio aerogel & PV Windows & PCM	31.73	-	38.76
Infiltration	5	50%	7.12	9.34	7.56
	6	100%	7.06	9.14	7.42
	7	Windows HR & 100%	13.53	22.31	14.87
Active	8	PV/T	2.40	2.67	2.46
	9	SAHP	30.79	-	41.06
Combined Scenario 1	10	PV/T & Bio-aerogel & PV Windows & PCM & Windows HR & 100%	27.24	-	32.94
Combined Scenario 2	11	SAHP & Bio-aerogel & PV Windows & PCM & Windows HR & 100%	-	-	-

Table 19: PBP - Intermittent heating - SP

PBP Commercial Price Case – Intermittent SP					
			PBP (years) with Inflation Rate Values		
Category	No.	Scenario Description	PBP when h_{SP}	PBP when h_0	PBP when h_{EU}
Combined Scenario 1	10	PV/T & Bio-aerogel & PV Windows & PCM & Windows HR & 100%	19.01	39.65	21.54
Combined Scenario 2	11	SAHP & Bio-aerogel & PV Windows & PCM & Windows HR & 100%	30.59	-	36.89

Table 20: PBP - Continuous supply - combined scenarios - Commercial Price - SP

Input-adjustments are introduced in Spanish demo too, in order to attain a spherical view of the retrofiting impact. Variable alterations are tested for the applicable-for-Spain intermittent combined scenarios.

This scenario-structure follows a distinctive approach, applied only in the Spanish demo case specifically:

- The insulation thickness is tested at the sizes of 2cm and 1cm for both types of aerogels;

- Windows (only PV Vacuum in the sun-side or additionally installation of vacuum glazing on the other -shady- side of the building);
- PCMs only in particular areas – specifically 7.7m²;
- A variety of window incorporation cases have been assumed
 - Only PV-VG windows on the sun-side area (PV-VG)
 - PV-VG on the sun-side area and Vacuum glazing windows the rest of them (ALL)
- SAHP of several capacities, (11, 7 and 5 kW);
- The rest assumptions follow the combined-scenarios-pattern of Table 9;

PBP – Intermittent Alternative SP					
			PBP (years) with Inflation Rate Values		
Category	No.	Scenario Description	PBP when h_{SP}	PBP when h_0	PBP when h_{EU}
Combined Scenarios	1	(2cm bio, PV-VG) & PVT	19.10	39.59	21.64
	2	(2cm silica, PV-VG) & PVT	16.31	30.78	18.20
	3	(2cm bio, ALL) & PVT	19.24	40.76	21.86
	4	(2cm silica, ALL) & PVT	16.41	31.04	18.31
	5	(1cm bio, ALL) & PVT	17.62	34.95	19.77
	6	(1cm silica, ALL) & PVT	16.06	29.84	17.86
	7	(2cm bio, PV-VG) & SAHP11	33.14	-	40.30
	8	(2cm silica, PV-VG) & SAHP11	26.30	-	31.45
	9	(2cm bio, ALL) & SAHP11	34.39	-	41.93
	10	(2cm silica, ALL) & SAHP11	25.29	-	30.12
	11	(1cm bio, ALL) & SAHP7	25.80	-	30.77
	12	(1cm silica, ALL) & SAHP7	22.78	50.50	26.86
	13	(1cm bio, ALL) & SAHP5	25.75	-	30.71
	14	(1cm silica, ALL) & SAHP5	22.72	50.35	26.79

Table 21: PBP - Intermittent heating - Alternative Input - SP

PV/T system accomplishes favourable results for the Spanish case. Less than 3 years are needed to recover the initial investment (Table 19 No.8). The photovoltaic system by itself achieves only 23% reduction in purchased energy; however, short recap period is accomplished by the scheme of economically good energy mixture (only 6.3% of electricity), relatively low initial investment, and gain of income from selling the excess solar energy.

In addition, WINCO's envelope bears PBP located inside the boundaries of the 10 years (at most) project requirements (Table 19 No.5 & No.6).

The installation-combo with full infiltration and insulation inputs, and PV/T system achieves 27 years, since the capital investment associated with the insulation category is quite high, linked to the large area of insulation (Table 12).

As best case-scenario of alternative simulations appears the one with Vacuum Glazing and PV-VG windows, silica aerogel of 1cm thickness and PV/T panels, attributed to No.6 of Table 21. The alternative cases contemplated for simulation purposes suggest that PV/T system brings shorter recap time than any size of Solar Assisted Heat Pump simulated (Table 21).

Regarding Table 21, it seems that significant influence on PBP causes the aerogel type category, where silica brings better outcomes. The insulation thickness does not imply considerable influence, while window type alterations bear an increase. Lower SAHP size (5kW) reduces PBP score, causing the fossil fuel consumption to abridge while electricity exploitation is almost 1.7

times higher acknowledging the original case. The series of alternative scenarios do not present any PBP shorter than the project's impact target.

The finalized case of SP simulation scenario assessed, imply the following:

- 2.0 cm of silica aerogel in pre-fabricated panels covering the external wall of the *three* apartments (floor area of 223.7 m²).
- Insulating breather membrane applied as envelope to the external wall and roof of the *three* apartments.
- PCM panels of a bedroom's internal ceiling.
- PV vacuum windows will be exploited everywhere except the basement, covering a total area of 14.4 m².
- Daylight louvers in the same area the PV/VG cover.
- Six (6) units of WHR system will be introduced.
- PV/T system panels extending to 10m² on the roof.

PBP FINAL – Intermittent SP					
			PBP (years) with Inflation Rate Values		
Category	No.	Scenario Description	PBP when h_{SP}	PBP when h_0	PBP when h_{EU}
Final Scenario		Silica & Membrane & PCM & PV-VG & Louvers & WHR & PV/T	19.02	40.86	21.54

Table 22: PBP – Intermittent heating – FINAL case SP

	Orig	Combined, 3 insulated
Purchased energy (kWh/m²)	129	59.7
Reduction (%)		53.7 %
Primary energy (kWh/m²)	146.5	69.5
Reduction (%)		52.5 %

Figure 18: Simulation of Energy consumption - Final Scenario – SP

2.3.3 Portugal (PT)

The inputs appraised for results depicted in Table 23, Table 24 and Table 25:

- Insulation Thickness: 5.00cm
- Area of Insulation and Infiltration blankets: Total wall area and roof area
- Windows: PV Vacuum Glazing Windows in the sun-side area of the building
- PCM: To the overall roof area
- SAHP of 11kW capacity
- 14 PV/T panels are exploited for the 24m²

Table 50 constitutes the reference of PBP calculation for intermittent heating.

PT Intermittent heating supply:

PBP – Intermittent PT					
			PBP (years) with Inflation Rate Values		
Category	No.	Scenario Description	PBP when h_{PT}	PBP when h_0	PBP when h_{EU}
Insulation	1	Bio-aerogel	37.81	-	28.66
	2	Silica-aerogel	19.45	25.83	16.43
	3	Bio aerogel & PV Windows	43.60	-	32.16
	4	Bio aerogel & PV Windows & PCM	-	-	34.05
Infiltration	5	50%	4.59	4.95	4.33
	6	100%	4.46	4.81	4.22
	7	Windows HR & 100%	8.54	9.72	7.79
Active	8	PV/T	25.58	41.63	19.96
	9	SAHP	-	-	-
Combined Scenario 1	10	PV/T & Bio-aerogel & PV Windows & PCM & Windows HR & 100%	-	-	36.47
Combined Scenario 2	11	SAHP & Bio-aerogel & PV Windows & PCM & Windows HR & 100%	-	-	-

Table 23: PBP - Intermittent heating - PT

PBP Commercial Price Case – Intermittent PT					
			PBP (years) with Inflation Rate Values		
Category	No.	Scenario Description	PBP when h_{PT}	PBP when h_0	PBP when h_{EU}
Combined Scenario 1	10	PV/T & Bio-aerogel & PV Windows & PCM & Windows HR & 100%	28.52	-	22.23
Combined Scenario 2	11	SAHP & Bio-aerogel & PV Windows & PCM & Windows HR & 100%	42.94	-	32.05

Table 24: PBP - Continuous heating - Combined scenarios - Commercial Price – PT

Table 51 presents the simulation for the Continuous heating assumption simulated.

PT Continuous heating supply:

PBP – Continuous PT					
			PBP (years) with Inflation Rate Values		
Category	No.	Scenario Description	PBP when h_{PT}	PBP when h_0	PBP when h_{EU}
Insulation	1	Bio-aerogel	16.14	20.43	37.81
	2	Silica-aerogel	7.05	7.86	19.45
	3	Bio aerogel & PV Windows	16.82	21.47	-
	4	Bio aerogel & PV Windows & PCM	18.01	23.38	-
Infiltration	5	50%	0.84	0.86	4.59
	6	100%	0.81	0.83	4.46
	7	Windows HR & 100%	1.81	1.88	8.54
Active	8	PV/T	16.22	21.68	25.58
	9	SAHP	-	-	-
Combined Scenario 1	10	PV/T & Bio-aerogel & PV Windows & PCM & Windows HR & 100%	16.65	21.41	-
Combined Scenario 2	11	SAHP & Bio-aerogel & PV Windows & PCM & Windows HR & 100%	19.18	25.34	-

Table 25: PBP - Continuous heating - PT

Infiltration retrofitting category ensues favourable results. WINCO's breathable membrane brings ideal recap time for both the 100% and 50% approach, connected with the fact that the original infiltration capacity of the existing building marks a relatively poor score. The breathable membrane combined with WHR system delivers almost 2 years for the virtual continuous case (Table 25 No.7) and 10 years for intermittent (Table 23).

Insulation inputs do not manage to acquire the desired purchased energy reduction; 42% is the best outcome associated with insulation category (Table 50 of **APPENDIX A**).

Interesting results concern the PV/T recap period, with values of 26 and 16 years for intermittent and continuous heat delivery accordingly.

Both supply type cases demonstrate no PBP value for SAHP system. The occurred purchased energy -amelioration is quite inadequate when simulating SAHP, compared to the original case scenario. The difference is estimated in the order of 10kWh/m² per year purchased energy for both continuous and intermittent case, therefore no PBP can be achieved.

The reason is of decreased economic efficiency of the photovoltaic system in the Portuguese demo lies on the fact that only 15% of the purchased energy reduction is achieved after PV/T system is simulated. Moreover, the energy mixture consists 94% of electricity; fact that according to Table 10 and Table 11 considerably increases the final cost value of purchased energy.

Finally, via the guidance of D2.2. and interpreting the occupants requirements, the definitive, applied retrofit scenario implies the following:

- The simulation considers the overall building.
- WHR system will be introduced only in one room; therefore, only one unit will be used.
- PV vacuum windows will be exploited in the south façade and only in 1.6 m² of area.
- PV panels of 1200W capacity (3 panels) located on roof.
- SAHP of 11kW covering DHW and space heating requirements.
- Fan Coil units (as part of the new heating system installation)

PBP FINAL – Intermittent PT					
			PBP (years) with Inflation Rate Values		
Category	No.	Scenario Description	PBP when h _{PT}	PBP when h ₀	PBP when h _{EU}
Final Scenario		PV-VG & WHR & SAHP & PV	5.12	5.63	4.82

Table 26: PBP – Intermittent heating – FINAL case PT

The current assumption brings a 75% reduction in purchased energy index, while 74% less primary energy is used compared with the original case.

Purchased energy (kWh/m ²)	115.4	28.4
Reduction (%)	-	75%
Primary energy (kWh/m ²)	163.0	42.3
Reduction (%)	-	74%

Figure 19: Simulation of Energy consumption - Final Scenario – PT

2.3.4 Greece (GR)

The simulations regarding the Greek demo cases introduce the following inputs while acknowledging Table 12:

- Insulation Thickness: 5.00cm
- Area of Insulation and Infiltration blankets: Total wall area and roof area
- Windows: PV Vacuum Glazing Windows in the sun-side area of the building
- PCM: To the overall roof area
- SAHP of 11kW capacity
- 13 PV/T panels are exploited for the 26m²

GR Intermittent heating supply:

PBP – Intermittent GR					
			PBP (years) with Inflation Rate Values		
Category	No.	Scenario Description	PBP when h_{GR}	PBP when h_0	PBP when h_{EU}
Insulation	1	Bio-aerogel	-	-	-
	2	Silica-aerogel	44.57	-	45.29
	3	Bio aerogel & PV Windows	-	-	-
	4	Bio aerogel & PV Windows & PCM	-	-	-
Infiltration	5	50%	11.05	15.10	11.11
	6	100%	10.38	13.90	10.43
	7	Windows HR & 100%	32.72	-	33.12
Active	8	PV/T	8.70	11.50	8.74
	9	SAHP	26.19	-	26.57
Combined Scenario 1	10	PV/T & Bio-aerogel & PV Windows & PCM & Windows HR & 100%	45.17	-	45.83
Combined Scenario 2	11	SAHP & Bio-aerogel & PV Windows & PCM & Windows HR & 100%	-	-	-

Table 27: PBP - Intermittent heating - GR

PBP Commercial Price Case – Intermittent GR					
			PBP (years) with Inflation Rate Values		
Category	No.	Scenario Description	PBP when h_{GR}	PBP when h_0	PBP when h_{EU}
Combined Scenario 1	10	PV/T & Bio-aerogel & PV Windows & PCM & Windows HR & 100%	30.76	-	31.14
Combined Scenario 2	11	SAHP & Bio-aerogel & PV Windows & PCM & Windows HR & 100%	-	-	-

Table 28: PBP - intermittent heating - Commercial Price - GR

GR Continuous heating supply:

PBP – Continuous GR					
			PBP (years) with Inflation Rate Values		
Category	No.	Technology	PBP when h_{GR}	PBP when h_0	PBP when h_{EU}
Insulation	1	Bio-aerogel	25.16	-	25.38
	2	Silica-aerogel	14.39	21.52	14.47
	3	Bio aerogel & PV Windows	24.23	46.56	24.46
	4	Bio aerogel & PV Windows & PCM	14.87	22.49	14.96

Infiltration	5	50%	2.91	3.17	2.92
	6	100%	2.72	2.96	2.73
	7	Windows HR & 100%	4.65	5.33	4.66
Active	8	PV/T	1.01	1.06	1.01
	9	SAHP	10.87	14.71	10.92
Combined Scenario 1	10	PV/T & Bio-aerogel & PV Windows & PCM & Windows HR & 100%	22.23	41.89	22.43
Combined Scenario 2	11	SAHP & Bio-aerogel & PV Windows & PCM & Windows HR & 100%	29.87	-	30.19

Table 29: PBP - Continuous heating - GR

Regarding the simulations of the Greek demo, a series of alternative inputs associated mainly with the combined scenarios is resembled:

- Insulation thickness reduction from 5cm to 2cm
- Insulation only on the first and second floor ($230.7 \text{ m}^2 + 67.6 \text{ m}^2$)
- Replacement of PV windows with conventional vacuum glazing windows (11.2 m^2)
- Installation of PCM only in one living room (25.5 m^2)
- WHR installation only in two living rooms
- Utilization of the original boiler as the backup heater for active package instead of electric backup heater
- Reduction of SAHP capacity from 11kW to 2.8kW
- Simulation for both types of aerogels

GR Intermittent heating supply Alternative Input Scenarios:

PBP – Intermittent Alternative GR					
			PBP (years) with Inflation Rate Values		
Category	No.	Scenario Description	PBP when h_{GR}	PBP when h_0	PBP when h_{EU}
Combined Scenario 1 (Bio)	1	PV/T & Bio-aerogel & PV Windows & PCM & Windows HR & 100%	37.33	-	37.86
Combined Scenario 2 (Bio)	2	SAHP & Bio-aerogel & PV Windows & PCM & Windows HR & 100%	-	-	-
Combined Scenario 1 (Silica)	3	PV/T & Silica-aerogel & PV Windows & PCM & Windows HR & 100%	28.02	-	28.37
Combined Scenario 2 (Silica)	4	SAHP & Silica-aerogel & PV Windows & PCM & Windows HR & 100%	-	-	-

Table 30: PBP - Intermittent heating - Alternative Input - GR

The common heating practise usually occurred in Greece is via intermittent use. However, the use of heat (or coolness) is often applied for more hours than the common intermittent supply. Continuous and intermittent supply approach show significant result variations; with Table 29 demonstrating improved scores in every testing category. In overall, the continuous assumption demonstrates encouraging outcome with the PBP of infiltration group ranging below 10 years. Recurrent case exhibits decent recap time for PV/T with 11.5 years when inflation rate is granted zero. Second shortest payback corresponds to breathable membrane (Table 27 No.5 & No.6).

Payback values associated with combination of infiltration technologies and WHR (Table 27 No.7) show insufficient recap times, since the benefit bearing incorporation equals only 9% better than the original scenario (Table 53 of **APPENDIX A**). Since Greek living culture and customs imply natural daily ventilation, the incorporation of WHR system does not affect indoor conditions.

On the other hand, the same case in Table 29 performs close to 5 years, due to the improvement reaching 36% according to the simulations.

In general, the active technologies during continuous supply score decently but still out of project impact limits. In case of SAHP for recurrent case, despite acquiring ameliorations in purchased energy levels, the energy mixture of retrofitted scenario implies not favorable.

The difference occurred in SAHP results when compared with Table 29, is affiliated with the fact that continues heating simulation considers the existing backup heating preserved after retrofitting while the intermittent heating simulations do not. The latter applies also for Table 30.

PV/T panels installation bring the best PBP rate for every type of heating supply regarding the Greek demo.

The applied retrofit simulation for the implies only the first floor apartment and not the overall building as received in the previous simulations. The floor area of the dwelling occupies almost 90 m².

- Breathable airtight membrane on the ceiling of the workshop located in the ground floor (90 m²).
- Prefabricated panels with silica and breathable membrane on the southern and northern facades (externally – 30.7 m²). The silica thickness is of 4.0 cm.
- PV vacuum windows will be exploited in the south façade.
- PV/T for electricity production, DHW and space heating. The latter will be supplemented by the existing oil boiler). There will be 6 PV/T modules placed on the roof.
- Smart Control System
- Commercial double glazed PVC windows

PBP FINAL – Intermittent GR					
			PBP (years) with Inflation Rate Values		
Category	No.	Scenario Description	PBP when h_{GR}	PBP when h_0	PBP when h_{EU}
Final Scenario		Silica-aerogel & Breathable membrane & PV-VG & Commercial Double windows & PV/T	8.08	10.28	8.11

Table 31: PBP – Intermittent heating – FINAL case GR

	Original	Final Case
Purchased energy (kWh/m2)	120.9	46.4
Reduction (%)	-	62%
Primary energy (kWh/m2)	143.5	55.6
Reduction (%)	-	61%

Figure 20: Simulation of Purchased Energy - Final Scenario – GR

2.3.5 Finland (FI)

In case of Finland, the retrofitting follows a different approach. The Finnish case implements only one SUREFIT technology, the light louvers effecting only the indoor comfort. Commercial Ground Source Heat Pump unit is exploited together with PV panels for the Finnish demo building. In addition, the Finnish case implements a commercial product by WINCO, the vapour barrier, effecting wall moisture.

The simulations conducted include only the continuous delivery of heating, which is the case that Finnish demo employs. In addition, the parameters considered are:

- Commercial EPS Insulation Thickness: 10.0 cm
- Area of Insulation and Infiltration blankets: Total wall area and roof area
- GSHP of 30.9 kW capacity
- 84 commercial highly- efficient bi-facial PV panels are exploited for the 140 m²

The price values of commercial inputs are contemplated by the Finnish project partners.

PBP – Continuous FI					
			PBP (years) with Inflation Rate Values		
Category	No.	Scenario Description	PBP when h_{FI}	PBP when h_0	PBP when h_{EU}
Insulation	1	EPS	24.33	39.79	21.82
Infiltration & Insulation	2	EPS & water vapor barrier	12.68	-	25.78
Active	3	GSHP	8.24	9.78	7.87
	4	PV	4.84	5.36	4.68

Table 32: PBP - Continuous heating – FI

The commercial active systems cover their purchase cost in less than 10 years.

Final Case parameters:

- Commercial EPS Insulation Thickness of 10.0 cm together with 90.0 cm gravel placed on roof.
- Insulation with mineral wool (15.0 cm thickness) for all balcony walls.
- Water vapour barrier membrane incorporated only in one balcony wall (this input cannot be modelled)
- Insulation of pipe system with 2.0 cm insulator.
- Heat Recovery by centralized mechanical balanced ventilation produced by a pre-fabricated machine room installed on the roof.
- Daylight louvers for 3 windows and the balcony, covering 10 m².
- The 84 highly-efficient PV panels
- Commercial GSHP of 35.0 kW capacity

PBP FINAL – Intermittent FI					
			PBP (years) with Inflation Rate Values		
Category	No.	Scenario Description	PBP when h_{FI}	PBP when h_0	PBP when h_{EU}
Final Scenario		Roof Commercial Insulation & balcony com. Insulation & pipe com. Insulation & com. HR & louvers & com. PV & com. GSHP	18.20	26.28	16.64

Table 33: PBP – Intermittent heating – FINAL case FI

	Original	Combined
Purchased energy (kWh/m2)	163.6	65.4
Reduction (%)		60.0 %
Primary energy (kWh/m2)	102.8	56.3
Reduction (%)		45.3 %

Figure 21: Simulation of Purchased Energy - Final Scenario – FI

2.4 Conclusions

SUREFIT project addresses and adapts to the diversity of markets, geographies, building types and sizes, local heating supply approaches, local architecture styles and climates, and finally to the occupants' requirements. These, constitute the input-parameters affecting each retrofitting strategy and action to any project-implementation-location.

Building size is directly connected with return of investment related to retrofitting. Larger-scale installations bring rapid results in comparison with small installations.

Regions located in the north part of Europe usually apply the continuous heating approach, since greater heat loads have to be delivered, and larger difference between indoor and outdoor temperature has to be covered, in order to acquire acceptable and viable conditions for the occupants. On the contrary, southern locations close to the Mediterranean area are supplied by intermittent heating loads. By simulating both approaches to all demo sites one can clearly observe that the continuous approach returns better PBP results to any type of technology, however the energy consumption cost is increased.

The influence of location parameter can be clearly defined by the much-better-performance of photovoltaic units in the partner-countries where the frequency of sunny days per annum is high, and days' duration is longer. Therefore, the norm shows that PV/T system performs better when simulated in Mediterranean area. In the current case though, and as referred to the corresponding chapter, the Portuguese demonstration building does not follow this pattern. On the other hand, with reference to the passive category, the scores achieved by infiltration and insulation on the northern demos are quite better than those produced in the south (in regard of the applicable heating supply cases per country).

The majority of the simulations show that SAHP unit is not that efficient regarding time intervene for earning back the investment. Only the British simulation shows quite decent PBP values of SAHP when comprised with other SUREFIT technologies. The reason of low scores when SAHP is incorporated, affiliates with the fact that energy mixture after retrofitting is not economically ameliorated, as the major part is occupied by high-priced electricity.

Long PBP values occur also to every insulation category and type. This pattern applies to every demonstration site simulated. It is concluded that according to EIA the silica aerogels perform economically better when compared to bio-aerogels; while PCM and WHR technology influence negatively the economic parameter connected with energy purchase loads. The values are ameliorated when the assumption of commercial prices is attributed to the calculations.

The economic analysis concludes that generally the infiltration group is accompanied by the best recap times. The incorporation of breathable membrane bears recap indexes located in the established by the project boundaries.

Concluding, the current Deliverable together with the D2.2 make the first assessment of the ideal technology combinations for each particular demo.

In combination with decisions and preferences of the occupants, the demo location, the guideline of project and the findings of the D2.4 and of D2.2, the final case scenario was conceived.

In the boundaries of sustainability assessment, the economic parameter is evaluated for each final case scenario:

The British demo case demonstrates a very poor recap time regarding the final case simulation. The unfavorable results of final case simulation derive from the problematic overall energy mixture brought by the retrofitting; since the annual benefit from year zero is of a lesser magnitude than 300 €. The AaC value only surpasses the border of 300 € after the 17th year of exploitation, when the EU average inflation rate is contemplated.

The Spanish demo acquires not quite favourable results regarding the final case scenario. The achieved PBP index locates around the 20 years (Table 22), while the accomplished reduction values 53.7% for purchased energy and 52.5% for primary compared to the original scenario (Figure 18).

In case of the other occupant of Iberian Peninsula, a reduction of 75% in purchased energy (Figure 19) is achieved, when the final case scenario is simulated. In addition to that, the PBPs scored for the Portuguese demo retrofitting are acceptable ranging below the spectrum of 10 years (Table 26).

Regarding the retrofitting inputs decided for Greece, the outcome is favourable for both the purchase-reduction and the recap time values. PBP is estimated in less than 10 years (Table 31), while consumption decline surpasses the project's requirement scoring 62% (Figure 20).

When applying the principle of payback period calculation in the case of Finnish demo, the results surpass the 10 years requirement. This is linked to the magnitude of difference resulting between the values of investment cost (C_i) and benefits reaped when retrofitting scenario is simulated (AaC). The C_i value is estimated almost 920,000 €, bringing back a considerable annual benefit.

This study though produces a theoretical investigation of SUREFIT incorporations, and the economic factor is further analyzed in *WP8 – "Economic, social and environmental assessments"*.

3 Environmental impact of SUREFIT technologies and combined solutions

The next step of a Sustainability Analysis involves the Assessment of Environmental Impact. The latter, evaluates the environmental consequences of an enterprise, a policy or a plan. Similar to the Economic Impact Analysis it constitutes a mean for documentation of decision making. The International Association for Impact Assessment (IAIA) determines the environmental impact assessment as *“the process of identifying, predicting, evaluation and mitigating the biophysical, social and other relevant effects of development proposals, prior to major decisions being taken and commitment made”*¹⁷.

In the boundaries of the current deliverable, environmental assessment will provide an early indication of the expected change in an environmental factor, within a defined area after incorporating the retrofit scenarios¹⁸.

3.1 Methodology

The assessment occurs inside the confines of CO₂ emissions-reduction percentage following the simulations provided by D2.2. As in the Economic Assessment, the retrofit scenario will be evaluated in comparison with the original one; in this case though only the reduction percentage achieved through retrofitting is demonstrated.

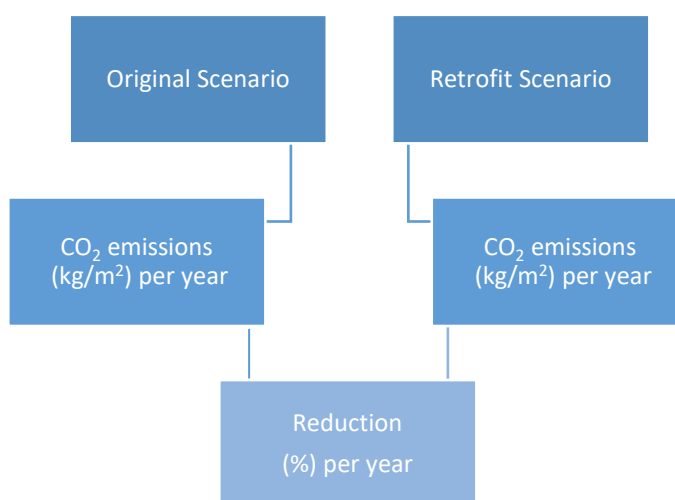


Figure 22: Environmental Comparison Scenarios

3.2 Assumptions

CO₂ emission monitoring follows mainly the course of Table 9 and the alterations, the case scenarios and the variable parameters assessed and considered during the progression of economic evaluation and deliverable D2.2. Influence of SUREFIT on CO₂ emissions reduction of the demonstration buildings is assessed following the guideline of project’s ideal impact. This means scoring a carbon reduction equivalent to 60% compared with the original scenario.

¹⁷ https://www.iaia.org/pdf/IAIAMemberDocuments/Publications/Guidelines_Principles/Principles%20of%20IA.PDF

¹⁸ <https://www.unhcr.org/protection/environment/4a97d1039/frame-toolkit-framework-assessing-monitoring-evaluating-environment-refugee.html>

Significant role to the environmental condition plays each partner-country's emission factor. However, this index does not significantly influences the reduction percentage of CO₂ outflow; but rather describes the energy production path efficiency, and the emission-monitor-process demonstrated by each country.

3.3 Results

3.3.1 United Kingdom (UK)

The below results are connected with the template of Table 16 and Table 18.

CO ₂ - Continuous Supply UK											
Description	Original	Bio/Slc	Bio & PV-VG	Bio & PV-VG & PCM	Inf. Scen. 50%	Inf. Scen. 100%	WHR & 100%	PV/T	SAHP	CS1	CS2
CO ₂ Emissions (kg/m ²)	42.7	25.1	23.7	23.5	24.6	21.3	22.8	41.7	30.2	14.3	9.4
Reduction (%)	-	41%	44%	45%	42%	50%	47%	2%	29%	67%	78

Table 34: CO₂ emissions - Continuous supply - UK

CO ₂ influence – Combined Continuous UK			
Description	Original	CS1	CS2
CO ₂ Emissions (kg/m ²)	42.7	16.7	11.6
Reduction (%)	-	61%	73%

Table 35: CO₂ emissions - Continuous supply - Alternative Input – UK

The simulation of final scenario despite the

CO ₂ Emissions (kg/m ²)	42.7	14.0
Reduction (%)	-	67%

Figure 23: CO₂ emissions - Final Case – UK

3.3.2 Spain (SP)

CO ₂ influence - Intermittent Supply SP											
Description	Original	Bio/Slc	Bio & PV-VG	Bio & PV-VG & PCM	Inf. Scen. 50%	Inf. Scen. 100%	WHR & 100%	PV/T	SAHP	CS1	CS2
CO ₂ Emissions (kg/m ²)	26.6	15.2	13.6	13.4	17.2	17.0	19.2	20.6	13.9	7.9	6.2
Reduction (%)		42.8%	48.7%	49.4%	35.2%	35.9%	27.8%	22.5%	47.8%	70.3%	76.7%

Table 36: CO₂ emissions - Intermittent supply - SP

For Table 37, the scenarios are number in accordance with Table 21 cases.

CO ₂ influence - Intermittent Alternative Supply SP								
Description	Original	1	3	5	7	9	11	13
CO ₂ Emissions (kg/m ²)	26.6	10.1	9.2	10.1	10.1	9.2	9.3	10.0
Reduction (%)		62.0 %	65.6 %	62.0 %	62.1 %	65.3 %	64.9 %	62.3 %

Table 37: CO₂ emissions - Intermittent supply - Alternative Combined – SP

Emissions (kg-CO ₂ /m ²)	25.5	11.8
Reduction (%)		53.9 %

Figure 24: CO₂ emissions – Final Case – SP

3.3.3 Portugal (PT)

Table 23 and Table 24 are guidelines for the results below

CO ₂ influence - Intermittent Supply PT											
Description	Original	Bio/Slc	Bio & PV-VG	Bio & PV-VG & PCM	Inf. Scen. 50%	Inf. Scen. 100%	WHR & 100%	PV/T	SAHP	CS1	CS2
CO ₂ Emissions (kg/m ²)	28.3	16.3	16.2	16.1	17.7	17.5	20.6	23.3	26.6	11.8	15.2
Reduction (%)	-	43%	43%	43%	37%	38%	27%	18%	6%	58%	46%

Table 38: CO₂ emissions - Intermittent supply - PT

CO ₂ influence - Continuous Supply PT											
Description	Original	Bio/Slc	Bio & PV-VG	Bio & PV-VG & PCM	Inf. Scen. 50%	Inf. Scen. 100%	WHR & 100%	PV/T	SAHP	CS1	CS2
CO ₂ Emissions (kg/m ²)	57.1	20.6	20.4	20.4	23.3	22.7	28.5	48.9	55.4	14.5	19.7
Reduction (%)	-	64%	64%	64%	59%	60%	50%	14%	3%	75%	65%

Table 39: CO₂ emissions - Continuous supply – PT

The final scenario case for Portuguese demo, together with the adequate PBP, purchased and primary energy reduction, it bears also great environmental effect:

CO ₂ Emissions (kg/m ²)	28.3	7.2
Reduction (%)	-	75%

Figure 25: CO₂ emissions - Final Case – PT

3.3.4 Greece (GR)

CO ₂ influence - Intermittent Supply GR											
Description	Original	Bio/Slc	Bio & PV-VG	Bio & PV-VG & PCM	Inf. Scen. 50%	Inf. Scen. 100%	WHR & 100%	PV/T	SAHP	CS1	CS2
CO ₂ Emissions (kg/m ²)	18.2	15.5	14.1	13.8	15.7	15.5	16.8	19.1	18.3	13.0	15.9
Reduction (%)	-	15%	23%	24%	14%	15%	7%	-5%	-1%	29%	13%

Table 40: CO₂ emissions - Intermittent supply – GR

CO ₂ influence - Continuous Supply GR											
Description	Original	Bio/Slc	Bio & PV-VG	Bio & PV-VG & PCM	Inf. Scen. 50%	Inf. Scen. 100%	WHR & 100%	PV/T	SAHP	CS1	CS2
CO ₂ Emissions (kg/m ²)	39.3	23.1	20.0	19.8	23.4	22.5	26.4	31.9	38.1	13.7	21.4
Reduction (%)	-	41%	49%	50%	40%	43%	33%	19%	3%	65%	46%

Table 41: CO₂ emissions - Continuous supply - GR

CO ₂ influence - Intermittent Alternative Supply GR			
Description	Original	CS1	CS2
CO ₂ Emissions (kg/m ²)	18.2	11.6	17.3
Reduction (%)	-	36%	5%

Table 42: CO₂ emissions - Intermittent supply - Alternative Combined – GR

The Greek final case scenario results:

CO ₂ Emissions (kg/m ²)	36.6	14.3
Reduction (%)	-	61%

Figure 26: CO₂ emissions – Final Case – GR

3.3.5 Finland (FI)

CO ₂ influence - Continuous Supply FI					
Description	Original	EPS	EPS & 100%	PV	GSHP
CO ₂ Emissions (kg/m ²)	31.7	28.8	28.5	31.2	21.9
Reduction (%)		9.2%	10.0%	1.7%	30.9%

Table 43: CO₂ emissions - Continuous supply – FI

CO ₂ Emissions (kg/m ²)	32.3	10.2
Reduction (%)		68.3 %

Figure 27: CO₂ emissions - Final Case – FI

3.4 Conclusions

The evaluation of SUREFIT contribution, with a view to environmental benefit, is benchmarked by the CO₂ emissions reduction parameter brought by retrofitting. Noticeable impacts identified in the index of air quality and are discerned via the implemented simulations. According to the findings, the scenarios composing means of carrying favourable for the project's ideal impact results are primarily the combined scenarios, achieving (and exceeding in some cases) approximately the ideal 60% emissions reduction proposed to every demo-site.

Regarding the demos located in UK and Spain the best results are ensued during the simulation of combined scenario number 2 (with SAHP). Greek and Portuguese demos on the other hand, result better while the combined scenario with PV/T is resembled. Then, the insulation category follows, with reduction values overly close to 45%, while the least influence on CO₂ reduction is generally brought by simulating the active techs independently.

Regarding the UK demo and its existing heating supply approach, both combined scenarios demonstrate favourable emission results. Combination of technologies with the PV/T produces 15.7 kg of CO₂ per m² for one year period, while only 12 kg emissions causes the combined scenario 2. A 68% and 75% reduction compared with the original case is accomplished correspondingly, composing both scenarios ideal for the case.

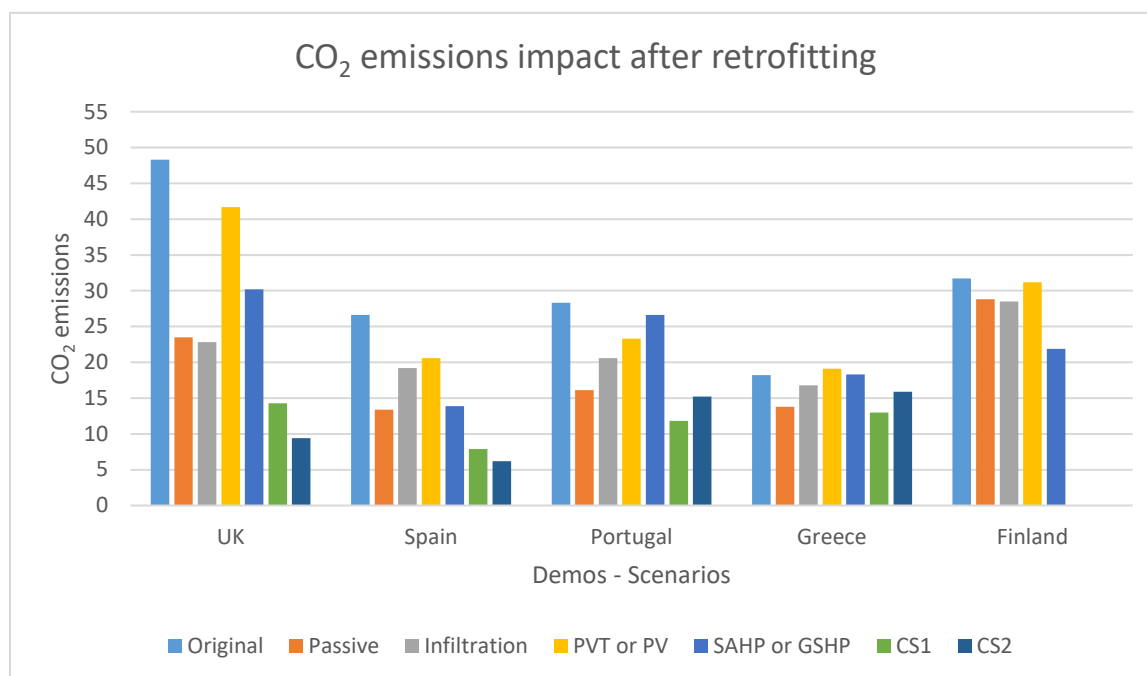


Figure 28: SUREFIT influence on CO₂ emissions

The combined scenarios of Spanish demo deliver adequate environmental impact when compared with the 26.6 kg/m² associated with the original case; bearing 70.3% and 76.7% reduction of carbon emissions when combined scenarios 1 and 2 are introduced respectively (Table 36). Every, assumption taken for the composition of Table 37 meet the environmental impact parameters supposed by the project.

When considering the applicable heating supply method in Portugal, the best case arises at the incorporation of insulation, infiltration and photovoltaics acquiring 58% reduction of emissions.

Implementation of retrofit scenarios in Greece (Table 40) and Finland (Table 43) does not bear any significant air quality amelioration. In both cases, the benefit index is much lower than the proposed one and managing to reach only the half percentage reduction from the 60% advertised by the project. The best CO₂ mitigation appears at CS1 for the Greek demo and for GSHP for the Finnish building.

The development of final case for each demo show that retrofitting actions can achieve the advertised ideal impact of SUREFIT project. Except Spanish demo, the rest of the cases significantly surpass the required CO₂ emissions reduction target, exceed it for even 24% (Figure 25). The case of Spain is close to the boarder of 60% though the best technology combination was simulated.

The environmental factor is further analyzed in WP8 – “Economic, social and environmental assessments”.

4 Social assessment

The sociological dimension of the renovations will be studied only in terms of those parameters that are within the possibilities and the purpose of this project. Consequently, they will be limited to parameters such as people's participation in decision making, being kept informed about services and decisions, their satisfaction with the renovation regarding comfort and well-being, the degree of disturbance during renovation and of course the rent price and value for money.

The therefrom derived data will be combined with the environmental as well as the economic assessment of the renovation in order to obtain a thorough and comprehensive understanding of the social impact. This will be achieved towards the end of the project, when the post renovation data will be available and will be reported in the framework of WP8.

In the present deliverable will be reported the activities related to the social parameters of the renovation that took place prior to renovation. It will also be reported the planned post – renovation activities regarding the social assessment.

4.1 Methodology

The methodology that will be followed in the case of the SUREFIT project for the assessment of social aspects of the renovations will include the following:

- **Occupant survey:** a standardized occupant satisfaction survey, including parameters such as thermal comfort, visual comfort, IAQ, desired changes, value for money and other.
- **Interview:** face to face discussion with the people related to the demonstration buildings in order to understand their habits and practices in living in the demonstration building and record their needs and complaints regarding the building.
- **On-site inspections:** expert tours to assess the building's condition and identify issues.
- **Physical measurements:** these measurements aim to record and assess the following parameters:
 - thermal conditions (e.g. infrared thermal imaging, sensors/meters for temperature, relative humidity, etc.)
 - lighting and visual environment (e.g. illuminance meters)
 - IAQ (e.g. sensors for CO₂ concentrations, VOC, formaldehyde, CO, respirable particles)
 - energy efficiency, assessed via audit, sensors, meters or bills etc.
 - Domestic Hot Water: assessed via meters or bills
 - leakage tests

The physical measurements will take place in the framework of WP6 and will be reported in the corresponding deliverables.

- **Environmental aspects:** the environmental impact of the renovation is reported in the present deliverable in Chapter 3 and is based on the CO₂ emissions reduction due to the renovations as has been theoretically calculated by AALTO University. More details on the environmental impact will be found in the relevant deliverable D2.2. The environmental impact will be also assessed at the end of the project in the framework of WP8 and specifically in D8.2-Environmental assessment.

- **Economic aspects:** the economic aspects of the renovations are also reported in the present deliverable by means of calculating the cost of each intervention as well as the total cost of the combined interventions and of course by calculating the payback period.

4.2 Results

In the following paragraphs are presented the results from the pre-occupancy a) questionnaires and b) on-site inspections and interviews.

4.2.1 Pre- and post-occupancy surveys

The purpose of the pre and post occupancy surveys is to record the point of view of the people associated with the houses (tenants and owners) to be retrofitted and take it into consideration during the interventions. The SUREFIT questionnaires include aspects related to temperature and temperature control, heating/cooling systems and the control of those systems, Indoor Air Quality, ventilation, noise and lighting. They also include questions relevant to the most important needs of the houses according to tenants and owners point of view, as well as the amount of money that the owners would be willing to pay for the improvement of their house needs, the rent increase that would ask after such renovations and the rent increase that the tenants would be willing to pay. An informed consent form accompanying the survey describes the purpose of the survey, the party requesting the information, and reassures the respondents that results will be kept confidential.

4.2.1.1 Pre-occupancy survey

The content of the questionnaire and its format (e-survey, digital copy or hard copy) was discussed with the partners that are responsible for each demo site. It was decided to create one questionnaire for all five demo sites, which was later translated to four more languages according to the demo site countries: Portugal, Finland, Spain and Greece. In the Spanish demo site it has been requested also a hard copy of questionnaire for the participant's convenience. The answers were automatically received by AMS and were then shared with the relevant partners i.e. the partners responsible for each demo site: UNNOT, AALTO, ISQ, CJR and FSM. The e-survey (online survey) can be found under the following link: <https://surefitproject.eu/questionnaire-en/>. The results of the questionnaire for each one of the demonstration building are presented in details in the following paragraphs:

4.2.1.1.1 Portugal

The temperature inside the house, as it was described by the only resident, can be characterised as problematic. As it can be seen from the Figure below, the resident feels cold throughout the year, even during the warm summer period. This house did not have any heating or cooling system at the time this survey took place. Later, for energy study purposes, heaters were placed in the house.

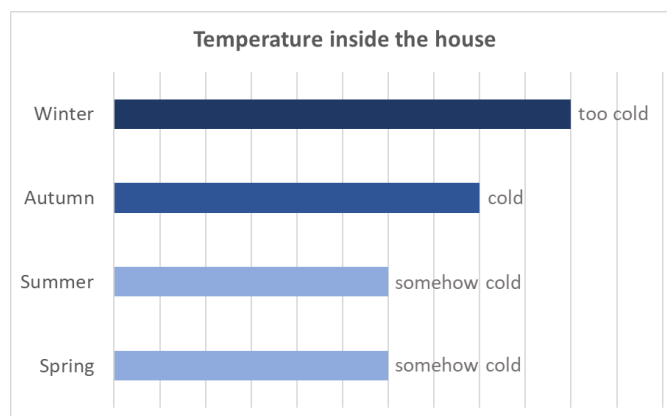


Figure 29 – Temperature inside the Portuguese house as characterised by the resident.

Regarding the IAQ of the house, the air is characterised by the resident as draughty, humid, smelly but at the same time fresh.

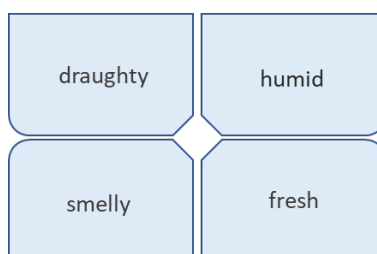


Figure 30 – Characterization of IAQ by the resident of the Portuguese house.

The air related issues are being adjusted by the resident by opening/closing windows in a regular basis throughout the whole year and there is no ventilation system in the house. The resident uses only a few rooms of the house (kitchen and sleeping room) and the windows in these rooms are open for an average of 20hours/week.

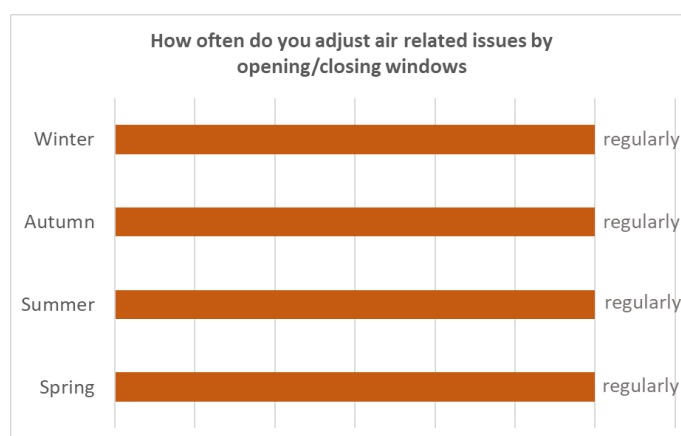


Figure 31 – Adjustment of air related issues by opening/closing windows in the Portuguese house.

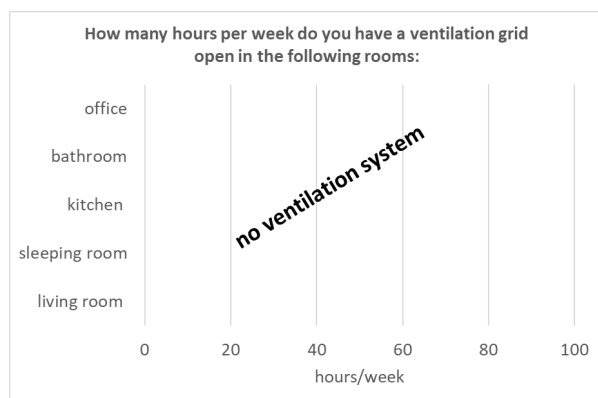


Figure 32 – Operation of the ventilation grid in the Portuguese house.

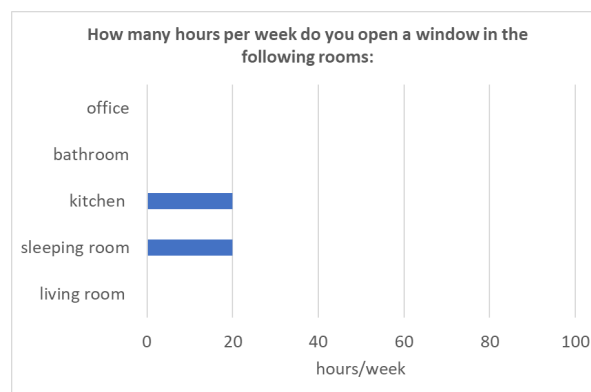


Figure 33 – Open windows in specific rooms in the Portuguese house.

From twelve (12) noise sources that were mentioned in the questionnaire, the resident has chosen three: neighbours, outdoor construction activities and road traffic that annoying her. The amount of annoyance per case is shown in the Figure below.

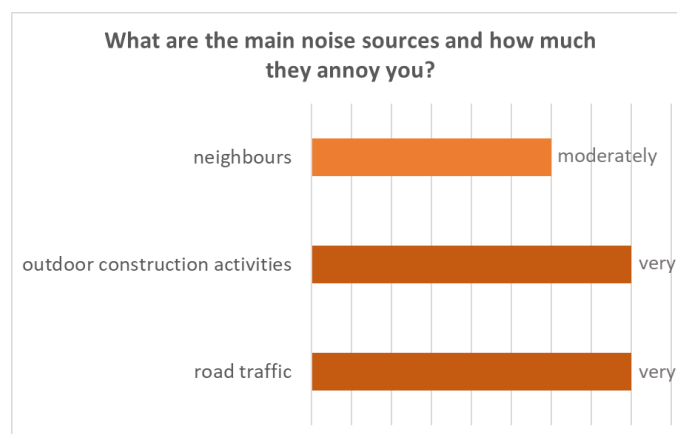


Figure 34 – Main noise sources as reported by the resident of the Portuguese house.

The resident has to adjust lighting manually and by occasionally switching on/off desk/task lights as well as the overhead lights. Besides that, the resident uses in a regular basis window blinds and shades to adjust the light indoors.

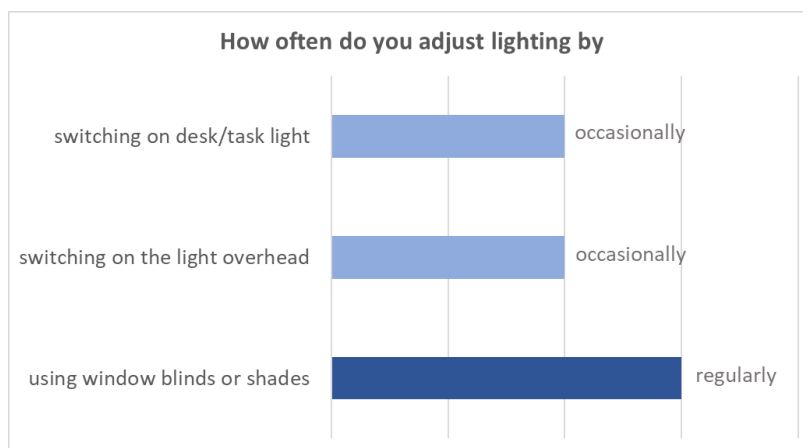


Figure 35 – Lighting adjustment in the Portuguese house.

Consequently to the above, the resident is neither satisfied nor unsatisfied with the typical indoor conditions regarding the natural as well as the artificial light in the Portuguese house.

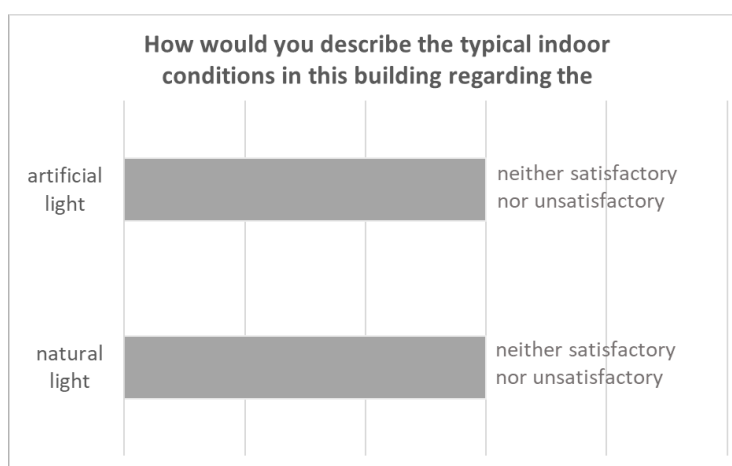


Figure 36 – Indoor conditions regarding the artificial and natural light in the Portuguese house.

In addition, the resident characterises the sun exposure of the building as average, does not consider any overheating issue through the windows and feels neither comfortable nor uncomfortable with the glare through the windows.

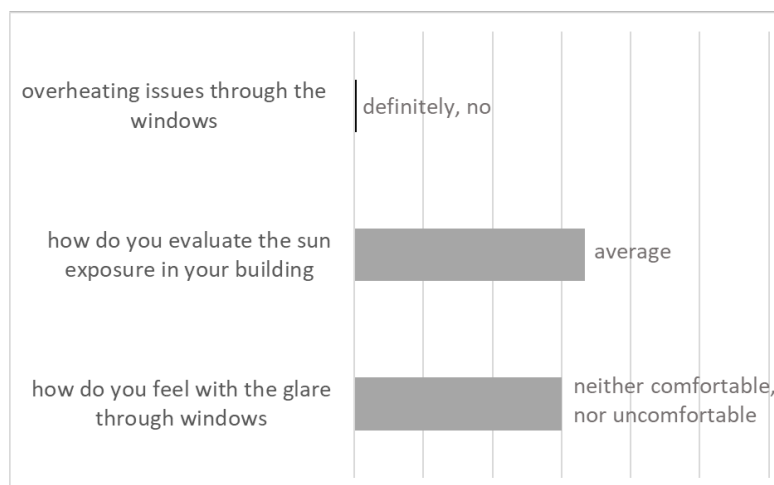


Figure 37 – Sun exposure, overheating and glare through windows in the Portuguese house.

Finally, the resident was asked about the most important needs that should be improved in the Portuguese house. The answer received was the humidity issues, the indoor air and the noise. The next question (which is theoretical) was how much rent increase the resident would be willing to pay in case the important needs were improved by certain amounts. The answers received were 0% and it can be assumed that this is due to the fact that the Portuguese house is a social house and therefore the resident does not have to pay rent for the residency.

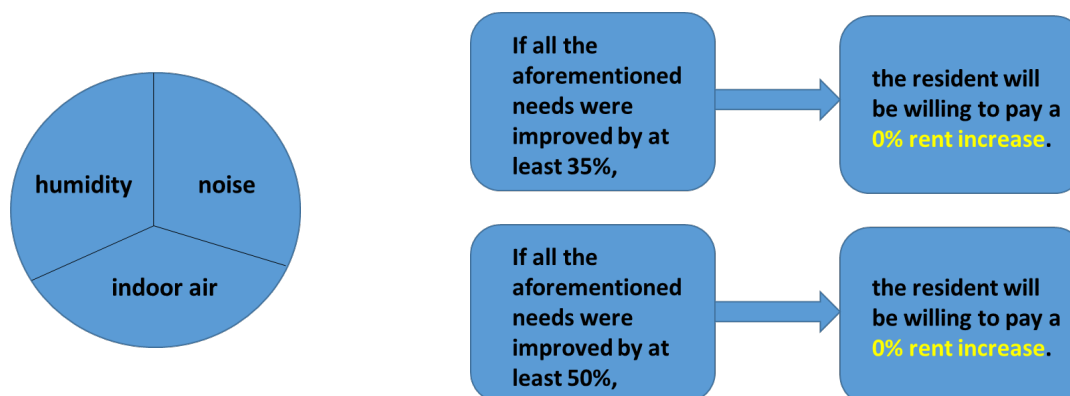


Figure 38 – The most important needs that the resident would like to improve in the house

Figure 39 – The rent increase that the resident is willing to pay.

4.2.1.1.2 Greece

The temperature inside the apartment of the first floor, as it was described by one of the residents, can be characterised as problematic. As it can be seen from the Figure below, the resident feels **too cold** and cold in the Winter and Autumn, respectively and too hot in the

Summer. The only season with acceptable (neutral) indoor temperature is Spring. This apartment has central heating and air-condition units for cooling purposes.

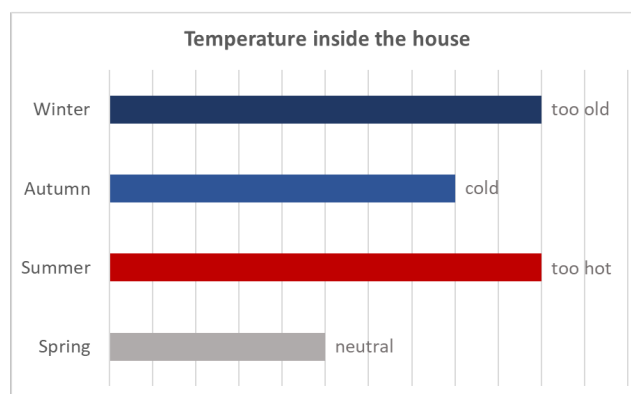


Figure 40 – Temperature inside the Greek apartment as characterised by an resident.

As it is shown in the Figures below, the control of the cooling system (air condition units) has to used regularly during Summer, Autumn and Spring, however, the heating control system is never used.

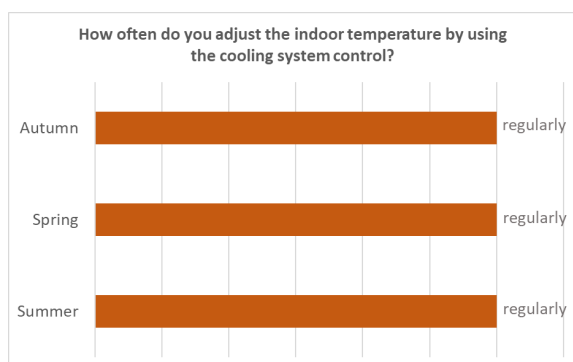


Figure 41 – Adjustment of indoor temperature by using the cooling system control in the Greek apartment.

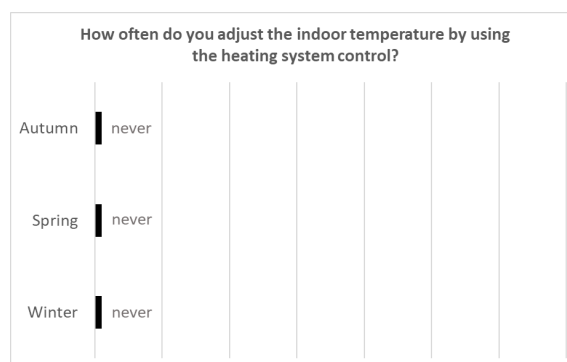


Figure 42 – Adjustment of indoor temperature by using the heating system control in the Greek apartment.

The IAQ of the apartment is characterised by one of the residents as rather acceptable and more specifically as: draughty, neither humid nor dry, odourless and somehow fresh.



Figure 43 – Characterization of IAQ by an resident of the Greek apartment.

However, there is a regular adjustment of the air related issues throughout the year by opening/closing windows, which is a common habit for most of the people all over Greece due to the mild weather conditions.

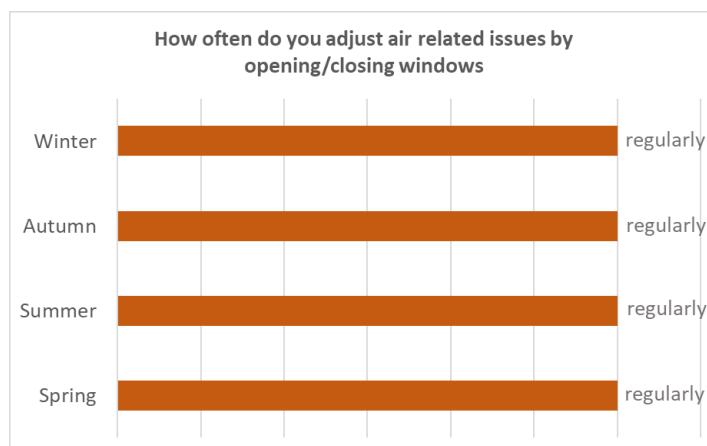


Figure 44 – Adjustment of air related issues by opening/closing windows in the Greek apartment.

More specifically, the bathroom window is constantly open, while the windows in the main rooms (living room and sleeping rooms) stay open for 30h/week. There is no ventilation system in the apartment.

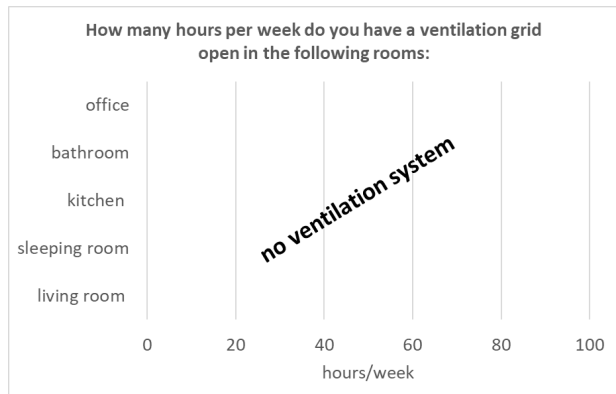


Figure 45 – Operation of the ventilation grid in the Greek apartment.

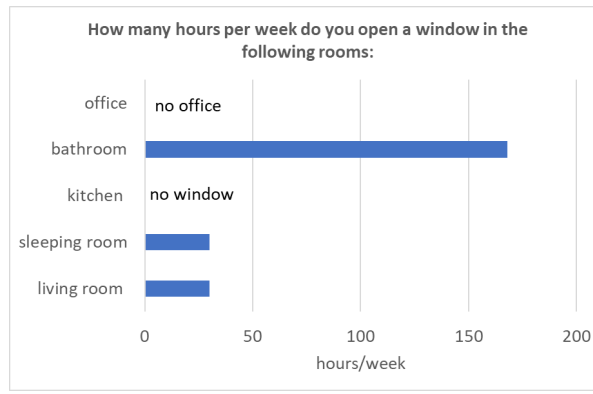


Figure 46 – Open windows in specific rooms in the Greek apartment.

From twelve (12) noise sources that were mentioned in the questionnaire, seven (7) annoying the resident: noise from indoor air/HVAC system, neighbours, outdoor ventilation systems, noise from community buildings, from outdoor leisure, outdoor construction activities and road traffic. The amount of annoyance per case is shown in the Figure below and it is significant for most of the cases.

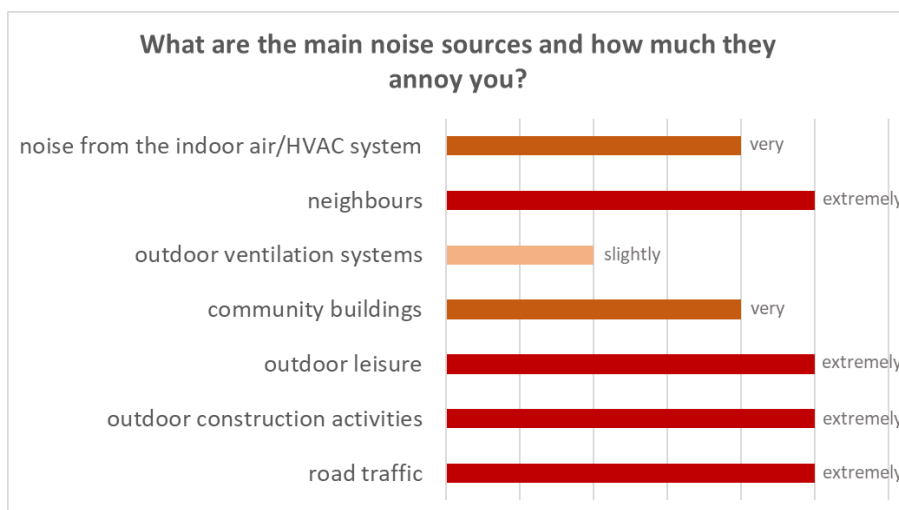


Figure 47 – Main noise sources as reported by an resident of the Greek apartment.

The resident has to adjust lighting manually and by regularly switching on/off desk/task lights as well as the overhead lights.

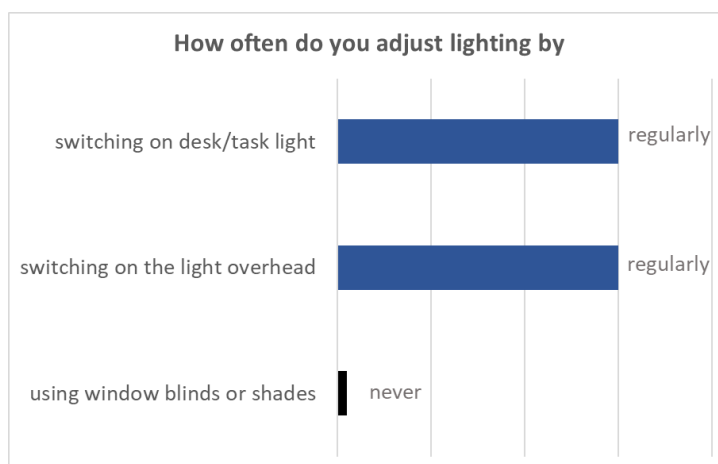


Figure 48 – Lighting adjustment in the Greek apartment.

The resident is neither satisfied nor unsatisfied with the typical indoor conditions regarding the artificial light, and unsatisfied with the indoor conditions regarding the natural light of the Greek apartment.

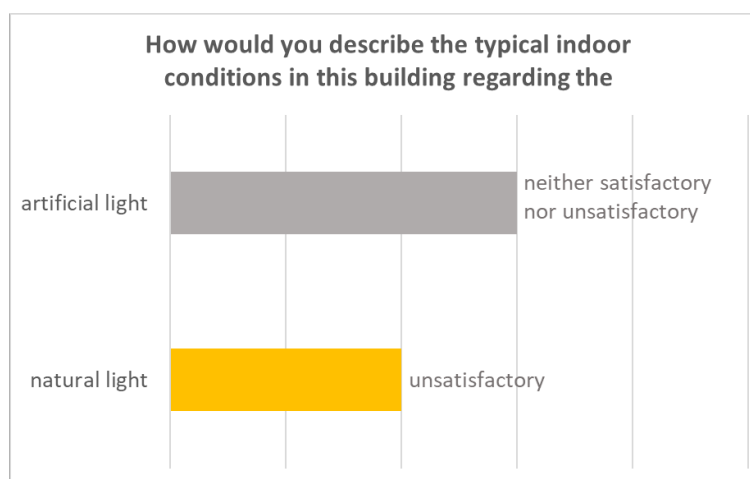


Figure 49 – Indoor conditions regarding the artificial and natural light in the Greek apartment.

In addition, the resident characterises the sun exposure of the building as average and reports overheating issues through windows.

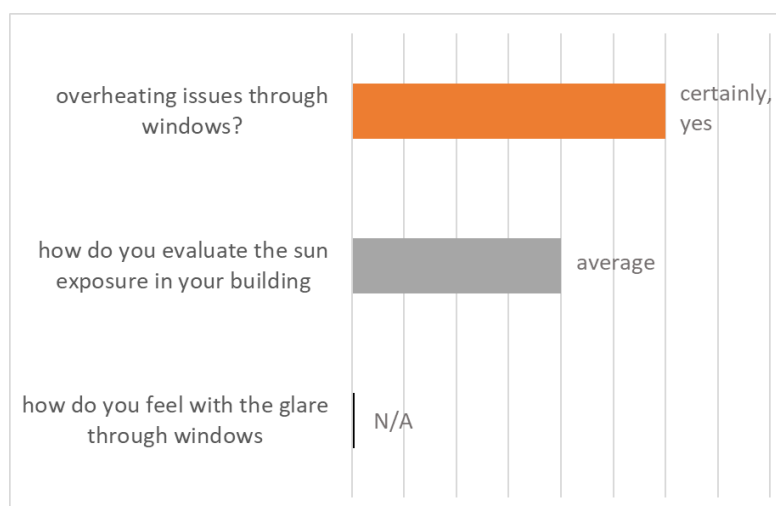


Figure 50 – Sun exposure, overheating and glare through windows in the Greek apartment.

The owner (also resident) of the Greek apartment considers as the most important needs of his house the heating and cooling, as well as the noise from various sources. He didn't reply to the theoretical questions of how much money he would be willing to pay for a renovation in order to improve the aforementioned needs nor to the question how much he would increase the rent after the renovations.

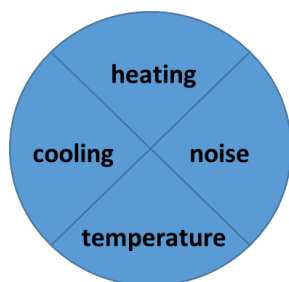


Figure 51 – The most important needs that the resident (also owner) would like to improve in the house.

The owner (that is also resident) didn't reply how much would be willing to pay in order to improve all the aforementioned needs by at least 35%.

Figure 52 – The amount of money that the resident (also owner) is willing to pay.

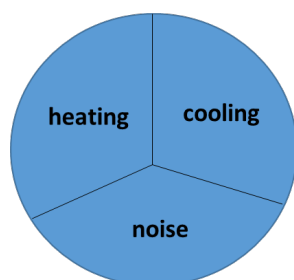


Figure 53 – The 3 most important needs that the resident (also owner) would like to improve in the house

The owner (that is also resident) didn't reply how much would be willing to pay in order to improve the 3 most important needs by at least 50%.

Figure 54 – The amount of money that the resident (also owner) is willing to pay.

The owner (that is also resident) didn't reply how much he would increase the rent after the renovation.

Figure 55 – The rent increase that the resident (also owner) would ask for after the renovation.

4.2.1.1.3 UK

The temperature inside the house, as it was described by the two residents, can be characterised as rather problematic. As it can be seen from the Figure below, the residents feel cold in the Winter, hot in the Summer and somehow cold in the Autumn. The house has central heating system and no cooling system.

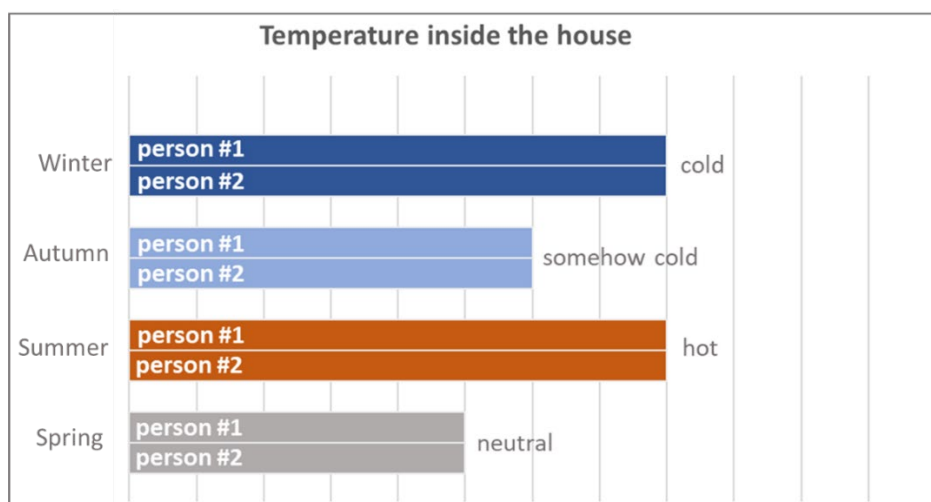


Figure 56 – Temperature inside the UK house as characterised by the residents.

As it is shown in the Figure below, the control of the heating system is used occasionally during Spring by both residents, and occasionally/regularly in the Autumn.

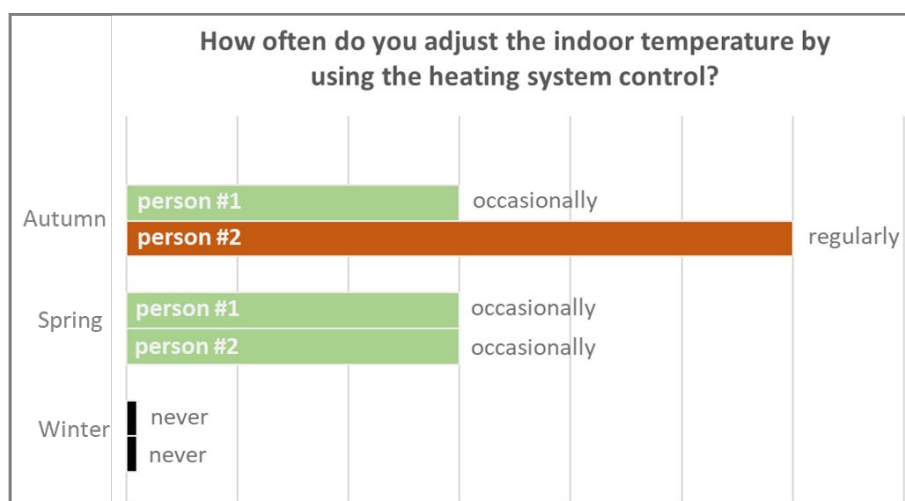


Figure 57 – Adjustment of indoor temperature by using the heating system control in the UK house.

The two residents gave different characterisation regarding the IAQ in the UK house which is presented in the Figure below.

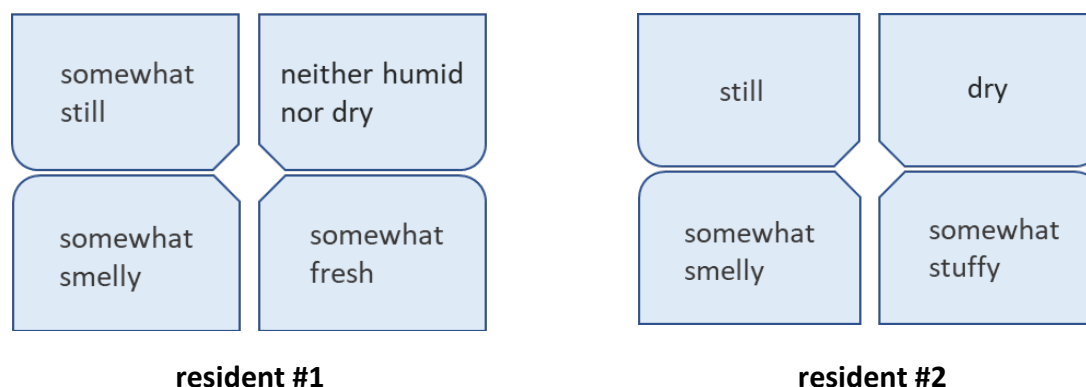


Figure 58 – Characterization of IAQ by the residents of the UK house.

Moreover, there are different habits between the two residents as far as the adjustment of air related issues by opening/closing windows. As it can be seen from the Figure below, person#1 uses windows occasionally for during the three seasons, whereas person#2 uses the windows regularly throughout the whole year in order to adjust air related issues.

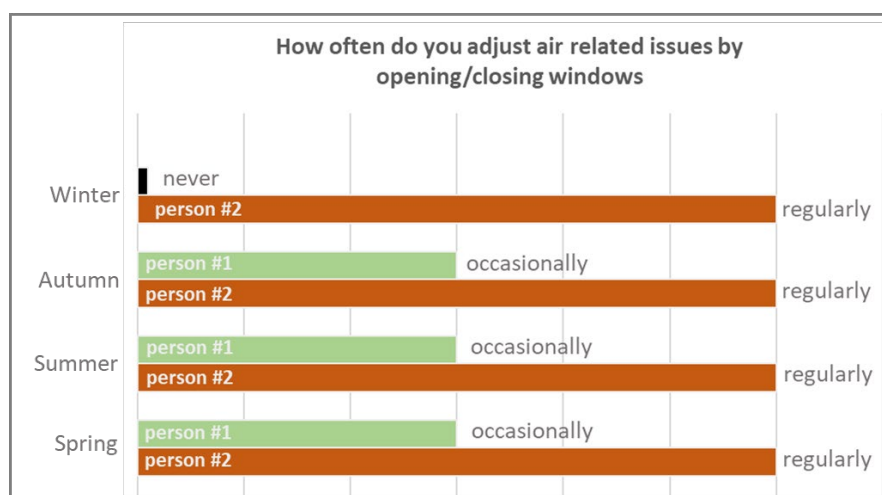


Figure 59 – Adjustment of air related issues by opening/closing windows in the UK apartment.

More specifically, the average hours that the two residents open the windows in various rooms is presented in the following Figure. Moreover, there is no ventilation system in the house.

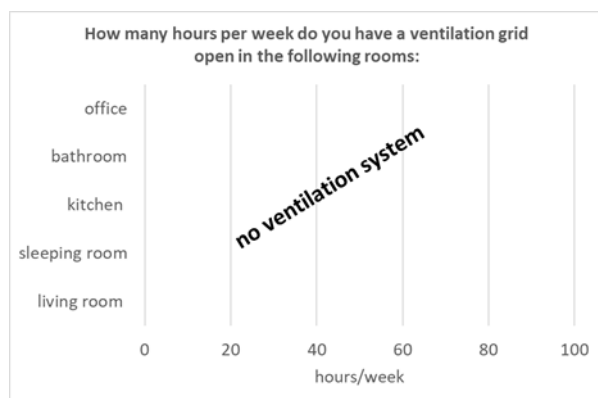


Figure 60 – Operation of the ventilation grid in the UK house.

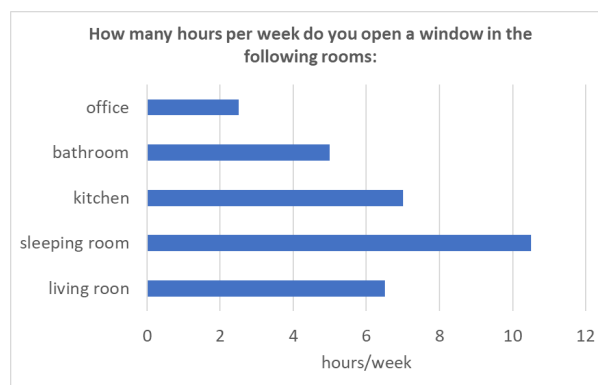


Figure 61 – Open windows in specific rooms in the UK house.

The residents of the UK house don't seem to face significant noise issues. More specifically, from the twelve (12) noise sources that were mentioned in the questionnaire, only two (2) annoy the residents in a moderate or slight degree: noise from neighbours and from outdoor construction activities.

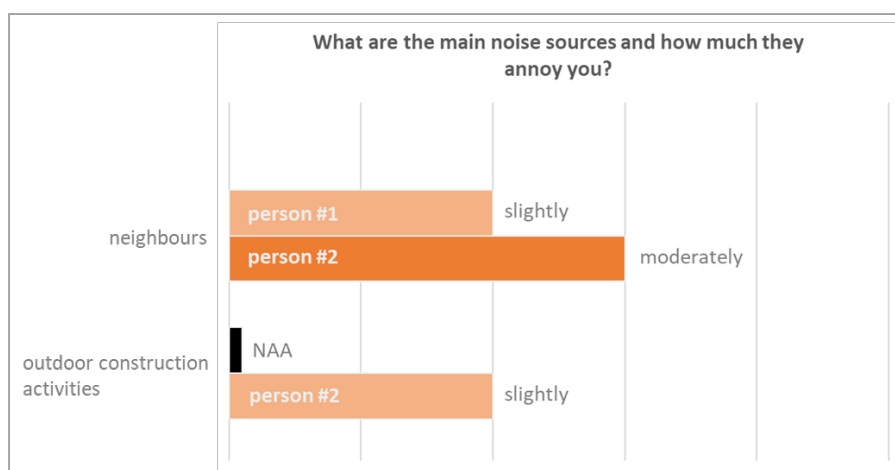


Figure 62 – Main noise sources as reported by the residents of the UK house.

The residents adjust lighting manually and by regularly switching on/off desk/task lights. One person switches on/off the light overhead occasionally.

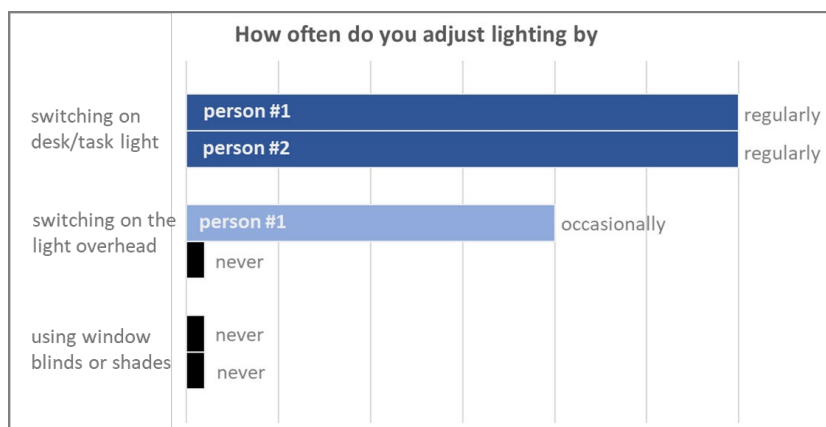


Figure 63 – Lighting adjustment in the UK house.

Regarding the typical indoor conditions in the UK house, the residents are satisfied with the natural light, whereas they appear to have different feelings concerning the artificial light (satisfied and unsatisfied).

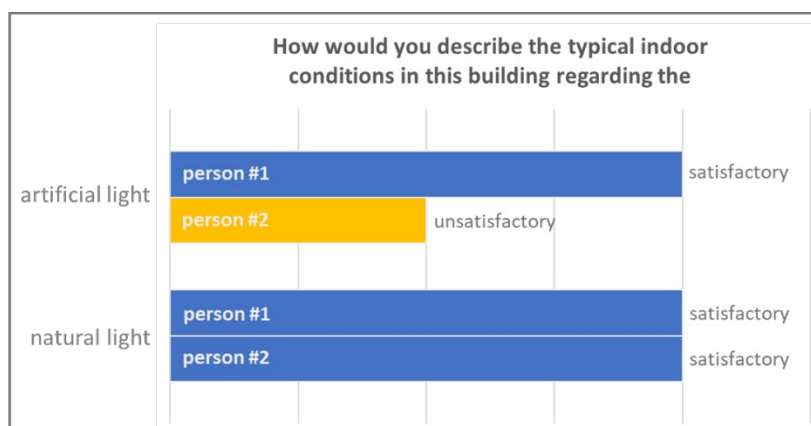


Figure 64 – Indoor conditions regarding the artificial and natural light in the UK house.

In addition, the residents characterise the sun exposure of the building as good, and they feel comfortable with the glare through the windows. Regarding any overheating issues though windows, the answers are maybe and certainly, yes.



Figure 65 – Sun exposure, overheating and glare through windows in the UK house.

Finally, the residents of the house were asked about the needs of the house as well as about the three most important of those. The first resident (also owner of the house) mentioned a number of needed improvement related to lighting, cooling, ventilation, heating, noise, temperature and indoor air quality, from which the three most important are noise, heating temperature control and indoor air. He would be willing to pay 10keuro in order to improve the aforementioned needs of the house by 35% and 25keuro to improve by 50% the three most important of the needs. Finally, the owner would ask for a 25% rent increase after the renovation. The second resident considers exactly the same three most important needs as the owner, while she will be willing to accept a 25% rent increase if those needs were improved by at least 50%.

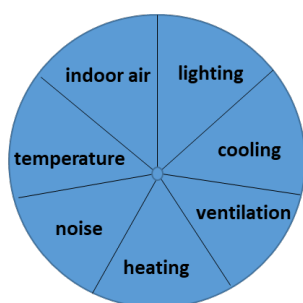


Figure 66 – The most important needs that the resident #1 (also owner) would like to improve in the house

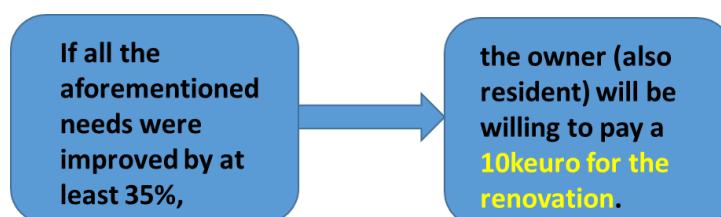


Figure 67 – The amount of money that the resident #1 (also owner) will be willing to pay for the renovation.

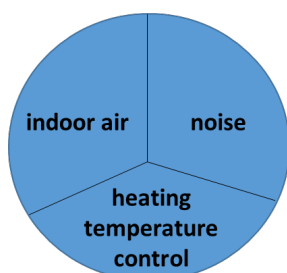


Figure 68 – The 3 most important needs that the resident #1 (also owner) would like to improve in the house

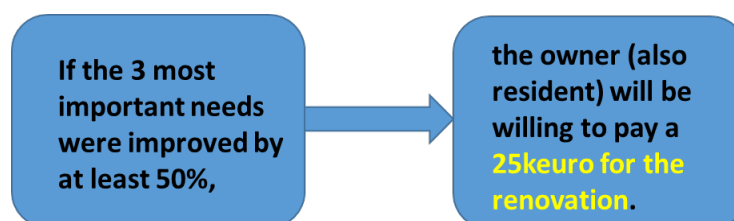


Figure 69 – The amount of money that the resident #1 (also owner) will be willing to pay for the renovation.

The owner (that is also resident) would increase the rent by 25% after the renovation.

Figure 70– The owner would ask for a 25% rent increase after the renovation.

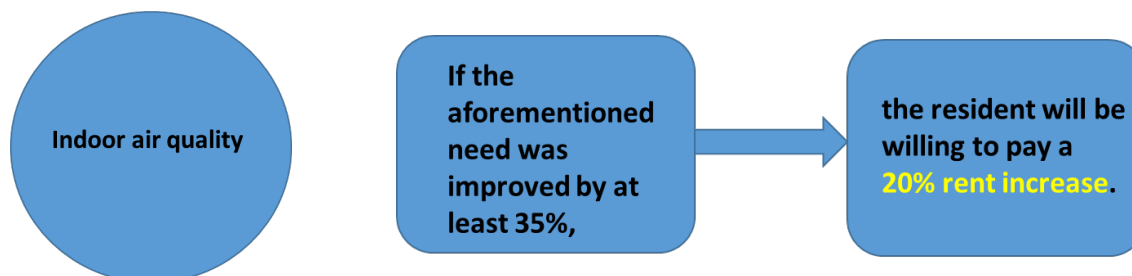


Figure 71 – The most important need that the resident #2 would like to improve in the house

Figure 72 – The rent increase that the resident #2 is willing to pay.

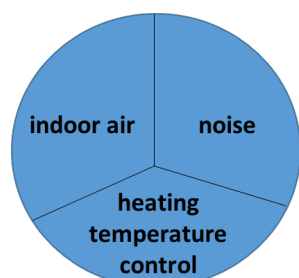


Figure 73 – The 3 most important needs that the resident #2 would like to improve in the house

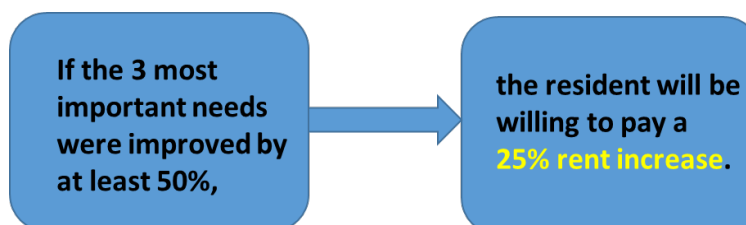


Figure 74 – The rent increase that the resident #2 is willing to pay.

4.2.1.1.4 Spain

The temperature inside the house, as it was described by a resident in one of the houses that will be renovated, can be characterised as acceptable, except during the Summer period when it is characterised as too hot. The house has central heating system but no cooling system.

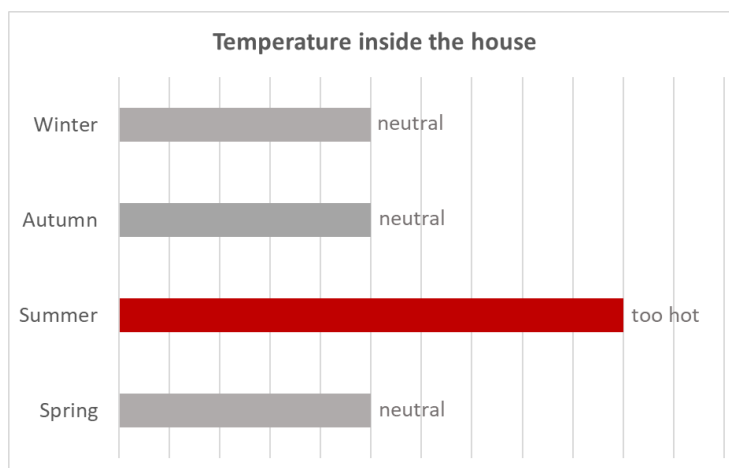


Figure 75 – Temperature inside the Spanish house as characterised by a resident.

There are occasional adjustments of the temperature during Autumn and Spring, and regular adjustments during Winter.

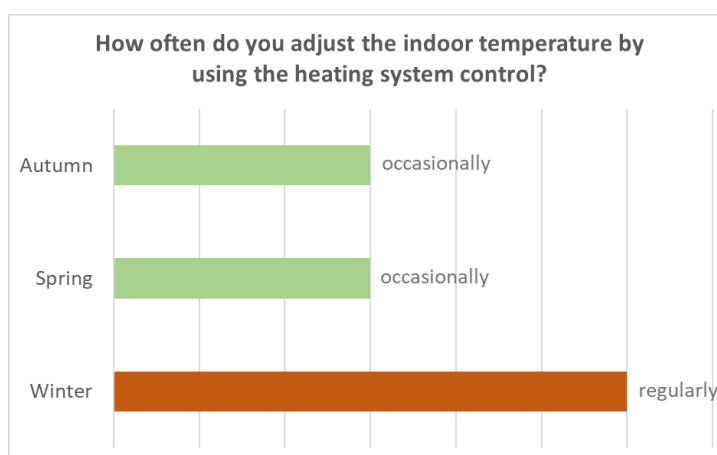


Figure 76 – Adjustment of indoor temperature by using the heating system control in a Spanish house.

The resident characterised the IAQ in the house as somewhat draughty, somewhat humid, odourless and somewhat fresh.

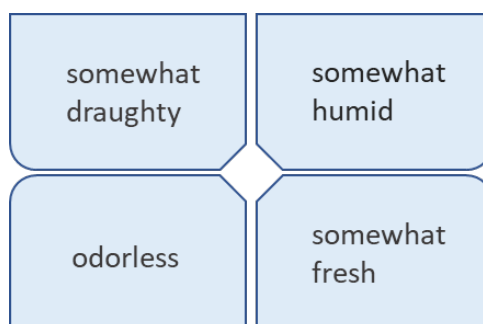


Figure 77 – Characterization of IAQ by a resident of the Spanish house.

The air related issues are being adjusted by the resident by opening/closing windows in a regular basis during the Summer period and occasionally during the rest seasons.

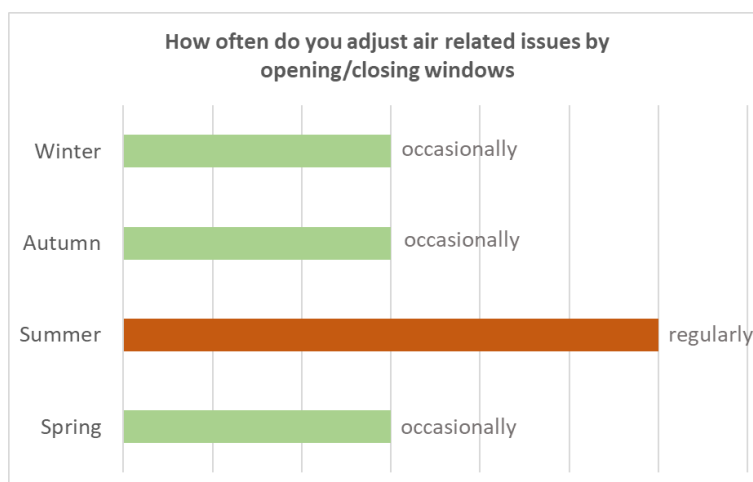


Figure 78 – Adjustment of air related issues by opening/closing windows in a Spanish house.

The hours per week that the windows are open in each of the rooms are presented in the following Figure. Finally, there is no ventilation system in the house.

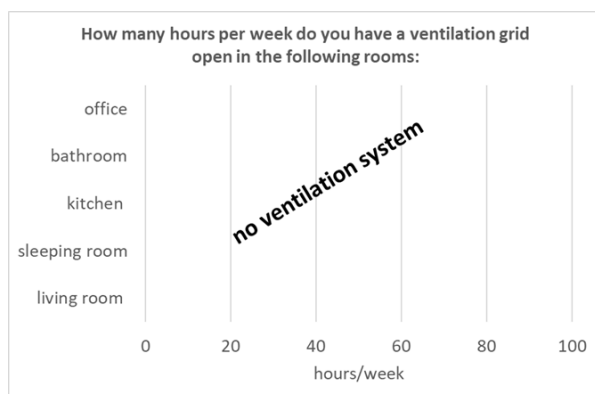


Figure 79 – Operation of the venilation grid in a Spanish house.

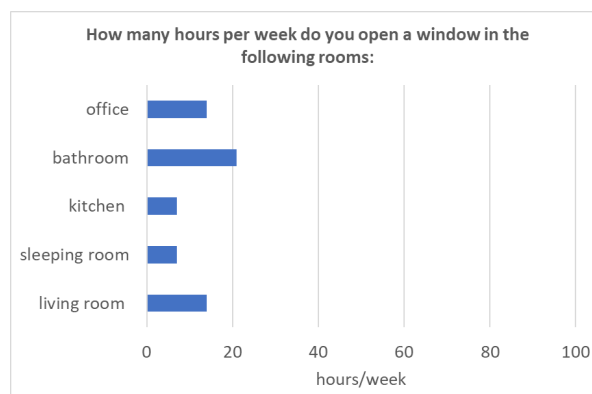


Figure 80 – Open windows in specific rooms in a Spanish house.

Concerning the various noise sources, the resident mentioned slight annoyance from indoor air/HVAC system and from road traffic, as well as moderate annoyance from the neighbours and outdoor construction activities.

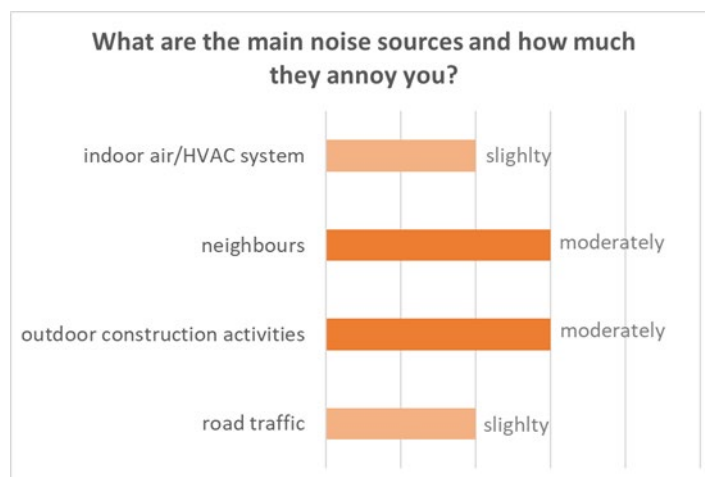


Figure 81 – Main noise sources as reported by a resident of a Spanish house.

The resident adjusts lighting manually by regularly switching on/off desk/task lights and occasionally switching on/off the light overhead. Also, the resident uses regularly the blinds/shades in order to adjust light indoors.

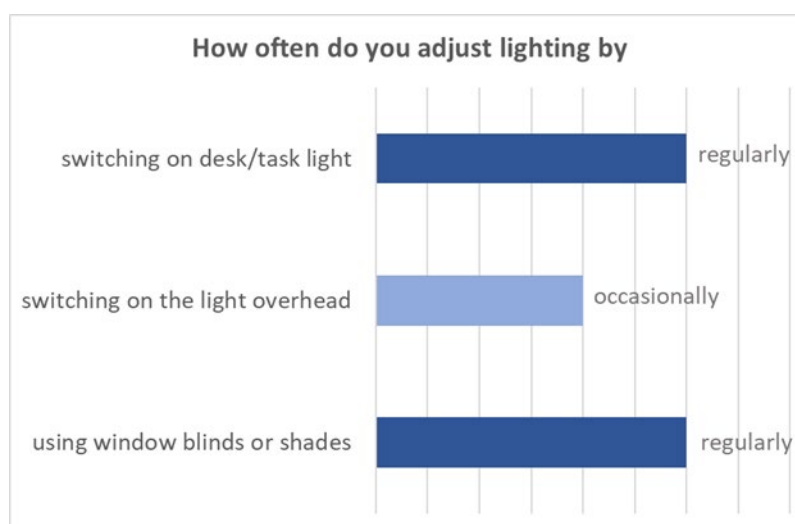


Figure 82 – Lighting adjustment in a Spanish house.

Regarding the typical indoor conditions in the house, the resident is satisfied with the natural and the artificial light.

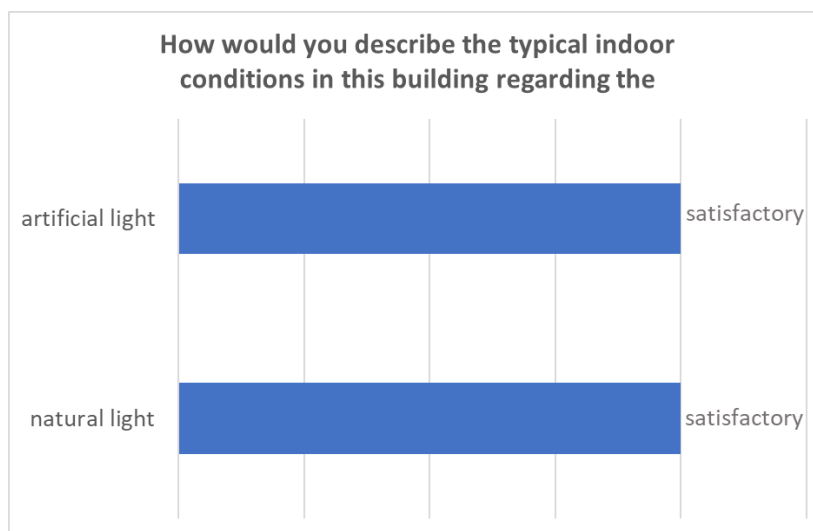


Figure 83 – Indoor conditions regarding the artificial and natural light in a Spanish house.

In addition, the resident characterise the sun exposure of the building as good, and they feel comfortable with the glare through the windows. Moreover, there is no overheating issues through windows.

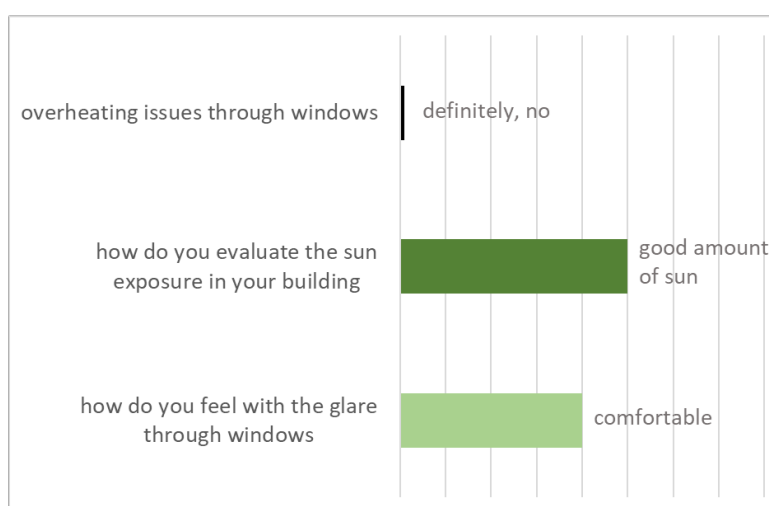


Figure 84 – Sun exposure, overheating and glare through windows in a Spanish house.

Finally, the resident (also owner) of one of the houses in Spain that are going to be renovated mentioned the most important needs of the house (Figures below) but didn't want to reply to the theoretically question about how much money will be willing to pay to improve those needs.

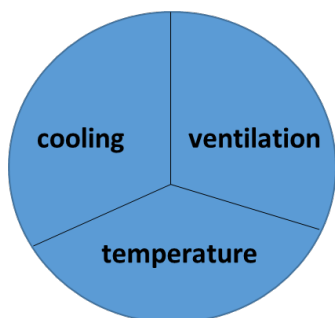


Figure 85 – The most important needs that the resident (also, owner) would like to improve in the house

The owner (that is also resident) didn't reply how much would be willing to pay in order to improve all the aforementioned needs by at least 35%.

Figure 86 – The amount of money that the resident (also, owner) will be willing to pay for the renovation.

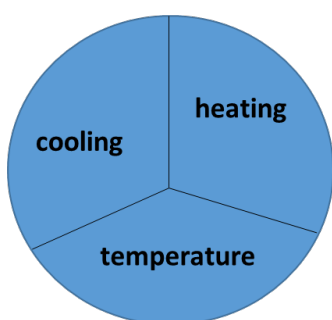


Figure 87 – The 3 most important needs that the resident (also, owner) would like to improve in the house

The owner (that is also resident) didn't reply how much would be willing to pay in order to improve the 3 most important needs by at least 50%.

Figure 88 – The amount of money that the resident (also, owner) will be willing to pay for the renovation.

The owner (that is also resident) didn't reply how much he would increase the rent after the renovation.

Figure 89 – The rent increase that the resident (also owner) would ask for after the renovation.

4.2.1.1.5 Finland

In the Finish apartments there have been three residents who replied to the questionnaire, therefore there are different opinions and feelings about all the different aspects that were set as questions to the residents. In some cases we can export a common trend of the opinions while in other cases this was not feasible.

Regarding the indoor temperature of the apartments, it is characterised as cold and too cold during the Winter, hot and too hot during the Summer, neutral to cold in Autumn and neutral to cold during the Spring season. The following Figure presents the relevant answers of the residents.

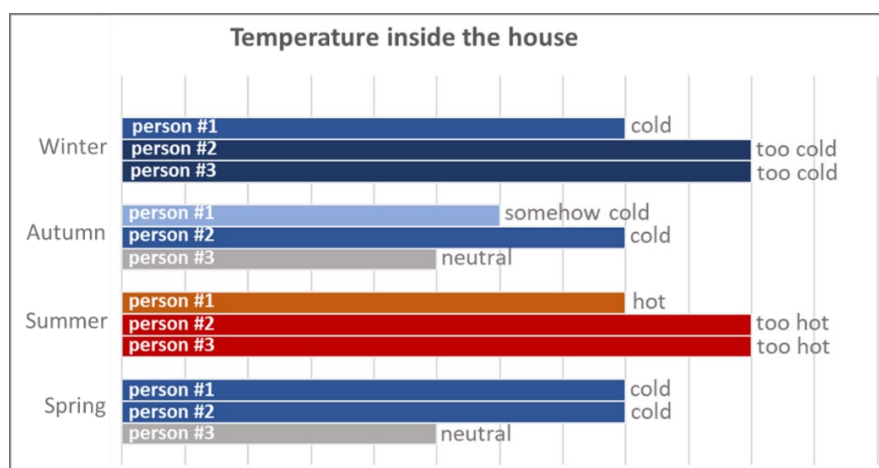


Figure 90 – Temperature inside the Finish apartments as characterised by the residents.

In general, there is no adjustments of the indoor temperature by using the heating system control, except for one resident who mentioned occasional adjustments in Autumn and Winter.

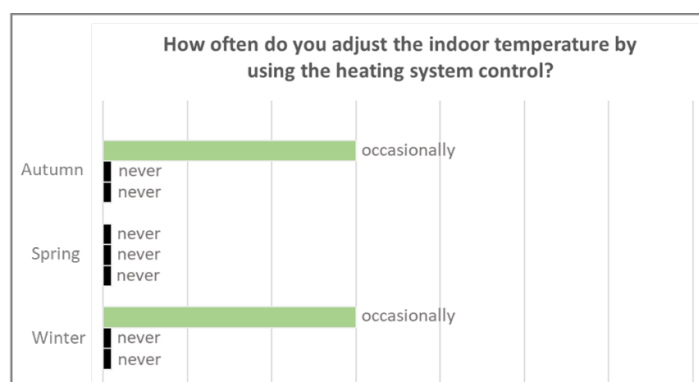


Figure 91 – Adjustment of indoor temperature by using the heating system control in the Finish apartments.

The comments of the three residents regarding the IAQ are presented in the following Figure. Some trends can be exported from the answers: the air is dry/somewhat dry, smelly/somewhat smelly and stuffy for two of the three residents.

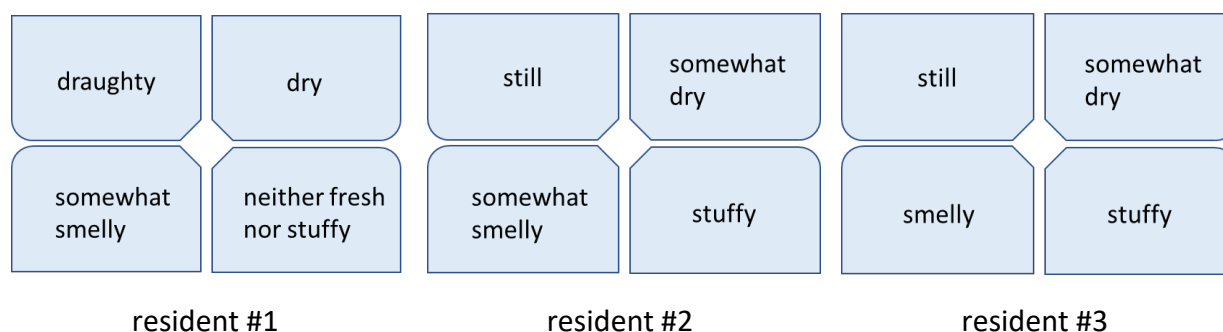


Figure 92 – Characterization of IAQ by the residents of the Finish apartments.

Based on the answers of the three residents, there is regular opening/closing windows in order to adjust air related issues in all for seasons. The details are shown in the following Figure.

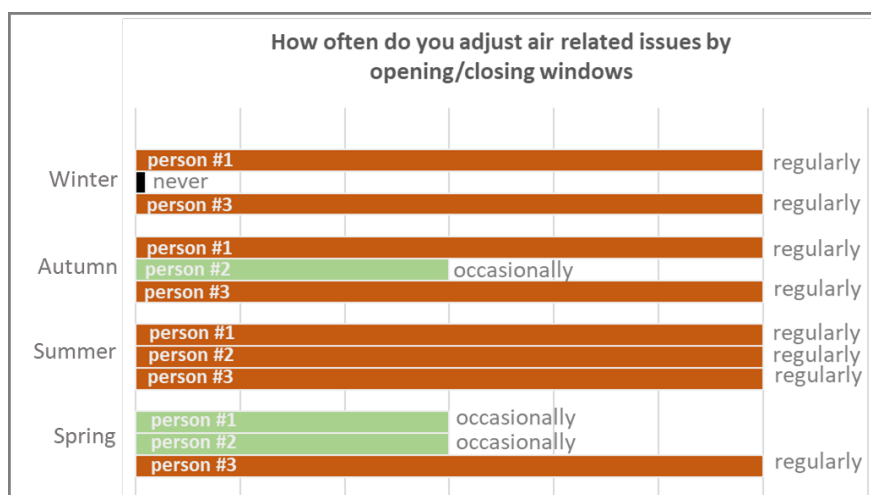
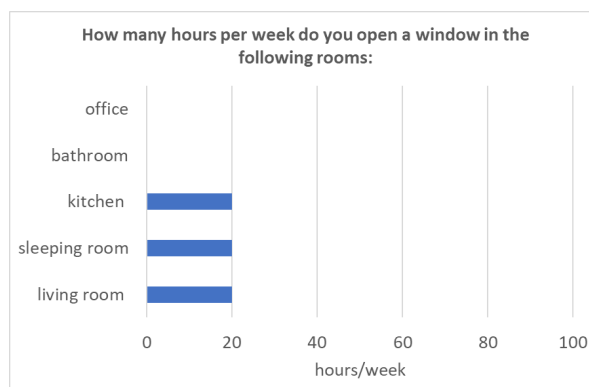
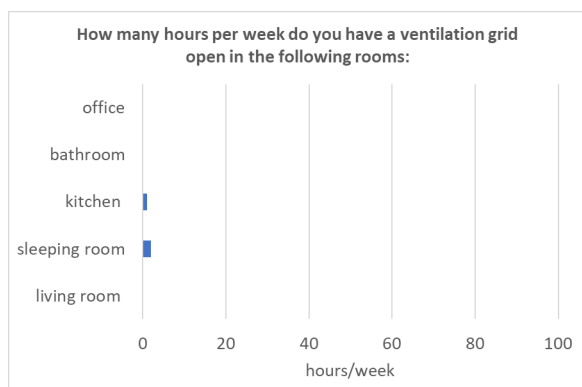
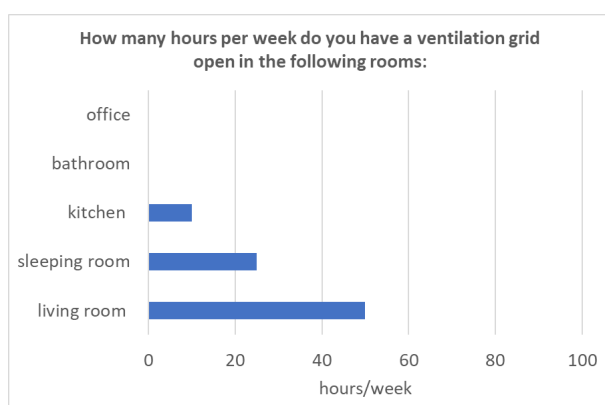


Figure 93 – Adjustment of air related issues by opening/closing windows in the Finish apartments.

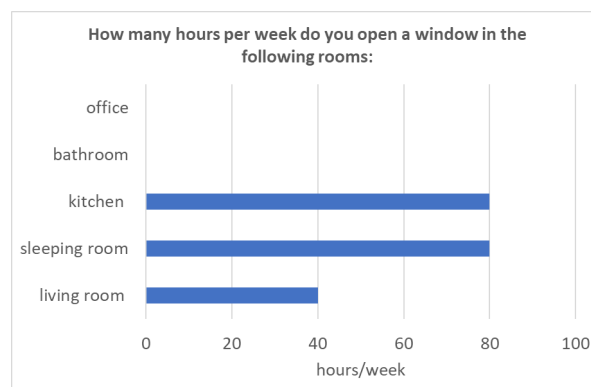
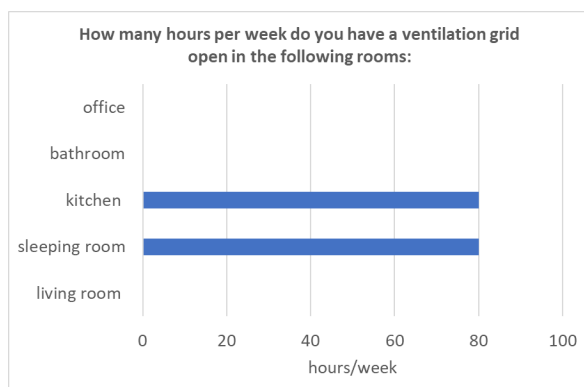
The hours per week that the windows stay open in each apartment are shown in the following Figures. There are also ventilation grids and the operation hours are also shown in the Figures below.



resident #1



resident #2



resident #3

Figure 94 – Operation of the ventilation grid in the Finish apartments.

Figure 95 – Open windows in specific rooms in the Finish apartments.

There are many noise sources that have been reported by the three residents of the Finish apartments. The noise sources as well as the degree of annoyance for each one of the residents is presented in the Figure below.

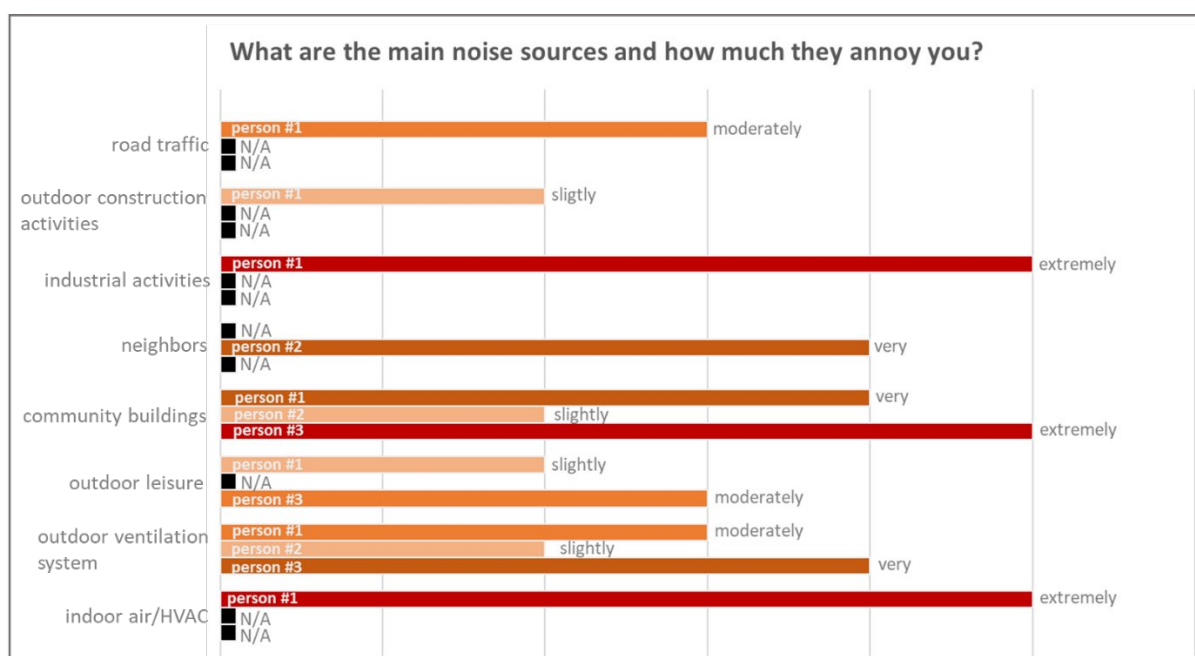


Figure 96 – Main noise sources as reported by the residents of the Finish apartments.

The residents adjust lighting manually and by occasionally/regularly switching on/off desk/task lights and the lights overhead. There is one resident who also mentioned the use of blinds/shades for adjusting light issues.

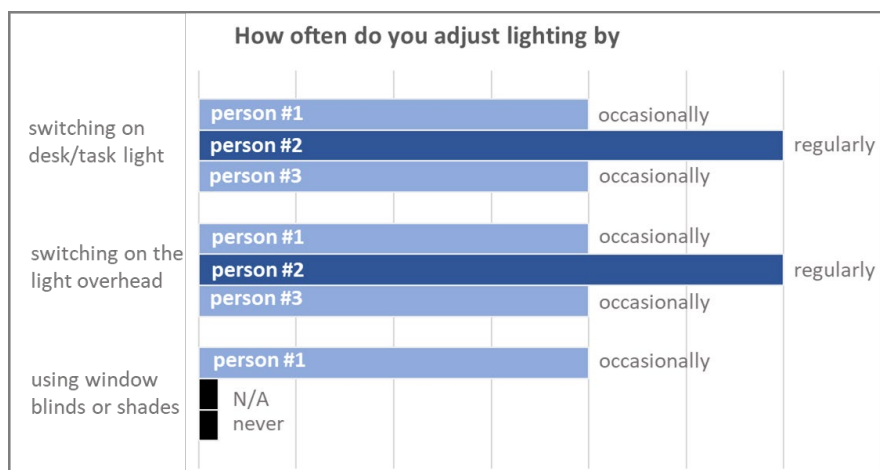


Figure 97 – Lighting adjustment in the Finish apartments.

In general, the residents are satisfied by the natural and the artificial light conditions in the Finish apartments, with the exception of one resident who is very unsatisfied from the artificial light in the apartment.

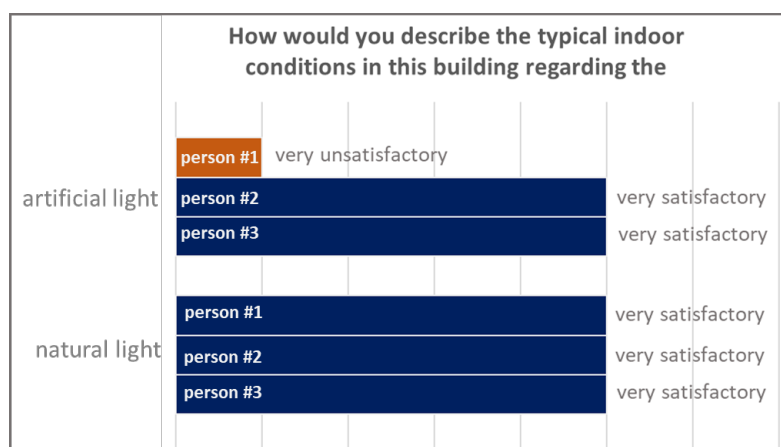


Figure 98 – Indoor conditions regarding the artificial and natural light in the Finish apartments.

All three residents reported certain overheating issues through the windows, the sun exposure is good and only in one case is characterized as average, while regarding the glare through windows there are three different answers: from very uncomfortable to very comfortable situation.

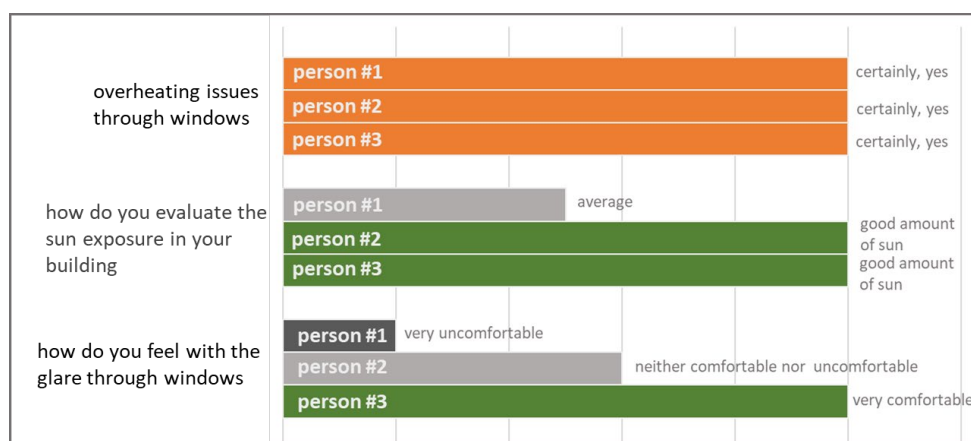


Figure 99 – Sun exposure, overheating and glare through windows in the Finish apartments.

Finally, the three residents mentioned the important needs of their apartments that need to be improved. The answers are presented in the following Figures. The residents mentioned issues related to heating/cooling, air-tightness, noise and air quality (ventilation and odours). All three residents were positive to a rent increase (5-15%) if their needs were improved by certain amounts.

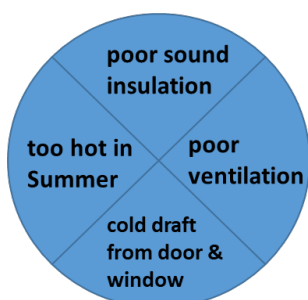


Figure 100 – The most important needs that the resident #1 would like to improve in the house

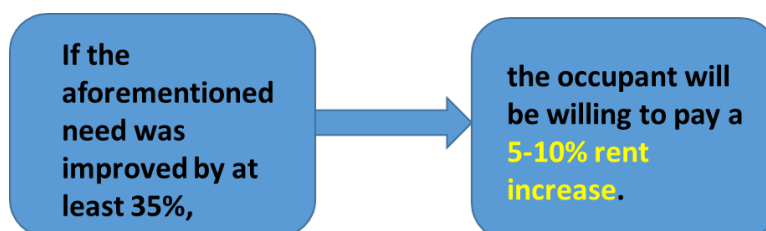


Figure 101 – The rent increase that the resident #1 is willing to pay.

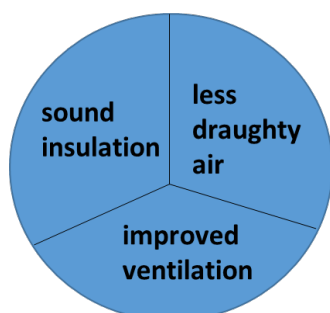


Figure 102 – The 3 most important needs that the resident #1 would like to improve in the house

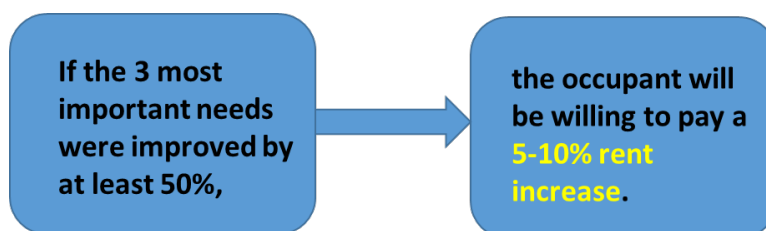


Figure 103 – The rent increase that the resident #1 is willing to pay.

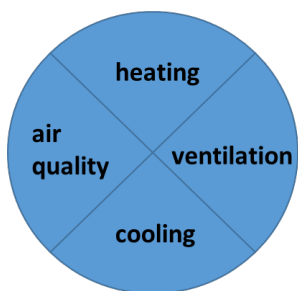


Figure 104 – The most important needs that the resident #2 would like to improve in the house

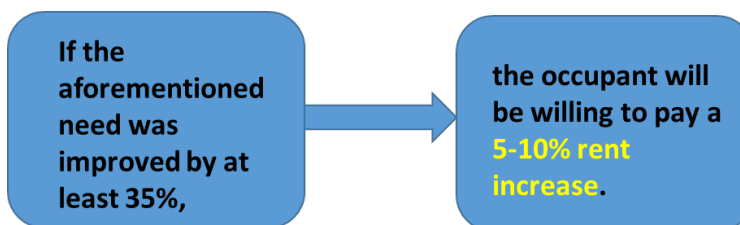


Figure 105 – The rent increase that the resident #2 is willing to pay.

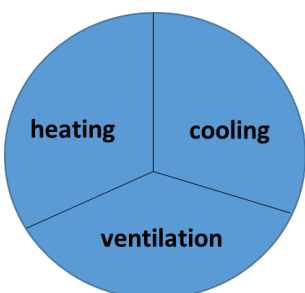


Figure 106 – The 3 most important needs that the resident #2 would like to improve in the house

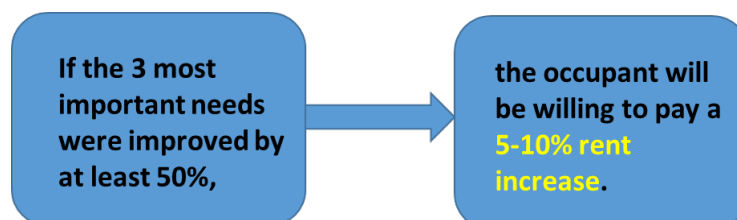


Figure 107 – The rent increase that the resident #2 is willing to pay.

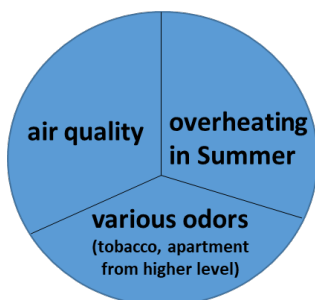


Figure 108 – The 3 most important needs that the resident #3 would like to improve in the house

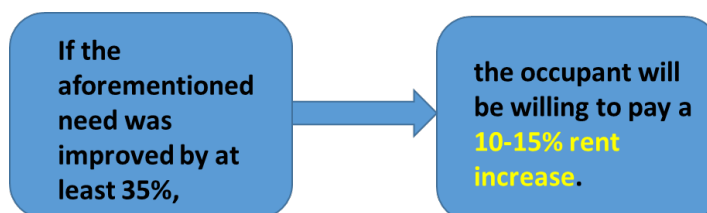


Figure 109 – The rent increase that the resident #3 is willing to pay.



Figure 110 – The 3 most important needs that the resident #3 would like to improve in the house

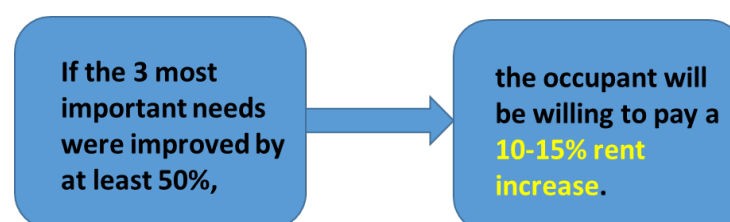


Figure 111 – The rent increase that the resident #3 is willing to pay.

4.2.1.2 Post-occupancy survey

The post-occupancy surveys will be shared to the residents of the houses after the renovations and towards the end of the project. The content of the questionnaires will be similar to that of the pre occupancy surveys and will aim to investigate whether the residents are satisfied with the renovation, whether their needs were respected, to report any disturbances during the renovations works, as well as their satisfaction with the opportunity to participate in the decision making process of the renovation. In addition, during and after the renovation will be examined and reported the retrofitting time, the off-site development (pre-fabricated panels), and the development of skills for the workers. The results will be reported in the framework of WP8.

4.2.2 Pre-occupancy on-site inspections and interviews

During the first year of the Surefit project implementation, the partners responsible for the renovation in each demo site performed the appropriate actions in order to assess together with the residents the condition of the houses and the most important issues. Besides the pre occupancy surveys, onsite inspections took place and also, interviews with the residents. The outcome of these actions are presented in the following paragraphs.

4.2.2.1 Portugal

The partners from ISQ performed an on-site visit to the building and interviewed the resident. During the interview, the resident reported significant difficulties in achieving thermal comfort conditions inside the house. Since the house is naturally ventilated, the resident frequently operates the windows in order to guarantee indoor air quality. However, the resident also identified improvements in air quality, humidity and noise as being the most important issues to be dealt in a renovation intervention. The building, which is now used in a social housing context, was constructed in **1970** and has two floors with a gross area of 115 m² and a living area of 77 m². It is located in Carvoeira (Mafra Municipality). The façade is constituted by structurally resistant stone masonry with two layers of plaster. Internal walls are composed of single ceramic brick masonry and the first-floor pavement is made of wood structure and wood flooring. The windows **are single glazed** with a wood frame. In recent years, the building has been the target of punctual interventions that seek to safeguard minimum living condition, such as the replacement of the roof in 2016. Despite this effort, due to existing cracks in walls and **poor insulation**, the house has a number of **water infiltrations and damp or high humidity**. The house is heated with a 1200 W electric radiator in winter and there is no cooling system installed in the building.



Figure 112 – The house in Portugal.

4.2.2.1 Greece

The partners from AMS visited the building and had a discussion with one of the residents of the 1st floor, where most of the interventions will take place. The building was built in **1981** and located in the city of Peristeri, Attica. The orientation of the two main facades is north-south. The building is attached with two other buildings on the east and west sides. The building accommodates two small spaces on the ground floor of 45m² and 25m² that used to be shops, one family apartment (4 persons) of approximately 100m² on the first floor and another apartment (2 persons) of approximately 100m² on the second floor. Each apartment has a living room, three bedrooms, kitchen and bathroom. The building is constructed with concrete pillars and the walls are made of bricks of six hollows and dimensions of 19x9x6cm, using an installation of single brick - polystyrene layer - single brick that offers thermal insulation.



Figure 113 – The apartment in Greece.

However, after 40 years, the polystyrene layer has definitely suffered damage and is not considered to contribute to the thermal insulation of the building. The roof has 8cm coating of cement mortar for waterproofing that also offers a kind of thermal insulation. The building has single glazed aluminium frame windows. These sliding sash windows are of 8mm single glass. Apart from the sliding sash external blinds, each of the two floors has also awnings attached to exterior wall of the building. These awnings are always in use in order to for the tenants to keep their privacy from the surrounding buildings. Heating is supplied through diesel boiler and there is a cooling system provided by air conditions: one in the one space on the ground floor, three in the first floor (8btu, 8btu and 24btu) and the same in the apartment of the second floor. Hot water is supplied by low pressure water system from a triple-energy boiler that is flexible to work also with a solar collector and electricity.

Prior to renovation, air leakage test was performed to the apartment of the 1st floor that will be the main space of the building to receive the interventions. The evaluation was conducted by implementing the Blower Door test according to the method A of the ISO 9972-2015. The test revealed high percentage of losses from the apartment's shell that results in its inefficient heating or cooling.

4.2.2.2 UK

The partners from UNNOT have a clear view of this building's condition and deficiencies. It is a semi-detached house, located at Nottingham, UK, with the outlook shown in the following Figures. The house has a total 92m² which is constructed in 1948, with 2 bedrooms, 1 bathrooms, 1 toilet, 1 living room, 1 dining room and 1 kitchen. According to the UK government EPC evaluation, this house is assessed as **band D** (score:56) and the current primary energy consumption use for only lighting, heating and hot water is estimated as 306kWh/m² per year, with bill estimated for £1034 per year. Moreover, based on this assessment, the house currently produces approximately **5.5 tonnes of carbon emission every year**.



Figure 114 – The house in the UK.

The floor plan layout is illustrated in the Figure below. The house is built with **solid brick external wall without any insulation**, with **no insulated pitched roof** and 100mm insulated loft. **The ground floor is all solid with no insulation. All the windows are fully renovated with double glazing in 2012.** The building façade U-value performance is measured from December 2020 to January 2021. Due to the degradation of the building façade over more than 70 years, the U-value of the south/north external wall is 2.1 W/m²K, with west external wall of 2.0 W/m²K. Besides, the U-value of the double-glazing window is 2.4 W/m²K. The U-value of the attic floor and roof are 0.89 W/m²K and 0.22 W/m²K. Moreover, it is found the airtightness is poor with

main building and attic space separately conducted by implementing the Pulse airtightness test according to the method A of the BS EN 9972-2015, which has air change rate of 0.67ACH and 16.7ACH respectively.



Figure 115 – UK building plan layout.

The house uses boilers and radiators as the main heating system to provide both space heating and hot water, which is powered by natural gas. The room radiators can be controlled with room thermostat and TRVs. **And low energy lighting is fixed in each room.** The NG8 district is mainly owned by local people of Nottingham with three quarters of houses are owned by the owners, and only one quarter of houses are privately or socially rented houses.

4.2.2.3 Spain

These mill houses are located in San Pedro Regalado neighbourhood in Valladolid (Spain). The houses were constructed **in the 50s** of last century and are based on the use of walls and load-bearing partitions, on which rest some vaults made of **simple hollow bricks**. Each house consist of a ground floor, first floor, basement and patio at the back of the plot. The plots have approximately from 60m². The current state differs slightly between each of the houses, although **all of them share the need for reform to adapt their old structures to the requirements of current comfort, isolation, energy efficiency and improvement in CO₂ emissions**. 3 single homes are considered for renovation 96, 97 and 97m² of living area (accounting for a total 290m² renovation), with a northeast-southwest orientation. Windows vary from **single glazed (4mm thick) with aluminium frame to double glazed (4+6+4 thick) with P.V.C frame**, depending on each house. **There is no thermal insulation**. Heating is supplied mainly through **gas boiler with panel emitters/radiators, and individual electric radiators**, depending on the house. **There is no cooling system**. Hot water is supplied by low pressure water system from the same diesel boiler or from an electric water heater. The U-value is 2W/m²K for walls and 5.8W/m²K for windows, approximately. **Energy usage: G** (Energy Certification of Existing Buildings).



Figure 116 – The houses in Spain.

4.2.2.4 Finland

The partners from AALTO have a clear view of the building's conditions and deficiencies. It is a **prefabricated** apartment building located in the city of Helsinki. It is the largest of a community of 9 similar buildings. It was built in **1969** using concrete elements with **standard insulation** but has later been **modernized with high efficiency windows** and **improved thermal insulation in some external walls**. The gross floor area is 5260 m². All apartments are the same, with two bedrooms, a living room with a balcony, a kitchen and a bathroom. The basement contains garages, storage rooms, a common sauna area and laundry rooms. The building is oriented towards south.

The building is heated with a **municipal district heating system**. The primary energy consumption of the building is 100-120 kWh/m², giving it an energy efficiency **class C** (on a scale from A to G). The district heating system can be partly or completely replaced using exhaust air or ground-source heat pumps, as is the current trend in Finland. **The house has mechanical exhaust ventilation with no heat recovery**. This could be complemented with heat pumps or replaced with a balanced mechanical exhaust ventilation system for better thermal comfort.

The residents complain about the apartments overheating in summer, due to solar exposure. Windows blinds could help reduce the excessive solar gains. At the same time, the balcony wall is very leaky and poorly insulated, resulting in a cold feeling in winter. Blower door experiments also revealed the kitchen windows to be a significant source of draught, which means the window seals need fixing. The indoor air is stuffy and sometimes smelly, indicating a need for improved ventilation. The sound insulation is also lacking as residents report hearing their neighbours' conversations. The thermal insulation of heat distribution pipes is old and brittle and in need of replacement. The roof could also be rebuilt and water systems upgraded to modern standards.



Figure 117 – The apartments in Finland.

4.2.3 Post-occupancy on-site inspections and interviews

Similar to the pre-occupancy actions reported in the previous paragraphs, after the renovation and towards the end of the project will take place onsite inspections and interviews. The results will be reported in the framework of WP8.

4.3 Conclusions

The sociological dimension of the renovations was studied in this initial stage of the project with the help of the pre-occupancy surveys, the onsite inspections and the interviews/discussions with the residents. All these actions aimed to enable as much as possible the participation of the residents in decision making and focused on important aspects like the needs of the houses regarding heating and cooling, ventilation, noise, lighting, Indoor Air Quality etc., rent price and value for money.

The same processes will be followed after the renovation through the post-occupancy surveys where it will be examined whether the occupants' demands would have been fulfilled.

Conclusions

Sustainability reporting bears insights regarding future decisions management tools, concepts and demonstrates the influence, impact and effect in a broader context in response to a complex and highly interactive economic, environmental, and social environment. The conclusion of a sustainability report delivers key performance indicators.

The assets required to actualize perspectives of supportability detailing can be critical. Many of the tools and processes referred and applied in this deliverable are regulated toward incremental change as a part of continuous improvement. The D2.2 simulations, which considered as guideline for current study's development were conducted towards the best case scenario results while minimizing negative societal impacts and emphasizing positive societal influence.

Regarding the economic environmental influence, the achievement of less than 10 years is not quite applicable to every case scenario. Based on the findings, and when taking into consideration the final cases, which will be potentially applied to the demos, the Greek and Portuguese demo meet the project's requirement of ≤ 10 years. The Spanish and Finish demos acquire recap after a short time period, while UK retrofitting bears a quite unprofitable energy mixture, resulting in very long payback period. Deliverable D2.4 distinctly clarifies that the best technology when evaluated from the economic scope is the Breathable membrane developed by WINCO.

A carbon dioxide emission assessment was implemented as per the environmental context of the broader sustainability analysis. The final case scenarios simulated for each country resulted to a CO₂ emissions decrease located in confines of SUREFIT requirements. Except the Spanish demo, every other simulation of D2.2 produced a $\geq 60\%$ decrease of carbon emissions. The particular observation of technologies' CO₂ effect indicates the active category of technologies less effective, while the passive ones score better. An exception occurred in case of the GSHP of the Finnish demo, where the unit to be incorporated is commercially provided.

Complementary to the financial and environmental content of the assessment, the social aspects were also considered. This was realized through the involvement of the stakeholders (owners, tenants, residents etc.) in the decision making process through surveys, interviews and onsite inspections. At the current "pre-occupancy" state of the project, the people gave information about heating, cooling, ventilation, lighting, noise and IAQ issues and freely expressed how they feel in living in the specific houses, their needs and the desired improvements. The main issues that have been recorded are related to heating/cooling, ventilation, IAQ and sound insulation and have been also taken into account during the retrofitted scenarios. Finally, the owners expressed their intentions (on a theoretical basis) of the investment amount that could spent for a specific renovation and the consequent rent increase, while the tenants indicated the rent increase that could accept for the improvement of the house condition.

Further analysis of the interactive sustainability branches will take place at WP8 – *"Economic, social and environmental assessments"*.

5 APPENDIX A

5.1 Simulations - United Kingdom (UK)

Purchased energy use (kWh/m2/year)		Passive			Infiltration			Active		Combination		
		Original	Insulation	Insulation + Windows	Insulation + Windows + PCM	Membrane 50%	Membrane 100%	Window HR system	PV/T system	SAHP	Passive + Infiltration + PV/T	Passive + Infiltration + SAHP
Gas heating total		182.3	98.5	93.9	93.1	96.5	80.6	87.8	0	0	0	0
Space heating		182.3	98.5	93.9	93.1	96.5	80.6	87.8	0	0	0	0
DHW		0	0	0	0	0	0	0	0	0	0	0
Electricity total		24.5	22.3	20	20	21.9	21.2	21.5	180.7	130.9	61.7	40.9
Equip + Light		8.6	8.6	6.4	6.4	8.6	8.6	8.6	6.4	8.6	5.6	7
HVAC aux		0.2	0.1	0.1	0.1	0.1	0.1	0.4	5.6	0.4	0.9	0.3
Space heating (dinning room)		7.4	5.3	5.2	5.2	4.9	4.2	4.2	7.1	7.4	2.9	3
DHW		8.3	8.3	8.3	8.3	8.3	8.3	8.3	0	0	0	0
Backup heating		0	0	0	0	0	0	0	161.6	72.5	52.3	9.1
Heat pump		0	0	0	0	0	0	0	0	42	0	21.5
Solar energy total				2.7	2.7				13.8		13.7	
PV self-consumption				2.3	2.3				9.2		7.1	
PV sold				0.4	0.4				4.6		6.6	
PV self-consumption rate				85%	85%				67%		52%	
		Passive			Infiltration			Active		Combination		
		Original	Insulation	Insulation + Windows	Insulation + Windows + PCM	Membrane 50%	Membrane 100%	Window HR system	PV/T system	SAHP	Passive + Infiltration + PV/T	Passive + Infiltration + SAHP
Purchased energy (kWh/m2)		206.8	120.8	113.9	113.1	118.4	101.8	109.3	180.7	130.9	61.7	40.9
Reduction (%)		-	42%	45%	45%	43%	51%	47%	13%	37%	70%	80%
Primary energy (kWh/m2)		242.7	144.8	136.1	135.2	141.9	122.9	131.5	271.1	196.4	92.6	61.4
Reduction (%)		-	40%	44%	44%	42%	49%	46%	-12%	19%	62%	75%
CO2 Emissions (kg/m2)		42.7	25.1	23.7	23.5	24.6	21.3	22.8	41.7	30.2	14.3	9.4
Reduction (%)		-	41%	44%	45%	42%	50%	47%	2%	29%	67%	78%
		Passive			Infiltration			Active		Combination		
		Original	Insulation	Insulation + Windows	Insulation + Windows + PCM	Membrane 50%	Membrane 100%	Window HR system	PV/T system	SAHP	Passive + Infiltration + PV/T	Passive + Infiltration + SAHP
Indoor conditions												
T<20 (%)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T>25 (%)		0.4	0.5	0.1	0.1	0.7	0.9	0.8	0.4	0.4	0.3	0.3
T_max (degC)		29.1	29.0	26.8	26.4	29.3	29.4	29.4	29.1	29.1	27.3	27.3
CO2 < 1200 (%)		100.0	100.0	100.0	100.0	96.8	3.3	100.0	100.0	100.0	100.0	100.0
CO2 < 1800 (%)		100.0	100.0	100.0	100.0	100.0	6.8	100.0	100.0	100.0	100.0	100.0

Table 44: Simulation - Continuous - UK



Purchased energy use (kWh/m ² /year)		Combination	
		Passive + Infiltration + PV/T	Passive + Infiltration + SAHP
	Original		
Gas heating total	182.3	72	13.2
Space heating	182.3	0	0
DHW	0	0	0
Backup heating	0	72	13.2
Electricity total	24.5	9	38.6
Equip + Light	8.6	4.6	8.6
HVAC aux	0.2	1	0.4
Space heating (dinning room)	7.4	3.4	3.8
DHW	8.3	0	0
Heat pump	0	0	25.8
Solar energy total		13.7	
PV self-consumption		4.8	
PV sold		8.9	
PV self-consumption rate		35%	
		Combination	
		Passive + Infiltration + PV/T	Passive + Infiltration + SAHP
	Original		
Purchased energy (kWh/m ²)	206.8	81	51.8
Reduction (%)	-	61%	75%
Primary energy (kWh/m ²)	242.7	94.9	72.8
Reduction (%)	-	61%	70%
CO ₂ Emissions (kg/m ²)	42.7	16.7	11.6
Reduction (%)	-	61%	73%
		Combination	
		Passive + Infiltration + PV/T	Passive + Infiltration + SAHP
	Original		
Indoor conditions			
T<20 (%)	0.0	0.0	0.0
T>25 (%)	0.4	0.3	0.3
T _{max} (degC)	29.1	27.3	27.3
CO ₂ < 1200 (%)	100.0	100.0	100.0
CO ₂ < 1800 (%)	100.0	100.0	100.0

Table 45: Simulation - Alternative Scenarios Continuous - UK

Purchased energy use (kWh/m ² /year)			
		Original	Combination Final Case
Gas heating total		182.3	0
	Space heating	182.3	0
	DHW	0	0
	Backup heating	0	0
Electricity total		24.5	60.8
	Equip + Light	8.6	7.7
	HVAC aux	0.2	0.8
	Space heating (dinning room)	7.4	6
	DHW	8.3	0
	SAHP	0	23.3
	GSHP	0	23
Solar energy total			2.9
	PV self-consumption		2.8
	PV sold		0.1
PV self-consumption rate			97%
		Original	Combination Passive + Infiltration + PV/T
Purchased energy (kWh/m ²)		206.8	60.8
Reduction (%)		-	71%
Primary energy (kWh/m ²)		242.7	91.2
Reduction (%)		-	62%
CO ₂ Emissions (kg/m ²)		42.7	14.0
Reduction (%)		-	67%
		Original	Combination Passive + Infiltration + PV/T
Indoor conditions			
	T<20 (%)	0.0	0.0
	T>25 (%)	0.4	0.3
	T _{max} (degC)	29.1	27.3
	CO ₂ < 1200 (%)	100.0	100.0
	CO ₂ < 1800 (%)	100.0	100.0

Table 46: Simulation – Final Case - UK



5.2 Simulations – Spain (SP)

Original		Passive			Infiltration			Active		Combined	
Energy type	Orig	Insu	Insu+Wind	Insu+Wind+PCM	Memb50	Memb100	Memb100+Vent	PVT	SAHP	All+PVT	All+SAHP
Fuel tot	115.0	58.0	51.1	50.2	68.1	67.2	77.5	97.2	26.2	33.1	0.1
SH	99.2	42.1	35.2	34.3	52.3	51.4	61.6	99.4	99.3	33.7	33.6
DHW	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7
Elec tot	19.4	19.3	18.2	18.2	19.3	19.3	19.8	6.6	45.6	6.9	32.4
Equip + Light	19.2	19.2	18.1	18.1	19.2	19.2	19.2	12.4	19.4	12.4	18.4
HVAC aux	0.2	0.1	0.1	0.1	0.1	0.1	0.6	0.1	0.2	0.3	0.5
Heating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.2	0.0	13.5
Solar energy total											
Solar heat	0	0	0	0	0	0	0	17.22	68.69	16.77	33.00
PV total	0	0	1.08	1.08	0	0	0	12.82	0	12.81	1.07
PV sold	0	0	0	0	0	0	0	5.88	0	5.80	0
PV self-consumption rate	0.0 %	0.0 %	100.0 %	100.0 %	0.0 %	0.0 %	0.0 %	54.1 %	0.0 %	54.7 %	100.0 %
PV total, rel	0	0	34.9	34.9	0	0	0	191.0	0	190.9	34.6
Purchased energy (kWh/m2)											
	Orig	Insu	Insu+Wind	Insu+Wind+PCM	Memb50	Memb100	Memb100+Vent	PVT	SAHP	All+PVT	All+SAHP
	134	77	69	68	87	86	97	104	72	40	33
Reduction (%)		-42.5 %	-48.5 %	-49.1 %	-35.0 %	-35.7 %	-27.6 %	-22.8 %	-46.6 %	-70.2 %	-75.8 %
Primary energy (kWh/m2)											
	152.4	91.1	82.1	81.2	102.0	101.0	112.8	113.9	96.9	45.9	49.1
Reduction (%)		-40.2 %	-46.1 %	-46.7 %	-33.0 %	-33.7 %	-26.0 %	-25.2 %	-36.4 %	-69.9 %	-67.8 %
Emissions (kg-CO2/m2)											
	26.6	15.2	13.6	13.4	17.2	17.0	19.2	20.6	13.9	7.9	6.2
Reduction (%)		-42.8 %	-48.7 %	-49.4 %	-35.2 %	-35.9 %	-27.8 %	-22.5 %	-47.8 %	-70.3 %	-76.7 %
Energy cost (€)											
	3,617	2,426	2,215	2,195	2,638	2,619	2,864	2,434	3,436	1,126	2,059
Fuel	2,386	1,202	1,059	1,041	1,413	1,394	1,608	2,016	543	687	2
Electricity	1,231	1,224	1,155	1,155	1,225	1,225	1,256	418	2,892	440	2,058
Max investment (€)		11,910	14,027	14,218	9,791	9,987	7,534	11,829	1,818	24,909	15,578
Indoor conditions											
	Orig	Insu	Insu+Wind	Insu+Wind+PCM	Memb50	Memb100	Memb100+Vent	PVT	SAHP	All+PVT	All+SAHP
T_max (degC)	30.5	29.6	29.1	28.5	29.9	30.2	30.2	30.4	30.4	28.3	28.3
T < 18 (%)	26	6	2	2	15	18	22	26	26	8	8
T > 25 (%)	13	13	12	12	14	14	11	13	13	10	10
CO2 < 1200 (%)	41	44	45	45	36	24	100	41	41	100	100
CO2 < 1800 (%)	98	99	99	99	98	96	100	98	98	100	100

Table 47: Simulation – intermittent - SP



Energy type	Orig	All (2cm, sun wind) + PVT	All (2cm, all wind) + PVT	All (1cm, all wind) + PVT	All (2cm, sun wind) + SAHP11	All (2cm, all wind) + SAHP11	All (1cm, all wind) + SAHP7	All (1cm, all wind) + SAHP5
Fuel tot	115.0	39.2	34.4	39.2	19.9	16.4	17.9	22.7
SH	99.2							
DHW	15.7							
Elec tot	19.4	12.2	12.2	12.2	32.1	31.3	30.4	28.9
Equip + Light	19.2							
HVAC aux	0.2							
Electric heating	0.0							
Total renewable energy	0	30.9	30.7	31.0	24.4	23.6	23.2	20.4
Solar/ambient heat	0	17.0	16.8	17.1	23.3	22.5	22.1	19.3
PV total	0	13.9	13.9	13.9	1.1	1.1	1.1	1.1
PV sold	0	6.35	6.35	6.35	0	0	0	0
PV self-consumption rate	0.0 %	54.3 %	54.3 %	54.3 %	100.0 %	100.0 %	100.0 %	100.0 %
	Orig	All (2cm, sun wind) + PVT	All (2cm, all wind) + PVT	All (1cm, all wind) + PVT	All (2cm, sun wind) + SAHP11	All (2cm, all wind) + SAHP11	All (1cm, all wind) + SAHP7	All (1cm, all wind) + SAHP5
Purchased energy (kWh/m2)	134	51.4	46.6	51.4	52.0	47.7	48.3	51.6
Reduction (%)		-61.8 %	-65.4 %	-61.8 %	-61.3 %	-64.5 %	-64.1 %	-61.6 %
Primary energy (kWh/m2)	152.4	60.3	55.2	60.3	69.8	64.8	65.1	67.9
Reduction (%)		-60.4 %	-63.8 %	-60.4 %	-54.2 %	-57.5 %	-57.3 %	-55.4 %
Emissions (kg-CO2/m2)	26.6	10.1	9.2	10.1	10.1	9.2	9.3	10.0
Reduction (%)		-62.0 %	-65.6 %	-62.0 %	-62.1 %	-65.3 %	-64.9 %	-62.3 %
	Orig	All (2cm, sun wind) + PVT	All (2cm, all wind) + PVT	All (1cm, all wind) + PVT	All (2cm, sun wind) + SAHP11	All (2cm, all wind) + SAHP11	All (1cm, all wind) + SAHP7	All (1cm, all wind) + SAHP5
Indoor conditions								
T_max (degC)	30.5	29.1				28.8		28.8
T < 18 (%)	26.0	13.7				12.0		12.0
T > 25 (%)	13.3	10.4				8.3		8.3
CO2 < 1200 (%)	41.3	100.0				100.0		100.0
CO2 < 1800 (%)	98.1	100.0				100.0		100.0

Table 48: Simulation – Alternative Intermittent - SP

Energy type	Orig	Combined, 3 insulated
Fuel tot	109.5	46.7
SH	93.2	
DHW	16.2	
Elec tot	19.4	13.0
Equip + Light	19.2	
HVAC aux	0.2	
Electric heating	0.0	
Total renewable energy	0	25.3
Solar/ambient heat	0	14.2
PV total	0	11.1
PV sold	0	4.3
PV self-consumption rate	0.0 %	61.0 %
	Orig	Combined, 3 insulated
Purchased energy (kWh/m2)	129	59.7
Reduction (%)		53.7 %
Primary energy (kWh/m2)	146.5	69.5
Reduction (%)		52.5 %
Emissions (kg-CO2/m2)	25.5	11.8
Reduction (%)		53.9 %

Table 49: Simulation – Final Case – SP



5.3 Simulations - Portugal (PT)

	Reference case (intermittent heating)	Passive			Infiltration			Active [1]		Combination	
		Insulation	Insulation + Windows	Insulation + Windows + PCM	Membrane 50%	Membrane 100%	Window HR system	PV/T system	SAHP [2]	Passive + Infiltration + PV/T	Passive + Infiltration + SAHP
Oil heating total	18.3	18.3	18.3	18.3	18.3	18.3	18.3	4.5	3.7	4.5	3.7
DHW	18.3	18.3	18.3	18.3	18.3	18.3	18.3	0	0	0	0
Backup heating	0	0	0	0	0	0	0	4.5	3.7	4.5	3.7
Electricity total	97.1	49.5	49.2	48.7	55.3	54.3	66.8	88.5	102	43.1	57
Equip + Light	13.2	13.2	13.1	13.1	13.2	13.2	13.2	5.5	13.2	5.5	13.1
HVAC aux	0	0	0	0	0	0	2.2	0	0	1.2	2.2
Space heating	83.9	36.3	36.1	35.6	42.1	41.1	51.4	83	84	36.4	37
Backup heating	0	0	0	0	0	0	0	0	0	0	0
Heat pump	0	0	0	0	0	0	0	0	4.8	0	4.7
Solar energy total			0.2	0.2				49.6		49.6	0.2
PV self-consumption			0.2	0.2				8.7		9.6	0.2
PV sold			0	0				40.9		40	0
PV self-consumption rate			100%	100%				18%		19%	100%
	Reference case (intermittent heating)	Passive			Infiltration			Active		Combination	
		Insulation	Insulation + Vacuum Windows	Insulation + Vacuum Windows + PCM	Membrane 50%	Membrane 100%	Window HR system	PV/T system	SAHP	Passive + Infiltration + PV/T	Passive + Infiltration + SAHP
Purchased energy (kWh/m2)	115.4	67.8	67.5	67	73.6	72.6	85.1	93	105.7	47.6	60.7
Reduction (%)	-	41%	42%	42%	36%	37%	26%	19%	8%	59%	47%
Primary energy (kWh/m2)	163.0	92.1	91.6	90.9	100.7	99.2	117.8	136.4	155.7	68.7	88.6
Reduction (%)	-	44%	44%	44%	38%	39%	28%	16%	4%	58%	46%
CO2 Emissions (kg/m2)	28.3	16.3	16.2	16.1	17.7	17.5	20.6	23.3	26.6	11.8	15.2
Reduction (%)	-	43%	43%	43%	37%	38%	27%	18%	6%	58%	46%
	Reference case (intermittent heating)	Passive			Infiltration			Active		Combination	
		Insulation	Insulation + Windows	Insulation + Windows + PCM	Membrane 50%	Membrane 100%	Window HR system	PV/T system	SAHP	Passive + Infiltration + PV/T	Passive + Infiltration + SAHP
Indoor conditions											
T<20 (%)	49.0	33.5	33.6	33.9	36.7	36.9	42.9	49.2	49.1	38.6	38.4
T>25 (%)	7.1	2.7	2.2	0.0	3.8	3.9	2.0	7.0	7.1	0.2	0.5
T_max (degC)	27.9	26.3	26.2	25.7	26.5	26.5	26.8	27.9	27.9	26.0	26.1
CO2 < 1200 (%)	34.2	38.5	39.0	42.2	23.6	16.3	100.0	34.2	34.1	100.0	100.0
CO2 < 1800 (%)	72.5	75.5	75.7	76.2	61.6	33.6	100.0	72.3	72.4	100.0	100.0

Table 50: Simulation – Intermittent - PT

	Reference case (continuous heating)	Passive			Infiltration			Active [1]		Combination	
		Insulation	Insulation + Windows	Insulation + Windows + PCM	Membrane 50%	Membrane 100%	Window HR system	PV/T system	SAHP [2]	Passive + Infiltration + PV/T	Passive + Infiltration + SAHP
Oil heating total	18.3	18.3	18.3	18.3	18.3	18.3	18.4	4.5	3.7	4.6	3.8
DHW	18.3	18.3	18.3	18.3	18.3	18.3	18.4	0	0	0	0
Backup heating	0	0	0	0	0	0	0	4.5	3.7	4.6	3.8
Electricity total	210.8	66.6	65.9	65.9	77.2	75.1	98	189.8	215.8	53.8	74.9
Equip + Light	13.2	13.2	13.1	13.1	13.2	13.2	13.2	7.6	13.2	6.4	13.1
HVAC aux	0	0	0	0	0	0	2.2	0	0	1.3	2.2
Space heating	197.6	53.4	52.8	52.8	64	61.9	82.6	182.2	197.8	46.1	54.9
Heat pump	0	0	0	0	0	0	0	0	4.8	0	4.7
Solar energy total			0.2	0.2				49.6		49.6	0.2
PV self-consumption			0.2	0.2				21.1		16.8	0.2
PV sold			0	0				28.5		32.8	0
PV self-consumption rate			100%	100%				43%		34%	100%
	Reference case (continuous heating)	Passive			Infiltration			Active		Combination	
		Insulation	Insulation + Windows	Insulation + Windows + PCM	Membrane 50%	Membrane 100%	Window HR system	PV/T system	SAHP	Passive + Infiltration + PV/T	Passive + Infiltration + SAHP [1]
Purchased energy (kWh/m2)	229.1	84.9	84.2	84.2	95.5	93.4	116.4	194.3	219.5	58.4	78.7
Reduction (%)	-	63%	63%	63%	58%	59%	49%	15%	4%	75%	66%
Primary energy (kWh/m2)	332.4	117.5	116.5	116.5	133.3	130.2	164.4	287.3	325.2	84.8	115.4
Reduction (%)	-	65%	65%	65%	60%	61%	51%	14%	2%	74%	65%
CO2 Emissions (kg/m2)	57.1	20.6	20.4	20.4	23.3	22.7	28.5	48.9	55.4	14.5	19.7
Reduction (%)	-	64%	64%	64%	59%	60%	50%	14%	3%	75%	65%
	Reference case (continuous heating)	Passive			Infiltration			Active		Combination	
		Insulation	Insulation + Windows	Insulation + Windows + PCM	Membrane 50%	Membrane 100%	Window HR system	PV/T system	SAHP	Passive + Infiltration + PV/T	Passive + Infiltration + SAHP
Indoor conditions											
T<20 (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T>25 (%)	7.1	2.7	2.2	0.0	3.8	3.9	2.0	7.0	7.1	0.2	0.5
T_max (degC)	27.9	26.3	26.2	25.7	26.5	26.5	26.8	27.9	27.9	26.0	26.1
CO2 < 1200 (%)	35.5	39.5	40.0	43.2	24.3	16.3	100.0	35.4	35.4	100.0	100.0
CO2 < 1800 (%)	73.3	75.8	76.2	76.9	61.8	32.6	100.0	73.3	73.2	100.0	100.0

Table 51: Simulation - Continuous - PT

	Reference case (intermittent heating)	Final combination (without insulation)
Oil heating total	18.3	0
DHW	18.3	0
Electricity total	97.1	28.4
Equip + Light	13.2	6.9
HVAC aux	0	1.7
Electric radiators	83.9	0
Heat pump	0	19.8
Solar energy total		23.9
PV self-consumption		11.3
PV sold		12.6
PV self-consumption rate		47%
Purchased energy (kWh/m ²)	115.4	28.4
Reduction (%)	-	75%
Primary energy (kWh/m ²)	163.0	42.3
Reduction (%)	-	74%
CO ₂ Emissions (kg/m ²)	28.3	7.2
Reduction (%)	-	75%
	Reference case (intermittent heating)	Final combination (without insulation)
Indoor conditions		
T<20 (%)	49.0	55.6
T>25 (%)	7.1	5.3
T _{max} (degC)	27.9	27.7
CO ₂ < 1200 (%)	34.2	100.0
CO ₂ < 1800 (%)	72.5	100.0

Table 52: Simulation – Final Case – PT



5.4 Simulations – Greece (GR)

		Passive			Infiltration			Active		Combination	
	Original	Insulation	Insulation + Windows	Insulation + Windows + PCM	Membrane 50%	Membrane 100%	Window HR system	PV/T system	SAHP	Passive + Infiltration + PV/T	Passive + Infiltration + SAHP
Oil heating total	36.8	30.6	27.9	27.2	30.9	30.2	32.1	0	0	0	0
Space heating & DHW	36.8	30.6	27.9	27.2	30.9	30.2	32.1	0	0	0	0
Electricity total	14.8	13	11.7	11.5	13.1	13.1	14.6	33.4	32	22.7	27.8
Equip + Light	10.2	10.2	8.6	8.6	10.2	10.2	10.2	4.8	10.2	4.7	9.1
HVAC aux	0.1	0.1	0.1	0.1	0.1	0.1	1.4	0.2	0.1	0.9	1.2
Space cooling	4.5	2.7	3	2.8	2.8	2.8	3	4.4	4.5	2.8	2.9
Backup heating	0	0	0	0	0	0	0	24	0	14.3	0
Heat pump	0	0	0	0	0	0	0	0	17.2	0	14.6
Solar energy total			1.7	1.7				20.3		20.3	
PV self-consumption			1.7	1.7				9.3		9.8	
PV sold			0	0				11		10.5	
PV self-consumption rate			100%	100%				46%		48%	
		Passive			Infiltration			Active		Combination	
	Original	Insulation	Insulation + Windows	Insulation + Windows + PCM	Membrane 50%	Membrane 100%	Window HR system	PV/T system	SAHP	Passive + Infiltration + PV/T	Passive + Infiltration + SAHP
Purchased energy (kWh/m2)	51.6	43.6	39.6	38.7	44	43.3	46.7	33.4	32	22.7	27.8
Reduction (%)	-	16%	23%	25%	15%	16%	9%	35%	38%	56%	46%
Primary energy (kWh/m2)	67.0	56.9	51.6	50.5	57.4	56.7	61.4	59.8	57.3	40.6	49.8
Reduction (%)	-	15%	23%	25%	14%	15%	8%	11%	14%	39%	26%
CO2 Emissions (kg/m2)	18.2	15.5	14.1	13.8	15.7	15.5	16.8	19.1	18.3	13.0	15.9
Reduction (%)	-	15%	23%	24%	14%	15%	7%	-5%	-1%	29%	13%
		Passive			Infiltration			Active		Combination	
	Original	Insulation	Insulation + Windows	Insulation + Windows + PCM	Membrane 50%	Membrane 100%	Window HR system	PV/T system	SAHP	Passive + Infiltration + PV/T	Passive + Infiltration + SAHP
Indoor conditions											
T<20 (%)	49.1	46.9	39.6	40.8	46.7	46.3	47.7	49.0	49.1	40.6	40.3
T>25 (%)	21.4	22.1	26.2	26.3	22.4	24.3	21.9	21.4	21.5	26.4	26.5
T_max (degC)	28.7	27.8	28.6	28.6	27.8	27.8	28.2	28.7	28.7	28.7	28.7
CO2 < 1200 (%)	20.3	20.6	20.8	20.7	12.8	8.4	100.0	20.2	20.3	100.0	100.0
CO2 < 1800 (%)	79.6	79.9	80.8	80.6	66.4	46.2	100.0	79.6	79.6	100.0	100.0

Table 53: Simulation – Intermittent - GR



	Reference case (continuous heating and cooling)	Passive			Infiltration			Active [1]		Combination	
		Insulation	Insulation + Windows	Insulation + Windows + PCM	Membrane 50%	Membrane 100%	Window HR system	PV/T system	SAHP	Passive + Infiltration + PV/T	Passive + Infiltration + SAHP
Oil heating total	109.3	56.5	46.6	45.9	57.3	54.2	64.8	99.2	61.7	35.7	13.1
Space heating & DHW	109.3	56.5	46.6	45.9	57.3	54.2	64.8	0	0	0	0
Backup heating	0	0	0	0	0	0	0	99.2	61.7	35.7	13.1
Electricity total	18.2	14.3	13.4	13.4	14.4	14.4	16.3	10	38.2	7.5	31.3
Equip + Light	10.2	10.2	9	9	10.2	10.2	10.2	4.5	10.2	4.3	9.4
HVAC aux	0.8	0.2	0.1	0.1	0.2	0.2	1.5	1.4	0.2	0.9	1.2
Space cooling	7.2	3.9	4.3	4.3	4	4	4.6	4.1	7.2	2.3	4.8
Heat pump	0	0	0	0	0	0	0	0	20.6	0	15.9
Solar energy total			1.7	1.7				20.3		20.3	1.6
PV self-consumption			1.7	1.7				9.7		9.3	1.6
PV sold			0	0				10.6		11	0
PV self-consumption rate			100%	100%				48%		46%	100%
	Reference case (continuous heating and cooling)	Passive			Infiltration			Active		Combination	
		Insulation	Insulation + Windows	Insulation + Windows + PCM	Membrane 50%	Membrane 100%	Window HR system	PV/T system	SAHP	Passive + Infiltration + PV/T	Passive + Infiltration + SAHP
Purchased energy (kWh/m2)	127.5	70.8	60	59.3	71.7	68.6	81.1	109.2	99.9	43.2	44.4
Reduction (%)	-	44%	53%	53%	44%	46%	36%	14%	22%	66%	65%
Primary energy (kWh/m2)	152.8	87.7	75.2	74.5	88.8	85.4	100.5	127.0	136.2	52.7	70.4
Reduction (%)	-	43%	51%	51%	42%	44%	34%	17%	11%	66%	54%
CO2 Emissions (kg/m2)	39.3	23.1	20.0	19.8	23.4	22.5	26.4	31.9	38.1	13.7	21.4
Reduction (%)	-	41%	49%	50%	40%	43%	33%	19%	3%	65%	46%
	Reference case (continuous heating and cooling)	Passive			Infiltration			Active		Combination	
		Insulation	Insulation + Windows	Insulation + Windows + PCM	Membrane 50%	Membrane 100%	Window HR system	PV/T system	SAHP	Passive + Infiltration + PV/T	Passive + Infiltration + SAHP
Indoor conditions											
T<20 (%)	0.6	0.9	0.1	0.0	0.6	0.5	0.5	0.0	0.6	0.4	0.4
T>25 (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T_max (degC)	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
CO2 < 1200 (%)	21.7	21.4	23.9	23.6	13.3	10.4	100.0	22.0	21.7	100.0	100.0
CO2 < 1800 (%)	79.7	80.2	81.9	81.7	67.2	48.6	100.0	61.8	79.5	100.0	100.0

Table 54: Simulation – Continuous - GR

	Original	Combination	
		Passive + Infiltration + PV/T	Passive + Infiltration + SAHP
Oil heating total	36.8	27.3	0
Space heating & DHW	36.8	0	0
Backup heating	0	27.3	0
Electricity total	14.8	7.6	30.2
Equip + Light	10.2	4.2	10.2
HVAC aux	0.1	0.7	1.2
Space cooling	4.5	2.7	2.8
Heat pump	0	0	16
Solar energy total		20.3	
PV self-consumption		6.7	
PV sold		13.6	
PV self-consumption rate		33%	
	Original	Combination	
		Passive + Infiltration + PV/T	Passive + Infiltration + SAHP
Purchased energy (kWh/m2)	51.6	34.9	30.2
Reduction (%)	-	32%	41%
Primary energy (kWh/m2)	67.0	43.6	54.1
Reduction (%)	-	35%	19%
CO2 Emissions (kg/m2)	18.2	11.6	17.3
Reduction (%)	-	36%	5%
	Original	Combination	
		Passive + Infiltration + PV/T	Passive + Infiltration + SAHP
Indoor conditions			
T<20 (%)	44.2	42.0	42.2
T>25 (%)	20.7	19.5	19.6
T_max (degC)	28.7	28.0	28.0
CO2 < 1200 (%)	20.3	100.0	100.0
CO2 < 1800 (%)	79.6	100.0	100.0

Table 55: Simulation – Alternative Combined - GR

	Original	Final combination (ceiling insulation, 50% airtightness improvement)
Oil heating total	105.6	39.8
Space heating & DHW	105.6	39.8
Electricity total	15.3	6.6
Equip + Light	10.4	4.2
HVAC aux	0.3	0
Space cooling	4.6	2.4
Solar energy total		24.4
PV self-consumption		8.6
PV sold		15.8
PV self-consumption rate		35%
	Original	Final combination (ceiling insulation, 50% airtightness improvement)
Purchased energy (kWh/m2)	120.9	46.4
Reduction (%)	-	62%
Primary energy (kWh/m2)	143.5	55.6
Reduction (%)	-	61%
CO2 Emissions (kg/m2)	36.6	14.3
Reduction (%)	-	61%
	Original	Final combination (ceiling insulation, 50% airtightness improvement)
Indoor conditions		
Proportion of time, T<20 degC (%)	22.9	6.1
Proportion of time, T>25 degC (%)	7.1	15.5
T_max (degC)	28.7	29.9
Proportion of time, CO2 < 1200 ppm (%)	26.3	13.4
Proportion of time, CO2 < 1800 ppm (%)	83.3	72.8

Table 56: Simulation – Final Case – GR



5.5 Simulations – Finland (FI)

	Original	Insulation	Insu+Inf	Insu+Inf+Pipes	Ventilation	Vent+VAV	Vent-high	Vent-high+VAV	PV	GSHP	GSHP+Rad	All, Planned	All, Adv1	All, Adv2	All, Adv3
District heating total	129.2	116.0	114.9	103.4	95.8	94.2	95.2	93.6	129.2	80.3	78.8	27.7	25.7	21.7	14.3
SH + vent	85.8	72.9			51.8	51.7			85.8	53.3		7.4			
DHW	42.6	42.6			42.6	42.6			42.6	26.5		7.9			
Electricity total	34.2	34.1	34.1	34.0	33.7	33.1	33.7	33.1	28.5	44.1	44.0	37.7	36.8	29.9	29.4
Equip + Light, tenant	24.3	24.3	24.3		26.2	26.2			21.8	26.2		23.0			
Equip + Light, facility	1.8	1.8	1.8												
HVAC aux	5.0	4.8	4.8		4.6	4.0			4.3	4.7		3.9			
Heating	0.0	0.0	0.0		0.0	0.0			0.0	10.2		9.4			
Sauna	3.0	3.0	3.0		2.9	2.9			2.6	3.0		2.7			
Renewable energy total	0.0	0.0			0.0				5.7	37.2		35.8	36.5	37.8	34.8
lar/ambient/ground heat										37.2	37.9	30.1	30.8	26.3	23.4
PV total															
PV self-consumption, all									5.4			5.6	5.5	8.7	8.6
PV sold, all									0.3			0.2	0.2	2.8	2.9
Self-consumption, all (%)									93.9			96.9	95.7	67.4	66.6
Self-consumption, facility									2.6			3.5	3.3	4.3	4.1
PV sold, facility									3.2			2.2	2.5	7.2	7.4
consumption, facility (%)									44.6			61.2	56.8	37.2	35.9
PV total, rel									215.7			215.6			
	Original	Insulation	Insu+Inf	Insu+Inf+Pipes	Ventilation	Vent+VAV	Vent-high	Vent-high+VAV	PV	GSHP	GSHP+Rad	All, Planned	All, Adv1	All, Adv2	All, Adv3
Purchased energy (kWh/m ²)	163.4	150.0	148.9	137.4	129.5	127.3	128.9	126.7	157.6	124.4	122.8	65.4	62.5	51.6	43.6
Reduction (%)	0%	-8.2 %	-8.8 %	-15.9 %	-20.7 %	-22.1 %	-21.1 %	-22.5 %	-3.5 %	-23.8 %	-24.8 %	-60.0 %	-61.8 %	-68.4 %	-73.3 %
Primary energy (kWh/m ²)	105.6	98.8	98.3	92.5	88.4	86.8	88.0	86.5	98.7	93.1	92.2	59.1	57.0	46.8	42.4
Reduction (%)	0%	-6.4 %	-6.9 %	-12.4 %	-16.3 %	-17.8 %	-16.6 %	-18.1 %	-6.5 %	-11.9 %	-12.7 %	-44.0 %	-46.0 %	-55.7 %	-59.9 %
Emissions (kg/m ²)	31.7	28.8	28.5	26.0	24.3	23.9	24.2	23.8	31.2	21.9	21.6	9.7	9.2	7.6	6.0
Reduction (%)	0%	-9.2 %	-10.0 %	-17.9 %	-23.3 %	-24.6 %	-23.7 %	-25.1 %	-1.7 %	-30.9 %	-32.0 %	-69.4 %	-71.0 %	-75.9 %	-81.2 %
Energy cost (€), facility only															
District heating	38,339	34,244	33,915	30,570	27,908	27,406	27,708	27,212	38,339	24,801	24,349	8,212	7,557	6,548	4,099
Electricity	5,625	5,550	5,544	5,499	5,358	5,024	5,354	5,020	4,893	11,295	11,204	9,817	9,379	8,157	7,902
Total	43,965	39,793	39,459	36,069	33,267	32,430	33,062	32,232	43,233	36,097	35,553	18,029	16,936	14,705	12,001
Reduction (%)	0%	-9.5 %	-10.2 %	-18.0 %	-24.3 %	-26.2 %	-24.8 %	-26.7 %	-1.7 %	-17.9 %	-19.1 %	-59.0 %	-61.5 %	-66.6 %	-72.7 %
Indoor conditions	Original	Insulation	Insu+Inf	Insu+Inf+Pipes	Ventilation	Vent+VAV	Vent-high	Vent-high+VAV	PV	GSHP	GSHP+Rad	All, Planned	All, Adv1	All, Adv2	All, Adv3
T<21 (%)	0.00	0.00	0.00		0.00							0.00			
T>25 (%)	13.4	14.7	14.67		16.2							13.57			
T>27 (%)		4.8	4.77		4.6							2.08			
T _{max} (degC)	30.3	30.4	30.37		30.6							28.42			
CO ₂ < 1200 (%)	100														
CO ₂ < 1800 (%)	100														

Table 57: Simulation - Continuous - FI

	Original	Combined
District heating total	133.6	31.7
SH + vent	89.2	16.4
DHW	42.6	15.3
Electricity total	30.0	33.7
Equip + Light, tenant	18.9	19.4
Equip + Light, facility	3.9	3.4
HVAC aux	5.0	3.8
Heat pump	0.0	9.1
Sauna	2.1	1.8
Renewable energy total	0.0	37.3
Ground heat		31.6
PV total		5.7
PV self-consumption, all		5.4
PV sold, all		0.3
Self-consumption, all (%)		94.3
PV self-consumption, facility		
PV sold, facility		
Self-consumption, facility (%)		
PV total, rel		
	Original	Combined
Purchased energy (kWh/m2)	163.6	65.4
Reduction (%)	0%	-60.0 %
Primary energy (kWh/m2)	102.8	56.3
Reduction (%)	0%	-45.3 %
Emissions (kg/m2)	32.3	10.2
Reduction (%)	0%	-68.3 %
	Original	Combined
Indoor conditions		
T < 18 degC (%)	0.0	0.0
T > 25 degC (%)	11.9	0.1
T_max (degC)	30.3	25.2
CO2 < 1200 ppm (%)	100	100
CO2 < 1800 ppm (%)	100	100

Table 58: Simulation – Final Case - FI

6 APPENDIX B

TCE Estimation Example

inflation	5.00%	0.0500
Present Value of electricity (€/kWh)	0.24	
Present Value of Gas (€/kWh)	0.12	
Reference Case electr. (kWh)	7428.15	Reference electr. Consumption (EUR) € 1,782.76
Reference Case Gas (kWh)	1399.95	Reference Gas Consumption (EUR) € 167.99
Retrofit Case electr. (kWh)	4153.95	Retrofit Case electr. (EUR) € 996.95
Retrofit Case Gas (kWh)	1399.95	Retrofit Case Gas (EUR) € 167.99

Table 59: Estimation of TCE_o and TCE_r for WINCO's breathable membrane during the case of 100% infiltration impact for intermittently heated PT demo

Table 59 takes into account the data from Table 50 and Table 12 which are associated with intermittent heat supply of the building, in order to calculate the consumption in kWh of Reference/Original Case and Retrofit case. Table 10 and Table 11 are discerned as inputs for the above calculation, under the influence of $h_{EU}=5.00\%$.

inflation	5.00%	0.0500
Present Value of electricity (€/kWh)	0.24	
Present Value of Gas (€/kWh)	0.12	
Reference Case electr. (kWh)	7428.15	Reference electr. Consumption (EUR) € 1,782.76
Reference Case Gas (kWh)	1399.95	Reference Gas Consumption (EUR) € 167.99
Retrofit Case electr. (kWh)	6770.25	Retrofit Case electr. (EUR) € 1,624.86
Retrofit Case Gas (kWh)	344.25	Retrofit Case Gas (EUR) € 41.31

Table 60: Estimation of TCE_o and TCE_r for PV/T impact for intermittently heated PT demo

Table 60 takes into account Table 50 for intermittent heat supply of the PT demo. Table 10 and Table 11 are used for €/kWh values. The consumption in euros for Original and Retrofit cases are calculated under the influence of $h_{EU}=5.00\%$.

7 APPENDIX C

7.1 Insulation - Cost

Bio – Aerogel Blanket					
Manufacturing/ Purchased Cost (€)	46.5 / m ² (10mm thickness)				
Labour (€)	-				
Materials (€)	-				
Consumables (€)	-				
Energy (€)	-				
Overheads (€)	-				
Other (€)	-				
Margin or VAT	20%				
Total manufacturing/purchased cost(€)	55.8 /m² (10mm thickness)				
Auxiliary Cost					
Thermal adhesive (€)	7.6 /m ²				
Timber frame (€)	3.1 /m ²				
Reinforcement mesh (€)	1.7 /m ²				
12.5mm plasterboard (€)	3.5 /m ²				
finish coating (€)	5.0 /m ²				
Installation Cost					
Demo	UK	SP	PT	GR	FI
Labour (€/m ²)	17.6	-	7.88	10.0	-
Materials (€/m ²)	40.9	-	5.26	-	-
Consumables (€/m ²)		-		2.0	-
Energy (€/m ²)		-		-	-
Other (€/m ²)		-		10.0	-
Total installation cost (€/m²)	58.5	-	13.0	22.0	-
Installation Time					
Installation Time (h/m ²)	2.88	0.25	-	0.7	-
Lifespan	Manufacturer info (UNOTT) : 30 years				

Table 61: Bio - aerogel Cost

Silica – Aerogel Blanket	
Manufacturing/ Purchased Cost (€)	15.9 /m ² (10mm thickness)
Labour (€)	-
Materials (€)	-
Consumables (€)	-
Energy (€)	-
Overheads (€)	-
Other (€)	-
Margin or VAT	20%
Total manufacturing/purchased cost(€)	19.08 /m² (10mm thickness)
Auxiliary Cost	
Thermal adhesive (€)	7.6 /m ²
Timber frame (€)	3.1 /m ²
Reinforcement mesh (€)	1.7 /m ²
12.5mm plasterboard (€)	3.5 /m ²
finish coating (€)	5.0 /m ²

Installation Cost					
Demo	UK	SP	PT	GR	FI
Labour (€/m ²)	17.6	6.0	7.88	10.0	-
Materials (€/m ²)	40.9	-	5.26	-	-
Consumables (€/m ²)		-		-	-
Energy (€/m ²)		-		-	-
Other (€/m ²)		10.0		10.0	-
Total installation cost (€/m²)	58.5	16.0	13.0	22.0	-
Installation Time					
Installation Time (h/m ²)	2.88	0.25	-	0.7	-
Lifespan	Manufacturer info: 60 years				

Table 62: Silica - aerogel Cost

PCM panels					
Manufacturing/ Purchased Cost (€	96.0 /m ²				
Labour (€)	-				
Materials (€)	-				
Consumables (€)	-				
Energy (€)	-				
Overheads (€)	-				
Other (€)	-				
Margin or VAT	-				
<i>Total manufacturing/purchased cost (€)</i>	<i>96.0 /m²</i>				
Installation Cost					
Demo	UK	SP	PT	GR	FI
<i>Total installation cost (€/m²)</i>	<i>10.0</i>				
Installation Time					
Installation Time (h/m ²)	2.88	0.25	-	0.7	-
Lifespan	Manufacturer info (PCMproducts) : 25 years				

Table 63: PCM Cost

Louvers - Blinds				
Product Name	RETROLux A	RETROLux 50	RETROLux 20	RETROLux 20 as insert
Manufacturing/ Purchased Cost (€/m²)	160	190	250	220
Installation Cost				
Total installation cost (€/m²)	50% added on the above cost			
Installation Time				
Lifespan	Manufacturer info (UNOTT) : 20 years			

Table 64: Blinds – Louvers Cost

PV vacuum widows (PV-VG)	
Manufacturing/ Purchased Cost (€/m ²)	504.0
Labour (€/m ²)	-
Materials (€/m ²)	-
Consumables (€/m ²)	-
Energy (€/m ²)	-
Overheads (€/m ²)	-

Other (€/m²)	-				
Margin or VAT	20%				
Total manufacturing/purchased cost(€/m²)	605.0				
Installation Cost					
Demo	UK	SP	PT	GR	FI
Labour (€/m²)	22.6	6.0	222/un.	55.8	-
Materials (€/m²)	-	-	25/un.	-	-
Consumables (€/m²)	-	15.0	-	-	-
Energy (€/m²)	-	3.0	-	-	-
Other (€/m²)	-	-	-	40.0	-
Total installation cost (€/m²)	22.6	24.0	247/un.	95.0	-
Installation Time					
Installation Time (h/m²)	0.13	0.25	-	0.5	-
Lifespan	Manufacturer info (UNOTT) : 20 years				

Table 65: PV Vacuum Glazing Windows Cost

7.2 Infiltration - Cost

Breathable membrane by WINCO					
Manufacturing/ Purchased Cost (€)	6.0 /m²				
Labour (€)	2.1 /m²				
Materials (€)	3.6 /m²				
Consumables (€)	0.09 /m²				
Energy (€)	-				
Overheads (€)	-				
Other (€)	0.21 /m²				
Margin or VAT	80%				
<i>Total manufacturing/purchased cost(€)</i>	<i>10.8 /m²</i>				
Auxiliary					
Adhesive for vertical joints (€)	0.07 /m²				
Wind-stop (€)	0.30 /m²				
Staples, screws, nails, adhesive tape, counter-batten (€)	-				
Installation Cost					
Demo	UK	SP	PT	GR	FI
Labour (€/m²)	10.0				
Materials (€/m²)	4.0				
Consumables (€/m²)	-				
Energy (€/m²)	-				
Other (€/m²)	-				
<i>Total installation cost (€/m²)</i>	<i>14.0</i>				
Installation Time					
Installation Time (h/m²)	<i>0.3</i>				
Lifespan	Manufacturer info (UNOTT) : 20 years				

Table 66: WINCO's breathable SKYTECH membrane Cost

Window Heat Recovery (WHR)	
Manufacturing/ Purchased Cost (€)	360.0 /unit
Labour (€)	-

Materials (€)	-				
Consumables (€)	-				
Energy (€)	-				
Overheads (€)	-				
Other (€)	-				
Margin or VAT	20%				
Total manufacturing/purchased cost(€/m²)	432.0 /unit				
Auxiliary Cost					
Joint Sealing (€)	9.0 /m				
Installation Cost					
Demo	UK	SP	PT	GR	FI
Labour (€/unit)	90.0	90.0	222.0	80.0	-
Materials (€/unit)	-	-	25.0	15.0	-
Consumables (€/unit)	300.0	300.0	-	-	-
Energy (€/unit)	-	-	-	-	-
Other (€/unit)	-	-	-	-	-
Total installation cost (€/unit)	459.0	459.0	247.0	95.0	-
Installation Time					
Installation Time (h/unit)	12.0	12.0	-	8.0	-
Lifespan	Manufacturer info (UNOTT) : 20 years				

Table 67: Window Heat Recovery system Cost

7.3 Active Technologies - Cost

SOLIMPEKS PV/T Panels					
Manufacturing/ Purchased Cost (€)	300.0 /unit				
Labour (€)					
Materials (€)					
Consumables (€)					
Energy (€)					
Overheads (€)					
Other (€)					
Margin or VAT	15%				
<i>Total manufacturing/purchased cost(€)</i>	<i>350.0 /unit</i>				
Auxiliary					
inverter, cable, assembly tool set, piping, boiler, circulation pump, etc. (€)	300.0 /unit				
Installation Cost					
Demo	UK	SP	PT	GR	FI
Labour (€)	-				
Materials (€)	-				
Consumables (€)	-				
Energy (€)	-				
Other (€)	-				
<i>Total installation cost (€)</i>	<i>140 /unit</i>				
Installation Time					
Installation Time (h/unit)	2.0				
Lifespan	Manufacturer info (SOLIMPEKS) : 20 years				

Table 68: PV/T panels Cost

PV Panels for Finland	
Total manufacturing/purchased cost(€)	1000 /kW
Auxiliary	
inverter, cable, assembly tool set, piping, boiler, circulation pump, etc. (€)	300.0 /unit
Installation Cost	
Total installation cost (€)	15493.00

Table 69: PV panels for FI demo Cost

Solar Assisted Heat Pump (SAHP)					
SAHP Capacity (kW)	2.8	5.0	7.0	11.0	
Manufacturing/ Purchased Cost (€)	1323.0	1701.0	2205.0	3535.0	
Labour (€)	-				
Materials (€)	-				
Consumables (€)	-				
Energy (€)	-				
Overheads (€)	-				
Other (€)	-				
Margin or VAT	5%				
Total manufacturing/purchased cost(€)	1389.0	1786.0	2315.0	3711.0	
Auxiliary					
Demo	UK	SP	PT	GR	FI
Thermal storage cylinder (€)	2453.0	5335.0	1298.0	2434.0	-
Installation Cost					
Demo	UK	SP	PT	GR	FI
Labour (€)	300 /un.	200 /un.	291 /un.	200 /un.	-
Materials (€)	-	150 /un.	185 /un.	140 /un.	-
Consumables (€)	450 /un.	-	-	-	-
Energy (€)	-				
Other (€)	-				
Total installation cost (€)	750 /un.	350 /un.	476 /un.	340 /un.	-
Installation Time					
Installation Time (h/unit)	48.0				
Lifespan	Manufacturer info (SOLIMPEKS) : 20 years				

Table 70: SAHP Cost

Solar Assisted Heat Pump (SAHP)	
Labour (€)	2200.0 (per ground source thermal collector)
Materials (€)	4132.0 (for 4 kW GSHP – 1033.0 per 1 kW of heat capacity)
Consumables (€)	3596.0
Energy (€)	
Overheads (€)	
Other (€)	
Margin or VAT	20%
Total manufacturing/purchased cost(€)	11913.0
Installation Cost	



Labour (€)	2200.0
Materials (€)	6400.0
Consumables (€)	-
Energy (€)	-
Other (€)	-
Total installation cost (€)	8600.0
Installation Time	
Installation Time (h/unit)	240.0
Lifespan	Manufacturer info (UNOTT) : 25 years

Table 71: GSHP Cost

8 APPENDIX D

8.1 Portugal (PT)

8.1.1 Passive for PT

PBP calculation for Continuous and Intermittent heat supply of Portuguese demo under EU average inflation rate:

$$h_{EU} = 5.00\%$$

Table 50 and Table 51 from **APPENDIX A** consist the guideline for PBP estimation:

Bio-Aerogel:

BIO AEROGEL		
Lifetime	30	years
Total manufacturing with profit margin (20%)	€ 279.00	per m ²
Auxiliary	€ 20.90	per m ²
Installation	€ 13.00	per m ²
Total per m2	€ 312.90	per m ²
The wall area	181.34	m ²
Total Investment (C _i) BIO	€ 56,741.29	

Table 72: C_i of Bio Aerogel PT

Year	Reference cost Electricity	Reference cost Gas	TECo	Retrofitted Cost Electricity	Retrofitted Cost Gas	TCe _r	Avoided annual Cost (AaC)	Cumulative Savings (CS)	Balance (Ba)
0	€ 3,870.29	€ 167.99	€ 4,038.28	€ 1,222.78	€ 167.99	€ 1,390.77	€ 2,647.51	€ 2,647.51	(€ 54,093.77)
1	€ 4,063.80	€ 176.39	€ 4,240.20	€ 1,283.91	€ 176.39	€ 1,460.31	€ 2,779.89	€ 5,427.40	(€ 51,313.89)
2	€ 4,266.99	€ 185.21	€ 4,452.21	€ 1,348.11	€ 185.21	€ 1,533.32	€ 2,918.88	€ 8,346.28	(€ 48,395.00)
3	€ 4,480.34	€ 194.47	€ 4,674.82	€ 1,415.52	€ 194.47	€ 1,609.99	€ 3,064.83	€ 11,411.11	(€ 45,330.18)
4	€ 4,704.36	€ 204.20	€ 4,908.56	€ 1,486.29	€ 204.20	€ 1,690.49	€ 3,218.07	€ 14,629.18	(€ 42,112.11)
5	€ 4,939.58	€ 214.41	€ 5,153.98	€ 1,560.61	€ 214.41	€ 1,775.01	€ 3,378.97	€ 18,008.15	(€ 38,733.14)
6	€ 5,186.56	€ 225.13	€ 5,411.68	€ 1,638.64	€ 225.13	€ 1,863.76	€ 3,547.92	€ 21,556.07	(€ 35,185.22)
7	€ 5,445.88	€ 236.38	€ 5,682.27	€ 1,720.57	€ 236.38	€ 1,956.95	€ 3,725.32	€ 25,281.38	(€ 31,459.91)
8	€ 5,718.18	€ 248.20	€ 5,966.38	€ 1,806.60	€ 248.20	€ 2,054.80	€ 3,911.58	€ 29,192.96	(€ 27,548.32)
9	€ 6,004.09	€ 260.61	€ 6,264.70	€ 1,896.93	€ 260.61	€ 2,157.54	€ 4,107.16	€ 33,300.12	(€ 23,441.16)
10	€ 6,304.29	€ 273.64	€ 6,577.94	€ 1,991.77	€ 273.64	€ 2,265.42	€ 4,312.52	€ 37,612.64	(€ 19,128.65)
11	€ 6,619.51	€ 287.33	€ 6,906.83	€ 2,091.36	€ 287.33	€ 2,378.69	€ 4,528.14	€ 42,140.78	(€ 14,600.50)
12	€ 6,950.48	€ 301.69	€ 7,252.17	€ 2,195.93	€ 301.69	€ 2,497.62	€ 4,754.55	€ 46,895.33	(€ 9,845.95)
13	€ 7,298.01	€ 316.78	€ 7,614.78	€ 2,305.73	€ 316.78	€ 2,622.50	€ 4,992.28	€ 51,887.61	(€ 4,853.67)
14	€ 7,662.91	€ 332.62	€ 7,995.52	€ 2,421.01	€ 332.62	€ 2,753.63	€ 5,241.89	€ 57,129.51	€ 388.22
15	€ 8,046.05	€ 349.25	€ 8,395.30	€ 2,542.06	€ 349.25	€ 2,891.31	€ 5,503.99	€ 62,633.49	€ 5,892.21
16	€ 8,448.35	€ 366.71	€ 8,815.06	€ 2,669.17	€ 366.71	€ 3,035.88	€ 5,779.19	€ 68,412.68	€ 11,671.39
17	€ 8,870.77	€ 385.05	€ 9,255.82	€ 2,802.62	€ 385.05	€ 3,187.67	€ 6,068.15	€ 74,480.83	€ 17,739.54
18	€ 9,314.31	€ 404.30	€ 9,718.61	€ 2,942.76	€ 404.30	€ 3,347.05	€ 6,371.55	€ 80,852.38	€ 24,111.09
19	€ 9,780.03	€ 424.51	€ 10,204.54	€ 3,089.89	€ 424.51	€ 3,514.41	€ 6,690.13	€ 87,542.51	€ 30,801.22
20	€ 10,269.03	€ 445.74	€ 10,714.76	€ 3,244.39	€ 445.74	€ 3,690.13	€ 7,024.64	€ 94,567.15	€ 37,825.86
21	€ 10,782.48	€ 468.02	€ 11,250.50	€ 3,406.61	€ 468.02	€ 3,874.63	€ 7,375.87	€ 101,943.02	€ 45,201.73
22	€ 11,321.60	€ 491.43	€ 11,813.03	€ 3,576.94	€ 491.43	€ 4,068.36	€ 7,744.66	€ 109,687.68	€ 52,946.39
23	€ 11,887.68	€ 516.00	€ 12,403.68	€ 3,755.79	€ 516.00	€ 4,271.78	€ 8,131.90	€ 117,819.58	€ 61,078.29



24	€ 12,482.07	€ 541.80	€ 13,023.86	€ 3,943.57	€ 541.80	€ 4,485.37	€ 8,538.49	€ 126,358.07	€ 69,616.78
25	€ 13,106.17	€ 568.89	€ 13,675.06	€ 4,140.75	€ 568.89	€ 4,709.64	€ 8,965.42	€ 135,323.48	€ 78,582.20
26	€ 13,761.48	€ 597.33	€ 14,358.81	€ 4,347.79	€ 597.33	€ 4,945.12	€ 9,413.69	€ 144,737.17	€ 87,995.88
27	€ 14,449.55	€ 627.20	€ 15,076.75	€ 4,565.18	€ 627.20	€ 5,192.38	€ 9,884.37	€ 154,621.54	€ 97,880.25
28	€ 15,172.03	€ 658.56	€ 15,830.59	€ 4,793.44	€ 658.56	€ 5,452.00	€ 10,378.59	€ 165,000.13	€ 108,258.84
29	€ 15,930.63	€ 691.49	€ 16,622.12	€ 5,033.11	€ 691.49	€ 5,724.60	€ 10,897.52	€ 175,897.65	€ 119,156.36
30	€ 16,727.16	€ 726.06	€ 17,453.22	€ 5,284.77	€ 726.06	€ 6,010.83	€ 11,442.39	€ 187,340.04	€ 130,598.75

Table 73: PBP calculation of Bio-aerogel (Continuous) PT

Year	Reference cost Electricity	Reference cost Gas	TECo	Retrofitted Cost Electricity	Retrofitted Cost Gas	TCEr	Avoided annual Cost (AaC)	Cumulative Savings (CS)	Balance (Ba)
0	€ 1,782.76	€ 167.99	€ 1,950.75	€ 908.82	€ 167.99	€ 1,076.81	€ 873.94	€ 873.94	(€ 55,867.35)
1	€ 1,871.89	€ 176.39	€ 2,048.29	€ 954.26	€ 176.39	€ 1,130.65	€ 917.63	€ 1,791.57	(€ 54,949.72)
2	€ 1,965.49	€ 185.21	€ 2,150.70	€ 1,001.97	€ 185.21	€ 1,187.19	€ 963.51	€ 2,755.08	(€ 53,986.20)
3	€ 2,063.76	€ 194.47	€ 2,258.24	€ 1,052.07	€ 194.47	€ 1,246.55	€ 1,011.69	€ 3,766.77	(€ 52,974.51)
4	€ 2,166.95	€ 204.20	€ 2,371.15	€ 1,104.68	€ 204.20	€ 1,308.87	€ 1,062.27	€ 4,829.05	(€ 51,912.24)
5	€ 2,275.30	€ 214.41	€ 2,489.71	€ 1,159.91	€ 214.41	€ 1,374.32	€ 1,115.39	€ 5,944.44	(€ 50,796.85)
6	€ 2,389.06	€ 225.13	€ 2,614.19	€ 1,217.91	€ 225.13	€ 1,443.03	€ 1,171.16	€ 7,115.59	(€ 49,625.69)
7	€ 2,508.52	€ 236.38	€ 2,744.90	€ 1,278.80	€ 236.38	€ 1,515.19	€ 1,229.72	€ 8,345.31	(€ 48,395.98)
8	€ 2,633.94	€ 248.20	€ 2,882.15	€ 1,342.74	€ 248.20	€ 1,590.94	€ 1,291.20	€ 9,636.51	(€ 47,104.77)
9	€ 2,765.64	€ 260.61	€ 3,026.25	€ 1,409.88	€ 260.61	€ 1,670.49	€ 1,355.76	€ 10,992.27	(€ 45,749.01)
10	€ 2,903.92	€ 273.64	€ 3,177.57	€ 1,480.37	€ 273.64	€ 1,754.02	€ 1,423.55	€ 12,415.82	(€ 44,325.46)
11	€ 3,049.12	€ 287.33	€ 3,336.44	€ 1,554.39	€ 287.33	€ 1,841.72	€ 1,494.73	€ 13,910.55	(€ 42,830.74)
12	€ 3,201.57	€ 301.69	€ 3,503.27	€ 1,632.11	€ 301.69	€ 1,933.80	€ 1,569.46	€ 15,480.01	(€ 41,261.27)
13	€ 3,361.65	€ 316.78	€ 3,678.43	€ 1,713.72	€ 316.78	€ 2,030.49	€ 1,647.94	€ 17,127.95	(€ 39,613.34)
14	€ 3,529.73	€ 332.62	€ 3,862.35	€ 1,799.40	€ 332.62	€ 2,132.02	€ 1,730.33	€ 18,858.28	(€ 37,883.00)
15	€ 3,706.22	€ 349.25	€ 4,055.47	€ 1,889.37	€ 349.25	€ 2,238.62	€ 1,816.85	€ 20,675.13	(€ 36,066.15)
16	€ 3,891.53	€ 366.71	€ 4,258.24	€ 1,983.84	€ 366.71	€ 2,350.55	€ 1,907.69	€ 22,582.83	(€ 34,158.46)
17	€ 4,086.11	€ 385.05	€ 4,471.15	€ 2,083.03	€ 385.05	€ 2,468.08	€ 2,003.08	€ 24,585.90	(€ 32,155.38)
18	€ 4,290.41	€ 404.30	€ 4,694.71	€ 2,187.18	€ 404.30	€ 2,591.48	€ 2,103.23	€ 26,689.13	(€ 30,052.15)
19	€ 4,504.94	€ 424.51	€ 4,929.45	€ 2,296.54	€ 424.51	€ 2,721.06	€ 2,208.39	€ 28,897.53	(€ 27,843.76)
20	€ 4,730.18	€ 445.74	€ 5,175.92	€ 2,411.37	€ 445.74	€ 2,857.11	€ 2,318.81	€ 31,216.34	(€ 25,524.95)
21	€ 4,966.69	€ 468.02	€ 5,434.72	€ 2,531.94	€ 468.02	€ 2,999.96	€ 2,434.75	€ 33,651.09	(€ 23,090.19)
22	€ 5,215.03	€ 491.43	€ 5,706.45	€ 2,658.54	€ 491.43	€ 3,149.96	€ 2,556.49	€ 36,207.58	(€ 20,533.70)
23	€ 5,475.78	€ 516.00	€ 5,991.77	€ 2,791.46	€ 516.00	€ 3,307.46	€ 2,684.32	€ 38,891.90	(€ 17,849.39)
24	€ 5,749.57	€ 541.80	€ 6,291.36	€ 2,931.04	€ 541.80	€ 3,472.83	€ 2,818.53	€ 41,710.43	(€ 15,030.86)
25	€ 6,037.04	€ 568.89	€ 6,605.93	€ 3,077.59	€ 568.89	€ 3,646.47	€ 2,959.46	€ 44,669.89	(€ 12,071.40)
26	€ 6,338.90	€ 597.33	€ 6,936.23	€ 3,231.47	€ 597.33	€ 3,828.80	€ 3,107.43	€ 47,777.32	(€ 8,963.97)
27	€ 6,655.84	€ 627.20	€ 7,283.04	€ 3,393.04	€ 627.20	€ 4,020.24	€ 3,262.80	€ 51,040.12	(€ 5,701.17)
28	€ 6,988.63	€ 658.56	€ 7,647.19	€ 3,562.69	€ 658.56	€ 4,221.25	€ 3,425.94	€ 54,466.06	(€ 2,275.22)
29	€ 7,338.07	€ 691.49	€ 8,029.55	€ 3,740.83	€ 691.49	€ 4,432.31	€ 3,597.24	€ 58,063.30	€ 1,322.01
30	€ 7,704.97	€ 726.06	€ 8,431.03	€ 3,927.87	€ 726.06	€ 4,653.93	€ 3,777.10	€ 61,840.40	€ 5,099.12

Table 74: PBP calculation of Bio-aerogel (Intermittent) PT

**Silica-Aerogel:**

SILICA AEROGEL		
Lifetime	60	years
Total manufacturing with profit margin (20%)	€ 95.40	per m ²
Auxiliary	€ 20.90	per m ²
Installation	€ 13.00	per m ²
Total per m2	€ 129.30	per m ²
The wall area	181.34	m ²
Total Investment (Ci) SILICA	€23,447.26	

Table 75: Ci of Silica Aerogel for PT

Year	Reference cost Electricity	Reference cost Gas	TECo	Retrofitted Cost Electricity	Retrofitted Cost Gas	TCEr	Avoided annual Cost (AaC)	Cumulative Savings (CS)	Balance (Ba)
0	€ 3,870.29	€ 167.99	€ 4,038.28	€ 1,222.78	€ 167.99	€ 1,390.77	€ 2,647.51	€ 2,647.51	(€ 20,799.75)
1	€ 4,063.80	€ 176.39	€ 4,240.20	€ 1,283.91	€ 176.39	€ 1,460.31	€ 2,779.89	€ 5,427.40	(€ 18,019.86)
2	€ 4,266.99	€ 185.21	€ 4,452.21	€ 1,348.11	€ 185.21	€ 1,533.32	€ 2,918.88	€ 8,346.28	(€ 15,100.98)
3	€ 4,480.34	€ 194.47	€ 4,674.82	€ 1,415.52	€ 194.47	€ 1,609.99	€ 3,064.83	€ 11,411.11	(€ 12,036.15)
4	€ 4,704.36	€ 204.20	€ 4,908.56	€ 1,486.29	€ 204.20	€ 1,690.49	€ 3,218.07	€ 14,629.18	(€ 8,818.09)
5	€ 4,939.58	€ 214.41	€ 5,153.98	€ 1,560.61	€ 214.41	€ 1,775.01	€ 3,378.97	€ 18,008.15	(€ 5,439.12)
6	€ 5,186.56	€ 225.13	€ 5,411.68	€ 1,638.64	€ 225.13	€ 1,863.76	€ 3,547.92	€ 21,556.07	(€ 1,891.20)
7	€ 5,445.88	€ 236.38	€ 5,682.27	€ 1,720.57	€ 236.38	€ 1,956.95	€ 3,725.32	€ 25,281.38	€ 1,834.12
8	€ 5,718.18	€ 248.20	€ 5,966.38	€ 1,806.60	€ 248.20	€ 2,054.80	€ 3,911.58	€ 29,192.96	€ 5,745.70
9	€ 6,004.09	€ 260.61	€ 6,264.70	€ 1,896.93	€ 260.61	€ 2,157.54	€ 4,107.16	€ 33,300.12	€ 9,852.86
10	€ 6,304.29	€ 273.64	€ 6,577.94	€ 1,991.77	€ 273.64	€ 2,265.42	€ 4,312.52	€ 37,612.64	€ 14,165.38
11	€ 6,619.51	€ 287.33	€ 6,906.83	€ 2,091.36	€ 287.33	€ 2,378.69	€ 4,528.14	€ 42,140.78	€ 18,693.52
12	€ 6,950.48	€ 301.69	€ 7,252.17	€ 2,195.93	€ 301.69	€ 2,497.62	€ 4,754.55	€ 46,895.33	€ 23,448.07
13	€ 7,298.01	€ 316.78	€ 7,614.78	€ 2,305.73	€ 316.78	€ 2,622.50	€ 4,992.28	€ 51,887.61	€ 28,440.35
14	€ 7,662.91	€ 332.62	€ 7,995.52	€ 2,421.01	€ 332.62	€ 2,753.63	€ 5,241.89	€ 57,129.51	€ 33,682.24
15	€ 8,046.05	€ 349.25	€ 8,395.30	€ 2,542.06	€ 349.25	€ 2,891.31	€ 5,503.99	€ 62,633.49	€ 39,186.23
16	€ 8,448.35	€ 366.71	€ 8,815.06	€ 2,669.17	€ 366.71	€ 3,035.88	€ 5,779.19	€ 68,412.68	€ 44,965.42
17	€ 8,870.77	€ 385.05	€ 9,255.82	€ 2,802.62	€ 385.05	€ 3,187.67	€ 6,068.15	€ 74,480.83	€ 51,033.56
18	€ 9,314.31	€ 404.30	€ 9,718.61	€ 2,942.76	€ 404.30	€ 3,347.05	€ 6,371.55	€ 80,852.38	€ 57,405.12
19	€ 9,780.03	€ 424.51	€ 10,204.54	€ 3,089.89	€ 424.51	€ 3,514.41	€ 6,690.13	€ 87,542.51	€ 64,095.25
20	€ 10,269.03	€ 445.74	€ 10,714.76	€ 3,244.39	€ 445.74	€ 3,690.13	€ 7,024.64	€ 94,567.15	€ 71,119.89
21	€ 10,782.48	€ 468.02	€ 11,250.50	€ 3,406.61	€ 468.02	€ 3,874.63	€ 7,375.87	€ 101,943.02	€ 78,495.76
22	€ 11,321.60	€ 491.43	€ 11,813.03	€ 3,576.94	€ 491.43	€ 4,068.36	€ 7,744.66	€ 109,687.68	€ 86,240.42
23	€ 11,887.68	€ 516.00	€ 12,403.68	€ 3,755.79	€ 516.00	€ 4,271.78	€ 8,131.90	€ 117,819.58	€ 94,372.31
24	€ 12,482.07	€ 541.80	€ 13,023.86	€ 3,943.57	€ 541.80	€ 4,485.37	€ 8,538.49	€ 126,358.07	€ 102,910.80
25	€ 13,106.17	€ 568.89	€ 13,675.06	€ 4,140.75	€ 568.89	€ 4,709.64	€ 8,965.42	€ 135,323.48	€ 111,876.22
26	€ 13,761.48	€ 597.33	€ 14,358.81	€ 4,347.79	€ 597.33	€ 4,945.12	€ 9,413.69	€ 144,737.17	€ 121,289.91
27	€ 14,449.55	€ 627.20	€ 15,076.75	€ 4,565.18	€ 627.20	€ 5,192.38	€ 9,884.37	€ 154,621.54	€ 131,174.28
28	€ 15,172.03	€ 658.56	€ 15,830.59	€ 4,793.44	€ 658.56	€ 5,452.00	€ 10,378.59	€ 165,000.13	€ 141,552.87
29	€ 15,930.63	€ 691.49	€ 16,622.12	€ 5,033.11	€ 691.49	€ 5,724.60	€ 10,897.52	€ 175,897.65	€ 152,450.38

*Table 76: PBP calculation of Silica-aerogel (**Continuous**) PT*



Year	Reference cost Electricity	Reference cost Gas	TECo	Retrofitted Cost Electricity	Retrofitted Cost Gas	TCEr	Avoided annual Cost (AaC)	Cumulative Savings (CS)	Balance (Ba)
0	€ 1,782.76	€ 167.99	€ 1,950.75	€ 908.82	€ 167.99	€ 1,076.81	€ 873.94	€ 873.94	(€ 22,573.33)
1	€ 1,871.89	€ 176.39	€ 2,048.29	€ 954.26	€ 176.39	€ 1,130.65	€ 917.63	€ 1,791.57	(€ 21,655.69)
2	€ 1,965.49	€ 185.21	€ 2,150.70	€ 1,001.97	€ 185.21	€ 1,187.19	€ 963.51	€ 2,755.08	(€ 20,692.18)
3	€ 2,063.76	€ 194.47	€ 2,258.24	€ 1,052.07	€ 194.47	€ 1,246.55	€ 1,011.69	€ 3,766.77	(€ 19,680.49)
4	€ 2,166.95	€ 204.20	€ 2,371.15	€ 1,104.68	€ 204.20	€ 1,308.87	€ 1,062.27	€ 4,829.05	(€ 18,618.21)
5	€ 2,275.30	€ 214.41	€ 2,489.71	€ 1,159.91	€ 214.41	€ 1,374.32	€ 1,115.39	€ 5,944.44	(€ 17,502.83)
6	€ 2,389.06	€ 225.13	€ 2,614.19	€ 1,217.91	€ 225.13	€ 1,443.03	€ 1,171.16	€ 7,115.59	(€ 16,331.67)
7	€ 2,508.52	€ 236.38	€ 2,744.90	€ 1,278.80	€ 236.38	€ 1,515.19	€ 1,229.72	€ 8,345.31	(€ 15,101.95)
8	€ 2,633.94	€ 248.20	€ 2,882.15	€ 1,342.74	€ 248.20	€ 1,590.94	€ 1,291.20	€ 9,636.51	(€ 13,810.75)
9	€ 2,765.64	€ 260.61	€ 3,026.25	€ 1,409.88	€ 260.61	€ 1,670.49	€ 1,355.76	€ 10,992.27	(€ 12,454.99)
10	€ 2,903.92	€ 273.64	€ 3,177.57	€ 1,480.37	€ 273.64	€ 1,754.02	€ 1,423.55	€ 12,415.82	(€ 11,031.44)
11	€ 3,049.12	€ 287.33	€ 3,336.44	€ 1,554.39	€ 287.33	€ 1,841.72	€ 1,494.73	€ 13,910.55	(€ 9,536.71)
12	€ 3,201.57	€ 301.69	€ 3,503.27	€ 1,632.11	€ 301.69	€ 1,933.80	€ 1,569.46	€ 15,480.01	(€ 7,967.25)
13	€ 3,361.65	€ 316.78	€ 3,678.43	€ 1,713.72	€ 316.78	€ 2,030.49	€ 1,647.94	€ 17,127.95	(€ 6,319.31)
14	€ 3,529.73	€ 332.62	€ 3,862.35	€ 1,799.40	€ 332.62	€ 2,132.02	€ 1,730.33	€ 18,858.28	(€ 4,588.98)
15	€ 3,706.22	€ 349.25	€ 4,055.47	€ 1,889.37	€ 349.25	€ 2,238.62	€ 1,816.85	€ 20,675.13	(€ 2,772.13)
16	€ 3,891.53	€ 366.71	€ 4,258.24	€ 1,983.84	€ 366.71	€ 2,350.55	€ 1,907.69	€ 22,582.83	(€ 864.44)
17	€ 4,086.11	€ 385.05	€ 4,471.15	€ 2,083.03	€ 385.05	€ 2,468.08	€ 2,003.08	€ 24,585.90	€ 1,138.64
18	€ 4,290.41	€ 404.30	€ 4,694.71	€ 2,187.18	€ 404.30	€ 2,591.48	€ 2,103.23	€ 26,689.13	€ 3,241.87
19	€ 4,504.94	€ 424.51	€ 4,929.45	€ 2,296.54	€ 424.51	€ 2,721.06	€ 2,208.39	€ 28,897.53	€ 5,450.27
20	€ 4,730.18	€ 445.74	€ 5,175.92	€ 2,411.37	€ 445.74	€ 2,857.11	€ 2,318.81	€ 31,216.34	€ 7,769.08
21	€ 4,966.69	€ 468.02	€ 5,434.72	€ 2,531.94	€ 468.02	€ 2,999.96	€ 2,434.75	€ 33,651.09	€ 10,203.83
22	€ 5,215.03	€ 491.43	€ 5,706.45	€ 2,658.54	€ 491.43	€ 3,149.96	€ 2,556.49	€ 36,207.58	€ 12,760.32
23	€ 5,475.78	€ 516.00	€ 5,991.77	€ 2,791.46	€ 516.00	€ 3,307.46	€ 2,684.32	€ 38,891.90	€ 15,444.64
24	€ 5,749.57	€ 541.80	€ 6,291.36	€ 2,931.04	€ 541.80	€ 3,472.83	€ 2,818.53	€ 41,710.43	€ 18,263.17
25	€ 6,037.04	€ 568.89	€ 6,605.93	€ 3,077.59	€ 568.89	€ 3,646.47	€ 2,959.46	€ 44,669.89	€ 21,222.63
26	€ 6,338.90	€ 597.33	€ 6,936.23	€ 3,231.47	€ 597.33	€ 3,828.80	€ 3,107.43	€ 47,777.32	€ 24,330.06
27	€ 6,655.84	€ 627.20	€ 7,283.04	€ 3,393.04	€ 627.20	€ 4,020.24	€ 3,262.80	€ 51,040.12	€ 27,592.86
28	€ 6,988.63	€ 658.56	€ 7,647.19	€ 3,562.69	€ 658.56	€ 4,221.25	€ 3,425.94	€ 54,466.06	€ 31,018.80
29	€ 7,338.07	€ 691.49	€ 8,029.55	€ 3,740.83	€ 691.49	€ 4,432.31	€ 3,597.24	€ 58,063.30	€ 34,616.04

Table 77: PBP calculation of Silica-aerogel (Intermittent) PT**Bio-Aerogel & PV Vacuum Windows:**

PV VACUUM WINDOWS		
Lifetime	20	years
Total manufacturing with profit margin (20%)	€ 605.00	per m2
Auxiliary	€ 0.00	per m2
Installation	€ 247.00	per unit
Units installed	3	Units
Window area without sun	3.80	m2
Total Investment VACUUM WINDOWS	€ 3,040.00	

Table 78: Ci of Vacuum Windows for PT

Ci: Table 72 + Table 78 = **59,598.45 €**



Year	Reference cost Electricity	Reference cost Gas	TECo	Retrofitted Cost Electricity	Retrofitted Cost Gas	TCEr	Avoided annual Cost (AaC)	Cumulative Savings (CS)	Balance (Ba)
0	€ 3,870.29	€ 167.99	€ 4,038.28	€ 1,209.92	€ 167.99	€ 1,377.92	€ 2,660.36	€ 2,660.36	(€ 57,120.92)
1	€ 4,063.80	€ 176.39	€ 4,240.20	€ 1,270.42	€ 176.39	€ 1,446.81	€ 2,793.38	€ 5,453.75	(€ 54,327.54)
2	€ 4,266.99	€ 185.21	€ 4,452.21	€ 1,333.94	€ 185.21	€ 1,519.15	€ 2,933.05	€ 8,386.80	(€ 51,394.49)
3	€ 4,480.34	€ 194.47	€ 4,674.82	€ 1,400.64	€ 194.47	€ 1,595.11	€ 3,079.70	€ 11,466.50	(€ 48,314.78)
4	€ 4,704.36	€ 204.20	€ 4,908.56	€ 1,470.67	€ 204.20	€ 1,674.87	€ 3,233.69	€ 14,700.19	(€ 45,081.10)
5	€ 4,939.58	€ 214.41	€ 5,153.98	€ 1,544.20	€ 214.41	€ 1,758.61	€ 3,395.37	€ 18,095.56	(€ 41,685.72)
6	€ 5,186.56	€ 225.13	€ 5,411.68	€ 1,621.41	€ 225.13	€ 1,846.54	€ 3,565.14	€ 21,660.71	(€ 38,120.58)
7	€ 5,445.88	€ 236.38	€ 5,682.27	€ 1,702.48	€ 236.38	€ 1,938.87	€ 3,743.40	€ 25,404.11	(€ 34,377.18)
8	€ 5,718.18	€ 248.20	€ 5,966.38	€ 1,787.61	€ 248.20	€ 2,035.81	€ 3,930.57	€ 29,334.67	(€ 30,446.61)
9	€ 6,004.09	€ 260.61	€ 6,264.70	€ 1,876.99	€ 260.61	€ 2,137.60	€ 4,127.10	€ 33,461.77	(€ 26,319.51)
10	€ 6,304.29	€ 273.64	€ 6,577.94	€ 1,970.84	€ 273.64	€ 2,244.48	€ 4,333.45	€ 37,795.23	(€ 21,986.06)
11	€ 6,619.51	€ 287.33	€ 6,906.83	€ 2,069.38	€ 287.33	€ 2,356.71	€ 4,550.13	€ 42,345.35	(€ 17,435.94)
12	€ 6,950.48	€ 301.69	€ 7,252.17	€ 2,172.85	€ 301.69	€ 2,474.54	€ 4,777.63	€ 47,122.98	(€ 12,658.30)
13	€ 7,298.01	€ 316.78	€ 7,614.78	€ 2,281.49	€ 316.78	€ 2,598.27	€ 5,016.51	€ 52,139.49	(€ 7,641.79)
14	€ 7,662.91	€ 332.62	€ 7,995.52	€ 2,395.57	€ 332.62	€ 2,728.18	€ 5,267.34	€ 57,406.83	(€ 2,374.45)
15	€ 8,046.05	€ 349.25	€ 8,395.30	€ 2,515.35	€ 349.25	€ 2,864.59	€ 5,530.71	€ 62,937.54	€ 3,156.25
16	€ 8,448.35	€ 366.71	€ 8,815.06	€ 2,641.11	€ 366.71	€ 3,007.82	€ 5,807.24	€ 68,744.78	€ 8,963.49
17	€ 8,870.77	€ 385.05	€ 9,255.82	€ 2,773.17	€ 385.05	€ 3,158.21	€ 6,097.60	€ 74,842.38	€ 15,061.10
18	€ 9,314.31	€ 404.30	€ 9,718.61	€ 2,911.83	€ 404.30	€ 3,316.12	€ 6,402.48	€ 81,244.87	€ 21,463.58
19	€ 9,780.03	€ 424.51	€ 10,204.54	€ 3,057.42	€ 424.51	€ 3,481.93	€ 6,722.61	€ 87,967.47	€ 28,186.19
20	€ 10,269.03	€ 445.74	€ 10,714.76	€ 3,210.29	€ 445.74	€ 3,656.03	€ 7,058.74	€ 95,026.21	€ 35,244.93

Table 79: PBP calculation of Bio-aerogel & PV Vacuum Windows (**Continuous**) PT

Year	Reference cost Electricity	Reference cost Gas	TECo	Retrofitted Cost Electricity	Retrofitted Cost Gas	TCEr	Avoided annual Cost (AaC)	Cumulative Savings (CS)	Balance (Ba)
0	€ 1,782.76	€ 167.99	€ 1,950.75	€ 903.31	€ 167.99	€ 1,071.31	€ 879.44	€ 879.44	(€ 58,901.84)
1	€ 1,871.89	€ 176.39	€ 2,048.29	€ 948.48	€ 176.39	€ 1,124.87	€ 923.42	€ 1,802.86	(€ 57,978.43)
2	€ 1,965.49	€ 185.21	€ 2,150.70	€ 995.90	€ 185.21	€ 1,181.11	€ 969.59	€ 2,772.45	(€ 57,008.84)
3	€ 2,063.76	€ 194.47	€ 2,258.24	€ 1,045.70	€ 194.47	€ 1,240.17	€ 1,018.07	€ 3,790.51	(€ 55,990.77)
4	€ 2,166.95	€ 204.20	€ 2,371.15	€ 1,097.98	€ 204.20	€ 1,302.18	€ 1,068.97	€ 4,859.48	(€ 54,921.80)
5	€ 2,275.30	€ 214.41	€ 2,489.71	€ 1,152.88	€ 214.41	€ 1,367.29	€ 1,122.42	€ 5,981.90	(€ 53,799.38)
6	€ 2,389.06	€ 225.13	€ 2,614.19	€ 1,210.52	€ 225.13	€ 1,435.65	€ 1,178.54	€ 7,160.44	(€ 52,620.85)
7	€ 2,508.52	€ 236.38	€ 2,744.90	€ 1,271.05	€ 236.38	€ 1,507.44	€ 1,237.47	€ 8,397.91	(€ 51,383.38)
8	€ 2,633.94	€ 248.20	€ 2,882.15	€ 1,334.60	€ 248.20	€ 1,582.81	€ 1,299.34	€ 9,697.25	(€ 50,084.04)
9	€ 2,765.64	€ 260.61	€ 3,026.25	€ 1,401.33	€ 260.61	€ 1,661.95	€ 1,364.31	€ 11,061.55	(€ 48,719.73)
10	€ 2,903.92	€ 273.64	€ 3,177.57	€ 1,471.40	€ 273.64	€ 1,745.04	€ 1,432.52	€ 12,494.07	(€ 47,287.21)
11	€ 3,049.12	€ 287.33	€ 3,336.44	€ 1,544.97	€ 287.33	€ 1,832.30	€ 1,504.15	€ 13,998.22	(€ 45,783.06)
12	€ 3,201.57	€ 301.69	€ 3,503.27	€ 1,622.22	€ 301.69	€ 1,923.91	€ 1,579.36	€ 15,577.58	(€ 44,203.71)
13	€ 3,361.65	€ 316.78	€ 3,678.43	€ 1,703.33	€ 316.78	€ 2,020.11	€ 1,658.32	€ 17,235.90	(€ 42,545.39)
14	€ 3,529.73	€ 332.62	€ 3,862.35	€ 1,788.50	€ 332.62	€ 2,121.11	€ 1,741.24	€ 18,977.14	(€ 40,804.15)
15	€ 3,706.22	€ 349.25	€ 4,055.47	€ 1,877.92	€ 349.25	€ 2,227.17	€ 1,828.30	€ 20,805.44	(€ 38,975.85)
16	€ 3,891.53	€ 366.71	€ 4,258.24	€ 1,971.82	€ 366.71	€ 2,338.53	€ 1,919.72	€ 22,725.16	(€ 37,056.13)
17	€ 4,086.11	€ 385.05	€ 4,471.15	€ 2,070.41	€ 385.05	€ 2,455.45	€ 2,015.70	€ 24,740.86	(€ 35,040.43)
18	€ 4,290.41	€ 404.30	€ 4,694.71	€ 2,173.93	€ 404.30	€ 2,578.23	€ 2,116.49	€ 26,857.34	(€ 32,923.94)
19	€ 4,504.94	€ 424.51	€ 4,929.45	€ 2,282.62	€ 424.51	€ 2,707.14	€ 2,222.31	€ 29,079.65	(€ 30,701.63)
20	€ 4,730.18	€ 445.74	€ 5,175.92	€ 2,396.76	€ 445.74	€ 2,842.49	€ 2,333.43	€ 31,413.08	(€ 28,368.20)

Table 80 PBP calculation of Bio-aerogel & PV Vacuum Windows (**Intermittent**) PT



Bio-Aerogel & PV Vacuum Windows & PCM:

PCM		
Lifetime	25	years
Total Purchased cost	€ 96.00	per m2
Auxiliary	€ 0.00	
Installation	€ 10.00	per m2
Total per m2	€ 106.00	per m2
Total Area Utilized	48.01	m2
Total Investment PCM	€ 5,089.06	

Table 81: Ci of PCMs for PT

$$Ci = \text{Table 72} + \text{Table 78} + \text{Table 81} = 65,263.63 \text{ €}$$

Year	Reference cost Electricity	Reference cost Gas	TECo	Retrofitted Cost Electricity	Retrofitted Cost Gas	TCEr	Avoided annual Cost (AaC)	Cumulative Savings (CS)	Balance (Ba)
0	€ 3,870.29	€ 167.99	€ 4,038.28	€ 1,209.92	€ 167.99	€ 1,377.92	€ 2,660.36	€ 2,660.36	(€ 62,209.98)
1	€ 4,063.80	€ 176.39	€ 4,240.20	€ 1,270.42	€ 176.39	€ 1,446.81	€ 2,793.38	€ 5,453.75	(€ 59,416.60)
2	€ 4,266.99	€ 185.21	€ 4,452.21	€ 1,333.94	€ 185.21	€ 1,519.15	€ 2,933.05	€ 8,386.80	(€ 56,483.55)
3	€ 4,480.34	€ 194.47	€ 4,674.82	€ 1,400.64	€ 194.47	€ 1,595.11	€ 3,079.70	€ 11,466.50	(€ 53,403.84)
4	€ 4,704.36	€ 204.20	€ 4,908.56	€ 1,470.67	€ 204.20	€ 1,674.87	€ 3,233.69	€ 14,700.19	(€ 50,170.16)
5	€ 4,939.58	€ 214.41	€ 5,153.98	€ 1,544.20	€ 214.41	€ 1,758.61	€ 3,395.37	€ 18,095.56	(€ 46,774.78)
6	€ 5,186.56	€ 225.13	€ 5,411.68	€ 1,621.41	€ 225.13	€ 1,846.54	€ 3,565.14	€ 21,660.71	(€ 43,209.64)
7	€ 5,445.88	€ 236.38	€ 5,682.27	€ 1,702.48	€ 236.38	€ 1,938.87	€ 3,743.40	€ 25,404.11	(€ 39,466.24)
8	€ 5,718.18	€ 248.20	€ 5,966.38	€ 1,787.61	€ 248.20	€ 2,035.81	€ 3,930.57	€ 29,334.67	(€ 35,535.67)
9	€ 6,004.09	€ 260.61	€ 6,264.70	€ 1,876.99	€ 260.61	€ 2,137.60	€ 4,127.10	€ 33,461.77	(€ 31,408.57)
10	€ 6,304.29	€ 273.64	€ 6,577.94	€ 1,970.84	€ 273.64	€ 2,244.48	€ 4,333.45	€ 37,795.23	(€ 27,075.12)
11	€ 6,619.51	€ 287.33	€ 6,906.83	€ 2,069.38	€ 287.33	€ 2,356.71	€ 4,550.13	€ 42,345.35	(€ 22,525.00)
12	€ 6,950.48	€ 301.69	€ 7,252.17	€ 2,172.85	€ 301.69	€ 2,474.54	€ 4,777.63	€ 47,122.98	(€ 17,747.36)
13	€ 7,298.01	€ 316.78	€ 7,614.78	€ 2,281.49	€ 316.78	€ 2,598.27	€ 5,016.51	€ 52,139.49	(€ 12,730.85)
14	€ 7,662.91	€ 332.62	€ 7,995.52	€ 2,395.57	€ 332.62	€ 2,728.18	€ 5,267.34	€ 57,406.83	(€ 7,463.51)
15	€ 8,046.05	€ 349.25	€ 8,395.30	€ 2,515.35	€ 349.25	€ 2,864.59	€ 5,530.71	€ 62,937.54	(€ 1,932.81)
16	€ 8,448.35	€ 366.71	€ 8,815.06	€ 2,641.11	€ 366.71	€ 3,007.82	€ 5,807.24	€ 68,744.78	€ 3,874.43
17	€ 8,870.77	€ 385.05	€ 9,255.82	€ 2,773.17	€ 385.05	€ 3,158.21	€ 6,097.60	€ 74,842.38	€ 9,972.04
18	€ 9,314.31	€ 404.30	€ 9,718.61	€ 2,911.83	€ 404.30	€ 3,316.12	€ 6,402.48	€ 81,244.87	€ 16,374.52
19	€ 9,780.03	€ 424.51	€ 10,204.54	€ 3,057.42	€ 424.51	€ 3,481.93	€ 6,722.61	€ 87,967.47	€ 23,097.13
20	€ 10,269.03	€ 445.74	€ 10,714.76	€ 3,210.29	€ 445.74	€ 3,656.03	€ 7,058.74	€ 95,026.21	€ 30,155.87

Table 82: PBP calculation of Bio-aerogel & PV Vacuum Windows & PCMs (Continuous) PT

Year	Reference cost Electricity	Reference cost Gas	TECo	Retrofitted Cost Electricity	Retrofitted Cost Gas	TCEr	Avoided annual Cost (AaC)	Cumulative Savings (CS)	Balance (Ba)
0	€ 1,782.76	€ 167.99	€ 1,950.75	€ 894.13	€ 167.99	€ 1,062.13	€ 888.62	€ 888.62	(€ 63,981.72)
1	€ 1,871.89	€ 176.39	€ 2,048.29	€ 938.84	€ 176.39	€ 1,115.23	€ 933.06	€ 1,821.68	(€ 63,048.67)
2	€ 1,965.49	€ 185.21	€ 2,150.70	€ 985.78	€ 185.21	€ 1,170.99	€ 979.71	€ 2,801.39	(€ 62,068.96)
3	€ 2,063.76	€ 194.47	€ 2,258.24	€ 1,035.07	€ 194.47	€ 1,229.54	€ 1,028.69	€ 3,830.08	(€ 61,040.27)
4	€ 2,166.95	€ 204.20	€ 2,371.15	€ 1,086.82	€ 204.20	€ 1,291.02	€ 1,080.13	€ 4,910.21	(€ 59,960.14)
5	€ 2,275.30	€ 214.41	€ 2,489.71	€ 1,141.16	€ 214.41	€ 1,355.57	€ 1,134.13	€ 6,044.34	(€ 58,826.00)
6	€ 2,389.06	€ 225.13	€ 2,614.19	€ 1,198.22	€ 225.13	€ 1,423.35	€ 1,190.84	€ 7,235.18	(€ 57,635.16)
7	€ 2,508.52	€ 236.38	€ 2,744.90	€ 1,258.13	€ 236.38	€ 1,494.52	€ 1,250.38	€ 8,485.57	(€ 56,384.78)



8	€ 2,633.94	€ 248.20	€ 2,882.15	€ 1,321.04	€ 248.20	€ 1,569.24	€ 1,312.90	€ 9,798.47	(€ 55,071.88)
9	€ 2,765.64	€ 260.61	€ 3,026.25	€ 1,387.09	€ 260.61	€ 1,647.71	€ 1,378.55	€ 11,177.02	(€ 53,693.33)
10	€ 2,903.92	€ 273.64	€ 3,177.57	€ 1,456.45	€ 273.64	€ 1,730.09	€ 1,447.47	€ 12,624.49	(€ 52,245.85)
11	€ 3,049.12	€ 287.33	€ 3,336.44	€ 1,529.27	€ 287.33	€ 1,816.60	€ 1,519.85	€ 14,144.34	(€ 50,726.01)
12	€ 3,201.57	€ 301.69	€ 3,503.27	€ 1,605.73	€ 301.69	€ 1,907.43	€ 1,595.84	€ 15,740.18	(€ 49,130.16)
13	€ 3,361.65	€ 316.78	€ 3,678.43	€ 1,686.02	€ 316.78	€ 2,002.80	€ 1,675.63	€ 17,415.81	(€ 47,454.53)
14	€ 3,529.73	€ 332.62	€ 3,862.35	€ 1,770.32	€ 332.62	€ 2,102.94	€ 1,759.41	€ 19,175.23	(€ 45,695.12)
15	€ 3,706.22	€ 349.25	€ 4,055.47	€ 1,858.84	€ 349.25	€ 2,208.08	€ 1,847.39	€ 21,022.61	(€ 43,847.73)
16	€ 3,891.53	€ 366.71	€ 4,258.24	€ 1,951.78	€ 366.71	€ 2,318.49	€ 1,939.75	€ 22,962.37	(€ 41,907.98)
17	€ 4,086.11	€ 385.05	€ 4,471.15	€ 2,049.37	€ 385.05	€ 2,434.41	€ 2,036.74	€ 24,999.11	(€ 39,871.23)
18	€ 4,290.41	€ 404.30	€ 4,694.71	€ 2,151.84	€ 404.30	€ 2,556.13	€ 2,138.58	€ 27,137.69	(€ 37,732.65)
19	€ 4,504.94	€ 424.51	€ 4,929.45	€ 2,259.43	€ 424.51	€ 2,683.94	€ 2,245.51	€ 29,383.20	(€ 35,487.15)
20	€ 4,730.18	€ 445.74	€ 5,175.92	€ 2,372.40	€ 445.74	€ 2,818.14	€ 2,357.78	€ 31,740.98	(€ 33,129.36)

Table 83: PBP calculation of Bio-aerogel & PV Vacuum Windows & PCMs (*Intermittent*) PT

8.1.2 Infiltration for PT

WINCO Breathable Membrane 50% and 100% infiltration:

SKYTECH Breathable Membrane		
Lifetime	30	years
Total Purchased cost	€ 10.80	per m2
Auxiliary	€ 0.37	
Installation	€ 14.00	per m2
Total per m2	€ 25.17	per m2
Total Area Utilized	181.34	m2
Total Investment PCM	€ 4,564.33	

Table 84: Ci of Skytech Membrane for 50% and 100% infiltration for PT

Year	Reference cost Electricity	Reference cost Gas	TECo	Retrofitted Cost Electricity	Retrofitted Cost Gas	TCEr	Avoided annual Cost (AaC)	Cumulative Savings (CS)	Balance (Ba)
0	€ 3,870.29	€ 167.99	€ 4,038.28	€ 1,417.39	€ 167.99	€ 1,585.39	€ 2,452.90	€ 2,452.90	(€ 2,111.43)
1	€ 4,063.80	€ 176.39	€ 4,240.20	€ 1,488.26	€ 176.39	€ 1,664.66	€ 2,575.54	€ 5,028.44	€ 464.11
2	€ 4,266.99	€ 185.21	€ 4,452.21	€ 1,562.67	€ 185.21	€ 1,747.89	€ 2,704.32	€ 7,732.75	€ 3,168.43
3	€ 4,480.34	€ 194.47	€ 4,674.82	€ 1,640.81	€ 194.47	€ 1,835.28	€ 2,839.53	€ 10,572.29	€ 6,007.96
4	€ 4,704.36	€ 204.20	€ 4,908.56	€ 1,722.85	€ 204.20	€ 1,927.05	€ 2,981.51	€ 13,553.80	€ 8,989.47
5	€ 4,939.58	€ 214.41	€ 5,153.98	€ 1,808.99	€ 214.41	€ 2,023.40	€ 3,130.59	€ 16,684.38	€ 12,120.06
6	€ 5,186.56	€ 225.13	€ 5,411.68	€ 1,899.44	€ 225.13	€ 2,124.57	€ 3,287.12	€ 19,971.50	€ 15,407.17
7	€ 5,445.88	€ 236.38	€ 5,682.27	€ 1,994.41	€ 236.38	€ 2,230.80	€ 3,451.47	€ 23,422.97	€ 18,858.64
8	€ 5,718.18	€ 248.20	€ 5,966.38	€ 2,094.13	€ 248.20	€ 2,342.34	€ 3,624.04	€ 27,047.02	€ 22,482.69
9	€ 6,004.09	€ 260.61	€ 6,264.70	€ 2,198.84	€ 260.61	€ 2,459.45	€ 3,805.25	€ 30,852.26	€ 26,287.93
10	€ 6,304.29	€ 273.64	€ 6,577.94	€ 2,308.78	€ 273.64	€ 2,582.43	€ 3,995.51	€ 34,847.77	€ 30,283.44
11	€ 6,619.51	€ 287.33	€ 6,906.83	€ 2,424.22	€ 287.33	€ 2,711.55	€ 4,195.28	€ 39,043.06	€ 34,478.73
12	€ 6,950.48	€ 301.69	€ 7,252.17	€ 2,545.43	€ 301.69	€ 2,847.13	€ 4,405.05	€ 43,448.10	€ 38,883.78
13	€ 7,298.01	€ 316.78	€ 7,614.78	€ 2,672.70	€ 316.78	€ 2,989.48	€ 4,625.30	€ 48,073.41	€ 43,509.08
14	€ 7,662.91	€ 332.62	€ 7,995.52	€ 2,806.34	€ 332.62	€ 3,138.96	€ 4,856.57	€ 52,929.97	€ 48,365.64
15	€ 8,046.05	€ 349.25	€ 8,395.30	€ 2,946.66	€ 349.25	€ 3,295.90	€ 5,099.39	€ 58,029.37	€ 53,465.04
16	€ 8,448.35	€ 366.71	€ 8,815.06	€ 3,093.99	€ 366.71	€ 3,460.70	€ 5,354.36	€ 63,383.73	€ 58,819.40
17	€ 8,870.77	€ 385.05	€ 9,255.82	€ 3,248.69	€ 385.05	€ 3,633.73	€ 5,622.08	€ 69,005.81	€ 64,441.49
18	€ 9,314.31	€ 404.30	€ 9,718.61	€ 3,411.12	€ 404.30	€ 3,815.42	€ 5,903.19	€ 74,909.00	€ 70,344.67



19	€ 9,780.03	€ 424.51	€ 10,204.54	€ 3,581.68	€ 424.51	€ 4,006.19	€ 6,198.35	€ 81,107.35	€ 76,543.02
20	€ 10,269.03	€ 445.74	€ 10,714.76	€ 3,760.76	€ 445.74	€ 4,206.50	€ 6,508.26	€ 87,615.61	€ 83,051.28
21	€ 10,782.48	€ 468.02	€ 11,250.50	€ 3,948.80	€ 468.02	€ 4,416.83	€ 6,833.68	€ 94,449.29	€ 89,884.96
22	€ 11,321.60	€ 491.43	€ 11,813.03	€ 4,146.24	€ 491.43	€ 4,637.67	€ 7,175.36	€ 101,624.65	€ 97,060.32
23	€ 11,887.68	€ 516.00	€ 12,403.68	€ 4,353.55	€ 516.00	€ 4,869.55	€ 7,534.13	€ 109,158.78	€ 104,594.45
24	€ 12,482.07	€ 541.80	€ 13,023.86	€ 4,571.23	€ 541.80	€ 5,113.03	€ 7,910.83	€ 117,069.61	€ 112,505.28
25	€ 13,106.17	€ 568.89	€ 13,675.06	€ 4,799.79	€ 568.89	€ 5,368.68	€ 8,306.38	€ 125,375.99	€ 120,811.66
26	€ 13,761.48	€ 597.33	€ 14,358.81	€ 5,039.78	€ 597.33	€ 5,637.11	€ 8,721.70	€ 134,097.68	€ 129,533.35
27	€ 14,449.55	€ 627.20	€ 15,076.75	€ 5,291.77	€ 627.20	€ 5,918.97	€ 9,157.78	€ 143,255.46	€ 138,691.13
28	€ 15,172.03	€ 658.56	€ 15,830.59	€ 5,556.36	€ 658.56	€ 6,214.92	€ 9,615.67	€ 152,871.13	€ 148,306.80
29	€ 15,930.63	€ 691.49	€ 16,622.12	€ 5,834.18	€ 691.49	€ 6,525.66	€ 10,096.45	€ 162,967.58	€ 158,403.26
30	€ 16,727.16	€ 726.06	€ 17,453.22	€ 6,125.89	€ 726.06	€ 6,851.95	€ 10,601.28	€ 173,568.86	€ 169,004.53

Table 85: PBP calculation of 50% Infiltration (**Continuous**) PT

Year	Reference cost Electricity	Reference cost Gas	TECo	Retrofitted Cost Electricity	Retrofitted Cost Gas	TCeR	Avoided annual Cost (AaC)	Cumulative Savings (CS)	Balance (Ba)
0	€ 1,782.76	€ 167.99	€ 1,950.75	€ 1,015.31	€ 167.99	€ 1,183.30	€ 767.45	€ 767.45	(€ 3,796.88)
1	€ 1,871.89	€ 176.39	€ 2,048.29	€ 1,066.07	€ 176.39	€ 1,242.47	€ 805.82	€ 1,573.27	(€ 2,991.06)
2	€ 1,965.49	€ 185.21	€ 2,150.70	€ 1,119.38	€ 185.21	€ 1,304.59	€ 846.11	€ 2,419.38	(€ 2,144.95)
3	€ 2,063.76	€ 194.47	€ 2,258.24	€ 1,175.35	€ 194.47	€ 1,369.82	€ 888.42	€ 3,307.80	(€ 1,256.53)
4	€ 2,166.95	€ 204.20	€ 2,371.15	€ 1,234.11	€ 204.20	€ 1,438.31	€ 932.84	€ 4,240.63	(€ 323.69)
5	€ 2,275.30	€ 214.41	€ 2,489.71	€ 1,295.82	€ 214.41	€ 1,510.23	€ 979.48	€ 5,220.11	€ 655.79
6	€ 2,389.06	€ 225.13	€ 2,614.19	€ 1,360.61	€ 225.13	€ 1,585.74	€ 1,028.45	€ 6,248.57	€ 1,684.24
7	€ 2,508.52	€ 236.38	€ 2,744.90	€ 1,428.64	€ 236.38	€ 1,665.02	€ 1,079.88	€ 7,328.44	€ 2,764.12
8	€ 2,633.94	€ 248.20	€ 2,882.15	€ 1,500.07	€ 248.20	€ 1,748.28	€ 1,133.87	€ 8,462.31	€ 3,897.99
9	€ 2,765.64	€ 260.61	€ 3,026.25	€ 1,575.08	€ 260.61	€ 1,835.69	€ 1,190.56	€ 9,652.88	€ 5,088.55
10	€ 2,903.92	€ 273.64	€ 3,177.57	€ 1,653.83	€ 273.64	€ 1,927.47	€ 1,250.09	€ 10,902.97	€ 6,338.64
11	€ 3,049.12	€ 287.33	€ 3,336.44	€ 1,736.52	€ 287.33	€ 2,023.85	€ 1,312.60	€ 12,215.57	€ 7,651.24
12	€ 3,201.57	€ 301.69	€ 3,503.27	€ 1,823.35	€ 301.69	€ 2,125.04	€ 1,378.23	€ 13,593.79	€ 9,029.47
13	€ 3,361.65	€ 316.78	€ 3,678.43	€ 1,914.51	€ 316.78	€ 2,231.29	€ 1,447.14	€ 15,040.93	€ 10,476.60
14	€ 3,529.73	€ 332.62	€ 3,862.35	€ 2,010.24	€ 332.62	€ 2,342.86	€ 1,519.49	€ 16,560.43	€ 11,996.10
15	€ 3,706.22	€ 349.25	€ 4,055.47	€ 2,110.75	€ 349.25	€ 2,460.00	€ 1,595.47	€ 18,155.89	€ 13,591.57
16	€ 3,891.53	€ 366.71	€ 4,258.24	€ 2,216.29	€ 366.71	€ 2,583.00	€ 1,675.24	€ 19,831.14	€ 15,266.81
17	€ 4,086.11	€ 385.05	€ 4,471.15	€ 2,327.10	€ 385.05	€ 2,712.15	€ 1,759.00	€ 21,590.14	€ 17,025.81
18	€ 4,290.41	€ 404.30	€ 4,694.71	€ 2,443.46	€ 404.30	€ 2,847.76	€ 1,846.96	€ 23,437.10	€ 18,872.77
19	€ 4,504.94	€ 424.51	€ 4,929.45	€ 2,565.63	€ 424.51	€ 2,990.15	€ 1,939.30	€ 25,376.40	€ 20,812.07
20	€ 4,730.18	€ 445.74	€ 5,175.92	€ 2,693.91	€ 445.74	€ 3,139.65	€ 2,036.27	€ 27,412.67	€ 22,848.34
21	€ 4,966.69	€ 468.02	€ 5,434.72	€ 2,828.61	€ 468.02	€ 3,296.64	€ 2,138.08	€ 29,550.75	€ 24,986.42
22	€ 5,215.03	€ 491.43	€ 5,706.45	€ 2,970.04	€ 491.43	€ 3,461.47	€ 2,244.99	€ 31,795.74	€ 27,231.41
23	€ 5,475.78	€ 516.00	€ 5,991.77	€ 3,118.54	€ 516.00	€ 3,634.54	€ 2,357.23	€ 34,152.97	€ 29,588.64
24	€ 5,749.57	€ 541.80	€ 6,291.36	€ 3,274.47	€ 541.80	€ 3,816.27	€ 2,475.10	€ 36,628.07	€ 32,063.74
25	€ 6,037.04	€ 568.89	€ 6,605.93	€ 3,438.19	€ 568.89	€ 4,007.08	€ 2,598.85	€ 39,226.92	€ 34,662.59
26	€ 6,338.90	€ 597.33	€ 6,936.23	€ 3,610.10	€ 597.33	€ 4,207.43	€ 2,728.79	€ 41,955.71	€ 37,391.38
27	€ 6,655.84	€ 627.20	€ 7,283.04	€ 3,790.61	€ 627.20	€ 4,417.81	€ 2,865.23	€ 44,820.95	€ 40,256.62
28	€ 6,988.63	€ 658.56	€ 7,647.19	€ 3,980.14	€ 658.56	€ 4,638.70	€ 3,008.50	€ 47,829.44	€ 43,265.11
29	€ 7,338.07	€ 691.49	€ 8,029.55	€ 4,179.15	€ 691.49	€ 4,870.63	€ 3,158.92	€ 50,988.36	€ 46,424.03
30	€ 7,704.97	€ 726.06	€ 8,431.03	€ 4,388.10	€ 726.06	€ 5,114.16	€ 3,316.87	€ 54,305.23	€ 49,740.90

Table 86: PBP calculation of 50% Infiltration (**Intermittent**) PT



Year	Reference cost Electricity	Reference cost Gas	TECo	Retrofitted Cost Electricity	Retrofitted Cost Gas	TCEr	Avoided annual Cost (AaC)	Cumulative Savings (CS)	Balance (Ba)
0	€ 3,870.29	€ 167.99	€ 4,038.28	€ 1,378.84	€ 167.99	€ 1,546.83	€ 2,491.45	€ 2,491.45	(€ 2,072.88)
1	€ 4,063.80	€ 176.39	€ 4,240.20	€ 1,447.78	€ 176.39	€ 1,624.17	€ 2,616.02	€ 5,107.48	€ 543.15
2	€ 4,266.99	€ 185.21	€ 4,452.21	€ 1,520.17	€ 185.21	€ 1,705.38	€ 2,746.83	€ 7,854.30	€ 3,289.97
3	€ 4,480.34	€ 194.47	€ 4,674.82	€ 1,596.18	€ 194.47	€ 1,790.65	€ 2,884.17	€ 10,738.47	€ 6,174.14
4	€ 4,704.36	€ 204.20	€ 4,908.56	€ 1,675.98	€ 204.20	€ 1,880.18	€ 3,028.38	€ 13,766.85	€ 9,202.52
5	€ 4,939.58	€ 214.41	€ 5,153.98	€ 1,759.78	€ 214.41	€ 1,974.19	€ 3,179.79	€ 16,946.64	€ 12,382.31
6	€ 5,186.56	€ 225.13	€ 5,411.68	€ 1,847.77	€ 225.13	€ 2,072.90	€ 3,338.78	€ 20,285.42	€ 15,721.10
7	€ 5,445.88	€ 236.38	€ 5,682.27	€ 1,940.16	€ 236.38	€ 2,176.55	€ 3,505.72	€ 23,791.15	€ 19,226.82
8	€ 5,718.18	€ 248.20	€ 5,966.38	€ 2,037.17	€ 248.20	€ 2,285.37	€ 3,681.01	€ 27,472.16	€ 22,907.83
9	€ 6,004.09	€ 260.61	€ 6,264.70	€ 2,139.03	€ 260.61	€ 2,399.64	€ 3,865.06	€ 31,337.22	€ 26,772.89
10	€ 6,304.29	€ 273.64	€ 6,577.94	€ 2,245.98	€ 273.64	€ 2,519.62	€ 4,058.31	€ 35,395.53	€ 30,831.20
11	€ 6,619.51	€ 287.33	€ 6,906.83	€ 2,358.28	€ 287.33	€ 2,645.60	€ 4,261.23	€ 39,656.76	€ 35,092.43
12	€ 6,950.48	€ 301.69	€ 7,252.17	€ 2,476.19	€ 301.69	€ 2,777.88	€ 4,474.29	€ 44,131.05	€ 39,566.72
13	€ 7,298.01	€ 316.78	€ 7,614.78	€ 2,600.00	€ 316.78	€ 2,916.78	€ 4,698.00	€ 48,829.05	€ 44,264.72
14	€ 7,662.91	€ 332.62	€ 7,995.52	€ 2,730.00	€ 332.62	€ 3,062.62	€ 4,932.90	€ 53,761.96	€ 49,197.63
15	€ 8,046.05	€ 349.25	€ 8,395.30	€ 2,866.50	€ 349.25	€ 3,215.75	€ 5,179.55	€ 58,941.51	€ 54,377.18
16	€ 8,448.35	€ 366.71	€ 8,815.06	€ 3,009.83	€ 366.71	€ 3,376.54	€ 5,438.53	€ 64,380.03	€ 59,815.70
17	€ 8,870.77	€ 385.05	€ 9,255.82	€ 3,160.32	€ 385.05	€ 3,545.36	€ 5,710.45	€ 70,090.49	€ 65,526.16
18	€ 9,314.31	€ 404.30	€ 9,718.61	€ 3,318.33	€ 404.30	€ 3,722.63	€ 5,995.98	€ 76,086.46	€ 71,522.13
19	€ 9,780.03	€ 424.51	€ 10,204.54	€ 3,484.25	€ 424.51	€ 3,908.76	€ 6,295.78	€ 82,382.24	€ 77,817.91
20	€ 10,269.03	€ 445.74	€ 10,714.76	€ 3,658.46	€ 445.74	€ 4,104.20	€ 6,610.56	€ 88,992.80	€ 84,428.47
21	€ 10,782.48	€ 468.02	€ 11,250.50	€ 3,841.39	€ 468.02	€ 4,309.41	€ 6,941.09	€ 95,933.89	€ 91,369.57
22	€ 11,321.60	€ 491.43	€ 11,813.03	€ 4,033.45	€ 491.43	€ 4,524.88	€ 7,288.15	€ 103,222.04	€ 98,657.71
23	€ 11,887.68	€ 516.00	€ 12,403.68	€ 4,235.13	€ 516.00	€ 4,751.13	€ 7,652.55	€ 110,874.59	€ 106,310.27
24	€ 12,482.07	€ 541.80	€ 13,023.86	€ 4,446.88	€ 541.80	€ 4,988.68	€ 8,035.18	€ 118,909.78	€ 114,345.45
25	€ 13,106.17	€ 568.89	€ 13,675.06	€ 4,669.23	€ 568.89	€ 5,238.12	€ 8,436.94	€ 127,346.72	€ 122,782.39
26	€ 13,761.48	€ 597.33	€ 14,358.81	€ 4,902.69	€ 597.33	€ 5,500.02	€ 8,858.79	€ 136,205.50	€ 131,641.18
27	€ 14,449.55	€ 627.20	€ 15,076.75	€ 5,147.82	€ 627.20	€ 5,775.02	€ 9,301.73	€ 145,507.23	€ 140,942.90
28	€ 15,172.03	€ 658.56	€ 15,830.59	€ 5,405.22	€ 658.56	€ 6,063.77	€ 9,766.81	€ 155,274.05	€ 150,709.72
29	€ 15,930.63	€ 691.49	€ 16,622.12	€ 5,675.48	€ 691.49	€ 6,366.96	€ 10,255.15	€ 165,529.20	€ 160,964.87
30	€ 16,727.16	€ 726.06	€ 17,453.22	€ 5,959.25	€ 726.06	€ 6,685.31	€ 10,767.91	€ 176,297.11	€ 171,732.78

Table 87: PBP calculation of 100% Infiltration (Continuous) PT

Year	Reference cost Electricity	Reference cost Gas	TECo	Retrofitted Cost Electricity	Retrofitted Cost Gas	TCEr	Avoided annual Cost (AaC)	Cumulative Savings (CS)	Balance (Ba)
0	€ 1,782.76	€ 167.99	€ 1,950.75	€ 996.95	€ 167.99	€ 1,164.94	€ 785.81	€ 785.81	(€ 3,778.52)
1	€ 1,871.89	€ 176.39	€ 2,048.29	€ 1,046.80	€ 176.39	€ 1,223.19	€ 825.10	€ 1,610.91	(€ 2,953.42)
2	€ 1,965.49	€ 185.21	€ 2,150.70	€ 1,099.14	€ 185.21	€ 1,284.35	€ 866.35	€ 2,477.26	(€ 2,087.07)
3	€ 2,063.76	€ 194.47	€ 2,258.24	€ 1,154.09	€ 194.47	€ 1,348.57	€ 909.67	€ 3,386.93	(€ 1,177.40)
4	€ 2,166.95	€ 204.20	€ 2,371.15	€ 1,211.80	€ 204.20	€ 1,415.99	€ 955.15	€ 4,342.09	(€ 222.24)
5	€ 2,275.30	€ 214.41	€ 2,489.71	€ 1,272.39	€ 214.41	€ 1,486.79	€ 1,002.91	€ 5,345.00	€ 780.67
6	€ 2,389.06	€ 225.13	€ 2,614.19	€ 1,336.01	€ 225.13	€ 1,561.13	€ 1,053.06	€ 6,398.06	€ 1,833.73
7	€ 2,508.52	€ 236.38	€ 2,744.90	€ 1,402.81	€ 236.38	€ 1,639.19	€ 1,105.71	€ 7,503.77	€ 2,939.44
8	€ 2,633.94	€ 248.20	€ 2,882.15	€ 1,472.95	€ 248.20	€ 1,721.15	€ 1,161.00	€ 8,664.76	€ 4,100.43
9	€ 2,765.64	€ 260.61	€ 3,026.25	€ 1,546.59	€ 260.61	€ 1,807.21	€ 1,219.05	€ 9,883.81	€ 5,319.48
10	€ 2,903.92	€ 273.64	€ 3,177.57	€ 1,623.92	€ 273.64	€ 1,897.57	€ 1,280.00	€ 11,163.81	€ 6,599.48
11	€ 3,049.12	€ 287.33	€ 3,336.44	€ 1,705.12	€ 287.33	€ 1,992.45	€ 1,344.00	€ 12,507.81	€ 7,943.48



12	€ 3,201.57	€ 301.69	€ 3,503.27	€ 1,790.38	€ 301.69	€ 2,092.07	€ 1,411.20	€ 13,919.00	€ 9,354.68
13	€ 3,361.65	€ 316.78	€ 3,678.43	€ 1,879.89	€ 316.78	€ 2,196.67	€ 1,481.76	€ 15,400.76	€ 10,836.43
14	€ 3,529.73	€ 332.62	€ 3,862.35	€ 1,973.89	€ 332.62	€ 2,306.51	€ 1,555.85	€ 16,956.61	€ 12,392.28
15	€ 3,706.22	€ 349.25	€ 4,055.47	€ 2,072.58	€ 349.25	€ 2,421.83	€ 1,633.64	€ 18,590.25	€ 14,025.92
16	€ 3,891.53	€ 366.71	€ 4,258.24	€ 2,176.21	€ 366.71	€ 2,542.92	€ 1,715.32	€ 20,305.57	€ 15,741.24
17	€ 4,086.11	€ 385.05	€ 4,471.15	€ 2,285.02	€ 385.05	€ 2,670.07	€ 1,801.09	€ 22,106.65	€ 17,542.33
18	€ 4,290.41	€ 404.30	€ 4,694.71	€ 2,399.27	€ 404.30	€ 2,803.57	€ 1,891.14	€ 23,997.79	€ 19,433.47
19	€ 4,504.94	€ 424.51	€ 4,929.45	€ 2,519.24	€ 424.51	€ 2,943.75	€ 1,985.70	€ 25,983.49	€ 21,419.16
20	€ 4,730.18	€ 445.74	€ 5,175.92	€ 2,645.20	€ 445.74	€ 3,090.94	€ 2,084.98	€ 28,068.47	€ 23,504.15
21	€ 4,966.69	€ 468.02	€ 5,434.72	€ 2,777.46	€ 468.02	€ 3,245.48	€ 2,189.23	€ 30,257.71	€ 25,693.38
22	€ 5,215.03	€ 491.43	€ 5,706.45	€ 2,916.33	€ 491.43	€ 3,407.76	€ 2,298.69	€ 32,556.40	€ 27,992.07
23	€ 5,475.78	€ 516.00	€ 5,991.77	€ 3,062.15	€ 516.00	€ 3,578.15	€ 2,413.63	€ 34,970.03	€ 30,405.70
24	€ 5,749.57	€ 541.80	€ 6,291.36	€ 3,215.26	€ 541.80	€ 3,757.05	€ 2,534.31	€ 37,504.34	€ 32,940.01
25	€ 6,037.04	€ 568.89	€ 6,605.93	€ 3,376.02	€ 568.89	€ 3,944.91	€ 2,661.02	€ 40,165.36	€ 35,601.03
26	€ 6,338.90	€ 597.33	€ 6,936.23	€ 3,544.82	€ 597.33	€ 4,142.15	€ 2,794.08	€ 42,959.44	€ 38,395.11
27	€ 6,655.84	€ 627.20	€ 7,283.04	€ 3,722.06	€ 627.20	€ 4,349.26	€ 2,933.78	€ 45,893.22	€ 41,328.89
28	€ 6,988.63	€ 658.56	€ 7,647.19	€ 3,908.16	€ 658.56	€ 4,566.72	€ 3,080.47	€ 48,973.69	€ 44,409.36
29	€ 7,338.07	€ 691.49	€ 8,029.55	€ 4,103.57	€ 691.49	€ 4,795.06	€ 3,234.49	€ 52,208.18	€ 47,643.85
30	€ 7,704.97	€ 726.06	€ 8,431.03	€ 4,308.75	€ 726.06	€ 5,034.81	€ 3,396.22	€ 55,604.39	€ 51,040.07

Table 88: PBP calculation of 100% Infiltration (Intermittent) PT

WINCO Breathable Membrane 100% infiltration & WHR system:

WHR		
Lifetime	20	years
Total Purchased cost	€ 432.00	per m2
Auxiliary	€ 19.80	
Installation	€ 247.00	per m2
Total per m2	2	per m2
Total Investment PCM	€ 1,397.60	

Table 89: Ci of 100% infiltration & WHR for PT

$$Ci = \text{Table 84} + \text{Table 89} = 6,567.27 \text{ €}$$

Year	Reference cost Electricity	Reference cost Gas	TECo	Retrofitted Cost Electricity	Retrofitted Cost Gas	TCEr	Avoided annual Cost (AaC)	Cumulative Savings (CS)	Balance (Ba)
0	€ 3,870.29	€ 167.99	€ 4,038.28	€ 1,799.28	€ 168.91	€ 1,968.19	€ 2,070.09	€ 2,070.09	(€ 3,891.84)
1	€ 4,063.80	€ 176.39	€ 4,240.20	€ 1,889.24	€ 177.36	€ 2,066.60	€ 2,173.59	€ 4,243.68	(€ 1,718.24)
2	€ 4,266.99	€ 185.21	€ 4,452.21	€ 1,983.71	€ 186.23	€ 2,169.93	€ 2,282.27	€ 6,525.96	€ 564.03
3	€ 4,480.34	€ 194.47	€ 4,674.82	€ 2,082.89	€ 195.54	€ 2,278.43	€ 2,396.39	€ 8,922.35	€ 2,960.42
4	€ 4,704.36	€ 204.20	€ 4,908.56	€ 2,187.04	€ 205.31	€ 2,392.35	€ 2,516.21	€ 11,438.55	€ 5,476.63
5	€ 4,939.58	€ 214.41	€ 5,153.98	€ 2,296.39	€ 215.58	€ 2,511.97	€ 2,642.02	€ 14,080.57	€ 8,118.64
6	€ 5,186.56	€ 225.13	€ 5,411.68	€ 2,411.21	€ 226.36	€ 2,637.57	€ 2,774.12	€ 16,854.69	€ 10,892.76
7	€ 5,445.88	€ 236.38	€ 5,682.27	€ 2,531.77	€ 237.68	€ 2,769.44	€ 2,912.82	€ 19,767.51	€ 13,805.59
8	€ 5,718.18	€ 248.20	€ 5,966.38	€ 2,658.36	€ 249.56	€ 2,907.92	€ 3,058.47	€ 22,825.98	€ 16,864.05
9	€ 6,004.09	€ 260.61	€ 6,264.70	€ 2,791.27	€ 262.04	€ 3,053.31	€ 3,211.39	€ 26,037.37	€ 20,075.44
10	€ 6,304.29	€ 273.64	€ 6,577.94	€ 2,930.84	€ 275.14	€ 3,205.98	€ 3,371.96	€ 29,409.33	€ 23,447.40
11	€ 6,619.51	€ 287.33	€ 6,906.83	€ 3,077.38	€ 288.90	€ 3,366.28	€ 3,540.56	€ 32,949.88	€ 26,987.96
12	€ 6,950.48	€ 301.69	€ 7,252.17	€ 3,231.25	€ 303.34	€ 3,534.59	€ 3,717.58	€ 36,667.47	€ 30,705.54
13	€ 7,298.01	€ 316.78	€ 7,614.78	€ 3,392.81	€ 318.51	€ 3,711.32	€ 3,903.46	€ 40,570.93	€ 34,609.00



14	€ 7,662.91	€ 332.62	€ 7,995.52	€ 3,562.45	€ 334.43	€ 3,896.89	€ 4,098.64	€ 44,669.57	€ 38,707.64
15	€ 8,046.05	€ 349.25	€ 8,395.30	€ 3,740.57	€ 351.16	€ 4,091.73	€ 4,303.57	€ 48,973.14	€ 43,011.21
16	€ 8,448.35	€ 366.71	€ 8,815.06	€ 3,927.60	€ 368.71	€ 4,296.32	€ 4,518.75	€ 53,491.88	€ 47,529.96
17	€ 8,870.77	€ 385.05	€ 9,255.82	€ 4,123.98	€ 387.15	€ 4,511.13	€ 4,744.68	€ 58,236.57	€ 52,274.64
18	€ 9,314.31	€ 404.30	€ 9,718.61	€ 4,330.18	€ 406.51	€ 4,736.69	€ 4,981.92	€ 63,218.49	€ 57,256.56
19	€ 9,780.03	€ 424.51	€ 10,204.54	€ 4,546.69	€ 426.83	€ 4,973.52	€ 5,231.01	€ 68,449.50	€ 62,487.57
20	€ 10,269.03	€ 445.74	€ 10,714.76	€ 4,774.03	€ 448.17	€ 5,222.20	€ 5,492.57	€ 73,942.07	€ 67,980.14

Table 90: PBP calculation of 100% Infiltration & WHR (**Continuous**) PT

Year	Reference cost Electricity	Reference cost Gas	TECo	Retrofitted Cost Electricity	Retrofitted Cost Gas	TCEr	Avoided annual Cost (AaC)	Cumulative Savings (CS)	Balance (Ba)
0	€ 1,782.76	€ 167.99	€ 1,950.75	€ 1,226.45	€ 167.99	€ 1,394.44	€ 556.31	€ 556.31	(€ 5,405.62)
1	€ 1,871.89	€ 176.39	€ 2,048.29	€ 1,287.77	€ 176.39	€ 1,464.16	€ 584.12	€ 1,140.43	(€ 4,821.50)
2	€ 1,965.49	€ 185.21	€ 2,150.70	€ 1,352.16	€ 185.21	€ 1,537.37	€ 613.33	€ 1,753.76	(€ 4,208.17)
3	€ 2,063.76	€ 194.47	€ 2,258.24	€ 1,419.77	€ 194.47	€ 1,614.24	€ 644.00	€ 2,397.76	(€ 3,564.17)
4	€ 2,166.95	€ 204.20	€ 2,371.15	€ 1,490.76	€ 204.20	€ 1,694.95	€ 676.20	€ 3,073.95	(€ 2,887.97)
5	€ 2,275.30	€ 214.41	€ 2,489.71	€ 1,565.29	€ 214.41	€ 1,779.70	€ 710.01	€ 3,783.96	(€ 2,177.97)
6	€ 2,389.06	€ 225.13	€ 2,614.19	€ 1,643.56	€ 225.13	€ 1,868.69	€ 745.51	€ 4,529.46	(€ 1,432.46)
7	€ 2,508.52	€ 236.38	€ 2,744.90	€ 1,725.74	€ 236.38	€ 1,962.12	€ 782.78	€ 5,312.25	(€ 649.68)
8	€ 2,633.94	€ 248.20	€ 2,882.15	€ 1,812.02	€ 248.20	€ 2,060.23	€ 821.92	€ 6,134.17	€ 172.24
9	€ 2,765.64	€ 260.61	€ 3,026.25	€ 1,902.62	€ 260.61	€ 2,163.24	€ 863.02	€ 6,997.18	€ 1,035.25
10	€ 2,903.92	€ 273.64	€ 3,177.57	€ 1,997.75	€ 273.64	€ 2,271.40	€ 906.17	€ 7,903.35	€ 1,941.42
11	€ 3,049.12	€ 287.33	€ 3,336.44	€ 2,097.64	€ 287.33	€ 2,384.97	€ 951.48	€ 8,854.82	€ 2,892.90
12	€ 3,201.57	€ 301.69	€ 3,503.27	€ 2,202.52	€ 301.69	€ 2,504.22	€ 999.05	€ 9,853.87	€ 3,891.95
13	€ 3,361.65	€ 316.78	€ 3,678.43	€ 2,312.65	€ 316.78	€ 2,629.43	€ 1,049.00	€ 10,902.88	€ 4,940.95
14	€ 3,529.73	€ 332.62	€ 3,862.35	€ 2,428.28	€ 332.62	€ 2,760.90	€ 1,101.45	€ 12,004.33	€ 6,042.40
15	€ 3,706.22	€ 349.25	€ 4,055.47	€ 2,549.70	€ 349.25	€ 2,898.94	€ 1,156.52	€ 13,160.85	€ 7,198.92
16	€ 3,891.53	€ 366.71	€ 4,258.24	€ 2,677.18	€ 366.71	€ 3,043.89	€ 1,214.35	€ 14,375.20	€ 8,413.27
17	€ 4,086.11	€ 385.05	€ 4,471.15	€ 2,811.04	€ 385.05	€ 3,196.09	€ 1,275.07	€ 15,650.27	€ 9,688.34
18	€ 4,290.41	€ 404.30	€ 4,694.71	€ 2,951.59	€ 404.30	€ 3,355.89	€ 1,338.82	€ 16,989.09	€ 11,027.16
19	€ 4,504.94	€ 424.51	€ 4,929.45	€ 3,099.17	€ 424.51	€ 3,523.69	€ 1,405.76	€ 18,394.85	€ 12,432.93
20	€ 4,730.18	€ 445.74	€ 5,175.92	€ 3,254.13	€ 445.74	€ 3,699.87	€ 1,476.05	€ 19,870.91	€ 13,908.98

Table 91: PBP calculation of 100% Infiltration & WHR (**Intermittent**) PT

8.1.3 Active Technologies for PT

PV/T		
Lifetime	30	years
Total Purchased cost	€ 350.00	per m2
Installation	€ 140.00	
Auxiliary	€ 300.00	per m2
Maintenance	€ 140.00	
Energy Sold to the Grid	€ 2856	kWh
Price per kWh	€ 140.00	Total
Total Income of energy sold to the grid	€ 0.04	
PV units (1.66 m ²)	14	per m2
Total Investment PVT	€ 11,060.00	

Table 92: Ci of PVT for PT



Year	Reference cost Electricity	Reference cost Gas	TECo	Retrofitted Cost Electricity	Retrofitted Cost Gas	TCEr	Income Solar en Sold	Avoided annual Cost (AaC)	Cumulative Savings (CS)	Balance (Ba)
0	€ 3,870.29	€ 167.99	€ 4,038.28	€ 3,484.73	€ 41.31	€ 3,526.04	€ 114.24	€ 512.24	€ 512.24	(€ 10,547.76)
1	€ 4,063.80	€ 176.39	€ 4,240.20	€ 3,658.96	€ 43.38	€ 3,702.34	€ 119.95	€ 512.10	€ 1,024.34	(€ 10,035.66)
2	€ 4,266.99	€ 185.21	€ 4,452.21	€ 3,841.91	€ 45.54	€ 3,887.46	€ 125.95	€ 544.70	€ 1,569.04	(€ 9,490.96)
3	€ 4,480.34	€ 194.47	€ 4,674.82	€ 4,034.01	€ 47.82	€ 4,081.83	€ 132.25	€ 578.94	€ 2,147.98	(€ 8,912.02)
4	€ 4,704.36	€ 204.20	€ 4,908.56	€ 4,235.71	€ 50.21	€ 4,285.92	€ 138.86	€ 614.88	€ 2,762.86	(€ 8,297.14)
5	€ 4,939.58	€ 214.41	€ 5,153.98	€ 4,447.49	€ 52.72	€ 4,500.22	€ 145.80	€ 652.63	€ 3,415.49	(€ 7,644.51)
6	€ 5,186.56	€ 225.13	€ 5,411.68	€ 4,669.87	€ 55.36	€ 4,725.23	€ 153.09	€ 692.26	€ 4,107.75	(€ 6,952.25)
7	€ 5,445.88	€ 236.38	€ 5,682.27	€ 4,903.36	€ 58.13	€ 4,961.49	€ 160.75	€ 733.87	€ 4,841.62	(€ 6,218.38)
8	€ 5,718.18	€ 248.20	€ 5,966.38	€ 5,148.53	€ 61.03	€ 5,209.56	€ 168.78	€ 777.56	€ 5,619.18	(€ 5,440.82)
9	€ 6,004.09	€ 260.61	€ 6,264.70	€ 5,405.96	€ 64.09	€ 5,470.04	€ 177.22	€ 823.44	€ 6,442.62	(€ 4,617.38)
10	€ 6,304.29	€ 273.64	€ 6,577.94	€ 5,676.25	€ 67.29	€ 5,743.54	€ 186.08	€ 871.62	€ 7,314.24	(€ 3,745.76)
11	€ 6,619.51	€ 287.33	€ 6,906.83	€ 5,960.07	€ 70.65	€ 6,030.72	€ 195.39	€ 922.20	€ 8,236.44	(€ 2,823.56)
12	€ 6,950.48	€ 301.69	€ 7,252.17	€ 6,258.07	€ 74.19	€ 6,332.26	€ 205.16	€ 975.31	€ 9,211.74	(€ 1,848.26)
13	€ 7,298.01	€ 316.78	€ 7,614.78	€ 6,570.97	€ 77.90	€ 6,648.87	€ 215.42	€ 1,031.07	€ 10,242.81	(€ 817.19)
14	€ 7,662.91	€ 332.62	€ 7,995.52	€ 6,899.52	€ 81.79	€ 6,981.31	€ 226.19	€ 1,089.62	€ 11,332.44	€ 272.44
15	€ 8,046.05	€ 349.25	€ 8,395.30	€ 7,244.50	€ 85.88	€ 7,330.38	€ 237.50	€ 1,151.11	€ 12,483.54	€ 1,423.54
16	€ 8,448.35	€ 366.71	€ 8,815.06	€ 7,606.72	€ 90.17	€ 7,696.90	€ 249.37	€ 1,215.66	€ 13,699.20	€ 2,639.20
17	€ 8,870.77	€ 385.05	€ 9,255.82	€ 7,987.06	€ 94.68	€ 8,081.74	€ 261.84	€ 1,283.44	€ 14,982.65	€ 3,922.65
18	€ 9,314.31	€ 404.30	€ 9,718.61	€ 8,386.41	€ 99.42	€ 8,485.83	€ 274.93	€ 1,354.62	€ 16,337.27	€ 5,277.27
19	€ 9,780.03	€ 424.51	€ 10,204.54	€ 8,805.73	€ 104.39	€ 8,910.12	€ 288.68	€ 1,429.35	€ 17,766.61	€ 6,706.61
20	€ 10,269.03	€ 445.74	€ 10,714.76	€ 9,246.02	€ 109.61	€ 9,355.63	€ 303.11	€ 1,507.81	€ 19,274.43	€ 8,214.43

Table 93: PBP calculation of PVT (Continuous) PT

Year	Reference cost Electricity	Reference cost Gas	TECo	Retrofitted Cost Electricity	Retrofitted Cost Gas	TCEr	Income Solar en Sold	Avoided annual Cost (AaC)	Cumulative Savings (CS)	Balance (Ba)
0	€ 1,782.76	€ 167.99	€ 1,950.75	€ 1,624.86	€ 41.31	€ 1,666.17	€ 114.24	€ 284.58	€ 284.58	(€ 10,775.42)
1	€ 1,871.89	€ 176.39	€ 2,048.29	€ 1,706.10	€ 43.38	€ 1,749.48	€ 119.95	€ 273.05	€ 557.63	(€ 10,502.37)
2	€ 1,965.49	€ 185.21	€ 2,150.70	€ 1,791.41	€ 45.54	€ 1,836.95	€ 125.95	€ 293.70	€ 851.33	(€ 10,208.67)
3	€ 2,063.76	€ 194.47	€ 2,258.24	€ 1,880.98	€ 47.82	€ 1,928.80	€ 132.25	€ 315.39	€ 1,166.72	(€ 9,893.28)
4	€ 2,166.95	€ 204.20	€ 2,371.15	€ 1,975.03	€ 50.21	€ 2,025.24	€ 138.86	€ 338.16	€ 1,504.87	(€ 9,555.13)
5	€ 2,275.30	€ 214.41	€ 2,489.71	€ 2,073.78	€ 52.72	€ 2,126.50	€ 145.80	€ 362.06	€ 1,866.94	(€ 9,193.06)
6	€ 2,389.06	€ 225.13	€ 2,614.19	€ 2,177.47	€ 55.36	€ 2,232.83	€ 153.09	€ 387.17	€ 2,254.10	(€ 8,805.90)
7	€ 2,508.52	€ 236.38	€ 2,744.90	€ 2,286.34	€ 58.13	€ 2,344.47	€ 160.75	€ 413.53	€ 2,667.63	(€ 8,392.37)
8	€ 2,633.94	€ 248.20	€ 2,882.15	€ 2,400.66	€ 61.03	€ 2,461.69	€ 168.78	€ 441.20	€ 3,108.83	(€ 7,951.17)
9	€ 2,765.64	€ 260.61	€ 3,026.25	€ 2,520.69	€ 64.09	€ 2,584.78	€ 177.22	€ 470.26	€ 3,579.09	(€ 7,480.91)
10	€ 2,903.92	€ 273.64	€ 3,177.57	€ 2,646.73	€ 67.29	€ 2,714.02	€ 186.08	€ 500.77	€ 4,079.87	(€ 6,980.13)
11	€ 3,049.12	€ 287.33	€ 3,336.44	€ 2,779.06	€ 70.65	€ 2,849.72	€ 195.39	€ 532.81	€ 4,612.68	(€ 6,447.32)
12	€ 3,201.57	€ 301.69	€ 3,503.27	€ 2,918.02	€ 74.19	€ 2,992.20	€ 205.16	€ 566.45	€ 5,179.13	(€ 5,880.87)
13	€ 3,361.65	€ 316.78	€ 3,678.43	€ 3,063.92	€ 77.90	€ 3,141.81	€ 215.42	€ 601.78	€ 5,780.91	(€ 5,279.09)
14	€ 3,529.73	€ 332.62	€ 3,862.35	€ 3,217.11	€ 81.79	€ 3,298.90	€ 226.19	€ 638.87	€ 6,419.78	(€ 4,640.22)
15	€ 3,706.22	€ 349.25	€ 4,055.47	€ 3,377.97	€ 85.88	€ 3,463.85	€ 237.50	€ 677.81	€ 7,097.58	(€ 3,962.42)
16	€ 3,891.53	€ 366.71	€ 4,258.24	€ 3,546.87	€ 90.17	€ 3,637.04	€ 249.37	€ 718.70	€ 7,816.28	(€ 3,243.72)
17	€ 4,086.11	€ 385.05	€ 4,471.15	€ 3,724.21	€ 94.68	€ 3,818.89	€ 261.84	€ 761.63	€ 8,577.92	(€ 2,482.08)
18	€ 4,290.41	€ 404.30	€ 4,694.71	€ 3,910.42	€ 99.42	€ 4,009.84	€ 274.93	€ 806.72	€ 9,384.63	(€ 1,675.37)



19	€ 4,504.94	€ 424.51	€ 4,929.45	€ 4,105.94	€ 104.39	€ 4,210.33	€ 288.68	€ 854.05	€ 10,238.69	(€ 821.31)
20	€ 4,730.18	€ 445.74	€ 5,175.92	€ 4,311.24	€ 109.61	€ 4,420.85	€ 303.11	€ 903.75	€ 11,142.44	€ 82.44

Table 94: PBP calculation of PVT (Intermittent) PT

SAHP		
Lifetime	15	years
Total manufacturing with profit margin (5%)	€ 3,710.70	per panel
Installation	€ 750.00	per panel
Auxiliary cost	€ 4,998.00	per panel
Maintenance	€ 180.00	per year
Total Investment SAHP	€ 9,458.70	

Table 95: Ci of SAHP for PT

Year	Reference cost Electricity	Reference cost Gas	TECo	Retrofitted Cost Electr	Retrofitted Cost Gas	TCEr	Income Solar en Sold	Avoided annual Cost (AaC)	Cumulative Savings (CS)	Balance (Ba)
0	€ 3,870.29	€ 167.99	€ 4,038.28	€ 3,962.09	€ 33.97	€ 3,996.05	€ 42.23	€ 42.23	(€ 9,416.47)	€ 3,870.29
1	€ 4,063.80	€ 176.39	€ 4,240.20	€ 4,160.19	€ 35.66	€ 4,195.86	(€ 135.66)	(€ 93.43)	(€ 9,552.13)	€ 4,063.80
2	€ 4,266.99	€ 185.21	€ 4,452.21	€ 4,368.20	€ 37.45	€ 4,405.65	(€ 133.44)	(€ 226.88)	(€ 9,685.58)	€ 4,266.99
3	€ 4,480.34	€ 194.47	€ 4,674.82	€ 4,586.61	€ 39.32	€ 4,625.93	(€ 131.12)	(€ 357.99)	(€ 9,816.69)	€ 4,480.34
4	€ 4,704.36	€ 204.20	€ 4,908.56	€ 4,815.94	€ 41.29	€ 4,857.23	(€ 128.67)	(€ 486.66)	(€ 9,945.36)	€ 4,704.36
5	€ 4,939.58	€ 214.41	€ 5,153.98	€ 5,056.74	€ 43.35	€ 5,100.09	(€ 126.11)	(€ 612.77)	(€ 10,071.47)	€ 4,939.58
6	€ 5,186.56	€ 225.13	€ 5,411.68	€ 5,309.58	€ 45.52	€ 5,355.09	(€ 123.41)	(€ 736.18)	(€ 10,194.88)	€ 5,186.56
7	€ 5,445.88	€ 236.38	€ 5,682.27	€ 5,575.06	€ 47.79	€ 5,622.85	(€ 120.58)	(€ 856.76)	(€ 10,315.46)	€ 5,445.88
8	€ 5,718.18	€ 248.20	€ 5,966.38	€ 5,853.81	€ 50.18	€ 5,903.99	(€ 117.61)	(€ 974.37)	(€ 10,433.07)	€ 5,718.18
9	€ 6,004.09	€ 260.61	€ 6,264.70	€ 6,146.50	€ 52.69	€ 6,199.19	(€ 114.49)	(€ 1,088.86)	(€ 10,547.56)	€ 6,004.09
10	€ 6,304.29	€ 273.64	€ 6,577.94	€ 6,453.82	€ 55.33	€ 6,509.15	(€ 111.22)	(€ 1,200.08)	(€ 10,658.78)	€ 6,304.29
11	€ 6,619.51	€ 287.33	€ 6,906.83	€ 6,776.52	€ 58.09	€ 6,834.61	(€ 107.78)	(€ 1,307.85)	(€ 10,766.55)	€ 6,619.51
12	€ 6,950.48	€ 301.69	€ 7,252.17	€ 7,115.34	€ 61.00	€ 7,176.34	(€ 104.16)	(€ 1,412.02)	(€ 10,870.72)	€ 6,950.48
13	€ 7,298.01	€ 316.78	€ 7,614.78	€ 7,471.11	€ 64.05	€ 7,535.16	(€ 100.37)	(€ 1,512.39)	(€ 10,971.09)	€ 7,298.01
14	€ 7,662.91	€ 332.62	€ 7,995.52	€ 7,844.66	€ 67.25	€ 7,911.91	(€ 96.39)	(€ 1,608.78)	(€ 11,067.48)	€ 7,662.91
15	€ 8,046.05	€ 349.25	€ 8,395.30	€ 8,236.90	€ 70.61	€ 8,307.51	(€ 92.21)	(€ 1,700.99)	(€ 11,159.69)	€ 8,046.05

Table 96: PBP calculation of SAHP (Continuous) PT

Year	Reference cost Electricity	Reference cost Gas	TECo	Retrofitted Cost Electr	Retrofitted Cost Gas	TCEr	Income Solar en Sold	Avoided annual Cost (AaC)	Cumulative Savings (CS)	Balance (Ba)
0	€ 1,782.76	€ 167.99	€ 1,950.75	€ 1,872.72	€ 33.97	€ 1,906.69	€ 44.06	€ 44.06	(€ 9,414.64)	€ 1,782.76
1	€ 1,871.89	€ 176.39	€ 2,048.29	€ 1,966.36	€ 35.66	€ 2,002.02	(€ 133.73)	(€ 89.67)	(€ 9,548.37)	€ 1,871.89
2	€ 1,965.49	€ 185.21	€ 2,150.70	€ 2,064.67	€ 37.45	€ 2,102.12	(€ 131.42)	(€ 221.09)	(€ 9,679.79)	€ 1,965.49
3	€ 2,063.76	€ 194.47	€ 2,258.24	€ 2,167.91	€ 39.32	€ 2,207.23	(€ 128.99)	(€ 350.08)	(€ 9,808.78)	€ 2,063.76
4	€ 2,166.95	€ 204.20	€ 2,371.15	€ 2,276.30	€ 41.29	€ 2,317.59	(€ 126.44)	(€ 476.52)	(€ 9,935.22)	€ 2,166.95
5	€ 2,275.30	€ 214.41	€ 2,489.71	€ 2,390.12	€ 43.35	€ 2,433.47	(€ 123.76)	(€ 600.28)	(€ 10,058.98)	€ 2,275.30
6	€ 2,389.06	€ 225.13	€ 2,614.19	€ 2,509.62	€ 45.52	€ 2,555.14	(€ 120.95)	(€ 721.23)	(€ 10,179.93)	€ 2,389.06
7	€ 2,508.52	€ 236.38	€ 2,744.90	€ 2,635.11	€ 47.79	€ 2,682.90	(€ 118.00)	(€ 839.23)	(€ 10,297.93)	€ 2,508.52
8	€ 2,633.94	€ 248.20	€ 2,882.15	€ 2,766.86	€ 50.18	€ 2,817.04	(€ 114.90)	(€ 954.13)	(€ 10,412.83)	€ 2,633.94
9	€ 2,765.64	€ 260.61	€ 3,026.25	€ 2,905.20	€ 52.69	€ 2,957.90	(€ 111.64)	(€ 1,065.77)	(€ 10,524.47)	€ 2,765.64
10	€ 2,903.92	€ 273.64	€ 3,177.57	€ 3,050.46	€ 55.33	€ 3,105.79	(€ 108.22)	(€ 1,173.99)	(€ 10,632.69)	€ 2,903.92
11	€ 3,049.12	€ 287.33	€ 3,336.44	€ 3,202.99	€ 58.09	€ 3,261.08	(€ 104.64)	(€ 1,278.63)	(€ 10,737.33)	€ 3,049.12



12	€ 3,201.57	€ 301.69	€ 3,503.27	€ 3,363.14	€ 61.00	€ 3,424.13	(€ 100.87)	(€ 1,379.50)	(€ 10,838.20)	€ 3,201.57
13	€ 3,361.65	€ 316.78	€ 3,678.43	€ 3,531.29	€ 64.05	€ 3,595.34	(€ 96.91)	(€ 1,476.41)	(€ 10,935.11)	€ 3,361.65
14	€ 3,529.73	€ 332.62	€ 3,862.35	€ 3,707.86	€ 67.25	€ 3,775.11	(€ 92.76)	(€ 1,569.16)	(€ 11,027.86)	€ 3,529.73
15	€ 3,706.22	€ 349.25	€ 4,055.47	€ 3,893.25	€ 70.61	€ 3,963.86	(€ 88.39)	(€ 1,657.56)	(€ 11,116.26)	€ 3,706.22

Table 97: PBP calculation of SAHP (Intermittent) PT

8.1.1 Combined Scenario 1 (PVT) for PT

The Total Capital Investment of the combined scenario 1:

Ci: Table 81 + Table 89 + Table 92= **92,239.14 €**

Year	Reference cost Electricity	Reference cost Gas	TECo	Retrofitted Cost Electricity	Retrofitted Cost Gas	TCEr	Income Solar en Sold	Avoided annual Cost (AaC)	Cumulative Savings (CS)	Balance (Ba)
0	€ 3,870.29	€ 167.99	€ 4,038.28	€ 987.77	€ 42.23	€ 1,030.00	€ 114.24	€ 3,008.29	€ 3,008.29	(€ 63,861.66)
1	€ 4,063.80	€ 176.39	€ 4,240.20	€ 1,037.16	€ 44.34	€ 1,081.50	€ 119.95	€ 3,132.94	€ 6,141.23	(€ 60,728.72)
2	€ 4,266.99	€ 185.21	€ 4,452.21	€ 1,089.01	€ 46.56	€ 1,135.57	€ 125.95	€ 3,296.59	€ 9,437.81	(€ 57,432.13)
3	€ 4,480.34	€ 194.47	€ 4,674.82	€ 1,143.46	€ 48.88	€ 1,192.35	€ 132.25	€ 3,468.42	€ 12,906.23	(€ 53,963.71)
4	€ 4,704.36	€ 204.20	€ 4,908.56	€ 1,200.64	€ 51.33	€ 1,251.97	€ 138.86	€ 3,648.84	€ 16,555.07	(€ 50,314.88)
5	€ 4,939.58	€ 214.41	€ 5,153.98	€ 1,260.67	€ 53.89	€ 1,314.56	€ 145.80	€ 3,838.28	€ 20,393.35	(€ 46,476.60)
6	€ 5,186.56	€ 225.13	€ 5,411.68	€ 1,323.70	€ 56.59	€ 1,380.29	€ 153.09	€ 4,037.19	€ 24,430.54	(€ 42,439.40)
7	€ 5,445.88	€ 236.38	€ 5,682.27	€ 1,389.89	€ 59.42	€ 1,449.31	€ 160.75	€ 4,246.05	€ 28,676.59	(€ 38,193.35)
8	€ 5,718.18	€ 248.20	€ 5,966.38	€ 1,459.38	€ 62.39	€ 1,521.77	€ 168.78	€ 4,465.36	€ 33,141.95	(€ 33,728.00)
9	€ 6,004.09	€ 260.61	€ 6,264.70	€ 1,532.35	€ 65.51	€ 1,597.86	€ 177.22	€ 4,695.62	€ 37,837.57	(€ 29,032.37)
10	€ 6,304.29	€ 273.64	€ 6,577.94	€ 1,608.97	€ 68.78	€ 1,677.75	€ 186.08	€ 4,937.40	€ 42,774.98	(€ 24,094.97)
11	€ 6,619.51	€ 287.33	€ 6,906.83	€ 1,689.42	€ 72.22	€ 1,761.64	€ 195.39	€ 5,191.27	€ 47,966.25	(€ 18,903.69)
12	€ 6,950.48	€ 301.69	€ 7,252.17	€ 1,773.89	€ 75.84	€ 1,849.72	€ 205.16	€ 5,457.84	€ 53,424.09	(€ 13,445.85)
13	€ 7,298.01	€ 316.78	€ 7,614.78	€ 1,862.58	€ 79.63	€ 1,942.21	€ 215.42	€ 5,737.73	€ 59,161.82	(€ 7,708.12)
14	€ 7,662.91	€ 332.62	€ 7,995.52	€ 1,955.71	€ 83.61	€ 2,039.32	€ 226.19	€ 6,031.62	€ 65,193.44	(€ 1,676.51)
15	€ 8,046.05	€ 349.25	€ 8,395.30	€ 2,053.50	€ 87.79	€ 2,141.29	€ 237.50	€ 6,340.20	€ 71,533.64	€ 4,663.69
16	€ 8,448.35	€ 366.71	€ 8,815.06	€ 2,156.17	€ 92.18	€ 2,248.35	€ 249.37	€ 6,664.21	€ 78,197.84	€ 11,327.90
17	€ 8,870.77	€ 385.05	€ 9,255.82	€ 2,263.98	€ 96.79	€ 2,360.77	€ 261.84	€ 7,004.42	€ 85,202.26	€ 18,332.32
18	€ 9,314.31	€ 404.30	€ 9,718.61	€ 2,377.18	€ 101.63	€ 2,478.81	€ 274.93	€ 7,361.64	€ 92,563.90	€ 25,693.96
19	€ 9,780.03	€ 424.51	€ 10,204.54	€ 2,496.04	€ 106.71	€ 2,602.75	€ 288.68	€ 7,736.72	€ 100,300.62	€ 33,430.68
20	€ 10,269.03	€ 445.74	€ 10,714.76	€ 2,620.84	€ 112.04	€ 2,732.89	€ 303.11	€ 8,130.56	€ 108,431.18	€ 41,561.23

Table 98: PBP calculation of Combined Scenario 1 (Continuous) PT

Year	Reference cost Electricity	Reference cost Gas	TECo	Retrofitted Cost Electricity	Retrofitted Cost Gas	TCEr	Income Solar en Sold	Avoided annual Cost (AaC)	Cumulative Savings (CS)	Balance (Ba)
0	€ 1,782.76	€ 167.99	€ 1,950.75	€ 791.32	€ 41.31	€ 832.63	€ 114.24	€ 1,118.12	€ 1,118.12	(€ 91,121.02)
1	€ 1,871.89	€ 176.39	€ 2,048.29	€ 830.88	€ 43.38	€ 874.26	€ 119.95	€ 1,148.27	€ 2,266.39	(€ 89,972.75)
2	€ 1,965.49	€ 185.21	€ 2,150.70	€ 872.43	€ 45.54	€ 917.97	€ 125.95	€ 1,212.68	€ 3,479.08	(€ 88,760.06)
3	€ 2,063.76	€ 194.47	€ 2,258.24	€ 916.05	€ 47.82	€ 963.87	€ 132.25	€ 1,280.32	€ 4,759.40	(€ 87,479.74)
4	€ 2,166.95	€ 204.20	€ 2,371.15	€ 961.85	€ 50.21	€ 1,012.06	€ 138.86	€ 1,351.33	€ 6,110.73	(€ 86,128.41)
5	€ 2,275.30	€ 214.41	€ 2,489.71	€ 1,009.94	€ 52.72	€ 1,062.67	€ 145.80	€ 1,425.90	€ 7,536.63	(€ 84,702.51)
6	€ 2,389.06	€ 225.13	€ 2,614.19	€ 1,060.44	€ 55.36	€ 1,115.80	€ 153.09	€ 1,504.20	€ 9,040.83	(€ 83,198.31)
7	€ 2,508.52	€ 236.38	€ 2,744.90	€ 1,113.46	€ 58.13	€ 1,171.59	€ 160.75	€ 1,586.41	€ 10,627.23	(€ 81,611.91)
8	€ 2,633.94	€ 248.20	€ 2,882.15	€ 1,169.13	€ 61.03	€ 1,230.17	€ 168.78	€ 1,672.73	€ 12,299.96	(€ 79,939.18)



9	€ 2,765.64	€ 260.61	€ 3,026.25	€ 1,227.59	€ 64.09	€ 1,291.68	€ 177.22	€ 1,763.36	€ 14,063.32	(€ 78,175.82)
10	€ 2,903.92	€ 273.64	€ 3,177.57	€ 1,288.97	€ 67.29	€ 1,356.26	€ 186.08	€ 1,858.53	€ 15,921.85	(€ 76,317.29)
11	€ 3,049.12	€ 287.33	€ 3,336.44	€ 1,353.42	€ 70.65	€ 1,424.07	€ 195.39	€ 1,958.46	€ 17,880.30	(€ 74,358.84)
12	€ 3,201.57	€ 301.69	€ 3,503.27	€ 1,421.09	€ 74.19	€ 1,495.28	€ 205.16	€ 2,063.38	€ 19,943.68	(€ 72,295.46)
13	€ 3,361.65	€ 316.78	€ 3,678.43	€ 1,492.14	€ 77.90	€ 1,570.04	€ 215.42	€ 2,173.55	€ 22,117.23	(€ 70,121.91)
14	€ 3,529.73	€ 332.62	€ 3,862.35	€ 1,566.75	€ 81.79	€ 1,648.54	€ 226.19	€ 2,289.23	€ 24,406.46	(€ 67,832.68)
15	€ 3,706.22	€ 349.25	€ 4,055.47	€ 1,645.09	€ 85.88	€ 1,730.97	€ 237.50	€ 2,410.69	€ 26,817.14	(€ 65,422.00)
16	€ 3,891.53	€ 366.71	€ 4,258.24	€ 1,727.34	€ 90.17	€ 1,817.52	€ 249.37	€ 2,538.22	€ 29,355.37	(€ 62,883.77)
17	€ 4,086.11	€ 385.05	€ 4,471.15	€ 1,813.71	€ 94.68	€ 1,908.39	€ 261.84	€ 2,672.13	€ 32,027.50	(€ 60,211.64)
18	€ 4,290.41	€ 404.30	€ 4,694.71	€ 1,904.40	€ 99.42	€ 2,003.81	€ 274.93	€ 2,812.74	€ 34,840.24	(€ 57,398.90)
19	€ 4,504.94	€ 424.51	€ 4,929.45	€ 1,999.62	€ 104.39	€ 2,104.00	€ 288.68	€ 2,960.38	€ 37,800.61	(€ 54,438.53)
20	€ 4,730.18	€ 445.74	€ 5,175.92	€ 2,099.60	€ 109.61	€ 2,209.20	€ 303.11	€ 3,115.39	€ 40,916.01	(€ 51,323.13)

Table 99: PBP calculation of Combined Scenario 1 (**Intermittent**) PT

8.1.2 Combined Scenario 2 (SAHP) for PT

The Total Capital Investment of the combined scenario 2:

Ci: Table 81 + Table 89 + Table 95= **90,205.98 €**

Year	Reference cost Electricity	Reference cost Gas	TECo	Retrofitted Cost Electr	Retrofitted Cost Gas	TCEr	Income Solar en Sold	Avoided annual Cost (Aac)	Cumulative Savings (CS)	Balance (Ba)
0	€ 3,870.29	€ 167.99	€ 4,038.28	€ 1,375.16	€ 34.88	€ 1,410.05	€ 2,628.23	€ 2,628.23	(€ 62,027.21)	€ 3,870.29
1	€ 4,063.80	€ 176.39	€ 4,240.20	€ 1,443.92	€ 36.63	€ 1,480.55	€ 2,579.65	€ 5,207.88	(€ 59,447.57)	€ 4,063.80
2	€ 4,266.99	€ 185.21	€ 4,452.21	€ 1,516.12	€ 38.46	€ 1,554.58	€ 2,717.63	€ 7,925.51	(€ 56,729.94)	€ 4,266.99
3	€ 4,480.34	€ 194.47	€ 4,674.82	€ 1,591.92	€ 40.38	€ 1,632.31	€ 2,862.51	€ 10,788.02	(€ 53,867.43)	€ 4,480.34
4	€ 4,704.36	€ 204.20	€ 4,908.56	€ 1,671.52	€ 42.40	€ 1,713.92	€ 3,014.63	€ 13,802.65	(€ 50,852.79)	€ 4,704.36
5	€ 4,939.58	€ 214.41	€ 5,153.98	€ 1,755.10	€ 44.52	€ 1,799.62	€ 3,174.37	€ 16,977.02	(€ 47,678.43)	€ 4,939.58
6	€ 5,186.56	€ 225.13	€ 5,411.68	€ 1,842.85	€ 46.75	€ 1,889.60	€ 3,342.08	€ 20,319.10	(€ 44,336.34)	€ 5,186.56
7	€ 5,445.88	€ 236.38	€ 5,682.27	€ 1,934.99	€ 49.09	€ 1,984.08	€ 3,518.19	€ 23,837.29	(€ 40,818.15)	€ 5,445.88
8	€ 5,718.18	€ 248.20	€ 5,966.38	€ 2,031.74	€ 51.54	€ 2,083.28	€ 3,703.10	€ 27,540.39	(€ 37,115.05)	€ 5,718.18
9	€ 6,004.09	€ 260.61	€ 6,264.70	€ 2,133.33	€ 54.12	€ 2,187.45	€ 3,897.25	€ 31,437.64	(€ 33,217.80)	€ 6,004.09
10	€ 6,304.29	€ 273.64	€ 6,577.94	€ 2,240.00	€ 56.82	€ 2,296.82	€ 4,101.12	€ 35,538.76	(€ 29,116.68)	€ 6,304.29
11	€ 6,619.51	€ 287.33	€ 6,906.83	€ 2,352.00	€ 59.66	€ 2,411.66	€ 4,315.17	€ 39,853.93	(€ 24,801.51)	€ 6,619.51
12	€ 6,950.48	€ 301.69	€ 7,252.17	€ 2,469.60	€ 62.65	€ 2,532.24	€ 4,539.93	€ 44,393.86	(€ 20,261.58)	€ 6,950.48
13	€ 7,298.01	€ 316.78	€ 7,614.78	€ 2,593.08	€ 65.78	€ 2,658.86	€ 4,775.93	€ 49,169.79	(€ 15,485.65)	€ 7,298.01
14	€ 7,662.91	€ 332.62	€ 7,995.52	€ 2,722.73	€ 69.07	€ 2,791.80	€ 5,023.72	€ 54,193.51	(€ 10,461.93)	€ 7,662.91
15	€ 8,046.05	€ 349.25	€ 8,395.30	€ 2,858.87	€ 72.52	€ 2,931.39	€ 5,283.91	€ 59,477.42	(€ 5,178.02)	€ 8,046.05

Table 100: PBP calculation of Combined Scenario 2 (**Continuous**) PT

Year	Reference cost Electricity	Reference cost Gas	TECo	Retrofitted Cost Electr	Retrofitted Cost Gas	TCEr	Income Solar en Sold	Avoided annual Cost (Aac)	Cumulative Savings (CS)	Balance (Ba)
0	€ 1,782.76	€ 167.99	€ 1,950.75	€ 1,046.52	€ 33.97	€ 1,080.49	€ 870.26	€ 870.26	(€ 89,335.72)	€ 1,782.76
1	€ 1,871.89	€ 176.39	€ 2,048.29	€ 1,098.85	€ 35.66	€ 1,134.51	€ 733.78	€ 1,604.04	(€ 88,601.94)	€ 1,871.89
2	€ 1,965.49	€ 185.21	€ 2,150.70	€ 1,153.79	€ 37.45	€ 1,191.24	€ 779.47	€ 2,383.51	(€ 87,822.47)	€ 1,965.49
3	€ 2,063.76	€ 194.47	€ 2,258.24	€ 1,211.48	€ 39.32	€ 1,250.80	€ 827.44	€ 3,210.95	(€ 86,995.03)	€ 2,063.76
4	€ 2,166.95	€ 204.20	€ 2,371.15	€ 1,272.05	€ 41.29	€ 1,313.34	€ 877.81	€ 4,088.76	(€ 86,117.22)	€ 2,166.95



5	€ 2,275.30	€ 214.41	€ 2,489.71	€ 1,335.65	€ 43.35	€ 1,379.00	€ 930.70	€ 5,019.46	(€ 85,186.52)	€ 2,275.30
6	€ 2,389.06	€ 225.13	€ 2,614.19	€ 1,402.44	€ 45.52	€ 1,447.95	€ 986.24	€ 6,005.70	(€ 84,200.28)	€ 2,389.06
7	€ 2,508.52	€ 236.38	€ 2,744.90	€ 1,472.56	€ 47.79	€ 1,520.35	€ 1,044.55	€ 7,050.25	(€ 83,155.73)	€ 2,508.52
8	€ 2,633.94	€ 248.20	€ 2,882.15	€ 1,546.19	€ 50.18	€ 1,596.37	€ 1,105.78	€ 8,156.02	(€ 82,049.96)	€ 2,633.94
9	€ 2,765.64	€ 260.61	€ 3,026.25	€ 1,623.50	€ 52.69	€ 1,676.19	€ 1,170.07	€ 9,326.09	(€ 80,879.89)	€ 2,765.64
10	€ 2,903.92	€ 273.64	€ 3,177.57	€ 1,704.67	€ 55.33	€ 1,760.00	€ 1,237.57	€ 10,563.66	(€ 79,642.32)	€ 2,903.92
11	€ 3,049.12	€ 287.33	€ 3,336.44	€ 1,789.90	€ 58.09	€ 1,848.00	€ 1,308.45	€ 11,872.10	(€ 78,333.88)	€ 3,049.12
12	€ 3,201.57	€ 301.69	€ 3,503.27	€ 1,879.40	€ 61.00	€ 1,940.40	€ 1,382.87	€ 13,254.97	(€ 76,951.01)	€ 3,201.57
13	€ 3,361.65	€ 316.78	€ 3,678.43	€ 1,973.37	€ 64.05	€ 2,037.42	€ 1,461.01	€ 14,715.98	(€ 75,490.00)	€ 3,361.65
14	€ 3,529.73	€ 332.62	€ 3,862.35	€ 2,072.04	€ 67.25	€ 2,139.29	€ 1,543.06	€ 16,259.05	(€ 73,946.93)	€ 3,529.73
15	€ 3,706.22	€ 349.25	€ 4,055.47	€ 2,175.64	€ 70.61	€ 2,246.25	€ 1,629.22	€ 17,888.26	(€ 72,317.72)	€ 3,706.22