What's behind the label: how an EPC label change hides the full range of possible retrofits

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Abstract

The French Energy Performance Certificate (EPC) is used to define long-term energy performance targets for residential buildings: improving the energy label to at least the B label.

However, these objectives described in terms of EPC label do not allow us to describe and quantify the extent of energy renovation that is required. The aim of this study is to explain the kind of retrofit and its cost using a statistical approach, with two explanations: the nature of the technical measures and their cost. As an example, we will present the results for achieving high-efficient renovation (label A or B) for all the initial EPC labels.

To do this, we use the French EPC method in its 2021 version to determine all the possible combinations of retrofit package described as compatible with all the possible EPC label changes. For each retrofit package, the calculation determines the energy consumption after retrofit, based on the standard EPC calculation, the new energy label obtained, and the investment required per retrofit measure.

To study label changes, the calculations are based on 2,300 homes described in a public survey. With a maximum of 8 retrofit measures per renovation package studied, we have a combination leading to a total of around one million calculations for all the dwellings studied. We then carry out a statistical study of the costs of the retrofit package calculated in this way.

Overall, the cost of high-efficient renovation is in the range of €200 to €350/m² of living space (direct cost), depending on the type of property, the initial EPC class and the final level achieved. As expected, the lower the initial performance of the building, the higher the cost of high-performance renovation. For given label changes, there is therefore a "home retrofit package" configuration for which the investment costs are minimal and configurations with very high costs, but which correspond to rare combinations. The knowledge of what is behind the EPC label change clarifies energy efficiency policy objectives in terms of technology and the type of retrofit possible and/or necessary, particularly for the building industry and the introduction of targeted financial incentive.

Introduction

The French energy performance certificate (EPC) (in French *Diagnostic de Performance Énergétique* - DPE) scheme was issued from the EPBD directive (EUR-Lex 2021) and was implemented in France in 2006 and is mandatory for selling or renting a dwelling. Since 2006 this EPC scheme has been made more reliable and strengthened by major reforms in 2013 and in 2021. This latest revision of the EPC scheme is part of a wider policy to speed up the energy-efficient renovation of buildings, of which the EPC is one of the key tools (MTE 2023). The French EPC is used nowadays to monitor the performance of the French building stock and to set national energy and/or climate efficiency targets. In addition, the EPC has a significant impact on the price for the sale of dwellings (Notaire de France 2023).

Thus, the 2021 French Climate and Resilience Act (in French *loi Climat et Résilience* (MTE 2021)) has introduced a scheme for formulating public renovation policy based on EPC classes. This Climate and Resilience Act has set out requirements for renovation in terms of EPC classes, the most tangible of which is the ban on renting out properties rated F and G (Noguès et al. 2023).

These EPC classes (Figure 1) are used to classify dwellings as "efficient" (classes A and B), "fairly efficient" (class C), and "heat sinks" (i.e. very badly insulated dwellings) (classes F and G). A "high-efficient renovation" is defined as an improvement in energy class to achieve labels A or B and possibly C (for the least efficient initial dwellings, with labels F or G). The objective for 2050 is to renovate the entire building stock to low energy consumption level (MTE 2017).

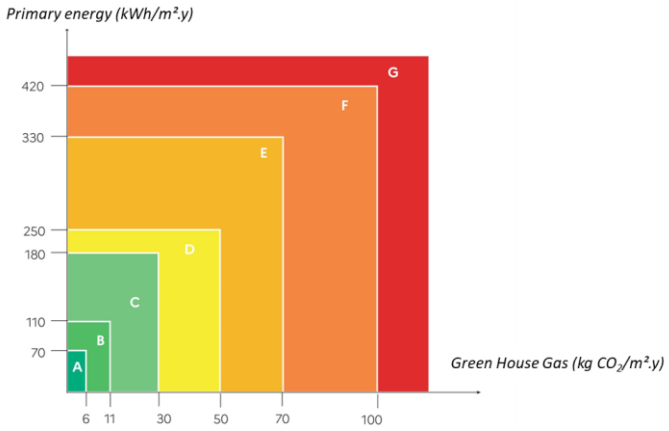

Figure 1. French EPC label integrating energy consumption and greenhouse gas emissions expressed in kWh of primary energy and kg of carbon dioxide equivalent per unit area (adapted from MTECT 2023)

However, these objectives, described in terms of EPC label, do not make it possible to define the energy retrofit required to achieve the target even though the current EPC proposes recommendations for improving the performance on an individual basis (i.e. for each EPC carried out) and with a cost assessment.

Studies on the cost of shifting from one EPC class to another have been carried out in the past for France, but they are based on unexplained transitions, with no explicit technical solution, and with the results given either in €/m² (Giraudet et al. 2020) or in kWh/year of € invested (France Stratégie 2022).

The latest assessment of the French residential building stock reveals that on average the building stock is labelled D (around 30% of the building stock) and around 4.8 million of dwellings are considered "heat sink" (F and G EPC labels) (i.e. 15.7% of housing stock) (ONRE 2023). We must notice that on average Single Family Housing (SFH) are less efficient than Multi-Family Housing (MFH).

Since its introduction, the French EPC has been the subject of much criticism including:

- The different valuation (differences of 2 to 3 EPC classes) of the same or similar dwellings (Chocron 2023) and the associated uncertainty. Part of this discrepancy can be explained by the method itself (Raynaud et al. 2019) (default value vs. observed value) but also by the errors or different parameter evaluation of the EPC Assessors (Chocron 2023, Astier 2024). Moreover, the French EPC method results in two dwellings with similar characteristics but different surface areas being rated differently (Astier et al. 2024).
- The thermal resistance of walls and the performance of equipment may be overestimated, particularly because of faulty workmanship (Astier et al. 2024).
- The prebound effect which is the over-prediction of consumption in inefficient building (Galving and Sunikka-Blank 2016) observed in France (Cayla et al. 2010) like in other countries.

- The difference between the parameters of the energy consumption considered in the French EPC (space heating, domestic hot water (DHW), air conditioning, lighting, and auxiliaries (ventilation, pump…)) and the overall consumption (all types of final consumption including appliances) of a dwelling in the case of a comparison with smart metering systems (Matheron 2023).

In our case, these limitations are not so important as we are working within the same EPC framework with a before-and-after approach (i.e. class change).

The aim of this study is to explain the nature of the retrofits and theirs costs for private housing[1] to achieve a high-efficient renovation, using a statistical approach. Two explanations are given for the relationship between EPC class changes and the determination of the required renovation packages: one on the technical side (nature of the technical measures implemented), and the other on the economic side (costs of the technical measures implemented).

In the following we describe the results that make it possible to achieve high-efficient renovation (achieving label A or B) as defined above. It should be noted that in this study, we present results that are not weighted to reflect the representativeness of the simulated homes in the French housing stock. The aim is not to simulate the future renovation market or the total cost for the entire housing stock, but to analyse the costs of all technical options[2].

Methodology

EPC calculation method

To calculate the EPC label, we use a software developed in-house by EDF (*Electricité de France*) based on the 3CL method in its 2021 version (CEREMA 2021). The 3CL method is the calculation methodology used to calculate the French EPC label and described in a 149-pages document (JORF 2021), which the general principles are summarised below. The 3CL method used to calculate the energy consumption for the French EPC is a monthly conventional method that includes 5 end-uses (heating, cooling, DHW, lighting and auxiliaries) and depends on the geolocation of the dwelling.

The software used in this study is simply a coding of the 3CL method which calculates a set of systematic combinations of renovation measures associated with their cost for a given dwelling. It can also be used to process a set of dwellings and retrofits described in a database in a single run. This software determines all the possible combinations of retrofit described as compatible with all the possible EPC class changes. For each retrofit package, the calculation tool determines the energy consumption after the implemented measures, based on the standard EPC calculation, the new energy and climate labels obtained, and the investment required for each retrofit measure. To analyse label changes, the calculation is based on the 2,300 dwellings[3] described in the PHEBUS[4] survey (MTE 2018). This database describes the performance levels of walls (buildings), heating equipment and DHW. In the absence of all the information in the PHEBUS EPC database, simplifications[5] have been made to carry out the calculations.

The heating demand according to the 3CL methodology is calculated on the basis of heating degree-days with a set indoor temperature of 19°C. For the annual space heating consumption ($C_{heating}^{annual}$), the calculation can be summarized as the sum of monthly consumption based on energy demand and the efficiency of space heating equipment (η), taking set-temperature management and inertia (I) into account:

$$C_{heating}^{annual} = \frac{1}{\eta} * I * \sum_{m=1}^{m=12}\left[\left(\sum_{j=1}^{j=n}\left(b_j * S_j * U_j\right) + TB + AL\right) * (1 - f)\right] \quad \text{eq. 1}$$

with:

η = heating system efficiency (including generation, distribution, regulation, and emission)

f = fraction of heating demand covered by free heat gain

[1] The cost for social housing can be very different from those observed on the diffuse residential energy renovation market.

[2] Market simulation will be another stage in the PREMOCLASSE project and will be carried out using the Res-IRF tool. See (Giraudet et al. 2021).

[3] 1,697 SFHs and 645 MFHs.

[4] The aim of the PHEBUS (housing performance, equipment, energy demands and end-uses) survey is to provide a snapshot of the energy performance of the stock of main residences, by analysing them according to the characteristics of their occupants, household equipment, energy use and energy consumption. A second part of the survey consists of having an official EPC to measure the dwelling's energy performance (MTE 2018).

[5] Distribution of windows glazing surfaces by orientation, estimation of thermal bridges.

I = intermittence factor

AL = heat loss through air renewal (W/K)

TB = heat loss through thermal bridges (W/K)

bj = heat loss reduction coefficient for wall j (1 for external walls)

Sj = surface of wall j (m²)

Uj = thermal transmittance coefficient of wall j (W/(m².K))

DHW annual consumption (C_{DHW}^{annual}) is based on the maximal number of occupants which depends on living area and can be summarized by equation 2:

$$C_{DHW}^{annual} = \frac{1}{\eta} * \sum_{m=1}^{m=12} \left[1.163 * N_{eq} * 56 * \left(10 - T_m\right) * n_m \right] \quad \text{eq. 2}$$

with:

η = DHW system efficiency (including generation, distribution, and storage)

N_{eq} = equivalent number of adults

T_m = average monthly cold-water temperature (°C)

N_m = number of days occupied during the month

In contrast to a detailed calculation like space heating and DHW, lighting consumption is calculated on a flat-rate basis, with a power of 1.4 W/m² multiplied by the number of hours of operation over the month. For the consumption of ventilation auxiliaries, the calculation is similar, with the average power of the auxiliaries multiplied by the number of operating hours (8700h).

Designing retrofit packages

Of all the possible retrofit packages for the renovation of dwellings, some technical solutions are impossible (e.g. roof insulation for an intermediate flat) or unlikely (e.g. installation of an air/air heat pump to replace a gas boiler (CEREN 2023)). We have therefore restricted our study to the most likely cases. While all walls can be insulated in the case of SFH, this is not the case for some MFHs. In all cases, ventilation and windows can be replaced. the list of possible retrofits is as follows:

- Roof (lost or converted attic space, terrace).
- Wall, facade: Internal Wall Insulation (IWI) or External Wall Insulation (EWI) in SFH.
- Floor and basement insulation.
- Double-glazed window and external door.
- Ventilation: single flow or double flow with heat recovery.

In terms of heat supply, a range of equipment is analysed: heat pump (HP), fossil boilers, direct electric heating combined with domestic hot water (DHW) equipment (see appendices 1 and 2).

The simulations of the retrofits were carried out by separating the types of housing (SFH and MFH). To date, the simulation tool and the database of dwellings used can only simulate retrofit on the scale of a single dwelling, which for MFHs limits the possibilities for External Thermal Insulation (ETI) measure on the scale of the building, thereby reducing the cost of renovation. However, collective thermal systems can be simulated. With a maximum of 8 items, we have a combination of 1,500 retrofit packages for SFHs and 250 packages for MFHs, leading to a total of more than 800,000 simulations for all the 2,300 dwellings described by an EPC in the PHEBUS database.

In the remainder of this document, we will only select the retrofit packages that lead to an ambitious refurbishment (EPC label A or B – and C for F and G dwellings) and called “high-efficient renovation”.

Retrofit Cost

A range of data sources (Effinergie 2021, ADEME 2019, Osso et al. 2022) was analysed to estimate the investment costs associated with energy-efficient renovation, supplemented where necessary by professional database (Batiprix[6]). To the best of our knowledge, the database of retrofit costs used in the EPC recommendations is not public and cannot therefore be used in this study.

The direct costs used in this study (Table 1) only consider the “efficiency improvement” of the retrofit without including the additional costs incurred (aesthetics, rewiring of the electrical or hydraulic network…), whereas

[6] https://www.batiprix.com/

there are virtually none for the space heating or DHW equipment this may be important for the building envelope. These additional costs can be high and can act as a barrier.

In terms of the cost-effectiveness of the retrofitting measures, there is a wide spread of costs, which can vary up to threefold for the same retrofit package. Part of this variation can be explained by technical criteria that can be modelled using extensive factors (e.g. number of m^2 of insulation) or intensive factors (e.g. thermal resistance value). Another part of the variation is explained by qualitative criteria (e.g. brand of heat pump or reputation of the installer) (Osso et al. 2018) that cannot be modelled in this study.

In the remainder of this document, we will only select the retrofit packages that lead to a high-efficient renovation (EPC label A or B - and C for F and G dwellings).

Table 1. Retrofit direct cost in SFH (€ inc VAT - supplied and installed)

Retrofit	Cost	Retrofit	Cost
Hybrid heat pump	€14,000	Door	€1,500
Air-to-water heat pump	€12,000	Double glazing window	€1,000
Air-to-water heat pump (inc. DHW)	€13,700	Walls IWI	€30 /m²
Lost attic space insulation	€16 /m²	Walls EWI	€159 /m²
Converted attic insulation	€42 /m²	Floor	€28 /m²
Wood pellet boiler	€13,600	Pellet stove	€6,000
Direct Electric Heating	€860	Ventilation Single Flow	€1,670
Air-to-air heat pump	€70 /m²	Ventilation Double Flow	€5,900
Oil boiler	€7,800	Thermodynamic Water Heater	€2,800
Gas boiler	€4,400		

Results

The cost of high-efficient renovation

In all cases, the distribution of retrofit total costs expressed per unit of floor area (living space area in m²) is asymmetrical and skewed towards higher values (distribution tail spread to the right) (Figure 2). For a given change in EPC label, there is therefore:

- a minimum investment cost corresponding to a favourable "dwelling-retrofit package" combination, and,
- for particular configurations of "dwelling-retrofit package" combinations, very high costs but statistically infrequent because few households will choose them because of economic constraints.

The number of retrofit packages allowing a high-efficient renovation is even smaller when starting from a low-performance EPC label. In fact, to go from a G label to at least a C label, it is necessary to carry out a larger package of renovation than to go from a C to a B label, where a single action may suffice. In addition to the cost, it is technically difficult to achieve class A for homes in initial class G because the number of possible packages is low (Figure 3), unlike homes in class C (Figure 4).

It should be noted that the spread of costs per package that we are simulating is not due to the spread in observed prices, but solely to the diversity of house types and retrofit packages and the aggregation of arrival labels. In this study, the dispersion of package prices stems only from the disparity in the characteristics of the housing stock (type of SFH/MFH, location in the building, surface area, level of insulation, type of heating equipment…) than from the dispersion of prices for the same action observed on the market. So, the true cost spread combining disparity of building and retrofit market price is not assessed here.

Table 2. Cost of retrofit (€/m² of living space area - median value) according to the initial EPC "energy" labels to achieve high-efficient renovation.

EPC	SFH			EPC	MFH		
↓Initial final →	A	B	C	↓Initial final →	A	B	C
C	242	210	-	C	214	168	-
D	288	244	-	D	238	204	-
E	301	292	-	E	246	232	
F	310	315	281	F	458	282	188
G	347	353	335	G	321	296	208

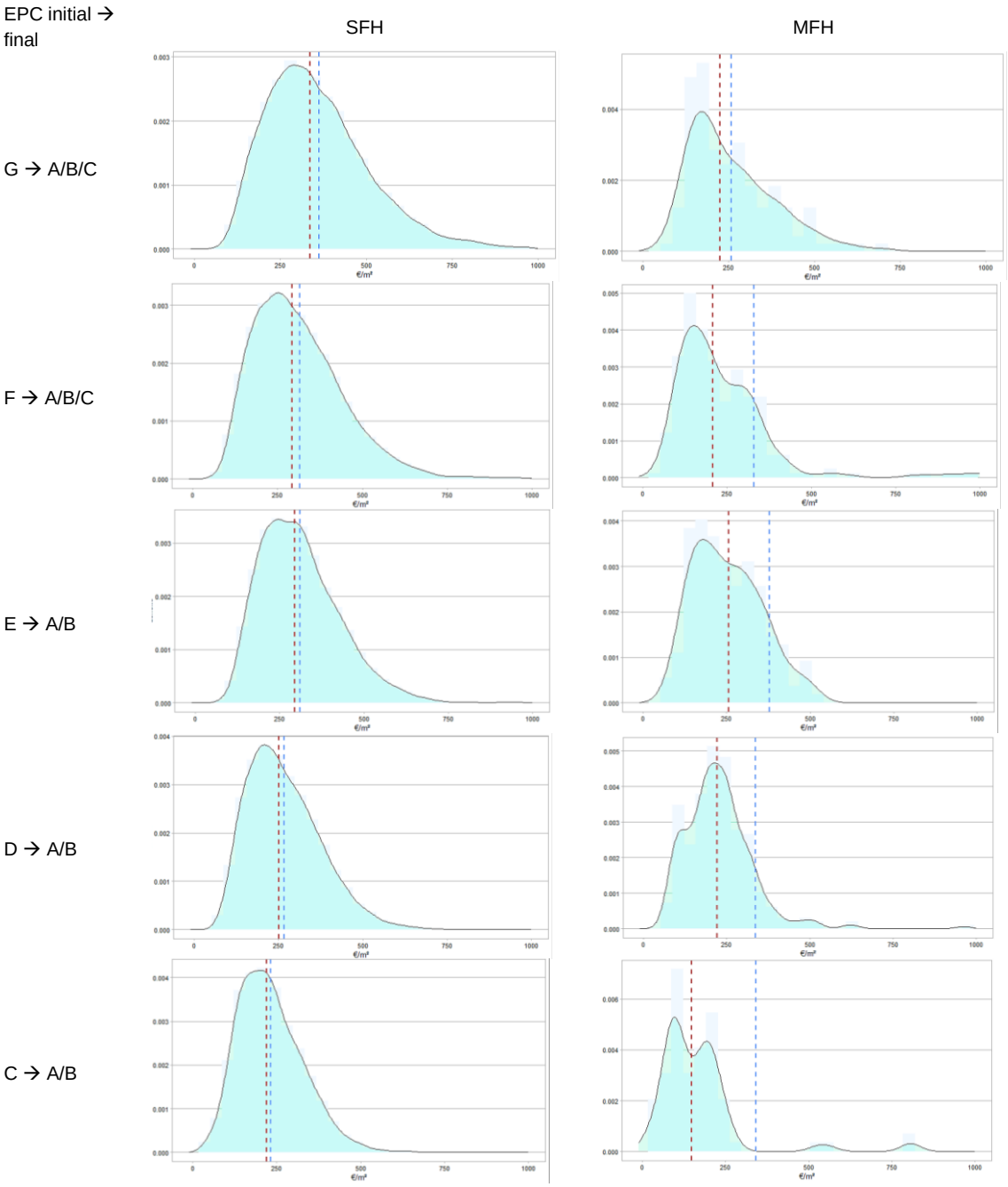

Figure 2. Distribution of costs (€/m² of living space area) calculated for an energy-efficient renovation. Blue dotted line: average value, red: median value. X-axis: price per unit area, Y-axis: number of occurrences

Overall, the cost of moving up to class A or B decreases when the initial performance is better (Table 2). Example for SFH: from €350/m² to go from class G to A, to €240/m² to go from class C to A.

For MFHs, the cost of high-efficient renovation is lower, from €320/m² for class G to A, to €210/m² for class C to A, partly because we are not simulating EWI which is an expensive technique compared to IWI.

For classes F and G, reaching class A is not much more expensive (less than 4% extra cost on average) than reaching class C for SFH. For MFHs, on the other hand, the difference between achieving class C or A is significant (50% extra cost).

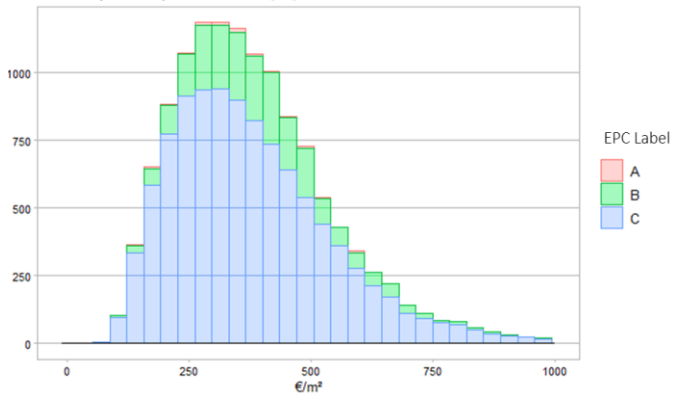

Figure 3. Distribution of costs (€/m² living space) to carry out a high-efficient renovation for SFHs with an initial EPC G label.

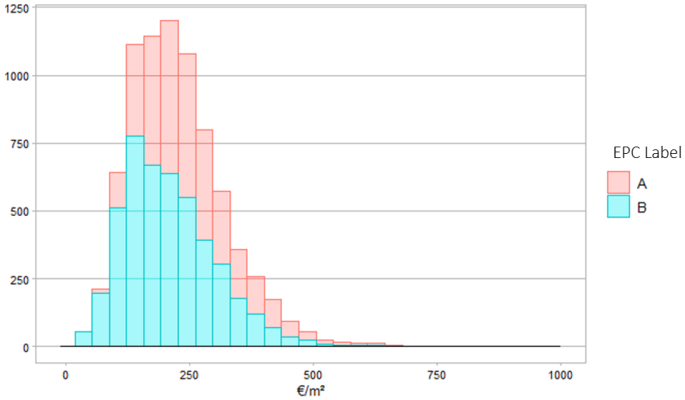

Figure 4. Distribution of costs (€/m² living space) to carry out a high-efficient renovation for SFHs with an initial EPC C label.

If we compare the minimum costs (i.e. 1st quartile) for SFH in label G or C to carry out an efficient renovation (respectively 246 €/m² and 150 €/m²), the difference is significant even if the possibility of limiting to class C for dwellings in G exists. For MFHs, the minimum cost of access (i.e. 1st quartile) to efficient renovation is much lower than for MIs, for both G and C initial labels, at €154/m² and €97/m² respectively.

Technical solutions

The more efficient the original dwelling, the greater the number of retrofit packages that can be used to carry out an efficient renovation. This is because the least energy-efficient homes have to carry out a combination of several refurbishment measures in order to achieve the desired energy efficiency label. For these dwellings, simple retrofit is virtually out of the question because it is not efficient enough to get them out of the lowest energy labels.

For MFHs, because of the specific configurations of these dwellings and lesser technical solutions and the limitations of our simulation, the range of renovation actions is more limited.

For SFH, the costliest retrofit packages include insulation of all the walls (EWI, floor, roof, window, and door), double-flow ventilation and a heating system with or without DHW (biomass boiler, air-water or hybrid heat pump, air-air heat pump and thermodynamic water heater (TWH)) These retrofit packages cost on average between €55,000 and €60,000 per dwelling (€500 to €800/m²).

In the case of MFHs, the costliest retrofit packages include insulation of certain walls (IWI, floor, or roof) depending on the configuration of the MFH, ventilation and a heating system (collective or individual single- or dual-service heat pump) and DHW equipment where appropriate. These retrofit packages cost on average between €30,000 and €40,000 per dwelling.

Limits of the study for multi-family dwellings

While this study makes it possible overall to calculate a large set of technical solutions for a large number of types of dwelling, this is not true for all cases, and in particular for MFHs in intermediate energy classes (i.e. C and D). This can be explained both by the low number of MFHs in the PHEBUS database in this segment (Table 3) crossed with a low number of retrofit packages (Table 1).

Table 3. Number of dwellings by initial EPC class. (Source PHEBUS, recalculation by the authors).

	G	F	E	D	C
MI	396	347	476	370	102
LC	153	134	171	158	29

This is clearly shown by the significant difference between the mean and median values of the costs on the distributions (Figure 2) for the small numbers.

Comparison with other evaluations

The renovation costs calculated here do not consider recent and significant changes in the cost of the retrofit[7] (INSEE 2024) and are of the same order of magnitude as those found in the literature (200-300 €/m² for an MFH and 300 €/m² for an SFH) (ADEME, Enertech 2016). If we analyze in detail the cost of EPC class changes from some previous studies (Giraudet et al. 2020), we find slightly different values, but without systematically positive or negative differences compared to this study:

- From G class to A €442/m²; to B €353/m² and to C €271/m² versus respectively €347/m²; €353/m²; €335/m² in this study.
- From F class to A €382/m²; to B €287/m² and to C €204/m² versus respectively €310/m²; €315/m²; €281/m² in this study.
- From E class to A €331/m²; to B €232/m² versus respectively €301/m²; €292/m² in this study.
- From D class to A €271/m²; to B €169/m² versus respectively €288/m²; €244/m² in this study.
- From C class to A €199/m²; to B €93/m² versus respectively €242/m²; €210/m² in this study.

Compared with the previous study by (Giraudet et al. 2020), we estimate less costly transitions for the least efficient dwellings (F & G classes) and more costly transitions for the most efficient dwellings (C & D classes).

However, the higher cost for houses is not always found in other studies. For example, the study by (DGT 2023) suggests that renovation costs are higher in collective housing: average renovation costs for a change of 2 EPC classes for an "energy sink" are €270/m² for SFHs and €360/m² for MFHs. For a change of 3 EPC classes, the cost for a SFH is €320/m² and €640/m² for a MFH. In this study, the change of 3 EPC classes (from F to C, Table 4) is more expensive for a MFH €188/m² and less expensive for a SFH €281/m². It should be noted that the cost of the retrofits involved in the (DGT 2023) study are largely subsidized, which may partly explain the extra cost as proposed in the study or if the subsidized renovations are not the least costly measures compared to other studies.

As the retrofit cost database for EPC efficiency measure is not public, we need to look at the EPCs one by one. If we look at a single EPC as an example (DPE 2023), for an SFH a change in class from C to A according to the recommendations of the EPC certificate, the cost is between €156/m² and €234/m² depending on the retrofit proposed (EWI, replacement of some windows, single flow ventilation, solar or TWH). These values are consistent with this study (median cost of €242/m² - Table 2). It should be noted that for the same set of retrofit package, if we start from a lower label (label D) by changing the type of heating equipment, the cost remains the same because the proposed retrofit does not concern heating equipment. This example highlights the fact that there is no obviously strong link between a change of label and retrofit cost.

Conclusion

Overall, the cost of high-efficient renovation is in the range of €200 to €350/m², depending on the initial EPC class and the type of dwelling (SFH vs. MFH). We need to bear in mind that these costs relate only to the direct costs of energy renovation and do not include ancillary costs like aesthetics.

On average, moving up to class A of the EPC involves a much higher additional cost than for other final EPCs, which reflects the fact that the remaining actions are generally the most expensive.

By cross-referencing these retrofit simulations with the volume of housing to be renovated and the financial trade-offs made by households, it will be possible to estimate the cost of efficient renovation of the housing stock, and above all to describe the nature of the retrofit required to achieve this (flow of actions and materials) and the impact on the building sectors involved (volume of activity required). This study will also make it possible to define and quantify the types of dwelling for which high-performance renovation is the least costly,

[7] Building maintenance and improvement price index (IPEA). IPEA index for residential buildings of 128.0 in Q4 2023 compared with 105.7 in Q4 2020. base 100 in 2015 (INSEE 2024).

and therefore likely to be easy to finance, and conversely, the types of dwelling for which all solutions are expensive.

There are differences in costs depending on the type of housing and the constraints are greater for MFHs. For classes F and G, reaching class A is not much more expensive (less than 4% extra cost on average) than reaching class C for SFH. For MFHs, on the other hand, the difference between achieving class C or A is significant (50% extra cost).

Depending on the EPC class, the choice of retrofit package to reach a certain class may vary from one starting label to another, with the lowest EPC labels having to carry out the most retrofit measures by default. Intermediate EPC labels may have more choice because fewer different retrofit measures are required.

In addition, this study does not consider the subsidies available to different households, and their consequences in terms of distorting the cost matrix as a function of out-of-pocket expenses, which would be interesting to study in the future.

Finally, the fact that the more EPC classes there are to be skipped, the more different renovation measures there are to be carried out, raises questions for the construction sector, as this requires enormous coordination of the different renovations. And we know that the market has a problem coordinating various retrofits with the different trades, which requires very close monitoring with the multiplication of craftsmen (plumber, electrician, builder, etc.) on the same site.

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Appendices

Appendix 1. Simulated retrofit package on space heating and DHW equipment for SFHs

Energy and initial heating system	**Travaux**	
	Space heating	**Related DHW retrofit**
Electricity / direct heating	air-to-air HP, direct electric heating, air-to-air HP, and direct electric heating	TWH, Solar DHW, electric DHW
Gas/ boiler Oil and LPG / boiler Biomass / boiler Electricity / boiler	condensing boiler, air-to-water HP, hybrid HP	TWH, solar DWH
	Dual-service heat pump (inc. DHW)	-
Biomass / pellet stove	air-to-air HP, wood stove and direct electric heating	TWH, Solar DHW, electric DHW

Appendix 2. Simulated retrofit package on space heating and DHW equipment for MFHs

Energy and initial heating system	**Travaux**	
	Space heating	**Related DHW retrofit**
Electricity / direct heating	air-to-air HP, direct electric heating, air-to-air HP, and direct electric heating	TWH, Solar DHW, electric DHW
Gas / collective boiler	condensing collective boiler, collective water-to-water, or air-to-water HP	Collective DHW produced by heat pump or boiler
Gaz / individual boiler	condensing boiler, air-to-water HP	TWH, Solar DHW, electric DHW or from the dual-service boiler
Oil and LPG / individual boiler biomass / individual boiler	air-to-water HP, air-to-air HP	TWH, Solar DHW, electric DHW
Biomass / wood stove	air-to-air HP, direct electric heating	TWH, Solar DHW, electric DHW