Co-Benefits Estimation for Building Rehabilitation Strategies in Portugal

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Abstract

In Portugal, residential buildings represent 17% of the country's energy consumption and account for one-sixth of the GHG emissions. Simultaneously, Portugal is in the top five European countries with the highest fuel poverty rate, with 19.4% of the population not being able to afford having thermal comfort in their homes. In 2018, the Energy Performance in Buildings Directive, EPBD, was updated, leading member countries to develop the integration and reinforcement of long term rehabilitation strategies, promoting the fight against fuel poverty, the reduction of energy consumption needs, the improvement of energy efficiency and the increased usage of renewable energy sources. This study aims to fully explore and estimate the extensive range of consequential benefits that arise from three energy-efficient rehabilitation scenarios and assess the economic viability, both from a private investor and a government perspective. For that, a focus was made on the AML region and buildings with the construction that dates back from 1960 to 1990. It was concluded that, contrary to the investor who renovates to rent the house, from the point of view of a private investor who wants to renovate and sell the house, it is a very attractive investment. As for the typical owner, who wants to renovate the home where he/she lives, it is concluded that the investment is not viable just by itself. However, if the government steps in and gives a subsidy, one scenario arises to be advantageous compared to the others.

Keywords: Energy-efficient; Residential buildings; Rehabilitation; Thermal Comfort; Fuel poverty.

1. Introduction

In a world that never stops, energy is a basic need for humanity's survival and evolution. So naturally, as the world progresses, the demand for energy increases. One of the main challenges today is to make this growth sustainable for the economy, environment and society.

The rapidly increasing demand for energy worldwide raises concerns over the potential lack of supply, negative environmental impacts, and energy resources depletion [1]. Residential buildings account for around 25% of the total energy consumption in the EU in 2015 [2, 3]. There has been an upward trend in energy demand that is likely to continue in the future. Some drivers are population growth, the increasing demand for thermal comfort and other building services, and the increasing time spent inside buildings [1]. For these reasons, energy-efficiency in buildings is a high priority topic for energy policy at regional, national and international levels [1].

Considering that most residencies in Europe, particularly in Portugal, were built before 1990, and that energy prices are high and many people cannot afford basic thermal comfort, it is urgent to ensure, in a sustainable way, that everyone can afford comfortable housing.

However, household income is not increasing as fast as energy costs [4]. Hence, energy subsidies and direct financial support for household heating cannot provide a sustainable long-term solution to fuel poverty. These measures require continuous public budget allocation without generating added value or economic growth [4]. It is estimated that 65% of the Excess Winter Mortality is due to cold and cold associated diseases, while between 30%-50% is due to housing conditions [4]. Portugal is the second country in EU-27 with the highest excess winter death index, surrounded by other countries with warm climates [4]. Therefore, the adaptation of residential buildings is the key to reducing mortality levels due to cold winter and hot summer temperatures. Consequently, it is vital to understand how to overcome or improve this phenomenon. A study [5] suggests that if energy-efficiency enthusiasm for new buildings were applied to existing buildings, rehabilitations would become a significant part of the overall construction market in the coming years.

For this reason, the European Commission first launched, in 2002, the Energy Performance in Buildings Directive, EPBD. More recently, in 2018, the EPBD suffered modifications, which made member countries develop the integration and reinforcement of long term rehabilitation strategies, promoting the fight against fuel poverty, the reduction of energy consumption needs, the improvement of energy efficiency and the increased usage of renewable energy sources, with the end goal being reaching decarbonisation in buildings by 2050 (reduce the EU GHG emissions in 2050 by 80–95% (compared to 1990)) [6].

Considering the significant discomfort levels that Portugal encounters, and allying with the new directive, the green deal, the renovation way, and all of the investment mobilisation that the EU is experiencing, such as the PRR[1], it is urgent and pertinent to invest in energy-efficient houses sustainably.

This study's primary goal is to understand the economic viability of energy-efficient renovations in Portugal and assess how much the government can financially incentivise the population to rehabilitate their homes.

[1]The *Plano de recuperação e Resiliência de Portugal* (Portugal's Recovery and Resilience Plan) is part of the unprecedented effort made by the EU to emerge stronger from the COVID-19 crisis by enabling Portugal to promote ecological and digital transitions and strengthen the resilience and cohesion of EU members [7].

2. Methodology

2.1. Building Type & Climate Selection

This study's focus is on multi-family residential buildings built from 1960 to 1990, with an average area of 75.8m^2 and, in particular, located at *Área Metropolitana de Lisboa*, AML.

2.2. Rehabilitation Scenarios

Three rehabilitation scenarios are studied:

- **Scenario 1: Basic Comfort**
  This is the simplest scenario and also the one that requires the lowest investment. The goal is to reach at least the minimum energy performance that has been regulated. It is based mainly on improving the house's thermal insulation through wall insulations and the implementation of double windows.

- **Scenario 2: All-electric**
  Besides the measures from the first scenario, this one also includes some extra comfort level, with a MultiSplit and a heat pump AQS.

- **Scenario 3: Renewables + Self-sufficient**
  This final scenario goes beyond energy efficiency, as it includes all measures from the previous scenarios and adds solar panels, trying to be as environmentally friendly as possible. This is also the most expensive scenario.

The economic viability of the three rehabilitation scenarios is studied and presented from the government's point of view and three types of investors – the one who lives in the renovated house, the one who rents it, and the one who wants to sell it.

2.3. Research & Data Analysis Methodology

It is used a similar methodology to another study [8] by performing a cost-benefit (CB) analysis[2], starting from the existing literature about the different factors, monetising the relevant benefits so that a comprehensive quantitative analysis can be performed.

[2]consists of compiling a comprehensive list of all the incremental benefits and all the incremental costs [9].

With the CB analysis, the Capital Budgeting Approach is used to calculate each strategy's Net Present Value (NPV) to determine if it is a good investment. It also uses other metrics to analyse it thoroughly. In this stage, it is assumed that there is no government subsidy, and therefore the entire investment is private. The following expression computes NPV[10]:

$$\text{NPV} = \sum_{n=0}^{N} \frac{\text{CF}_n}{(1+i)^n} \tag{1}$$

where n is the time of the cash flow, i is the discount rate, which should be the same as the one for investments with similar risk, and CF_n is the net cash flow for period n. Other used financial metrics are:

- Modified Internal Rate of Return (MIRR):

$$MIRR = \sqrt[n]{\frac{FVCF}{PVCF}} - 1 \tag{2}$$

  where FVCF is the future value of positive cash flows discounted at reinvestment rate and PVCF is the present value of negative cash flows discounted at the financing rate, and n is the number of periods.

- Benefit-Cost Ration (BCR)

$$\text{BCR} = \frac{|\text{PV(Benefits)}|}{|\text{PV(Costs)}|} = \frac{\sum_{n=0}^{N} \frac{|\text{CF}_n(\text{Benefits})|}{(1+i)^n}}{\sum_{n=0}^{N} \frac{|\text{CF}_n(\text{Costs})|}{(1+i)^n}} \tag{3}$$

  where n is the time of cash flow, i is the discount rate of return for investments with similar risk, CF_n (Benefits) is the positive cash flows for period n, and CF_n (Costs) is the negative cash flow for period n.

In the second stage, the optimal relationship between the value of the government's renovation subsidy for each scenario and its consequent adherence rate is studied to maximise the outcome for the government. A higher subsidy leads to lower required investment from the private investor. At the same time, benefits stay the same, clearly creating a good incentive to increase the adherence rate, allowing more people (all in the best case) to live with thermal comfort. To compute the optimal relationship, it is also necessary to estimate the investors' willingness to pay for this type of rehabilitation, which is done using the same methodology as the CB analysis estimates.

Lastly, a scenario analysis is performed, which allows testing the credibility and reliability of the results by verifying the impact that they suffer from significant variations in the estimates that are more uncertain.

2.4. Assumptions for Data Collection

Throughout this study, several assumptions are made to have consistency in all estimations done further on:

- Number of inhabitants per dwelling:
  It is assumed constant and equal to 1.9 [11] until 2050.

- Inflation Rate:
  It is also considered constant during the 30 year period of this analysis. The values assumed are 1.44% in housing, water, electricity, gas and other fuel costs, 0.32% in health care costs and 0.78% in the global inflation rate [12].

- Discount Rate:
  This rate is estimated to be 1.79% and is assumed as a constant until 2050.

3. Cost-Benefits Estimation: Private Investor

A literature review is performed for each rehabilitation scenario and PI type/government to enable a cost-benefit (CB) analysis. In order to estimate each cost and benefit, an estimation approach similar to [5] is made.

3.1. Benefits

- **Energy Consumption Costs Savings**

  The costs savings from energy consumption reduction are taken from ADENE's study. Table 1 presents the total energy savings for the first year, per scenario. The savings for the next 30 years will consider the energy price inflation: 1.50% for electricity, 1.00% for gas, 0% for biomass and 3.4% for diesel.

- **Property Value**

	Economical Energy Savings [€]
Scenario 1	0.20
Scenario 2	1.46
Scenario 3	1.75

Table 1: Baseline yearly energy savings per m^2 per scenario. Data Source: ADENE.

Several studies are found on this matter, with the selling price premium ranging from 5.9% to 11.9%. Therefore, it is assumed that scenario 1 has the lowest premium, and scenario 3 has the highest premium value. For scenario 2, the average of the other two values is used, 8.9%. The absolute values are presented in table 2, and its rent premium, being defined as constant. These presented values apply for the first year. To adjust the respective values for the 30 year period, an inflation rate of 1.44% is considered.

	Sell Premium	Rent Premium
Scenario 1	89.18€	0.15€
Scenario 2	133.92€	0.15€
Scenario 3	178.66€	0.15€

Table 2: Sale and Rent Price Premiums for each scenario per m^2.

- **Healthcare Cost Savings**

  The only healthcare cost assumed in this study to be borne by the private investor is the loss of income due to the sick days leave. A saving potential of 3.54€ per dwelling is estimated to represent economically the fewer sick days taken because of inadequate housing conditions.

- **Comfort Value**

  Considering that comfort plays a significant role when owners decide to renovate their flats, the IMI's[3] coefficient of quality and comfort estimates its monetary equivalent value. A value of 1.33€/m^2 was obtained for scenario 1. As for scenarios 2 and 3, the same value of 2.12€/m^2 was considered.

3.2. Costs

- **Initial Investment Cost**

  The initial investment cost for each rehabilitation scenario in this study comes from ADENE's study. The values for each measure and the total for each scenario are displayed in table 3.

	Investment Cost
Scenario 1	55.70€
Scenario 2	109.37€
Scenario 3	119.66€

Table 3: Total Initial Investment Cost per m^2 for each scenario. Data Source: ADENE.

It is relevant to note that the additional measures from scenarios 2 and 3 will need full reinvestment within the 30 year period since the measures' lifespan is lower than 30 years.

- **Maintenance and Operational Costs**

  The annual maintenance costs are also deduced from ADENE's study. The measures from the first scenario do not require any maintenance. In contrast, maintenance costs from the additional measures from scenarios 2 and 3 are 0.54€/m^2 and 1.05€/m^2, respectively.

- **Taxes**

  Although energy savings represent savings in energy taxes, the property-added value will increase the burden of taxes for all private investors. Hence taxes are here considered as costs.

4. Cost-Benefits Estimation: Government

At this point, all initial investment is considered to be entirely private, meaning that it is assumed that there is no government subsidy, so the government has no costs, only benefits.

[3]IMI, *Imposto Municipal sobre Imóveis*, a yearly tax that property owners must pay as a percentage of the value of their property.

4.1. Economic & Societal Benefits

- **Construction & Employment**

  The values here estimated do not correspond directly to the benefits. Instead, these are the before tax values that will be used to calculate tax revenues coming from this sector due to the rehabilitation measures.

- **Healthcare Expense Savings**

  To estimate and quantify the major impacts that improved energy efficiency performance has on public health, this study focus on the following issues: ability to keep houses at adequate temperatures; decrease of mould and dampness, which are generally related to respiratory problems that represent the third most common cause of death in Portugal and the fifth most common cause of hospital admissions [13]; and fewer sick days leave. A summary of the government healthcare savings is made in table 4.

Asthma	0.103€
Extreme Weather	0.539€
Sick Days	0.011€
TOTAL	**0.653€**

Table 4: Government Healthcare Total savings per m^2.

4.2. Tax Balances

Many taxes are pertinent to study in the scope of this study. However difficult, it is indispensable, as it is the primary source of revenue for the government, delivering up to a total of 29.45€/m^2 for scenario 1 and 50.08€/m^2 for scenario 3 in the first year. This shows that, even though the government diminishes the energy-related tax revenues, the others rise enough to make up for the losses.

4.3. Environmental Benefits

Regarding environmental benefits, as there is no direct cost/revenue for the government associated with savings of GHG emissions, the concepts of the social cost of carbon and negative externality are used, applying the market value of CO_2 to find the economic value of 40€ per tonne of CO_2. The estimated emissions savings are 0.02€/m^2, 0.15€/m^2 and 0.17€/m^2 for scenarios 1, 2 and 3, respectively.

5. Results

After the CB analysis, the Capital Budgeting approach is used to calculate the NPV of each initiative to assess if each scenario is a good investment for each type of PI.

For the PIs who live in and rent the house, scenario 1 presents the highest NPV compared to the others, followed by scenario 2 and finally scenario 3, which demonstrates the lowest value of NPV. However, NPV for scenario 1 is far from ideal, as it is negative for both types of investors (-24.9€/m2 and -61.5€/m2, respectively). As for the PI who sells the renovated house, it seems like a very good investment, having the highest NPV of 55.4€/m2 for scenario 3, followed by 1 (31.7€/m2) and then 2 (21.9€/m2).

Regarding the government and considering that there are no costs for it, its NPV is, not surprisingly, positive. Moreover, it is very similar for every PI type when talking about the same scenario, averaging 55€/m2 for scenario 1, 83.3€/m2 for scenario 2 and 97€/m2 for scenario 3.

Even though NPV gives an idea of how good or bad an investment might be, it is also relevant to complement it with an analysis of the benefit-cost ratio. As there are no costs for the government, this calculation only makes sense for the three PI types. BCR for the PI who lives in the house ranges from 0.44 (in scenario 3) to 0.55 (in scenario 1). For the PI who rents the house, BCR is zero for all scenarios. This result is due to negative cash flows for this investor, as IMI taxes will increase further than expected gain in rent prices. Lastly, for the PI who sells the house, BCR is, as expected, above one for all scenarios, ranging from 1.2 in scenario 2 to 1.57 in scenario 1.

The next step is to calculate the best subsidy the government can give to incentivise PIs to invest in their houses. Due to its high profitability without subsidy and the low potential, respectively, sell and rent PIs were excluded for the rest of the study.

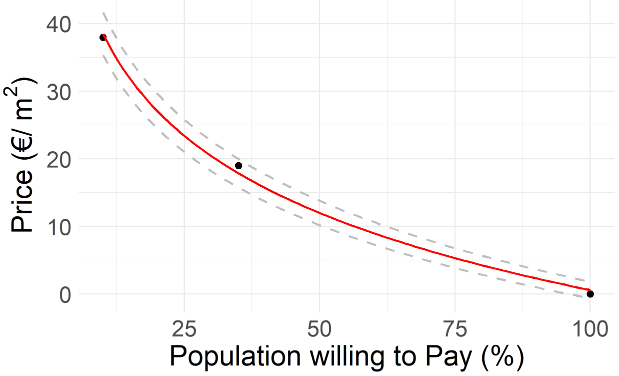

Figure 1: % of the population willing to pay for renovation scenario 1. Interpolation made through points shown in table 5.

To find the optimal subsidy amount that the Government should provide for the rehabilitation measures, it is necessary to better understand how the different subsidy levels will affect the number of houses renovated. Thus, the next step is to calculate the willingness to pay (WTP) for the different measures.

Having three points for each of the three scenarios (table 5) and using R[4] programming, a demand function is estimated (equation (4)) by the interpolation of the points through a logarithmic function:

$$P = a + b \cdot log(Q) \tag{4}$$

where P is the price to the investor, Q is the percentage of households that adhere to the rehabilitation measures, and a and b are the parameters of each scenario's interpolation (see results in table 6). The visualisation of the interpolation of the demand function for scenario 1 is presented on figure 1.

As Government's primary goal is to maximise the number of rehabilitations done (Q) while minimising the subsidy (S) given, it is necessary to find

[4] https://www.rstudio.com/

	Price WTP [€/m²] S1	S2	S3	Adherence Rate [%]
Point 1	0.0	0.0	0.0	100
Point 2	19.0	54.0	58.6	35
Point 3	38.0	108.0	117.1	10

Table 5: Adherence Rate for Rehabilitation Measures Given Certain Prices - used to interpolate WTP Function.

	S1	**S2**	**S3**
a	0.6	1.7	1.9
b	-16.5	-46.8	-50.7
Investment [€/m²]	55.7	158.4	171.8
Government NPV without subsidy [€/m²]	53.0	75.0	87.5

Table 6: Optimal Subsidy and Corresponding Adherence for each rehabilitation scenario.

the relationship between Q and S (equation (5)).

$$\begin{cases} Q = e^{\frac{P-a}{b}} \\ P = Investment - S \end{cases} \implies Q = e^{\frac{Investment - S - a}{b}} \tag{5}$$

The next step is to maximise the government NPV, maximising NPV per rehabilitation multiplied by the number of rehabilitations by choosing the optimal subsidy. Using the two functions, the function to be maximised is written in equation (6), with the parameters from table 6.

$$\begin{aligned} \textbf{max TOTAL NPV}^* &= (NPV - S) \cdot Q = \\ &= (\mathbf{NPV} - \mathbf{S}) \cdot \mathbf{e}^{\frac{\mathbf{Investment-S-a}}{\mathbf{b}}} \end{aligned} \tag{6}$$

In table 7, the optimal initial subsidies are presented, as well as the NPV for the Government per rehabilitation and for the private investor in each scenario and the % of people willing to pay given that subsidy level. Initial subsidy being calculated as the PV of lifetime subsidy times % initial investment on the lifetime investment PV.

Table 8 presents the government and the PI's final financial metrics after the subsidy is considered. It is relevant to affirm that the government is willing to subsidise much more, in relative terms, in

	S1	S2	S3
Optimal Lifetime Subsidy [€/m^2]	36.5	28.2	36.8
Initial Subsidy [€/m^2]	36.5	19.5	25.6
Adherence Rate at Optimal Subsidy [%]	32.3	6.4	7.3

Table 7: Optimal Subsidy and Corresponding Adherence.

scenario 1. This might be because the investment costs increase faster than the government's benefits when going from scenario 1 to 2 and from 2 to 3. With that being said, after the subsidy, the PI only has a positive NPV for scenario 1, although the other two are about half of what they were before the subsidy.

	PI Live			Government		
Scenario	S1	S2	S3	S1	S2	S3
NPV [€/m^2]	11.6	-40.4	-52.3	16.5	46.8	50.7
BCR	1.61	0.66	0.57	1.45	2.66	2.38
MIRR [%]	3.41	0.37	-0.11	3.06	5.16	4.77

Table 8: PI Live and Government Financial Metrics after Subsidy.

Regarding BCR, the investor has a much higher BCR in scenario 1 than in scenarios 2 and 3, which is no surprise, given the higher subsidy. It is also worth mentioning that the investor's BCR for scenario 1 with a subsidy is more than triple than it was before the subsidy, being now higher than 1, meaning that the benefits outweigh costs.

When looking at MIRR (see 2), the same conclusions can be taken since only scenario 1 has a higher MIRR than the private investor's discount rate, therefore being the only scenario that is theoretically worth investing in.

Lastly, a scenario analysis is made, changing most uncertain estimates by 20% positively and negatively, with its results being displayed in tables 9 and 10. As it is clearly seen, with these subsidy levels, the rehabilitations are beneficial for the Government in all three scenarios and respective cases, as NPV is always higher than 0, BCR is always higher than 1, and MIRR is always higher than the discount rate.

Thus, after the scenario analysis, it is possible to conclude that the results of this study hold, even though there is some variability in terms of the absolute values, the decision that each financial metric indicates for each scenario is constant.

6. Conclusions and Future work

6.1. Findings & Achievements

Several findings are possible to infer from this study's results.

Given that all three scenarios have positive NPVs for the private investor that aims to sell his/her flat after the rehabilitation, the energy-efficient renovations are a very attractive investment for this investor type. The same cannot be said about the other two types of investors, as their NPVs are negative for all three scenarios. For the Private Investor who wants to rent the renovated dwelling, it is particularly unfavourable as its NPV are much lower than what the government benefits from it. This makes it difficult for the government to help finance this type of investor and makes it not economically attractive for the owner to make such an investment. While the case of the private investor who owns and lives in the renovated home is somewhere between the previous two investors. Its NPVs are not positive as it is the case of the investor who wants to sell, but it is not as negative as for the private investor who rents, giving a larger margin for the government to subsidise and generate returns simultaneously.

It is possible to note that for scenarios 2 and 3, the government's subsidy is somewhat limited, as it is not enough to generate a positive NPV for the investor. Hence, it is plausible to state that theoretically, the only scenario worth investing in is scenario 1. However, some other non-math related key factors might play a relevant role when making a decision. These might be the feeling a PI gets of contributing to energy security and sustainability in scenario 3 and more luxurious comfort in scenario 2. Also,

Case	Scenario 1 Optimistic	Base	Pessimistic	Scenario 2 Optimistic	Base	Pessimistic	Scenario 3 Optimistic	Base	Pessimistic
NPV [€/m^2]	20.1	11.6	3.2	-27.3	-40.4	-53.6	-38.3	-52.3	-66.4
BCR	2.05	1.61	1.17	0.77	0.66	0.54	0.68	0.57	0.45
MIRR [%]	4.25	3.41	2.31	0.90	0.37	-0.26	0.51	-0.11	-0.87

Table 9: PI Live Financial Metrics Scenario Analysis.

Case	Scenario 1 Optimistic	Base	Pessimistic	Scenario 2 Optimistic	Base	Pessimistic	Scenario 3 Optimistic	Base	Pessimistic
NPV [€/m^2]	25.9	16.5	7.0	60.4	46.8	33.2	66.2	50.7	35.2
BCR	1.71	1.45	1.19	3.14	2.66	2.18	2.80	2.38	1.96
MIRR [%]	3.63	3.06	2.38	5.74	5.16	4.46	5.34	4.77	4.09

Table 10: Government Financial Metrics Scenario Analysis.

with the possible addition of other unmentioned benefits, scenarios 2 and 3 might become more attractive. Moreover, given that most owners who decide to renovate their homes tend to be less strict regarding economic metrics, the government's subsidy might be enough to convince some owners to rehabilitate their properties. Anyhow, it is necessary to note that it is only possible if the owner has the financial means to do it, as if he/she struggles financially, it might be impossible to make such investments.

Nonetheless, the results for scenario 1 are reassuring, as the subsidy given by the government allows for the generation economic return for both the owner and the government. This, allied with the fact that scenario 1 secures a basic comfort level for its occupants and it is the minimum energy-efficient renovation that EPBD compels, makes this conclusion preeminent.

Given the scenario analysis results, it is possible to conclude that this study's findings hold similar financial metrics, even with some changed estimates and different absolute values.

It is worth mentioning that when comparing with ELPRE's analysis [14], the benefits estimated in the present thesis are substantially lower, which is mainly due to the author's conservative approach and the fact that some significant ELPRE's benefits are not included in this study due to the lack of relevant data.

6.2. Future Work

One of the most complicated challenges in this work was finding relevant studies, with scopes similar to this work, in a way that reasonable assumptions could be made. Therefore, the lack of studies regarding some of the costs and benefits, namely willingness to pay for these measures, warrants a more profound analysis to be performed for each benefit and cost, with a particular focus on the rehabilitation measures from this work and in the climatic/geographic regions of interest. Moreover, when studying the willingness to pay, other external factors should be considered, for example, implementation barriers, as people living in flats need their neighbours to agree on particular renovations that include the whole building.

Other studies should be made regarding heating and cooling needs separately, as there might be considerable differences. Furthermore, to better understand the influence of the macroeconomic environment, it would also be interesting to add other variables in the scenario analysis, such as inflation and discount rates. In this study, the Covid-19 pandemic context was not included, given that it is assumed to be only temporary and this study having a focus on a 30 years time-frame. Nevertheless, it would be interesting to analyse benefits related to this context, given that people spend more time in their homes, such as even higher health benefits and increased productivity, since [5] linked productivity gains to better indoor air quality (productivity increased by 3%-8% due to indoor air quality).

Although this study is quite comprehensive, due to the complexity, some benefits were not taken into account, such as energy security and spillover effects from economic growth. The former being a highly important benefit for the government, as Portugal would become more self-sufficient and therefore depend less on other countries in terms of energy in the residential sector. This would be particularly focused on scenario 3, as besides consuming less energy, the measures also create renewable energy. It would also be interesting to study in the future what would be the impact that the new demand for energy and increased self-sufficiency would have on energy prices [15].

Another unstudied effect is that the energy cost savings will allow households to have more disposable income, which they can use to consume or invest in other sectors, contributing to economic growth.

Additionally, in conformity with [4], poor housing conditions can influence households negatively in many more ways than just financially. In step with [16], a correlation between mental health and housing have been examined. Based on [17], mental well-being and social contact can be affected by fuel poverty and the development of children. Inadequate housing indirectly affects children's educational attainment and emotional well-being. By contrast, good housing conditions, while providing other benefits, improve children's performance at school [4].

In future studies that aim to study more complex relationships, it is important to consider the rebound effect. While it is also crucial to be clear on the interaction between different benefits to avoid double-counting the same benefit [5]. Additionally, it would be beneficial to consider a phased investment instead of focusing on one year, as it has more lasting economic benefits. Lastly, it would also be interesting to analyse possible compensations for the private investor who rents it. For example, understanding whether tax benefits, such as IMI exemption or even support programs for long term rents after renovations works, would be enough to change the economic perspective of the private investor who rents their apartment.

Other perspectives on the potential of incentivising rehabilitations can be taken. For instance, according to [18], there is a positive correlation between education level and housing comfort. If the plan has a more long-term focus, one way to indirectly incentivise might therefore be to invest in measures that promote the education of the population, particularly on this topic. It is suggested by [3] other possibilities, such as financial facilities to encourage private capital investments, fiscal incentives that may indirectly reduce the cost of investments, measures addressing vulnerable consumers and fuel poverty or even measures addressing landlord-tenant problems. In fact, private investors who rent their place could be encouraged to do renovations through some fiscal benefits such as paying less rental and property taxes.

Lastly, in a future study, it would be interesting to use a macroeconomic model similar to the one used in [5], since it automatically estimates the complex relationships between the different variables in the study, which is particularly beneficial for the factors that affect public budgets, as the impacts are numerous and complex. This would be interesting both at the private investor and at a government and society level.

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