N°Affaire	Phase	Mission	Indice	Auteur	Validé
22133	Stage 2	EC	2	AV	CC

Retrofit of an apartment building

16 Swain's Ln, London N6 6QS, UK.

Embodied carbon calculation – Stage 2

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SOMMAIRE

1 - HYPOTHESIS

1.1 - Materials

Materials especially CO2 emitter and used in large volume have an important weight on the final results. It's crucial to choose them properly. For our study, the following values have been used:

Material	Batch	Embodied Carbon	Units	Life
Concrete reinforced 28/35 MPa	Substructure	327	$kg_{eq}CO2/m3$	Life*
Concrete reinforced 20/25	Superstructure	290	$kg_{eq}CO2/m3$	Life*
Rockwool knauf Rocksilk	Superstructure	158	$kg_{eq}CO2/m3$	Life*
PKOM4	M&E installation	704	$kg_{eq}CO2/kW$	17 years
PV SunPower Maxéon 3	M&E installation	77	$kg_{eq}CO2/m^2$	25 years
Triple glazed timber framed Windows	Superstructure	298	$kg_{eq}CO2/m^2$	50 years

Also, the embodied carbon of a 13.5 kWh Tesla battery is about 2700 $kg_{eq}CO2$.

*Note: “Life” refers to the assumed life span of 60 years for the building.

1.2 - Quantities

The quantities entered in the software are mainly provided by the cost estimation.
The ones missing are approximated and surcharged.

1.3 - Production site

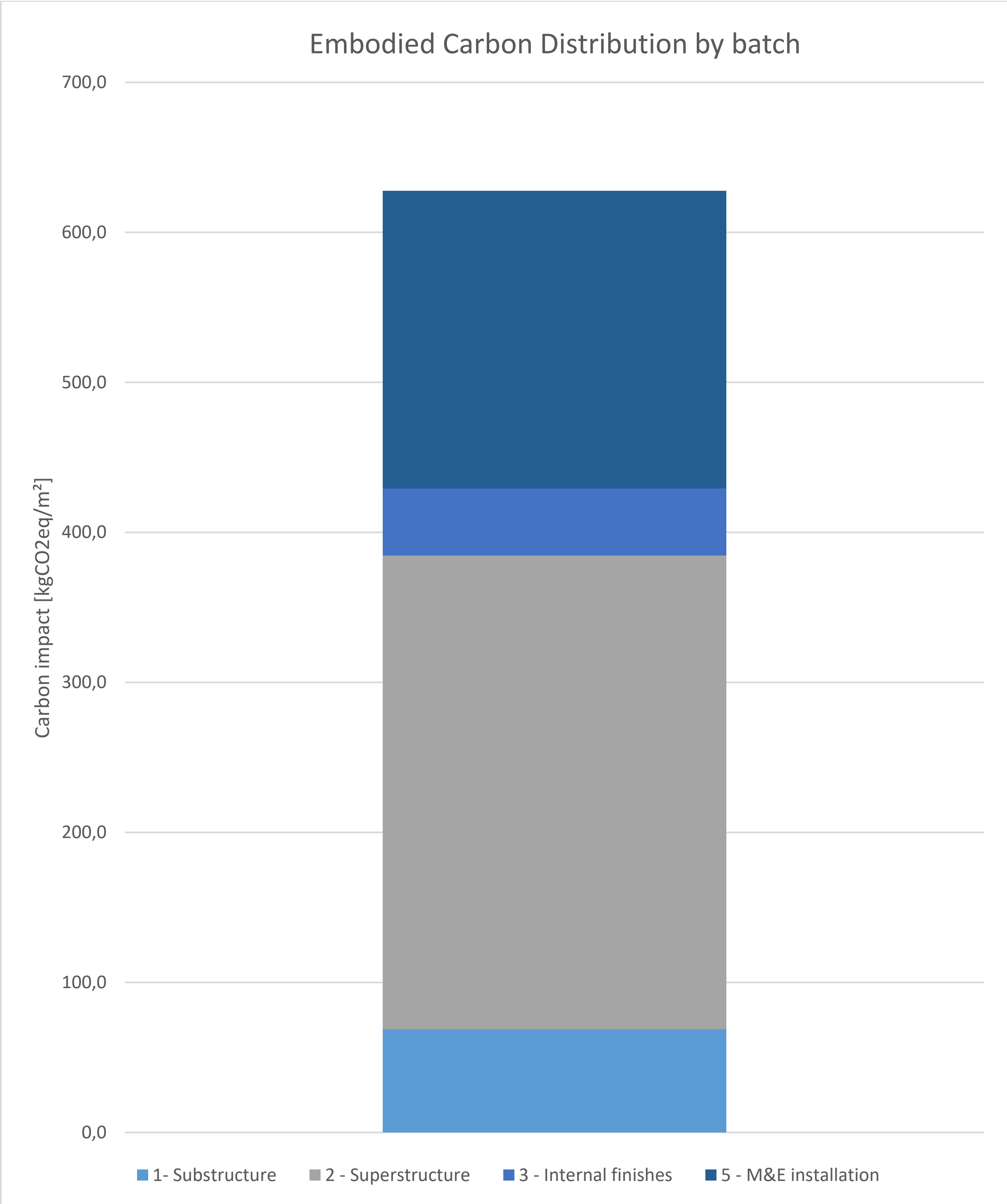
Several possibilities are given to us to approximate the transportation impact.
There are 4 production origins available: locally, nationally, Europe and World.
Some specific items are commonly made locally like concrete, so a distance of 50 km by truck. It's the distance from a local provider.
Generally, we consider that all products came from England, an additional 300 km (production site to local provider) is added in the calculation.
The windows and doors are estimated from Central Europe then the distance is around 1500 km.
The chosen PV panel are mostly made in Mexico, a general international distance of 10.000 km is taken.

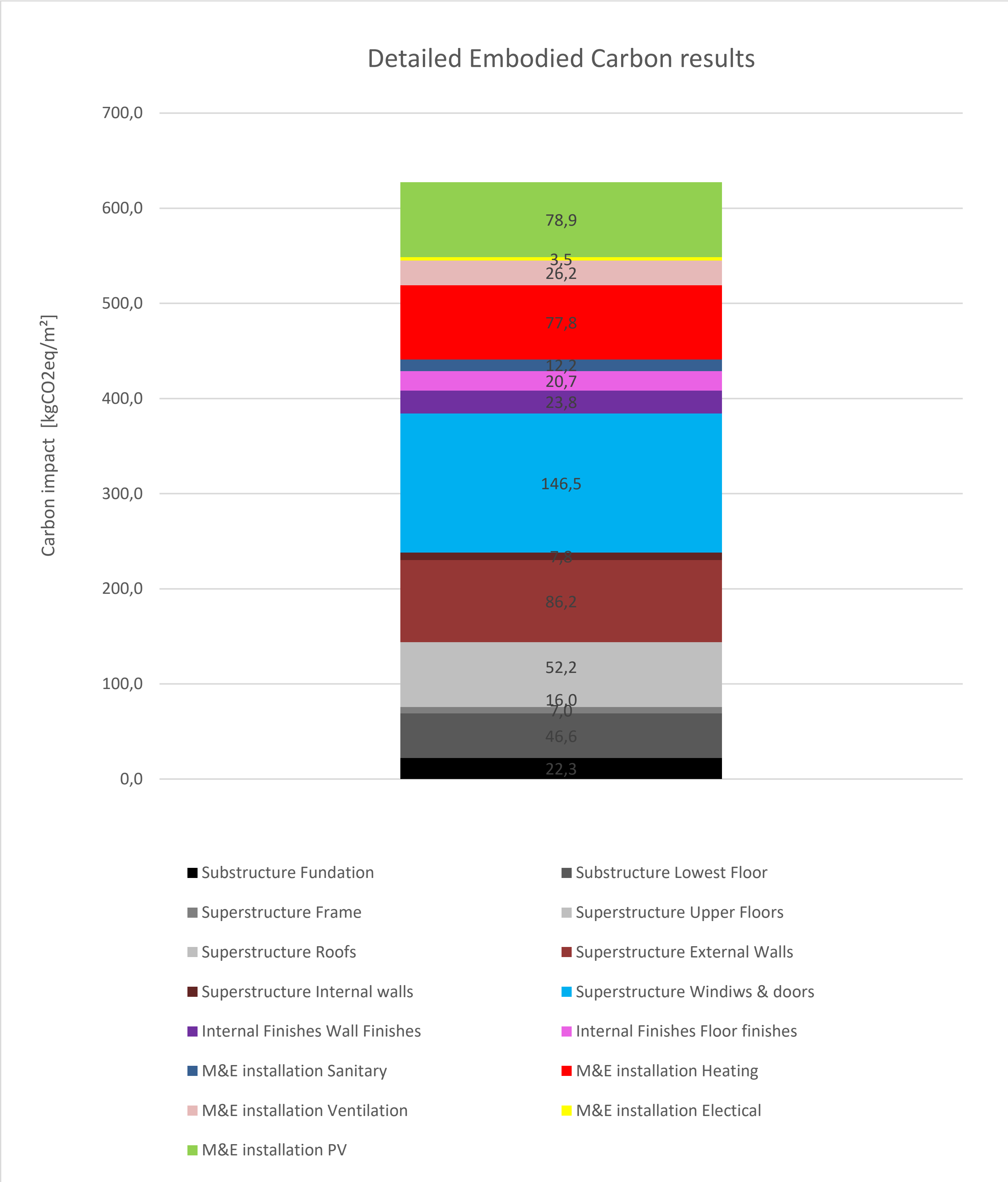
1.4 - What is considered ?

Every part of the building is taken into account from the structure to the finishes except the furniture, the repairs and the demolition.
Some items of the building may be missing in our study because they are not mentioned in the order cost estimate (economy and carbon haven't the same scope).
Also, there are elements such as sedum roofing or rainwater outlet that have not been include, due to the lack of information available regarding their associated embodied carbon.
Nevertheless, their impact is irrelevant compared to the volume of concrete.

Main results are detailed below.

A first analysis of the carbon impact of the entire building brings to light the superstructure (with mostly concrete and rockwool) and the equipments.




Detailed Embodied Carbon results
Carbon impact [kgCO2eq/m²]
700,0
600,0
500,0
400,0
300,0
200,0
100,0
0,0
78,9
3,5
26,2
77,8
12,2
20,7
23,8
146,5
7,8
86,2
52,2
16,0
7,0
46,6
22,3
Substructure Fundation
Substructure Lowest Floor
Superstructure Frame
Superstructure Upper Floors
Superstructure Roofs
Superstructure External Walls
Superstructure Internal walls
Superstructure Windiws & doors
Internal Finishes Wall Finishes
Internal Finishes Floor finishes
M&E installation Sanitary
M&E installation Heating
M&E installation Ventilation
M&E installation Electical
M&E installation PV

A finer analysis confirms the major impact of the pouring of reinforced concrete (a **third** of the total embodied carbon).
PV impact is around 12%, HVAC around 20 % (mainly the heat pumps) and the triple glazed windows are around a quarter

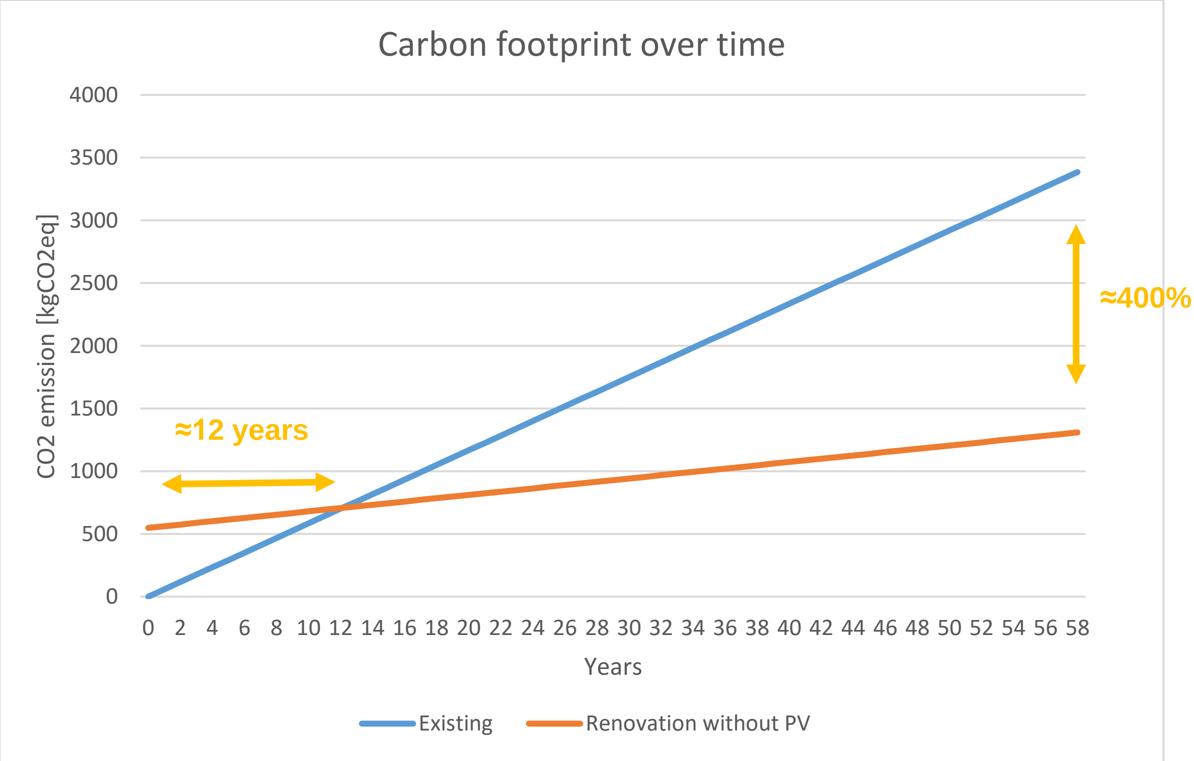
Nevertheless, the chosen model of solar panels has a tremendous effect on the distribution. In fact, with a default value on PV panels they weight more than the half of the embodied carbon.

2 - CARBON FOOTPRINT OVER TIME

The renovation work on the building has both a direct additional footprint (use of new materials) and a long-term reduction of its energy consumption (which implies a decrease of the carbon footprint in the building use).
The carbon footprint calculations over time analysis seeks to establish the point at which the total carbon emissions of the retrofit / refurbishment (including the embodied carbon of the materials), is less than the operational carbon emissions of the existing building.

	Before renovation work	After renovation work	Units
Heating consumption	181	17	kWh/yr/m²
DWH	31.1	14.9	kWh/yr/m²
Aux. electriciy	0	1.8	kWh/yr/m²
Other electrics needs	22	22	kWh/yr/m²
Impact CO2 / kWh	0.25 (gas)	0.233 (electricity)	$kg_{eq}CO2/kWh$
Carbon footprint	77	35	$kg_{eq}CO2/m^2/yr$

The graph shows that based on the hypotheses outlined in the table below, it would take 12 years to achieve a net energy saving resulting in a return on “carbon investments”.



With a carbon investment of 550 $kg_{eq}CO_2$, we get a 400% payback (2000$kg_{eq}CO_2$ saving over 60 years).

3 - PV CONSIDERATION

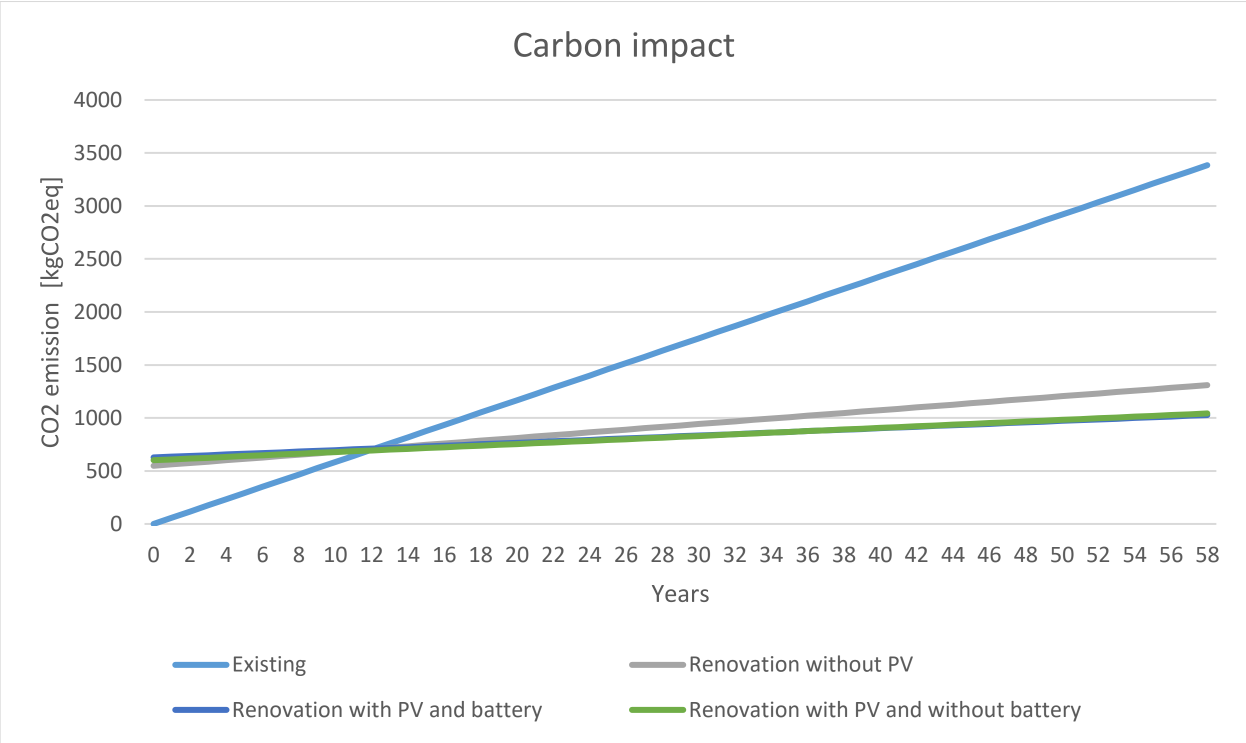
The following section also takes into account the PV and their associated impact. As part of this analysis an annual production of 13500 kWh and a Tesla battery lifespan of 25 years have also been considered.

The electricity carbon impact that we save when consuming our PV production is not the same when selling the electricity on the grid: **0.233 $kg_{eq}CO_2$** with the self-consumption and **0.082** with the electricity sold to the grid. We study the embodied carbon on one square meter of the building.

With battery			
Production		13500	kWh
Repartition	Self consumption	5375	kWh
	Grid sales	8063	kWh
	Self cons/m²	17,1178344	kWh/m²
	Grid sales/m²	25,6783439	kWh/m²
Grid sales impact	0,082	kgCO2/kWh	

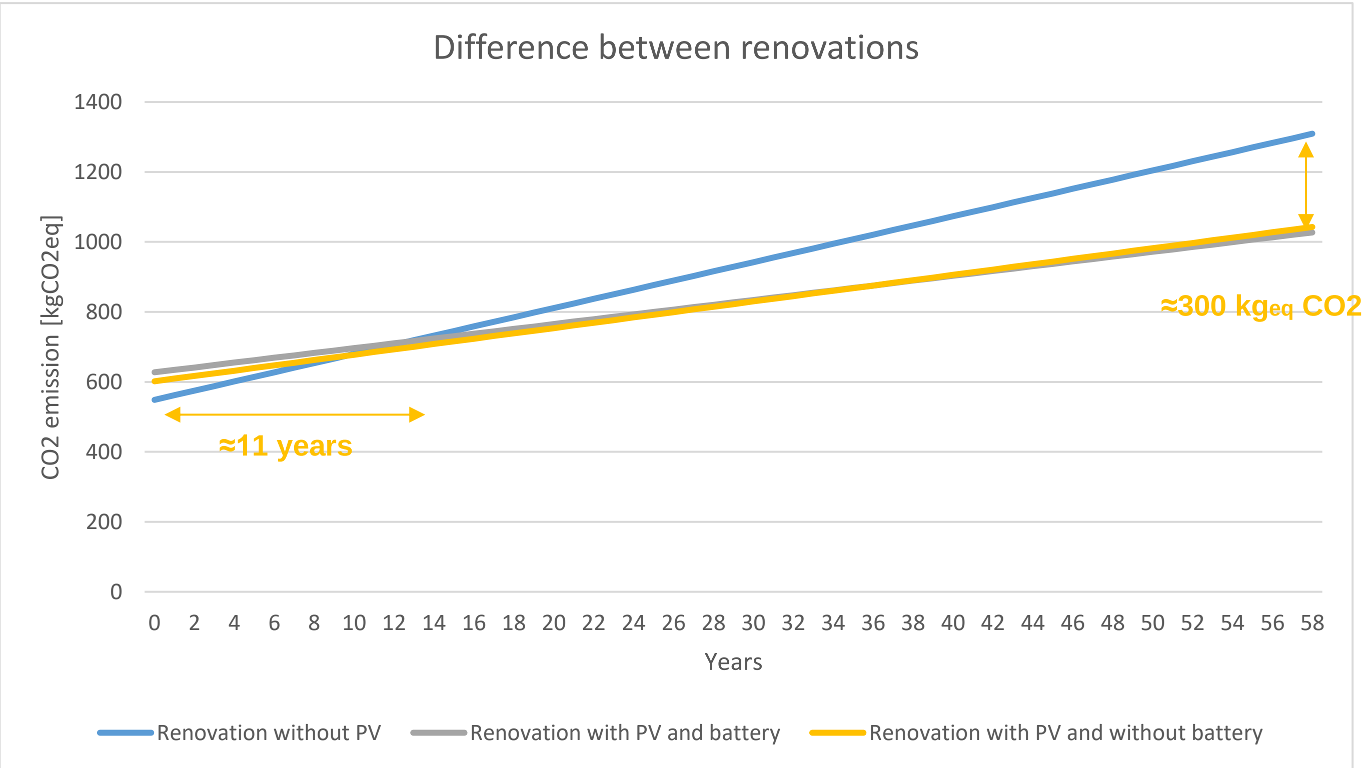
Without battery			
Production		13500	kWh
Repartition	Self consumption	3791	kWh
	Grid sales	9709	kWh
	Self cons/m²	12,07	kWh/m²
	Grid sales/m²	30,92	kWh/m²
Grid sales impact	0,082	kgCO2/kWh	

Graph 1



Graph 1 shows the carbon impact of the existing building compared to three different options including renovation without PVs, renovation with PVs but without battery and renovation with PVs and battery. The graph clearly shows that the difference between the renovation options is small compared to that of the existing carbon impact.

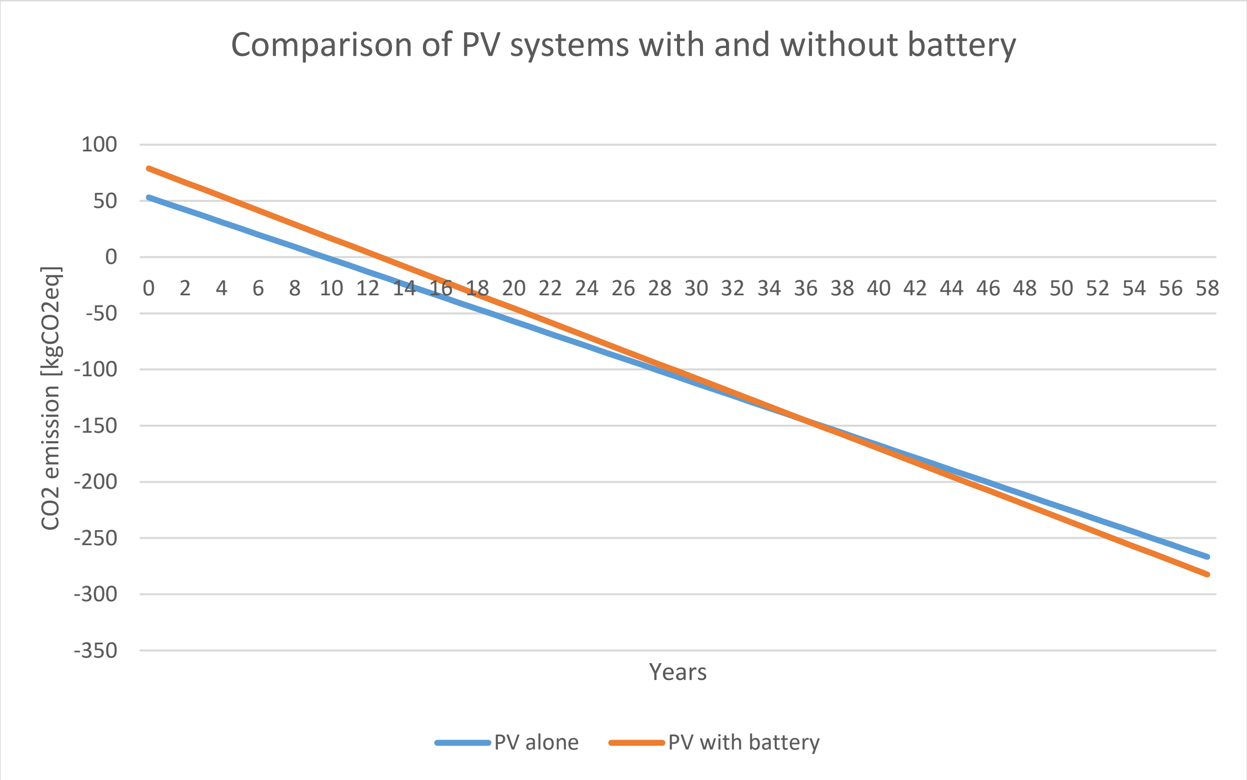
Graph 2



To have a better sight of the difference between the three scenarios of renovation, the existing scenario is removed from graph 2.
A PV system addition weights around 50-75 kg eq CO_2 per square meter to build and install. An overall saving would be achieved after 11 years and after 60 years an overall reduction of 300 kg eq CO_2/m^2. The difference between a renovation with PVs and battery compared to PVs without battery is relatively small.

Graph 3 :

Due to the small difference of the different renovation options tested in Graph 2, the following study was carried out. The embodied carbon of only the PV system and battery was tested, see comparison below:



The battery enables the increased consumption of electricity generated by the PVs, thus reducing the requirement to rely on the grid. The benefit from a carbon perspective is that the embodied carbon of the grid is four times higher than the local PV production.
However, the battery has a 2700 kgeqCO_2 impact to be built and only has a maximum of 25 years of lifespan. After 60 years there is no real carbon payback for a battery.

4 - CONCLUSION

Considering a building lifespan of only 60 years, the project (without PV) will have a 300% carbon return on investment (more with PV). This “return on investment” depends hugely on the carbon footprint of the English electrical mix.

Another relevant way to see it is by separating the different use:

Energy efficient renovation	Total	**50%**
	Efficient windows and doors	*23%*
	New equipment	*19%*
	Insulation	*8%*
Extension building	Sub and superstructure	**31%**
Esthetics	Finishes	**7%**
Renewable energy investment	PV system + battery	**12%**

5 - APPENDIX

		Carbon impact [kgCO2eq/m²]	**Carbon impact [kgCO2eq]**	**Proportion**
Substructure	Fundation	22,3	6993	3,5%
	Lowest Floor	46,6	14635	7,4%
Superstructure	Frame	7,0	2194	1,1%
	Upper Floors	16,0	5020	2,5%
	Roofs	52,2	16400	8,3%
	External Walls	86,2	27055	13,7%
	Internal walls	7,8	2445	1,2%
	Windiws & doors	146,5	46000	23,3%
Internal Finishes	Wall Finishes	23,8	7480	3,8%
	Floor finishes	20,7	6500	3,3%
M&E installation	Sanitary	12,2	3819	1,9%
	Heating	77,8	24421	12,4%
	Ventilation	26,2	8214	4,2%
	Electical	3,5	1100	0,6%
	PV	78,9	24769	12,6%