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Targeting Energy Poverty under the Energy Efficiency Obligation Scheme: A Survey-Based Analysis for Türkiye

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EXTENDED ABSTRACT

The recast of the European Union Energy Efficiency Directive (EU EED) has made it clear that Energy Efficiency Obligation Schemes (EEOS) can no longer be considered separately from energy poverty (EP) considerations. EEOS is designed to reduce energy consumption through efficiency improvements, and therefore its capacity to address EP is inherently linked to tackling dwelling-level inefficiencies. Although EP may also result from factors such as low income or high energy prices, these lie outside the scope of EEOS. To design socially effective schemes, it is essential to identify households that are both technically eligible for energy efficiency upgrades and vulnerable to EP. In anticipation of a potential EEOS in Türkiye, this study takes a proactive approach by proposing a data-driven targeting methodology based on microdata from the Survey of Income and Living Conditions (SILC).

Introduction / background

Traditional definitions of EP, typically based on income or energy expenditure, often fail to identify households that are structurally inefficient or socially vulnerable. They tend to underestimate hidden deprivation, especially in regions where poor housing conditions and affordability issues intersect[1]. To address this, composite indices are increasingly used to capture the multidimensional nature of EP. These indexes allow for the integration of various social, economic, and infrastructural indicators into a single, interpretable score. A critical step in constructing such indexes is the assignment of indicator weights. These weights may be determined through expert judgment, equal or arbitrary weighting, or more formal methods based on statistical or machine learning techniques. While expert-based or arbitrary weighting may be useful in some contexts, data-driven approaches are often preferred for being more transparent, replicable, and unbiased[2]. This study applies statistical and machine learning techniques to construct an Eligibility Index (EI) and classify households into priority energy-poor, at-risk, and regular groups. It offers a data-driven, robust, and reproducible framework that supports targeted and equitable policy design.

Methodology

The methodology follows a three-step process. First, households with at least one of four dwelling-level inefficiency indicators were identified and filtered. These indicators include leaking roofs or damp walls (leak_prob), poor insulation (insulation_prob), stove-based heating systems (conv_heating_system), and material deprivation (mat_dep), which may reflect outdated or inefficient appliances. Second, within this filtered group, eleven financial and energy-related vulnerability indicators were evaluated, and six were selected through exploratory data analysis to avoid redundancy. The selected indicators, low income (low_income), utility arrears (arrears_utility), inability to keep the home adequately warm (keep_adeq_warm), perceived insufficiency (sufficiency), limited access to nutritious food (nutrition), and other financial burden (o_burden), were used to

[1] Cin, R. (2025). *Evidence-based analysis of Türkiye's energy efficiency obligation scheme: Sectoral applications, energy poverty, flexibility options and policy implications* (Doctoral dissertation). Istanbul Technical University, Energy Institute.
[2] Siksnelyte-Butkiene, I., Streimikiene, D., Lekavicius, V., & Balezentis, T. (2021). Energy poverty indicators: A systematic literature review and comprehensive analysis of integrity. *Sustainable Cities and Society*, *67*, 102756. https://doi.org/10.1016/j.scs.2021.102756

construct the EI. The EI is a weighted linear combination of these six binary indicators, with weights derived from Multiple Correspondence Analysis (MCA). The final EI formula is as follows: EI = 0.339 × o_burden + 0.185 × keep_adeq_warm + 0.145 × low_income + 0.134 × arrears_utility + 0.106 × nutrition + 0.091 × sufficiency. EI scores range from 0 to 1, with higher values indicating greater financial vulnerability. Third, households were clustered using the k-prototypes algorithm based on their EI scores, inefficiency types, and regional identifiers. This segmentation produced three distinct household groups: Priority Energy-Poor, At-Risk, and Regular, forming a practical basis for geographically and technically targeted EEOS interventions.

Results

The distribution of the EI scores reveals a wide range of vulnerability levels. Among the structurally inefficient households, approximately 13% have an EI score above 0.6. To assess the effectiveness of the filtering approach, EI scores were also calculated for households without any inefficiency. Only about 1% of this group exceeded the 0.6 threshold. This result confirms that high EI scores are highly concentrated among inefficient households and supports the decision to construct the index only within this group. While a small share of households without structural inefficiencies may face financial vulnerability, they are not suitable targets for technical interventions under EEOS and would require support through alternative policy instruments. Additionally, households with multiple inefficiency types tend to have higher EI scores. Furthermore, EI scores vary significantly across regions. Higher EI scores are concentrated in the eastern and southeastern parts of Türkiye. In contrast, central and western regions show consistently lower EI scores.

To identify meaningful household segments for targeted interventions under a potential EEOS, clustering analysis was conducted. The aim was to let the data itself reveal vulnerability patterns based on multiple dimensions. The clustering incorporated EI scores, types of inefficiency present, and regional context. This structure captures financial vulnerability, the complexity of physical housing problems, and regional disparities, providing a data-driven basis for designing socially fair and practically viable EEOS interventions. The clustering produced three distinct household groups with clear differences in vulnerability profiles. The first cluster includes households with the highest EI scores and the most complex inefficiency problems. Many of these households experience overlapping structural inefficiency. They are disproportionately located in eastern and southeastern regions. This group corresponds to the Priority Energy-Poor households and represents the core target group for intensive EEOS interventions. It accounts for 14.7% of inefficient households. The second cluster reflects at-risk households with modest EI scores and typically one or two types of inefficiency. While they may not yet face severe deprivation, they remain vulnerable without preventive support. Representing 29.4% of inefficient households, this group is more evenly distributed across regions. The third cluster consists of households with the lowest EI scores and fewer inefficiency challenges. These Regular households are relatively better off, with either milder structural issues or greater financial resilience. They are more prevalent in central and western Türkiye. This group represents the majority, accounting for 55.9% of inefficient households.

Conclusion & discussions

In a context where Türkiye has yet to establish a dedicated EP policy, the implementation of an EEOS represents a key opportunity to integrate social goals into energy efficiency planning. This study offers a forward-looking framework to support policymakers in designing interventions that are both technically sound and socially just. By incorporating structural, financial, and spatial dimensions, the proposed methodology provides a replicable basis for identifying and prioritizing households most in need. The results highlight the need for differentiated policy responses. Priority Energy-Poor households require immediate and comprehensive interventions and should receive the highest level of support under EEOS. At-Risk households would benefit from preventive, targeted measures before their conditions worsen. Regular households, while less vulnerable, still face inefficiency problems and can be addressed through general tools such as co-financing.