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GRADO EN INGENIERÍA EN TECNOLOGÍAS INDUSTRIALES

TRABAJO FIN DE GRADO

ANALYSIS OF THE IMPACT OF SHALLOW RENOVATIONS AND ENERGY SAVING WORKSHOPS ON ENERGY POVERTY IN SPAIN

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Madrid

July 2026

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VALORACIÓN DEL IMPACTO SOBRE LA POBREZA ENERGÉTICA DE LAS REHABILITACIONES EXPRÉS Y DE TALLERES DE AHORRO ENERGÉTICO EN ESPAÑA

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Entidad Colaboradora: IIT, ICAI en colaboración con la fundación Naturgy

RESUMEN DEL PROYECTO

Este trabajo evalúa el impacto de las rehabilitaciones exprés y de los talleres de ahorro energético sobre la pobreza energética en España. Las rehabilitaciones redujeron el gasto energético requerido de las viviendas entre un 5 % y un 11 % y mejoraron el confort en todos los hogares, mientras que los talleres identificaron un ahorro potencial medio de 280 € anuales por hogar y demostraron que el acompañamiento sostenido es determinante para materializarlo. Se concluye que ambas intervenciones son complementarias y que su aplicación conjunta podría maximizar la reducción de la pobreza energética.

Palabras clave: pobreza energética, rehabilitaciones exprés, talleres de ahorro energético, gasto energético teórico, pobreza energética escondida

1. Introducción

La pobreza energética constituye uno de los principales retos sociales y energéticos en España. La Estrategia Nacional contra la Pobreza Energética la define como "toda situación en la que un hogar no puede acceder a los servicios energéticos esenciales cuando dichos servicios proporcionan unos niveles básicos y dignos de vida y salud" [1]. El fenómeno afecta especialmente a hogares con bajos ingresos y viviendas de baja eficiencia, lo que repercute directamente en el confort térmico, la salud y la calidad de vida de las personas.

Su medición se realiza mediante indicadores objetivos de pobreza energética, tanto de gasto desproporcionado (10 %, 2M y MIS) como de gasto insuficiente (M/2 y HEP), complementados con indicadores subjetivos de confort térmico. Entre todos ellos destaca el indicador de pobreza energética escondida (HEP), que se aplica a los hogares de renta baja cuyo gasto real no llega a la mitad de su gasto teórico [2] y detecta a los que reprimen su consumo para contener el gasto, algo que los indicadores de gasto real observado no capturan. En España, este indicador alcanzó una incidencia del 27,1 % en 2023 [3] lo que confirma que el infraconsumo constituye una realidad ampliamente extendida. Los indicadores subjetivos recogen la capacidad declarada del hogar para mantener una temperatura adecuada en invierno y en verano, complementando las métricas objetivas al incorporar la percepción del confort térmico de los ocupantes.

En este contexto, las rehabilitaciones exprés y los talleres de ahorro energético se presentan como herramientas de bajo coste para mejorar la situación de los hogares vulnerables. Las rehabilitaciones exprés son intervenciones de bajo coste y de rápida actuación que combinan medidas pasivas sobre la envolvente de la vivienda (sustitución de vidrios y carpintería, aislamiento de muros y techos) con medidas activas sobre los equipos (calefacción, electrodomésticos o iluminación), y su impacto se ha evaluado en los proyectos VAREX [4], [5]. Los talleres de ahorro energético, por su parte, no actúan sobre la vivienda sino que proponen a cada hogar tres tipos de medidas para reducir su

gasto energético: medidas contractuales, como acceder al bono social o ajustar la tarifa y la potencia; medidas sobre los hábitos de consumo, mediante educación energética; y la entrega de kits de microeficiencia, todo ello dentro del proyecto *Energía para Todos* de Aprendizaje y Servicio en ICAI [6].

2. Definición del proyecto

Este trabajo analiza el impacto de las rehabilitaciones exprés del proyecto financiadas por el Fondo Solidario de Rehabilitación Energética, evaluadas a través de la metodología VAREXy de los talleres de ahorro energético del proyecto Energía para Todos sobre la situación de pobreza energética de los hogares vulnerables en España. Las rehabilitaciones evalúan cómo las medidas pasivas y activas modifican el gasto energético requerido de la vivienda y las condiciones de confort del hogar, mientras que en los talleres se analiza en qué medida las recomendaciones contractuales, los cambios de hábitos y la entrega de kits de micro eficiencia se traducen en un ahorro para el hogar. En ambos casos evalúa su situación antes y después de la intervención.

El impacto de las rehabilitaciones se mide con indicadores objetivos de pobreza energética, complementados con indicadores subjetivos de confort térmico; en los talleres se estima el ahorro potencial de las recomendaciones y, mediante un seguimiento posterior, se comprueba en qué medida este llega a materializarse.

3. Descripción del modelo/sistema/herramienta

En la línea de rehabilitación, se calcula el gasto energético teórico de cada vivienda, que estima el gasto necesario para satisfacer las necesidades energéticas básicas del hogar a partir del tamaño, las características físicas y el equipamiento del hogar, así como de la zona climática, siguiendo el modelo de Gasto Energético Requerido desarrollado por la Cátedra de Energía y Pobreza [2]. Dado que los cuestionarios originales no recogían el número de ocupantes, un dato necesario para el cálculo del gasto energético teórico, esta variable se estima de forma indirecta a partir de otras características del hogar. El impacto de cada intervención se obtiene mediante la resimulación de la vivienda rehabilitada y el recálculo de los indicadores tras la obra.

En la línea de talleres, cada hogar tenía medidas asociadas para reducir su gasto. Cada tipo de medida lleva asociado un ahorro potencial distinto, por lo que se calcula para cada hogar cuánto podría ahorrar si las medidas recomendadas se llevaran a la práctica. Con posterioridad al taller, se realiza un seguimiento de los hogares, que permite comprobar en qué medida esas recomendaciones se han puesto en práctica y si ese ahorro potencial llega realmente a materializarse.

Para todo ello se emplean distintas herramientas de cálculo y procesamiento de datos. La herramienta DIAGNÓSTICO permite estimar el gasto energético teórico de cada vivienda, mientras que Excel se utiliza para organizar la información de los hogares y aplicar los distintos indicadores de pobreza energética. El tratamiento de los grandes volúmenes de datos y la elaboración de los gráficos se realizan con Python.

4. Resultados

Las rehabilitaciones redujeron el gasto energético teórico de las viviendas entre un 5,2 % y un 10,6 %, como se puede ver en la ilustración 1.a, lo que equivale a un ahorro anual estimado de entre 91 y 237 euros por hogar. Los indicadores objetivos muestran que la muestra se caracteriza principalmente por el gasto desproporcionado, mientras que cinco de los once hogares se encontraban en pobreza energética escondida antes de la intervención. Como se muestra en la Ilustración 1.b, las obras no modificaron la incidencia de esta condición, pero redujeron su profundidad en todos los casos evaluables, estrechando la brecha HEP entre un 9 % y un 30 %, en línea con los resultados de estudios previos sobre rehabilitación exprés [5]. Además, todos los hogares declararon una mayor capacidad para mantener una temperatura adecuada en invierno, verano o ambos tras la intervención, y cinco de los ocho que realizaron una reforma obtuvieron mejoras en al menos un indicador de bienestar, incluyendo el confort percibido, la salud física o ambos.

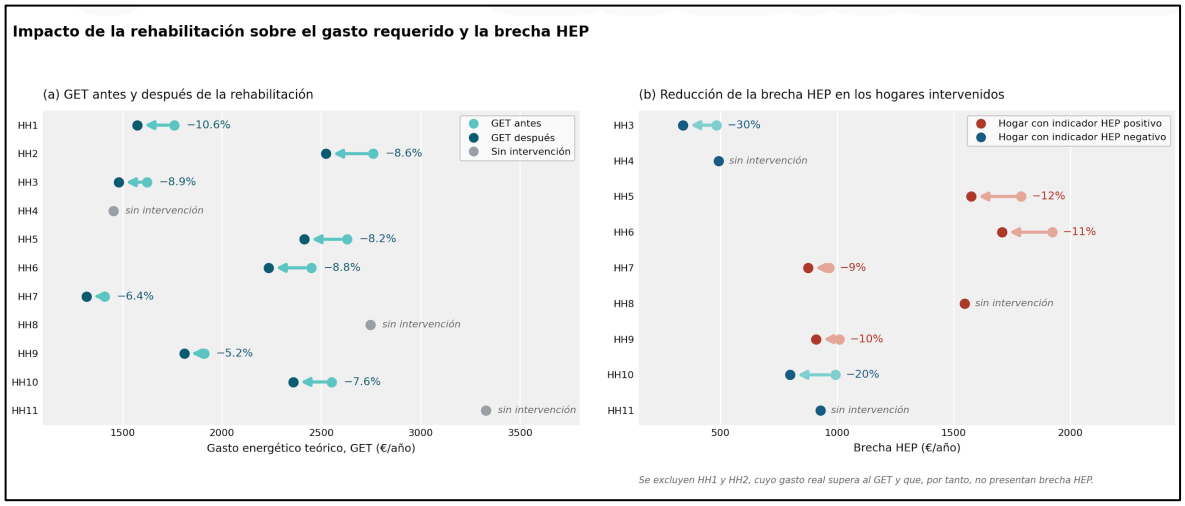

Ilustración 1: Impacto de las rehabilitaciones exprés por hogar: (a) Gasto Energético Teórico (GET) antes y después de la obra, y (b) reducción de la brecha HEP

Los talleres, por su parte, identificaron un ahorro potencial anual de unos 15.950 euros para los 57 hogares con ahorro cuantificable, lo que supone una media cercana a los 280 euros anuales por hogar. Este potencial se concentra en un 94,6 % en los 33 hogares con derecho al bono social. El kit de micro eficiencia, entregado a 71 hogares, es la principal vía de apoyo para los hogares que no son titulares del contrato eléctrico. El seguimiento no pudo realizarse en todos los casos, pero los hogares contactados confirmaron que las recomendaciones funcionan cuando se aplican. Sin embargo, sin un seguimiento continuado, pocas llegan a implementarse, lo que refuerza la importancia del acompañamiento [6].

5. Conclusiones

Del análisis conjunto se extraen cuatro conclusiones principales. La primera es que la pobreza energética de estos hogares es un problema estructural, que puede manifestarse de dos formas complementarias y ambas posibles: dedicar una parte excesiva de la renta a la energía o reprimir el consumo por debajo de lo necesario. Por eso, los indicadores de gasto real observado no bastan y conviene complementarlos con indicadores de gasto

requerido, como el HEP [2], e indicadores subjetivos. En segundo lugar, los impactos más relevantes de las dos intervenciones analizadas, respectivamente, la mejora del confort en las rehabilitaciones y la adquisición de conocimientos sobre el consumo energético en los talleres, son también los más difíciles de cuantificar, de modo que las evaluaciones basadas únicamente en el retorno económico infravaloran su efecto real. Tercera, la efectividad depende menos de las medidas propuestas que del proceso de implementación por los hogares, y la evidencia identifica el acompañamiento sostenido como el elemento clave para transformar el ahorro potencial en ahorro realizado [7]. Cuarta, los hogares con mayores necesidades, como los inquilinos de baja renta o los hogares sin titularidad del contrato, son también los que menos pueden beneficiarse de los instrumentos existentes.

Las dos intervenciones analizadas resultan complementarias: las rehabilitaciones aportan el mayor efecto estructural, pero exigen un régimen de tenencia adecuado, mientras que los talleres son escalables y accesibles para los hogares en los que la rehabilitación no es posible. Por esta razón, un programa integrado que combine ambas actuaciones podría ampliar su alcance y maximizar su impacto sobre la pobreza energética.

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ASSESSMENT OF THE IMPACT OF SHALLOW RENOVATIONS AND ENERGY-SAVING WORKSHOPS ON ENERGY POVERTY IN SPAIN

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ABSTRACT

This project evaluates the impact of shallow renovations and energy-saving workshops on energy poverty in Spain. Shallow renovations reduced the required energy expenditure of dwellings by between 5% and 11% and improved thermal comfort in all households, while the workshops identified average potential savings of €280 per household per year and showed that sustained support is essential for turning this potential into actual savings. The study concludes that both interventions are complementary and that their combined implementation could maximize the reduction of energy poverty.

Keywords: energy poverty, shallow renovations, energy-saving workshops, required energy expenditure, hidden energy poverty

1. Introduction

Energy poverty is one of the main social and energy-related challenges in Spain. The Spanish National Strategy against Energy Poverty defines it as "a household's lack of access to essential energy services, where such services provide basic levels and decent standards of living and health" [1]. The phenomenon particularly affects low-income households living in energy-inefficient homes, directly compromising thermal comfort, health, and overall quality of life.

Energy poverty is assessed using objective indicators, including both excessive expenditure indicators (10%, 2M, and MIS) and insufficient expenditure indicators (M/2 and HEP), complemented by subjective indicators of thermal comfort. Among these, the Hidden Energy Poverty (HEP) indicator is particularly relevant, as it identifies low-income households whose actual energy expenditure is less than half of their required energy expenditure [2]. It therefore captures households that deliberately underconsume energy to limit costs, a situation that cannot be detected through expenditure-based indicators alone. In Spain, this indicator reached an incidence of 27.1% in 2023 [3], confirming that energy underconsumption is a widespread phenomenon. Subjective indicators capture the household's self-reported ability to maintain an adequate indoor temperature in winter and summer, complementing objective expenditure-based indicators by reflecting the occupants' perceived thermal comfort.

In this context, shallow renovations and energy-saving workshops represent cost-effective tools to improve the situation of vulnerable households. Shallow renovations combine passive measures applied to the building envelope, such as window replacement and wall or roof insulation, with active measures targeting household equipment, including heating systems, appliances and lighting. Their impact has been evaluated within the VAREX projects [4], [5]. Energy-saving workshops, in contrast, do not modify the dwelling itself but provide households with three types of measures to reduce their energy costs: contractual measures, such as applying for the social tariff or

optimising electricity tariffs and contracted power; behavioural measures through energy education; and the provision of micro-efficiency kits, all within the framework of the Energy for All project [6].

2. Definition of the project

This project analyses the impact of the f the shallow renovations carried out under the Fondo Solidario de Rehabilitación Energética, assessed through the VAREX methodology, and the *Energía para Todos* project, an energy-saving workshops, on the energy poverty situation of vulnerable households in Spain. The renovation analysis evaluates how passive and active measures modify the dwelling's required energy expenditure and the household's thermal comfort conditions. The workshop analysis assesses the extent to which contractual recommendations, behavioural changes, and the installation of micro-efficiency kits translate into actual household savings. In both cases, households are evaluated before and after the intervention.

The impact of shallow renovations is assessed using objective energy poverty indicators complemented by subjective thermal comfort indicators. For the workshops, the potential savings associated with the recommended measures are estimated and subsequently verified through follow-up surveys to determine the extent to which these recommendations are effectively implemented.

3. Description of the model

For the renovation analysis, the required energy expenditure of each dwelling is calculated. The required energy expenditure represents the energy cost needed to maintain adequate indoor conditions based on the size of the household, dwelling's construction characteristics, equipment and climatic zone, following the required energy expenditure methodology developed by the Chair of Energy and Poverty [2]. Since the original questionnaires did not include household size, which is required for estimating theoretical energy expenditure, the number of occupants is estimated using other household characteristics. The impact of each renovation is obtained by re-simulating the upgraded dwelling and recalculating the energy poverty indicators after the intervention.

For the workshop analysis, each household had personalised recommendations assigned to reduce its energy expenditure. As each recommendation is associated with a different potential saving, the expected annual savings are estimated individually for every household. Follow-up interviews are then conducted to determine the extent to which these recommendations have been implemented and whether the estimated savings have actually been achieved.

Several analytical tools are used throughout the project. The DIAGNÓSTICO tool is used to estimate the required energy expenditure of each dwelling, while Microsoft Excel is used to organise household information and calculate the different energy poverty indicators. Large-scale data processing and graphical analysis are carried out using Python.

4. Results

Shallow renovations reduced the required energy expenditure of the analysed dwellings by between 5.2% and 10.6%, as shown in Figure 1(a), corresponding to estimated annual savings ranging from €91 to €237 per household. Objective indicators reveal that the sample is primarily characterised by excessive energy expenditure, while five of the eleven households experienced hidden energy poverty before the intervention. As illustrated in Figure 1(b), the renovations did not reduce the incidence of hidden energy poverty but decreased its severity in every assessable case, narrowing the HEP gap by between 9% and 30%, in agreement with previous studies on shallow renovations [5]. Furthermore, all households reported an improved ability to maintain an adequate indoor temperature in winter, summer, or both after the intervention, and five of the eight households that underwent a renovation reported improvements in at least one well-being indicator, including perceived thermal comfort, physical health, or both.

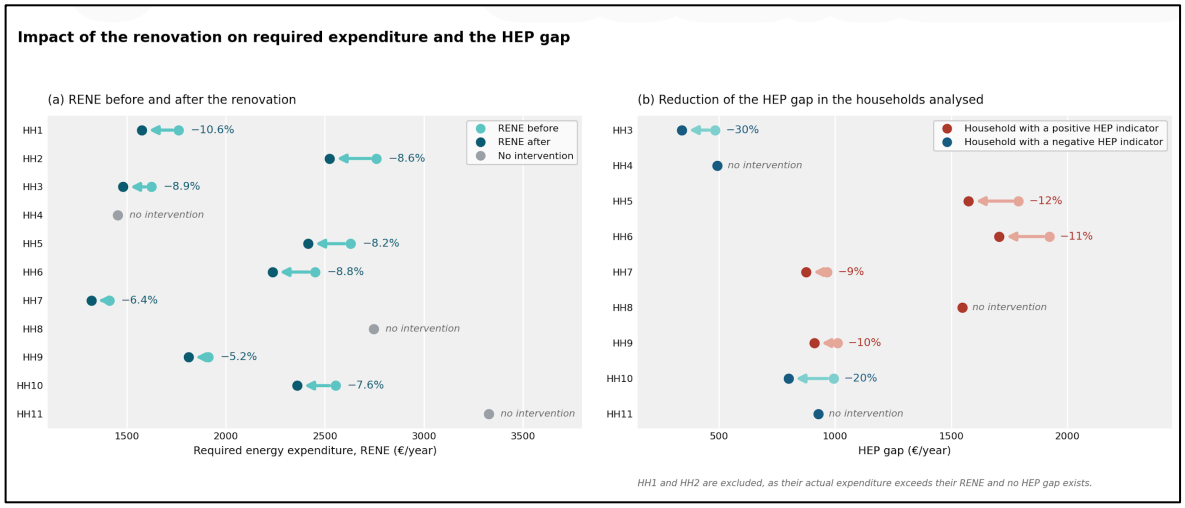

Figure 1 - Impact of shallow renovations by household: required energy expenditure before and after renovation (a) and reduction in the HEP gap (b).

The workshops identified annual potential savings of approximately €15,950 across the 57 households for which savings could be quantified, an average of nearly €280 per household per year. Around 94.6% of these savings were concentrated among the 33 households eligible for the social electricity tariff. The micro-efficiency kit, distributed to 71 households, served as the primary support mechanism for households that were not the holders of their electricity contracts. Although follow-up could not be completed for every household, the contacted participants confirmed that the recommendations are effective when implemented. However, without continued support, implementation remained limited, highlighting the importance of sustained assistance [6].

5. Conclusions

Four main conclusions can be drawn from the combined analysis. First, energy poverty in the analysed households is mainly an affordability issue, which can manifest in two complementary forms that may coexist: excessive energy expenditure relative to income and energy underconsumption below adequate levels. Consequently, expenditure-based indicators alone are insufficient and should be complemented with required expenditure indicators such as HEP [2]. Second, the most important benefits of both interventions are not easily quantified. Renovations mainly improve thermal comfort, while the

workshops mainly increase participants' knowledge and awareness of energy use. Consequently, assessments based solely on economic returns underestimate the overall benefits of these interventions. Third, the effectiveness of both interventions depends less on the proposed measures than on their actual implementation by households. The evidence identifies sustained follow-up and personalised support as the key factors in converting potential savings into realised savings [7]. Finally, the households with the greatest needs, including low-income tenants and households that are not the holders of their electricity contracts, are also those least able to benefit from the available support mechanisms.

Overall, both interventions are complementary. Shallow renovations provide the greatest long-term structural improvements but require suitable housing tenure conditions, whereas energy-saving workshops are more scalable and accessible for households where building renovation is not feasible. For this reason, an integrated program combining both interventions could broaden their reach and maximize their impact on reducing energy poverty.

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List of acronyms

- AEE – Actual Energy Expenditure
- ApS – Aprendizaje y Servicio (Service-Learning)
- BOE - Boletín Oficial del Estado (Official State Gazette)
- CNMC - Comisión Nacional de los Mercados y la Competencia (National Commission on Markets and Competition)
- CTE – Código Técnico de la Edificación (Spanish Technical Building Code)
- DHW – Domestic Hot Water
- ECODES – Fundación Ecología y Desarrollo (Ecology and Development Foundation)
- ECV – Encuesta de Condiciones de Vida (Living Conditions Survey)
- ENPE – Estrategia Nacional contra la Pobreza Energética (National Strategy against Energy Poverty)
- EPAH – EU Energy Poverty Advisory Hub
- EPF – Encuesta de Presupuestos Familiares (Household Budget Survey)
- EPOV – European Energy Poverty Observatory
- HBS – Household Budget Survey
- HEP – Hidden Energy Poverty
- HH – Household (used in tables: HH1–HH11)
- ICAI – Instituto Católico de Artes e Industrias (Catholic Institute of Arts and Industries)
- IDAE – Instituto para la Diversificación y Ahorro de la Energía (Institute for Energy Diversification and Saving)
- IIT – Instituto de Investigación Tecnológica (Institute for Technological Research)
- IMV – Ingreso Mínimo Vital (Minimum Vital Income)
- INE – Instituto Nacional de Estadística (National Statistics Institute)
- MIS – Minimum Income Standard
- NBE-CT-79 – Norma Básica de la Edificación, Condiciones Térmicas 1979 (Basic Building Standard on Thermal Conditions)
- OCU – Organización de Consumidores y Usuarios (Consumers and Users Organization)
- PREE – Programa de Rehabilitación Energética de Edificios (Energy Rehabilitation Programme for Buildings)
- PVPC – Precio Voluntario para el Pequeño Consumidor (Voluntary Price for Small Consumers)
- RAI – Renta Activa de Inserción (Active Insertion Income)
- TUR – Tarifa de Último Recurso (Last Resort Tariff)
- VAREX – VAloración de las Rehabilitaciones Exprés (Assessment of Express Renovations)
- VAT – Value Added Tax

Chapter 1. INTRODUCTION AND CONTEXT

1.1 ENERGY POVERTY: CONCEPT AND DIMENSIONS

Energy poverty can be defined as "any situation in which a household cannot access essential energy services that guarantee basic and decent standards of living and health, including adequate heating, hot water, cooling, lighting and energy to power appliances, in the relevant national context, and in light of existing national social policy and other relevant national policies, as a consequence of a number of factors, including at least one of the following: unaffordability, insufficient disposable income, high energy expenditure, and poor energy efficiency of homes" [1]. Energy poverty does not arise from a single cause, but from the interaction between economic constraints, social vulnerability and the technical characteristics of the dwelling.

From an economic perspective, energy poverty manifests in two main forms. The first is disproportionate energy expenditure, referring to households that dedicate an excessive part of their income for energy needs. The second is insufficient consumption, where households restrict their energy use below adequate levels due to affordability constraints [2]. This distinction is crucial. Not all high energy expenditure reflects vulnerability, and not all low energy expenditure reflects efficiency. A household may present low energy spending not because it is energy efficient, but because it cannot afford to consume the energy required to maintain adequate living standards. This second situation is commonly referred to as hidden energy poverty [2].

The social implications of energy poverty extend beyond purely economic constraints. The inability to maintain adequate indoor temperatures can directly affect household comfort and health, particularly during periods of extreme cold or heat [2]. These effects are more pronounced among vulnerable groups, such as elderly people or low-income households, whose capacity to adapt to adverse conditions is limited. In this way, energy poverty contributes to existing social inequalities by increasing the exposure of already vulnerable groups to inadequate living conditions.

The technical dimension of energy poverty is directly related to the required energy demand of the dwelling. Buildings with poor insulation and outdated systems exhibit higher theoretical energy needs to achieve adequate indoor conditions. When households lack the financial capacity to meet this required demand, under-consumption emerges [3]. In this sense, housing inefficiency acts as a structural driver of hidden energy poverty, as it increases the gap between required and actual energy expenditure.

Given its multidimensional nature, energy poverty cannot be effectively addressed through isolated measures [2]. Policies focused exclusively on income support, energy price intervention or building efficiency improvements are not enough. A coordinated approach

combining social protection, price regulation and structural energy renovation is therefore required.

Measuring energy poverty is particularly challenging due to its multidimensional nature. Indicators based solely on expenditure may misclassify households, as low energy spending can reflect either efficiency or deprivation. For this reason, objective indicators typically distinguish between disproportionate expenditure and insufficient consumption, while subjective measures provide insight into whether households are experiencing difficulties in maintaining adequate living conditions. Combining these approaches allows for a more accurate identification of both visible and hidden forms of energy poverty.

1.2 ENERGY POVERTY: POLICY CONTEXT IN EUROPE AND SPAIN

In Spain, energy poverty represents a structural social and environmental challenge. While its multidimensional nature has been outlined in the previous section, its magnitude and persistence confirm that it is not a temporary phenomenon but a consolidated vulnerability affecting a significant share of households. The interaction between low-income, high-energy prices and an energy-inefficient housing stock creates a cumulative exposure that places many families at risk of inadequate living conditions.

The recent energy crisis that began in 2022 acted as a critical inflection point, sharply intensifying a pre-existing vulnerability. The disruption of international gas markets following the Russian invasion of Ukraine led to sharp increases in gas and electricity prices across Europe [4]. In Spain, this price escalation was accompanied by broader inflationary pressures, which disproportionately affected low-income households whose energy expenditure already represented a substantial share of their income. As a result, in 2023, 20.7% of the population reported being unable to maintain adequate indoor temperature during winter, nearly double the European Union average of 10.6% according to Eurostat data [5]. Although the rate declined to 17.6% in 2024, Spain still exhibited one of the highest incidences of winter thermal deprivation within the European Union [6]. The persistence of this gap relative to the European average suggests that the crisis accelerated, rather than created, an underlying structural problem.

Objective indicators reveal that the problem is structural rather than episodic. Energy poverty in Spain affects a substantial share of households and is particularly pronounced among tenants: in 2023, hidden energy poverty (HEP) reached 14.6% among renters, compared to 10.5% among homeowners without a mortgage [6]. These patterns suggest that energy vulnerability is closely linked not only to income constraints but also to housing conditions and tenure status.

In response to this situation, policy measures in Spain developed along two main lines. In the short term, the Government implemented a series of emergency measures aimed at mitigating the immediate impact of price escalation: temporary VAT reductions on

electricity, the reinforcement of the social electricity tariff (*bono social eléctrico*), and the Iberian exception mechanism designed to limit the impact of gas prices on wholesale electricity markets [4]. In 2023, the *bono social* reduced the estimated energy poverty gap among its beneficiaries by 44% [2]. At the longer-term level, the Spanish Government had already adopted in 2019 the National Strategy against Energy Poverty 2019–2024 (ENPE), which established official monitoring indicators and defined policy objectives aimed at reducing both disproportionate expenditure and hidden energy poverty [7]. The ENPE represents the first systematic framework for addressing energy vulnerability in Spain in a coordinated manner, combining income support, price regulation and building renovation. In February 2026, the Spanish Government approved a new National Strategy against Energy Poverty 2026–2030 (ENPE 2026-2030), which builds on the results of the previous ENPE and introduces additional measures, including an energy poverty observatory and expanded renovation support for vulnerable households [1].

While these measures provided immediate relief, they also highlight the distinction between emergency responses and long-term structural solutions. Addressing energy poverty in a sustained manner requires not only price and income support mechanisms, but also interventions targeting the structural characteristics of the housing stock and the underlying drivers of energy vulnerability.

1.3 THE ROLE OF HOUSING IN ENERGY POVERTY

1.3.1 INFLUENCE OF HOUSING CHARACTERISTICS ON ENERGY CONSUMPTION

The physical characteristics of a dwelling constitute a key determinant of household energy consumption. Although income levels and energy prices have historically dominated the debate on energy poverty, growing evidence indicates that structural housing attributes (including age, typology, size, insulation quality, and installed thermal systems) are equally decisive in shaping the level of energy required to ensure adequate living conditions [8].

In a study conducted in the Netherlands, Brouner et al. [9] concluded that thermal energy consumption is primarily determined by structural dwelling characteristics, specifically age, building type, and construction quality, whereas electricity consumption is more closely associated with household composition and income level. A similar conclusion was reached for the United States by Salari and Javid [10], who identified five groups of variables explaining residential energy use: household sociodemographic composition, building characteristics, dwelling location, outdoor temperature, and energy prices. Their analysis demonstrates that building characteristics have an independent effect on energy consumption, beyond income and demographic factors. Earlier work by Raaij and Verhallen [8] further highlighted that consumers frequently lack awareness of the energy costs associated with their domestic behaviours, a knowledge gap that may simultaneously lead to thermal discomfort and energy waste.

In Spain, findings from the SPAHOUSEC II study indicate that climate conditions and dwelling typology are the main determinants of natural gas consumption in households with individual heating systems [11]. Earlier results from SECH-SPAHOUSEC show that heating represents approximately 42% of total residential energy consumption (2018), followed by appliances and lighting (32%) and domestic hot water (17%) [12]. The weight of heating in this distribution explains why building insulation is central to understanding household energy expenditure. SPAHOUSEC III (IDAE, 2026) [13] offers a more recent update to these figures. Unlike SPAHOUSEC II, which covered only natural gas heating, it expands the scope to all major household end uses (heating, cooling, hot water, cooking, appliances and lighting) and includes secondary residences alongside primary ones.

1.3.2 ENERGY EFFICIENCY, THERMAL COMFORT, AND REQUIRED ENERGY EXPENDITURE

Thermal comfort is commonly defined as the condition of mind that expresses satisfaction with the thermal environment [14]. Beyond subjective satisfaction, maintaining adequate indoor temperatures is a public health requirement. The World Health Organization recommends a minimum indoor temperature of 18°C, with higher values advised for households with elderly members, young children, or people with chronic illness [15]. Prolonged exposure to low indoor temperatures has been associated with increased morbidity, particularly among the elderly [16].

The energy efficiency of the dwelling largely determines the cost of reaching these conditions. In an efficient building, moderate consumption is sufficient to maintain adequate temperatures, whereas a poorly insulated envelope requires considerably more energy to achieve the same result. For low-income households, this cost barrier often translates into under-heating rather than overspending. This relationship has been widely documented in Southern Europe. In Spain, Sánchez-Guevara et al. [14] analysed minimal thermal habitability conditions in low-income dwellings and proposed integrating them into the definition of energy poverty, while Fernández-Agüera et al. [17] showed that thermal comfort and indoor air quality in low-income housing are strongly conditioned by the thermal performance of the building and occupant behaviour. Similar evidence from Portugal points in the same direction, where Palma et al. [18] identified substantial gaps between theoretical energy needs and actual household consumption, revealing widespread under-consumption in thermally inefficient dwellings. More broadly, this persistent underinvestment in building performance has been described as the “energy efficiency gap” [19]. Consequently, improving the thermal performance of the housing stock is not only an energy policy measure but also a public health strategy, as energy-efficiency improvements in social housing have been shown to reduce the health costs associated with inadequate temperature homes [20].

The relationship between dwelling energy efficiency, thermal comfort, and the economic cost required to achieve it is formalized through the concept of required or theoretical energy

expenditure. Barrella et al. [3] developed the Required ENergy Expenditure (RENE) model and applied it to the Spanish Household Budget Survey (EPF), defining it as the theoretical cost of energy that a household would need to pay in order to meet all its energy needs given its specific structural and socio-demographic conditions.

1.4 RESIDENTIAL RENOVATION MEASURES

The strong link between energy poverty and the structural characteristics of housing has driven the development of different typologies of intervention aimed at reducing household energy demand. These measures differ in their scope, cost, and time horizon of implementation. The ENPE 2019–2024 [6] organizes them under the principle that "the cheapest energy is the energy that is not consumed," distinguishing between long-term structural interventions, immediately applicable shallow renovation measures, and behavioural interventions.

1.4.1 DEEP RENOVATION

Deep renovation measures are those that act directly on the building or its thermal installations, with the objective of permanently reducing the dwelling's energy demand. The main actions of this type are the thermal insulation of facades, roofs, and floors, the replacement of windows with higher energy-performance frames, and the substitution of heating and cooling systems with more efficient equipment.

The potential impact of these interventions on energy poverty is significant. For instance, Barrella et al. [3] show that 30.7% of households living in buildings more than 25 years old experience hidden energy poverty, compared to 13.8% in more recent buildings, a difference largely explained by the poorer condition of the envelope and the lower efficiency of thermal systems. At the European level, the EU Renovation Wave estimates that 75% of the building stock is energy inefficient and identifies structural renovation as the only mechanism capable of permanently reducing the energy intensity of buildings [21].

In Spain, the Energy Rehabilitation Programme for Buildings (PREE) [6], managed by the Institute for Energy Diversification and Saving (IDAE), finances actions aimed at improving the thermal envelope and replacing installations in existing buildings through non-repayable grants. Its specific version for municipalities with fewer than 5,000 inhabitants, PREE 5000 adapts this aid scheme to the rural environment with higher subsidy intensities. Likewise, the Programme for Programmed Residential Rehabilitation Environments (PREE), promotes comprehensive energy renovations at the neighbourhood scale and may cover up to 100% of costs in areas with a high concentration of vulnerability [6].

Despite their structural effectiveness, these measures remain unevenly accessible. Deep renovation requires upfront capital and long planning horizons, which many vulnerable households cannot assume. The high initial investment cost, the landlord–tenant dilemma, fragmented ownership in multi-family buildings, and the administrative complexity of application processes limit their adoption precisely among the population segments where their potential impact would be greatest ([3], [22]).

1.4.2 SHALLOW RENOVATION AND MICRO-EFFICIENCY MEASURES

Given the difficulties of scaling deep structural renovation to the most vulnerable households, two additional levels of intervention have gained relevance: shallow renovation and micro-efficiency measures. Although both avoid the high cost and long execution times of deep renovation, they differ in scope and investment required.

Shallow renovation refers to targeted, non-structural improvements to a dwelling's envelope and equipment, such as window and exterior carpentry replacement, wall insulation, awning installation, and the replacement of appliances with more efficient equipment. These actions do not require construction permits or coordination among property owners, which overcomes the main obstacle of structural measures in rental housing. The ENPE 2019–2024 [6] includes this type of intervention under the category of "shallow rehabilitation in dwellings," aimed at facilitating efficiency improvements in households that cannot access comprehensive renovation. The ENPE also addresses the replacement of appliances with more efficient equipment [6], though these measures generally require greater investment than other shallow renovation actions and take longer to implement.

Micro-efficiency measures represent a further, more minimal level of intervention. These are low-cost actions, rapidly executed and involving minimal physical intervention in the dwelling. Among the most representative actions are the replacement of conventional lighting with LED technology and the installation of sealing strips or reflective elements that improve the efficiency of existing heating systems. These interventions reduce energy losses without modifying the structure of the building and can be implemented regardless of tenure status.

Although neither shallow renovation nor micro-efficiency measures achieve the same scale of impact as deep structural renovation, both offer key advantages over it: their implementation cost is considerably lower, their deployment does not require coordination among owners, and their effect on the energy bill can be perceived almost immediately. These characteristics make them particularly relevant instruments for households that, due to their tenure situation or financial constraints, do not have real access to structural measures.

1.4.3 BEHAVIOURAL INTERVENTIONS AND THEIR RELATIONSHIP WITH ENERGY SAVING WORKSHOPS

A third level of intervention, complementary to the previous ones, consists of behavioural interventions. Unlike physical measures, whether structural or micro-efficiency, these actions do not modify the condition of the dwelling but rather the consumption behaviours and habits of its occupants. Their objective is to reduce energy expenditure through changes in patterns of use of heating, lighting, appliances, and hot water, without requiring any material investment.

The relevance of this approach was pointed out by Raaij and Verhallen [8], who demonstrated that consumers frequently lack awareness of the energy costs associated with their domestic behaviours, and that this knowledge deficit may simultaneously lead to thermal discomfort and avoidable waste. Behavioural interventions aim to close this information gap through awareness-raising actions, training, and support. The ENPE 2019–2024 [6] includes this type of action within its Axis IV on consumer protection and social awareness.

1.5 PROJECT STRUCTURE

This work is organized into six chapters, each addressing a distinct aspect of the research in a structured and progressive manner. This chapter introduces the concept of energy poverty and its policy context in Europe and Spain, setting the framework for the rest of the study. The remaining chapters are organized as follows.

Chapter 2 constitutes the state of the art, structured around the key thematic areas of the research. It begins with a review of the main methodological approaches to measuring energy poverty, followed by an examination of market structure alongside income- and price-based mitigation policies. The chapter then surveys the existing literature on shallow energy renovation initiatives, as well as the principal programmes related to energy-saving workshops. It closes with a reflection on the specific contribution of the present project to the existing body of knowledge.

Chapter 3 sets out the methodology adopted for each of the two lines of intervention analysed in this study (shallow renovations and energy-saving workshops) detailing the data sources, indicators, and analytical procedures employed.

Chapter 4 presents the results and discussion of both interventions. It first covers the shallow renovations: household size, required expenditure, energy poverty indicators, and the impact of the interventions. It then covers the energy-saving workshops: the sample, energy awareness, and the impact of the recommendations, the micro-efficiency kit, and follow-up outcomes.

Chapter 5 presents the conclusions of the study, summarizing the impact of each intervention, the key findings across both, and their complementarity as combined strategies against energy poverty, as well as the limitations of the study and directions for future work.

As a final section, Chapter 6 contains the full bibliography, followed by an appendix presenting the alignment of the project with the United Nations Sustainable Development Goals.

Chapter 2. STATE OF THE ART

2.1 MEASURING ENERGY POVERTY

Measuring energy poverty is not straightforward. A useful way to organize the available approaches is to distinguish between objective indicators, based on quantitative household data, and subjective indicators, based on households' own perceptions. As shown in Figure 1, objective indicators can be further divided into those measuring disproportionate expenditure and those measuring insufficient expenditure or under-consumption [7].

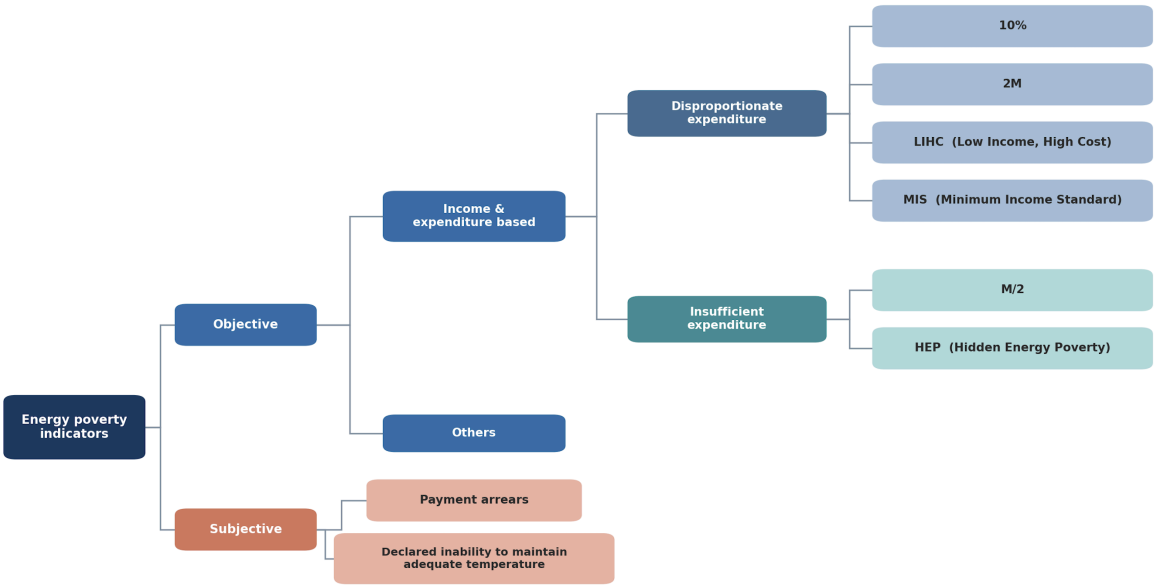

Figure 1: Classification of energy poverty indicators

The 10% indicator was the first measure of disproportionate expenditure, classifying a household as energy poor when it spends more than 10% of its income on energy. Its fixed threshold and tendency to produce false positives among high-income households led to its gradual abandonment, and it was not included among the main indicators selected by the European Energy Poverty Observatory (EPOV) [2] and neither by the EU Energy Poverty Advisory Hub (EPAH).

The 2M indicator was developed to address these limitations. A household is considered energy poor when its energy expenditure exceeds twice the national median share of income spent on energy. Unlike the 10% rule, its threshold is dynamic and adjusts to changes in household energy behaviour across the country. It was adopted by EPOV and EPAH and included in the Spanish National Strategy against Energy Poverty 2019–2024 (ENPE) as one

of its four main indicators [7]. Its main limitation is that it depends on the national median, which mean measures relative energy burden rather than absolute deprivation. It should be noted that, because the threshold is relative, a household's classification can change even if its own circumstances have not, simply because national spending patterns have shifted.

The MIS indicator (Minimum Income Standard) takes a different approach to disproportionate expenditure. Rather than comparing a household's energy share to the national median, it defines a basket of basic needs: a household is considered energy poor if its energy costs are so high that it cannot afford other essential items [2]. Although not selected by EPOV, the Chair of Energy and Poverty at Universidad Pontificia Comillas and (later) the Spanish Ministry for the Ecological Transition have incorporated it into its analytical framework as a valuable complement to 2M, since it provides an objective and absolute threshold [2].

Turning to insufficient expenditure, the M/2 indicator identifies households whose absolute energy spending, adjusted per consumption unit, falls below half the national median as potentially being in hidden energy poverty. Also included in the ENPE 2019–2024, it is the most widely used indicator for capturing under-consumption. Its main weakness is that it includes no income filter, meaning it cannot distinguish between households that spend little because they cannot afford more and those that do so for other reasons unrelated to vulnerability, such as high energy efficiency or extended absence from the home [6].

The main challenge when interpreting low energy expenditure is distinguishing high energy efficiency from deprivation-driven under-consumption. Addressing this requires a household-specific estimate of the energy each dwelling actually needs. This benchmark is provided by the concept of Required ENergy Expenditure (RENE), developed by Barrella et al. [3], which represents the theoretical cost of energy that a household would need to meet all its energy needs given its structural and socio-demographic characteristics.

In [3], the RENE is estimated using eight input parameters:

a) region of residence (as a proxy for climate zone)
b) household size
c) dwelling typology (apartment block or single-family house)
d) usable floor area
e) energy efficiency rate based on construction period
f) type of thermal energy carrier
g) appliance ownership rate
h) energy prices and applicable taxes.

These parameters capture both the physical characteristics of the dwelling and the socioeconomic context of the household, reflecting the multidimensional nature of energy demand outlined in previous sections. The thermal component of the RENE model (Required Thermal Energy Expenditure, RTEE) is calculated in line with the Spanish Building Technical Code (CTE 2019) [23]. The Code sets a reference indoor temperature of 20°C and assumes that the entire dwelling is heated continuously (24 hours a day, 7 days a week). This

regulatory framework illustrates the link between the physical state of the building and the cost of thermal comfort: an old and poorly insulated dwelling will have a structurally higher RTEE than a new and energy-efficient building to reach the same indoor temperature. The weighted national average RENE in 2019 amounted to €1,997 per year, with heating accounting for 56% of the total [3].

The HEP indicator (Hidden Energy Poverty) addresses the main limitation of M/2 more precisely, by including an income threshold. The concept of hidden energy poverty was first defined by Meyer et al. [24] in the Belgian context, identifying households whose abnormally low energy expenditure reflects forced under-consumption rather than efficiency. The phenomenon has since been documented in several European countries, including Central and Eastern Europe [25], Italy [26] Austria [27], and Greece [28], as well as in Australia [29] and the United States through the energy equity gap approach [30]. Moreover, the methodological proposal by Barrella et al, 2022 [3] is grounded in the concept of required energy expenditure. This theoretical expenditure is estimated using the RENE model (Required Energy Expenditure), developed by the Energy and Poverty Chair at Universidad Pontificia Comillas, which considers factors such as the region of residence, dwelling size and typology, construction period, type of heating system, and prevailing energy prices [3]. The HEP indicator then compares this theoretical required expenditure with the household's actual energy spending. A household is classified as hidden energy poor when its actual spending falls significantly below (<RENE/2) what it would need to maintain adequate living conditions, making this indicator particularly well-suited to evaluating the impact of renovation interventions.

The ENPE 2019–2024 subsequently incorporated the HEP indicator into its official monitoring framework, recognizing that actual expenditure alone cannot fully capture energy vulnerability [6]. Figure 2 illustrates how both the RENE/2 and HEP indicators evolved between 2016 and 2019, showing that hidden energy poverty is not an episodic phenomenon but a persistent structural condition.

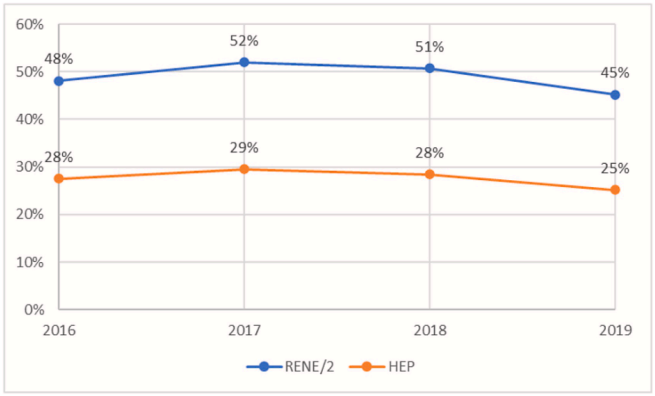

Figure 2: Share of Spanish households in energy poverty according to the RENE/2 (insufficient consumption, no income filter) and HEP (insufficient consumption, income-filtered) indicators, 2016–2019. Source: Barrella et al. [3]."

Empirical results from the HEP analysis reinforce the central role of building age as a structural determinant. Barrella et al. [3] find that 30.7% of households living in buildings 25 years or older experience hidden energy poverty, compared to 13.8% of those in more recent dwellings. This difference (more than double) cannot be explained solely by income disparities; it reflects the limitations imposed by thermally inefficient buildings on households' capacity to meet their energy needs. Moreover, 72% of households in the lowest five income deciles live in buildings older than 25 years [3], highlighting the strong intersection between economic vulnerability and poor housing quality.

Subjective indicators add an essential complementary dimension. Their main value is that they capture the lived experience of families, allowing objective results to be cross-checked against households' own perception of their situation [2]. Their inherent limitation is subjectivity, as responses reflect personal assessments rather than measured temperatures or actual expenditure levels.

No single indicator is sufficient to capture the full complexity of energy poverty, and combining multiple metrics is necessary to obtain a robust picture [22].

2.2 *ELECTRICITY AND GAS MARKETS AND MITIGATION POLICIES*

Understanding the structure of the electricity and gas markets and existing mitigation measures is relevant to this work for two reasons. First, energy prices are one of the three main drivers of energy poverty, alongside household income and dwelling efficiency. Second, the interventions analysed in this thesis take place in a context where vulnerable households already receive some level of protection through these measures, which must be considered when interpreting the results obtained.

2.2.1 MARKET STRUCTURE

In Spain, the electricity market is liberalized, although two contracting options coexist: the free market and the regulated tariff known as PVPC (*Precio Voluntario para Pequeños Consumidores* or voluntary price for small consumers) available to domestic consumers with contracted power under 10 kW. The PVPC is directly indexed to the wholesale market, exposing its beneficiaries to international price volatility. Following the 2022 energy crisis, Spain and Portugal agreed with the European Commission on the so-called Iberian Exception, a mechanism that temporarily capped the price of gas used for electricity generation, reducing the impact of wholesale volatility on household electricity bills [4].

The natural gas market in Spain is similarly structured around two coexisting options. Consumers may contract their supply either through the liberalized market, where prices are set by competing retailers, or through the regulated tariff known as TUR (*Tarifa de Último Recurso* or last resort tariff), which is set by the government and serves as a price reference for consumers in the regulated market. As with electricity, gas prices in Spain are closely

linked to international wholesale markets, making them highly sensitive to geopolitical events and supply disruptions, as demonstrated during the 2021–2022 energy crisis when household gas bills increased dramatically across Europe. However, in the gas bill case, this volatility has been more significant in the free market.

2.2.2 INCOME AND PRICE-BASED MITIGATION MEASURES

The main protection measures implemented in Spain are the social electricity tariff (*bono social eléctrico*), which provides bill discounts to vulnerable consumers; temporary VAT reductions on electricity introduced after the 2022 crisis (**¡Error! No se encuentra el origen de la referencia.**,[6]). In the thermal supplies, the equivalent instrument is the *bono social térmico*, a direct annual payment introduced in 2018 and aimed at vulnerable households that use natural gas, propane, or heating oil as their primary energy source for heating, DHW (Domestic Hot Water) and cooking. Unlike the *bono social eléctrico*, which provides a percentage discount on the bill, the *bono social térmico* is a fixed lump-sum transfer, limiting its ability to adjust to fluctuations in energy prices or individual consumption levels. Besides, it's added value is the amount's dependence on the climate zone where the household lives.

2.3 SHALLOW ENERGY RENOVATIONS INITIATIVES

The shallow renovation initiatives analysed in this project are primarily grounded in the findings of the VAREX research framework (*VAloración Rehabilitaciones EXprés* or Assessment of shallow renovations*), developed by the Instituto de Investigación Tecnológica* (IIT) at *Universidad Pontificia Comillas*, and commissioned by Fundación Naturgy. The VAREX project was developed to evaluate the real impact of shallow renovation interventions on vulnerable households. Beyond this core reference, a growing body of comparable studies and programmes at both national and international levels provides additional evidence supporting the effectiveness and limitations of this type of intervention. Two editions of the project have been carried out to date.

The first edition, VAREX-2022 [31], analysed the impact of shallow renovation measures in 54 vulnerable households in Catalonia. The results showed a reduction in the HEP indicator from 89% to 79% of households after the intervention, as well as a 26% decrease in the energy poverty gap. Regarding the effectiveness of individual measures, appliance replacement proved to be the most effective in reducing the percentage of households experiencing hidden energy poverty, with a 25% decrease, while window replacement was the most effective in reducing the energy poverty gap, achieving a 45% reduction.

The second edition, VAREX-2024 [32], significantly expanded the scope of the study, analysing 416 households across 7 Autonomous Communities. The results showed an average saving of 6.24% in theoretical energy expenditure, decreasing from €1,873 to €1,758, and a 14.51% reduction in the energy poverty gap. A key finding of this edition is that combined micro-efficiency measures are significantly more effective than when

implemented individually and therefore should not be underestimated despite their low individual cost.

However, both editions identified important limitations. On the one hand, households in situations of severe energy poverty, whose actual expenditure is less than one quarter of their theoretical expenditure, rarely manage to exit their situation solely through micro-efficiency measures, pointing to the need for deeper interventions in such cases. On the other hand, the difficulty in obtaining real energy bills before and after the interventions limits the ability to assess the impact on households' actual energy expenditure.

Beyond the Varex framework, additional academic evidence supports the relevance of shallow rehabilitation as a tool to mitigate energy poverty. Luján Torres et al. (2022) [33] conducted a study in Valencia directly comparable to VAREX, analysing the impact of low-cost rehabilitation measures on vulnerable households. Their findings reinforce the idea that light interventions can produce measurable reductions in energy burden, particularly when targeted at households with moderate levels of vulnerability.

At the European level, the German programme Stromspar-Check represents one of the most closely aligned initiatives with the micro-efficiency interventions analysed in VAREX. The programme combines household energy advice with the direct installation of low-cost efficiency measures implemented by trained advisors. According to the Energy Poverty Advisory Hub (2023) [34], the programme has reached more than 382,000 households since its launch, generating annual savings of between €100 and €250 per dwelling and reducing CO_2 emissions by approximately 300 kg per household. Beyond environmental savings, the initiative demonstrates how micro-efficiency programmes can simultaneously address energy vulnerability and labour market inclusion.

Nevertheless, the literature emphasizes that advisory and subsidy-based programmes are subject to structural evaluation challenges. Grösche and Vance (2009) [35] identify free ridership as a potential source of bias, since some beneficiaries may have implemented efficiency measures independently of public intervention. This suggests that evaluations of such programmes should account for behaviour that would have occurred regardless of the intervention, to avoid overestimating their real impact.

A further limitation frequently identified in light retrofit programmes is the difficulty of obtaining reliable pre- and post-intervention energy bills, which restricts the ability to fully assess real expenditure reductions and behavioural adjustments. This reinforces the need for robust evaluation methodologies capable of distinguishing between theoretical savings, actual savings and behavioural effects.

2.4 *ENERGY-SAVING WORKSHOPS INITIATIVES*

Energy-saving workshops and accompaniment programmes have emerged in recent years as a key complementary strategy to technical rehabilitation measures in the fight against energy poverty. The two main Spanish initiatives on which this project is based are the following.

The *Escuela de Energía* (Energy School) of Fundación Naturgy [36] is an energy training programme aimed at vulnerable households in Spain. Since its creation in 2017, it has delivered more than 3,800 workshops addressed to families and social sector professionals, training over 43,800 people across 925 municipalities. The workshops focus on understanding energy bills, accessing the social tariff, and adopting more efficient consumption habits.

A key aspect identified by the Energy School is the importance of follow-up support in enhancing the effectiveness of the workshops. An initial evaluation based on 470 case files showed that only 15% of participants implemented the recommendations provided. In a separate analysis conducted with 80 households that received continuous support from social services, implementation rates increased to 80%. This contrast highlights the decisive role of personalized accompaniment in translating training into sustained behavioural change. This contrast highlights that the involvement of social workers and personalized follow-up are decisive factors in ensuring that training translates into real changes in households' energy-related behaviour.

The *Energía para Todos* project, developed within the framework of the Service-Learning (ApS, *Aprendizaje y servicio*) subject at the School of Engineering (ICAI) of the Universidad Pontificia Comillas, represents another relevant initiative in this field [37]. Since 2022, the project has supported more than 180 vulnerable households through workshops delivered by university students, combining personalized energy advice with the distribution of micro-efficiency kits and subsequent follow-up of participating households. However, its implementation has revealed several limitations: the difficulty in contacting participants after the workshop, the gradual loss of training content over time, and the challenge of obtaining post-intervention energy bills to quantify the real impact on households' energy expenditure.

This approach is not unique to Spain. At the European level, the H2020 project STEP, Solutions to Tackle Energy Poverty [38] demonstrated the scalability and effectiveness of this model across nine countries with high rates of energy poverty. STEP developed national support networks and carried out extensive training and outreach activities, benefiting over 16,000 consumers and training more than 1,000 frontline professionals. A central lesson of the project was that collaboration with trusted figures such as social workers, nurses, volunteers, and energy ombudsmen proved particularly effective in reaching the most vulnerable households, and that one-to-one sessions tailored to each household's specific circumstances yielded significantly better outcomes than standardized approaches.

These findings directly reinforce the conclusions drawn from the Energy School and Energía para Todos regarding the decisive role of personalized accompaniment. Nevertheless, Simcock and Bouzarovski [39] argue that energy advice should be framed as a complementary instrument within a broader policy mix, rather than as a stand-alone solution, given that the structural roots of energy poverty extend beyond behavioural change.

2.5 CONTRIBUTION OF THE PROJECT

In Spain, energy poverty remains a persistent structural challenge. In 2024, more than 17% of households experienced disproportionate energy expenditure, while 12.6% failed to reach even half of the national median energy expenditure [6]. In response to this situation, shallow energy renovations and energy-saving workshops emerge as complementary interventions with the potential to reduce energy vulnerability through accessible and scalable measures.

This work is motivated by a dual dimension. From a social perspective, energy poverty remains a persistent form of inequality in Spain, and evaluating interventions targeting vulnerable households is essential to better understand their real impact. From an energy perspective, improving efficiency in the existing residential building stock is one of the most practical ways to advance towards a more sustainable energy model. The interventions analysed in this study offer an accessible and scalable way to address both dimensions simultaneously.

This work builds on the VAREX and Energía para Todos projects, extending their scope in three directions. First, it adopts a multidimensional assessment framework based on seven complementary energy poverty indicators, combining objective and subjective measures to provide a more complete picture of households' energy situation. The objective assessment includes the 10%, 2M and MIS indicators of disproportionate expenditure together with the M/2 and HEP indicators of insufficient expenditure, while the subjective assessment considers households' reported inability to keep the home adequately warm in winter, adequately cool in summer, and arrears on utility bills. By combining these indicators, the study provides a more comprehensive evaluation of the impact of the interventions than would be possible using a single measure alone. Second, it extends the study of the impact of energy-saving workshops through the follow-up of participating households, assessing the extent to which recommendations are implemented and their potential effect on actual energy expenditure. Third, it carries out a systematic comparison of the effectiveness of shallow energy renovations and energy-saving workshops, identifying which type of intervention produces greater improvements and in which contexts.

Chapter 3. METHODOLOGY

3.1 GENERAL STRUCTURE OF THE METHODOLOGY

This chapter describes the methodology applied to assess the impact of the two interventions studied in this work. Figure 3 summarizes its overall structure. The left branch corresponds to the shallow renovations evaluated through the VAREX methodology, applied to a sample of households served by Fundación Naturgy in Getafe. The right branch corresponds to the energy-saving workshops of the Energía para Todos project. Both strands follow a parallel logic: a diagnosis of the household situation, the application of a specific simulation or diagnostic tool (DIAGNÓSTICO and ENERSOC), and the quantification of the impact of each intervention. Their results converge in the final chapters, where the conclusions of both analyses support the proposal of an integrated program against energy poverty. The following sections describe each strand in detail.

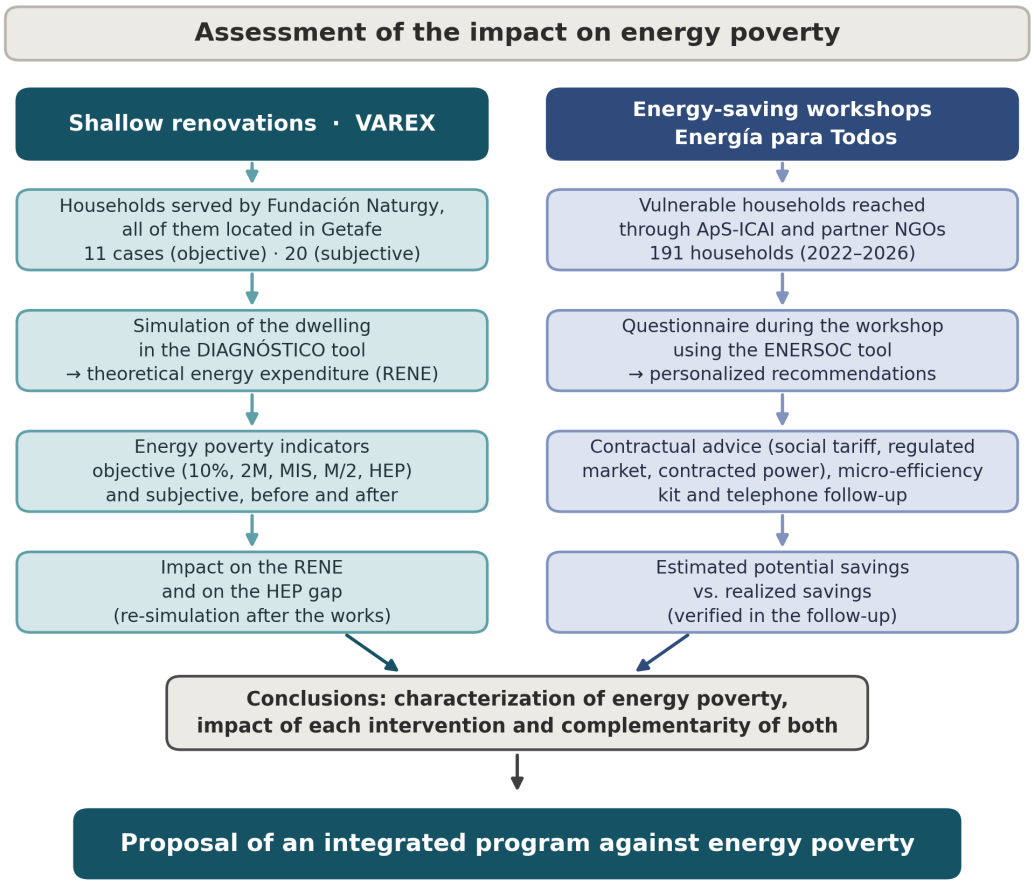

Figure 3: Methodological structure of the work: parallel analysis of the two interventions.

3.2 METHODOLOGY OF THE SHALLOW RENOVATION ANALYSIS

3.1.1 DATA COLLECTION AND FILTERING

The data used in this study come from the VAREX Project, developed in collaboration with Fundación Naturgy, through questionnaires administered to households in the municipality of Getafe.

Sub-sample for Objective Analysis

Of the 39 cases in the initial selection, not all contained the information necessary to calculate the objective indicators of energy poverty. The calculation of these indicators (10%, 2M, M/2, HEP and MIS) requires simultaneously having data on annual household income, energy expenditure (electricity and, where applicable, gas), household size, and basic characteristics of the dwelling (surface and year of construction) and type of electricity market (regulated or free).

Following the review and validation of each case, 28 households were excluded due to the absence of one or more of these variables. Consequently, the analysis was carried out on the remaining 11 households, which met all data requirements.

Sub-sample for Subjective Analysis

Of the 39 cases that make up the initial selection, not all contained the information necessary to carry out the analysis of subjective thermal comfort indicators. To determine which cases were valid for this analysis, the availability of responses to indicators relating to the perception of cold and heat in the dwelling, both in winter and in summer, was reviewed.

Following this review, 20 cases were obtained: those that include actual responses to the subjective comfort indicators, whether in winter, in summer, or in both seasons. These are the cases considered valid and on which the subsequent analysis is conducted.

3.1.2 METHODOLOGICAL FRAMEWORK FOR SAMPLE CHARACTERIZATION

Before assessing the impact of the implemented interventions, a descriptive analysis of the study sample is conducted to characterize the households included in the evaluation and provide the necessary context for interpreting the subsequent results. This characterization aims to identify the main features of the dwellings, the retrofit measures implemented, and the socioeconomic and energy-related conditions of the participating households prior to the intervention. To this end, the analysis is organized into five blocks: dwelling characteristics, type of retrofit carried out, socioeconomic profile, baseline energy situation, and climatic conditions. The findings of this descriptive analysis are presented in the Results section, while this chapter focuses on the methodological approach followed for the impact assessment.

3.1.3 ESTIMATION OF THE NUMBER OF HOUSEHOLD MEMBERS

The number of persons per household (household size) is a necessary input variable both for the calculation of the Theoretical Energy Expenditure (TEE) and for the energy poverty indicators that depend on this variable, as well as for the computation on a per equivalent person basis. However, this variable was not recorded in the original questionnaires, constituting one of the main methodological challenges of this study.

In the absence of this data, household size was estimated through an indirect, multi-method approach, combining four complementary proxy variables that were applied simultaneously and cross-validated against one another.

Method 1 - Household income and the modified OECD equivalence scale

Rather than providing a direct estimate of household size, this method establishes a lower bound based on income consistency. The declared annual household income was cross-referenced with the modified OECD equivalence scale ([3], [22]), which converts total household income into a comparable per-person figure by assigning a weight of 1.00 to the first adult, 0.50 to each additional adult, and 0.30 to each child under 14:

$$UC2 = 1 + 0.5 \times (\text{number of adults} - 1) + 0.3 \times \text{number of children under 14}$$

Since all households in the sample were attended by social entities due to their energy vulnerability situation, their equivalent income is expected to fall below the maximum equivalent income of the fifth decile, set at 15,372 €/year according to HBS 2022 data [32]. This condition defines a minimum household size: the smallest number of occupants for which the resulting equivalent income remains below this threshold. Household sizes below this value would imply income levels inconsistent with the vulnerability profile of the sample

Method 2 - Electricity expenditure as an inverse proxy

The declared monthly electricity expenditure was converted to annual consumption in kWh by dividing by the applicable electricity price per kWh for each household. For households on the regulated tariff (PVPC), the mean annual PVPC price for 2025 was used (0.1364 €/kWh), obtained from REE/ESIOS data[2]. For households on the free market, the price declared in the questionnaire was applied.

[2] The price used (0.1364 €/kWh for regulated tariff households, and the declared price for free market households) refers only to the variable energy component and does not include VAT, the fixed capacity charge, or other taxes. Since the expenditure declared by households corresponds to the total bill, dividing by this price results in an overestimation of actual electricity consumption. This limitation should be taken into account when interpreting the results.

The resulting annual electricity consumption was compared against two complementary references. The first, the median annual electricity consumption in Getafe derived from the 2021 Census of Population and Housing intensity-of-use data (INE, 2021), which records a municipal median of 2,239 kWh/year, is used here to contextualize the consumption levels observed in the sample rather than as a direct estimation tool. The mean annual electricity consumption of the sample is 3,193 kWh/year, notably above the municipal median, with individual values ranging from approximately 1,200 to 7,000 kWh/year. This wide variability reflects the heterogeneous nature of the sample: some households show relatively low consumption, consistent with the underconsuming behaviour frequently observed in energy-poor households, who are often unable to afford sufficient energy use to reach thermal comfort ([3], [32]). Higher consumption levels, on the other hand, are also expected in this profile of households, given the low energy efficiency of their dwellings and appliances, usually older, inefficient equipment and poorly insulated homes being common characteristics of vulnerable households. In the most extreme cases, consumption is further inflated by the use of electric radiators as the primary heating system.

The second reference, and the one directly employed for the estimation, is the consumption patterns by number of occupants documented in the new IDAE study on residential energy consumption and expenditure in Spain [40], which shows a clear positive relationship between household size and electricity consumption, with single-person households consuming significantly less than multi-person households. Each household's estimated annual electricity consumption was matched against this reference to infer the most likely number of occupants.

However, for households using electric radiators as their primary heating system, heating consumption is included in the electricity bill and inflates the apparent number of occupants, since the reference values reflect typical appliance and lighting use. In these cases, the estimate from Method 2 was adjusted downward and greater weight was assigned to Method 4.

Method 3 - Total energy expenditure as an inverse proxy

For households where both electricity and gas expenditure data were available, the total annual energy expenditure was calculated by summing the declared monthly electricity and gas costs and multiplying by twelve. One household operating under a flat-rate electricity tariff was excluded from this method, as the fixed monthly payment does not reflect actual energy consumption and therefore cannot be used as a basis for occupancy estimation.

The resulting total annual energy expenditure was compared against the median total energy expenditure by household size documented in the IDAE study on residential energy consumption and expenditure in Spain [40]. As can be seen in Figure 4, there

is a clear positive relationship between household size and total energy spending. The estimated household size corresponds to the number of occupants whose associated median expenditure most closely matches the calculated annual value.

Unlike Method 2, this approach incorporates both electricity and gas expenditure, providing a more complete picture of the household's total energy use. This is particularly relevant for households whose heating system relies on gas, where electricity expenditure alone would underestimate total energy consumption and therefore household size. However, the same limitation identified in Method 2 applies in both directions: households with inefficient heating systems, older appliances, or poorly insulated dwellings may present higher expenditure than expected for their actual size, leading to a potential overestimate of occupants, while households that severely under consume due to economic constraints may present lower expenditure than expected, leading to an underestimate. In cases where this method yielded an unusually high estimate inconsistent with the other methods, greater weight was assigned to the remaining methods in the final convergence step.

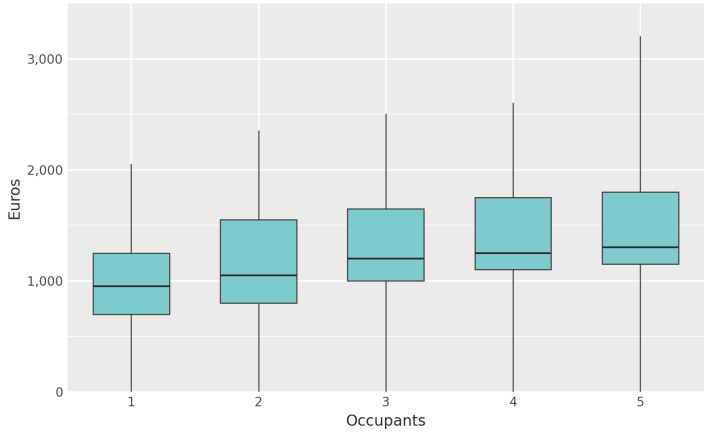

Figure 4: Box plot of annual energy expenditure (€) by number of household occupants [40]

Method 4 - Cross-referencing dwelling surface area with census data

For each household in the sample, the dwelling surface area was used as a proxy for household size. The 2021 Census of Population and Housing data for Getafe District 2 (INE, 2021) was used to calculate the mean floor area per occupant for each surface bracket. This value was then applied to the exact dwelling surface area of each household to derive a continuous estimate of household size, subsequently rounded to the nearest integer.

The dwellings in the sample have a mean surface area of 60.4 m² and a median of 61 m², ranging from 54 to 70 m². This is notably below the mean dwelling size in Getafe as a whole (73.3 m², INE Census 2021) and well below the national median, which

falls in the 76–90 m² range. Given this narrow and relatively small surface area range, the method provides limited variability, resulting in an estimated household size of approximately two occupants for all cases.

As a result, dwelling size may not always provide the most accurate representation of household occupancy, especially in vulnerable households with a potential high level of overcrowding [41] or older individuals living alone at home. In situations where electricity consumption was disproportionately high relative to the dwelling size, this was considered a potential indication of higher occupancy, leading to a greater reliance on Method 2.

Final estimation

The final household size was determined by integrating four estimation methods: income below equivalence threshold (Method 1), electric consumption (Method 2), total energy expenditure (Method 3), and dwelling surface area per occupant (Method 4). Priority was given to Method 4 as the primary reference, given its direct relationship with physical household capacity, with Methods 2 and 3 used as corroborating or overriding evidence where relevant.

Method 1 was used solely as a lower-bound indicator rather than as an estimate. In cases where Methods 2 and 3 consistently pointed to a markedly different size than Method 4, their combined signal was considered sufficient to depart from the surface-area estimate. Civil status served as an additional lower bound throughout: a married or cohabiting household was not assigned fewer than two occupants regardless of other indicators. One systematic adjustment was applied: for households using electric radiators as their primary heating system, Method 2 estimates were treated with caution, as elevated electricity consumption in these cases reflects heating load rather than occupancy, leading to an overestimate of household size.

3.1.4 ENERGY POVERTY INDICATORS

The indicators used in this study are divided into two broad categories: objective indicators, based on quantitative household data, and subjective indicators, based on households' own perceptions.

Regarding subjective indicators, thermal comfort is assessed through survey responses on households' ability to maintain an adequate temperature in their home. Two dimensions are considered: comfort in winter, evaluating whether households are able to keep their dwelling sufficiently warm during the cold months, and comfort in summer, evaluating whether they are able to maintain an adequately cool environment during the warm months. In addition, a

payment arrears indicator is included to capture a dimension of energy poverty not covered by expenditure-based metrics [32].

The theoretical energy expenditure for each household is estimated using the DIAGNÓSTICO tool [42], developed by the *Cátedra de Energía y Pobreza* at *Universidad Pontificia Comillas*. The tool is based on the Required Energy Needs Expenditure (RENE) model, a bottom-up approach that estimates the energy expenditure required for a household to meet both its thermal and non-thermal energy needs. The estimation incorporates key household- and dwelling-specific characteristics, including the building features, climatic zone, occupancy, and household composition, thereby providing a tailored benchmark against which actual energy expenditure can be assessed.

Once this value is obtained, a set of objective energy poverty indicators is calculated using the methodology described in the *Informe de Indicadores de Pobreza Energética en España* [2]. Within the objective category, a further distinction is made between indicators of disproportionate expenditure, which identify households spending an excessive share of their income on energy, and indicators of insufficient expenditure, which capture households that are under-consuming energy relative to their needs.

The primary indicator used in this study is the Hidden Energy Poverty (HEP) indicator. This indicator classifies a household as being in hidden energy poverty if two conditions are simultaneously met: first, the household is under-consuming energy, meaning its actual energy expenditure (AEE) is lower than half of its theoretical energy expenditure (AEE < RENE/2); and second, the household has a low income, belonging to the five lowest equivalized income deciles.

The HEP indicator is evaluated in terms of both its extent (HEP extent), reflecting the percentage of households in hidden energy poverty, and its depth (HEP depth), also referred to as the energy poverty gap. The latter metric is defined as the difference between half the theoretical energy expenditure and the actual expenditure of each household (RENE/2 – AEE) and captures the economic distance separating a household from the minimum required energy expenditure. Additionally, a severe version of this gap is also estimated, defined as the difference between a quarter of the theoretical expenditure and the real expenditure, capturing the most extreme cases of hidden energy poverty ([31], [32]).

In addition to the HEP indicator, a set of complementary objective indicators are calculated to broaden the analysis:

- 2M: classifies a household as energy poor if its energy expenditure as a share of income exceeds twice the national median ratio. This indicator captures disproportionate energy spending.
- MIS (Minimum Income Standard): an absolute indicator of disproportionate expenditure that assesses whether a household's remaining income after covering energy costs falls below a minimum acceptable living standard.

- M/2: classifies a household as energy poor if its absolute energy expenditure is below half the national median.
- 10%: classifies a household as energy poor if it spends more than 10% of its income on energy.

These indicators are applied to each household in the sample, enabling a comprehensive and multidimensional assessment of energy poverty that covers disproportionate expenditure, insufficient consumption, payment difficulties, and perceived thermal comfort.

3.2 METHODOLOGY OF THE ENERGY-SAVING WORKSHOPS' ANALYSIS

3.2.1 DATA SOURCE AND SAMPLE

The data used in this section come from the *Energía para Todos* project, an initiative developed within the ApS-ICAI at Universidad Pontificia Comillas since 2022, in collaboration with ECODES, A+Familias, Caritas Madrid and the Spanish Red Cross. The project reaches vulnerable households through workshops delivered by university students, combining personalized energy advice with the distribution of micro-efficiency kits and subsequent follow-up of participating households. It builds on the methodology of ECODES's *Ni Un Hogar Sin Energía* program and on the work of the *Cátedra de Energía y Pobreza (IIT-Comillas)*, and pursues a dual aim: that students carry out a service for the community and reflect on it [37].

The project is structured in four phases. In the first phase, students receive in-person training at Comillas, delivered by ECODES, on energy advising and on the use of ENERSOC, a web tool that automatically generates a personalized energy diagnosis for each household. In the second phase, students are divided into groups to run advising sessions and efficiency workshops for vulnerable families at the premises of the remaining collaborating NGOs; each session combines personalized advice based on ENERSOC, presentations on good energy habits, electricity and gas bills, and the social tariff, and a round of questions. In the third phase, families collect a micro-efficiency kit designed for their specific needs by the students. In the fourth phase, students follow up with each family through two telephone calls: the first, about two weeks after the workshop, concerns the request for changes to the bill and the social tariff; the second, about four weeks after, concerns whether those changes were obtained, together with the collection and installation of the kit [37].

The dataset comprises 191 households visited between 2022 and 2026, for whom a diagnostic questionnaire was completed during the workshop. The questionnaire collected sociodemographic information, housing characteristics, energy systems, appliance inventory, and electricity billing data, and provided specific recommendations to each household.

3.2.2 CHARACTERIZATION OF THE SAMPLE

A descriptive analysis of the 191 households is carried out prior to the impact assessment, in order to contextualize the sample and interpret the results appropriately. The characterization is organized around four dimensions.

The first dimension covers the sociodemographic profile of households, including the gender and age distribution of residents, employment status, monthly income, household size and composition, and the presence of vulnerability situations such as receipt of the Minimum Vital Income (IMV), large family status, or minimum pension.

The second dimension covers the housing characteristics, including floor area, building age, tenure type, and a set of habitability conditions directly linked to energy performance: presence of damp, air infiltration, type of glazing, and self-reported thermal discomfort in winter and summer. The thermal equipment of the dwellings is also assessed, including heating and domestic hot water systems and supply type, and the predominant type of lighting.

The third dimension covers the pre-intervention energy profile of each household, including the type of electricity contract (regulated or free market), ownership of the contract, payment status, bill understanding, current status of the social tariff (*bono social*), and monthly electricity consumption.

The fourth dimension covers the distribution of micro-efficiency kits, analysing which physical measures were proposed for participating households, whether and how many kits were assigned and which categories of measures were most frequently distributed.

3.2.3 ASSESSMENT OF WORKSHOP IMPACT

The workshop or diagnostic visit is followed by a semi-structured follow-up process (ideally after two weeks and one month), carried out by the university students involved in the project, to find out whether the recommendations provided during the workshop have been implemented and collect updated billing data where possible.

In the context of this project, the research team additionally followed up on 31 households, which were visited between late 2024 and March 2025. Of these, contact was successfully established with 8 households. The remaining 23 could not be reached: the majority did not answer repeated calls, others hung up, and in some cases the person who answered had no knowledge of the workshop or the project. This outcome significantly limited the scope of the follow-up analysis and is likely explained by a combination of factors: changes in phone numbers, changes in residence, and the time elapsed between the initial workshop visit and

the follow-up call. This limitation is taken into account in the interpretation of results presented in the following sections.

The impact of the workshops is assessed along several complementary aspects. The first is the adoption of the contractual and tariff recommendations (the social tariff, the switch to the regulated tariff, and the reduction of contracted power) and the economic savings associated with each line. The second is the distribution and installation of the micro-efficiency kit and its estimated savings. The third is the realized implementation of these recommendations and the barriers encountered, drawn from the follow-up outcomes described above. In addition, a survey administered before the workshop characterizes the household's baseline level of beliefs, awareness, and knowledge regarding energy consumption and the support measures available to them; because it is a pre-workshop survey with no follow-up counterpart, it describes the starting point of participants rather than a change produced by the workshop. The results of these analyses are presented in the results section.

Chapter 4. RESULTS AND DISCUSSION

4.1 RESULTS OF THE SHALLOW RENOVATION ANALYSIS

This section presents the results of the assessment of the impact of shallow renovations on energy poverty, based on the VAREX sample of households in the municipality of Getafe. Building on the data collection and filtering process described in Section 3.1, the analysis is organized into six stages. First, a descriptive characterization of the study sample is presented, providing an overview of the dwelling characteristics, the type of retrofit implemented, the socioeconomic profile of the households, their baseline energy situation, and the climatic conditions. Second, household size is estimated, as this variable is required for several calculations and direct information on the number of occupants was not available for all cases. Third, the baseline required energy expenditure (RENE) is calculated for each household using the DIAGNÓSTICO tool. Fourth, the objective energy poverty indicators (10%, 2M, M/2, HEP, and MIS) are evaluated for the pre-renovation period, thereby characterizing the sample's initial energy vulnerability. Fifth, the analysis examines the subjective dimension of energy poverty through self-reported thermal comfort in winter and summer, based on data from 20 households with valid responses. Finally, the estimated impact of the renovation measures is assessed by comparing pre- and post-intervention theoretical energy expenditure and energy poverty indicators, thereby evaluating the potential effectiveness of the implemented measures.

4.1.1 CHARACTERIZATION OF THE RETROFIT AND THE HOUSEHOLD

A descriptive analysis of the 39 selected households is carried out to contextualize who the study households are before proceeding to the calculation of impact. The variables are organized into five blocks: dwelling characteristics, type of retrofit, socioeconomic profile, baseline energy situation, and climate.

Dwelling Characteristics

All dwellings in the sample are located in the municipality of Getafe, in the southern metropolitan area of Madrid. The age of the dwellings is homogeneous: of the 30 cases with available data, 26 (87%) were built between 1966 and 1970, with a median year of construction of 1968. This age is significant because it means the dwellings were built before the entry into force of the first Spanish thermal regulation (NBE-CT-79) and therefore lack any insulation requirements for facades or window frames.

Regarding floor level, the 39 households are distributed across all floors of the building: 5 dwellings are located on the ground floor and 2 on the top floor (sixth), while the remaining 32 cases are spread across the intermediate floors (first to fifth). This distribution is relevant from a thermal demand perspective, as ground-floor and top-floor households are more thermally exposed due to contact with the ground or the roof, respectively.

The habitable floor area, available for 30 of the 39 households, is equally homogeneous: the median stands at approximately 59 m², with a minimum of 46 m² and a maximum of 71 m².

Type of Retrofit Carried Out

The predominant intervention has been the replacement of external joinery (windows and doors), present in practically all households, frequently combined with painting works and, in some cases, damp treatment or, in one case, the installation of ventilation and extraction systems. Other less frequent interventions include the installation of air conditioning units, awnings, or bathroom refurbishment.

The average cost of the intervention, calculated from the 34 cases with available data, amounts to €4,654 (€4,520) excluding VAT (median: €4,398), with values ranging from €500 to €11,170. Practically all of the retrofits (33/34) took place in August 2023.

Socioeconomic Profile

Socioeconomic data show the lowest response rates across all variable blocks. Among households with available information and of Spanish nationality, the available information is as follows.

Regarding employment status, of the 11 households with available data, 7 declare themselves employed and 4 unemployed. In terms of tenure, the majority of households are outright owners without a mortgage [22], followed by owners with a mortgage (3) and tenants (2); there is also one case of a reduced-rent tenant.

Concerning income, using the annual household income, the sample shows an average of €11,770/year (~€981/month) and a median of €10,800/year (~€900/month), with values ranging from a minimum of €2,240 to a maximum of €21,138. When adjusted for household composition using the OECD-modified equivalence scale, the equivalent income averages €8,663/year (~€722/month) and shows a median of €9,696/year (~€808/month), ranging from €1,120 to €14,092/year.

These figures confirm a clearly low or very low income profile, with the median falling below Spain's at-risk-of-poverty threshold, estimated at around €12,000–14,000 per year for a single-person household according to INE data.

Regarding benefits and subsidies, of the 19 households with available data, 5 declare receiving some form of assistance, although none of them has applied for help with bill payments. Cases recorded include the social electricity tariff (*bono social eléctrico*) [9], unemployment benefit, and the Active Insertion Income scheme (RAI) [4], as well as other forms of support such as telecare services or disability allowances.

Baseline Energy Situation

Regarding the market type, of the 21households with available data, 12 operate under the free market and 9 under the regulated market (PVPC). The predominant tariff is the flat-rate tariff (11 households versus 9 with time-of-use pricing).

The price per kWh declared at the time of the survey shows an average of €0.21/kWh for households in the free market with available data, with values ranging from €0.14 to €0.33/kWh. In the 2025 follow-up, the 4 households with updated data show an average price of €0.14/kWh, suggesting an improvement in contractual conditions following the intervention.

The self-reported monthly electricity expenditure, available for 11 households, shows a median of €50/month and a mean of €57/month. Gas expenditure, available for 10 households, yields a median of €42.5/month and a mean of €85/month, reflecting considerably greater dispersion. Of all households with available information, 12 declare using natural gas in their dwelling.

Climatic Zone of Getafe/Madrid

Getafe is located in climatic zone D3 according to the Spanish Technical Building Code (CTE), corresponding to the city of Madrid and its metropolitan area. This zone is characterized by a continental Mediterranean climate with cold winters and very hot summers: mean temperatures in January hover around 5–6 °C, with lows that can drop below 0 °C, while in July and August maximum temperatures routinely exceed 35 °C, with increasingly frequent and intense heatwave episodes. Climatic severity is therefore high in both seasons, implying a substantial potential energy demand for both heating and cooling.

This context is particularly relevant for households in energy poverty, given that the inability to maintain comfortable temperatures in winter or summer has direct consequences for the health and wellbeing of occupants (ref. 24).

4.1.2 RESULTS OF THE HOUSEHOLD SIZE ESTIMATION

The estimated household sizes ranged from 1 to 3 occupants across the 11 cases, with results presented in Table 1. The majority of households were assigned 2 occupants, consistent with the predominance of married or formerly married individuals in the sample and the surface area values recorded. Three households were assigned a single occupant, all corresponding to separated or widowed individuals with consistently low energy consumption across Methods 2 and 3. In these cases, the convergence between methods was strong enough to depart from the surface-area estimate, which systematically pointed to 2 occupants.

Three households presented particular challenges. Household HH1 could not be assessed through Methods 2 or 3, as the household was on a flat-rate electricity tariff, making consumption data unavailable. The final estimate of 2 occupants, therefore, relied exclusively on Method 4 and the married civil status of the participant. In the case of HH4, Method 2 indicated 4 occupants while Method 4 suggested 2; the two methods yielded a plausible range rather than converging on a single value, and 3 was assigned as the most consistent intermediate estimate given the survey respondent's married status. Finally, household HH10 presented a severe inconsistency between declared income and electricity expenditure, making Methods 1 and 2 unreliable. The final estimate of 3 occupants was based on civil status, dwelling size, and the total energy consumption attributable to electric radiator use.

HOUSEHOLD ID	CIVIL STATUS	M1 INCOME	M2 ELEC. CONS.	M3 TOTAL EXP.	M4 M²	FINAL EST.	JUSTIFICATION
HH1	Married	≥1	*	*	1.81	**2**	M4 only available; civil status confirms ≥2
HH2	Divorced	≥1	2-3	4+	2.02	**2**	M4 and M2 converge
HH3	Separated	≥1	1	2	1.81	**1**	M2 low; civil status supports single occupant
HH4	Married	≥1	4	1-2	2.17	**3**	M2 points to 4; M4 lower bound 2; midpoint + married
HH5	Divorced	≥1	3-4 (radiator)	1-2	1.87	**2**	M2 inflated by electric radiators; M4 and M3 support 2
HH6	Widowed	≥1	1 (radiator)	1	1.81	**1**	M2 and M3 converge at 1; widowed supports single occupant
HH7	Separated	≥1	1	1	1.90	**1**	M2, M3 converge at 1; civil status supports single occupant
HH8	Married	≥2	1-2	2	1.99	**2**	All methods converge at 2
HH9	Married	≥2	3-4	1-2	2.07	**2**	M4 and M1 confirm 2; M3 supports; married
HH10	Married	≥1	4+ (radiator)	3	2.10	**3**	Severe inconsistency; M2/M3 inflated by radiators; married + m²
HH11	Married	≥2	1-2	4+	2.17	**2**	M4, M1 and M2 converge at 2

Table 1: Household size estimation

4.1.3 REQUIRED ENERGY EXPENDITURE

To obtain the RENE of each household, the DIAGNÓSTICO tool (based on the RENE model) was supplied with a set of household-specific inputs: the number of occupants, the floor area, the presence or absence of air conditioning and the conditioned floor area, the heating system (gas boiler, electric radiators, or heat pump), the domestic hot water system, and the ownership of an oven, a washing machine, and a dishwasher. For households with incomplete information, a set of conservative assumptions was adopted: the regulated tariff was assumed when the contract type was unknown, 50% of the dwelling was assumed to be cooled when cooling was not reported, a gas boiler was assumed when the heating system was not reported (being the most common system in the sample), and the domestic hot water system was inferred from the heating system.

The tool was parameterized with 2023 energy prices, differentiating regulated and free-market contracts for both electricity and gas. For the regulated market, the fixed and variable terms of the natural gas tariff of last resort (RL1 and RL2) were taken from the corresponding resolution published in the BOE (*Boletín Oficial del Estado*, Official State Gazette) [43], while the regulated electricity terms were obtained from the electricity bill comparator of the CNMC (*Comisión Nacional de los Mercados y la Competencia*, National Commission on Markets and Competition) [44], with the system charges established by Order TED/1138/2023 [45]. These parameters are reported in Table 2. For free-market contracts, where the fixed-term data were not available, only the variable terms were modified, and the regulated fixed terms were retained. The resulting RENE combines, for each household, the theoretical expenditure on electricity and on fuel (natural gas).

Energy	Period / tariff	Fixed term (€/month)	Variable term (€/kWh)
Gas	RL1 (low)	4.43 €/month	0.045722 €/kWh
Gas	RL2 (standard)	8.30 €/month	0.042823 €/kWh
Electricity	P1 (peak)	2.11525 €/month	0.208856 €/kWh
Electricity	P2 (standard)	0.11189 €/month	0.114111 €/kWh
Electricity	P3 (off-peak)	----------	0.117634 €/kWh

Table 2: Energy price parameters of the regulated market (2023) – Source: [43], [44], [45]

The estimated RENE ranged from approximately 1,410 to 3,330 €/year (around 118 to 277 €/month), with a mean of 2,229 €/year and a median of 2,450 €/year. Despite the relative homogeneity of the sample, the variation is substantial, with the highest estimated expenditure exceeding twice the lowest. This dispersion is noteworthy given that all

dwellings are located within the same municipality, belong to a relatively narrow floor-area range (54–70 m²), and are subject to the same climatic conditions.

The variation is therefore explained mainly by the energy configuration of each household, in particular the heating system and the associated domestic hot water supply, rather than by dwelling size or location. Electric resistive heating results in the highest theoretical expenditures, whereas the lowest value corresponds to the dwelling equipped with a heat pump. Among households using natural gas, the remaining variation is comparatively limited and seems to be linked to differences in energy contracts.

Comparing theoretical energy expenditure with households' reported expenditure reveals a widespread pattern of under-consumption. In nine of the eleven households, reported energy spending is lower than the estimated RENE, while in five cases it falls below 50% of the theoretical requirement, meeting the threshold used to identify hidden energy poverty through the HEP indicator. The largest discrepancies are observed in dwellings heated with electric resistive radiators. Two of these households report spending only between one-fifth and one-third of their estimated energy needs, representing the lowest expenditure-to- RENE ratios in the sample. This finding is consistent with the high operating costs of resistive heating, which substantially increase theoretical energy requirements and, consequently, the gap between required and affordable actual consumption. Although under-consumption is also present in some gas-heated dwellings, the results suggest that the heating system influences not only the level of theoretical energy expenditure but also the extent to which households are forced to consume below their energy needs.

4.1.4 OBJECTIVE ENERGY POVERTY INDICATORS

The objective energy poverty indicators provide a multidimensional assessment of household vulnerability by capturing different manifestations of energy deprivation. While some indicators identify households that devote an excessive share of their income to energy expenditure, others focus on households whose spending is insufficient to meet their energy needs. The results presented below are based on the eleven households for which complete income and expenditure data were available.

The indicators associated with excessive energy expenditure identify a significant incidence of energy poverty within the sample. The 10% indicator identified 5 households (45%). The 2M indicator flagged 7 households (64%) in both its per-household and per-equivalent-person formulation. A positive result under either indicator means the household is spending disproportionately on energy relative to its income.

A different pattern emerges when underconsumption indicators are examined. The M/2 indicator, which classifies a household as energy poor when its energy expenditure falls below half the national median equivalized expenditure, identified no households (0%). The MIS indicator, which identifies energy poverty when, after accounting for the minimum income standard, a household lacks sufficient resources to cover its energy bill, flagged 8 households (73%) at both the household and per-person level.

The results are also consistent with the presence of hidden energy poverty. The HEP indicator identified 5 households (45%) as energy poor. These households spend less than half of their theoretical energy expenditure requirement, suggesting that affordability constraints are leading them to consume substantially less energy than would be needed to achieve adequate living conditions. This finding suggests that affordability constraints are forcing households to reduce their energy use well below the level required to satisfy basic thermal and electricity needs. Rather than appearing as high spenders or accumulating unpaid bills, these households cope by limiting consumption, often at the expense of comfort and well-being. The fact that nearly half of the sample meets this stricter definition reinforces the evidence of widespread underconsumption.

Taken together, the objective indicators point primarily to a problem of disproportionate expenditure relative to income rather than of severe under-consumption. The disproportionate-expenditure indicators are the most prevalent, with MIS flagging eight households and 2M and 10% flagging seven and five respectively, while under-consumption is captured only by HEP, positive in five cases, and by no household under M/2. Overall, these findings provide an objective profile of energy poverty within the sample and highlight the importance of combining multiple indicators, as each captures a different dimension of energy vulnerability.

4.1.5 SUBJECTIVE ENERGY POVERTY INDICATORS

The Getafe vulnerable household questionnaire covered thermal comfort, affordability of heating and cooling, building condition, and economic strain, based on households' perceptions and experiences of their dwellings. These subjective indicators complement the quantitative energy-poverty metrics by capturing the lived experience of the home, which the expenditure-based indicators alone do not reveal. They are particularly relevant for identifying hidden energy poverty, in which households restrict consumption rather than fall into arrears, thereby remaining invisible to indicators based on payment default. This section reports the responses of the 20 households for which subjective data were available. Coverage varies by item, from 18 or 19 households for the core comfort questions to only 7 for the post-retrofit items, so each result is reported against the number of households that actually answered rather than the full sample.

Thermal comfort and affordability

The responses reveal widespread thermal discomfort throughout the year. In winter, 17 of the 18 responding households (94%) reported that cold conditions affect how they use their dwelling, while 14 of 19 (74%) reported feeling cold indoors. More than half of respondents (10 of 18, 56%) stated that they could not afford adequate heating. Summer conditions appear to be even more problematic. All 17 households that answered the corresponding question reported that heat affects the use of their dwelling, and 15 of 19 (79%) reported feeling excessively hot indoors. Furthermore, 12 of 18 households (67%) indicated that they could not afford to maintain an adequate indoor temperature during the summer months. Taken together, these

results suggest that thermal deprivation is not limited to winter heating needs but extends across both seasons.

Building conditions and thermal vulnerability

The housing conditions reported by respondents help explain the high levels of thermal discomfort and affordability difficulties observed above. Air infiltration through windows was reported by 12 of the 17 households that answered the question (71%), while 8 of the 12 households that assessed the façade considered it to be in poor condition. Deficiencies in the building envelope increase heat losses during winter and heat gains during summer, making it more difficult and costly to maintain adequate indoor temperatures. These conditions are consistent with the large proportion of households reporting cold indoor environments, difficulties in affording adequate heating or cooling, and thermal discomfort even when heating systems are in use.

General dampness was reported by 9 of the 15 households that answered the question (60%), while leaks and interior-wall damp were reported by 2 of 8 and 3 of 10 households, respectively. Beyond its implications for habitability, dampness can further reduce thermal comfort and increase energy needs by worsening the thermal performance of the dwelling. Other reported problems, including lack of natural light, unpleasant odours, external noise, and insufficient dwelling size, were comparatively less frequent and appear less directly related to energy vulnerability. Overall, the results suggest that deficiencies affecting the thermal performance of the dwelling (particularly air leakage, poor façade conditions, and dampness) are more relevant to households' energy situation than other housing-quality concerns.

Economic strain on energy

The subjective indicators also reveal substantial energy-related financial stress. Two-thirds of responding households (10 of 15) reported experiencing difficulties related to energy costs, and more than half (8 of 15) considered their energy expenditure excessive. In contrast, no respondent reported electricity bill arrears or supply disconnections during the previous year. This combination of significant perceived difficulty and very low levels of payment default is particularly noteworthy, as it suggests that many households cope by reducing consumption rather than by accumulating debt. This subjective evidence therefore supports the findings obtained from the objective indicators, which pointed to underconsumption and hidden energy poverty as the dominant forms of energy vulnerability within the sample.

Perceived effects of the retrofit

The post-retrofit questions were answered by only seven households. Nevertheless, six of the seven respondents reported being able to maintain an adequate indoor temperature after the intervention, both in winter and in summer. Although the limited coverage prevents robust conclusions regarding the effectiveness of the

renovations, the available responses point to a generally positive perceived impact on thermal comfort.

4.1.6 CONSISTENCY OF THE RESULTS AT THE INDIVIDUAL HOUSEHOLD LEVEL

This section relates the theoretical energy expenditure, the objective indicators, and the subjective comfort responses at the level of each individual household, assessing whether the different measures provide a consistent picture of energy vulnerability and what their combined interpretation reveals. The relationship between theoretical and actual expenditure is examined using their ratio (AEE/ RENE) reported in Table 3. This ratio divides the sample into two groups: households spending at or above their theoretical needs, and households spending well below them.

Table 3 presents the household-level results for the eleven households with complete objective data. For each household, it reports the required energy expenditure (RENE), the actual energy expenditure (AEE), the AEE/RENE ratio, the results of the five objective energy poverty indicators (10%, 2M, M/2, HEP, and MIS), and the reported adequacy of indoor temperature (Temp OK). To facilitate interpretation, the table uses a color-coding scheme: green indicates a favourable outcome, meaning that the household was not classified as energy poor by the corresponding indicator or reported adequate indoor thermal comfort, whereas red indicates the opposite, identifying households classified as energy poor or reporting inadequate thermal comfort.

HH	RENE (€/year)	AEE (€/year)	AEE/ RENE (%)	10%	2M	M/2	HEP	MIS	Temp ok in winter	Temp ok in summer
HH1	1,761	2,424	138%							
HH2	2,761	4,560	165%							
HH3	1,623	1,140	70%							
HH4	1,453	960	66%							
HH5	2,630	840	32%							
HH6	2,450	528	22%							
HH7	1,411	444	31%							
HH8	2,747	1,200	44%							
HH9	1,910	900	47%							
HH10	2,553	1,560	61%							
HH11	3,329	2,400	72%							

Table 3: Energy expenditure, objective indicators, and reported thermal comfort by household

Despite the diversity of expenditure patterns observed across the sample, none of the eleven households is flagged by the M/2 indicator. No household reports an energy expenditure below half the national equivalized median, indicating that none reaches the threshold of severe under-consumption captured by this indicator. Therefore, the distinction between households, lies in how this baseline condition interacts with the other objective indicators and with reported thermal comfort outcomes.

Only two households exceed their theoretical requirement, the over-consuming households HH1 (138%) and HH2 (165%). Both households exceed their RENE and are identified by the 10%, 2M and MIS indicators, which is consistent with a situation of disproportionate energy expenditure rather than under-consumption. HH1 reports winter discomfort, while HH2 reports summer discomfort, suggesting that high expenditure does not translate into adequate comfort across seasons, potentially due to the low thermal efficiency of the dwellings.

The remaining nine households spend below their theoretical requirement, although they do not form a homogeneous group. Their situations can be grouped into four distinct patterns according to how the objective indicators interact with reported thermal comfort.

The first group, moderate under-consumers, HH3 (70%) and HH4 (66%), spends moderately below their RENE and is identified by 2M, which captures a disproportionately high share of income spent on energy, and by MIS, which indicates that their residual income after energy costs falls below the minimum income standard. Both report adequate winter comfort and summer discomfort. Their expenditure falls clearly below the theoretical requirement, yet not far enough to cross the stricter HEP and M/2 thresholds, which places them in an intermediate position rather than in clear hidden energy poverty. Combined with discomfort reported only in summer, this suggests that cooling, rather than heating, is the unmet need in these dwellings, while still reflecting the affordability constraints captured by the objective indicators.

The second group, compound vulnerability, consists of HH5 alone (32%), the only household identified by the 10%, 2M, HEP and MIS indicators simultaneous. It is heated with electric resistive radiators, which raise its theoretical requirement well above the level implied by gas boilers or heat pumps and largely explain the wide distance between its theoretical and reported expenditure. Spending barely a third of its theoretical requirement while triggering these four indicators, it represents the most severe objective profile in the sample. Yet it reports adequate winter comfort and discomfort only in summer. The contrast between this set of objective flags and the reported winter comfort suggests severely restricted consumption that the household has come to accept as normal.

The third group, hidden energy poverty households, HH6 (22%), HH7 (31%), HH8 (44%) and HH9 (47%), share the under-consumption signature, all identified by HEP, but differ in reported comfort. HH6 and HH7 are additionally flagged by MIS, indicating a residual income below the minimum standard, while HH8 and HH9 are not. Among them, HH6 shows the widest gap between theoretical and reported expenditure in the entire sample, a distance its electric resistive radiators help explain. Even with this gap, HH6 reports adequate comfort in both winter and summer, a surprising result that points to consumption restricted to the point of being accepted as normal. HH7 likewise reports adequate winter comfort, while HH8 and HH9 report winter discomfort, so for these two the objective indicators and the subjective responses reinforce one another. HH8 additionally reports summer discomfort. These households illustrate that the severity of energy vulnerability cannot be inferred from expenditure patterns alone, as similar objective profiles may correspond to different comfort outcomes.

The fourth group (the Energy Burdened), HH10 (61%) and HH11 (72%), is identified by 10%, and 2M but not by HEP, and both report winter discomfort. What differentiates them is income: HH10 declares only 187 € per month and is flagged by MIS, while HH11 has a higher income of 1,750 € per month, and even though its energy spending is also higher, that income keeps it above the MIS threshold, so the indicator does not flag it.

Read together, the household-level analysis shows that disproportionate expenditure relative to income, rather than under-consumption, is the more prevalent dimension across the sample, with MIS, 2M and 10% each flagging a majority or near-majority of households. This does not imply high consumption: nine of the eleven households spend below their theoretical requirement, so the disproportion arises from low incomes rather than from excessive energy use. The objective and subjective readings usually align, but not always: households with very low consumption such as HH5, HH6 and HH7 report adequate winter comfort, whereas others report discomfort, which confirms that each household's situation is characterized fully only when theoretical need, real expenditure, and lived experience are read together.

This interpretation is reinforced by the payment data: no household reported arrears on utility bills or supply disconnections during the previous year. The combination of widespread disproportionate energy expenditure and almost no payment default suggests that households manage financial pressure by restricting or adjusting their energy use instead of falling behind on payments. This highlights the limitations of relying exclusively on conventional indicators of financial hardship and reinforces the need to assess energy poverty through a combination of objective indicators, reported thermal comfort, and payment-related information in order to obtain a more comprehensive picture of household energy vulnerability.

4.1.7 ENERGY IMPACT OF THE SHALLOW RENOVATIONS

The impact of each renovation on theoretical energy expenditure was estimated by modelling the improvement introduced. Most interventions in the sample are passive measures acting on the envelope, mainly the replacement windows, together with painting and damp treatment. A few renovations also included active measures, such as a SIBER ventilation system, a bathroom extractor and a split air-conditioning unit, in some cases combined with envelope works within the same intervention.

Each renovation measure was assigned a demand-reduction percentage representing the expected decrease in the building's energy demand resulting from the intervention, whether through the improved thermal performance of the envelope, such as new windows or insulation, or through the higher efficiency of the active systems installed. This percentage was incorporated into the DIAGNÓSTICO tool, and the dwelling was subsequently re-simulated using the updated parameters to calculate a new theoretical energy expenditure, following the methodology established in the VAREX-2022 [31] procedure.

Consequently, the post-renovation theoretical expenditure was not obtained by directly applying the percentage savings to the pre-renovation expenditure (as applied in the most cases of VAREX-2024). Instead, it resulted from a complete re-simulation of the dwelling after incorporating the effects of the intervention.

Furthermore, two simplifications were adopted for lack of sufficient information. Painting was not credited with any demand reduction, since the purpose behind it (decorative or thermal) and the type of paint applied were not recorded, so no thermal effect could be reliably attributed. For the replacement of windows the size, number and original condition of the elements were not available either. Moreover, the simulation tool does not distinguish between partial and complete replacement of exterior carpentry, treating any window replacement as if all windows in the dwelling had been replaced. Consequently, the estimated reduction in energy demand is applied to the entire building envelope rather than only to the renovated elements. Therefore, the variation in estimated energy savings across households reflects the specific characteristics of each dwelling captured by the simulation, rather than the scale of the intervention itself.

Table 4 presents the theoretical energy expenditure before and after the intervention (RENE pre and RENE post), together with the estimated annual energy savings for the eleven households.

HH	Renovation	RENE pre (€/year)	RENE post (€/year)	Annual savings (€)	Reduction (%)
HH1	Windows + painting	1,761	1,575	186	10.6%
HH2	Windows + painting	2,761	*2,524*	*237*	*8.6%*
HH3	SIBER ventilation system	1,624	1,480	144	8.9%
HH4	Renounced, not executed	1,453	-	-	-
HH5	Windows + bathroom extractor	2,630	2,415	215	8.2%
HH6	Windows + damp treatment	2,450	2,235	216	8.8%
HH7	Windows	1,411	1,320	91	6.4%
HH8	No renovation data	2,747	-	-	-
HH9	Windows + shutter cord	1,910	1,811	100	5.2%
HH10	Kitchen ceiling repair + split AC	2,553	2,359	194	7.6%
HH11	No renovation data	3.329	-	-	-

Table 4: RENE before and after shallow renovations and estimated energy savings by household

As shown in Table 4, the impact of the renovations on theoretical energy expenditure varies across the sample depending on the type of intervention implemented and the characteristics of each dwelling. All retrofitted households experienced a reduction in their theoretical energy expenditure following the renovation, although the magnitude of the savings varies across cases, with three households showing no change.

Three households show no change in theoretical expenditure for data or retrofit constraints. HH4 renounced the planned bathroom renovation, which was therefore never carried out, leaving its post-renovation RENE identical to the pre-renovation value. HH8 and HH11 have no renovation recorded in the available data, and their theoretical expenditure consequently remains unchanged. As a result, no improvement in energy performance can be attributed to the programme for these three households.

The windows interventions implemented in HH1, HH2, HH5, HH6, HH7 and HH9 reduced the theoretical energy expenditure by between 5.2% and 10.6%. Although these values are lower than the 13% demand-reduction percentage assigned to the measure, this difference is expected. The 13% reduction applies only to the heating and cooling demand affected by the renovation, whereas the theoretical energy expenditure (RENE) also includes other energy uses that remain unchanged. Consequently, when the dwelling is re-simulated in the DIAGNÓSTICO tool, the reduction in total theoretical energy expenditure is smaller than the nominal demand-reduction percentage associated with the intervention.

HH10 underwent a ceiling repair in the kitchen together with the installation of a new split air-conditioning unit. For this household the intervention was modelled as an improvement in the dwelling's insulation and an improvement in the efficiency of the air-conditioning system, under the assumption that a cooling system was already present, since the survey did not indicate otherwise. Both measures therefore reduced the theoretical energy demand, and the resulting net reduction in theoretical expenditure was 7.6%.

HH3 represents a special case that falls outside the standard VAREX-2022 methodology. The dwelling had neither a heating nor a cooling system installed before the renovation and was instead equipped with a SIBER mechanical ventilation system. However, the DIAGNÓSTICO tool does not allow a dwelling to be modelled without a heating system, making it necessary to assume the presence of climate-control equipment before the intervention. Consequently, the estimated savings depend on the assumptions made regarding the pre-renovation conditions. Assuming that both heating and cooling systems had been available before the intervention results in an estimated reduction of 8.9%. In contrast, assuming that only a heating system was present leads to a lower pre-renovation theoretical expenditure and, consequently, no estimated savings from the intervention. Since these results rely on assumptions that cannot be verified from the available information, HH3 cannot be interpreted on the same basis as the other households.

Overall, the shallow renovation measures produced modest but consistent reductions in theoretical energy expenditure when implemented, with most estimated savings ranging from 5% to 11%. These findings suggest that the interventions improved the energy performance of the dwellings without fundamentally altering their overall energy demand. At the same time, the results highlight that the estimated impact is influenced by the specific characteristics of each dwelling, particularly the presence or absence of climate-control systems, as illustrated by HH3.

4.1.8 POST RENOVATION HEP ASSESSMENT

Prior to the implementation of the shallow renovations, five of the eleven households (45%) were identified as experiencing HEP Since the interventions are expected to reduce the required energy expenditure of the dwelling, this section evaluates whether these improvements are sufficient to modify the HEP status of the households or, where this is not the case, to reduce the severity of hidden energy poverty by narrowing the HEP gap.

Table 5 presents the HEP status of each household after the implementation of the shallow renovations, together with the HEP gap before and after the intervention and the corresponding percentage reduction. While the HEP indicator identifies whether a household remains in hidden energy poverty, the HEP gap provides additional information on the severity of the condition by quantifying the difference between half of the required energy expenditure and the household's actual energy expenditure.

To facilitate interpretation, the table uses a color-coding scheme: green indicates a favourable outcome, meaning that the household was not classified as energy poor according to the HEP indicator after the renovation, whereas red identifies households that remained in hidden energy poverty. A zero reduction indicates that no intervention was made, while a dash (–) indicates that the household's actual energy expenditure exceeded its required energy expenditure and, therefore, no HEP gap exists.

Household	HEP after	HEP gap after (€/year)	HEP gap before (€/year)	HEP gap reduction (%)
HH1		-	-	-
HH2		-	-	-
HH3		340.4	483.96	30%
HH4		493.39	493.39	0%
HH5		1575.09	1789.65	12%
HH6		1706.85	1922.41	11%
HH7		875.9	966.53	9%
HH8		1547.02	1547.02	0%
HH9		910.53	1010.35	10%
HH10		799.29	993.20	20%
HH11		928.81	928.81	0%

Table 5: HEP status after the renovation and changes in the HEP gap

As shown in Table 5, the shallow renovations did not modify the overall incidence of hidden energy poverty within the sample. Five of the eleven households (45%) remained classified as HEP after the intervention, indicating that the estimated reductions in required energy expenditure were not sufficient to change the HEP status of any household.

Nevertheless, the interventions reduced the HEP gap in all households for which a reduction in the required energy expenditure was estimated. The greatest improvement was observed in HH3, where the HEP gap decreased by 30%, followed by HH10 with a 20% reduction. Although neither household was classified as HEP before or after the intervention, these results reflect a greater margin between actual and minimum required energy expenditure. Among the households that remained in hidden energy poverty, the reduction in the HEP gap ranged from 9% to 12%, with the largest decrease observed in HH5 (12%), followed by HH6 (11%), HH9 (10%), and HH7 (9%).

Overall, these results indicate that the estimated energy savings achieved through the shallow renovations primarily reduced the severity of hidden energy poverty rather than its prevalence. While the interventions lowered the minimum energy expenditure required to achieve adequate thermal comfort, the reduction was generally insufficient to move vulnerable households above the HEP threshold, suggesting that additional or more comprehensive measures would be necessary to eliminate hidden energy poverty in the most disadvantaged cases.

4.1.9 COST-EFFECTIVENESS AND WELL-BEING IMPACT OF THE SHALLOW RENOVATIONS

Beyond the reduction in theoretical energy expenditure, it is also relevant to assess how the cost of each renovation relates to the savings it generates. One way to evaluate this is through the simple payback period, defined as the number of years required for the estimated annual energy cost savings to recover the initial investment. The simple payback period was calculated by dividing the cost of each intervention by its estimated annual monetary savings. Table 6 presents the resulting values for the households in which a renovation was carried out and resulted in energy savings.

HH	Renovation	Cost (€)	Annual savings (€)	Payback (years)	Improved wellbeing	Improvement in maintaining a comfortable temperature?
HH1	Windows (4) + painting	4,422.70	186	~24	–	Yes, in winter
HH2	Windows (1) + painting	3,380.21	237	~14	Yes (perception of comfort)	Yes, in summer
HH3	SIBER ventilation system	500.00	144	~3,5	Yes (other aspects)	Yes, in winter
HH5	Windows (3)+ bathroom extractor	6,316.72	215	~29	Yes (physical health)	Yes, in summer and winter
HH6	Windows (4) + damp treatment	7,052.82	216	~33	–	Yes, in winter
HH7	Windows	9,402.03	91	~103	Yes (perception of comfort and health)	Yes, in summer and winter
HH9	Windows + shutter cord	2,700.00	100	~27	Yes (perception of comfort)	Yes, in summer
HH10	Kitchen ceiling repair + split AC	2,430.00	194	~13	–	Yes, in winter

Table 6: Payback period of the shallow renovations and reported wellbeing improvement

The renovation costs show noticeable variability across households, even though most interventions consisted of replacing exterior window carpentry. This variability is partly explained by differences in the scope of the works, as the number of replaced windows ranged from a single window unit in HH2 to four units in HH1 and HH6. However, some cases cannot be readily explained by the available information. In particular, HH7 records the highest renovation cost in the sample, although the intervention is only described as window replacement, with no further details regarding the number or characteristics of the elements replaced. By contrast, HH2 presents a relatively high investment despite the intervention being reported as the replacement of a single window. Since the renovation costs were provided directly by Naturgy, they are reported without modification and no additional assumptions have been made to explain these differences.

The estimated simple payback periods vary substantially across the sample, reflecting differences in both renovation costs and annual energy cost savings. However, the relationship between investment cost and payback should be interpreted with caution. While the investment reflects the actual extent of each intervention, the estimated energy savings are obtained using the DIAGNOSTICO tool, which assumes that all windows and exterior carpentry elements of the dwelling are replaced, regardless of the number of units actually renovated. As a result, households such as HH1 and HH6, where four windows were replaced, and HH5, where three windows were replaced, achieve estimated savings of a similar magnitude to HH2, where only one window was replaced, consequently leading to payback periods that are generally lower than would be expected given the larger scale of the intervention.

The estimated simple payback periods vary substantially across the sample, reflecting differences in both renovation costs and annual energy cost savings. For the window-carpentry interventions, the estimated payback ranges from approximately 14 years to over 100 years. Although a payback period of approximately 103 years appears unusually high, it is largely explained by the comparatively low required energy expenditure of HH7, both before and after the renovation. Consequently, even though the percentage reduction in energy demand is similar to that achieved in other households, the absolute reduction in theoretical energy expenditure, and therefore the annual monetary savings, is much smaller, resulting in a substantially longer payback period. By contrast, the shortest payback periods are observed in HH2, HH3 and HH10, primarily because of their lower intervention costs rather than exceptionally large energy savings. Overall, households with similar reductions in theoretical energy expenditure may exhibit markedly different payback periods due to differences in investment costs.

It should also be noted that the payback periods are based on estimated savings derived from the reduction in theoretical energy expenditure. Theoretical expenditure represents the energy required to maintain adequate indoor comfort conditions rather than the households' actual energy consumption. Consequently, the estimated monetary savings used in the calculation may differ from the savings experienced in practice, particularly in households that consume less energy than their theoretical requirements.

This gap between theoretical and actual savings points to what the payback period fails to capture, whereas the energy poverty gap attempts to address it. In households that already restrict their consumption below what they need, a lower theoretical requirement does not necessarily translate into a smaller bill, because the bill was never proportionate to the requirement in the first place. The more meaningful effect of the renovation is not monetary. It lies in the possibility of converting part of the repressed demand into comfort, so that the same expenditure now delivers a warmer or more stable indoor environment.

This interpretation is consistent with the reported outcomes. Several of the households that underwent a renovation reported improvements in their well-being following the intervention, including enhanced thermal comfort, better physical health, or both. These findings suggest that the benefits of the renovations are not fully reflected by the estimated economic return alone. While the payback period captures the direct monetary savings associated with lower theoretical energy expenditure, it does not account for improvements in living conditions experienced by the households.

4.2 RESULTS OF THE ENERGY-SAVING WORKSHOPS ANALYSIS

This section presents the main results from the analysis of data collected within the *Energía para Todos* project, covering 191 households visited between 2022 and 2026. The analysis is structured into four main blocks. It begins with a characterization of the sample, including sociodemographic factors, housing conditions, and the initial energy situation of participating households. This is followed by an assessment of energy awareness and knowledge, based on a survey conducted during the workshop with a subset of households (starting from 2024). The third block evaluates the potential impact of the recommendations and micro-efficiency kits delivered during the workshops. The section closes with the follow-up process, reporting how many households could be contacted, the extent of the information obtained, and the realized outcomes observed among them. Taken together, these results allow for an assessment of the impact of the workshops, the effectiveness of the follow-up process, and the overall contribution of the intervention.

4.2.1 SAMPLE CHARACTERIZATION

The following sections present the results of the sample characterization, structured around four dimensions: the sociodemographic profile of the households, their housing conditions, their energy situation prior to the workshop, and the distribution of micro-efficiency kits among participating households.

Sociodemographic profile

The 191 households that participated comprise a total of 390 residents. Women constitute the majority, both as household representatives (78.9%) and among the adult population (61.2%). In terms of age, the distribution is concentrated in children and working-age individuals, while older adults represent a relatively small share. Figure 5 presents the gender and age distribution of the population analysed.

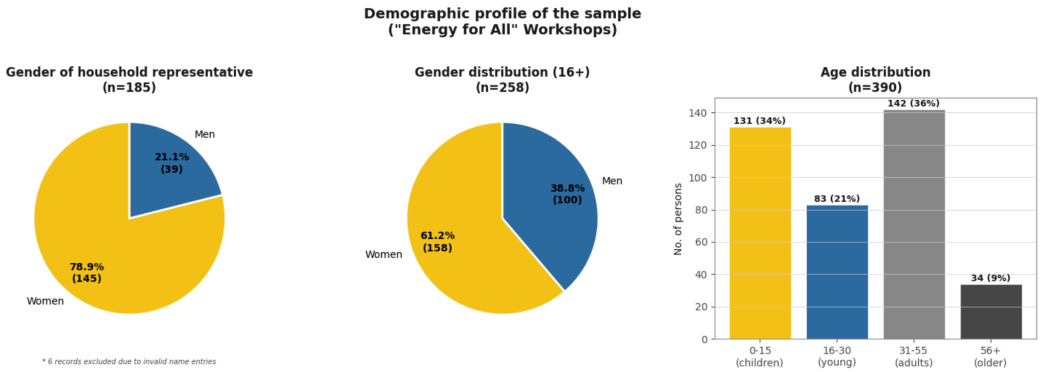

Figure 5: Demographic profile of the sample: gender and age distribution of participating households.

The sample presents a markedly vulnerable socioeconomic profile. Of the 149 households with available income data, the median monthly household income is €700 (below the relative poverty line in Spain in all the workshop years, Spanish SILC), and 39.6% report incomes below €600 per month, a threshold that in the Spanish context is broadly associated with severe economic vulnerability [4]. The mean income of €932 per month is notably higher than the median, suggesting the presence of a small number of households with significantly higher incomes that pull the average upward. Among households with data on composition, the mean household size is 3.5 persons, and 17.7% are classified as large families. Fifteen households receive the Minimum Vital Income (IMV) and 13 receive a minimum pension, reflecting a high concentration of households dependent on public support. 73 households are in one of the special circumstances defined in the social tariff criteria[3].

Figure 6 shows the full income distribution and household size breakdown for the sample.

[3] The special circumstances defined in the social tariff criteria are: disability (recognized degree equal to or above 33%); gender-based violence (accredited by social services or the competent authority); victim of terrorism (status recognized under current legislation); dependency (recognized dependency of grade II or III); and single-parent family (a household formed by a single parent with at least one dependent minor).

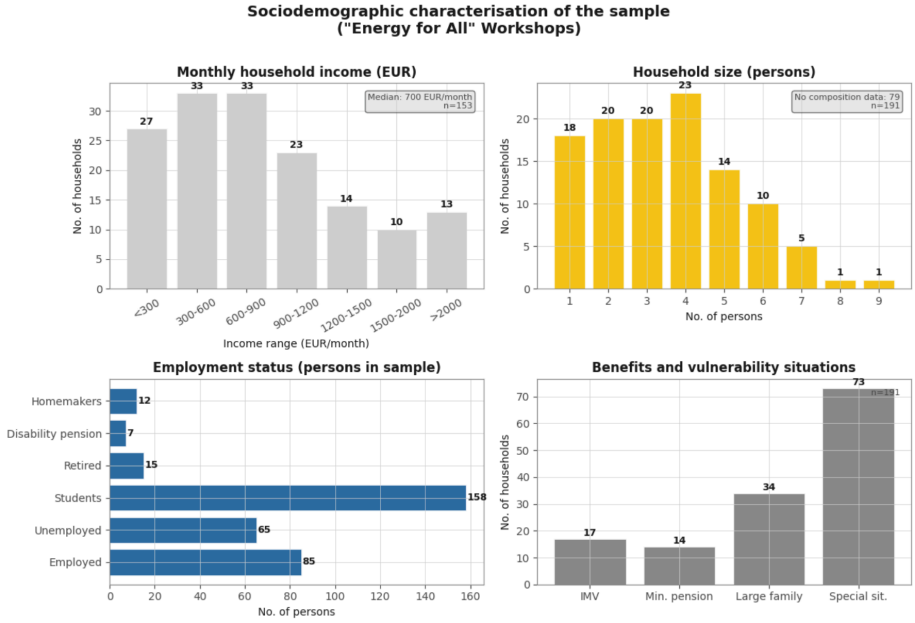

Figure 6: Sociodemographic profile of the sample: monthly household income, household size, employment status, and vulnerability situations.

Housing characteristics

The dwellings in the sample are predominantly small urban flats located in Madrid (94.8%). The median floor area is 65 m², and 84.4% of households live in rented accommodation, a proportion that is particularly relevant in the context of energy interventions, since tenants generally lack the possibility of undertaking structural improvements (landlord-tenant dilemma). In terms of building age, 44.1% of the dwellings for which data are available were built before 1981, meaning they predate the first Spanish thermal regulation (NBE-CT-79) and were constructed without any mandatory insulation requirements. Figure 7 presents the distribution of building age, tenure type, and floor area across the sample.

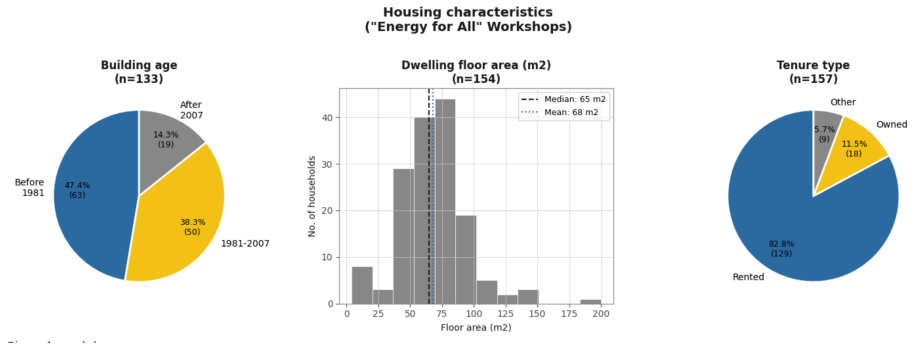

Figure 7: Housing characteristics of the sample: building age, tenure type, and floor area.

The habitability conditions of the dwellings reflect significant deficiencies. Damp is reported by 44.1% of households, air infiltration through windows or doors by 76.5%, and single glazing is present in 66.5% of cases. As a potential consequence of these conditions, 40.9% of households report being unable to keep their home sufficiently warm in winter, and 41.0% report excessive heat in summer. These problems tend to accumulate, on average, each household presents 2.5 habitability problems out of the five assessed, and 47.1% of households report three or more simultaneously. Only 4 households out of 191 report none of the five problems. Figure 8 illustrates the distribution of habitability problems and their accumulation across the sample.

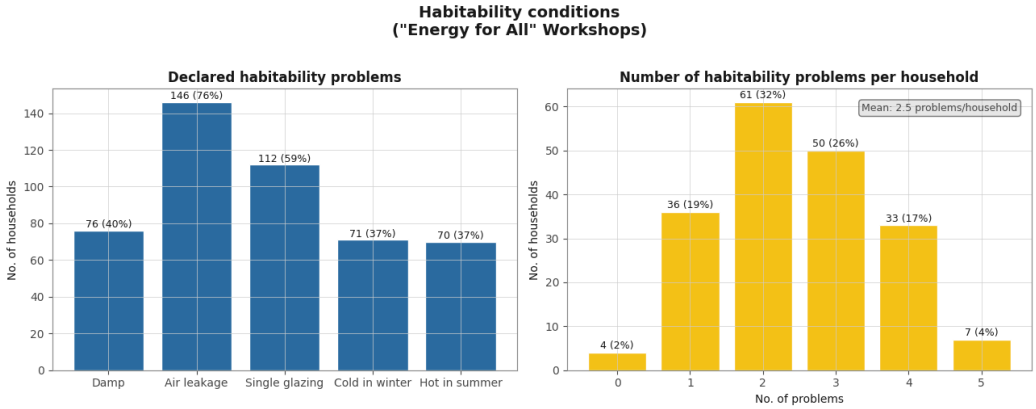

Figure 8: Declared habitability problems and accumulation per household.

The thermal equipment of the dwellings also presents notable inefficiencies. Regarding heating, individual systems predominate (87 households), followed by central heating (34) and portable appliances (31), while 21 households have no heating system at all. In terms of supply, natural gas is the most common (85 households), but 45 households rely on electric resistance heaters, a technology associated with significantly higher energy costs. For domestic hot water, gas is again the primary supply (89 households), followed by electricity (69 households), and 18 households report their water heater to be in poor condition. Regarding lighting, only 62 households have fully LED lighting, while 43 use low-energy bulbs and 58 still rely on incandescent or halogen bulbs, which are considerably less efficient. Figure 9 presents the distribution of heating systems, domestic hot water supply, and lighting types across the sample.

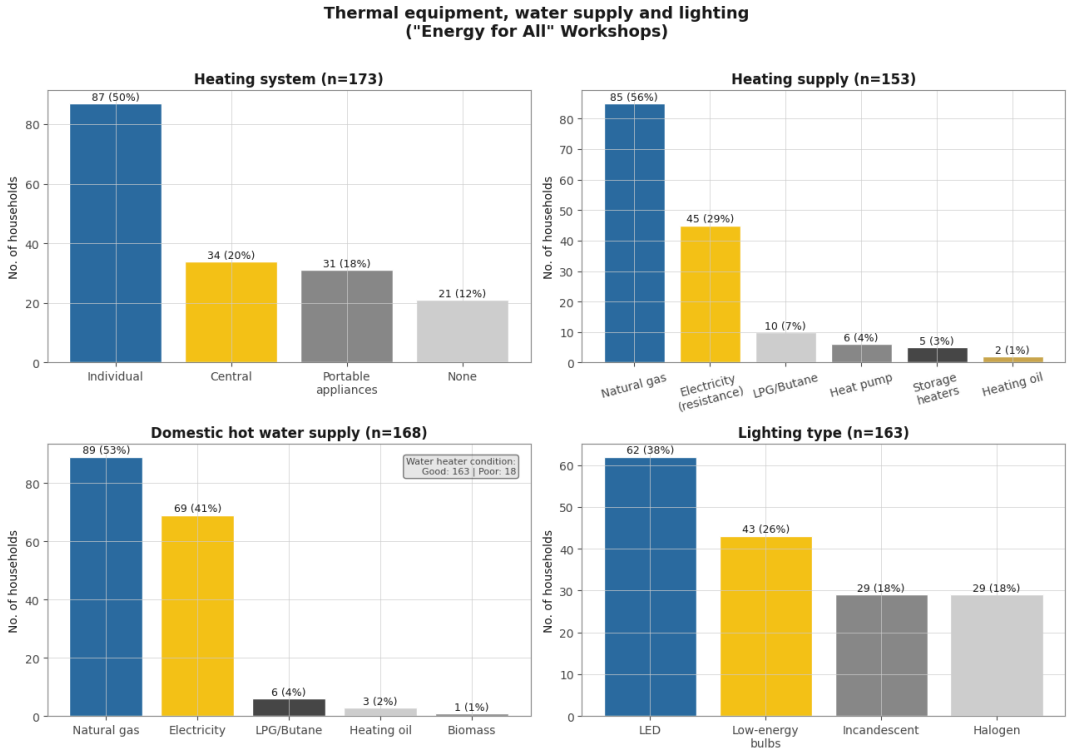

Figure 9: Thermal equipment and lighting: heating system, heating supply, domestic hot water supply, and lighting type.

Micro-efficiency kit distribution

Some of the participating households received a physical kit of micro-efficiency measures during or after the workshop. These kits were designed for the specific needs identified during the diagnostic visit and included items across five main categories: thermal insulation (draught seals, door bottom seals, window insulation film, roller shutter insulators, and radiator reflector panels), thermal comfort (blankets and portable heaters), electrical management (power strips with switches and timer programmers), lighting (LED bulbs E27, E14, and T8 tubes), and water saving (tap aerators). In a small number of isolated cases, appliance replacements were also proposed.

Of the 191 households in the sample, 71 (37%) received at least one physical measure, while the remaining 120 (63%) received personalized energy advice without any accompanying material. Among the 71 households that confirmed to have received a kit[4], the mean number of units delivered was 12.1, with a total of 862

[4] It has not been possible to verify whether the other 120 households have received the kits, but all the kits were delivered to the NGOs' offices

units distributed, ranging from 1 unit in the least equipped household to 25 in the most.

The types of measures delivered are consistent with the household deficiencies identified in the sample, particularly the high rates of air infiltration (76.5%) and single glazing (66.5%), which explain the predominance of draught seals, door bottom seals, and window insulation film in the kits distributed. The most frequently distributed category was thermal insulation, reaching 66 households with a total of 370 units, followed by lighting (51 households, 204 units) and electrical management (62 households, 86 units). At the individual item level, the power strip with switch was the most widely distributed item, reaching 53 households, followed by the tap aerator (46 households) and the door bottom seal and LED bulb E27 (41 households each). Figure 10 presents the distribution by category and by individual item.

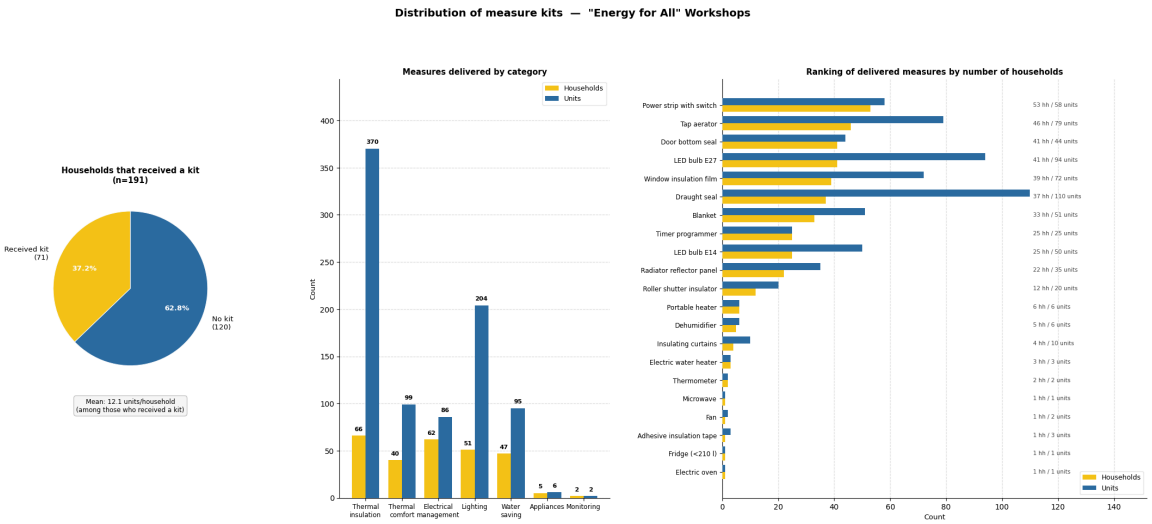

Figure 10: Pre-intervention energy profile

Pre-intervention energy profile

At the time of the workshop, contract ownership and bill comprehension reveal significant barriers among the households visited. Only 77 of the 191 households (40.3%) are registered as contract holders, while 54 (28.3%) are not, and no data are available for the remaining 31.4%. Regarding payment status, 76.2% of households report being up to date with their bills, while 23.8% are behind on payments. Bill understanding is notably low: 53.5% report not understanding their electricity bill at all, 29.8% understand it only partially, and just 16.5% report understanding it fully, which is precisely what motivates this initiative. Figure 11 presents the distribution of contract ownership, payment status, and bill comprehension across the sample.

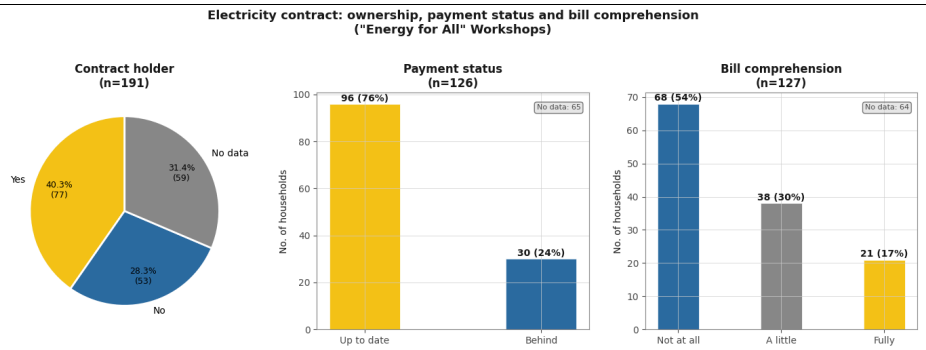

Figure 11: Electricity contract characteristics: ownership, payment status, and bill comprehension

Households were roughly equally distributed across the free market (29.8%) and the regulated market (29.3%), with no contract data available for the remaining 40.8%. Monthly electricity consumption shows considerable variation across the sample: the median is 220 kWh, while the mean is higher at 263 kWh, suggesting the presence of a small number of households with particularly high consumption that pull the average upward.

Against this backdrop, the uptake of the social tariff (*bono social*) remains remarkably low. The vast majority of households were not benefiting from it, of the 122 households with social tariff data, 86 (70.5%) were not holding one. Of the 77 contract holders, 33 are eligible for social tariff but do not currently hold it (21 under the severe vulnerable category and 12 under the standard vulnerable category), which suggests that many eligible households are not accessing the support available to them. Of the remaining 36 that did hold one, the most common modalities were the vulnerable consumer category (12 households) and the 40% discount (11 households).

Figure 12 summarizes the electricity market type, social tariff status, and monthly consumption across the sample.

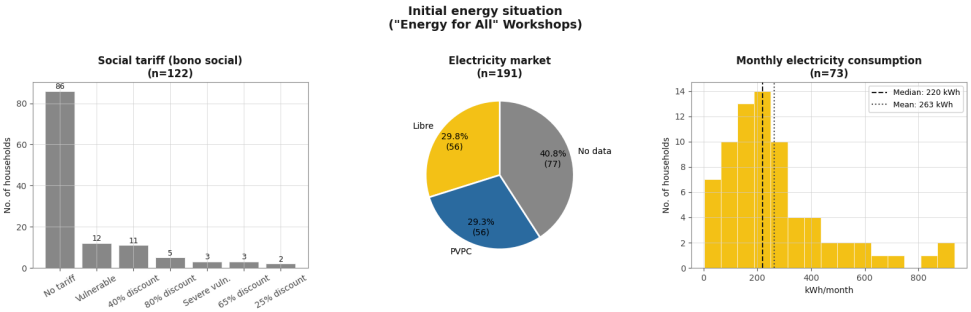

Figure 12: Initial energy situation of the sample: electricity market type, social tariff status, and monthly electricity consumption

4.2.2 ENERGY AWARENESS AND KNOWLEDGE ASSESSMENT

To characterize households' energy awareness and knowledge before participating, a survey was administered to a subset of 44 households prior to the workshops. The survey covers two complementary dimensions.

The first part asks two attitudinal questions: households were asked whether they believe it is possible to reduce their energy bill by changing habits and whether they are familiar with the social tariff available to vulnerable consumers. These questions capture both the household's perceived ability to influence their own energy expenditure and their awareness of the support measures available to them, particularly relevant given that most households in the sample are eligible for the *bono social* but do not currently have it. These results are shown in Figure 13.

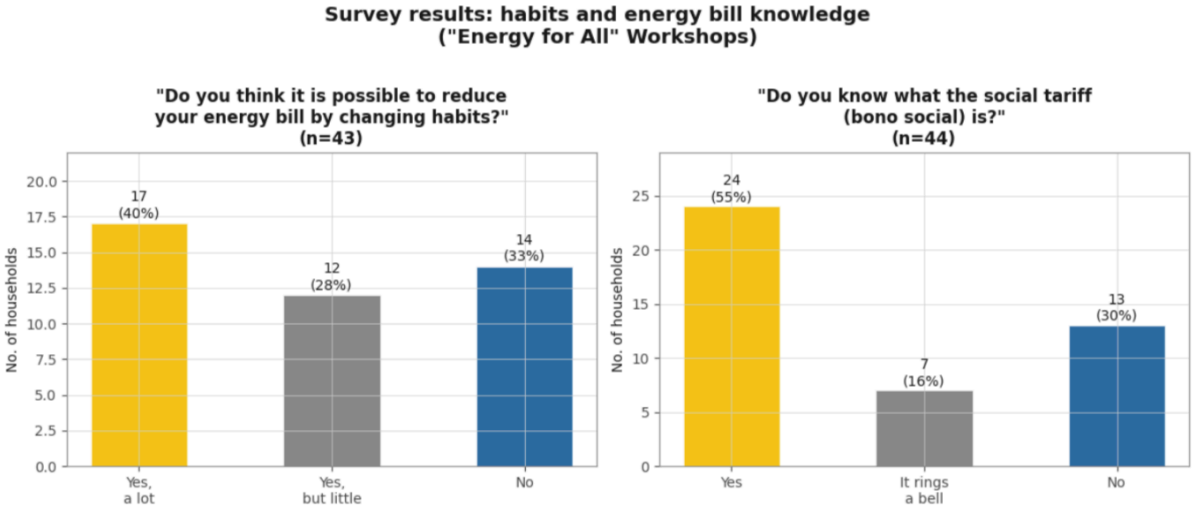

Figure 13: Survey results on energy habits and social tariff awareness

The second part of the survey tests energy knowledge through four true/false questions on everyday domestic consumption. The topics covered are the relative energy use of ironing versus watching television, the effect of ice build-up in the freezer, the difference in energy consumption between cold and hot washing machine cycles, and whether heavy oven use helps save energy. For each question, the proportion of correct, incorrect, and *don't know* responses is reported, and an overall score out of four is calculated per household to assess the level of energy literacy in the sample. The results by question and the score distribution are shown in Figure 14.

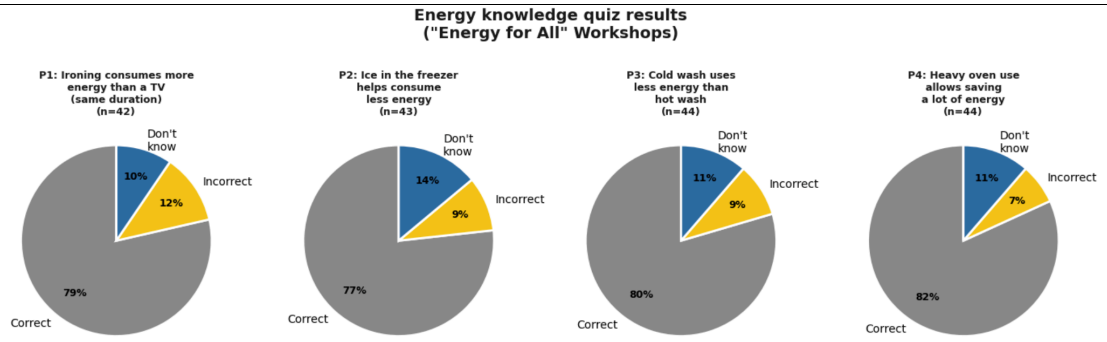

Figure 14: Energy knowledge quiz results among workshop participants

One important limitation of this analysis is that the survey was conducted before the workshop and not repeated afterward, so it captures the participants' starting point rather than the workshop's effect on their awareness and knowledge.

4.2.3 IMPACT OF CONTRACTUAL AND TARIFF RECOMMENDATIONS

Assessing the impact of the Energía para Todos workshops on contractual and tariff recommendations requires distinguishing between potential and realized savings. The recommendations provided during the diagnostic visit target three main areas: *bono social* activation, switching to the regulated market (PVPC) and reduction of contracted power. In all cases, the analysis is necessarily based on potential rather than realized savings, given the limited availability of follow-up data. The barriers that prevent potential savings from being realized are discussed at the end of this section.

***Bono social* activation**

The activation of the social tariff is the highest-potential single recommendation across the sample. Among the 77 contract holders in the dataset, 33 are eligible for the *bono social* but do not currently hold it, representing a substantial gap given that this tariff discount exists precisely for households in the socioeconomic situation documented in this sample. Of these 33 households, 21 fall under the vulnerable severe category and 12 under the standard vulnerable category.

Using the median monthly invoice amount recorded in the dataset (€63.98/month, equivalent to €767.76/year) as a reference bill, the estimated aggregate annual saving from *bono social* activation for these 33 households amounts to approximately €15,087 per year: around €10,480 attributable to severely vulnerable households (mean saving of €499 per household per year) and €4,607 to vulnerable households (mean saving of €384 per household per year). It should be noted that the discount percentages applied (65% for severely vulnerable and 50% for vulnerable) correspond to the values in force during the first half of 2025 ([4], [6]). These

percentages are subject to a gradual reduction following the post-crisis normalization of energy prices: from July 2025 they will fall to 57.5% and 42.5% respectively, which means the potential saving will decrease progressively over time [6].

Two caveats apply to this estimate. First, it uses the median invoice as a reference, which may not accurately reflect the actual bill of each eligible household. Second, and more importantly, the saving is contingent on a series of administrative steps. As these households are already contract holders, the remaining conditions are being in the regulated market (PVPC) and successfully completing the application process.

Switching to the regulated market (PVPC)

Of the 191 households, 45 were advised to switch from the free market to the regulated PVPC tariff. This recommendation does not generate a directly quantifiable saving in monetary terms, but it is justified on two grounds. First, it is a mandatory prerequisite for accessing the *bono social*, as the discount can only be applied to regulated-market contracts [4]. Second, the PVPC offers a regulatory protection compared to the free market, which is particularly relevant in a sample where 53.5% of households report being unable to understand their electricity bill, a situation that makes them especially vulnerable to commercial practices of free-market suppliers [4].

Reduction of contracted power

Among the 94 households for which both current and recommended contracted power data are available, the distribution across three categories is as follows. Thirty-eight households (40.4%) already have a contracted power equal to the recommended level and require no action. Twenty-five households (26.6%) have a contracted power higher than recommended, with a mean current power of 4.75 kW against a mean recommended power of 3.04 kW, therefore an average excess of 1.71 kW (median: 1.2 kW). The remaining 31 households (33.0%) have a contracted power lower than recommended, with a mean current power of 2.97 kW against a mean recommended level of 4.38 kW, suggesting that these households may be experiencing supply limitations or micro cuts due to insufficient contracted capacity.

For the 25 households where a power reduction is recommended, the estimated annual saving uses the reference values provided by Fundación Naturgy's Energy School [36]: €30 per household per year for households in the regulated market and €41 per household per year for households in the free market. Of the 25 eligible households, 11 are in the PVPC market (estimated saving: €330/year in total) and 13 are in the free market (estimated saving: €533/year in total), with one household having no market data available. The aggregate estimated saving from power

reduction amounts to €863 per year, with a mean saving of €34.5 per household per year.

Summary and aggregate potential

Table 7 summarizes the savings potential by line of recommendation for the households where improvement margin exists and the savings are quantifiable.

Measure	Households	Mean saving/HH/year	Total estimated saving/year
Bono social (severely vulnerable)	21	€499	€10,480
Bono social (vulnerable)	12	€384	€4,607
Power reduction (PVPC)	11	€30	€330
Power reduction (free market)	13	€41	€533
Switch to PVPC	45	Instrumental	
Total quantifiable			~€15,950/year

Table 7: Estimated annual savings potential by recommended measure

The aggregate quantifiable saving potential of approximately €15,950 per year is heavily concentrated in the social tariff recommendation, which accounts for 94.6% of the total. This figure illustrates why *bono social* activation is consistently prioritized as the central recommendation of the workshops.

Realized impact:

The savings potential estimated in the previous section is not uniformly distributed across the sample. The primary source of variability lies in each household's position relative to the social tariff (*bono social*): whether they are already benefiting from it, eligible but not yet receiving it, or ineligible. A secondary, independent source of variability is the alignment between contracted power and actual household needs.

Regarding the *bono social*, three subgroups can be distinguished among the 77 contract holders. The first comprises the 36 households already holding the social tariff, for whom this avenue of saving has been exhausted. The second, and analytically most relevant, group consists of the 33 households that are eligible but not currently receiving it: 21 under the severely vulnerable category and 12 under the vulnerable category, with estimated annual savings of €499 and €384 per household respectively. The third group comprises contract holders who do not meet the socioeconomic criteria for the bono social, for whom this recommendation is not applicable regardless of need.

Contracted power misalignment constitutes an additional source of variability. Of the 94 households with complete data, 25 (26.6%) have contracted power above the recommended level, with a mean excess of 1.71 kW and a saving potential of €34.52 per year per household. Conversely, 31 households (33.0%) present the inverse situation, with contracted power below the recommended level, which generates supply constraints rather than saving opportunities and represents a distinct form of vulnerability not captured by expenditure-based indicators.

4.2.4 IMPACT OF MICRO-EFFICIENCY KIT

Unlike the contractual and tariff recommendations analysed in the previous section, which require administrative action by the household to generate savings, the micro-efficiency kit provides direct material support, with its potential impact depending on the installation and use of physical measures. This distinction is analytically relevant: while measures such as the social tariff or a power reduction require households to engage in administrative processes, interventions such as draught seals or LED bulbs can generate savings once installed. At the same time, the absence of pre- and post-intervention billing data for kit recipients means that the impact assessment in this section is necessarily based on estimated rather than realized savings, drawing on evidence from the literature at the level of individual measures.

In addition to the contractual and tariff recommendations, a physical micro-efficiency kit was assigned to 71 of the 191 households (37.2%), with a mean of 12.1 items per household and a total of approximately 862 units. As described in section 4.2.1, the composition of the kits was directly aligned with the habitability problems identified during the diagnostic visit. The remaining 120 households (62.8%) received personalized energy advice, but did not declared to have received any accompanying material.

The potential saving associated with each category of measures distributed can be estimated on the basis of available evidence, though it should be noted that actual savings depend on usage patterns and the degree of implementation.

Lighting (260 units: primarily LED bulbs E27 and E14) is the second largest category. According to the IDAE, lighting accounts for approximately 12% of total household electricity consumption and replacing bulbs with more efficient technology can generate savings of over 80% in lighting consumption while maintaining the same light comfort level [46]. According to the OCU (*Organización de Consumidores y Usuarios* or Consumer and users organization, Spain's main independent consumer organization), switching from incandescent or halogen bulbs to LED equivalents can generate annual savings of up to €50 per household in Spain, rising to over €500 across a ten-year period compared to halogen technology [47]. For the 58 households in the sample still using incandescent or halogen bulbs, LED replacement therefore represents one of the highest-return measures available in the kit.

Thermal insulation (302 units: draught seals, door-bottom seals, window insulating film, radiator reflector panels, roller-shutter insulators) is the largest category. Draught seals and similar measures targeting gaps in doors and windows have been estimated to reduce heat losses by up to 25% in dwellings [48], particularly relevant given that 76.5% of households in the sample reported air infiltration through windows or doors.

Electrical management (93 units: power strips with switches and timer programmers). According to the IDAE, standby consumption accounts for approximately 10.7% of total household energy use, equivalent to around €100 per household per year [46]. Power strips with switches allow households to eliminate this "phantom consumption" entirely for the connected devices. The timer programmer for the electric water heater is estimated to generate savings of €71 per household per year [36].

Thermal comfort measures (118 units: blankets, duvets, portable heaters) **and water saving** (95 units: tap aerators) do not generate direct electricity savings but contribute to reducing heating demand and increasing comfort, and water heating costs, respectively, with effects that are difficult to quantify precisely without household-level post-intervention consumption data.

While post-intervention billing data are not available for the kit recipients in this sample, the per-measure estimates presented above suggest that a household receiving items across multiple categories, including LED bulbs, draught seals, a power strip with switch, and a timer programmer for the water heater, could potentially save in the order of €220 per year: approximately €50 from LED replacement [47], up to €100 from standby elimination via power strips [46], and €71 from the water heater timer programmer [36], with additional but unquantified savings from thermal insulation measures.

Comparable programmes provide a broader reference. The Stromspar-Check documented annual savings of between €100 and €250 per household through professionally installed micro-efficiency measures [34]. VAREX-2024 is taken as the main reference here, as it draws on a larger and more reliable sample (416 households). It found that micro-efficiency measures are considerably more effective when applied jointly than individually: households that received thermocovers, generally combined with two or three additional measures such as LED bulbs, power strips, and draught seals, achieved the largest overall reduction in theoretical energy expenditure, 8.86% [32]. Applied to the average theoretical energy expenditure before the intervention in that sample (€1,873/year), this 8.86% reduction represents approximately €166 per household per year (0.0886 × €1,873).

It should be noted that the Stromspar-Check involved professional installation of measures [34], whereas in Energía para Todos the items are provided for self-installation, which may reduce actual uptake and therefore the realized saving relative to the potential. The VAREX-2024 kits [32] were also self-installed, which makes them a more directly comparable reference in this respect.

Three limitations specific to the kit impact analysis should be acknowledged. First, the absence of pre- and post-intervention billing data for kit recipients prevents verification of

the estimated savings against actual consumption changes. Second, the Energía para Todos kit relies on self-installation by households, as do the VAREX-2024 kits [32], in contrast to the Stromspar-Check [34], where measures were professionally installed. This may reduce effective uptake and therefore lower the realized savings relative to the theoretical potential. Third, the per-measure estimates assume correct and consistent use of the items provided, which cannot be guaranteed without follow-up monitoring.

Beyond these limitations, the kit appears to play a particularly relevant role for a specific subset of the sample: the 54 non-titular households unable to access the *bono social* or request a reduction in contracted power, since both measures require ownership of the electricity contract. For these households, the micro-efficiency kit represents the only form of direct material support available independently of contract status. As a result, the kit functions not merely as a complement to contractual recommendations, but as the primary form of tangible intervention for a significant share of the most administratively constrained households in the sample.

4.2.5 FOLLOW-UP OUTCOMES

The follow-up process constitutes a key component of the *Energía para Todos* project [37]. Its methodology is inspired by the evaluation carried out for the Fundación Naturgy's Energy School [36] and consists of two phases. The first one is the collection of electricity invoices, which takes place during the workshop visit: students gather the household's most recent bill, record consumption and expenditure data, and note the contract conditions. The second phase is the follow-up contact, typically conducted by telephone, WhatsApp, or email, between two weeks and one month after the initial visit, with the objective of collecting updated billing data and assessing whether the recommendations have been implemented.

Short-term follow-up

Out of a total of 191 cases, follow-up was successfully conducted for 31, covering the period from 2022 to 2026. These records combine the follow-up carried out by ApS student volunteers in earlier editions with the round of calls conducted for the present study.

The qualitative information available for these cases varies notably in depth: while some records contain only brief confirmations (e.g. receipt of kit items or minor contract changes), others provide more comprehensive information, reflecting regular contact between students and households over several months through different communication channels. In the remaining 160 cases, follow-up could not be completed due to relocation, loss of contact, or the inability to reach the original participant.

Across all editions, a recurrent pattern emerges: households quickly forget having attended the workshop, invoices are difficult to obtain, and trust must be actively built before substantive information can be gathered. These challenges are aligned with findings from the Energy School, which reports that 40% of the 470 households could not be reached, and that only 15% of those contacted had implemented the recommended measures.

Long-term follow-up

As part of the overall follow-up recorded in the project database, this study includes the phone calls conducted by the author with 31 households participating in the workshop editions between October 2024 and March 2025. Unlike the short-term contact described above, these calls took place approximately one year after the corresponding workshops, and this part of the analysis draws on first-hand experience of the follow-up process. Prior to the telephone calls, an email was sent to each household to inform them that they would be contacted, with the aim of providing context and facilitating the conversation. Contact was then attempted by telephone on at least two occasions at different times of day before recording the final outcome.

Of the 31 households, successful communication was established with 8 (25.8%), while the remaining 23 (74.2%) could not be reached. The breakdown of the not answered calls is as follows: in 9 cases (29.0% of the total), calls were not answered despite repeated attempts; in 4 cases (12.9%), respondents hung up right after the purpose of the call was explained; in 3 cases (9.7%), respondents stated they did not recall the project or the workshop, suggesting that the intervention had limited lasting impact; and in the remaining 7 cases (22.6%), the contact number was unreachable (e.g. switched off, non-existent, or with no available contact information).

Among the 8 households with whom contact was successfully established, the depth of information obtained also varied. In 5 cases, it was possible to gather responses to all four structured follow-up questions: (1) whether any micro-efficiency measures had been installed, (2) whether the household had perceived changes in comfort or energy expenditure, (3) what the most recent invoice amount was, and (4) what specific changes had been applied to the contract or consumption habits. In the remaining 3 cases, contact was established but responses were partial, either the person could not recall the details of the workshop visit, or they were unable to answer questions about the contract because they were not the bill holder.

Realized impact: evidence from follow up

Taking together the student-led records and the calls conducted for this study, the follow-up evidence covers outcomes ranging from brief confirmations of kit receipt to sustained exchanges over several months. Three broad patterns emerge.

The first corresponds to successful implementation with a quantifiable outcome. One household reduced its monthly bill from €28 to €23 through a combination of behavioural changes and physical measures (€60/year saved). A second household reported a reduction from more than €100 to €57 per month (over €516/year), although the specific measures implemented could not be recalled. A third household successfully activated the *bono social*, reducing its bill to €23/month and saving approximately €840/year. These cases confirm that the recommendations can produce tangible results when implemented, with savings broadly consistent in magnitude with the potential estimates presented above.

The second pattern corresponds to partial or null implementation of the recommendations. Several households reported perceived improvements without being able to quantify them precisely. Among the households successfully reached, two reported reductions in their electricity bills that they were unable to estimate accurately. In one case, the participant had received the energy-efficiency kit and observed a lower bill but could not recall the exact savings achieved. In another, the participant had adopted the consumption-scheduling recommendations provided during the workshop and reported a similar perceived reduction. Additionally, one household indicated that the energy-saving practices learned during the workshop were subsequently shared with flat mates in a shared dwelling, thereby extending the intervention's influence beyond the original participant. By contrast, some households were unable to implement the recommendations at all. One participant, who rented only a single room, lacked the authority to make changes either to the dwelling itself or to the electricity contract. This limitation illustrates a broader structural barrier faced by non-contract holders, restricting their ability to benefit from certain intervention measures, as discussed further below.

The third, and most frequent, pattern is incomplete follow-up due to relocation, loss of contact, or disengagement. This finding is consistent with the Energy School's evidence showing that approximately 40% could not be reached during follow-up processes [36].

Discussion

The follow-up evidence suggests that the main barriers to implementation are structural rather than informational. Several households reported being aware of the recommended actions but had not implemented them months later, mainly due to lack of time, administrative difficulties, or limited capacity to navigate the process independently. This finding is consistent with the Energy School's evidence showing that implementation rates in one-off workshop formats remain around 15%, while continuous accompaniment models can raise implementation to approximately 80% [36]. Contract ownership constitutes a second major structural barrier. The 54 non-titular households are excluded from the *bono social*, market switch, and contracted power reduction recommendations regardless of their level of need, leaving the micro-efficiency kit and behavioural advice as the only directly actionable forms of support available to them.

Chapter 5. CONCLUSIONS

This chapter presents the main conclusions of the study, which assessed the impact of two complementary intervention strategies to alleviate energy poverty among vulnerable households in Spain. The first strategy was a program of shallow renovations, consisting of low-cost renovation measures implemented in 11 dwellings in Getafe. Their impact was assessed through simulations using the DIAGNÓSTICO tool together with a set of objective and subjective energy poverty indicators. The second comprised a series of energy-saving workshops delivered through the *Energía para Todos* project, which proposed contractual, behavioral, and micro-efficiency measures to participating households without requiring physical interventions in the dwelling.

The first subsection summarizes the impact of the shallow renovations, whereas the second does the same for the workshops. The third presents the key findings that cut across both strands, while the fourth discusses the complementarity between the two intervention strategies. Finally, the chapter concludes with the analysis's limitations and the lines of future work they suggest.

5.1 IMPACT OF THE SHALLOW RENOVATIONS

The shallow renovation program addressed the energy performance of the dwellings through low-cost physical interventions. Most of them were passive measures applied to the building envelope, mainly the replacement of windows, complemented in some cases by damp treatment, painting, or repair of a deteriorated ceiling. A smaller number of interventions consisted of active measures on the dwelling's equipment, including the installation of a mechanical ventilation system and a split air-conditioning unit. Where a renovation was implemented and could be evaluated, its effect on the theoretical energy expenditure was modest but consistent. The window-carpentry interventions reduced the RENE by between 5.2% and 10.6%, corresponding to estimated annual savings of between 91 and 237 euros per household. The magnitude of these reductions mainly depends on the initial distribution of theoretical energy demand within each dwelling. Because these passive measures improved the thermal performance of the building envelope, they reduced the share of energy demand associated with heat transfer through the envelope, lowering both winter heat losses and summer heat gains, thereby improving indoor conditions throughout the year.

Beyond reducing theoretical energy expenditure, the renovations also affected the hidden dimension of energy poverty. Five of the eleven households were in hidden energy poverty before the intervention, spending less than half of their required energy expenditure. The renovations did not modify the incidence of this condition, since no household crossed the HEP threshold, but they reduced its severity in every case where a saving was estimated, narrowing the HEP gap by between 9% and 30%. For these households, the lower energy

requirement does not translate directly into a smaller bill, because their expenditure was already below what they needed. The benefit manifests instead as an increased capacity to achieve adequate indoor conditions with the same level of spending.

These quantitative findings are consistent with the outcomes reported by the households themselves (subjective indicators). Five of the eight households that underwent a renovation reported improvements in at least one wellbeing indicator, including better perceived thermal comfort, improved physical health, or both. Furthermore, all eight households reported an improved ability to maintain a comfortable indoor temperature in winter, summer, or both after the renovation. These reported benefits are not captured by the reduction in theoretical energy expenditure or by the payback period (described thereafter), yet they represent a central part of the impact of the renovations for the households living in the dwellings, particularly for those whose consumption was previously repressed below their needs.

The results obtained from the other objective indicators further support this interpretation. The objective indicators showed that the sample is characterized primarily by disproportionate expenditure rather than severe underconsumption, with the 10%, 2M, and MIS indicators flagging a larger share of households than the underconsumption indicators do. The dominance of the disproportionate-expenditure branch is confirmed by the behaviour of the underconsumption indicators: the M/2 indicator, which classifies a household as energy poor when its energy expenditure falls below half the national median, identified no households in the sample, while underconsumption was captured only by the HEP indicator, positive in five cases. These findings highlight the HEP indicator as a particularly valuable tool for identifying hidden energy poverty. Unlike relative-threshold indicators such as M/2, it accounts for households' theoretical energy requirements and their economic capacity, enabling the detection of situations of constrained energy consumption that would otherwise remain invisible. When complemented with subjective evidence, it provides a more comprehensive and reliable assessment of hidden energy poverty.

From an economic perspective, however, the cost-effectiveness of the renovations is uneven across the sample. The estimated payback periods range from around 14 years to over 100 years, reflecting differences in both the cost of the intervention and the annual savings it generates. The longest payback periods are generally associated with households with low required energy expenditure, where similar percentage reductions translate into relatively small monetary savings. The actual economic benefit may differ from the estimated one, as households experiencing energy poverty may respond to the lower energy requirements in different ways. Some may reduce their energy bills while maintaining the same level of comfort, whereas others may use the potential savings to improve indoor conditions without substantially changing their expenditure. In practice, the benefits are likely to be distributed between lower energy costs and improved thermal comfort. Consequently, shallow renovations are rarely justified on purely economic grounds. Their main value lies in reducing the required energy expenditure while improving thermal comfort and well-being, dimensions of the intervention that are not fully captured by conventional payback calculations.

5.2 *IMPACT OF THE ENERGY-SAVING WORKSHOPS*

The Energy Saving Workshops address energy poverty through a combination of complementary actions targeting different dimensions of household energy use. These include recommendations on electricity contracts and tariffs, the distribution of micro-efficiency kits, and personalized guidance on everyday energy practices. Together, these actions aim not only to reduce household energy expenditure but also to strengthen households' capacity to make informed energy-related decisions over the longer term.

The largest share of the estimated savings from the *Energía para Todos* workshops is associated with contractual and tariff optimization. The estimated annual savings amount to approximately 15,950 euros across the 57 households for which savings could be identified, with 94.6% of this total concentrated in the 33 households eligible for the social tariff but not yet receiving it. For these households, the estimated annual savings reach 499 euros per year for those in the severely vulnerable category and 384 euros for those in the vulnerable one. By comparison, reducing the contracted power offers a more modest saving of around 35 euros per household per year, while switching to the regulated market does not yield general direct economic benefits but is a necessary prerequisite for accessing the social tariff. These results highlight that the greatest opportunity to reduce household energy expenditure lies less in new measures than in ensuring that eligible households receive the financial support to which they are already entitled, a support that is not being claimed despite existing precisely for their situation

The micro-efficiency kit differs from the contractual recommendations because its benefits do not depend on households completing administrative procedures. Whereas contractual measures only yield savings once the application process concludes with a positive response, the kit's benefits begin as soon as the measures are installed. The 71 households that confirmed to have received a kit were provided with measures covering five complementary areas (thermal insulation, lighting, electrical management, thermal comfort, and water saving), addressing multiple sources of unnecessary consumption or thermal discomfort within the dwelling. According to estimates reported in the literature, the individual measures provide annual savings ranging from approximately 50 to 100 euros, meaning that a household receiving measures across the five categories could save around 220 euros per year. This estimate is consistent with the average saving of 166 euros per household reported in the VAREX-2024 project [32]. Although the potential savings are lower than those associated with the social tariff, they can be achieved immediately and without requiring any contractual modification. This makes the kit particularly valuable for the 54 households that do not hold the electricity contract and therefore cannot directly benefit from measures such as the social tariff, switching to the regulated market, or contracted-power adjustments. For these households, expenditure reductions depend entirely on the kit and on behavioural changes, with the kit standing out as the only intervention that physically modifies the conditions of the dwelling.

The workshops, however, extend beyond contractual advice and material assistance. Their educational component addresses a barrier that is less visible but equally important: limited energy literacy. The awareness survey conducted before the sessions showed that more than half of the participants did not understand their electricity bill at all. Under these circumstances, teaching households how their electricity contract, tariff structure, and consumption affect their energy costs becomes a prerequisite for the effectiveness of any other intervention, since a household that cannot read its bill can neither recognize an excess of contracted power nor identify a more advantageous tariff nor sustain more efficient habits over time. This is also the component whose effect is the most durable: unlike a tariff change or a physical measure, which act once, the knowledge acquired during the workshop remains available to the household and can be applied to future decisions about its contract and consumption. Behavioural changes reinforce this durability, as they are the dimension over which households have the greatest immediate control, and actions such as shifting electricity use to cheaper tariff periods, avoiding standby consumption, or improving the use of heating and appliances reduce energy expenditure without requiring administrative procedures or physical interventions. The impact of this component is difficult to quantify and does not appear in the estimated savings, but the follow-up evidence, which includes households that reported lower bills after adopting these practices and one that shared these practices with the other members of the shared dwelling, indicates that it is real and, unlike the other channels, self-sustaining.

The follow-up is where the distance between potential and realized impact becomes visible, and its main conclusion is diagnostic rather than quantitative. The low proportion of households that could be reached is not merely a data limitation but a finding in itself: it reflects the fragility of the link between a one-off workshop and the households it serves, and it explains why so much of the estimated potential never materializes. The few cases that could be traced confirm that the recommendations work when they are implemented, with realized savings in line with the estimates, but they also show that implementation is the exception rather than the rule when contact is not sustained. The decisive conclusion is therefore that the follow-up is not a measurement stage appended to the intervention but a constitutive part of it. Where the barriers are structural (lack of time, administrative complexity, or absence of the contract), information alone does not close the gap, and only continued accompaniment does. This reframes the workshop not as a self-contained event but as the entry point to a longer process, whose effectiveness depends on the capacity to maintain contact with the household after the session has ended.

5.3 KEY FINDINGS

The combined analysis of the shallow renovations and the Energy Saving Workshops reveals four consistent findings that emerge across both samples and summarize the main contributions of this study to the evaluation of energy poverty interventions.

The first finding is that energy poverty in these households is fundamentally an affordability problem, although it manifests itself in two complementary ways. In the renovation sample, although almost all households reported actual energy expenditure below their required energy expenditure, only a subset was classified as experiencing hidden energy poverty according to the HEP indicator. Nevertheless, the objective indicators identified disproportionate expenditure as the dominant pattern. This does not imply that these households spent more than their required energy expenditure, but rather that their actual energy expenditure represented a disproportionate burden relative to their available income. With a mean monthly household income of 980 euros in the renovation sample, even moderate energy expenditures can represent a significant share of the household budget.

The workshop sample reflects the same underlying situation from the income perspective, with a median monthly household income of 700 euros and a large proportion of households unable to maintain adequate indoor temperatures. Rather than representing completely opposite forms of energy poverty, disproportionate expenditure and underconsumption are two expressions of the same imbalance between the cost of achieving adequate energy conditions and the financial resources available to households. This finding also has an important methodological implication: when energy consumption is suppressed below energy needs, objective indicators based on relative thresholds alone underestimate the extent of the problem, whereas indicators that incorporate required energy expenditure and income, such as HEP or MIS, are able to identify it.

The second finding is that the overall impact of both interventions extends beyond what can be measured in monetary terms. In the renovation strand, the estimated payback period reflects the reduction in theoretical energy expenditure but does not capture the improvements in thermal comfort and health reported by the households, which constitute the principal benefit for those experiencing hidden energy poverty.

Similarly, in the workshops, the estimated savings quantify the effects of contractual recommendations and micro-efficiency kits but fail to reflect the value of the educational component, which strengthens households' capacity to manage their energy use over time. As a result, the most meaningful outcomes of both interventions are also the most difficult to quantify, meaning that evaluations based exclusively on financial returns are likely to underestimate their overall impact.

The third finding is that the effectiveness of both interventions depends less on the measures themselves than on how households ultimately implement them. When the proposed actions are successfully adopted, they produce benefits consistent with their expected impact. However, the final outcome depends on households' capacity and decisions. Contractual

recommendations only generate savings if the necessary administrative procedures are completed, whereas the lower energy requirements achieved through renovations may be translated into lower energy bills, improved indoor comfort, or a combination of both, depending on how households respond to the intervention. In both cases, the realized impact is shaped not only by the intervention itself but also by what happens afterward. The evidence consistently identifies sustained accompaniment, rather than additional information or additional measures, as the key element in helping households transform the potential benefits of the interventions into realized ones.

The fourth finding is that households with the greatest needs are also the least able to benefit from existing instruments. Tenure status and electricity contract ownership act as structural barriers: tenants are generally unable to undertake structural improvements to the dwelling, while individuals living in shared accommodation who rent only a room often have no authority to modify either the dwelling or the electricity contract. Similarly, the 54 households that do not hold the electricity contract are excluded from the social tariff, the regulated-market switch, and contracted-power adjustments regardless of their level of need. These barriers are compounded by the difficulty of maintaining contact with the most unstable households, who are also the least likely to complete the recommended actions. Consequently, the most vulnerable profiles identified across both samples (low-income tenants, room renters without decision-making capacity over the dwelling, and households that do not hold the electricity contract) are also those least effectively served by the available interventions. This explains why neither intervention, considered in isolation, is sufficient to address the multiple dimensions of energy poverty.

5.4 COMPLEMENTARITY OF BOTH INTERVENTIONS

Beyond their individual results, the two studies complement each other in what they allow to observe. The shallow renovations and the energy-saving workshops propose different types of measures, physical improvements to the dwelling in one case, and contractual, material, and behavioural support in the other, so that analysing them in parallel makes it possible to identify the strengths of each approach and the situations in which one is more appropriate than the other. The renovations show the largest structural effect, since they permanently reduce the energy required by the dwelling, but they depend on a suitable tenure regime and involve a significant investment. The workshops show a smaller effect per measure, but they are low-cost, easily scalable, and applicable to households where a renovation is not possible, including tenants and households without contract ownership, in some cases. Neither type of measure emerges as superior across the board: each one performs best precisely where the other is weakest.

The two studies are also methodologically complementary. The workshop sample is considerably larger, which gives a more reliable picture of the profile of energy-vulnerable households, their housing conditions, and the barriers they face. The renovation sample is much smaller, but each household is analysed in depth, with objective and subjective

indicators computed before and after the intervention, which allows the impact to be measured at the individual level with a precision that a large sample does not permit. Each design is therefore more reliable in a different aspect, breadth of characterization in one case and depth of impact measurement in the other, and reading them together provides a more complete picture of energy poverty than either study alone: the workshops describe the extent and profile of the problem, while the renovations quantify what a specific intervention changes within it.

Comparing the two studies also makes their respective margins of improvement easier to identify. The renovation analysis shows the value of computing energy poverty indicators before and after the intervention, a practice that the workshop strand could adopt if billing data were systematically collected, allowing its impact to be measured with objective indicators rather than estimated from the literature. Conversely, the workshop strand shows the value of a structured follow-up process and of characterizing the household beyond the dwelling, elements that would enrich the renovation analysis, where the information available after the works is limited. In this sense, each project points to the main weakness of the other and offers a tested way of addressing it.

Taken together, these considerations support the combination of both interventions within an integrated approach: an initial diagnosis and workshop as the entry point, applicable to any household regardless of tenure, followed by the delivery of micro-efficiency measures, accompanied support for the administrative steps, and shallow renovation where the tenure regime allows it, with sustained follow-up throughout. Such a configuration would combine the scale and accessibility of the workshops with the structural impact of the renovations, and would extend to the resulting program the strongest analytical elements of each study: the indicator-based impact measurement developed for the renovations and the follow-up methodology developed for the workshops.

5.5 LIMITATIONS AND FUTURE WORK

This section examines the limitations of each project, outlines improvements that could address them, and describes how the two could come together in a single, more complete study. It first goes through the limitations of the shallow renovation analysis and then those of the energy-saving workshops, followed by the lines of future work for each one. It closes by outlining how the two interventions could be combined into a larger study that draws on the strengths of both.

5.5.1 LIMITATIONS OF THE SHALLOW RENOVATION ANALYSIS

The first limitation of the renovation analysis is the size of the sample and the number of households for which the impact of the renovations could actually be evaluated. The study is based on eleven households, of which only eight could be evaluated, since in three cases the planned reform was renounced or no intervention was recorded in the available data. A

sample of this size allows each household to be analysed in considerable depth; nevertheless, it does not permit statistical analysis, the identification of robust patterns, or the extrapolation of the conclusions to similar situations beyond the sample. Individual households with particular characteristics can also have a visible effect on the aggregate results, which reinforces the need to interpret the findings as specific to the cases studied rather than as generalizable evidence.

The second limitation concerns the estimation of the energy savings. The savings are derived from the reduction in theoretical energy expenditure simulated with the DIAGNOSTICO tool, which assumes the replacement of all windows and exterior carpentry elements of the dwelling, regardless of the number of units actually renovated. As a result, the estimated savings and the payback periods computed from them tend to be more favourable than the actual scope of some interventions would justify, particularly in households where only part of the windows were replaced. Besides, these estimates could not be verified against billing data, and since theoretical expenditure represents the energy required to reach adequate conditions rather than the energy actually consumed, the monetary savings experienced in practice may differ from the estimated ones, especially in households that consume less than they require.

A third limitation concerns the quality and completeness of the input data. Some household characteristics had to be estimated, as was the case for the number of household members that was inferred for the whole sample. Moreover, the renovation costs were provided directly by Naturgy without a detailed breakdown, which prevents explaining some of the differences observed between interventions of similar description. In addition, the subjective information available after the works is limited, as the post-retrofit questions were answered by only a subset of households, thereby restricting evidence on perceived impact to a few cases.

Finally, three households required specific treatment because of the nature of their interventions: a mechanical ventilation system, a retrofitting not carried out, and the installation of a split air-conditioning unit, which are not contemplated by the VAREX-2022 methodology on which the analysis is based. The results for these households should therefore be read with additional caution.

5.5.2 LIMITATIONS OF THE ENERGY-SAVING WORKSHOP ANALYSIS

The main limitation of the workshop analysis is the heterogeneity of the information across editions. The project has been running since 2022 and its data collection has improved over time, which means that some variables are only available for the most recent years: the awareness survey, for instance, was introduced in 2024 and administered to a subset of 44 households, so it does not cover the full sample. Missing data affect several key variables, including income, market type, and social tariff status, which reduces the effective sample available for each part of the analysis and requires the results to be interpreted with respect to the subset of households for which data exist.

The second limitation is that the impact assessment is based on potential rather than realized savings. The savings associated with the contractual recommendations are contingent on the completion of administrative processes by the households, which does not always occur and often depends on factors beyond the household's control. The per-measure estimates for the micro-efficiency kit are drawn from the literature and assume proper installation and consistent use of the items provided, which cannot be confirmed without post-intervention data. The awareness survey, administered only before the sessions and not repeated afterward, characterizes the starting point of the participants but does not measure the effect of the workshop on their knowledge.

The third limitation is the low coverage of the follow-up. Follow-up could be completed for a small share of participants, and the long-term calls conducted for this study reached only a fraction of the households contacted. The realized outcomes are therefore documented for a reduced number of cases, and the information they provide is self-reported and could not be verified against invoices in most instances. This limitation is not merely operational: as discussed in the previous sections, the difficulty of maintaining contact with the participating households is itself one of the study's findings, but it constrains the strength of the conclusions that can be drawn about realized impact.

5.5.3 FUTURE WORK ON THE SHALLOW RENOVATION ANALYSIS

The most direct improvement would be to simulate each dwelling with the actual scope of the intervention, so that the estimated savings reflect the number of windows actually replaced rather than the full replacement assumed by the tool. This would require recording the details of each intervention systematically, including the number and characteristics of the elements replaced and a breakdown of the costs, information that would also allow the differences in cost between similar interventions to be explained rather than merely reported.

A second line of improvement is the verification of the estimated savings against real data. The systematic collection of billing data before and after each renovation (as pursued in previous VAREX projects) would enable comparison of the theoretical reduction with the observed changes in consumption and expenditure. This would help to distinguish the part

of the savings that materializes as a lower bill from the part that is converted into additional comfort, and to compute the full set of energy poverty indicators after the intervention.

Finally, future editions would benefit from a larger sample, which would enable statistical analysis of the results, segmentation of the impact by type of intervention and household profile, and more robust conclusions about which renovations deliver the greatest improvement.

5.5.4 FUTURE WORK ON THE ENERGY-SAVING WORKSHOP ANALYSIS

Ensuring that, during the initial session, participants are willing to collaborate on future follow-up calls and confirming that their contact information remains up to date would help overcome one of the main operational barriers identified during the follow-up. Furthermore, repeating the awareness survey immediately after the workshop would enable assessment of the session's learning effect, which is currently the least well-documented component of the intervention.

On the analytical side, computing the objective energy poverty indicators requires both billing and income data for each household, and at present these are not available for the whole sample. Although households are asked to provide their invoice and income information at the time of the workshop, a considerable number do not supply them, which prevents the indicators from being calculated. Ensuring that this information is collected from all participating households, and complementing it with equivalent billing data after the intervention, would make it possible to compute the objective indicators for the workshop sample before and after the workshop. This would replace the estimated savings with empirical measurements and would place the assessment of the workshops on the same analytical footing as that of the renovations. Doing so would allow the impact of the workshops to be assessed directly through objective energy poverty indicators, reducing the reliance on literature-based estimates and making the results more robust and comparable across editions.

On the program side, the results of this study suggest that the main challenge lies not in designing effective interventions, but in ensuring that they are successfully implemented. Households would benefit from continued support throughout the implementation process, particularly with administrative procedures such as applying for the social tariff, assistance with installing the micro-efficiency kit measures, and a structured follow-up strategy planned from the outset rather than introduced only at the end of the program.

5.5.5 TOWARD A JOINT STUDY OF BOTH INTERVENTIONS

The natural continuation of this work is a coordinated study in which both interventions are applied to the same households or a similar sample and evaluated within a common analytical framework. Such a design would begin with the workshop as the entry point, applicable to any household regardless of tenure, and would add the shallow renovation where the tenure regime allows it, with sustained accompaniment and follow-up throughout. Applying the same set of objective and subjective indicators to all households, before and after each intervention, would make the impacts of the two measures directly comparable, and would allow the effect of their combination to be distinguished from the sum of their separate effects.

A study of this kind would also address the main limitations identified in both strands. The follow-up methodology developed for the workshops would provide the post-intervention data that the renovation analysis lacks, while the indicator-based impact measurement developed for the renovations would provide the empirical assessment that the workshop analysis lacks. With a sufficiently large sample and an observation period extending beyond the first year, it would be possible to establish which intervention, or which combination and sequence of interventions, delivers the greatest and most durable reduction in energy poverty for each household profile, and in particular whether the integrated approach outlined in this work reaches the profiles that each intervention, separately, leaves behind.

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APPENDIX I: ALIGNMENT WITH THE SUSTAINABLE DEVELOPMENT GOALS

This project is framed within the commitments of the 2030 Agenda, aligning with several Sustainable Development Goals (SDGs). Shallow retrofit measures and energy-saving workshops, together with their technical, statistical and social assessment, make a meaningful contribution to the achievement of the following goals:

SDG 1: No Poverty

Energy poverty directly affects the living conditions of the most vulnerable households, limiting their ability to meet basic needs. Shallow retrofitting interventions and energy-saving workshops help alleviate this situation by reducing energy expenditure and improving their quality of life, with the aim of enabling households to overcome energy poverty or, at least, to reduce their energy poverty gap.

SDG 7: Affordable and Clean Energy

This project promotes a more efficient and accessible use of energy through the implementation of low-cost retrofit measures. These interventions allow households to reduce their energy consumption without compromising comfort, ensuring fairer access to energy while also contributing to a cleaner energy system by lowering overall demand and associated emissions.

SDG 11: Sustainable Cities and Communities

Energy-inefficient dwellings generate inequalities and limit the quality of life of their inhabitants. Rapid energy retrofit measures contribute directly to improving vulnerable residential buildings and indirectly to promoting more comfortable, efficient, and sustainable housing. These interventions contribute to the improvement of the existing building stock and the reduction of urban inequalities, while also helping households reduce their energy consumption, thereby supporting more sustainable cities and communities.

SDG 13: Climate Action

The reduction in energy consumption resulting from rapid retrofit measures not only improves energy efficiency in the residential building stock, but also reduces the need for energy generation. As a result, associated emissions decrease, supporting decarbonisation. By lowering greenhouse gas emissions, these interventions contribute to mitigating climate change.