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Energy Efficiency Programs as a Pillar of Low-Carbon Development Strategy and Equitable Access: Evidence-Based Data from Greece

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Energy efficiency improvements and retrofitting programs in the residential sector, can play a pivotal role in the implementation of low-carbon development strategies while also cutting household energy costs. Limited access to affordable and reliable energy remains a significant barrier for low-income populations, restricting their ability to meet basic needs such as heating, lighting, and cooking and exacerbating social and economic inequalities. Integrating social equity into climate policies can mitigate environmental impacts and improve living conditions. However, vulnerable households are often underrepresented in energy efficiency programs due to economic barriers imposed by existing financial loan schemes. This study examines the accessibility of Greek energy efficiency initiatives for vulnerable households and confirms their systemic exclusion from the programs. The work underlines the need for targeted policy interventions and also correlates various factors affecting energy poverty to identify their importance as tools in the implementation of relative strategies.

1. Introduction

Targeting a low-carbon, sustainable future can be achieved by integrating energy efficiency principles at all contemporary energy domains. In the residential sector, energy inefficiency is a commonly met state, a multidimensional phenomenon arising from the interplay of social, economic, and spatial factors that contribute to energy vulnerability, particularly across the world. At the level of household is mainly expressed by the concept of energy poverty, also referred to as fuel poverty, which is widely defined in the literature as the “inability of a household to secure adequate access to essential energy services, such as heating, cooling, and electricity”. Although closely related to income poverty, energy poverty is not entirely synonymous with it. Low income may lead to restricted energy consumption, while high energy prices can force households to allocate a disproportionate share of their budget to energy, often at the expense of other basic needs, such as food (Thomson and Snell, 2013). This is why the term, along with the “targeted population characterization” (as energy poor), has evolved into a broader concept—shifting from a narrow focus on energy cost, such as spending over 10 % of household income on energy (Boardman, 1991), to encompassing a household’s inability to maintain an adequate indoor temperature (Lewis, 1982) and, more generally, to meet essential energy needs for end use (Bouzarovski, 2013).
Poverty and energy poverty have often a causal and effect relationship: it is clear that countries facing extreme poverty conditions (affecting more than 75 % of the total population) i.e. Equatorial Guinea, South Sudan's, Central African Republic etc. face energy poverty as well, but it must be noted that energy poverty also intensifies general poverty, limiting development and opportunities for improving the quality of life. However, energy poverty is also present in richer countries, like China, where only 0.6 % of the population is facing poverty and only the 40-50 % is enjoying energy security. This paradox is due to inequalities in energy infrastructure development and dependence on polluting forms of energy.

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At European, in 2022, 9.3 % of the EU population reported not being able to keep their homes warm (a 2.4 percentage point increase from 2021 (Eurostat, 2022)). The highest percentages were found in Bulgaria (22.5 %), Cyprus (19.2 %), Greece (18.7 %), Lithuania and Portugal (both 17.5 %), Spain (17.1 %), and Romania (15.2 %), while Finland, Luxembourg, Slovenia, Austria, Czechia, Sweden, and Estonia (1.4 %-3.4 %) reported the lowest.

Energy poverty has also significant social and health impacts: it stresses inequalities, stigmatization and social exclusion as people who are forced to live in thermally inadequate dwellings, are at a high risk of their health (i.e. respiratory and cardiovascular diseases on top of the psychological distress failing to meet societal standards). In economic terms, energy poverty reduces the disposable income: this also affects the level of energy consumption, the type of energy being consumed and in other cases results in arrears in the utility bills as well. In response, governments take on greater fiscal burdens through subsidies and social support programs, as inefficient energy use poses a significant challenge to low-carbon development strategies: relying solely on wood for heating, leads to increased air pollution, higher greenhouse gas emissions, and accelerated deforestation. Energy-poor households frequently depend on polluting energy sources, which hinders the transition to clean energy. That being said equitable policy mechanisms that address disparities in energy access, promoting renewable energy consumption (Uzar, 2020) should be accelerated.

Energy efficiency emerges as both a preventive and corrective tool against energy poverty: it reduces energy usage, lowers bills, allowing especially for the vulnerable households to benefit and become more resilient to energy prices' volatility. Integrating energy efficiency into national and regional strategies is crucial for decarbonization goals and socially just energy policy, making it a cornerstone of inclusive energy policies. As highlighted by Klemeš et al. (2021), methodologies rooted in Process Integration—such as Pinch Analysis and multi-resource optimisation—offer scalable tools to reduce resource demand and environmental burdens. Their integration into national programs could enhance the effectiveness of energy poverty mitigation strategies, particularly when extended to the level of smart regional planning.

In this context, in 2023, the EU's Energy Efficiency Directive redefined energy poverty as the inability to access essential energy services for living standards and health. This shift from economic or thermodynamic definitions to a rights-based approach includes allowances for vulnerable households through electricity and heating allowances or national energy efficiency programs (European Union, 2023).

However, vulnerable households are often underrepresented in energy efficiency programs due to economic barriers imposed by existing loan schemes. This study seeks to pinpoint that via energy efficiency energy poverty can be eradicated. To that end it examines the accessibility of Greek energy efficiency initiatives, and in particular of the "Exoikonomo 2021" program, for which that results of applications -evaluations are available. The analysis emphasizes the need for targeted policy interventions to the weak population categories and also aims to correlate various factors affecting energy poverty to identify their importance.

2. Energy Poverty (EP) indicators

Academic discourse on energy poverty has shifted from unidimensional indicators to multidimensional ones that consider energy efficiency, housing conditions, and socioeconomic variables. Bouzarovski and Petrova's (2015) conceptual framework bridges the traditional energy poverty and fuel poverty dichotomy by considering factors like thermal performance, building infrastructure quality, and low-carbon energy systems. These composite indicators provide a better understanding of vulnerability, capturing households that may not appear energy poor but still face limitations in accessing energy services. These tools offer stronger diagnostic capacity for policymakers to design targeted interventions aligning with social welfare and environmental objectives.

2.1 UK originated indicators

Energy poverty and the related indicators definition and characterization is originated in the UK, with the 10 % Index, introduced by Brenda Boardman in 1991, to be the first quantitative measure of energy poverty in the UK. It aimed to identify households spending more than 10 % of their disposable income on basic energy needs like heating, lighting, and cooking. The index laid the foundation for policy formulation and highlighted energy poverty as a separate social problem. However, it had limitations, including being an arbitrary threshold, static, and not considering the actual amount left over after meeting energy needs. This led to the need for a new indicator to capture and treat energy poverty more effectively. The 10 % Index remains the standard method for calculating fuel poverty in the UK (Hills, 2012) and worldwide (Al Kez et al., 2024).

The Low Income, High Costs (LIHC) Index was introduced in the UK in 2013 to measure energy poverty. It identifies households in energy poverty if they spend more than the national average to cover their energy needs and have disposable income below the national poverty line. The index is dynamic and adjusts to different socio-economic conditions. However, it is complex to calculate and may not be accurate or up-to-date, leading to difficulties in understanding by citizens and government decision-makers. The lack of data on geographical

location and energy efficiency has led to the introduction of a new indicator (Department of Energy and Climate Change, 2013).
The Low Income, Low Energy Efficiency (LILEE) index, introduced in the UK in 2021, identifies households as energy poor if they have an energy efficiency rating of D or lower and have disposable income below the national poverty line. This index combines energy poverty with low energy efficiency in housing, emphasizing structural causes and encouraging energy upgrade policies. However, it lacks the ability to identify energy under-consumption due to financial constraints (Department for Energy Security & Net Zero, 2025).

2.2 EU Level Originated Indicators

In 2018, four new European indicators were introduced in order to more efficiently monitor, and address the energy poverty and its determinants: categorizing it into two main categories: Subjective and objective indicators.

2.2.1 Subjective indicators

Consensual-based metrics assess households' energy situation, focusing on social dimensions like social exclusion and alienation. They identify 'hidden' energy poverty, where households reduce other needs to cover energy costs. The European Survey on Income and Living Conditions (EU-SILC) uses three main questions to assess energy poverty: keeping the dwelling warm, paying bills on time, and addressing serious house problems. The main subjective indicators according to the European Union are the IKHW or AW (Inability to Keep Home Warm) Index and the AUB or UB (Arrears on Utility Bills) Index (ODYSSEE-MURE, 2020). The IKHW Index measures the percentage of households unable to maintain adequate heating during winter, directly affecting quality of life and health problems. However, its subjective nature may lead to incorrect conclusions and limited scope. The AUB Index measures the percentage of households with utility bill arrears, reflecting financial difficulties and energy poverty. Both indicators have limitations, including ignoring other energy needs and underconsumption. Both indicators can help capture energy poverty more effectively.

2.2.2 Objective indicators

Energy poverty is assessed using expenditure-based metrics, which measure the amount a household spends on energy needs compared to its disposable income. These indicators express energy expenditure as a percentage of total household income and are used to measure energy poverty. The European Union's main objective indicators (EPAH, 2023a) are the 2 M (High Energy Expenditure Indicator) and the M/2 (Low Energy Expenditure Indicator). The 2M indicator identifies households with high energy expenditure, based on two basic data sets: energy expenditure and equivalent disposable income. It identifies financially burdened households with excessive energy expenditure but ignores the existence of high income, which can reduce the impact of high energy costs. The M/2 indicator, also known as the hidden energy poverty indicator, identifies cases of unusually low energy consumption due to insufficient financial capacity but fails to examine whether the low expenditure is due to potential energy efficiency in housing. These indicators are based on data from EU-SILC and national statistical offices, with the IKWH and AUB (ODYSSEE-MURE, 2020) indicators estimated in the Household Income and Living Conditions Survey in Greece (JustReDI, 2024).
In Greece, apart from the adoption of the indicators established by the European Union to measure the phenomenon, other national indicators have also been developed. In the framework of the National Action Plan for the fight against energy poverty in 2021 the I & IIeq indicator was established (MEE, 2023) as the main indicator for the calculation and monitoring the number of households that meet both of the following criteria: (a) Energy Underspending (Condition I): Their total annual energy cost is less than 80 % of what is needed to cover minimum energy needs and (b) Income Poverty (Condition IIeq): Their equivalized annual net income (adjusted using the OECD scale (EPAH, 2023b)), is below 60 % of the national median income, indicating relative poverty.

3. Greek targeted policies – energy efficiency programs – social

3.1 Overview of energy efficiency programs 2020-25

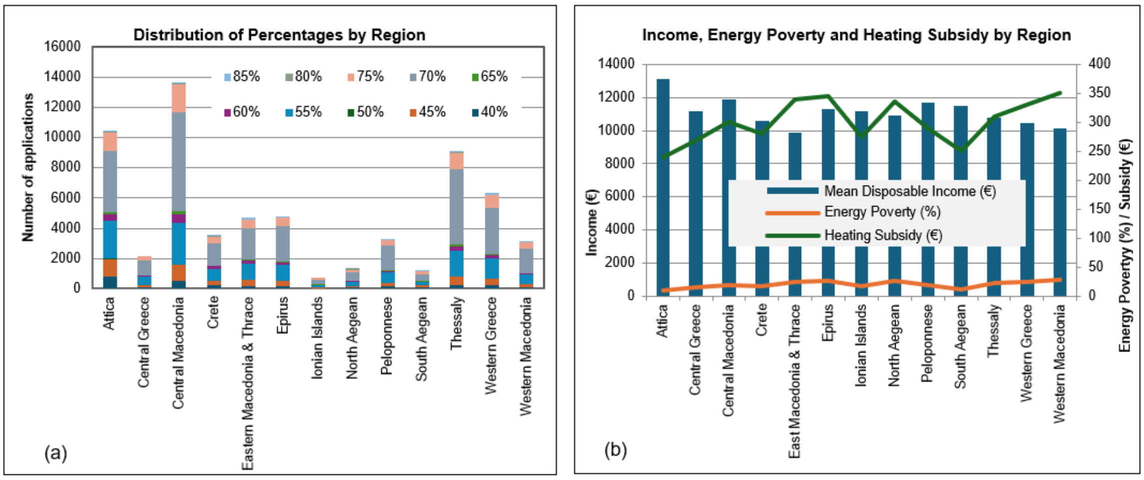
Addressing hidden energy poverty -where households silently reduce consumption to avoid costs- requires the use of more sophisticated and multidimensional indicators. This issue is particularly evident in Greece, where the economic crisis and volatility in energy prices have had a significant impact on household energy behavior. According to Eurostat (2024), 19 % of Greek households were unable to heat their homes properly in winter, and 32 % reported difficulty paying utility bills on time—rates significantly higher than the EU averages (9.2 % and 6.9 %, respectively). The situation is further exacerbated among vulnerable population groups—such as the unemployed, low-income pensioners, and single-parent families—where the incidence rates are significantly higher. Additionally, energy poverty in Greece exhibits strong geographical disparities, with its intensity being markedly greater in peripheral and mountainous regions (Papada and Kaliampakos, 2017). The combination of energy inefficient housing, high energy prices and low disposable income sustains an environment where thousands of households continue to live in conditions of thermal inefficiency and economic stress.

Greece has implemented a series of targeted energy efficiency programs for residential buildings, with a strong income-based subsidy structure. One of the most prominent ones is “Exoikonomo 2021” program (MEE, 2025), with a total budget of € 1.2 B (initial budget € 0.6 M). The program subsidized in a range of 40 % to 75 % (reaching 85 % additionally prioritizing persons with disabilities, large families and single parent families etc) also in dependence on income level and home ownership status (owner-occupied vs rented) energy efficiency retrofits, based on five income categories were used, with the highest subsidy (75 %) allocated to households with an individual income ≤ € 5,000 or a family income ≤ € 10,000. Eligible interventions included replacement of frames, installation/upgrade of thermal insulation, upgrading of heating/cooling systems, DHW system using Renewable Energy Sources (RES) and other saving interventions (Smart home, lighting upgrade). The program introduced several key innovations, including the elimination of the time-based application priority, the adoption of social evaluation criteria, and the establishment of a beneficiary list. Notably, for the first time, a dedicated budget of € 100 M was allocated specifically for vulnerable households, with tailored provisions for the aforementioned categories, aiming to better target interventions toward those with the greatest need. Also, areas affected by natural disasters, where offered an increased subsidy rate up to 10 % higher than standard thresholds.

3.2 Energy efficiency targeting low-income households

The analysis that follows highlights the need to adopt a multilevel approach considering the indicators used for targeting energy efficiency measures through the lens of energy poverty. “Exoikonomo 2021” program, prioritized indicators (mean disposable income) and social criteria (people with disabilities, large families, and single-parent households), also accounting the regional disparities as one may see in Figures 1a and 1b.

Figures 1a and 1b indicate that a significant share of subsidies is directed either to areas already facing severe energy poverty or, in part, to regions and individuals with social vulnerabilities. However, notable differences in the average subsidy per application and region are observed: Crete stands out with by far the highest amount, reaching around € 187,162 per application, while the South Aegean follows with a considerably lower but still elevated average of approximately € 46,637. At the other end, the North Aegean and Ionian Islands show the lowest subsidy levels, both slightly above € 11,500. Several mainland regions, including Central Greece, Western Macedonia, Peloponnese, and Attica, fall in a middle range, with subsidies ranging between € 12,700 and € 14,000, while Thessaly, Western Greece, Eastern Macedonia and Thrace, and Epirus, present relatively close values (~ € 10,300), suggesting also low levels of subsidy. Nevertheless, when the average disposable income is considered -alongside the geographical distribution of heating allowances and the percentage of recorded energy poverty- a serious inconsistency becomes evident in the targeting of support measures: regions with higher energy poverty get more generous heating subsidies (i.e. Western Macedonia, North Aegean, and Epirus, where over 25 % of households face energy poverty, receive the highest support, between € 335 - € 350 per year) however this is not reflected in the available grant per application of “Exoikonomo 2021” program as one would expect. In contrast, Attica and South Aegean, with much lower energy poverty rates (10 – 12 %), receive smaller heating subsidies, around € 240 – € 250 but are granted a considerable higher average amount per application.



Figures 1: (a) Percentages of allowances of Exoikonomo 2021 per region in Greece, (b) Mean disposable income, energy poverty, heating subsidy in Greek regions in 2022 (MEE, 2025)

Spearman's rho analysis was used to study the relationship between the percentage of subsidies granted through the “Exoikonomo 2021” program per region and four key energy poverty indicators: as arrears in energy bills, the ability to keep the home adequately warm, the 2M indicator (high energy expenditure), and the M/2 indicator (hidden energy poverty) (see Table 1). This non-parametric method is suitable for non-linear data and small sample sizes and measures the strength and direction of a monotonic relationship between two ranked variables. A negative value indicates one variable rises as the other falls, while a positive value indicates that both increase. Stronger relationships are indicated by values near + 1 or - 1, while no significant correlation is implied by values close to 0. The p-value is used to assess statistical significance, with a threshold of $p < 0.05$.

Table 1: Spearman's rho analysis for the four basic EP indicators (Author's Own Elaboration, 2025, based on data from JustRedi report (JustReDI, 2024), and MEE, 2025)

EP Indicator	Spearman’s rho	P-value	Interpretation
Ability to keep house warm	- 0.434	0.138	Fairly negative
Arrears on utility bills	+ 0.283	0.348	Weak positive
2M (High energy expenditure)	- 0.107	0.727	Very weak negative
M/2 (Hidden energy poverty)	+ 0.159	0.603	Very weak positive
Ability to keep house warm (Sub. lev. 75-85 %)	+ 0.021	0.947	Very weak positive

The correlation analysis between the share of subsidies allocated per region and the four core energy poverty indicators revealed largely non-significant patterns. The strongest observed relationship, though not statistically significant ($\rho = -0.434$, $p = 0.138$), was between subsidies and the inability to keep the home warm, suggesting that higher subsidy allocations may be associated with improved thermal adequacy at the household level. A weaker, positive correlation was found with utility bill arrears ($\rho = 0.283$, $p = 0.348$), potentially indicating a targeted distribution of subsidies toward regions experiencing higher energy-related financial stress. In contrast, the relationship with the 2 M indicator -representing households with high energy expenditure burdens—was negligible ($\rho = -0.107$, $p = 0.727$), implying limited responsiveness of this structural metric to policy-based interventions. Similarly, the M/2 index, capturing hidden energy poverty through abnormally low energy consumption, showed a weak and non-significant positive correlation ($\rho = 0.159$, $p = 0.603$), pointing to potential gaps in accessibility or awareness of subsidy programs among the most vulnerable populations. Collectively, these findings highlight that while subsidies may contribute to alleviating specific, experience-based dimensions of energy poverty, their association with structural or behavioral indicators remains limited without broader systemic and informational interventions. Moreover, the correlation results between high subsidy levels (75 - 85 %) and the ability to keep warm, does not indicate a complete absence of association ($\rho = 0.021$, $p = 0.947$), yet it remains weak enough to suggest that any strong relationship between subsidies and this particular indicator at the regional level is likely.

4. Conclusions

Energy poverty remains a multidimensional challenge, compounded by economic fragility, regional disparities, and an aging building stock. While targeted energy efficiency programs and social support mechanisms have contributed to eliminating partially its impacts, significant barriers persist—including the prevalence of hidden energy poverty, unintentional unequal regional access, and limited financing options. Enhancing the effectiveness of such interventions requires a comprehensive policy approach that simplifies administrative procedures, expands outreach to marginalized groups, and integrates both social and technical indicators into program design. Energy efficiency programs like “Exoikonomo 2021” (Exoikonomo’ can be translated as ‘Reduction/Saving of Energy Cost’) can act as a strong pillar to the deployment of low-carbon strategies but often do not include vulnerable households at the degree that might be required. This is particularly noticed by the current Spearman analysis where it is shown that the grants distribution is not presenting a strong monotonic correlation. The results of the analysis indicate that the regional distribution of subsidies appears to contribute to alleviating certain aspects of energy poverty. However, no significant impact is observed on more structural or ‘hidden’ dimensions of energy poverty. These findings suggest that more effective targeting of vulnerable groups, and enhanced accessibility to relevant support programs should be pursued. The latter should be combined with more efficient methods of monitoring the proper and more targeted distribution of grants. This work is a preliminary step in this direction since to the authors’ knowledge the approach followed in this work is presenting a relatively novel workflow, at least for Greece. However, additional data sets are needed in order to perform more extensive analysis and address uncertainties and particularities that may occur from the examination of a one -even of the largest- Greek energy efficiency program. The study concludes with the suggestion of the development of a new energy poverty indicator that considers additional sensitivities and may also combine existing indicators. It also recommends a more detailed monitoring of subsidies' economic status and prioritization to reflect financial status, particularly for vulnerable groups. Finally, the current Spearman analysis showed that grants are not fully directed to the most vulnerable, and additional economic criteria may be necessary for a more balanced distribution of funds to regions and people needing them. This will help avoid overspending in regions with less intense energy poverty. The findings are crucial for improving energy poverty identification and prioritization.

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