Three renovation packages

D2.2

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Executive summary

This report contains the methodology and steps used to design at least three renovation packages for the pilot site, that has been described previously in the baseline definition.

To carry out them, all the following elements have been taken into account:

- Baseline descriptions from Task 2.1
- Library of SOTA renovation options from WP1
- Innovative scan from WP1
- Requirements of building owner
- Knowledge and previous experiences of Exeleria, Chalmers and 3C-Pre

The three renovation packages proposed, following the DREEAM aim, should achieve a reduction of 75% of the primary energy of the building in a cost-efficient way, taking into account the implementation of renewable energy systems and the increment of the renovation scope to multiple buildings. The nZEB (nearly Zero-Energy Building) state of art boundaries have been applied in this task to reach the energy savings goals.

The results will be presented to the building owner, who will decide one concept between all the proposed.

The results obtained are:

Padiham:

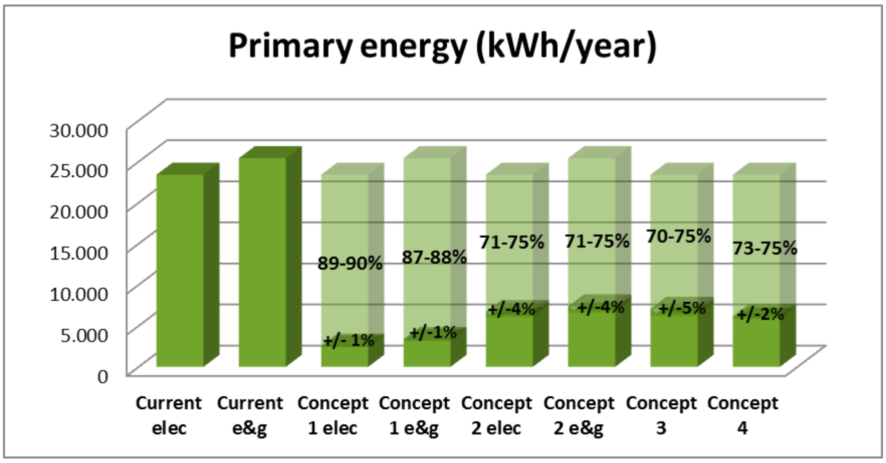
For the set of dwellings both electricity and gas & electricity supplied have been analysed many different solutions that include heat pumps (air-air and air-water), condensing gas boiler, and night storage units. Solar photovoltaic systems as main source of renewable energy. A ventilation system to solve the problem of moistures have been also included for all the concepts. More detailed information of each concept can be found in section “renovation concepts”.

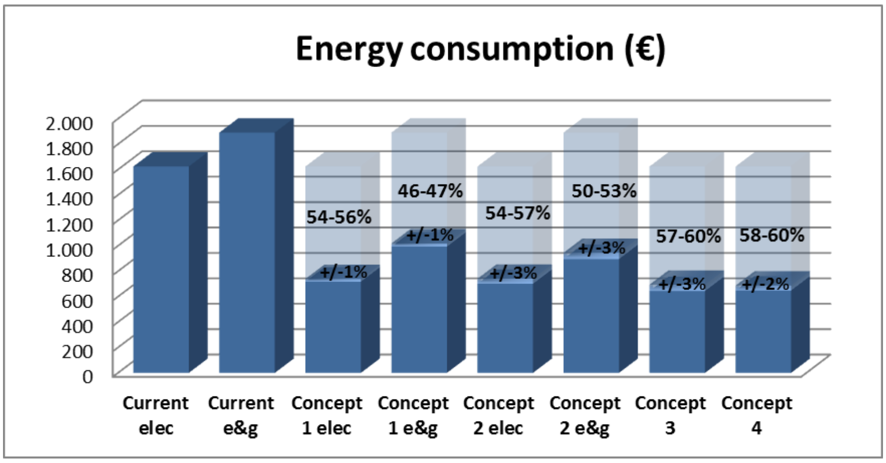
For this pilot site, two different analysis methods are considered depending on the starting point for the calculations, that are:

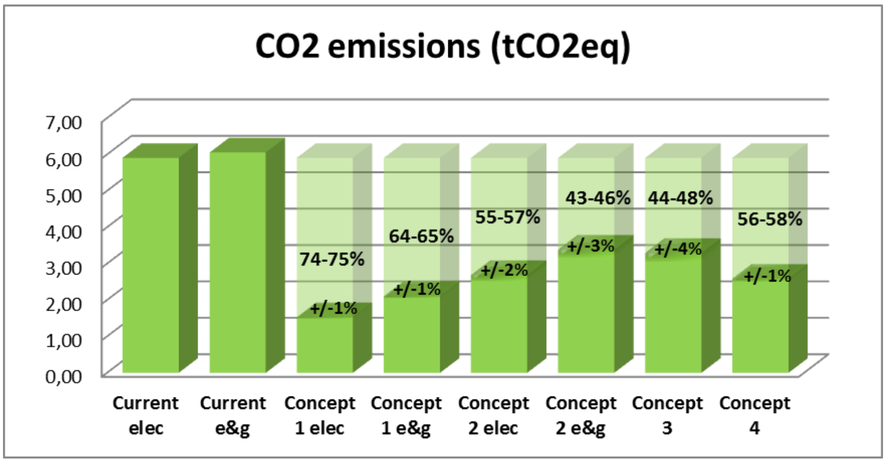
Analysis 1: starting in a renovation of the envelope and the main energy source to calculate the dimension of a PV system to reach a 75% of energy saving.

Analysis 2: starting with the biggest PV system as possible and a renovation of the main energy source to calculate the actions in the envelope required to reach a 75% of energy saving.

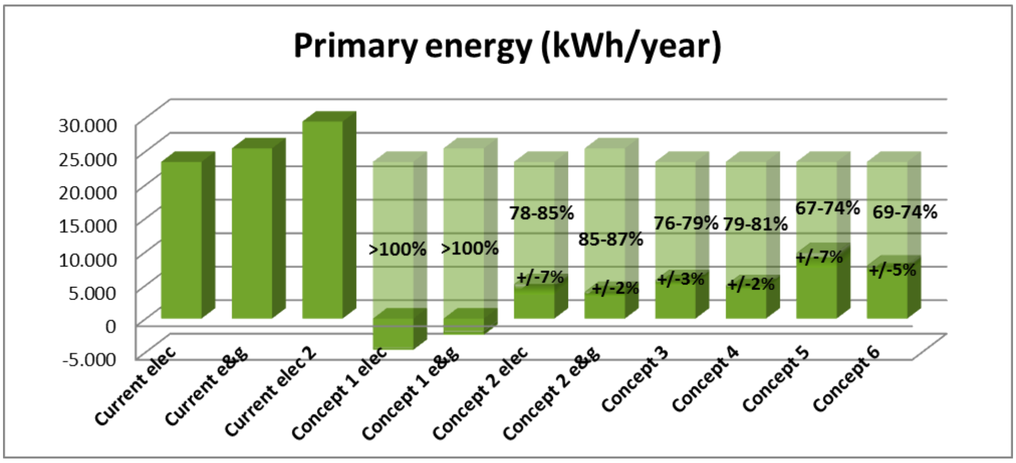
Analysis 1:






CO2 emissions (tCO2eq)
7,00
6,00
5,00
4,00
3,00
2,00
1,00
0,00
74-75%
+/-1%
64-65%
+/-1%
55-57%
+/-2%
43-46%
+/-3%
44-48%
+/-4%
56-58%
+/-1%
Current elec
Current e&g
Concept 1 elec
Concept 1 e&g
Concept 2 elec
Concept 2 e&g
Concept 3
Concept 4

Analysis 2:


Primary energy (kWh/year)
30.000
25.000
20.000
15.000
10.000
5.000
0
-5.000
>100%
>100%
78-85%
+/-7%
85-87%
+/-2%
76-79%
+/-3%
79-81%
+/-2%
67-74%
+/-7%
69-74%
+/-5%
Current elec
Current e&g
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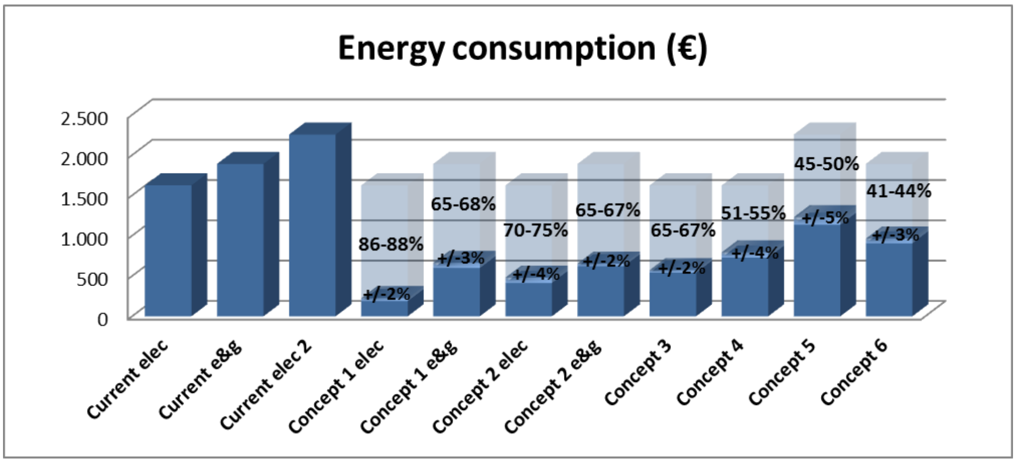
Concept 3
Concept 4
Concept 5
Concept 6


Energy consumption (€)
2.500
2.000
1.500
1.000
500
0
86-88%
+/-2%
65-68%
+/-3%
70-75%
+/-4%
65-67%
+/-2%
65-67%
+/-2%
51-55%
+/-4%
45-50%
+/-5%
41-44%
+/-3%
Current elec
Current e&g
Current elec 2
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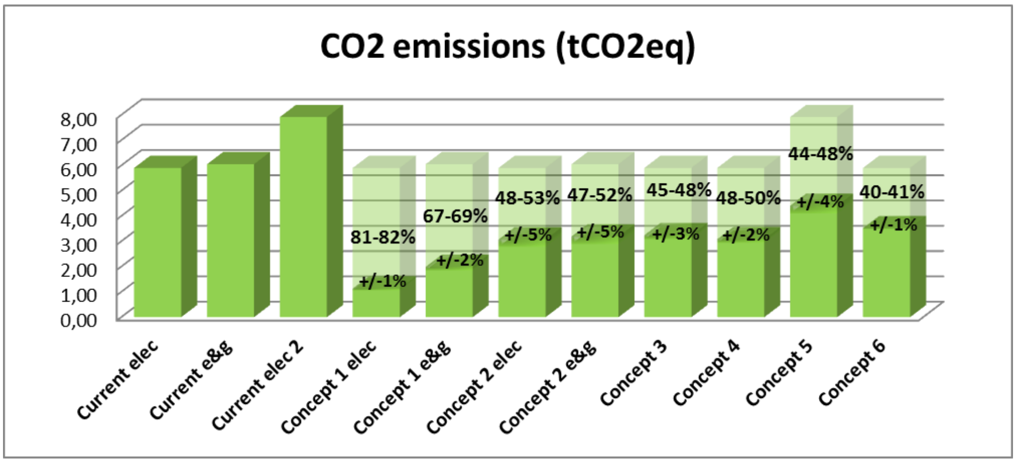
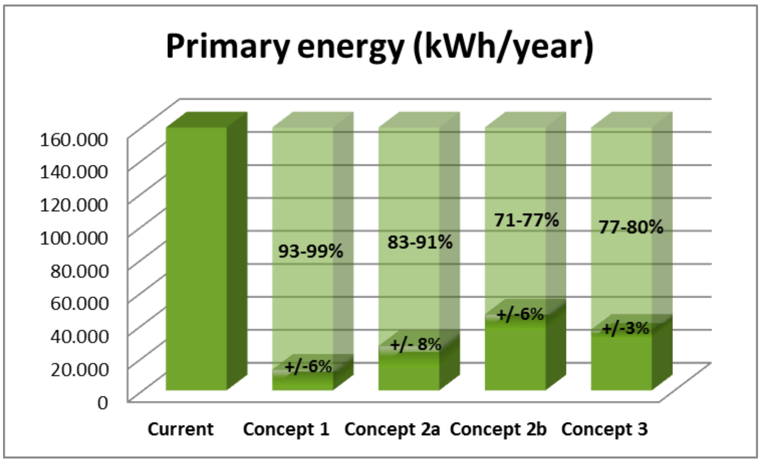
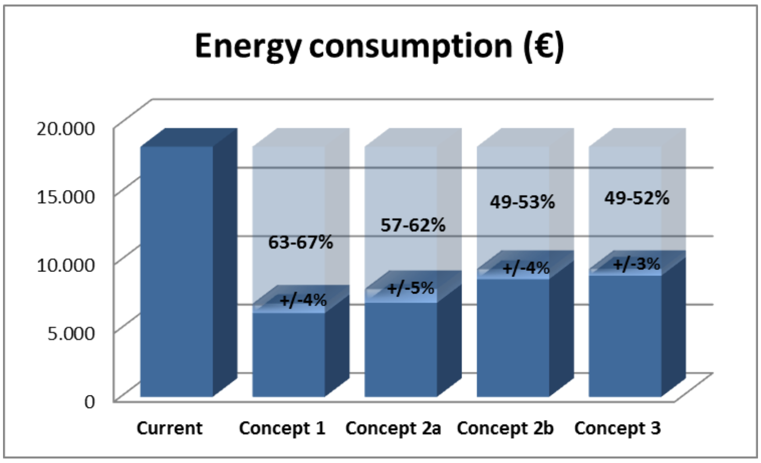
Concept 4
Concept 5
Concept 6

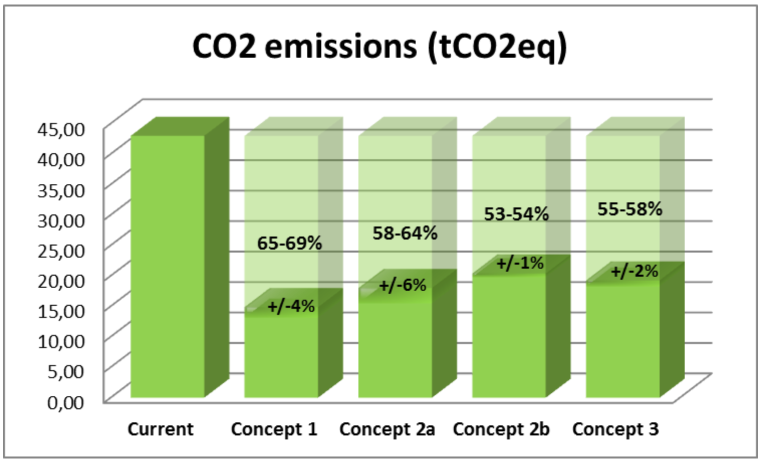

CO2 emissions (tCO2eq)
8,00
7,00
6,00
5,00
4,00
3,00
2,00
1,00
0,00
81-82%
+/-1%
67-69%
+/-2%
48-53%
+/-5%
47-52%
+/-5%
45-48%
+/-3%
48-50%
+/-2%
44-48%
+/-4%
40-41%
+/-1%
Current elec
Current e&g
Current elec 2
Concept 1 elec
Concept 1 e&g
Concept 2 elec
Concept 2 e&g
Concept 3
Concept 4
Concept 5
Concept 6

Treviso:

Most of the cases count with a deep envelope renovation to reduce as much as possible the heating losses in the buildings. The substitution of the current boiler for a new condensing one or the installation of air-water heat pumps have been considered All the concepts have a ventilation system with heat recovery as a request from ATER. Solar thermal and photovoltaic as renewable energy are also included in the concepts. More detailed information of each concept can be found in section "renovation concepts".

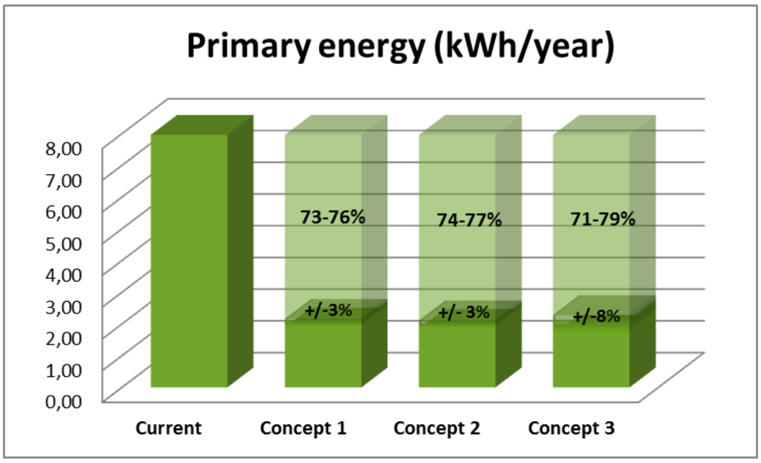


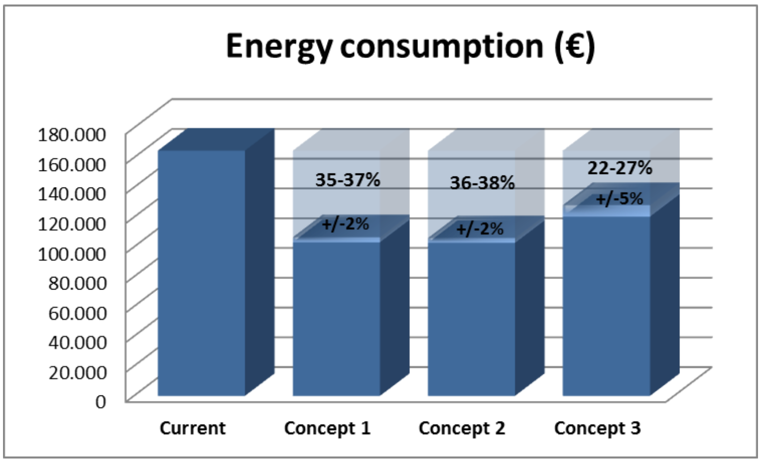


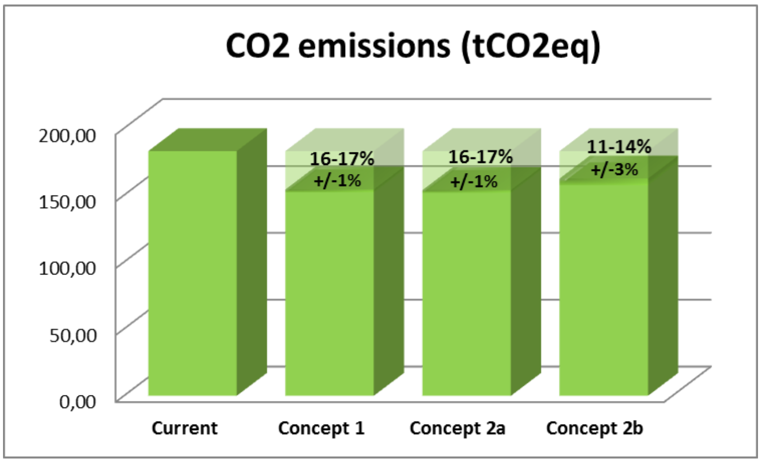


Landskrona:

Due to the good primary energy factor of the current District Heating system in Landskrona, there are no changes in the heating and DHW production. Therefore, the concepts proposed are focused in an improvement of the envelope and in the production of electricity by renewable energy, that in this case, photovoltaic the most suitable. More detailed information of each concept can be found in section “renovation concepts”.







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Pilot site

1 Qualitative concept ideas (Padiham)

1.1 Introduction

To elaborate the renovation concepts, a brainstorming between Exeleria, Chalmers an 3C-Pre has been made. On it, each part contributed to develop an overview of different solutions that can be applied in the pilot site.

The different solutions involve the following elements:

- Envelope:
  - Wall
  - Roof
  - Floor
  - Roof
  - Window
- Ventilation
- Heating system
- Renewable energy
- ESCO

An analysis of the advantages, disadvantages and possible innovations has been made. To have an idea of the impact of every solution proposed exeleria has calculated how affect them to the primary energy in the pilot site using the same energy simulation tool as in the baseline analysis.

1.2 Design of the renovation concepts

Once an scheme of different solutions has been designed, the next step is to mix them to create a renovation concept.

The proposed renovation concepts have been designed with the combination of one solution for each element: walls, ventilation, heating, etc.

The following figure represents the steps made to obtain a final solution:

Solutions	Ventilation	Roof	Wall (brick)	Window	Floor	Heating	RES	ESCO
I	**Central air out (one air out per unit), decentral air in (several air in) (for example via window frames)** Advantages: limited complexity and costs; risk of mold and humity covered; risk of health problems via air quality covered Disadvantages: no heat exchange possible, the reduction in the heating consumption can be lower than the consumption of the system Possible Innovations: several products available for decentral air in (none of them truely innovative though); smart management via sensors could qualify Impact: +3% Total Primary Energy	**Insulation from inside** Advantages: good insulation levels possible; limited effort, can be done from inside; improves air-tightness, cheap to insulation Disadvantages: heat bridges might remain, structural wooden beams might need to be "doubled-up" (might be needed for PV anyway) Possible Innovations: super insulation (not cost competitive) Impact: -4% Total Primary Energy Measure: Roof against unheated room 0,2 W/m2K (current 1,4 W/m2K)	**External insulation** Advantages: very good insulation levels possible, visual aspect Disadvantages: changes the looks of the building; either might leave heat bridges or requires exchange of windows as well to move them back to the insulation layer; some insulation systems might be subject to mold and fungi on outside Possible innovations: super insulation (not cost competitive in this case) Impact: -18% Total Primary Energy Measure: External walls 0,23 W/m2K (current 1,8 W/m2K)	**Exchange glazing and frame** Advantages: very good insulation levels possible; improves air-tightness (especially in combination with wall insulation measures); allows optimal positioning of new window regarding the insulation layer Disadvantages: requires some disturbing works; more expensive than just changing glazing; will reduce daylight factor Possible innovations: window frame integrated ventilation Impact: -3% Total Primary Energy Measure: Window 1,2 W/m2K (current 3,2 W/m2K)	**No changes** Advantages: cheap Disadvantages: low insulation level which is poblematic especially in the case where there is floor over air Possible innovations: none Impact: 0% Total Primary Energy	**Condensing gas boiler** Advantages: relatively cheap, effective and working technology, can be combined with solar thermic Disadvantages: requires well insulated envelope to reach DREEAM targets; requires grid connection, requires water circuit and radiators (not existing in some rooms) Possible innovations: combination with solar thermic/ storage Impact: -10% Total Primary Energy Measure: 85% efficiency boiler	**PV (roof)** Advantages: makes it substantially easier to achieve DREEAM targets; communicates the efforts of PfP better than other measures; plug-and-play Disadvantages: puts additional weight on roof; changes the look; location not ideal (trees, not very high, climate) Possible innovations: new PV modules; management, storage, trading scheme, combination with HVAC Impact: aprox. 264 kWh/year per panel	**Yes** Advantages: makes the system more economically valid, offers high inovation potential; potential new business case for PfP Disadvantages: legal frame conditions unclear; complex
II	**No controlled ventilation** Advantages: cheap Disadvantages: no heat recovery; in combination with a more air-tight envelope humidity problems might arise due to wrong ventilation; problems with mold related health issues might arise Possible Innovations: none Impact: 0% Total Primary Energy	**Exchange roof for a new one** Advantages: very good insulation levels; no remaining heat bridges; can be easily combined with PV, visual aspect Disadvantages: expensive; extensive works needed, waste generation Possible innovations: prefab solutions; integrated PV/ ventilation Impact: -2% Total Primary Energy Measure: Roof against external air 0,2 W/m2K (current unknow)	**Fill cavity** Advantages: decent insulation levels possible if cavity in the range of 10cm; cheap; limited planning effort; does not change the looks of the wall Disadvantages: limited insulation value; depending on rifts to the inside might require extensive sealing (that on the other hands benefits the air tightness), Importance of the cavity thickness Possible Innovations: aerogel based cavity insulation Impact: -15% Total Primary Energy (case of aerogel)y Measure: External walls 0,4 W/m2K (current 1,8 W/m2K)	**Add second skin window** Advantages: very good insulation levels possible; new window can be put in the (new) insulation layer to prevent/ limit heat bridges Disadvantages: depending on current window might be complicated; will significantly reduce daylight factor; might look awkward; Possible Innovations: integrated ventilation Impact: -2% Total Primary Energy	**Exchange make-up and add insulation** Advantages: can be complemented by floor heating, generally adds quality Disadvantages: creates disturbances, reduces room heigth (also reduces airvolume but to a neglectible extent of less than 5%) Possible innovations: super insulation, tailored floor heating Impact: -8% Total Primary Energy Measure: Floor 0,27 W/m2K (current 1,2 W/m2K)	**Heat pump (air or ground)** Advantages: combined with green electricity might allow reaching the DREEAM targets with less envelope changes; can use existing infrastructure (if radiators are there) or be combined with floor refitting, no gas grid connection necessary Disadvantages: worst COP in winter (if air) or high initial investment costs (if ground based) Possible innovations: combination with PV/ storage Impact: -60% Total Primary Energy Measure: 2,8 COP Heat pump	**Solar thermic modules for DHW (roof)** Advantages: pays of in sizes where PV does not; provides heat and domestic hot water even when tenants cannot afford electricity, does not require a big surface Disadvantages: more complex to install than PV, requires storage and water circuit Possible innovation: combined panels (thermal & PV) Impact: aprox 788 kWh/year per panel	**No**
III	**Controlled central ventilation with heat recovery** Advantages: heat recovery (80%) possible that is very lilely to pay off fast in the UK climate; air quality and risk of mold and humidity due to a more air tight envelopecovered Disadvantage: expensive and requires substantial planning; adds electricity consumption (might stop working if pre-paid budget runs out). Possible Innovations: Enthalpy Exchanger (exchanges humidty and heat); smart management via sensors		**Fill cavity + internal insulation** Advantages: provides good insulation levels; does not change the looks of the wall, easiness to install, solution well known by PfP Disadvantages: reduces internal area Potential innovations: aerogel for the internal insulation Impact: -18% Total Primary Energy Measure: External walls 0,23 W/m2K (current 1,8 W/m2K)	**Increase window sizes (down to ground)** Advantages: will increase dailight factor; will add quality; verygood insulation levels possible; visual aspect, increases solar gains in winter Disadvantages: waste generation, increases budget, increases heat transmissions losses Potential innovations: Impact: -4% Total Primary Energy y Measure: Window 2 m height		**Night storage electric units** Advantages: no gas grid connection necessary; might achieve the DREEAM targets when combined with renewable energy generation and a decent envelope; cheap; little disturbances Disadvantage: in combination with regular electricity mixes unlikely to achieve DREEAM targets Possible innovation:		
IV						**Centralized soil based heat pump system** Advantages: very efficient, allows shifting, can be combined with PV or solar themic and storage Disadvanatges: joint responsibility (what if someone does not pay?); Possible Innovation: storage; load management;		

Figure 1 List of renovation concepts

It can be possible that a renovation concept can be split having a different solution for the same element and the rest are identical.

After the renovation concepts have been defined, they have been presented to de building owners, who have made modifications according to their desires.

2 Assumptions (Padiham)

There are some factors to take into consideration when deciding to make an analysis of the renovation. These factors are: price of energy, primary energy factors and the emissions of carbon dioxide.

These factors vary in each pilot site due to many reasons like the market prices of the energy suppliers, government policies, the energy mix of the country which affects to the primary energy factor and the emission of carbon dioxide.

2.1 Price of energy

The dwellings are supplied by two different energy sources: electricity and gas.

The prices of them have been obtained from the bills provided by the tenants:

- Electricity (day): 0,203 €/kWh
- Electricity (night): 0,086 €/kWh
- Gas: 0,053 €/kWh

According to the energy policies in UK it is possible to export the electricity generated by a renewable energy system and obtain not only a price for the energy injected in the grid, also for the 100% of the energy generated by the system.

- Generation: 0,0464 €/kWh
- Export: 0,053 €/kWh

2.2 Primary energy factors

The final energy only reflects the consumption. Therefore, it is necessary to convert it to primary energy which encompass the energy in its different steps that are: production, storage, transport and consumption.

These values have been obtained by euroheat.org and are:

- Electricity: 2,0
- Natural gas: 1,0

2.3 Carbon dioxide emission

The environmental aspect of the renovation it is focused in de carbon dioxide. Apart from the energy savings in a renovation is also important the reduction in the carbon dioxide emissions due to the reduction of the primary energy of the building.

The values used are:

- Electricity: 0,420 kgC02/kWh
- Natural gas: 0,230 kgC02/kWh

3 Renovation concepts (Padiham)

According to the energy source in the dwellings we can have on one side 100% electricity dwellings and electricity and gas on the other. Therefore, that makes that not every solution can be suitable for all the dwellings.

In the next section we can see a brief description of each concept:

3.1 Concept 1

Suitable for 100% electricity and electricity & gas dwelling.

- Envelope: Insufflating the air cavity with PUR and internal aerogel wall insulation, MW for the roof and XPS for the floor (when possible). Triple-glazed windows.

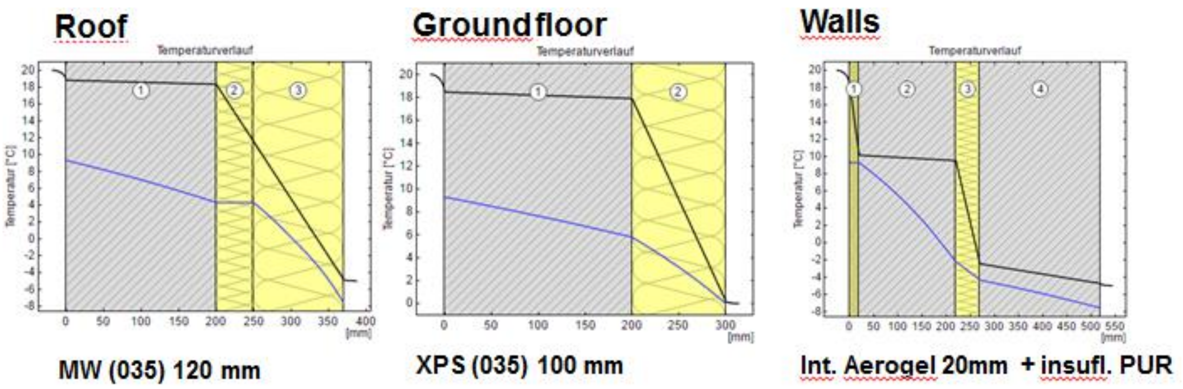


Figure 2 New insulation

The new U-Values obtained are:

Element	Current U-Value (W/m2K)	Proposed U-Value) (W/m2K)
External walls	1,20	0,26
Roof	0,58	0,19
Ground floor	3,87	0,32
Windows	2,80	1,20

The insulation of the floor is only feasible in the dwellings where it is faced against outside air:

- Heating and DHW by an air-water heat pump with an output of 10 kW with storage tank of 200L. The efficiency of the heat pump is 3,4.

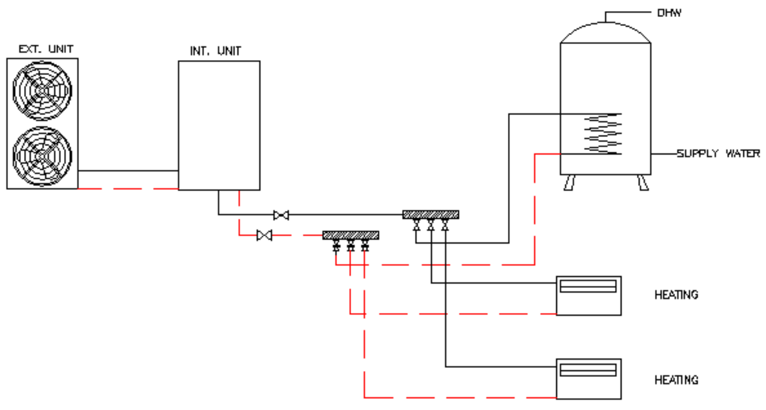


Figure 3 Air-water heat pump

- Ventilation: mechanical extract ventilation system. Includes demand control and CO2 and humidity sensors. Possibility of different programs: eco, night, etc.

Figure 4 Extract ventilation system

- Renewable energy: Photovoltaic integrated in the roof.

Figure 5 PV system

For the case of 100% electricity dwelling the terminal units must be changed and pipes installed.

3.2 Concept 2

Suitable for 100% electricity and electricity & gas dwelling.

- Envelope: Same as in concept 1.

- Heating and DHW by a gas condensing boiler with storage tank. The efficiency of the boiler is close to 98%.

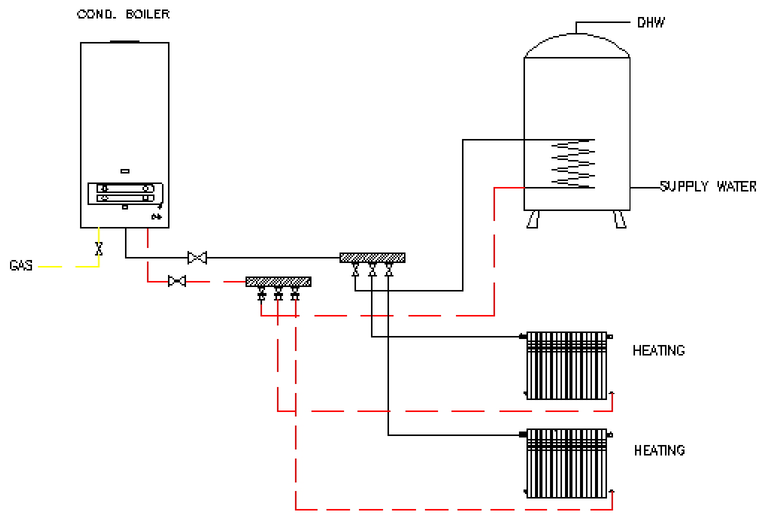


Figure 6 Condensing boiler

- Ventilation: mechanical extract ventilation system. Includes demand control and CO2 and humidity sensors. Possibility of different programs: eco, night, etc.
- Renewable energy: Photovoltaic integrated in the roof.

For the case of 100% electricity dwelling the terminal units must be changed and pipes installed.

3.3 Concept 3

Suitable for 100% electricity dwelling.

- Envelope: Same as in concept 1.
- Heating by night storage units. Compatible with two-period off peak electric tariff in a single 24-hour interval.

Figure 7 Night storage unit

- DHW by an electric boiler.

- Ventilation: mechanical extract ventilation system. Includes demand control and CO2 and humidity sensors. Possibility of different programs: eco, night, etc.
- Renewable energy: Photovoltaic integrated in the roof.

3.4 Concept 4

Suitable for 100% electricity dwelling.

- Envelope: Same as in concept 1.
- Heating by air-air heat pumps. The efficiency of the heat pump is 4,3.

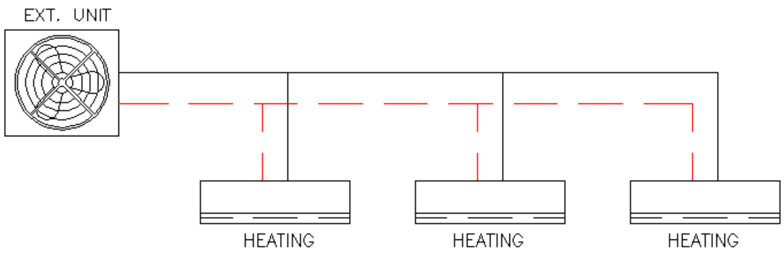


Figure 8 Air-air heat pump

- DHW by an electric boiler.
- Ventilation: mechanical extract ventilation system. Includes demand control and CO2 and humidity sensors. Possibility of different programs: eco, night, etc.
- Renewable energy: Photovoltaic integrated in the roof.

3.5 Concept 5

Suitable for 100% electricity dwelling.

- Envelope: Adding EPS in external walls and MW for the roof. Triple-glazed windows.

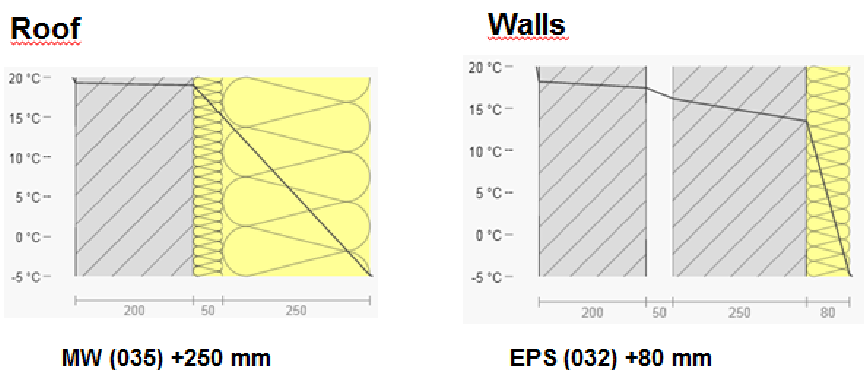


Figure 9 New insulation

The new U-Values obtained are:

Element	Current U-Value (W/m2K)	Proposed U-Value) (W/m2K)
External walls	1,20	0,29
Roof	0,58	0,11
Ground floor	3,87	=
Windows	2,80	1,20

- Heating by night storage units. Compatible with two-period off peak electric tariff in a single 24-hour interval.
- DHW by an electric boiler.
- Ventilation: individual ventilation system with heat recovery for each room.

Figure 10 Ventilation system

- Renewable energy: 3 kWp photovoltaic integrated in the roof.

3.6 Concept 6

Suitable for electricity & gas dwelling

- Envelope: Same as in concept 5.
- Heating and DHW by a gas condensing boiler with storage tank. The efficiency of the boiler is close to 98%.
- Ventilation: individual ventilation system with heat recovery for each room.
- Renewable energy: 3 kWp photovoltaic integrated in the roof.

4 Results (Padiham)

With the help of the simulation tool used in the baseline to analyse the energy consumption of the pilot site, all the renovation concepts proposed have been simulated in order to study the energy savings of each solution. An analysis of sensitivity has been made using the same procedure as in the baseline description with the parameters that can differ, resulting in different ranges.

In this case, two different analysis methods have been applied:

- Analysis 1: The starting point is a full renovation of the envelope, the energy source for the heating and DHW and ventilation system. In case that the target of energy saving is not reached, it will be covered by the necessary PV system.
- Analysis 2: In this case, the starting point is to have the maximal PV system possible and the renovation of the energy source for the heating and DHW and ventilation system. In case that the target of energy saving is not reached, it will be covered by the necessary envelope renovation.

4.1 Energy savings

For the energy savings calculation, the consumption related to lighting and appliances have not been taken into account. To establish energy saving measures in this consumption is a tricky issue due to a factors like the high amount of devices, the variety of efficiency of the devices, the user's behaviour of them, etc. Therefore, it cannot be taken into account for the DREEAM Project.

The following tables reflect briefly the energy saving obtained in each analysis method:

4.1.1 Analysis 1

Concept	Primary energy (kWh/year)		PV prod. (kWh/year)	Energy savings
	Before	After		
Concept 1: elec.	23.394	2.352 - 2.554	-	89 - 90 %
Concept 1: elec.&gas	25.404	3.124 - 3.366	-	87 - 88 %
Concept 2: elec.	23.394	5.849 - 6.664	1.179	71 - 75 %
Concept 2: elec.&gas	25.404	6.338 - 7.347	1.778	71 - 75 %
Concept 3	23.394	5.896 - 7.052	3.275	70 - 75 %
Concept 4	23.394	5.774 - 6.150	2.456	73 - 75 %

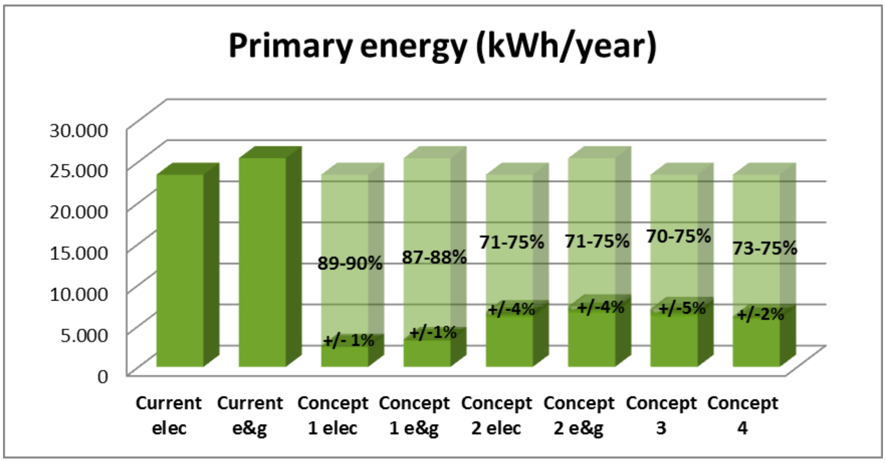


Figure 11 Primary energy overview

4.1.2 Concept 1: elec. A1

Concept 1 elec	Final energy (kWh/year)		Primary energy (kWh/year)		Primary energy savings
	Before	After	Before	After	
Heating	7.335	505 - 606	14.670	1.010 - 1.212	92 - 93 %
DHW	4.362	561	8.714	1.122	87 %
Ventilation	-	110	-	220	-
Total	11.697	1.176 - 1.277	23.394	2.352 - 2.554	89 - 90 %

4.1.3 Concept 1: elec.&gas A1

Concept 1 Elec&gas	Final energy (kWh/year)		Primary energy (kWh/year)		Primary energy savings
	Before	After	Before	After	
Heating	14.331	715 - 836	15.764	1.430 - 1672	89 - 91 %
DHW	4.820	622	9.640	1.244	87 %
Ventilation	-	225	-	450	-
Total	19.151	1.562 - 1.683	25.404	3.124 - 3.366	87 - 88 %

4.1.4 Concept 2: elec. A1

Concept 2 elec	Final energy (kWh/year)		Primary energy (kWh/year)		Primary energy savings
	Before	After	Before	After	
Heating	7.335	3.112 - 3.853	14.670	3.423 - 4.238	71 - 77 %

DHW	4.362	4.140	8.714	4.554	48 %
Ventilation	-	115	-	230	-
PV	-	-1.179		-2.358	-
Total	11.697	6.188 – 6.929	23.394	5.849 – 6.664	71 - 75 %

4.1.5 Concept 2: elec.&gas A1

Concept 2 Elec&gas	Final energy (kWh/year)		Primary energy (kWh/year)		Primary energy savings
	Before	After	Before	After	
Heating	14.331	4.007 - 4.925	15.764	4.408 - 5.418	66 - 72 %
DHW	4.820	4.578	9.640	5.036	48 %
Ventilation	-	225	-	450	-
PV	-	-1.778	-	-3.556	-
Total	19.151	7.032 - 7.950	25.404	6.338 - 7.347	71 - 75 %

4.1.6 Concept 3: elec. A1

Concept 3 elec	Final energy (kWh/year)		Primary energy (kWh/year)		Primary energy savings
	Before	After	Before	After	
Heating	7.335	1.746 - 2.324	14.670	3.492 - 4.648	68 - 76 %
DHW	4.362	4.362	8.724	8.724	0 %
Ventilation	-	115	-	230	-
PV	-	-3.275	-	-6.550	-
Total	11.697	2.948 - 3.526	23.394	5.896 - 7.052	70 - 75 %

4.1.7 Concept 4: elec. A1

Concept 4 elec	Final energy (kWh/year)		Primary energy (kWh/year)		Primary energy savings
	Before	After	Before	After	
Heating	7.335	703 - 891	14.670	1.406 - 1.782	76 - 88 %
DHW	4.362	4.362	8.724	8.724	0 %
Ventilation	-	278	-	556	-
PV	-	-2.456	-	-4.912	-
Total	11.697	2.887 - 3.075	23.394	5.774 - 6.150	73 - 75 %

4.1.8 Analysis 2

Concept	Primary energy (kWh/year)		Envelope renovation	Energy savings
	Before	After		
Concept 1: elec.	23.394	-4.296 - (-4.656)	No	> 100 %
Concept 1: elec.&gas	25.404	-1.788 - (-2.410)	No	> 100 %
Concept 2: elec.	23.394	3.597 - 5.138	No	78 - 85 %
Concept 2: elec.&gas	25.404	3.301 - 3.973	Yes/Partial	85 - 87 %
Concept 3	23.394	4.984 - 5.728	Yes/Partial	76 - 79 %
Concept 4	23.394	4.330 - 4.974	No	79 - 81 %
Concept 5	29.464	7.584 - 9.772	Yes	67 - 74 %
Concept 6	25.404	6.715 - 7.893	Yes	69 - 74 %

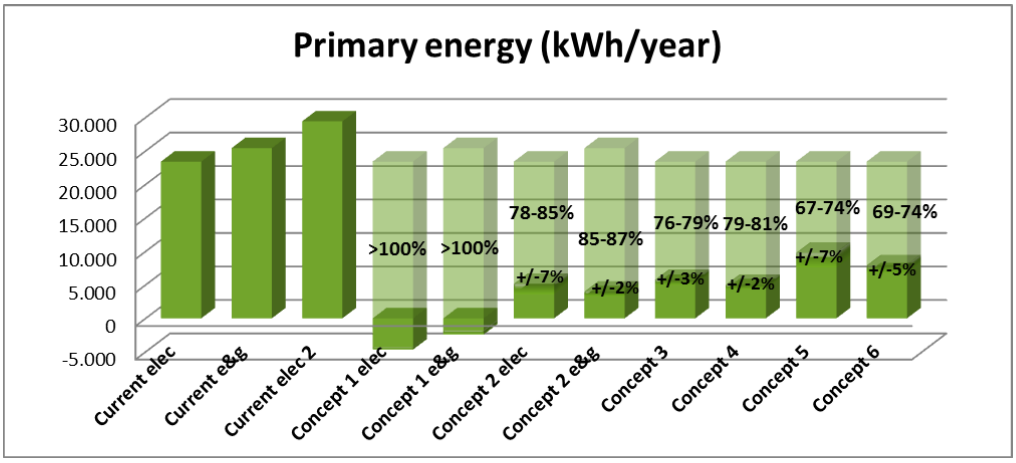


Figure 12 Primary energy overview

4.1.9 Concept 1: elec. A2

Concept 1 elec	Final energy (kWh/year)		Primary energy (kWh/year)		Primary energy savings
	Before	After	Before	After	
Heating	7.335	1.076 - 1.256	14.670	2.152 - 2.512	83 - 85 %
DHW	4.362	561	8.714	1.122	87 %
Ventilation	-	185	-	370	-
PV		-4.150		-8.300	-
Total	11.697	-2.148 - (-2.328)	23.394	-4.296 - (-4.656)	> 100 %

4.1.10 Concept 1: elec.&gas A2

Concept 1 Elec&gas	Final energy (kWh/year)		Primary energy (kWh/year)		Primary energy savings
	Before	After	Before	After	
Heating	14.331	1.509 - 1.820	15.764	3.018 - 3.640	77 - 81 %
DHW	4.820	622	9.640	1.244	87 %
Ventilation	-	484	-	968	-
PV	-	-3.820	-	-7.640	-
Total	19.151	-894 - (-1.205)	25.404	-1.788 - (-2.410)	> 100%

4.1.11 Concept 2: elec. A2

Concept 1 elec	Final energy (kWh/year)		Primary energy (kWh/year)		Primary energy savings
	Before	After	Before	After	
Heating	7.335	6.335 - 7.736	14.670	6.969 - 8.510	42 - 52 %
DHW	4.362	4.140	8.714	4.554	48 %
Ventilation	-	185	-	370	-
PV		-4.150		-8.300	-
Total	11.697	6.512 - 7.913	23.394	3.597 - 5.138	78 - 85 %

4.1.12 Concept 2: elec.&gas A2

Concept 2 Elec&gas	Final energy (kWh/year)		Primary energy (kWh/year)		Primary energy savings
	Before	After	Before	After	
Heating	14.331	4.959 - 5.570	15.764	5.455 - 6.127	62 - 65 %
DHW	4.820	4.578	9.640	5.036	48 %
Ventilation	-	225	-	450	-
PV	-	-3.820	-	-7.640	-
Total	19.151	5.942 - 6.553	25.404	3.301 - 3.973	85 - 87 %

4.1.13 Concept 3 A2

Concept 3 elec	Final energy (kWh/year)		Primary energy (kWh/year)		Primary energy savings
	Before	After	Before	After	
Heating	7.335	2.167 - 2.539	14.670	4.334 - 5.078	65 - 70 %
DHW	4.362	4.362	8.714	8.724	0 %

Ventilation	-	113	-	226	-
PV		-4.150		-8.300	-
Total	11.697	2.492 - 2.864	23.394	4.984 - 5.728	76 - 79 %

4.1.14 Concept 4 A2

Concept 4	Final energy (kWh/year)		Primary energy (kWh/year)		Primary energy savings
	Before	After	Before	After	
Heating	7.335	1.418 - 1.740	14.670	2.836 - 3.480	76 - 81 %
DHW	4.362	4.362	8.714	8.724	0 %
Ventilation	-	535	-	1.070	-
PV		-4.150		-8.300	-
Total	11.697	2.165 - 2.487	23.394	4.330 - 4.974	79 - 81 %

4.1.15 Concept 5

Concept 5	Final energy (kWh/year)		Primary energy (kWh/year)		Primary energy savings
	Before	After	Before	After	
Heating	9.960	2.929 - 4.023	19.920	5.858 - 8.046	60 - 71 %
DHW	4.772	2.777	9.544	5.554	42 %
Ventilation	-	581	-	1.162	-
PV	-	-2.495	-	-4.990	-
Total	14.732	3.792 - 4.886	29.464	7.584 - 9.772	67 - 74 %

4.1.16 Concept 6

Concept 6	Final energy (kWh/year)		Primary energy (kWh/year)		Primary energy savings
	Before	After	Before	After	
Heating	14.331	5.009 - 6.080	15.764	5.510 - 6.688	58 - 65 %
DHW	4.820	4.578	9.640	5.036	48 %
Ventilation	-	579	-	1.158	-
PV	-	-2.495	-	-4.990	-
Total	19.151	7.672 - 8.743	25.404	6.715 - 7.893	69 - 74 %

4.2 Economic study

Another important aspect in a renovation is the economical one. The following tables reflect the amount of money saved and the investment necessary to implement each concept. With these two values, the payback period can be calculated to check the profitability of the investment.

4.2.1 Analysis 1

Concept	Saved (€)	Investment (€)	Payback (years)
Concept 1: elec.	885 - 905	18.948,3	20,9 - 21,4
Concept 1: elec.&gas	872 - 897	23.482,7	26,2 - 26,9
Concept 2: elec.	883 - 923	19.494,2	21,1 - 22,1
Concept 2: elec.&gas	946 - 995	25.120,6	25,3 - 26,5
Concept 3	930 - 979	19.749,7	20,2 - 21,2
Concept 4	937 - 975	18.787,3	19,3 - 20,1

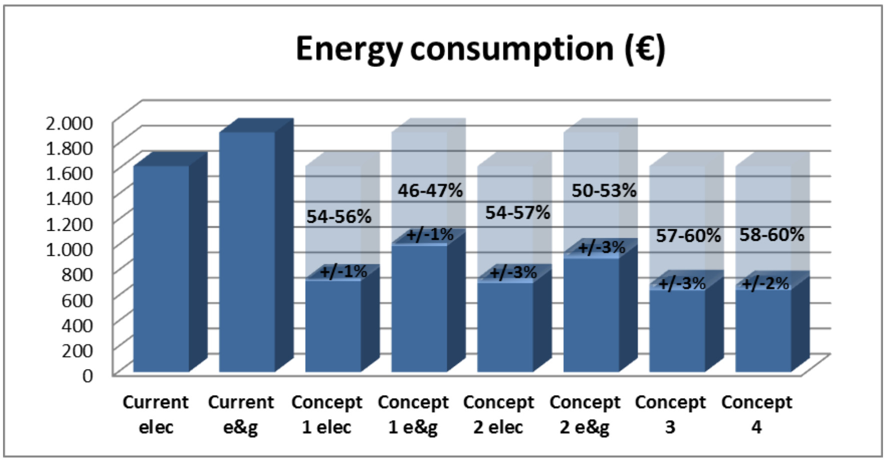


Figure 13 Economic savings overview

4.2.2 Concept 1: elec. A1

Item	Description	Cost/measure unit	Units	Total cost (€)
Ext. walls	Insufl. + aerogel	110 €/m2	39 m2	4.265,3
Roof	12 cm MW	8,3 €/m2	47,5 m2	391,4
Floor	10 cm XPS	64,4 €/m2	47,5 m2	3.056,6
Windows	New windows 1,2 W/m2K	449,5 €/m2	5,9 m2	2.652,1
Energy source	Air-water hp	6.525 €	1	6.525,0
Ventilation	Mech. ventilation	2.057,7 €	1	2.057,7
Total				**18.948,3**

Before (€)	After (€)	Saved (€)	Investment (€)	Payback (years)
1.623,8	718,2 - 739,3	884,5 - 905,0	18.948,3	20,9 - 21,4

4.2.3 Concept 1: elec.&gas A1

Item	Description	Cost/measure unit	Units	Total cost (€)
Ext. walls	Insufl. + aerogel	110 €/m2	93,6 m2	10.237,0
Roof	12 cm MW	8,3 €/m2	40,4 m2	332,9
Windows	New windows 1,2 W/m2K	449,5 €/m2	12,4 m2	5.573,9
Energy source	Air-water hp	4.025 €	1	4.025,0
Ventilation	Mech. ventilation	3.313,8 €	1	3.313,8
Total				**23,482,7**

Before (€)	After (€)	Saved (€)	Investment (€)	Payback (years)
1.890,8	994,1 - 1.018,7	872,1 - 896,7	23.482,7	26,2 - 26,9

4.2.4 Concept 2: elec. A1

Item	Description	Cost/measure unit	Units	Total cost (€)
Ext. walls	Insufl. + aerogel	110 €/m2	39 m2	4.265,3
Roof	12 cm MW	8,3 €/m2	47,5 m2	391,4
Floor	10 cm XPS	64,4 €/m2	47,5 m2	3.056,6
Windows	New windows 1,2 W/m2K	449,5 €/m2	5,9 m2	2.652,1
Energy source	Cond. boiler	4.886,9 €	1	4.886,9
Ventilation	Mech. ventilation	2.057,7 €	1	2.057,7
PV	1,4 kWp	2.184,0 €	1	2.184,0
Total				**19.494,2**

Before (€)	After (€)	Saved (€)	Investment (€)	Payback (years)
1.623,8	701,3 - 740,7	883,1 - 922,5	19.494,2	21,1 - 22,1

4.2.5 Concept 2: elec.&gas A1

Item	Description	Cost/measure unit	Units	Total cost (€)
Ext. walls	Insufl. + aerogel	110 €/m2	93,6 m2	10.237,0
Roof	12 cm MW	8,3 €/m2	40,4 m2	332,9
Windows	New windows 1,2 W/m2K	449,5 €/m2	12,4 m2	5.573,9
Energy source	Cond.boiler	2.386,9 €	1	2.386,9
Ventilation	Mech. ventilation	3.313,8 €	1	3.313,8
PV	2,1 kWp	3.276 €		3.276,0
Total				**25.120,6**

Before (€)	After (€)	Saved (€)	Investment (€)	Payback (years)
1.890,8	896,0 - 944,8	946,0 - 994,8	25.120,6	25,3 - 26,5

4.2.6 Concept 3: elec. A1

Item	Description	Cost/measure unit	Units	Total cost (€)
Ext. walls	Insufl. + aerogel	110 €/m2	39 m2	4.265,3
Roof	12 cm MW	8,3 €/m2	47,5 m2	391,4
Floor	10 cm XPS	64,4 €/m2	47,5 m2	3.056,6
Windows	New windows 1,2 W/m2K	449,5 €/m2	5,9 m2	2.652,1
Energy source	Night storage units	1.242,4 €	1	1.242,4
Ventilation	Mech. ventilation	2.057,7 €	1	2.057,7
PV	3,9 kWp	6.084,0 €	1	6.084,0
Total				**19.749,7**

Before (€)	After (€)	Saved (€)	Investment (€)	Payback (years)
1.623,8	644,5 - 694,2	929,6 - 979,3	19.749,7	20,2 - 21,2

4.2.7 Concept 4: elec. A1

Item	Description	Cost/measure unit	Units	Total cost (€)
Ext. walls	Insufl. + aerogel	110 €/m2	39 m2	4.265,3
Roof	12 cm MW	8,3 €/m2	47,5 m2	391,4
Floor	10 cm XPS	64,4 €/m2	47,5 m2	3.056,6
Windows	New windows 1,2 W/m2K	449,5 €/m2	5,9 m2	2.652,1
Energy source	Multi split	1.840 €	1	1.840,0
Ventilation	Mech. ventilation	2.057,7 €	1	2.057,7
PV	2,9 kWp	4.524,0 €	1	4.524,0
Total				**18.787,3**

Before (€)	After (€)	Saved (€)	Investment (€)	Payback (years)
1.623,8	648,6 - 686,8	937,0 - 975,2	18.787,3	19,3 - 20,1

4.2.8 Analysis 2

Concept	Saved (€)	Investment (€)	Payback (years)
Concept 1: elec.	1.398,8 - 1.435,4	16.382,7	11,4 - 11,7
Concept 1: elec.&gas	1.228,7 - 1.291,8	14.514,8	11,2 - 11,8
Concept 2: elec.	1.143,0 - 1.210,0	14.744,6	12,2 - 12,9
Concept 2: elec.&gas	1.237,1 - 1.269,6	21.907,0	17,2 - 17,7
Concept 3	1.051,0 - 1.083,0	18.560,1	17,1 - 17,6
Concept 4	830,5 - 895,9	11.697,7	13,1 - 14,1
Concept 5	1.024,9 - 1.119,0	26.191,0	23,4 - 25,5
Concept 6	926,9 - 983,9	23.000,0	23,4 - 24,8

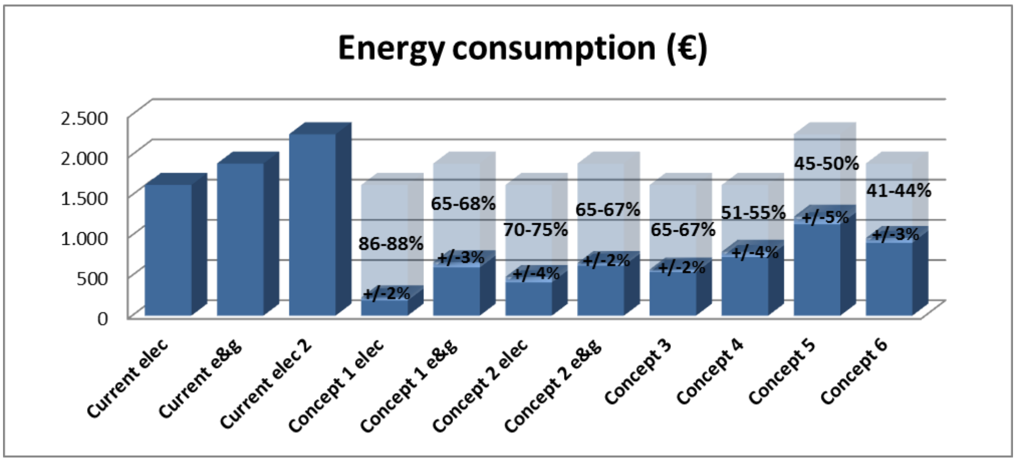


Figure 14 Economic savings overview

4.2.9 Concept 1: elec. A2

Item	Description	Cost/measure unit	Units	Total cost (€)
Energy source	Air-water hp	6.525 €	1	6.525,0
Ventilation	Mech. ventilation	2.057,7 €	1	2.057,7
PV	5 kWp	7.800 €	1	7.800
Total				**16.382,7**

Before (€)	After (€)	Saved (€)	Investment (€)	Payback (years)
1.623,8	188,5 - 225,0	1.398,8 - 1.435,4	16.382,7	11,4-11,7

4.2.10 Concept 1: elec.&gas A2

Item	Description	Cost/measure unit	Units	Total cost (€)
Energy source	Air-water hp	4.025 €	1	4.025
Ventilation	Mech. ventilation	3.313,8 €	1	3.313,8
PV	4,6 kWp	7.176 €	1	7.176
Total				**14.514,8**

Before (€)	After (€)	Saved (€)	Investment (€)	Payback (years)
1.890,8	598,9 - 662,1	1.228,7 - 1.291,8	14.514,8	11,2-11,8

4.2.11 Concept 2: elec. A2

Item	Description	Cost/measure unit	Units	Total cost (€)
Energy source	Cond. boiler	4.886,9 €	1	4.886,9
Ventilation	Mech. ventilation	2.057,7 €	1	2.057,7
PV	5 kWp	7.800 €	1	7.800
Total				**14.744,6**

Before (€)	After (€)	Saved (€)	Investment (€)	Payback (years)
1.623,8	413,8 - 480,3	1.143 - 1.210	14.744,6	12,2 - 12,9

4.2.12 Concept 2: elec.&gas A2

Item	Description	Cost/measure unit	Units	Total cost (€)
Ext. walls	Insufl.	33,4 €/m2	93,6 m2	3.123,4
Roof	12 cm MW	8,3 €/m2	40,4 m2	332,9
Windows	New windows 1,2 W/m2K	449,5 €/m2	12,4 m2	5.573,9
Energy source	Cond.boiler	2.386,9 €	1	2.386,9
Ventilation	Mech. ventilation	3.313,8 €	1	3.313,8
PV	4,6 kWp	3.276 €		7.176,0
Total				**21.907**

Before (€)	After (€)	Saved (€)	Investment (€)	Payback (years)
1.890,8	621,1 - 653,6	1.237,1 - 1.269,6	21.907	17,2 - 17,7

4.2.13 Concept 3: elec. A2

Item	Description	Cost/measure unit	Units	Total cost (€)
Ext. walls	Insufl.	33,4 €/m2	39 m2	1.301,4
Roof	15 cm MW	9,5 €/m2	47,5 m2	449,8
Floor	10 cm XPS	64,4 €/m2	47,5 m2	3.056,6
Windows	New windows 1,2 W/m2K	449,5 €/m2	5,9 m2	2.652,1
Energy source	Night storage units	1.242,4 €	1	1.242,4
Ventilation	Mech. ventilation	2.057,7 €	1	2.057,7
PV	5 kWp	7.800 €	1	7.800,0
Total				**19.749,7**

Before (€)	After (€)	Saved (€)	Investment (€)	Payback (years)
1.623,8	540,8 - 572,8	1.051,0 - 1.083,0	18.560,1	17,1 - 17,6

4.2.14 Concept 4: elec. A2

Item	Description	Cost/measure unit	Units	Total cost (€)
Energy source	Multi split	1.840 €	1	1.840,0
Ventilation	Mech. ventilation	2.057,7 €	1	2.057,7
PV	5 kWp	7.800,0 €	1	7.800,0
Total				**11.697,7**

Before (€)	After (€)	Saved (€)	Investment (€)	Payback (years)
1.623,8	728,0 - 793,3	830,5 - 895,9	11.697,7	13,1 - 14,1

4.2.15 Concept 5

Item	Description	Cost/measure unit	Units	Total cost (€)
Energy source	Stor.heaters +DHH tank	6.889 €	1	6.889,0
Envelope	Insult.+vent.	10.322,8 €	1	10.322,8
PV	3 kWp	8.028,0 €	1	8.028
Total				**26.191,0**

Before (€)	After (€)	Saved (€)	Investment (€)	Payback (years)
2.254,7	1.135,7 - 1.229,7	1.024,9 - 1.119,0	26.191,0	23,4 - 25,5

4.2.16 Concept 6

Item	Description	Cost/measure unit	Units	Total cost (€)
Energy source	Cond.boiler	3.698 €	1	3.698,0
Envelope	Insult.+vent.	10.322,8 €	1	10.322,8
PV	3 kWp	8.028,0 €	1	8.028
Total				**23.000,0**

Before (€)	After (€)	Saved (€)	Investment (€)	Payback (years)
1.890,8	906,9 - 963,9	926,9 - 983,9	23.000,0	23,4 - 24,8

4.3 Environmental study

The purpose of this assessment is to identify the impact produced in the Environment by each renovation concept. For it, the equivalent carbon dioxide saved due to the application of each concept has been calculated:

4.3.1 Analysis 1

Concept	Electricity		Gas		Total
	(kWh)	(tCO2eq)	(kWh)	(tCO2eq)	(tCO2eq)
Concept 1: elec.	10.420 - 10.521	4,38 - 4,42	-	-	4,38 - 4,42
Concept 1: elec.&gas	-260,6 - (-381,6)	-0,11 - (-0,16)	17.849,6	4,11	3,95 - 4,00
Concept 2: elec.	12.053,6	5,06	-7.252,0 - (7.993,0)	-1,67 - (-1,84)	3,22 - 3,39
Concept 2: elec.&gas	1.787,6	0,75	8.346,6 - 9.264,6	1,92 - 2,13	2,67 - 2,88
Concept 3	6.206,0 - 6.784,0	2,61 - 2,85	-	-	2,61 - 2,85
Concept 4	7.897,4 - 8.085,4	3,20 - 3,40	-	-	3,32 - 3,40

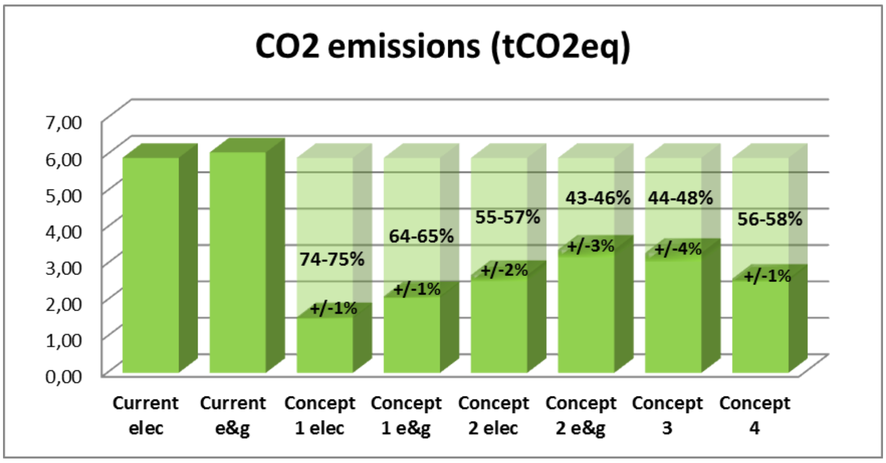


Figure 15 CO2 emissions overview

4.3.2 Analysis 2

Concept	Electricity		Gas		Total
	(kWh)	(tCO2eq)	(kWh)	(tCO2eq)	(tCO2eq)
Concept 1: elec.	11.355,0 - 11.535,0	4,77-4,84	-	-	4,77 - 4,84
Concept 1: elec.&gas	-96,6 - (-214,4)	-0,04-0,09	17.849,6	4,11	4,06 - 4,20
Concept 2: elec.	13.170,0	5,53	-10.475,0 - (-11.724,0)	-2,41 - (-2,70)	2,83 - 3,12
Concept 2: elec.&gas	2.604,4	1,09	7.701,6 - 8.312,6	1,77 - 1,91	2,86 - 3,01
Concept 3	6.343,0 - 6.715,0	2,66-2,82	-	-	2,66 - 2,82
Concept 4	6.720,0 - 7.042,0	2,82-2,96	-	-	2,82 - 2,96
Concept 5	8.349,0 - 9.066,0	3,51-3,81	-	-	3,51 - 3,81
Concept 6	1.720,4	0,72	7.190,6 - 7.356,6	1,65 - 1,69	2,38 - 2,41

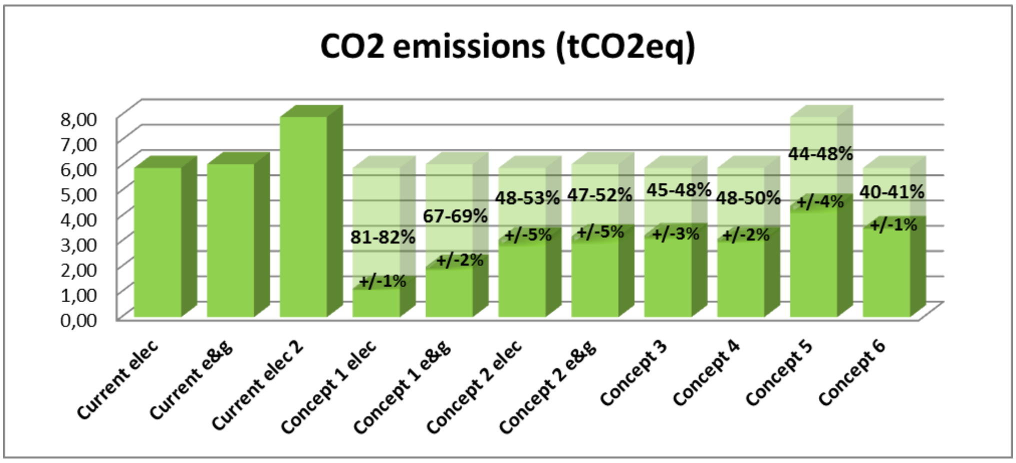


Figure 16 CO2 emissions overview

5 Conclusions (Padiham)

The initial situation of the pilot sites, in which the energy consumption is very high, allows to obtain the energy savings targeted easily.

In few concepts, the envelope renovation can be covered only by insufflating the air cavity, which makes it simple, adding an extra layer of insulation in the roof and in other cases with the substitution of the windows, that will correct the thermal bridges observed in the baseline. The new energy systems will reduce the consumption significantly due to the higher efficiency compared with the current systems. The addiction of the ventilation system will improve the comfort of the tenants. Due to the orientation of the roofs it is possible to add an important photovoltaic surface to reach the goal of the energy savings in the concepts which require it.

Due to the high price of the electricity, the analysis 2 is more convenient. To get the most of a photovoltaic system implies an important reduction for the tenants in their electric bills. The payback period obtained make it a reasonable renovation. The variation in the payback period produced by the modification of the parameters in the analysis of sensitivity is very small, around less than 2 years in both of the analysis calculated.

In connection with the reduction of carbon dioxide emissions, the concept number one obtains the highest reduction both for the case of 100% electric and electric & gas dwelling.

Treviso (IT)

Pilot site

6 Qualitative concept ideas (Treviso)

6.1 Introduction

To elaborate the renovation concepts, a brainstorming between Exeleria, Chalmers an 3C-Pre has been made. On it, each part contributed to develop an overview of different solutions that can be applied in the pilot site.

The different solutions involve the following elements:

- Envelope:
  - Wall
  - Roof
  - Floor
  - Roof
  - Window
- Ventilation
- Heating system
- Renewable energy
- ESCO

An analysis of the advantages, disadvantages and possible innovations has been made. To have an idea of the impact of every solution proposed exeleria has calculated how affect them to the primary energy in the pilot site using the same energy simulation tool as in the baseline analysis.

6.2 Design of the renovation concepts

Once an scheme of different solutions has been designed, the next step is to mix them to create a renovation concept.

The proposed renovation concepts have been designed with the combination of one solution for each element: walls, ventilation, heating, etc.

The following figure represents the steps made to obtain a final solution:

Solution	Ventilation	Roof	Wall (brick)	Window	Floor	Heating	RES	ESCO
I	**Central ventilation system** Advantages: high efficiency, low maintenance costs, central access to filters, possible synergy with thick outside insulation (for ventilation channels), higher quality filters possible. Free cooling Disadvantages: space for ventilation channels/ ducts, noise between appartments/ big equipment (storage), cleaning of pipes might be difficult, sound, additional sensors (CO2 or humidity) needed for optimal management Possible Innovations: enthalpy	**Insulation from inside** Advantages: good insulation levels possible; limited effort, can be done from inside; improves air-tightness, cheapest solution Disadvantages: heat bridges might remain, structural wooden beams might need to be "doubled-up" (might be needed for PV anyway) Possible Innovations: super insulation (not cost competitive)	**EWIS** Advantages: very good insulation levels possible. Disadvantages: changes the looks of the building, either might leave heat bridges or requires exchange of windows as well to move them back to the insulation layer; some insulation systmes might be subject to mold and fungi on outside Possible innovations: super insulation (not cost competitive in this case)	**Exchange glazing and frame** Advantages: very good insulation levels possible; improves air tightness (especially in combination with wall insulation measures); allows optimal positioning of new window regarding the insulation layer Disadvantages: requires some disturbing works; more expensive than just changing glazing; will reduce daylight factor Possible innovations: window frame integrated ventilation. U-Values close to 1 W/m2K	**No changes** Advantages: cheap Disadvantages: low insulation level which is poblematic especially in the areas where there is floor over air Possible innovations: none	**Condensing gas boiler** Advantages: relatively cheap, effective and working technology, can be combined with solar thermic Disadvantages: requires well insulated envelope to reach DREEAM targets; requires grid connection, requires water circuit and radiators (not existing in some rooms) Possible innovations: combination with solar thermic/ storage	**Solar thermal** Advantages: makes it substantially easier to achieve DREEAM targets; easy to install Disadvantages: puts additional weight on roof; changes the look; maintenance,requires an optimal surface un the roof Possible innovations: conbination with gas boiler	**Yes** Advantages: makes the system more economically valid, offers high inovation potential; potential new business Disadvantages: legal frame conditions unclear; complex
II	**No controlled ventilation** Advantages: cheap Disadvantages: no heat recovery; in combination with a more air-tight envelope humidity problems might arise due to wrong ventilation; problems with mold related health issues might arise Possible Innovations: none	**Exchange roof for a new one** Advantages: very good insulation levels; no remaining heat bridges; can be easily combined with PV, visual aspect Disadvantages: expensive; extensive works needed, waste generation Possible innovations: prefab solutions; integrated PV/ ventilation	**Ventilated facade** Advantages: good insulation levels possible. Visual aspect of the building. Possibility of include PV integrated in the façade. Disadvantages: High price compared with EWI system and also more thickness. Possible Innovations: PV integrated in facade	**Add second skin window** Advantages: very good insulation levels possible; new window can be put in the (new) insulation layer to prevent/ limit heat bridges Disadvantages: depending on current window might be complicated; will significantly reduce daylight factor; might look awkward; Possible Innovations: integrated ventilation	**Insulation of celler ceiling** Advantages: does not reduce space in the living floor Disadvantages: difficult to reach good insulation values with low thickness Possible innovations: super insulation	**Heat pump (air-water)** Advantages: combined with green electricity might allow reaching the DREEAM targets with less envelope changes; can use existing infrastructure (if radiators are there) or be combined with floor refitting, no gas grid connection necessary Disadvantages: worst COP in winter (if air) or high initial investment costs Possible innovations: combination	**Photovoltaic** Advantages: makes it substantially easier to achieve DREEAM targets; easy to install Disadvantages: puts additional weight on roof; changes the look; maintenance,requires an optimal surface un the roof Possible innovations: as external element in ventilated façade. Combination with heat pump system	**No**
III	**Extract ventilation system** Advantages: cheap way to renovate air. Decreases the accumulation of moisture and possible smokes. Disadvantage: no heating recovery system		**Internal insulation** Advantages: provides good insulation levels; does not generate waste, easiness to install Disadvantages: reduces internal area, very expensive solution Potential innovations: aerogel for the internal insulation	**Increase window sizes (down to ground)** Advantages: will increase dailight factor; will add quality; verygood insulation levels possible; visual aspect, increases solar gains in winter Disadvantages: waste generation, increases budget, increases heat transmissions losses				

Figure 17 List of renovation concepts

It can be possible that a renovation concept can be split having a different solution for the same element and the rest are identical.

After the renovation concepts have been defined, they have been presented to de building owners, who have made modifications according to their desires.

7 Assumptions (Treviso)

There are some factors to take into consideration when deciding to make an analysis of the renovation. These factors are: price of energy, primary energy factors and the emissions of carbon dioxide.

These factors vary in each pilot site due to many reasons like the market prices of the energy suppliers, government policies, the energy mix of the country which affects to the primary energy factor and the emission of carbon dioxide.

7.1 Price of energy

The dwellings are supplied by two different energy sources: electricity and gas.

The prices of them have been obtained from the bills provided by the tenants, taking the most recently one:

- Electricity (day): 0,21 €/kWh
- Gas: 0,08 €/kWh

The tariffs for generation and export of the electricity generated by a renewable energy system is not considered in the proposed options due to the legal impediment for ATER Treviso to sell electricity.

7.2 Primary energy factors

The final energy only reflects the consumption. Therefore, it is necessary to convert it to primary energy which encompass the energy in its different steps that are: production, storage, transport and consumption.

These values, obtained by DGR 967/2015 and DGR 1275/2015, are:

- Electricity: 2,42
- Natural gas: 1,05

7.3 Carbon dioxide emission

The environmental aspect of the renovation it is focused in de carbon dioxide. Apart from the energy savings in a renovation is also important the reduction in the carbon dioxide emissions due to the reduction of the primary energy of the building.

These values, obtained by DGR 967/2015 and DGR 1275/2015, are:

- Electricity: 0,4332 kgC02/kWh
- Natural gas: 0,1998 kgC02/kWh

8 Renovation concepts (Treviso)

The renovation concepts proposed are focused in the improvement of the envelope both of the heating and domestic hot water efficiency. All of the concepts have mechanical ventilation system with heating recovery.

In the next section we can see a brief description of each concept:

8.1 Concept 1

- Envelope: External wall insulation system, adding 160 mm of EPS and for the case of the wall with radiators 10 mm of aerogel in the internal side. For the roof, 200 mm of rock wool in the part against the unheated room and 80 mm of XPS in the boundary of the roof. For the floor 200 mm XPS. Triple-glazed windows.

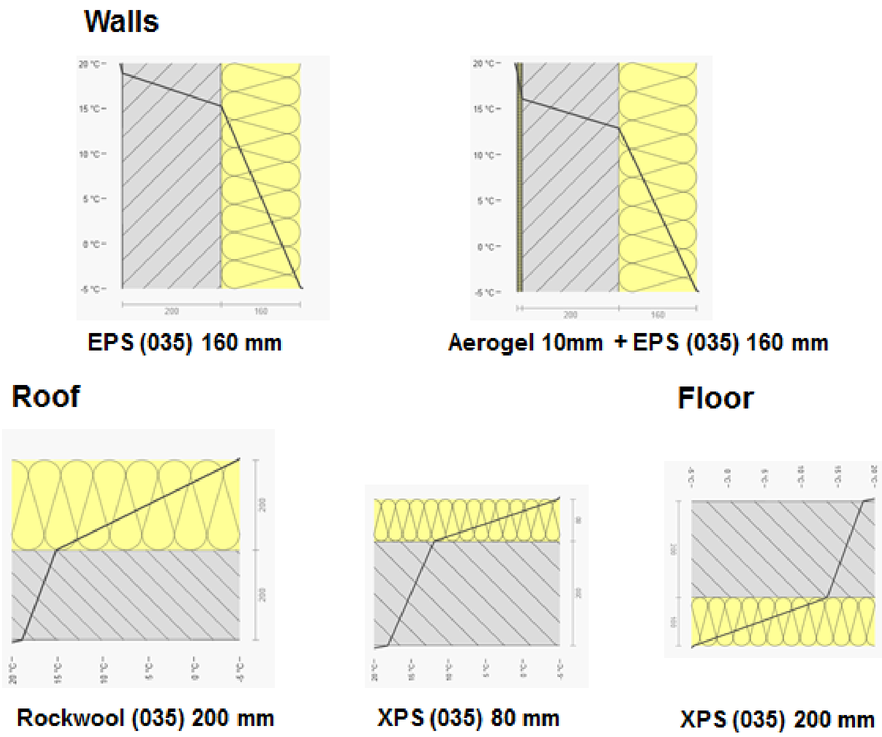


Figure 18 Insulation concept 1

The new U-Values obtained are:

Element	Current U-Value (W/m2K)	Proposed U-Value) (W/m2K)
External walls	0,99	0,18/0,16
Roof	1,06	0,18/0,31
Ground floor	1,00	0,26
Windows	2,34	1,10

- Heating and DHW by a condensing boiler with storage tank. The seasonal efficiency of the boiler is close to 97%.

Figure 19 Condensing boiler

- Ventilation: mechanical ventilation system with heating recovery. The average efficiency is up to 75% on temperature. Free-cooling possible thanks to the by-pass function. Control of the unit with a LCD display and remote control.

Figure 20 Heat recovery unit

- Renewable energy: Solar thermal system in the roof, which preheat water before the condensing boiler. The installation it is composed by 26 solar collectors (67,86 m^2) and a centralized storage tank of 1.500 l. The annual production of the system is 22.717 kWh.

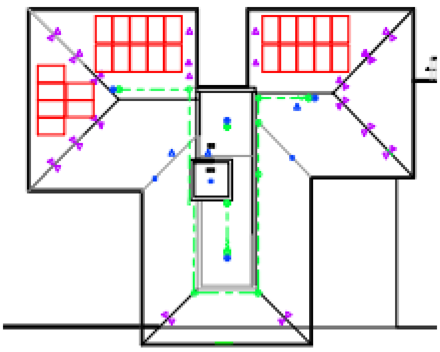


Figure 21 Solar thermal system

That can be also combined with a photovoltaic system to benefit from the all roof surface. A installation of 8,5 kWp has been considered. The annual production of it is around 8.000 kWh.

8.2 Concept 2

It is divided in two different alternatives according to the performance of the envelope renovation, obtaining in the option a very good insulation levels and option b an intermediate insulation.

- Envelope:
    - Option a (High envelope performance): Ventilated façade adding 120 mm of mineral wool. For the roof, 200 mm of rock wool in the part against the unheated room and 80 mm of XPS in the boundary of the roof. For the floor 200 mm XPS. Double-glazed windows.

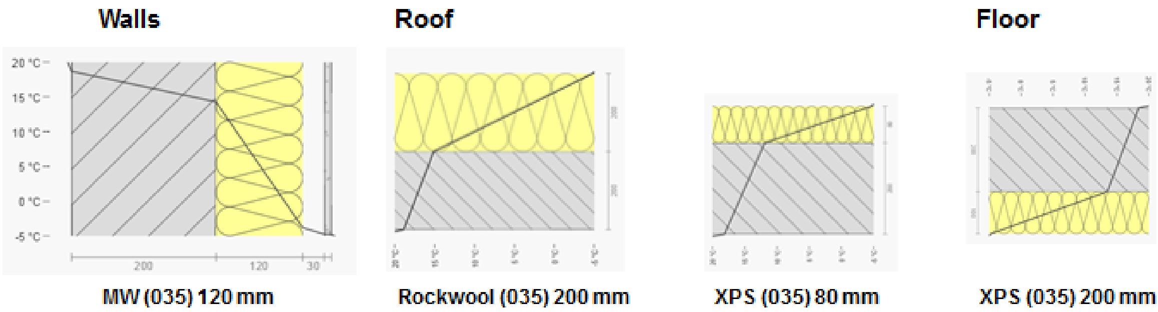


Figure 22 Insulation concept 2a

The new U-Values obtained are:

Element	Current U-Value (W/m2K)	Proposed U-Value) (W/m2K)
External walls	0,99	0,22
Roof	1,06	0,18/0,31
Ground floor	1,00	0,26
Windows	2,34	1,5

- Option b (Medium-high envelope performance): Ventilated façade adding 40 mm of mineral wool. For the roof 60 mm of rock wool and for the floor 40 mm XPS. Double-glazed windows.

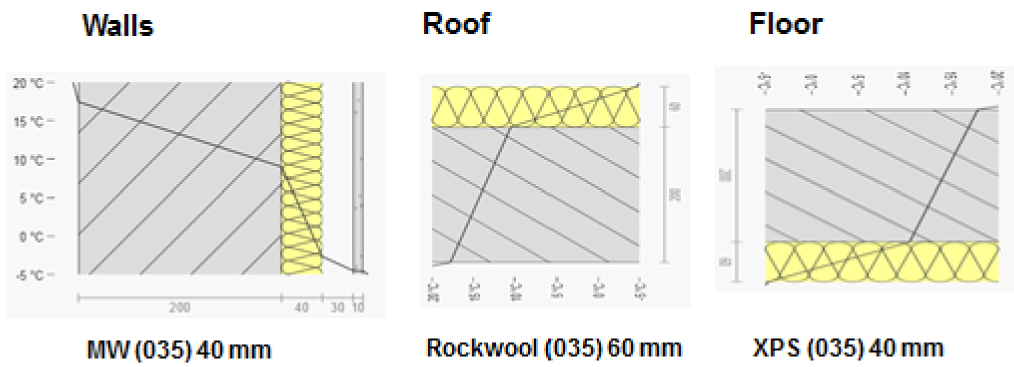


Figure 23 Insulation concept 2b

The new U-Values obtained are:

Element	Current U-Value (W/m2K)	Proposed U-Value) (W/m2K)
External walls	0,99	0,43
Roof	1,06	0,36
Ground floor	1,00	0,36
Windows	2,34	1,7

- Heating and DHW by a condensing boiler with storage tank. The efficiency of the boiler is close to 97%.
- Ventilation: mechanical ventilation system with heating recovery. The average efficiency is 75% on temperature. Free-cooling possible thanks to the by-pass function. Control of the unit with a LCD display and remote control.
- Renewable energy: Photovoltaic integrated in the façade as an external element of the ventilated façade in the walls oriented to the south. The total production of the PV system (around 13.000 kWh/year) will be storage in batteries.

8.3 Concept 3

- Envelope: Same as in concept 1.
- Heating and domestic hot water by an air-water heat pump with a storage tank for the DHW. The COP of the system, working with an output temperature of 65 ºC is 3,08.

Figure 24 Air-water heat pump

- Ventilation: mechanical ventilation system with heating recovery. The average efficiency is 75% on temperature. Free-cooling possible thanks to the by-pass function. Control of the unit with a LCD display and remote control.
- Renewable energy: The air-water heat pump with a high COP can be considered as renewable energy because a high percentage of the energy produced is taken from a renewable source (air).

9 Results (Treviso)

With the help of the simulation tool used in the baseline to analyse the energy consumption of the pilot site, all the renovation concepts proposed have been simulated in order to study the energy savings of each solution. An analysis of sensitivity has been made using the same procedure as in the baseline description with the parameters that can differ, resulting in different ranges.

9.1 Energy savings

The following tables reflect briefly the energy saving obtained:

Concept	Primary energy (kWh/year)		Primary energy savings
	Before	After	
Concept 1	159.486	1.976 - 12.494	93 - 99 %
Concept 2a	159.486	13.708 - 26.843	83 - 91%
Concept 2b	159.486	36.337 - 46.008	71 - 77 %
Concept 3	159.486	31.166 - 36.739	77 - 80 %

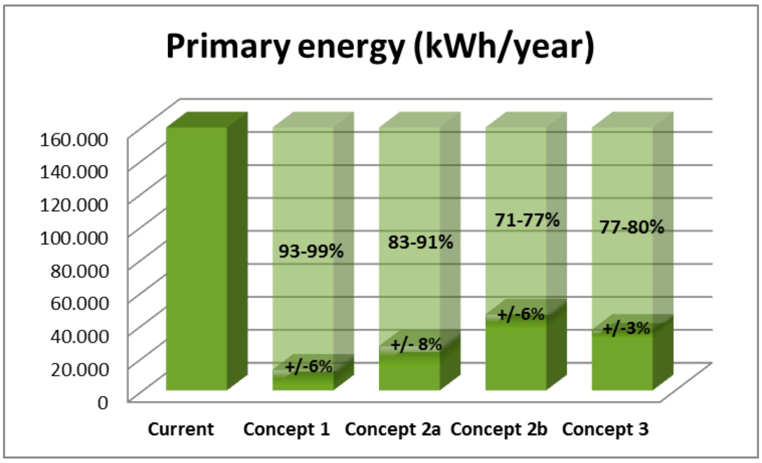


Figure 25 Primary energy overview

For the energy savings calculation, the consumption related to lighting and appliances have not been taken into account. To establish energy saving measures in this consumption is a tricky issue due to a factors like the high amount of devices, the variety of efficiency of the devices, the user's behaviour of them, etc. Therefore, it cannot be taken into account for the DREEAM Project.

9.1.1 Concept 1

Concept 1	Final energy (kWh/year)		Primary energy (kWh/year)		Primary energy savings
	Before	After	Before	After	
Heating	130.435	15.871 - 24.515	136.957	19.858 - 25.741	81 - 86 %
DHW	21.456	17.164	22.529	18.022	20 %
Solar thermal	-	-17.688	-	-18.572	-
Ventilation	-	2.106	-	5.054	-
PV	-	-8.000	-	-19.200	-
Total	151.891	9.460 - 18.097	159.486	1.976 - 11.045	93 - 99 %

9.1.2 Concept 2a

Concept 2a	Final energy (kWh/year)		Primary energy (kWh/year)		Primary energy savings
	Before	After	Before	After	
Heating	130.435	20.801 - 33.310	136.957	21.841- 34.976	74 - 84 %
DHW	21.456	17.164	22.529	18.022	20 %
PV	-	-13.000	-	-31.200	-
Ventilation	-	2.102	-	5.045	-
Total	151.891	27.067 - 39.576	159.486	13.708 - 26.843	83 - 91 %

9.1.3 Concept 2b

Concept 2b	Final energy (kWh/year)		Primary energy (kWh/year)		Primary energy savings
	Before	After	Before	After	
Heating	130.435	42.352 - 51.563	136.957	44.470 - 54.141	60 - 68 %
DHW	21.456	17.164	22.529	18.022	20 %
PV	-	-13.000	-	-31.200	-
Ventilation	-	2.102	-	5.045	-
Total	151.891	48.618 - 57.829	159.486	36337 - 46.008	71 - 77 %

9.1.4 Concept 3

Concept 3	Final energy (kWh/year)		Primary energy (kWh/year)		Primary energy savings
	Before	After	Before	After	
Heating	130.435	6.691 - 9013	136.957	16.058 - 17.054	84 - 88 %
DHW	21.456	4.189	22.529	10.054	55 %
Ventilation	-	2.106	-	5.045	-
Total	151.891	12.986 - 15.308	159.486	31.166 - 36.739	77 - 80 %

9.2 Economic study

Another important aspect in a renovation is the economical one. The following tables reflect the amount of money saved and the investment necessary to implement each concept. With these two values, the payback period can be calculated to check the profitability of the investment.

Concept	Saved (€)	Investment (€)	Payback (years)
Concept 1	11.469 - 12.161	640.174	52,6 - 55,8
Concept 2a	10.402 - 11.402	605.799	53,1 - 58,2
Concept 2b	8.600 - 9.679	434.388	44,9 - 48,6
Concept 3	8.937 - 9.424	681.922	72,3 - 76,3

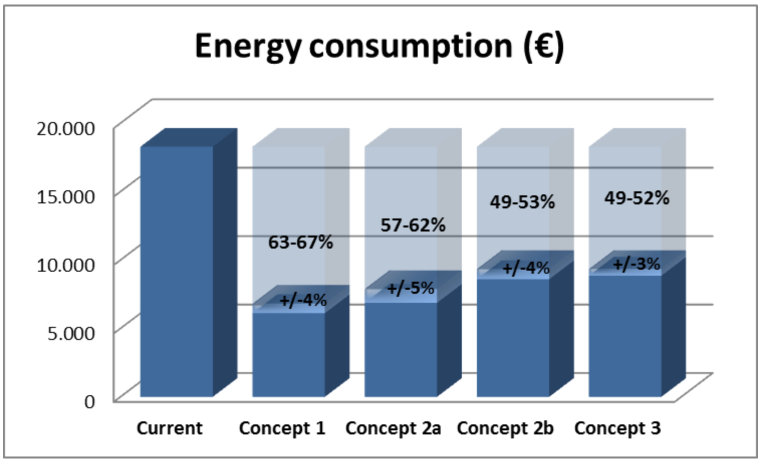


Figure 26 Economic savings overview

9.2.1 Concept 1

Item	Description	Cost/measure unit	Units	Total cost (€)
Ext. walls	16 cm EPS	95 €/m2	1.918 m2	182.210
	1 cm aerogel	94 €/m2	192 m2	18.048
Roof	20 cm RW/ 8 cm XPS	16 €/m2	393 m2	6.131
	8 cm XPS	26 €/m2	37 m2	973
Floor	20 cm XPS	58 €/m2	343 m2	20.031
Windows	New windows 1,1 W/m2K	625 €/m2	347 m2	216.876
Energy source	Condensing boiler	3.650 €	1	65.700
Ventilation	Mech. With heat recovery	3.795 €	1	68.310
Solar thermal	67,8 m2	36.896 €	1	36.869
PV	43 m2	25.000 €	1	25.000
Total				**640.147**

Before (€)	After (€)	Saved (€)	Investment (€)	Payback (years)
18.278,2	6.118 - 6.809	11.469 - 12.161	640.147	52,6 - 55,8

9.2.2 Concept 2a

Item	Description	Cost/measure unit	Units	Total cost (€)
Ext. walls	Vent. façade	143 €/m2	1.918 m2	274.274
Roof	20 cm RW	16 €/m2	393 m2	6.131
	8 cm XPS	26 €/m2	37 m2	973
Floor	20 cm XPS	58 €/m2	343 m2	20.031
Windows	New windows 1,5 W/m2K	340 €/m2	347 m2	117.980
Energy source	Condensing boiler	3.650 €	1	65.700
Ventilation	Mech. With heat recovery	3.795 €	1	68.310
PV system	200 m2	52.400 €	1	52.400
Total				**605.799**

Before (€)	After (€)	Saved (€)	Investment (€)	Payback (years)
18.278,2	6.875 - 7.876	10.402 - 11.402	605.799,1	53,1 - 58,2

9.2.3 Concept 2b

Item	Description	Cost/measure unit	Units	Total cost (€)
Ext. walls	Vent. façade	112 €/m2	1.918 m2	214.816
Roof	4 cm RW	8 €/m2	393 m2	3.612
Floor	4 cm XPS	34 €/m2	343 m2	11.491
Windows	New windows 1,7 W/m2K	210 €/m2	347 m2	72.870
Energy source	Condensing boiler	1.500 €	1	27.000
Ventilation	Mech. With heat recovery	2.900 €	1	52.200
PV system	200 m2	52.400 €	1	52.400
Total				**434.389**

Before (€)	After (€)	Saved (€)	Investment (€)	Payback (years)
18.278,2	8.599 - 9.336	8.942 - 9.679	434.389	44,9 - 48,6

9.2.4 Concept 3

Item	Description	Cost/measure unit	Units	Total cost (€)
Ext. walls	16 cm EPS	95 €/m2	1.918 m2	182.210
	1 cm aerogel	94 €/m2	192 m2	18.048
Roof	20 cm RW/ 8 cm XPS	16 €/m2	393 m2	6.131
	8 cm XPS	26 €/m2	37 m2	973
Floor	20 cm XPS	58 €/m2	343 m2	20.031
Windows	New windows 1,1 W/m2K	625 €/m2	347 m2	216.876
Energy source	Air-water heat pump	9.408 €	18	169.344
Ventilation	Mech. With heat recovery	3.795 €	1	68.310
Total				**681.922**

Before (€)	After (€)	Saved (€)	Investment (€)	Payback (years)
18.278,2	8.854 - 9.342	8.937 - 9.424	681.922,1	72,3 - 76,31

9.3 Environmental study

The purpose of this assessment is to identify the impact produced in the Environment by each renovation concept. For it, the equivalent carbon dioxide saved due to the application of each concept has been calculated:

Concept	Electricity		Gas		Total
	(kWh)	(tCO2eq)	(kWh)	(tCO2eq)	(tCO2eq)
Concept 1	5.894	2,55	127.900 - 136.537	25,55 - 27,28	28,11 - 29,83
Concept 2a	10.898	4,72	101.417 - 113.926	20,26 - 22,76	24,98 - 27,48
Concept 2b	10.898	4,72	89.470 - 92.375	17,88 - 18,46	22,60 - 23,18
Concept 3	-15.308 - (-12.986)	-6,63 - (-5,63)	151.891	30,35	23,72 - 24,72

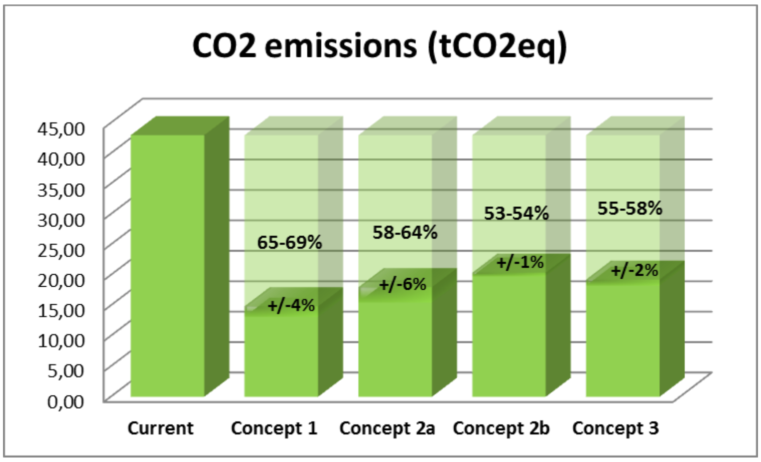


Figure 27 C02 emissions overview

10 Conclusions (Treviso)

The results obtained in the simulation show that in every case, the target of the energy saving is reached, specially concept 1, which is much higher.

A high improvement of the envelope means an important energy saving in the heating demand. The installation of a photovoltaic system helps to reduce in a high quantity the primary energy. Unfortunately, due to the multiple orientations of the building, there is not a big wall surface oriented to the south.

Another important improvement in the building is the addiction of the ventilation system with a heating recovery unit. This one will reduce the heating demand at the same time improve the comfort of the tenants.

All the concepts imply a good economic savings, around 550 €/year per dwelling. However, using the prices provided by ATER, the investment necessary is too high that make the payback period also high. Concept number 3 has the highest investment due to the price of the heat pump, that is more expensive than the condensing boiler.

The variation in the payback period produced by the modification of the parameters in the analysis of sensitivity is very small, around 2 or 3 years. The reason of that is the high investment prices, which implies a small variation in the payback period in case of modifications.

In connection with the reduction of carbon dioxide emissions, the concept 2a one obtains the highest reduction thanks to the production of the photovoltaic system. The reason of that is because the carbon dioxide emissions of the electricity is double higher than the gas.

Landskrona (SWE)

Pilot site

11 Qualitative concept ideas (Landskrona)

11.1 Introduction

To elaborate the renovation concepts, a brainstorming between Exeleria, Chalmers an 3C-Pre has been made. On it, each part contributed to develop an overview of different solutions that can be applied in the pilot site.

The different solutions involve the following elements:

- Envelope:
  - Wall
  - Roof
  - Floor
  - Roof
  - Window
- Ventilation
- Heating system
- Renewable energy
- ESCO

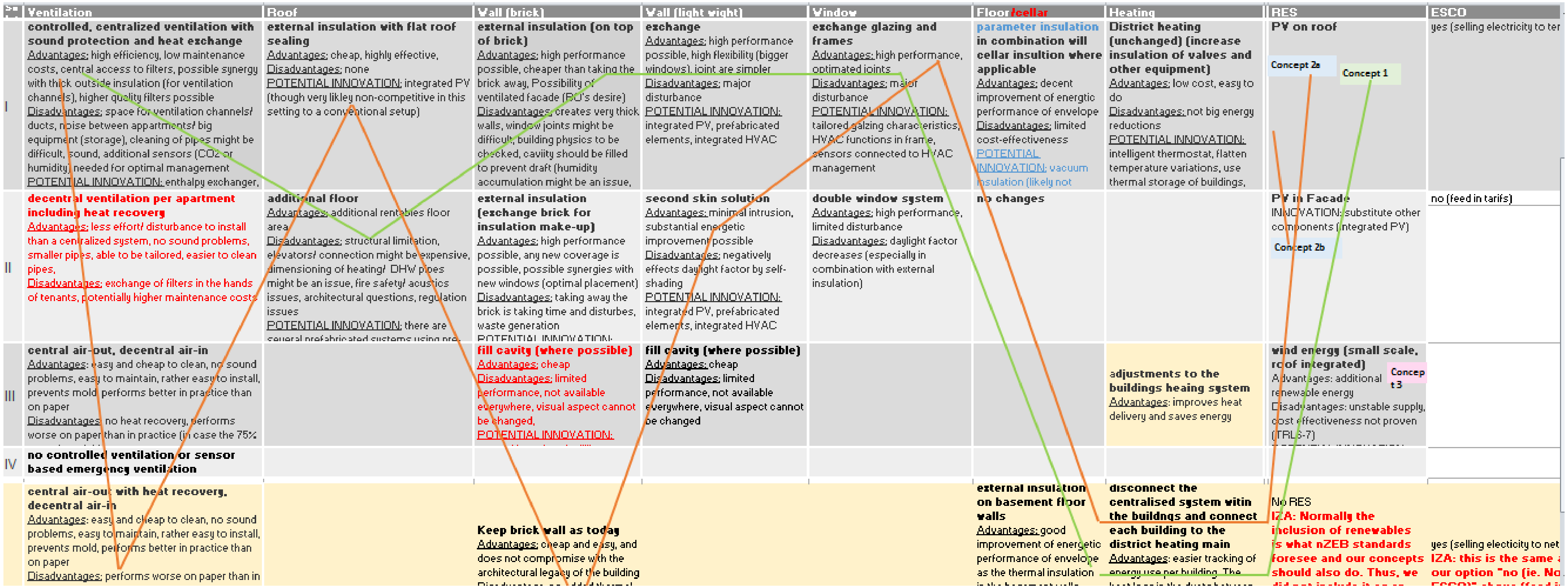
An analysis of the advantages, disadvantages and possible innovations has been made. To have an idea of the impact of every solution proposed exeleria has calculated how affect them to the primary energy in the pilot site using the same energy simulation tool as in the baseline analysis.

11.2 Design of the renovation concepts

Once an scheme of different solutions has been designed, the next step is to mix them to create a renovation concept.

The proposed renovation concepts have been designed with the combination of one solution for each element: walls, ventilation, heating, etc.

The following figure represents the steps made to obtain a final solution:



	Ventilation	Roof	Wall (brick)	Wall (light wight)	Window	Floor /cellar	Heating	RES	ESCO
I	**controlled, centralized ventilation with sound protection and heat exchange** Advantages: high efficiency, low maintenance costs, central access to filters, possible synergy with thick outside insulation (for ventilation channels), higher quality filters possible Disadvantages: space for ventilation channels/ ducts, noise between appartments/ big equipment (storage), cleaning of pipes might be difficult, sound, additional sensors (CO2 or humidity) needed for optimal management POTENTIAL INNOVATION: enthalpy exchanger,	**external insulation with flat roof sealing** Advantages: cheap, highly effective, Disadvantages: none POTENTIAL INNOVATION: integrated PV (though very likley non-competitive in this setting to a conventional setup)	**external insulation (on top of brick)** Advantages: high performance possible, cheaper than taking the brick away, Possibility of ventilated facade (BO's desire) Disadvantages: creates very thick walls, window joints might be difficult, building physics to be checked, caviity should be filled to prevent draft (humidity accumulation might be an issue,	**exchange** Advantages: high performance possible, high flexibility (bigger windows), joint are simpler Disadvantages: major disturbance POTENTIAL INNOVATION: integrated PV, prefabricated elements, integrated HVAC	**exchange glazing and frames** Advantages: high performance, optimated joints Disadvantages: major disturbance POTENTIAL INNOVATION: tailored galzing characteristics, HVAC functions in frame, sensors connected to HVAC management	**parameter insulation in combination will cellar insultion where applicable** Advantages: decent improvement of energtic performance of envelope Disadvantages: limited cost-effectiveness POTENTIAL INNOVATION: vacuum insulation (likely not	**District heating (unchanged) (increase insulation of valves and other equipment)** Advantages: low cost, easy to do Disadvantages: not big energy reductions POTENTIAL INNOVATION: intelligent thermostat, flatten temperature variations, use thermal storage of buildings,	**PV on roof**	yes (selling electricity to ter
II	**decentral ventilation per apartment including heat recovery** Advantages: less effort/ disturbance to install than a centralized system, no sound problems, smaller pipes, able to be tailored, easier to clean pipes, Disadvantages: exchange of filters in the hands of tenants, potentially higher maintenance costs	**additional floor** Advantages: additional rentables floor area Disadvantages: structural limitation, elevators/ connection might be expensive, dimensioning of heating/ DHW pipes might be an issue, fire safety/ acustics issues, architectural questions, regulation issues POTENTIAL INNOVATION: there are several prefabricated systems using pre-	**external insulation (exchange brick for insulation make-up)** Advantages: high performance possible, any new coverage is possible, possible synergies with new windows (optimal placement) Disadvantages: taking away the brick is taking time and disturbes, waste generation POTENTIAL INNOVATION:	**second skin solution** Advantages: minimal intrusion, substantial energetic improvement possible Disadvantages: negatively effects daylight factor by self-shading POTENTIAL INNOVATION: integrated PV, prefabricated elements, integrated HVAC	**double window system** Advantages: high performance, limited disturbance Disadvantages: daylight factor decreases (especially in combination with external insulation)	**no changes**		**PV in Facade** INNOVATION: substitute other components (integrated PV)	no (feed in tarifs)
III	**central air-out, decentral air-in** Advantages: easy and cheap to clean, no sound problems, easy to maintain, rather easy to install, prevents mold, performs better in practice than on paper Disadvantages: no heat recovery, performs worse on paper than in practice (in case the 75%		**fill cavity (where possible)** Advantages: cheap Disadvantages: limited performance, not available everywhere, visual aspect cannot be changed, POTENTIAL INNOVATION:	**fill cavity (where possible)** Advantages: cheap Disadvantages: limited performance, not available everywhere, visual aspect cannot be changed			**adjustments to the buildings heaing system** Advantages: improves heat delivery and saves energy	**wind energy (small scale, roof integrated)** Advantages: additional renewable energy Disadvantages: unstable supply, cost effectiveness not proven (TRL6-7)	
IV	**no controlled ventilation or sensor based emergency ventilation**								
	central air-out with heat recovery, decentral air-in Advantages: easy and cheap to clean, no sound problems, easy to maintain, rather easy to install, prevents mold, performs better in practice than on paper Disadvantages: performs worse on paper than in		**Keep brick wall as today** Advantages: cheap and easy, and does not compromise with the architectural legacy of the building			**external insulation on basement floor walls** Advantages: good improvement of energetic performance of envelope as the thermal insulation	**disconnect the centralised system witin the buildngs and connect each building to the district heating main** Advantages: easier tracking of energy use per building. The	No RES **IZA: Normally the inclusion of renewables is what nZEB standards foresee and our concepts should also do. Thus, we**	yes (selling electicity to net **IZA: this is the same a our option "no (ie. No**

Figure 28 List of renovation concepts

dreeam

It can be possible that a renovation concept can be split having a different solution for the same element and the rest are identical.

After the renovation concepts have been defined, they have been presented to de building owners, who have made modifications according to their desires.

12 Assumptions (Landskrona)

There are some factors to take into consideration when deciding to make an analysis of the renovation. These factors are: price of energy, primary energy factors and the emissions of carbon dioxide.

These factors vary in each pilot site due to many reasons like the market prices of the energy suppliers, government policies, the energy mix of the country which affects to the primary energy factor and the emission of carbon dioxide.

12.1 Price of energy

The dwellings are supplied by two different energy sources: electricity and district heating.

The prices of them have been obtained from the bills provided by the tenants, taking the most recently one. In the case of the district heating, which has different price along the year:

- Electricity (day): 0,21 €/kWh
- Gas: 0,08 €/kWh

According to the energy policies in Sweden it is possible to export the electricity generated by a renewable energy system. The price for the energy injected in the grid is:

- Export: 0,053 €/kWh

12.2 Primary energy factors

The final energy only reflects the consumption. Therefore, it is necessary to convert it to primary energy which encompass the energy in its different steps that are: production, storage, transport and consumption.

These values, obtained by Chalmers and Landskronaenergi, are:

- Electricity: 2,00
- District heating: 0,09

12.3 Carbon dioxide emission

The environmental aspect of the renovation it is focused in de carbon dioxide. Apart from the energy savings in a renovation is also important the reduction in the carbon dioxide emissions due to the reduction of the primary energy of the building.

These values, obtained by euroheat.org and Landskronaenergi, are:

- Electricity: 0,227 kgC02/kWh
- Natural gas: 0,0502 kgC02/kWh

13 Renovation concepts (Landskrona)

The renovation concepts proposed are focused in the improvement of the envelope and the installation of a PV system. For the heating and DHW there is no renovation possible due to de high efficiency of a district heating system. All of the concepts have mechanical ventilation system with heating recovery.

In the next section we can see a brief description of each concept:

13.1 Concept 1

- Envelope: External wall insulation system, adding 100 mm of mineral wool. For the cellar walls 60 mm XPS. Light wall completely removed. Triple-glazed windows. Additional floor for the roof.

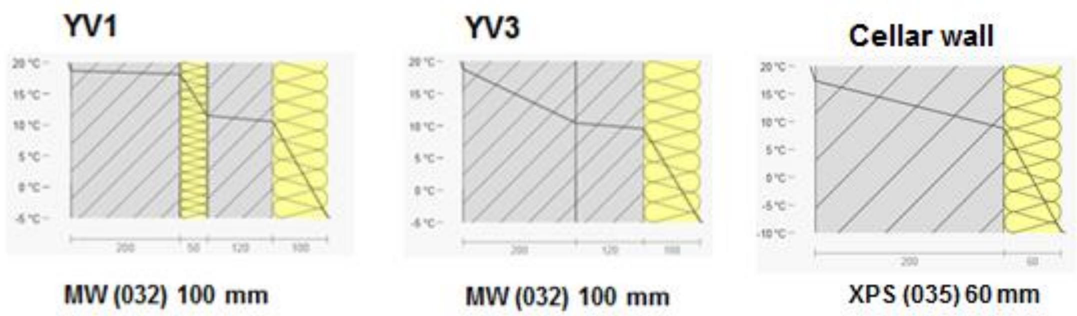


Figure 29 Insulation concept 1a

The new U-Values obtained are:

Element	Current U-Value (W/m2K)	Proposed U-Value) (W/m2K)
External walls (YV1)	0,59	0,22
External walls (YV2)	0,49	0,20*
External walls (YV3)	0,50	0,21
Ground floor	0,40	=
Cellar wall	1,07	0,38
Windows	2,00	0,90

*new wall

- No action in heating and DHW by the district heating system.

- Ventilation: centralized mechanical ventilation system with heating recovery. The maximum efficiency is 75% on temperature. Free-cooling possible thanks to the by-pass function. Control of the unit with a LCD display and remote control.

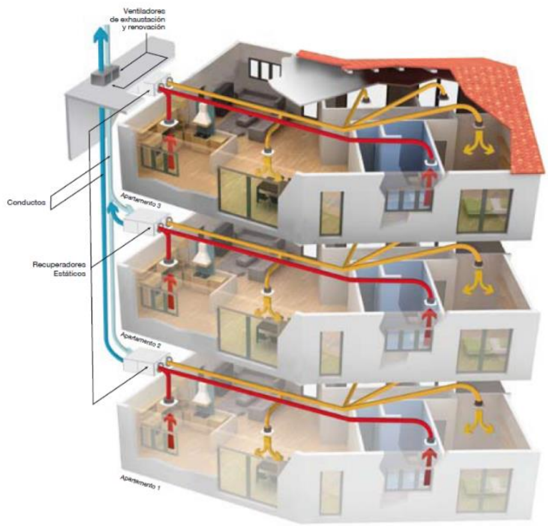


Figure 30 Centralized ventilation system

- Renewable energy: Solar photovoltaic system in the roof. The maximum installation available is 351,3 kWp (annual production 380.000 kWh). An installation of 30 kWp (32.500 kWh a year) will be necessary to reach the energy saving goal. The energy produced can be instantaneously consumed or injected to the grid.

Figure 31 Surface available on roof for PV system

13.2 Concept 2

- Envelope: Ventilated facade, adding 100 mm of mineral wool. For the cellar walls 60 mm XPS. Triple-glazed windows. Additional floor for the roof.

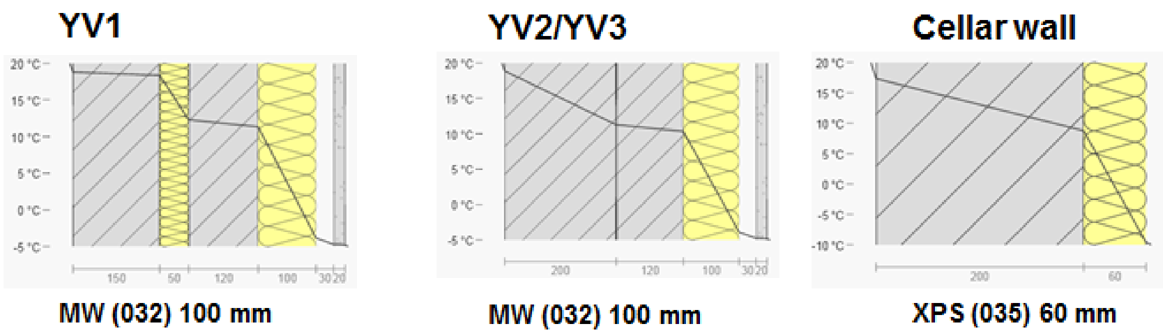


Figure 32 Insulation concept 1a

The new U-Values obtained are:

Element	Current U-Value (W/m2K)	Proposed U-Value) (W/m2K)
External walls (YV1)	0,59	0,20
External walls (YV2)	0,49	0,19
External walls (YV3)	0,50	0,20
Ground floor	0,40	=
Cellar wall	1,07	0,38
Windows	2,00	0,90

- No action in heating and DHW by the district heating system.

- Ventilation: centralized mechanical ventilation system with heating recovery. The maximum efficiency is 75% on temperature. Free-cooling possible thanks to the by-pass function. Control of the unit with a LCD display and remote control.

- Renewable energy: Solar photovoltaic system in the south facing façade (as element of the ventilated façade).The required installation is 44 kWp (32.500 kWh a year). The energy produced can be instantaneously consumed or injected to the grid.

Figure 33 PV integrated in façade

13.3 Concept 3

- Envelope: No actions for the external walls. For the roof 80 mm XPS. Triple-glazed windows.

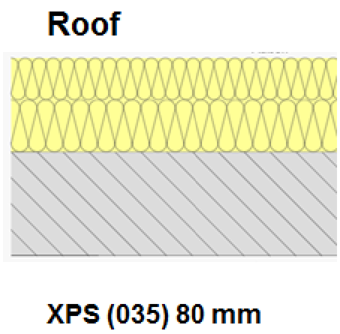


Figure 34 Insulation concept 2a

The new U-Values obtained are:

Element	Current U-Value (W/m2K)	Proposed U-Value) (W/m2K)
External walls (YV1)	0,59	=
External walls (YV2)	0,49	=
External walls (YV3)	0,50	=
Roof	0,38	0,20
Ground floor	0,40	=
Windows	2,00	0,90

- No action in heating and DHW by the district heating system.

- Ventilation: Extract ventilation system. Controlled by demand and by CO_2 and humidity sensors.

- Renewable energy: Solar photovoltaic system in the roof. The maximum installation available is 351,3 kWp (annual production 380.000 kWh). An installation of 31 kWp (33.500 kWh a year) will be necessary to reach the energy saving goal. The energy produced can be instantaneously consumed or injected to the grid.

14 Results (Landskrona)

With the help of the simulation tool used in the baseline to analyse the energy consumption of the pilot site, all the renovation concepts proposed have been simulated in order to study the energy savings of each solution. An analysis of sensitivity has been made using the same procedure as in the baseline description with the parameters that can differ, resulting in different ranges.

14.1 Energy savings

The following tables reflect briefly the energy saving obtained:

Concept	Primary energy (kWh/m2year)		Energy savings
	Before	After	
Concept 1	7,96	1,89 - 2,16	73 - 76 %
Concept 2	7,96	1,85 - 2,11	74 - 77 %
Concept 3	7,96	1,65 - 2,28	71 - 79 %

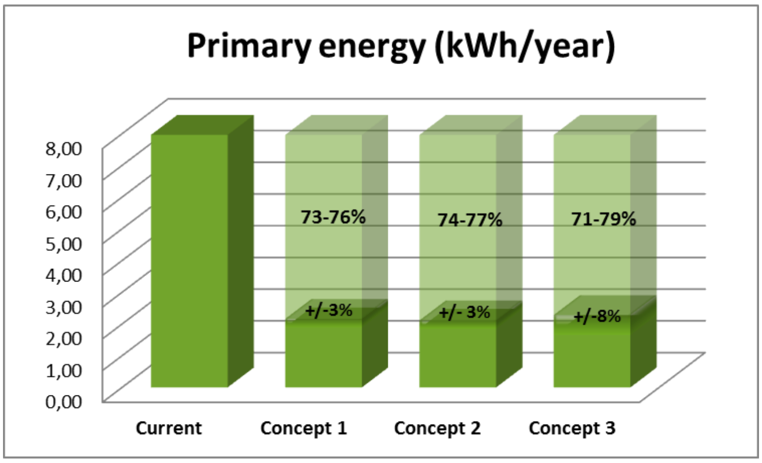


Figure 35 Primary energy overview

For the energy savings calculation, the consumption related to lighting and appliances have not been taken into account. To establish energy saving measures in this consumption is a tricky issue due to a factors like the high amount of devices, the variety of efficiency of the devices, the user's behaviour of them, etc. Therefore, it cannot be taken into account for the DREEAM Project.

14.1.1 Concept 1

Concept 1	Final energy (kWh/m2yr)		Primary energy (kWh/m2yr)		Primary energy savings
	Before	After	Before	After	
Heating	72,93	13,99 - 17,00	6,56	1,26 - 1,53	77 - 81 %
DHW	15,56	15,56	1,40	1,40	0 %
Ventilation	-	5,92	-	11,84	-
PV	-	-6,31	-	-12,61	-

Total	88,49	29,16 - 32,18	7,96	1,89 - 2,16	73 - 76 %

14.1.2 Concept 2

Concept 2	Final energy (kWh/m2yr)		Primary energy (kWh/m2yr)		Primary energy savings
	Before	After	Before	After	
Heating	72,93	13,55 - 16,47	6,56	1,22 - 1,48	77 - 81 %
DHW	15,56	15,56	1,40	1,40	0 %
Ventilation	-	5,92	-	11,84	-
PV	-	-6,31	-	-12,61	-
Total	88,49	28,73 - 31,64	7,96	1,85 - 2,11	74 - 77 %

14.1.3 Concept 3

Concept 2	Final energy (kWh/m2yr)		Primary energy (kWh/m2yr)		Primary energy savings
	Before	After	Before	After	
Heating	72,93	32,62 - 39,63	6,56	2,94 - 3,57	46 - 55 %
DHW	15,56	15,56	1,40	1,40	0 %
Ventilation	-	2,48	-	4,97	-
PV	-	-3,83	-	-7,65	-
Total	88,49	46,83 - 53,85	7,96	1,65 - 2,28	71 - 79 %

14.2 Economic study

Another important aspect in a renovation is the economical one. The following tables reflect the amount of money saved and the investment necessary to implement each concept. With these two values, the payback period can be calculated to check the profitability of the investment.

Concept	Saved (€)	Investment (€)	Payback (years)
Concept 1	58.150 - 61.466	2.106.020	34,3 - 36,2
Concept 2	58.737 - 61.947	2.596.533	41,9 - 44,2
Concept 3	36.567 - 44.292	1.584.520	35,8 - 43,3

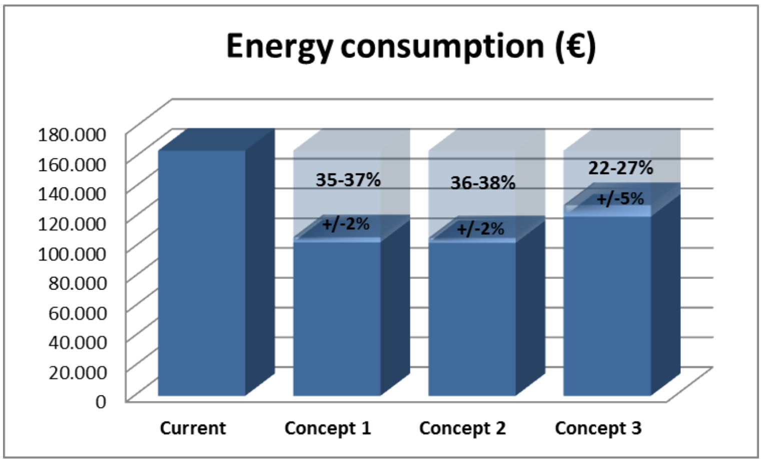


Figure 36 Economic savings overview

14.2.1 Concept 1

Item	Description	Cost/measure unit	Units	Total cost (€)
Ext. walls	EWI 10 cm MW	115 €/m2	5.612 m2	645.380
Cellar walls	6 cm XPS	63 €/m2	205 m2	12.854
Windows	New windows 0,9 W/m2K	776 €/m2	1.598 m2	1.224.707
Ventilation	Mech. with heat recovery	15.915 €	5	69.575
PV	410 m2	153.504 €	1	153.504
Total				**2.106.020**

Before (€)	After (€)	Saved (€)	Investment (€)	Payback (years)
164.706	103.240 - 106.556	58.150 - 61.466	2.106.020	34,3 - 36,2

14.2.2 Concept 2

Item	Description	Cost/measure unit	Units	Total cost (€)
Ext. walls	Ventilated 10 cm MW	196 €/m2	5.612 m2	1.102.197
Cellar walls	6 cm XPS	63 €/m2	205 m2	12.854
Windows	New windows 0,9 W/m2K	776 €/m2	1.598 m2	1.224.707
Ventilation	Mech. with heat recovery	15.915 €	5	69.575
PV	74,2 m2	187.200 €	1	187.200

Total	**2.596.533**

Before (€)	After (€)	Saved (€)	Investment (€)	Payback (years)
164.706	102.759 - 105.969	58.737 - 61.947	2.596.533	41,9 - 44,2

14.2.3 Concept 3

Item	Description	Cost/measure unit	Units	Total cost (€)
Roof	6 cm XPS	58 €/m2	2.970 m2	172.557
Windows	New windows 0,9 W/m2K	776 €/m2	1.598 m2	1.224.707
Ventilation	Extract ventilation	50.600 €	1	50.600
PV	365 m2	136.656 €	1	136.656
Total				**1.584.520**

Before (€)	After (€)	Saved (€)	Investment (€)	Payback (years)
164.545	120.414 - 128.139	36.567 - 44.292	1.584.520	35,8 - 43,3

14.3 Environmental study

The purpose of this assessment is to identify the impact produced in the Environment by each renovation concept. For it, the equivalent carbon dioxide saved due to the application of each concept has been calculated:

Concept	Electricity		District heating		Total
	(kWh)	(tCO2eq)	(kWh)	(tCO2eq)	(tCO2eq)
Concept 1	-47.945	-10,88	789.343 - 831.853	39,63 - 41,76	28,74 - 30,88
Concept 2	-47.945	-10,88	796.866 - 838.021	40,00 - 42,01	29,19 - 31,19
Concept 3	-13.440	-3,05	469.919 - 568.963	23,59 - 28,56	20,54 - 25,51

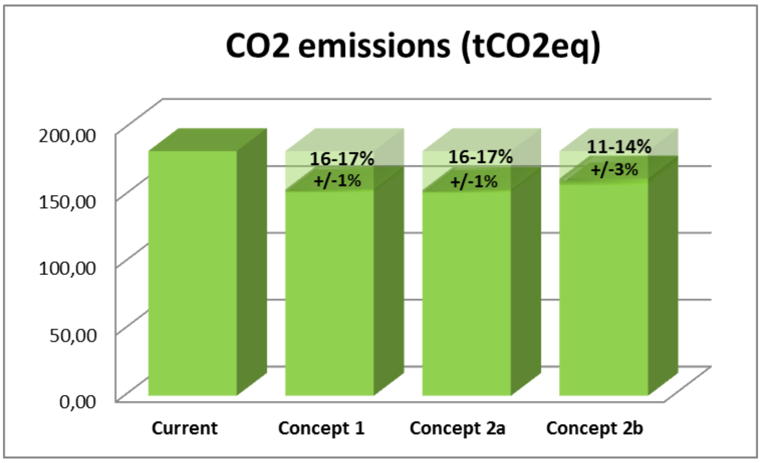


Figure 37 CO2 emissions overview

15 Conclusions (Landskrona)

The results obtained in the simulation show that in every case, the target of the energy saving is successfully reached. The main reason of having very low values of primary energy is that the high efficiency of the district heating which has a very low primary energy factor. It implies that a reduction on the heating and DHW demand will reduce the primary energy in a very low percentage.

The renovation of the envelope should include also the renovation of the external walls. If we compare concepts 1 and 2 with concept 3, we can see higher economic savings. Despite of the increment of the investment, higher savings reduce the payback period.

Another reason of that is the heat recovery system for the ventilation in the concepts 1 and 2, which can recover up to 75 % of the heat inside the building during the ventilation process. It also improves the comfort of the tenants.

The option of having a photovoltaic system integrated in the façade increases the investment significantly due to the higher price of a ventilated façade compared with an external wall insulation system. This would be interesting in case of having the maximum PV surface as possible.

The variation in the payback period produced by the modification of the parameters in the analysis of sensitivity is high, around less than 8. That shows the importance of these parameters in a very cold climatology as the Swedish.

From an ecological point of view, concepts 1 and 2 obtain a higher carbon dioxide emissions reduction.

16 Annexes

1. Conclusions between all the pilot sites
2. Analysis of sensitivity

Conclusions between the three pilot sites

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Executive summary

The following document summarizes briefly the conclusions obtained after the analysis of the renovation concepts proposed, not only for one pilot site, also between them.

That analysis will help to a better understanding of the baseline situation of each pilot site and to explain the reason why these results have been obtained and if they have sense.

The methodology followed to obtain these conclusions have been to obtain ratios of the consumption obtained in the baseline compared with some parameters as are: floor area, number of dwelling s, envelope area, wall area, window area. The reason of establish these ratios is to establish a parity between the pilot sites which allow to compare them in a feasible way.

The ratios calculated can be compared with the parameters obtained from the study of the renovation concepts. The most representative are the economic savings, the initial investment and the payback period of the renovation.

Table of contents

1 Results obtained

The following tables show the indicators that have been used to come to the conclusions explained in the next section.

The first table compares the current situation of the buildings:

	Final energy (Consumption) kWh/year			Final energy/Floor area kWh/m2year			Final energy/Dwelling kWh/year.dwelling		
	Padiham	Landskrona	Treviso	Padiham	Landskrona	Treviso	Padiham	Landskrona	Treviso
Heating	9.960	1.029.305	130.435	128,4	72,9	80,2	9.960	6.201	7.246
DHW	4.772	219.626	21.456	61,5	15,6	13,2	4.772	1.323	1.192
Lighting	1.706	240.835	16.208	22,0	17,1	10,0	1.706	1.451	900
Electric equ.	2.417	289.002	12.968	31,1	20,5	8,0	2.417	1.741	720
Total	**18.855**	**1.778.768**	**181.067**	**243,0**	**126,0**	**111,3**	**18.855**	**10.715**	**10.059**

	Final energy/Envelope surface kWh/m2year			Final energy/Wall surface kWh/m2year			Final energy/Glass surface kWh/m2year		
	Padiham	Landskrona	Treviso	Padiham	Landskrona	Treviso	Padiham	Landskrona	Treviso
Heating	71	93	41	129	183	68	1.285	644	376
DHW	34	20	7	62	39	11	616	137	62
Lighting	12	22	5	22	43	8	220	151	47
Electric equ.	17	26	4	31	51	7	312	181	37
Total	**135**	**162**	**56**	**243**	**317**	**94**	**2.433**	**1.113**	**522**

These are the parameters used for the comparison:

	Padiham	Landskrona	Treviso
Floor area (m2)	77,6	14.114	1.627
Dwellings	1	166	18
Envelope area (m2)	139,6	11.011	3.217
Wall area (m2)	77,5	5.612	1.918
Glass area (m2)	7,75	1.598	347
Envelope/floor	1,80	0,78	1,98
Wall/floor	1,00	0,40	1,18
Window/floor	0,10	0,11	0,21

The following tables represent the average values obtained in the economic and environmental part after the analysis of the proposed renovation concepts to reach the energy savings:

	Padiham	Landskrona	Treviso
Payback	15	35	55
Saving (€)	1.100	60.000	10.000
Saving/Dwelling (€)	1.100,0	361,4	555,6
Investment	16.200,0	2.000.000,0	600.000,0
Investment/floor area	208,8	141,7	368,9
Investment/Dwelling	16.200,0	12.048,2	33.333,3

CO2 reductions (tCO2eq)	Padiham	Landskrona	Treviso
Calculated	3,2	27,8	25,7
Calculated/Dwelling	3,2	0,2	1,4

Another parameters used to obtain the conclusions are the envelope performance of the building the price of energy:

Current U-Values (W/m2K)	Padiham	Landskrona	Treviso
Wall	1,2	0,50	0,99
Roof	0,58	0,38	1,06
Floor	3,87	0,40	1,00
Window	2,8	2,00	2,34

Price of the energy (€/kWh)	Padiham	Landskrona	Treviso
Electricity	0,203/0,086	0,127	0,210
Gas	0,053		0,080
District heating		0,078	

2 Conclusions between the 3 pilot sites

After the analysis of the comparison of the between the 3 pilot sites, the following conclusions have been obtained:

- In the case of Padiham, we can see that having a high initial consumption per floor area or per dwelling implies that the potential of renovation will be also high. This is reflected in the highest economic savings and the lowest payback period between the three pilot sites. The opposite can be observed in Treviso, which has obtained the lowest consumption ratios (around a half of Padiham).

- If we compare the ratio of consumption per envelope area with the economic savings we can conclude that the potential of reduction of heat loses is higher in case of more envelope. The pilot site in Landskrona is an exception due to the initial envelope performance, which are relatively good compared with the other two pilot sites.

- Apart of the fact of having a good initial envelope conditions in Landskrona, another reason that makes the renovation complicated to reach the goals of the DREEAM project is the District Heating. The District Heating is normally obtained from cogeneration, biomass, geothermal heating, etc. which make it to obtain a very low primary energy factor. The consequence of this is that a reduction of the heating and domestic hot water demand will not be very significant in the primary energy.

- A pilot site with a high percentage of glass surface has lower savings. The reason of this comes from the U-Value of the windows, which is higher than the one of the walls, implies higher heat transmission loses. Another conclusion we can obtain related to the glass surface is that the investment in the renovation is higher due to the price of the windows compared with the walls. That can be observed for the pilot site Treviso, which has around a 20% glass surface compared to the floor surface.

- An important factor in the renovation is the wall surface of the building. Due to it architectural shape, every dwelling in Treviso has 3 walls facing outside air obtaining the highest ratio of wall surface per construction surface of the three pilot sites. A consequence of this, is that the investment is increased.

- The price of energy plays a very important role in the economic savings. We can observe for Landskrona the cheapest price of energy, which implies lower energy savings comparing them with other pilot sites.

- Landskrona has the lowest carbon dioxide reductions due to the high quality of the energy from the District Heating system.

Analysis of sensitivity

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Executive summary

The following document summarizes briefly the analysis of sensitivity done for the task 2.2 Three renovation packages.

That analysis consists in obtaining as a result a range of values where the solution is in. The reason of this range is that the solution cannot be determined with accuracy due to some parameters that can differ as are: the room temperature, the thermal properties of the envelope and the air infiltrations.

1 Analysis of sensitivity

To obtain a certain value in the calculation of energy consumption in a house is a tricky issue due to the amount of parameters involved that cannot be determined with accuracy. It implies that the result obtained can differ in a range depending on how precise a parameter has been considered and its influence in the energy consumption.

In the Task 2.1 Baseline description, an analysis of sensitivity has been made to determinate the influence of some parameters and it variation produced in the energy consumption. The parameters selected for the analysis are:

- Room temperature:

  This parameter depends on the behavior of the tenant, who can modify it according to their meets. Some organizations (e.g. ASHRAE) determine an indoor temperature of 22 ºC as the optimal temperature during the heating period. The selection of the room temperature in the winter has an important influence in the heating consumption.

  The variation of the room temperature made in the simulation of the pilot sites shows that an increment or a decrease of 1 ºC implies a fluctuation in the heating consumption of 10 % approximately.

- Thermal properties of the envelope:

  Through the U-values of the components of the envelope (walls, roof, floor and windows) can be calculated the thermal behavior of the construction. The U-value, which is the rate of transfer of heat through a structure divided by the difference in temperature across that structure of a component (W/m2K), can be determined in different ways: in a practical way with an U-value measurement device, theoretically with the composition of the components or based on the normative of the period of construction. It is possible to obtain a deviation of the specific value.

  The role of the insulation in the energy consumption is critical. The variation in the energy consumption produced by de fluctuation of the U-values depends on many different factors as the climatology or the own value, which differs more when in case of a poor insulation. Therefore, a rule of variation cannot be defined.

- Air infiltrations:

  This is the amount of air entering in the building directly from the outside. It depends on many factors as for example weather conditions, wind speed or the geometry of the building among others. Infiltration typically occurs because of leakage around windows and doors, and leakage from the opening and closing of doors in the space.

  The impact of the infiltrations in the building is very significant in the energy consumption, mostly in countries where the climatology is very extreme.

More information about the differences between pilot sites and conclusions obtained during the renovation analysis can be found in the Annex Conclusions.

Once the fluctuation of the results has been considered, in the Task 2.2 "Three renovation packages" this analysis of sensitivity will be used to establish a range between 2 different scenarios:

Better scenario: This is the best solution where the results are more favourable for the renovation of the dwellings. The value of the parameters used are:

- Room temperature: It will be considered an indoor temperature 1 ºC less than the comfort one, which will result in less heating consumption.
- Thermal properties of the envelope: The U-values considered will be 15% better than the estimated. Therefore, the heating and cooling demand will be lower.
- Air infiltrations: A margin of error of 15% over the considered.

The consequence of the simulation using this parameters will be:

- ✓ More energy savings
- ✓ Less payback period
- ✓ More CO2 emissions reduction

Worse scenario: This is the worst case for the renovation of the dwellings where the results are less propitious. The value of the parameters used are:

- Room temperature: It will be considered an indoor temperature 1 ºC higher than the comfort one, which will result in a higher heating consumption.
- Thermal properties of the envelope: The U-values considered will be 15% worse than the estimated. Therefore, the heating and cooling demand will be higher.
- Air infiltrations: A margin of error of 15% under the considered.

The consequence of the simulation using this parameters will be:

- ✓ Less energy savings
- ✓ Higher payback period
- ✓ Lower CO2 emissions reduction

17 References

1. Euroheat.org
2. DGR 967/2015 and DGR 1275/2015
3. Landskronaenergi