Renovating a house in **Morangis**

APPENDIX - Detailed report: dynamic energy simulation

VELUX - LIVING PLACES - RENOVATION

ARTELIA / 16/05/2025 / 10820835

CONTENTS

BACKGROUND TO THE STUDY

ARTELIA is involved in the renovation of a privately-owned house located at 18 Rue Jules Hardouin Mansart, 91420 MORANGIS.

The aim is to take stock of the existing situation, determine priorities and propose several solutions in order to define strategic guidelines for the work to be carried out, identifying investment and operating costs.

A site visit was carried out by ARTELIA on 28/01/2025 to analyse the building's data and draw up a costed proposal for energy-saving programmes.

This Dynamic Energy Simulation (DES) study follows on from the energy audit, with the following objectives:

- Analysis of the audit report following a site visit
- Verify the relevance of the solutions proposed through the energy audit and ensure the reliability of the energy gains through digital simulation,
- Suggest additional energy solutions if justified,
- Convergence towards the proposal of a relevant energy scenario in view of the investment involved.

A. CONDITION OF THE BUILDING

1. SITE IDENTITY SHEET

Table1 - Identity sheet

Site identity sheet	
Asset name	Morangis
Address	18 Rue Jules Hardouin Mansart 91420 MORANGIS
Surface	78,81 m²
Year of construction	1948 - 1974
Type of establishment	Single house
Superstructure levels	1st floor + Attic
Types of energy consumed on site	Gas / Electricity
Energy production (heating and DHW)	Wall-hung low-temperature natural gas boiler
Fresh air supply	Natural ventilation Adjustable auto ventilation in WC and bathroom
Terminals	Steel radiators
Lighting	LED bulbs (100%)

2. SITE VISIT AND ANALYSIS OF TECHNICAL DOCUMENTS

2.1. DESCRIPTION OF THE BUILDING

2.1.1. Opaque walls

Table2 - Description of opaque walls

Surface concerned	Composition	Resistance Thermal (m².K/W)	Visual	Performance
Outside wall	Concrete block Without added insulation	0.43		
Low floor	Concrete or terracotta structure without insulation	2.33	/	
Attic	Wooden structure Weak 50 mm insulation more than 10 years old	2.72		

Thermal performance	Roof and attic	Walls	Low floor
Good	R≥ 7	R≥ 4.5	R≥ 3
Fair	4,5<R<7	3,7<R<4,5	2,5<R<3
Bad	R<= 4.5	R<= 3.7	R<= 2.5

Reference values:

The infiltration levels used for the study are as follows:

Table3 : Air infiltration levels used

Space concerned	Air infiltration (vol/h)
Building	1,7

This value was chosen in view of the deteriorated state of the building envelope.

ARTELIA recommendations:
The performance of the house's opaque structural elements is generally poor.
Priority will be given to insulating the vertical walls and roof.

2.1.2. Glazed walls

Table4 - Description of glazed walls

Surface concerned	Uw (W/m².k)	TLg	Fg	Sun protection	Visual	Performance
Joinery Exterior (Double glazing)	2,4	80	70	Store Ext		

Reference values :

Thermal performance		Uw Glazed walls
Good		Uw<= 1
Fair		1.2<Uw<1
Bad		Uw>=1,2

ARTELIA recommendations:
The joinery is double-glazed and fairly inefficient. It might be worth replacing them with more efficient joinery to improve thermal and acoustic comfort for occupants.

2.1.3. Energy production

2.1.3.1. Heating : Boiler

Heat is produced by a boiler in the kitchen (which provides heating and DHW).

Figure1 : Gas boiler

ARTELIA recommendations:
The boiler dates back to 2016, it is 9 years old. We recommend installing a new, more efficient heating production system, such as a heat pump, which offers greater energy efficiency, lower energy bills, fewer CO_2 emissions, a longer lifespan and easier maintenance.

2.1.4. Broadcast

2.1.4.1. Water radiators

The house is heated by water radiators. The water radiators installed are not optimised in terms of thermal regulation, as they are not fitted with thermostatic valves. Without these devices, it is impossible to automatically adjust the flow of hot water according to the ambient temperature, resulting in higher energy consumption and less precise thermal comfort.

Table5 : Radiator characteristics

Type of equipment	Water radiator
Year of installation	NC
Brands and models	NC
Type of control	Nothing
Level of obsolescence of the installation	Outdated
System energy performance	**Fair**

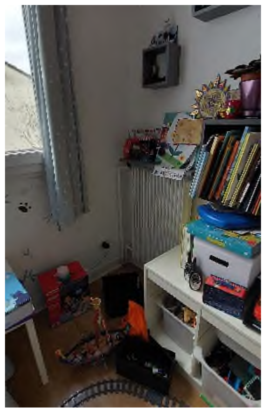
Kitchen	Living room	Lobby	Room
			

Figure2 : Water radiators

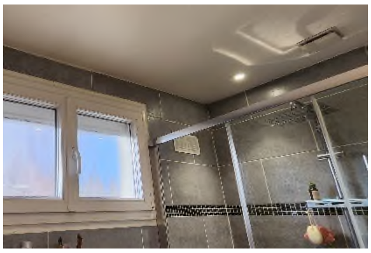
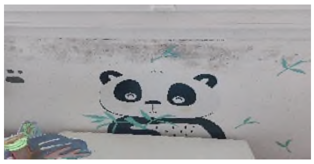
ARTELIA recommendations:
The addition of thermostatic valves would improve room-by-room control, limit overheating and generate significant energy savings.

2.2. VENTILATION

The bathroom and WC on the first floor have a controlled mechanical ventilation system (CMV), but it is not working properly, which has an impact on air renewal and moisture removal. The extraction of stale air is inadequate, leading to an accumulation of humidity, which encourages condensation and the risk of mould on the walls.

The ventilation grille in the kitchen has been removed.

Ventilation is natural in the rest of the house (air enters through the joinery).

Kitchen	Bathroom	Moulders
		 

ARTELIA recommendations:
Installing an inverted mechanical ventilation system (VMI) can be an interesting alternative to mechanical ventilation, especially in older homes with poor ventilation. It provides healthier air, better humidity management and improved thermal comfort, thanks to its system of blowing in preheated air. However, its effectiveness depends on the airtightness of the building and the circulation of air in the rooms.

2.3. LIGHTING

Table6 : Characteristics of lighting on site

Space concerned	Type of lighting	Type of order	Luminaire power	Evaluation
All zones	LED	Switch	2 W/m	**Good**

Details :

- Average number of luminaires: 20 .
- Average power per luminaire: 7 W (LED).
- Average daily use: 5 hours.

B. SED MODELLING

1. METHODOLOGY

An EDS is carried out in several stages:

1. Building modelling based on plans and construction data (insulation, glazing, etc.) and definition of building zoning by type of use: bedrooms, corridors, ...
2. Each type of use will be defined by operating hours, occupancy rates, technical equipment characterised by its power and regulation....
3. Definition of a weather file with hourly time intervals over one year, including data such as temperatures, air humidity, direct and diffuse sunshine, wind speed, etc.
4. Launch of the first simulations
5. Iterations to refine the model and/or calibrate it with energy bills

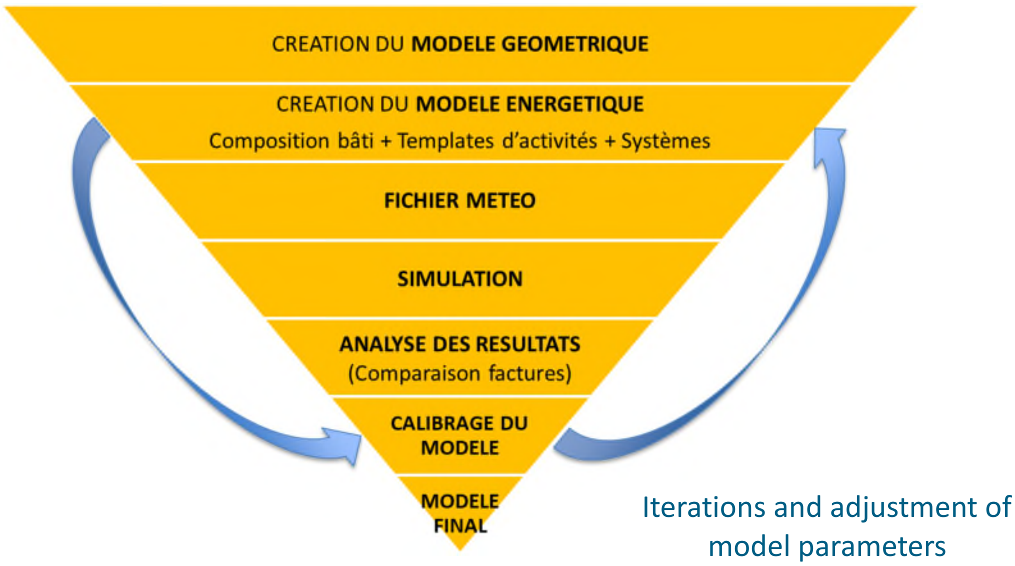


Figure3 : Stages in the production of an SED

2. SOFTWARE USED

The studies were carried out using Design Builder software (version 7.3.0), which uses the powerful Energy+ calculation engine developed by the US Department of Energy (version 8.9).

3. GEOMETRIC MODELLING

The 3D geometric model of the project was constructed based on the 2D plans and the site visit.

Zones are defined according to their use and heat treatment.

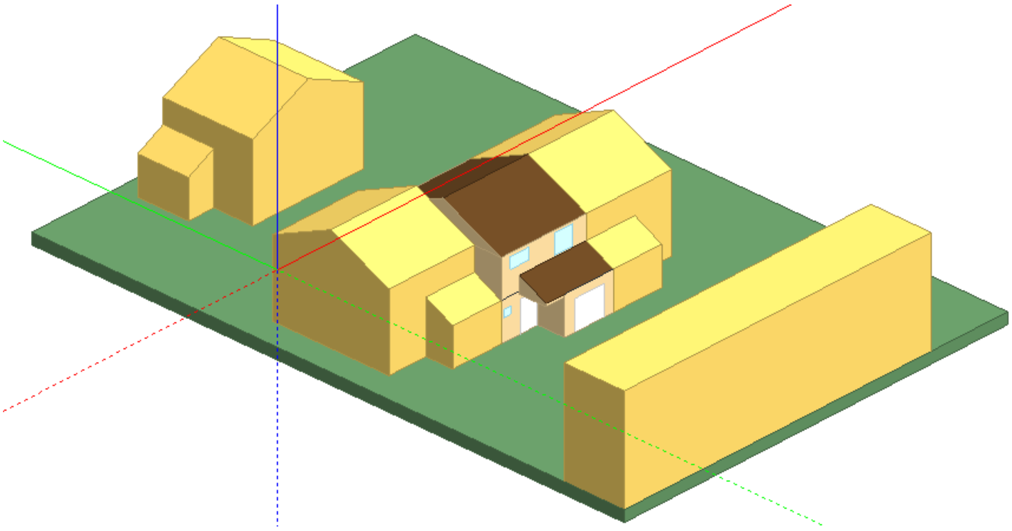


Figure4 : 3D modelling of the project

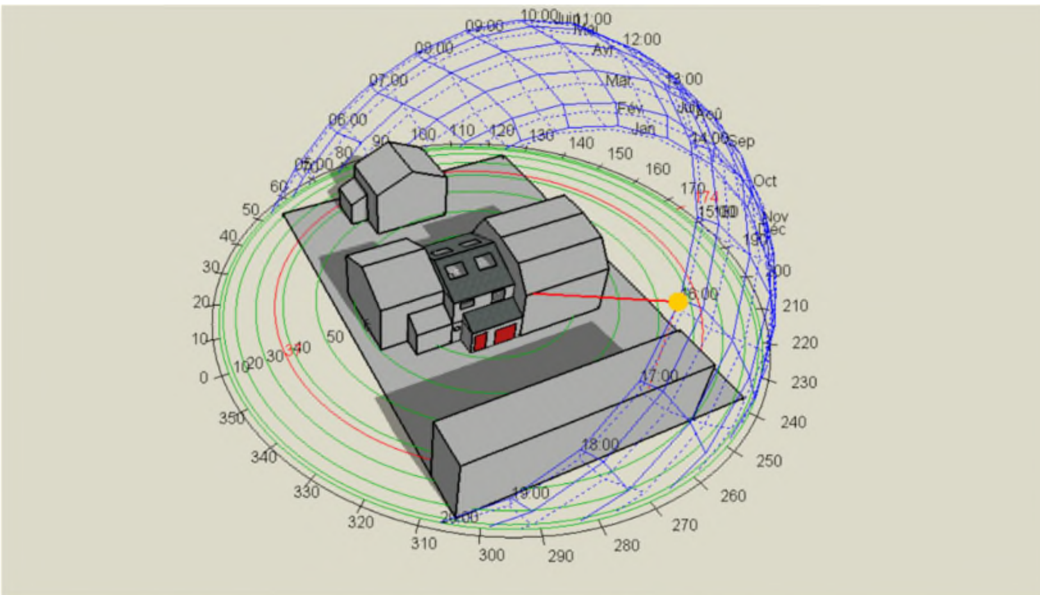


Figure5 : Project heliodon: 20/06 -16h

4. ENERGY MODELLING

The HVAC (Heating, Ventilation and Air Conditioning) systems were entered into the software in detail, based on the technical data collected and on on-site observations.

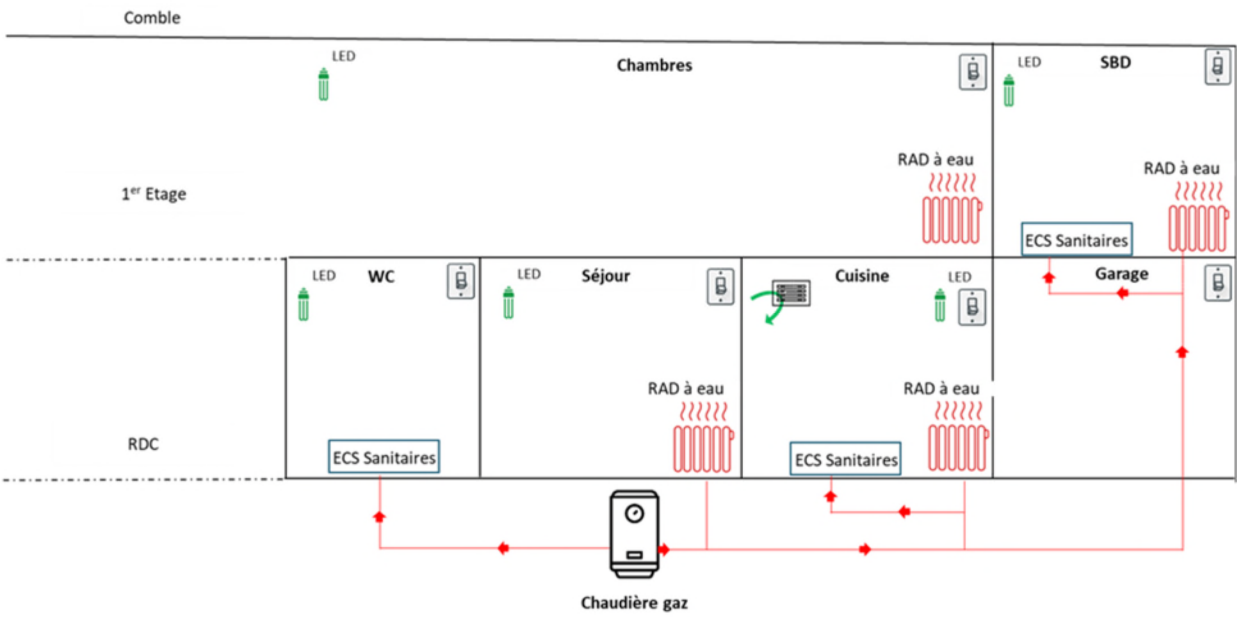


Figure6 - Extract from the HVAC system modelled in Design Builder

Each modelled zone is associated with a pre-definition (or "Template") representative of its use.

Each Template created groups together all the following assumptions and how they operate during the day:

> Occupancy density

> Set / reduced temperatures for heating and cooling and description of the thermal terminal

> Fresh air and extract air flow rates

> Lighting power and associated management

> Internal heat input from equipment

The uses modelled, representative of the overall operation of the site, are as follows:

Table7 - List of templates

Usage	Template no.
CHAMBER	1
HOLIDAY	2
ENTRY	3
STAIRCASE	4
SDB	5
SANITARY	6
GARAGE	7
DEGAGEMENT	8

4.1. REFERENCE WEATHER CONDITIONS

The SED was carried out using the Orly 2021 meteorological file.

The hourly distribution of this file is as follows:

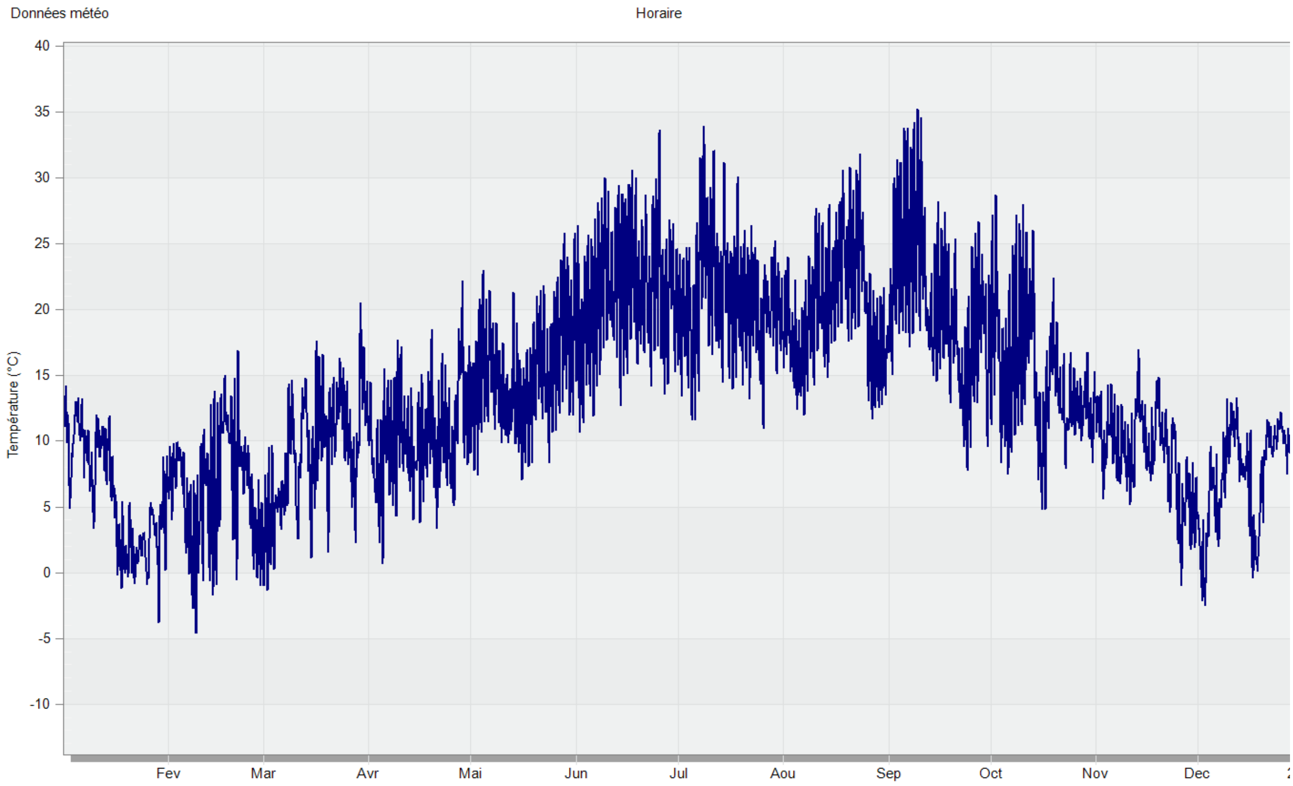


Figure7 -Hourly temperature weather file

4.2. ANALYSIS OF BILLED CONSUMPTION

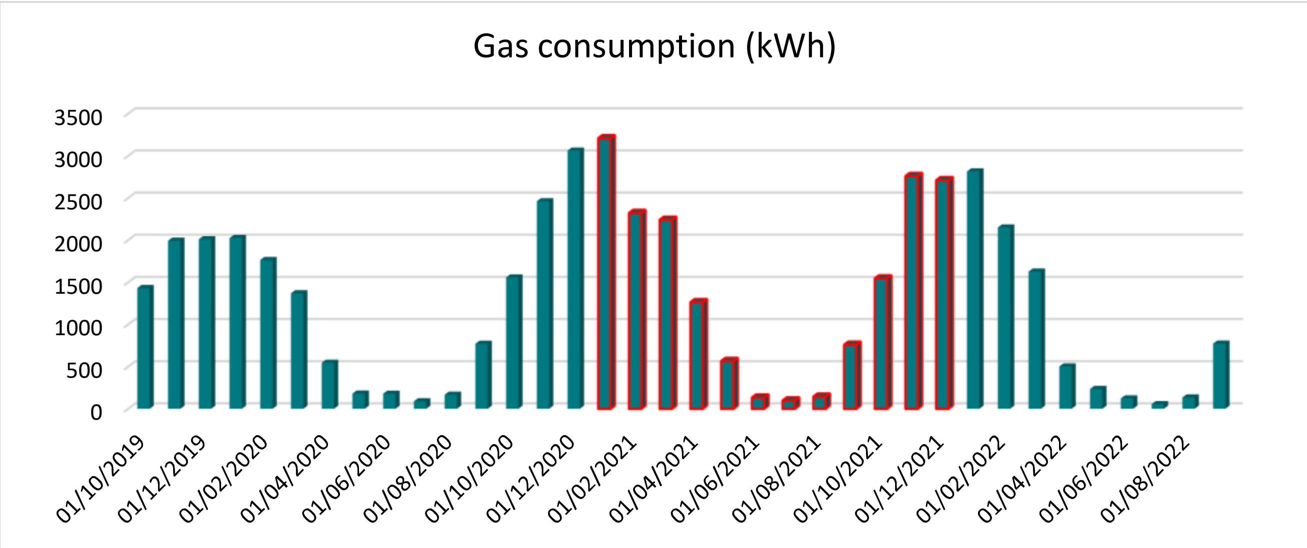
On the basis of the data provided, this chapter analyses the consumption data (electricity and gas) for the building as a whole, as there is no breakdown of consumption by use (no sub-metering).

A history of electricity consumption is available for 2021 and 2022, but it is incomplete.

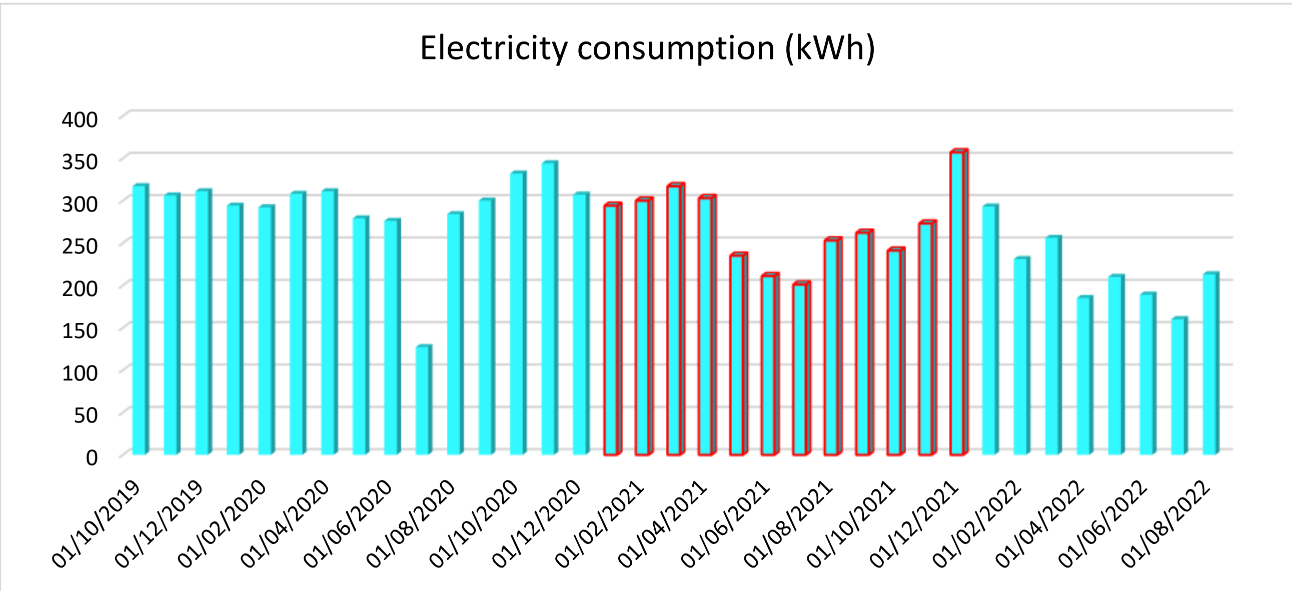
However, there are monthly statements of gas consumption for the years 2021, 2022, 2023 and 2024.

4.2.1. Annual gas consumption (heating)

The graph below shows monthly gas consumption from 2019 to 2022. This consumption is mainly for heating and domestic hot water.



4.2.2. Annual electricity consumption



According to the consumption history, the fullest and most recent year was 2021, with consumption of 21,015 kWh.

4.3. CALIBRATION OF THE SED MODEL

In order to get as close as possible to the actual energy behaviour of the house, an iterative process of simulations was carried out. This stage, known as "calibration", ensured that the model matched the billing data provided.

The gas and electricity consumption figures have been calculated on the basis of the readings provided, while the breakdown of consumption for the various items has been calculated on the basis of the information gathered during the visit.

Gas consumption (heating and DHW) and electricity consumption (lighting and equipment) in 2021 were used for calibration.

Table8 - Energy consumption for the building in 20 21

Fluid	KWh	kWh/m² (kWh/m²)
Gas	**17 768**	**228**
Electricity	**3 247**	**42**
Total	**21 015**	**270**

The energy consumption obtained by SED is broken down as follows:

Table9 - Calibrated SED gas and electricity consumption

Fluid	SED detail (kWh)	Calibration 2021 (kWh)	Difference (%)
GAS	**18 086**	**17 768**	**+1.7%**
Electricity	**3 336**	**3 247**	**+2.74%**
Total	**21 453**	**21 015**	**+2%**

Table10 - Consumption by item Calibrated SED

<table>
<tr><th>Fluid</th><th>Consumption item</th><th>Detail SED (KWh)</th><th>Detail SED (KWh/m²)</th><th>Total (KWh/m²)</th></tr>
<tr><td rowspan="2">GAS</td><td>Heating</td><td>15 629,25</td><td>200,4</td><td rowspan="5">275</td></tr>
<tr><td>DHW</td><td>2 457,00</td><td>31,5</td></tr>
<tr><td rowspan="3">ELECTRICITY</td><td>Lighting</td><td>263,25</td><td>3,4</td></tr>
<tr><td>Ventilation</td><td>360</td><td>4,5</td></tr>
<tr><td>Electrical equipment</td><td>2 752,43</td><td>35,3</td></tr>
</table>

Equipment details :

Equipment	Power	How it works
Fridge	150 W	24h/day * 8760 h * 40% (duty cycle)
Electric oven	2 000 W	1 h/day * 250 days/year
Electric hobs (induction or vitroceramic)	2 500 W	1.5 h/day * 240 days/year
Dishwasher	1 500 W	1 cycle of 1.5 h/day * 172 days/year
Microwave	1 000 W	0.6 h/day * 200 days/year
Extractor hood	200 W	1.5 h/day * 166 days/year
Small appliances (toaster, blender, coffee maker, kettle, etc.)	1 200 W	0.5 h/day * 342 days/year
Other miscellaneous equipment	Variable	Overall estimate

Sanitary DHW details :

Usage	Volume of hot water	How it works
Short showers (4 people)	120 L/day	325 days
Dishes (dishwasher)	15 L/day	325 days
Hand washing and miscellaneous	10 L/day	325 days
Total	**145 L/day**	325 days

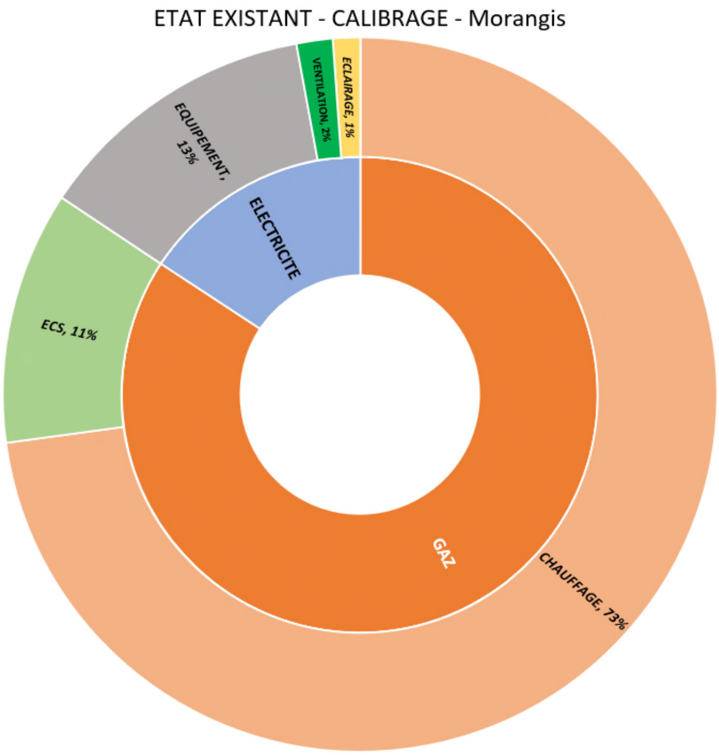


Figure8 - Breakdown of consumption by use and by fluid

Heating is the most energy-intensive item, accounting for 73% of the house's total consumption.

5. ECD ANALYSIS BEFORE WORK

The EPC assesses the energy performance of a building by measuring its primary energy consumption and its impact in terms of greenhouse gas emissions.

The energy consumption taken into account in calculating the EPC does not cover all the energy costs of the house, but only those linked to thermal comfort and the production of domestic hot water.

The **primary energy** consumption taken into account for the study is: **heating, ventilation, lighting and domestic hot water.**

The final energy to primary energy conversion coefficient is around **2.3**. This means that for every 1 kWh of final energy consumed, 2.3 kWh of primary energy are considered (taking into account losses linked to the production and transmission of electricity).

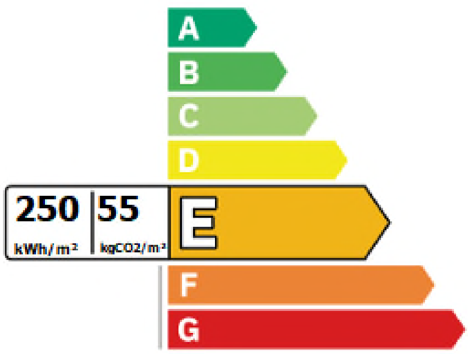
Fluid	Consumption item ECD	SED (KWh Ef/m²)	SED (KWh Ep/m²)	Total (KWhEp/m²)
GAS	Heating	**200,4**	**200,4**	**250**
	DHW	**31,5**	**31,5**	
ELECTRICITY	Lighting	**3,3**	**7,7**	
	Ventilation	**4,5**	**10,3**	
	Equipment	**Excluding ECD**	**Excluding ECD**	

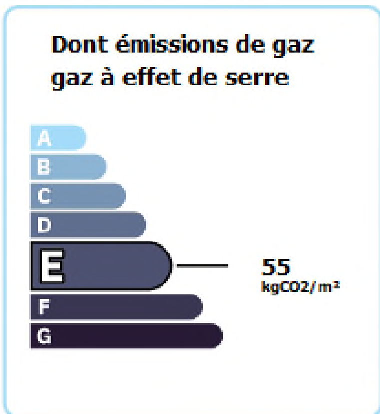
The ECD result is expressed in two indicators:

- **Energy consumption: in kWh/m²/year (primary energy).**
- **Greenhouse gas emissions (GHG): in kg CO_2/m²/year.**

The energy class ranges from A (very efficient) to G (very energy-intensive).

The home's current energy and climate performance:





Important information: **This calculation of the EPC is provided for information only and in no way constitutes an official diagnosis. For a certified result, an assessment by a certified diagnostician is required**.

C. ENERGY PERFORMANCE ACTIONS

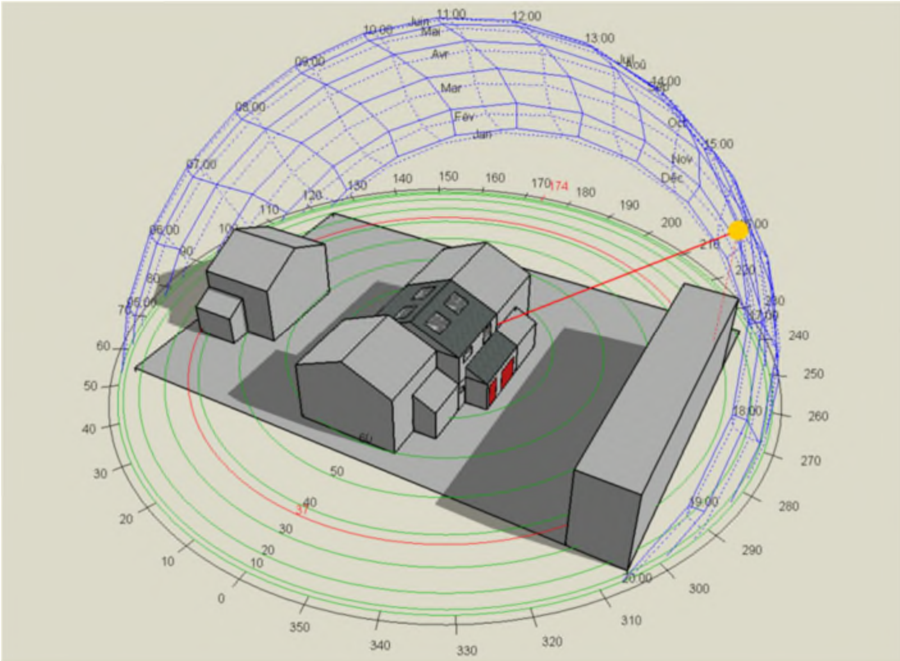
1. DEFINITION OF EPA

The following actions seem to us to be the most relevant with a view to improving the building's energy efficiency and durability, thereby improving the comfort of occupants and offering them a better quality of life. Each of the EPAs (Energy Performance Actions) is the subject of a dynamic thermal simulation to calculate the associated energy impact.

Table11 - Description of the Energy Performance Actions (EPAs) selected

APE		
0	***Modification work :*** ➢ *Extended stay* ➢ *Entrance extension* ➢ *Installation of zenithal openings* ➢ *Attic conversion*	
1	***Wall insulation (ITE)*** ➢ *External insulation of all walls facing the outside of the building (16 cm of glass wool insulation, ISOCOMPACT approved)*	***R>= 4.5 m2.K/W***
2	***High floor insulation*** ➢ *Insulation of the floor surface overlooking the lost attic Reference: Utherm Sarking K FRA sheet, 16 cm thick, R=7.4*	***R >= 7.4 m².K/W***
3	***Replacement of joinery*** ➢ *Replacing all the joinery with new, more thermally efficient joinery*	**Uw< = 1.3 W/m².K** **Tlg = 70%, Fsg = 40%**
4	***Ventilation*** ➢ *Installation of VMI (Mechanical Insufflation Ventilation)*	***SFP = 0.3***
5	***Heating*** ➢ *Replace the heating system with a dual-service air/water heat pump (heating and DHW)*	***PAC: SCOP ≥ 4.69*** ***200L thermo storage tank: COP ≥ 3.18***
6	***Control*** ➢ *Update the control system by installing thermostatic valves on radiators*	

2. MODELLING THE PROJECT AFTER WORKS



3. ENERGY GAINS FROM THE VARIOUS APE

Individual gains are calculated in relation to the calibrated model.

Table12 - Energy savings by EPA

APE		Individual gains compared to calibration			Investment (excluding extension work) (EXCL. VAT €)
		Energy (%)	Energy (kWh/m²)	Invoice (€)	
1	***Wall insulation (ITI)***	-38%	105,5	683 €	10 177 €
2	***High floor insulation (ITE)***	-5%	15,1	177 €	4 500 €
3	***Replacement of joinery***	-4%	10,7	152 €	8 670 €
4	***Ventilation: Installation of VMI***	**+1,2%**	**+3**	**+ 814 €**	**5 471 €**
5	***Heating: Installation of a heat pump***	-67%	184,0	831 €	18 700 €
6	***REGULATION - Optimisation of heating control - Installation of thermostatic valves***	-6%	17,5	190 €	5 880 €

The installation of a **Mechanical Insufflation Ventilation (MIV)** system leads to an **increase in** energy consumption, particularly due to the **continuous** operation of **the fan** and, in some cases, the **pre-heating of the supply air**. However, this additional consumption is largely offset by the benefits in terms of **comfort**.

VMI ensures constant air renewal, improving indoor air quality while limiting humidity and the risk of mould. It also helps to reduce cold air infiltration in winter, which improves occupants' thermal comfort. By maintaining a slight overpressure inside the home, it limits the entry of uncontrolled outside air, reducing unpleasant draughts.

So, although MIV represents an additional energy expense, its positive impact on comfort and air quality makes it an interesting solution, particularly in homes where natural ventilation is inadequate.

4. ENERGY GAINS FROM THE SCENARIOS

The associated energy savings are shown in the table below. It is calculated in relation to the calibrated consumption value, i.e. **275 kWh/m².**

The scenarios were selected on the basis of the cheapest and easiest-to-implement EPAs (Energy Performance Actions) and the priority actions to be implemented, namely insulation and replacement of glazing.

Table13 Energy consumption and gains by scenario

SCENARIO		Investment (HT)	Consumption (kWh/m²)	Gain Calibration
1	***Wall insulation (ITE)***	**20 557 €**	143	**-47%**
	High floor insulation (ITE)			
	REGULATION - Optimisation of heating control - Installation of thermostatic valves			
2	***Wall insulation (ITE)***	**44 728 €**	66	**-76%**
	High floor insulation (ITE)			
	REGULATION - Optimisation of heating control - Installation of thermostatic valves			
	Ventilation: Installation of VMI			
	Heating: Installation of a heat pump			
3	***Wall insulation (ITE)***	**53 398 €**	65	**-77%**
	High floor insulation (ITE)			
	REGULATION - Optimisation of heating control - Installation of thermostatic valves			
	Ventilation: Installation of VMI			
	Heating: Installation of a heat pump			
	Replacement of joinery			
Selected scenario	***Wall insulation (ITE)***	**56 500 €**	66	**-76%**
	High floor insulation (ITE)			
	REGULATION - Optimisation of heating control - Installation of thermostatic valves			
	Ventilation: Installation of VMI			
	Heating: Installation of a heat pump			
	Replacement of joinery			
	INT roof insulation: 8 cm of wood wool added			
	Attic radiator: 2 electric radiators (identical wattage and setpoint)			

The figure below shows changes in consumption by item:

Fluid	Consumption item ECD	SED (KWh Ef/m²)	Total (KWhEf/m²)	SED (KWh Ep/m²)	Total (KWhEp/m²)
ELECTRICITY	Heating	**14,6**	**66**	**33,6**	**70**
	DHW	**6,7**		**15,4**	
	Lighting	**3,3**		**7,5**	
	Ventilation	**5,9**		**13,6**	
	Equipment	**35.3 : Excluding ECD**		**Excluding ECD**	

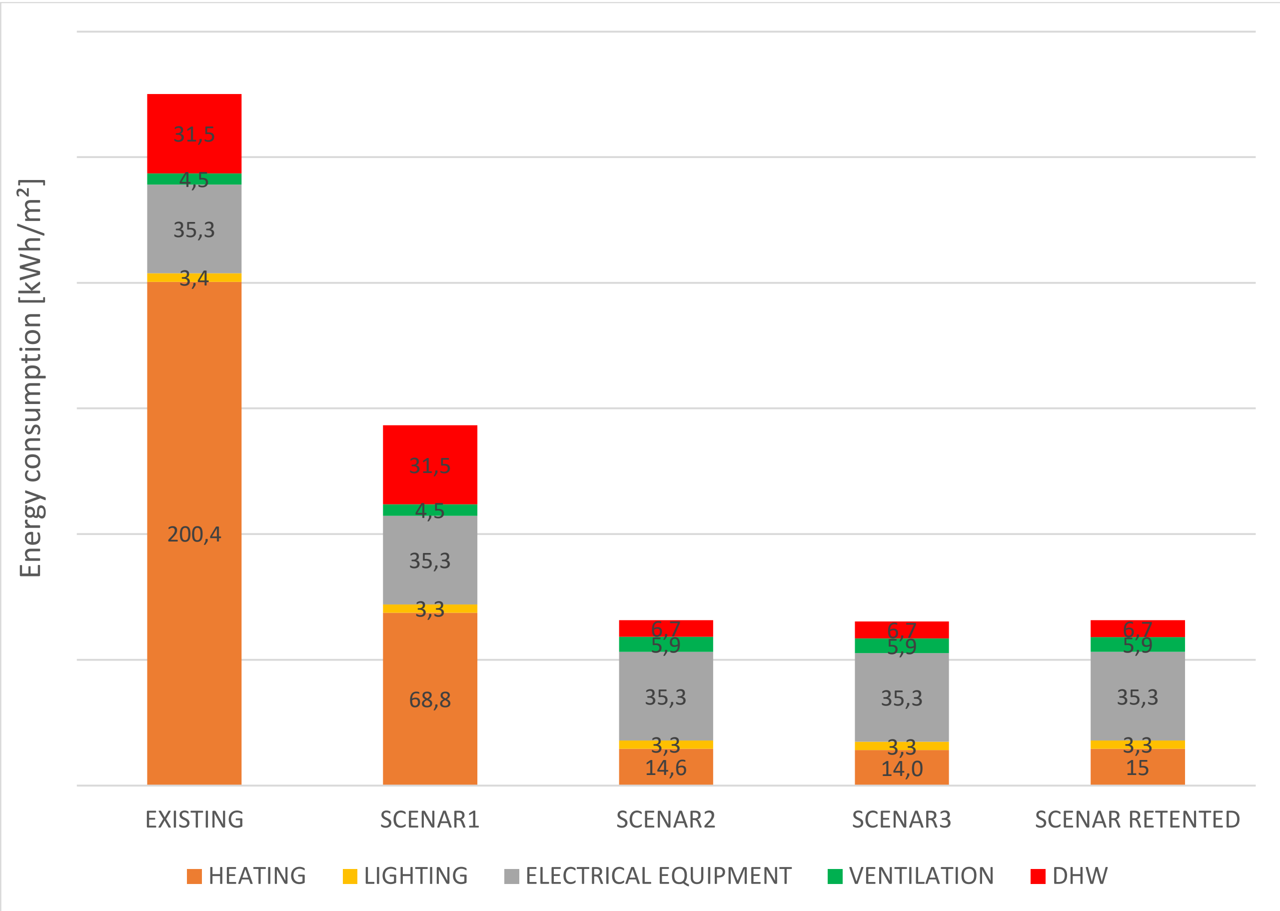


Figure9 Energy consumption by item and scenario

4.1. SELECTED SCENARIO

The chosen scenario combines all the most effective levers with a few additional optimisations:

Work on the envelope

- External wall insulation
- High floor insulation
- Interior roof insulation (8 cm wood wool)
- Replacement of joinery

Ventilation

- Installation of a mechanical ventilation system (VMI)

Heating and control

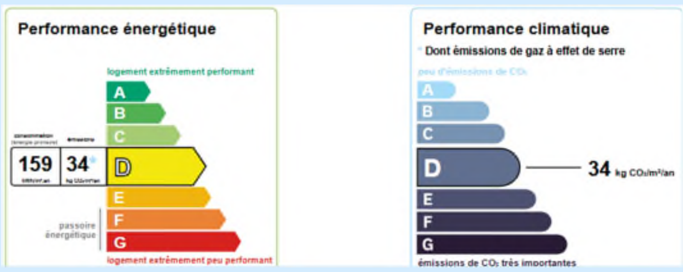
- Installation of a heat pump (dual-service air/water heat pump)
- Updating the control system with thermostatic valves
- Installing electric convector heaters in the attic

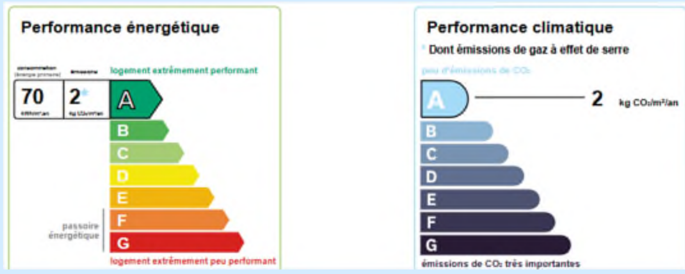
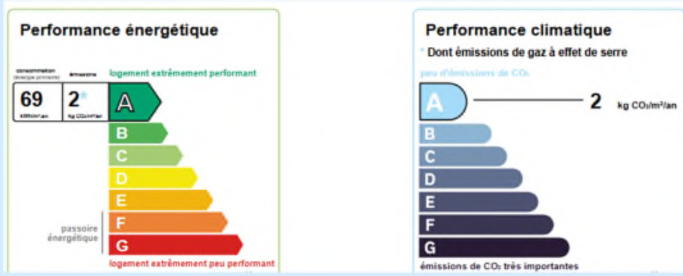
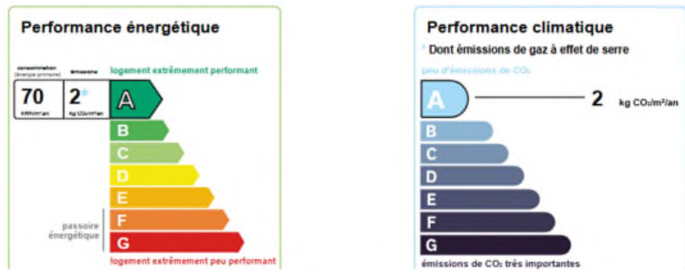
Indicator	Value
Initial consumption	275 kWh/m²/year
Consumption after works	66 kWh/m²/year
Overall gain	**-76%**

The scenario enables consumption to **be divided by more than 4**

5. EPC ANALYSIS AFTER WORK

The final energy to primary energy conversion coefficient is around **2.3**. This means that for every 1 kWh of final energy consumed, 2.3 kWh of primary energy are considered (taking into account losses linked to the production and transmission of electricity).

Status	Consumption SED (KWh Ep/m²)	Consumption EPD (KWh Ep/m²)	Energy label
Scenario 1	143	**159**	

Scenario 2	66	**70**	
Scenario 3	65	**69**	
Selected scenario	66	**70**	

Important information: **This calculation of the EPC is provided for information only and in no way constitutes an official diagnosis. For a certified result, an assessment by a certified diagnostician is required**.

D. CONCLUSIONS AND SUMMARY OF THE STUDY

As part of the refurbishment of a house in Morangis, a number of Energy Performance Actions (EPAs) were proposed and simulated individually, then grouped under three scenarios to maximise energy efficiency and improve occupant comfort.

Scenario 1, combining **APE1 (Wall insulation - ITE)**, **APE2 (High floor insulation - ITE**), **APE3 (Low floor insulation)** and **APE7 (REGULATION - Optimisation of heating control / installation of thermostatic valves)**, results in a consumption of **143 kWh/m².an**, an energy reduction of around **47%** compared with the reference consumption.

Scenario 2, incorporating the actions of scenario 1 with the addition of **APE5 (installation of VMI)** and **APE6 (installation of a heat pump)**, achieves a consumption of **66 kWh/m².an**, i.e. an estimated energy reduction of **76%** for an investment of around **€45,000 excluding VAT**.

Scenario 3, based on scenario 2 with the addition of **APE4 (replacement of joinery)**, offers a slightly higher energy reduction of around **77%**, with consumption reduced to **65 kWh/m².an** for an overall investment of around **€53,000 excluding VAT**.

<u>**Selected scenario**</u>

The scenario finally adopted goes beyond the three previous scenarios, incorporating **all the EPAs of scenario 3 as** well as **additional** measures:

- **Insulation of the interior roof** with 8 cm of wood wool
- Installation of two electric radiators in the attic for homogeneous treatment *[will later have been changed to water radiators].*

> 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 **2**.
>
> **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 heat pump and thermodynamic tank systems use mainly free and renewable energy (outside air), and some electricity to operate, On the basis of the SCOP / COP used in the project:

Heat pump: SCOP ≥ 4.69 → therefore **~79%** of the energy returned comes from the air (1 - 1/4.69)

Thermodynamic tank: COP ≥ 3.18 → **~69%** of the energy is from renewable sources (1 - 1/3.18)

This represents around 37 kWhEP that can be considered of renewable origin, or just over half of the renovated building's consumption, since most of the energy used (heating, DHW) is provided by these two items of equipment.

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