Renovation of a house in Morangis - Summary report of environmetal studies

VELUX - LIVING PLACES - RENOVATION

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Velux

Velux - Living places - Renovation

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ARTELIA - Transition et Performance Environnementale
16 rue Simone Veil
93400 Saint-Ouen-sur-Seine

CONTENTS

PURPOSE OF THE DOCUMENT

Artelia has been commissioned as part of the "Living Places Renovation" project initiated by VELUX France. The aim of this project is to experiment with renovation concepts in real-life situations, in order to improve the energy performance and interior comfort of existing homes, particularly single-family homes with convertible attic space.

The renovation of a house in Morangis is therefore part of this project, as a pilot.

To this end, various measures, studies and variants have been carried out to optimise the planned works and enable a comparison of results on a case-by-case basis.

To assess the performance of the renovation, the various studies and measurements were based, among other things, on the criteria of the "Active House Radar" label, which covers the following areas:

Comfort

- Thermal
- Visual
- Indoor air quality
- Acoustic quality

Energy

- Energy requirements
- Origin of energy consumed
- Energy consumption and equivalent CO2 impact

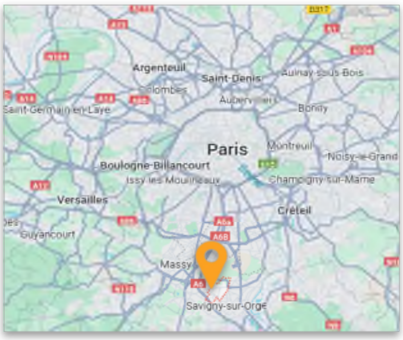
Environment

- Water consumption
- Sustainability: CO2 equivalent weight, origin of materials

The purpose of this document is to summarise the results of the various studies and measurements carried out, and also to show the variations that may have been made during the course of the project.

The full technical reports are attached.

1. PRESENTATION OF THE PROJECT

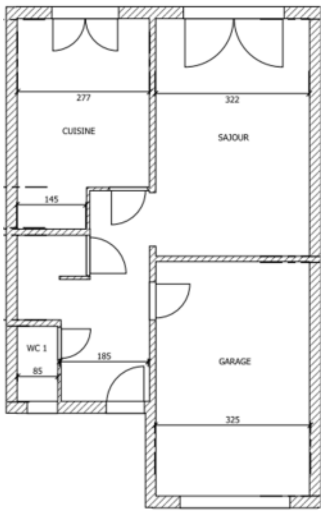


The house is a semi-detached house located in the Paris suburb of Morangis (Essonne), south of Paris.

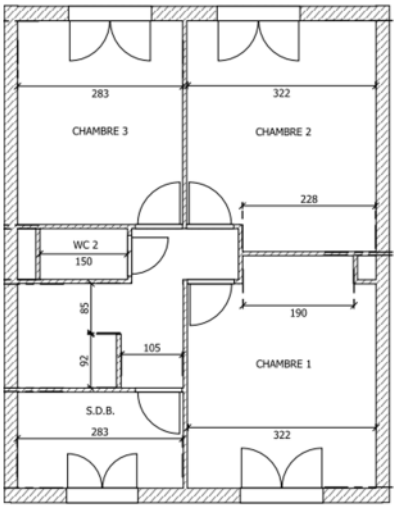
The house has a ground and ground floor, a garage on the ground floor, a courtyard with trees on the street side and a garden to the rear of the house.

The attic of the house has not been converted; it was used for storage.

Project sheet	
Year of construction	1948 - 1974
Living area	79 m²
Distribution of parts	Ground floor: Entrance Hall, WC, kitchen, living room, garage, storage space Ground floor: 3 bedrooms, shower room, WC and corridor
Heating system	Individual gas condensing boiler
Ventilation system	Single-flow ventilation for the WCs and shower room on ground floor 1
Envelope	No or very poor insulation throughout, PVC double-glazed windows
Guidelines	East-West



GROUND FLOOR



1st floor

2. SCOPE OF STUDIES

As part of this project, Artelia was commissioned to carry out various measurements and simulations. These various elements are listed below:

<u>On-site measurements:</u>

- Air quality
- Acoustic quality
- Housing materials, water consumption
- *Temperature measurements (excluding Active House)*

<u>Calculations and theoretical simulations:</u>

- Thermal comfort
- Energy consumption
- Autonomy in natural light
- Air quality
- LCA
- Loss of biodiversity

The main challenges facing the project were as follows:

> Improve the comfort, energy consumption and durability of your home with Active House radar, particularly in the attic.

> Define more precisely the scope of the work, any changes to the initial project and the final version to be implemented.

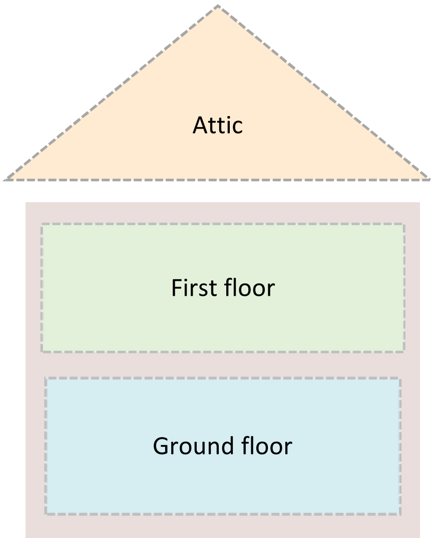
> Experimental temperature measurements to assess thermal comfort.

> Dwelling occupied during the works.

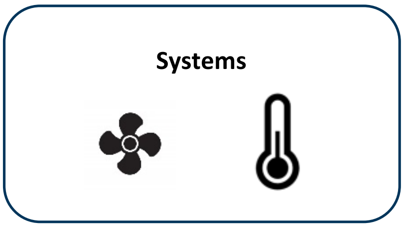
3. SCOPE OF WORK

3.1. GENERAL PRESENTATION

The figure below gives a brief overview of all the work initially planned for the house, as well as the main changes following the various measurements and studies carried out.



Work initially planned	VELUX additional or alteration work
External insulation Velux roof windows	Added interior insulation Modifying Velux types Interior lining added
Staircase extension to attic	Elimination of risers
EPS ITE New joinery	Glass wool ITE
Modification of the wall between the living room and the garage Enlarging the entrance	Addition of insulation between living room and garage Under screed insulation Motorisation of the living room sliding doors



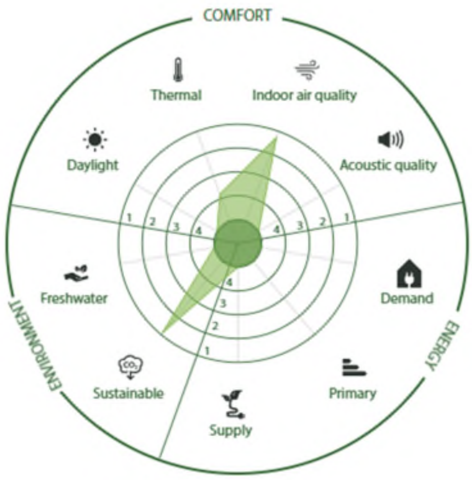
Initial state	Work initially planned	Amendment work
Individual gas boiler	Air/water heat pump	-
Single-flow CMV	Insufflation ventilation system	Acoustic insulation of ducts and technical cabinets. Additional air inlet/outlet.

3.2. DETAILED CHANGES

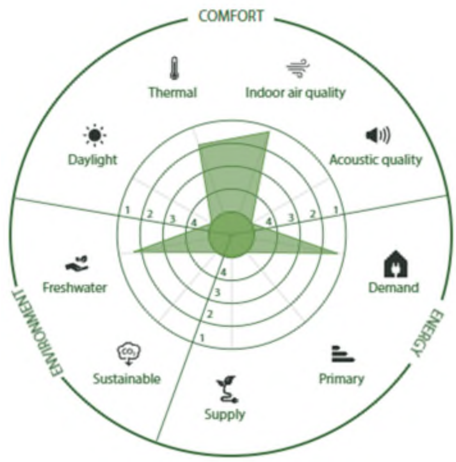
Element	Explanation	Carbon impact (kgCO2e/m²SHAB)	Thermal comfort	Final choice
External roof insulation	Reflexion on changing the polyurethane insulation (Utherm) to a more sustainable material such as glass wool or wood wool.	Glass wool: - 4,78 Wood wool: - 5,45	Wood wool: -11h at T≥26°C, -14h at T≥28°C	The cost of the Utherm was more accessible and lighter.
Internal insulation – Gable and slope	Addition due to high glass surface: improving thermal resistance. Study wood wool v.s. glass wool.	Glass wool: - +1,8 Wood wool: +3,24	Glass wool: +2h at T≥26°C, -9h at T≥28°C Wood wool: -8h at T≥26°C, -16h at T≥28°C	Even though glass wool was a little less carbonated, wood wool presented better thermal comfort quality for summer comfort.
Attic floor	Reflexion on adding mass to the building for summer comfort: exchanging wooden plates to Fermacell	Fermacell: +2,63	Fermacell: -25h at T≥26°C, -30h at T≥28°C	Fermacell has a higher inertia and allows to reduce the temperature in the attic during summertime.
Velux window sizes	Reducing glass surface to improve the summer comfort.	-	-101h at T≥26°, -54h at T≥28°C	Changing 4 x 3-in-1 FFKF08 into 2 x FFKF06 + 2 x MK06
Automatization of room windows	Motorisation of windows and sun shading allow to automatically control air inlet to cool the house during night and limit solar heat gain in summer.	Min +2	-121h at T≥26°, -126h at T≥28°C* **Includes a panel of modification – not only variable*	Motorisation of both attic windows and living room's window will allow air flow during summer nights.
External insulation	Replacing plastic based external insulation (polystyrene) by a less carbonated material with similar properties.	Glass wool: -4,78	-5h at T≥26°, -5h at T≥28°C	Wool external insulation instead of polystyrene. Additional improvement on construction site: no polystyrene marbles.

4. ACTIVE HOUSE RADAR

This section looks at the results of the Active House benchmark.
The results in the form of radars were extracted directly from the online site and can be seen below:



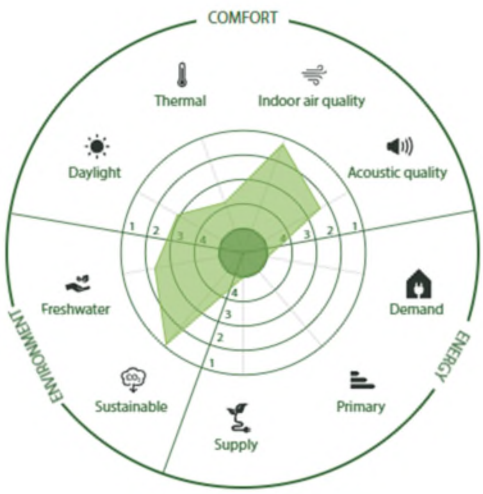
Morangis - Before works



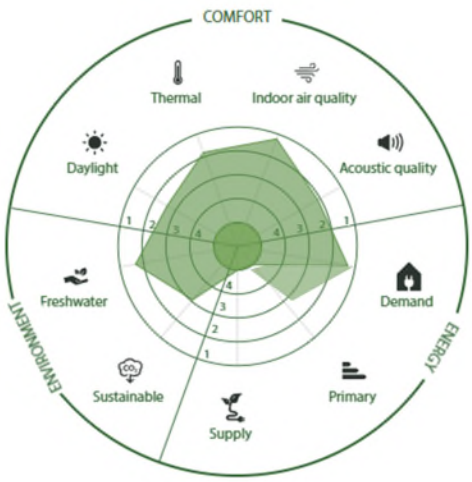
Morangis - After works

In the Active House radar, when the calculated value is lower than the 4th threshold, the element is classified as 'Out of category', which downgrades the entire theme and sets the score to 0.

However, it is not always representative when only one room or value is 'out of category'. For this reason, the Active House evaluation has been re-modelled taking into account the 'Out of Category' values at 4 (lowest score) - for a better comparison between projects:



Morangis - Before works



Morangis - After works

The table below shows the detailed results by theme:

	Before work		After works		
Active House theme	Radar	Radar w.o. Out of cat.	Radar	Radar w.o. Out of cat.	Explanations
Daylight	Out	2,9	Out	2,6 ↗	Addition of attic space, modified light transmission.
Thermal environment	3,8	3,8	1,8	1,8 ↗	Insulation, replacement of joinery, etc., modification of natural ventilation
Indoor air quality	1,3	1,3	1,3	1,3 →	*See dedicated section*
Acoustic quality	Out	2,4	Out	2,1	Replacement of joinery and insulation of the façade.
Energy demand	Out	Out	1,3	1,3 ↗	Insulation and modification of energy systems
Energy supply	Out	Out	Out	Out	No renewable energy
Primary energy	Out	Out	3	3 ↗	Reducing energy demand
Sustainable construction	1,1	1,1	Out	3,1↘	Adding new materials
Freshwater	Out	2,3	1,7	1,7↗	Changing the toilet flush and reducing the tap flow rate

5. SUMMARY OF MEASURES AND STUDIES

This section looks at the results by theme according to the active house radar.

Appendices detailing the various studies and measures are available.

COMFORT

5.1. VISUAL COMFORT

The full visual comfort study can be found in ***Appendix 1:*** *Visual comfort study*

5.1.1. Results before work

Zone	Surface area (m^2)	Calculated autonomy (Ac)	sDA Area in Range (%)	Compliant surface area (m^2)	Active House category
Bedroom 1	12	50	**95**	**11**	**1**
Bedroom 2	13	50	88	11	1
Bedroom 3	11	50	100	11	1
Living room	18	50	39	7	Out of category
Kitchen	12	50	55	6	3

The lighting autonomy targets are not met, except for bedroom 2, which faces south. This is due to the majority of the windows facing north.

> Ways of improving lighting autonomy:
> - Glazed areas should account for between 20% and 40% of the floor area.
> - Maximise south-facing openings for optimum light.
> - A zenithal opening (skylight) significantly increases lighting autonomy.
> - Limit shadows cast by neighbouring buildings or trees.

5.1.2. Results after work

Zone	Surface area (m²)	Calculated autonomy (Ac)	sDA Area in Range (%)	Compliant surface area (m²)	Active House category
Bedroom 1	12	50	85	10,2	1
Bedroom 2	13	50	81	10,5	1
Bedroom 3	11	50	99	10,9	1
Living room	26	50	35	9,1	Out of category
Kitchen	12	50	45	5,4	4
Attic	25	50	76	19	1

- The natural light index remained unchanged during the renovation, with the exception of the kitchen, where it fell. This is due to a reduction in the light transmission of the glazing (TLw) from 80% to 70%.
- The extension to the living room has reduced the compliance area in percentage terms compared with the previous one.
- The attic boasts excellent lighting autonomy.

5.2. THERMAL COMFORT

The full study on visual comfort can be found in ***Appendix 2:*** *Dynamic thermal simulation*

5.2.1. Results before work

Representative area	Surface area (m²)	Overrun (%)				Active House category WINTER	Active House category SUMMER
		High limit	Low limit	High limit	Low limit		
Bedroom 1	12	71 h	407 h	3,1%	17,8%	4	4
Bedroom 2	13	65 h	549 h	2,6%	22,1%	4	4
Bedroom 3	11	68 h	323 h	3,3%	15,6%	4	4
Living room	18	62 h	44 h	2,5%	1,4%	3	4
Kitchen	12	19 h	9 h	2,9%	1,3%	3	4

Thermal comfort is low, mainly due to poor insulation and ventilation.

5.2.2. Results after work

Representative area	Surface area (m²)	Overrun (%)				Active House category WINTER	Active House category SUMMER
		High limit	Low limit	High limit	Low limit		
Bedroom 1	12	3 h	0 h	0,1%	0,0%	2	2
Bedroom 2	13	2 h	0 h	0,1%	0,0%	2	2
Bedroom 3	11	3 h	0 h	0,1%	0,0%	2	2
Living room	26	0 h	0 h	0,0%	0,0%	1	1
Kitchen	12	0 h	0 h	0,0%	0,0%	1	1
Attic	25	11 h	0 h	0,7%	0,0%	3	2

> Thanks to improvements such as reinforced insulation, better heating management and optimised ventilation, the indoor environment offers more stable and pleasant thermal conditions.

For most of the time occupied, temperatures vary between **20°C and 26°C**, guaranteeing thermal comfort in line with the requirements of the standard. These adjustments ensure optimum well-being for occupants by maintaining an even, regulated temperature.

In addition, the solutions put in place prevent overheating in summer, ensuring optimum comfort all year round.

5.3. INDOOR AIR QUALITY

5.3.1. On-site measurements

To determine the initial state of the project in terms of indoor air quality, measurements were taken on site.

ISPIRA was commissioned to carry out these measurements, and their full report is available in ***Appendix 3****: Indoor air quality measurment report - ISPIRA*.

The elements measured during this campaign were:

- Particulate contamination (PM2.5) and particle counting
- Enumeration of bacterial flora
- Enumeration of fungal flora (yeasts and moulds)
- VOC index (Volatile Organic Compounds)
- Benzene
- Formaldehyde
- Nitrogen dioxide (NO2)
- Carbon monoxide (CO)
- Carbon dioxide (CO2)
- Comfort parameters (temperature and humidity)

All the samples and readings were taken between 28 January and 04 February 2025.

The measurement points are as follows:

> 1 external consultant

> 2 interior points

The parameters measured are detailed below.

Emplacement	Paramètres mesurés							
	Particules	Aérobio-contamination	COVT	Benzène	Formaldéhyde	NO_2	CO	T, HR et CO_2 Continu
Extérieur – Terrasse	X	X	X	X		X	X	X
Salon RDC	X	X	X	X	X	X	X	X
Chambre parentale R+1	X	X	X	X	X	X	X	X

The main conclusions of the measures are summarised in the table below:

No anomaly — No risk, improvement possible — Exceeding thresholds

Element measured	Conclusions	
Particulate concentration	No abnormal accumulation of particles was detected.	
Microbiological enumeration	No accumulation of fungal flora was detected.	
Total VOCs	Concentrations of TVOCs were higher than the outdoor reference value, but still below the level 1 threshold of 300 µg/m3 recommended by the German Federal Environment Agency. No health risk linked to this parameter has therefore been identified.	
VOC screening	Analyses carried out in the living room and parents' bedroom revealed the presence of several compounds that can be explained by exposure to cleaning products, air fresheners, the use of care and hygiene products (perfumes, deodorants, creams, lacquers) and furniture treated with varnishes or glues, where these substances can accumulate. These substances mainly come from domestic activities and the materials present in rooms, thus influencing indoor air quality. Regular ventilation would limit their accumulation and improve indoor air quality. All the compounds found remain well below existing reference values, and no health risk has been identified.	
Benzene	No abnormal accumulation of this compound was identified.	
Formaldehyde	No abnormal accumulation of this compound was identified.	
Nitrogen dioxide	No abnormal accumulation of this compound was identified.	
Carbon monoxide (CO)	CO measurements are satisfactory and well below the ANSES guide value.	
Carbon dioxide (CO2)	The average CO2 concentrations measured in the areas investigated were higher than the HCSP guide value (800 ppm) during the measurement campaign. Nevertheless, these exceedances are logical in a dwelling with no mechanical ventilation throughout. The concentrations measured are rarely extreme (>1500 ppm) and remain on average below 1000 ppm, which is satisfactory for this type of space.	
Temperature and relative humidity	The temperature and relative humidity parameters are within the comfort zone for the two spaces investigated.	

In view of the results, air quality in the house was generally satisfactory during the measurement period.

The CO2 level needs to be improved, and this will be dealt with by installing reverse mechanical ventilation.

> All rooms **scored 1** for indoor air quality, except for bedroom 1, which **scored 2.**

5.3.2. Simulations after works

The complete study on indoor air quality simulations can be found in ***Appendix 4***: *Indoor air quality simulations*.

----- Part in progress------

Zone	Surface area (m²)	Average CO2 concentration over one week (ppm)	MAX CO2 concentration over one week (ppm)	Active House category
Bedroom 1	12			
Bedroom 2	13			
Bedroom 3	11			
Salon	18			
Kitchen	12			
Attic	25			

Summary:

5.4. ACOUSTIC COMFORT

In order to determine the initial state of the project in terms of acoustic comfort, measurements were taken on site.

Artelia's GANTHA subsidiary was commissioned to carry out these measurements, and their full report is available at ***Appendix 5:*** *Acoustic measurements report.*

The audit focused on the following types of noise:

- Airborne noise between homes
- Impact noise between homes
- Airborne noise from façades and internal noise
- Equipment noise

5.4.1. Summary of on-site measurements

Regulatory compliance | Sufficient | Insufficient regulations

Measure	Premises	Measurement result	Regulatory threshold	Note Active House	
Indoor airborne noise	Living room⇔ Living room with neighbours	49 dB (DnT;A+C)	≤ 53 dB	4	
Indoor airborne noise	Room⇔ Neighbours	48 dB (DnT;A+C)	≤ 53 dB	4	
Transmission of impact noise	Living room⇔ Living room with neighbours	64 dB (L'nT,w)	≥ 58 dB	Out of category	
Transmission of impact noise	Room⇔ Neighbours	52 dB (L'nT,w)	≥ 58 dB	3	
Outdoor airborne noise	Street => Bedroom 1	31 dB	≥ 30 dB	-	
Outdoor airborne noise	Garden => Living room	30 dB	≥ 30 dB	-	
Equipment noise	Closed kitchen	40 dB	≤ 50 dB	4	
Internal noise	Bedroom 2	Lp = 26 dB(A)		2	
Internal noise	Bedroom 1	Lp = 26 dB(A)		1	
Internal noise	Living room	Lp = 26 dB(A)		1	

Correspondence with Active House:

- ²Inside system noise = equipment noise
- Outside noise = internal noise
- Acoustic privacy = interior airborne noise and impact sound transmission

5.4.2. Planned work and recommendations

Planned work	Work recommendations
Airborne noise between homes	
No alterations are planned as part of the renovation work. *Active House score improvement: none*	Installation of a thermo-acoustic lining on the walls: > BA13 cladding on metal frames independent of the wall, > 80 mm thick mineral or bio-sourced wool insulation between uprights, > for an improvement in the standardised weighted sound reduction ΔRw + C ≥ 8 dB. *Active House score improvement: 4- 3>*
Impact noise between homes	
No alterations are planned as part of the renovation work. *Active House score improvement: none*	In the living room, the only possible way to improve the existing situation is to **work on the flooring of the neighbouring house, which is not possible within the renovation programme.** Limiting noise in the neighbourhood: acoustic underlay on new floors with impact noise reduction **$\Delta_{L(w)}$≥ 18 dB.** *Active House score improvement: no figures available*
Airborne noise from façades, internal noise	
Thermal insulation of facades > Pegged or glued ITE with finishing plaster, > for an improvement in the standardised weighted sound reduction ΔRw + C ≥ -2 dB. Cover > Tiled roof over timber frame using the sarking process with polyurethane insulation, > minimum 80 mm thick wood wool insulation between rafters and BA 13 plasterboard, > for a sound reduction index Rw + Ctr ≥ 35 dB. External joinery > Glazed frames and glazed doors with thermal break double glazing with thermal break and minimum type 4(16)4 standard thermal double glazing from K-LINE, > air inlets in any joinery with Dn,e,w + Ctr ≥ 37 dB, Roof window with asymmetrical double glazing: > Glazing 76 roof window from Velux, with single-sided laminated acoustic glass of type 33.1(16Ar)4 or equivalent, *Active House score improvement: 2 -> 1*	Façade performance is already satisfactory in its current state, according to the regulations. As part of renovation and home improvement work, the planned principles will not degrade the performance of the building and will even have a positive effect. *Active House score improvement:* ***2 -> 1***
Equipment noise	
Creation of a technical room consisting of :	**Equipment room :**

> 20 cm cinder block wall, plastered, with a mass per unit area of 235 kg/m², with mineral wool or bio-sourced thermal insulation lining, sound reduction index Rw + C ≥ 54 dB, > insulated access door with 4-sided seal, sound reduction index Rw + C ≥ 27 dB. **Technical equipment installed:** > Thermor Aeromax 200 thermodynamic water heater with an Lw sound power level of 50 dB(A), > Daikin Altherma 3 PAC indoor module for an Lw sound power level of 44 dB(A). **Attic ventilation box :** Planned installation in the converted attic of a VMI Purevent supply air box, which generates a sound pressure level Lp of 29 dB(A) at 1 m from the air outlet at a flow rate of 200 m3/h. *Improvement Active House score: modification of equipment - not comparable*	Provide an insulated access door from the living room with a 4-sided seal to achieve a sound reduction index Rw + C ≥ 35 dB. **Outdoor heat pump unit:** Over and above the needs of the Active House, ensure compliance with regulatory constraints on neighbourhood protection: > emergence below 3 dB(A) at night [10pm; 7am], > emergence below 5 dB(A) during the day [7am; 10pm]. **Attic ventilation box:** The plenum will be encased in a soffit consisting of two BA13 plasterboard panels and a mineral wool mat at least 40 mm thick. An insulating inspection hatch will be installed with a sound reduction index Rw + C ≥ 30 dB. Provide an insulating and absorbent duct at least 1 m long (type Smo Phon or Phoniflex or equivalent) or rigid insulating and absorbent duct type CF from Trox with a sound attenuation of at least 10 dB(A). *Improvement of Active House score: modification of equipment - not quantifiable.* *Assumptions: score of 1 for all spaces except for the attic and the living room with a score of 2.*

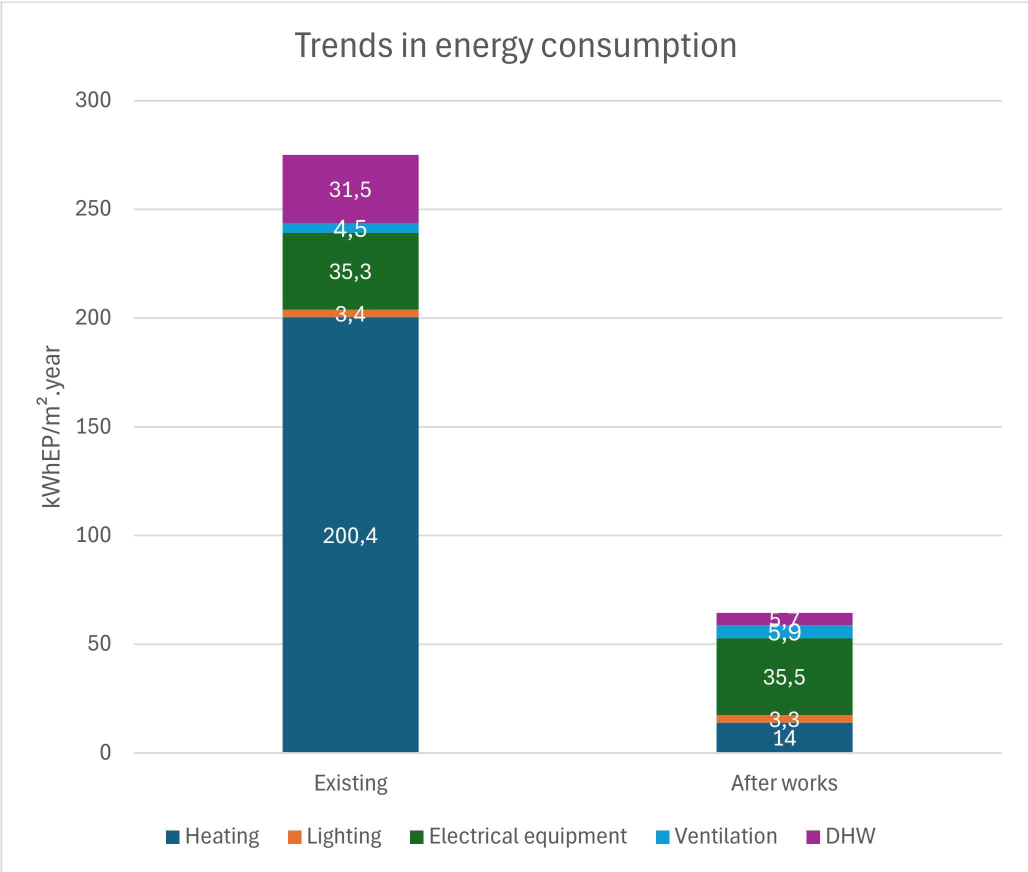
ENERGY

5.5. ENERGY CONSUMPTION

The full study of energy consumption estimates can be found in ***Appendix 6:*** *Dynamic energy simulation*

Energy requirements after renovation of the house are considerably reduced thanks to:

- Insulating the outside of your home
- Renewing windows
- Replacing a gas boiler with a heat pump
- Replacing a gas boiler with a thermodynamic water heater



This scenario results in an estimated final consumption of 66 kWh/m².an, compared with an initial consumption of 275 kWh/m².an, representing an overall energy saving of 76%. It offers an optimum compromise between energy performance and thermal comfort, at an investment of around €56,000 excluding VAT.

> According to the **Active House radar**, the score has gone from 'Out of category' to **1.3**.
> **This leap in performance also enables the energy label to be raised from E to A**, marking a major transformation of the home towards a highly efficient, sober and sustainable dwelling.

The project does not include the production of renewable energy for self-consumption. Nevertheless, the use of a heat pump and a thermodynamic storage tank will reduce the proportion of non-renewable primary energy consumption - as it is considered to be partially renewable. This represents around 37 kWhEP that can be considered renewable, or just over half the consumption of the renovated building.

The Active House score for primary energy performance is therefore **2**.

ENVIRONMENT

5.6. LIFE CYCLE ANALYSIS

The full life-cycle analysis study can be found in ***Appendix 7****: Life cycle analysis.*

Before any work is carried out, the impacts linked to the life cycle analysis are considered to be 0, as no materials are added.
The impacts are given here according to the RE2020 calculation methodology over 50 years for the final works planned.[1]

Ic Construction	Ic Construction
Batch 1: External works	0
Batch 2: Foundations and Infrastructure	0
Batch 3: Superstructure	26
Batch 4: Roofing - Waterproofing	54
Batch 5: Partitions - Lining	21
Batch 6: Facades	91
Batch 7: Interior cladding	14
Batch 8: HVAC	131
Batch 9: Sanitary installations	0
Batch 10: Power & lighting (CFO)	13
Batch 11: Low voltage (CFA)	2
Lot 12: Lifts	0
Lot 13: Photovoltaics	0

The table below shows the scores associated with the Active House label:

Project data			Active House score
Global Warming Potential (GWP)	7,04	kg CFC 11 eq/m²Sref.year	2
Depletion of the ozone layer	1,64E-05	kg ethylene eq/m²Sref.year	Out of scope
Photochemical Ozone Creation Potential (POCP)	5,32E-01	kg eq. SO_2/m²Sref.year	Out of scope
Acidification potential (AP)	2,24E-02	kg eq. $(PO4)^{3-}$/m²Sref.year	2

[1] *These studies do not include the modification of the Fermacell planned for the floor towards the gables (study finalised earlier).*

Eutrophication potential (EP)	7,18E-03	kg CFC 11 eq/m²Sref.year	3

		How to	
Recycled content	<5% by mass	Attic floor only	4
Recyclable or reusable content	10-30%	Estimate	3
Responsibly sourced wood	50 %	Information obtained	2
Declared origin (FDES)	40%	Individual and collective EHSFs	3

5.6.1. Comparison before and after Velux installation

In this section specifically, a distinction is made between the 'Base' scenario of the initial works planned before Velux's involvement in the project, and the 'Velux modified works' section.

Ic Construction (kgCO2e/m²)	Base	Velux Modif	Difference	Changes
Batch 1: External works	*0*	*0*	*0*	
Batch 2: Foundations and Infrastructure	*0*	*0*	*0*	
Batch 3: Superstructure	22	26	4	=> Addition of Fermacell, DRC insulation
Batch 4: Roofing - Waterproofing	54	54	0	
Batch 5: Partitions - Lining	12	21	9	=> Add Crawl insulation
Batch 6: Facades	103	91	-12	=> ITE modification
Batch 7: Interior cladding	24	14	-10	=> Paint modification
Batch 8: HVAC	131	131	0	
Batch 9: Sanitary installations	*0*	*0*	*0*	
Batch 10: Power & lighting (CFO)	9	13	4	=> Add PAC meter
Batch 11: Low voltage (CFA)	0	2	2	=> Add Somfy module
Lot 12: Lifts	0	0	0	
Lot 13: Photovoltaics	0	0	0	
Total	**355**	**352**	-3	

Indicative RE2020 thresholds	
2025	633
2028	567
2031	495

Velux's involvement in this renovation project has saved the equivalent of 3 $kgCO_2e/m^2$ over 50 years, in particular through the use of materials with a lower carbon impact.

Note: these results do not take into account the changes made at the end of May 2025 regarding the installation of Fermacell.

5.6.2. Carbon payback time

In this section, we look at the 'carbon payback time', i.e. the time required to offset the carbon emitted by the addition of new materials, compared with the benefits linked to the reduction in energy consumption.

To do this, we need to compare the energy-related carbon impact before and after the work.

Carbon impact of materials over 50 years ($kgCO_2e/m^2$)	Energy-related carbon impact - **before works** ($kgCO_2e/m^2$.**an**)	Energy-related carbon impact - **after works** ($kgCO_2e/m^2$.**an**)	Carbon gain on energy ($kgCO_2e/m^2$.**an**)	Carbon payback time
352	44	3,52	40,48	Calculation: 352/40.48 = **8.7 years**

This carbon payback time shows that the addition of new materials to the project is offset - in terms of carbon impact - after 8.7 years. Beyond this period, we can consider that we are 'gaining' carbon compared with the previous installation.

5.7. WATER CONSUMPTION

Most of the water consumption meters were measured before the work was carried out. There are two possible improvements: changing the toilet flush and reducing the water flow from the kitchen tap.

Equipment	Water consumption	Active house rating	Recommendations	Active house rating with recommendation
Toilet flush ground floor	Single control (double dummy) – guess 6 L / flush	2	3/6 L dual-flush installation	1
Toilet tap RDC	Not measurable at audit – hypothesis 7 l/min	3	-	3
Kitchen tap	9,7 l/min	Out of scope	Installation of an aerator or flow reducer	4
Bathroom tap	5 l/min	2	Installation of an aerator or flow reducer	1
Shower bathroom	3,7 l/min	1	-	1
Toilet flush 1st floor	Dual control – supposed 3/6 L	1	-	1

There is also a **rainwater collector** in the garden, which reduces drinking water consumption but does not count towards the final radar score.

APPENDICES

APPENDIX 1: VISUAL COMFORT STUDY
APPENDIX 2: DYNAMIC THERMAL SIMULATION
APPENDIX 3: INDOOR AIR QUALITY MEASURMENT REPORT - ISPIRA
APPENDIX 4: INDOOR AIR QUALITY SIMULATIONS
APPENDIX 5: ACOUSTIC MEASUREMENTS REPORT
APPENDIX 6: DYNAMIC ENERGY SIMULATION
APPENDIX 7: LIFE CYCLE ANALYSIS