

Climbing the Energy Ladder: Household Heating Fuel Choice in Jordan

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Research Article

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Abstract

This study examines the socioeconomic and geographic determinants of household heating fuel choice in Jordan, using a nationally representative sample of 18,434 households from the 2023 Demographic and Health Survey. Household fuel is classified into a three-tier energy-ladder hierarchy (traditional, transitional, and modern) and modeled using a partial proportional-odds specification that tests, rather than assumes, the proportional-odds assumption at each predictor level. The results reveal two structurally distinct transitions: an escape from traditional fuel, strongly governed by household wealth, rurality, and geography, and a further move into modern fuel, which depends more on local infrastructure and supply availability than on household income. Geography produces the largest effects; the northern highland governorates of Ajloun, Jarash, and Mafraq show dramatic entrenchment in biomass-based fuel use, while Aqaba exhibits a nearly fivefold advantage in cleaner fuel use relative to Amman. The wealth gradient is asymmetric, concentrated at the first transition, implying that income-targeted subsidies are effective at moving households off solid fuel but comparatively weak at further transitions to modern energy. Jordan's LPG-cylinder distribution system emerges as a notably inclusive instrument, reaching even informal and non-permanent dwellings. The findings point to three policy priorities: geographic targeting of energy-access interventions in governorates experiencing entrenchment, infrastructure investment to support the second energy transition, and targeted attention to the transitional-fuel lock-in observed in Zarqa. Testing proportional odds explicitly, rather than imposing a uniform energy ladder, constitutes the paper's principal methodological contribution.

1. Introduction

Energy consumption is a vital part of daily life, with households relying on it for cooking, heating, cooling, and lighting. Nevertheless, some Jordanian households face challenges in accessing clean, adequate energy sources due to economic and social barriers – a condition known as energy poverty. Previous studies have shown that household energy expenditure indirectly affects human development and that adapting to changes in energy prices takes a long time (M. M. Jaber & Szép, 2024b). Energy poverty in Jordan is defined as a condition that arises when a home's energy efficiency is low, and the household is unable to access modern, sustainable energy services due to economic and social barriers (M. Jaber, 2024). Because energy poverty is linked to social and economic capabilities, households facing higher levels of energy poverty suffer from social exclusion and an inability to maintain good health and access better educational opportunities (M. M. Jaber et al., 2025).

Research on energy poverty is increasing. According to the multidimensional energy poverty index, Jordanian households experience a moderate level of energy poverty, and Mafraq governorate has the highest energy poverty rate among Jordan's twelve governorates (M. M. Jaber, 2023; M. M. Jaber et al., 2025). Moreover, another study examined subjective indicators of energy poverty in Jordan and found that households in the Zarqa governorate face greater energy poverty, suffering more from an inability to cool adequately during summer than from an inability to heat adequately during winter (M. M. Jaber & Szép, 2024a). In addition, energy poverty in Jordan is inversely related to the human development index,

with areas experiencing higher rates of energy poverty suffering the lowest levels of human development, and vice versa (M. M. Jaber & Szép, 2024b).

A central theoretical lens for this study is the energy ladder, which posits that as household income rises, families progressively transition from traditional biomass fuels to cleaner, more efficient energy sources (Ahmad et al., 2023; Madhavan, 2024). The theoretical foundations of this framework, including its principal critique in the fuel-stacking literature, are reviewed in detail in Section 2.

Despite the progress the Hashemite Kingdom of Jordan has made in expanding access to energy sources, patterns of heating fuel use still differ markedly across governorates and between urban and rural areas. The research problem arises from the need to understand the social, economic, and demographic factors that influence household decisions about the type of fuel used for heating. Given the challenges associated with volatile energy prices, rising energy-poverty rates, and Jordan's commitment to Sustainable Development Goal 7, there is a pressing need for a rigorous study based on reliable national data to analyze this complex consumption behavior and to formulate evidence-based policies that promote energy justice and a sustainable transition.

This study addresses a clear gap in the energy-poverty literature on Jordan by analyzing the determinants of household heating fuel choice. Its results provide quantitative evidence to inform public policy on energy subsidies, targeted income support for energy-poor households, and reducing reliance on traditional fuels, thereby enhancing prospects for a just and sustainable energy transition. Situating these findings within the framework of SDG7 lends the study a strategic dimension and adds value for policymakers and researchers concerned with energy poverty, social protection, and sustainable energy in developing countries.

This study seeks to test a set of hypotheses grounded in economic theory and energy-ladder theory. First, there is a statistically significant relationship between socio-economic characteristics, such as income, education, and dwelling type, and the type of heating fuel used. Second, the higher the level of education and income, the greater the likelihood that households will use modern rather than traditional fuel sources. Third, patterns of fuel choice differ substantially across Jordanian governorates due to geographical and service-related disparities. Fourth, rural households are more likely to use traditional fuels than urban households due to poorer access to modern energy sources.

These research questions can therefore be summarized in four parts. What are the patterns of heating-fuel use among Jordanian households by governorate and by rural and urban areas? Which social, economic, and demographic factors influence households' choice of heating-fuel type? To what extent is the energy ladder reflected in the behavior of Jordanian households with respect to heating-fuel use? Are there statistically significant differences in the type of fuel used between households based on education, income, dwelling type, and the sex of the household head?

The remainder of the study is organized as follows. Section 2 presents a concise literature review of the energy-ladder concept and fuel stacking. Section 3 describes the research methodology and data.

Section 4 presents the main results. Section 5 discusses the findings in relation to the energy-ladder framework and Jordan's literature on energy poverty. Finally, Section 6 presents the conclusions and policy recommendations.

2. Literature review

Because human activities require energy, finding energy sources has been an important task for humankind since ancient times. Household energy use depends on several factors, such as the types of energy available, the nature of the required activity, and the ability to afford specific energy sources. Throughout history, humans have used energy in various forms; some come at no cost, such as biomass derived from animals, while others require effort to gather, such as firewood used for cooking and heating. The transition to modern energy can substantially improve the productivity of the poor by redirecting human resources, biomass, and land from fuel collection and production to income-generating activities. The choice that households make among different fuel types, with the foregoing taken into account, is known as the “energy ladder” theory.

The energy ladder is a concept that illustrates the primary sources of household energy across different income levels. It assumes that as people's incomes rise, they move up the “ladder” towards cleaner and more efficient energy sources (Roser, 2021). According to this model, households behave as utility-maximizing consumers in neoclassical economics, meaning they switch to more advanced energy sources as income rises (Van Der Kroon et al., 2013). The energy-ladder theory emerged during the 1990s as a conceptual framework for explaining the gradual shift in household fuel preferences in developing countries (Baldwin, 1987; Hosier & Dowd, 1987; Leach, 1992). A large number of studies subsequently focused on exploring the factors influencing this energy-transition process and its underlying mechanisms. Although demographic patterns, infrastructure development, and economic characteristics were taken into account, a body of research has shown that the energy-ladder model follows a linear, unidirectional path, in which households move from traditional biomass fuel to modern alternatives as income levels rise (Han et al., 2018).

Hiemstra-van der Horst and Hovorka (2008) offered three observations on the relationship between economic growth, modern fuel use, and the energy transition. First, a positive association was found between economic growth and modern fuel use across countries, suggesting that as countries industrialize, they rely more on oil and electricity and less on biomass. Second, research in Asia has shown that the shift to modern fuel use is driven by urbanization and development trends that increase access to modern fuel and raise household incomes. Finally, although the transition to modern fuel use in sub-Saharan Africa remains hypothetical, differences in energy use between income groups and the urban–rural divide suggest that a broad transition away from traditional biomass will be a fundamental feature of economic growth, urbanization, and industrialization.

According to Heltberg (2004), the energy-ladder model comprises three distinct stages. The first stage is characterized by general reliance on biomass. The second stage of fuel transition assumes that

households move to “transitional fuels” such as kerosene, coal, and charcoal as a result of rising income, urbanization, and biomass scarcity. The third and final stage of the transition is reflected in households’ reliance on LPG, natural gas, or electricity for cooking. The four elements of the classical model – availability, affordability, accessibility, and acceptability – strongly influence the choice of fuel source. As individuals climb the energy ladder, their overall well-being improves accordingly. This relationship is closely linked to consumption theory, which posits that as income rises, households consume more goods and choose higher-quality products. This assumption rests on the assumption that households use a single type of fuel for each specific domestic activity (Szép et al., 2023). Furthermore, the 5D model proposed by Wagner & Götz (2021) presents five fundamental dimensions of energy-system transformation – decarbonization, digitalization, decentralization, democratization, and the diversification of service orientation – which represent the pivotal pillars of the energy transition.

In a study by Leach (1992) on the energy transition in developing countries, it was noted that the shift towards sustainable energy sources is not driven primarily by increased demand for modern fuel, but rather by the socio-economic changes that reduce the barriers to its widespread adoption, especially among low-income households that rely on traditional biomass. Improvements in the distribution of sustainable fuel in urban and rural areas and the affordability of modern fuel technologies – whether through financial means or favorable market conditions that lower appliance prices – are among the most prominent of these changes.

Nevertheless, some studies indicate that the “energy ladder” concept is merely a theoretical hypothesis and that the actual reality of household energy use is more complex (Szép et al., 2023). Masera et al. (2000) criticized the energy-ladder theory for not adequately explaining the dynamics of household fuel consumption. Instead, they pointed out that “fuel stacking” is a common pattern in the urban and rural areas of developing countries, where households use a mix of fuels from different rungs of the ladder. Modern fuel cannot fully replace traditional fuel, but only partially complements it (Muller & Yan, 2018). Fuel stacking is common among households that are at the beginning or middle of their climb up the energy ladder, where they cannot fully dispense with traditional energy sources (Yadav et al., 2021). Although the energy-ladder model may help predict trends in household-sector energy use in many developing countries, it may not fully explain the dynamics of fuel use in those households. Figure 1 shows the energy-ladder and fuel-stacking models. As Masera et al. (2000) found in the case of Mexico, different fuel types can coexist within the home, allowing households to retain certain fuels because of preference or lifestyle (such as preferring gas over electricity for cooking). This strategy is also a means of preparing households for emergencies arising from income fluctuations or irregular and unreliable energy sources (such as keeping a kerosene heater in case gas prices rise during periods of low income, or in case modern-source supplies are interrupted). Empirical studies point to a pattern known as “climbing with stacking”, a combination of gradual progression up the energy ladder and continued stacking of fuel types (Alananga & Igangula, 2022; Choumert-Nkolo et al., 2019). Household fuel choices, therefore, depend on socio-economic progress, which is influenced by the surrounding context, including affordability, accessibility, technology, geography, and patterns of use (preferences, lifestyles, interests, culture, and so on). Current household energy scenes typically show a mix of different fuel types

(traditional, transitional, and modern) for each service. For example, although Jordan enjoys 100% access to electricity and is classified as an upper-middle-income country, it still relies heavily on kerosene for domestic heating (at 61%) (M. M. Jaber & Szép, 2024a)

In contrast to the energy-ladder model, the stacking model broadens the analysis and provides a more comprehensive understanding of the energy transition by portraying it as a multidimensional process, in which households do not follow a strictly linear path towards cleaner fuel but use a mix of different fuel sources simultaneously to meet their daily energy needs. As their socio-economic situation improves, households begin to reduce their reliance on primitive fuels while increasing their use of modern fuels as part of the transition process (Waleed & Mirza, 2023). The simultaneous consumption of different fuel types depends on the nature of domestic tasks and the technologies available to households. The factors influencing households' decisions about stove and fuel choices are complex and multidimensional, encompassing social, economic, and cultural considerations, as well as the availability and accessibility of clean stoves and fuels. Political, social, and environmental influences also play an important role. Among the principal determinants of this choice are the household's income level and the costs of acquiring and using appliances and fuel, including both initial and recurrent costs (Shankar et al., 2020). In a study tracing the determinants of modern cooking-fuel use in South Korea, the results indicated that demographic variables play an important role, with women, the elderly, and those with high educational levels more inclined to use electricity. Yet income levels did not show a strong association with the choice between electricity and gas, a pattern that deviates from the traditional energy-ladder hypothesis. Psychological and behavioral factors contributed substantially to this preference; although environmental attitudes alone did not predict household choices, environmentally friendly practices and a concern for health increased the likelihood of choosing electricity. From a technical and practical standpoint, users of electric central heating also adopted electric stoves, perhaps because of an interest in newer technology or unified energy systems; but despite its advantages in terms of safety and cleanliness, the share of Korean households that adopted electricity as a main cooking fuel did not exceed 7.2% in 2016 (Lee et al., 2024). In another study, the authors used Nepal Living Standards Survey data to explore the factors influencing households' choice of domestic fuel, finding that households with higher income and education tend to rely on clean fuel such as LPG or electricity – supporting the energy-ladder hypothesis – whereas rural households and those headed by women or older individuals, as well as homes far from markets, face greater difficulties in adopting clean energy sources. The authors also observed that a large household size increases the likelihood of relying on traditional sources such as firewood and animal dung, and that there is clear regional variation in clean-fuel use between households in the mountainous areas and the Terai plains compared with their counterparts in the hill regions (Giri & Goswami, 2018). In a study in the Brazilian state of Amazonas, researchers examined the factors behind cooking fuel choices among 179 households in 14 riverine communities that still lack a reliable electricity supply despite the “Light for All” efforts since 2003. The study relied on a multiple regression model to identify the effects of age, the number of cooking meals, community location, education, and the household head's income on this choice. The results showed a widespread “fuel-stacking” phenomenon, with many households committed to using multiple sources rather than

fully transitioning to modern fuels, thereby slowing the pace of the shift towards clean alternatives. Accessibility and fuel affordability proved more influential than income alone, with education playing an important role in steering household behavior toward cleaner fuel types (Gyamfi et al., 2020).

3. Methodology

This study draws on the household recode file of the 2023 Jordan Demographic and Health Survey, administered by the Department of Statistics in partnership with ICF under the USAID-funded DHS Program (Department of Statistics (DoS) & DHS Program, 2024). The survey employs a stratified, two-stage probability design; all descriptive and inferential statistics reported below apply the household sample weight so that the results are representative of Jordan's national household population rather than of the realized sample alone.

From the raw file of 19,475 households, the analysis excludes 586 households reporting no home heating, 439 reporting an unclassifiable ("other") fuel, and 16 with a missing ("don't know") response for the household head's education, none of which can be located on the fuel-choice ordinal scale or assigned a complete covariate vector. The resulting analysis sample comprises 18,434 households.

The dependent variable, Fuel Category, recodes the survey's 15 raw heating-fuel responses into the three-tier hierarchy conventional in the energy-ladder literature (Hosier & Dowd, 1987; Leach, 1992): Traditional (charcoal, wood, straw/shrubs/grass, agricultural-crop residues, animal dung, garbage/plastic, peat), Transitional (kerosene/paraffin, gasoline/diesel, alcohol/ethanol), and Modern (electricity, solar air heater, LPG/cooking gas). Independent variables comprise household size and the household head's age (continuous); area of residence and the head's sex (binary, reference categories Urban and Male); the composite DHS wealth index, entered as an ordinal score from 1 [poorest] to 5 [richest]; governorate (12 categories, reference Amman); dwelling type (reference Apartment, with the sparsely populated Hut/Barrack category merged into "Other/Informal" to resolve a perfect-separation problem); and the household head's highest educational attainment (reference No education/pre-school).

Because Fuel Category is ordinal, a proportional-odds (ordinal logistic) specification is the natural starting point, as it is more parsimonious than a multinomial model and respects the implied ordering: Traditional < Transitional < Modern. All models were estimated in Stata 13 using the user-written `gologit2` command, which fits a generalized ordered logit in which each predictor can be constrained to satisfy the proportional-odds assumption or left free to vary across the model's two cumulative cut-points — Cut 1 (Traditional vs. Transitional + Modern, the probability of escaping traditional fuel entirely) and Cut 2 (Traditional + Transitional vs. Modern, the probability of reaching fully modern fuel) — depending on what the data support. The survey design was declared using `svyset`, with the cluster as the primary sampling unit, the DHS sample stratum as the stratification variable, and the normalized household weight as the sampling weight; the resulting design comprised 26 strata and 965 primary sampling units.

Proportional odds was tested for each predictor using `gologit2`'s `autofit` procedure, which begins from a fully constrained model and sequentially frees any predictor whose Wald test rejects the parallel-lines

assumption at the .05 level (Williams, 2006). The resulting partial proportional-odds specification was then re-estimated under the `svy:` prefix, which `gologit2` has supported since version 3.0, so that the reported standard errors and confidence intervals are fully adjusted for the survey's clustering and stratification.

Proportional odds held — and the predictor was accordingly constrained to a single coefficient applying identically across both cut-points — for the household head's age; two of the three dwelling-type categories (Villa, but not Dar or Other/Informal); two of the three education categories (Primary and Higher, but not Secondary); and four of the eleven governorates (Balqa, Madaba, Karak, and Aqaba, but not Zarqa, Irbid, Mafrq, Jarash, Ajloun, Tafila, or Ma'an). The remaining predictors — household size, area of residence, sex of household head, the wealth index, and the seven governorates just listed — were left free, meaning each has two distinct coefficients reported in Table 2. A final Wald test confirmed that the eight remaining cross-equation constraints could not be jointly rejected ($\chi^2(8) = 12.70$, $p = 0.122$), indicating that the resulting partial proportional-odds specification is well supported by the data.

Four limitations should be noted. First, the survey provides no detail on the simultaneous use of multiple fuel types for heating (fuel stacking); the analysis is therefore confined to each household's reported main heating fuel. Second, the survey does not collect household income or expenditure data, so the composite wealth index is used throughout as a proxy for income, a coarser measure than direct expenditure on heating fuel would provide. Third, the cross-sectional design precludes causal inference; reported associations describe the 2023 pattern of fuel use, not transitions over time. Fourth, `gologit2` flagged 510 in-sample households (2.8 percent of the analysis sample) for which the fitted model implies a predicted probability below zero for at least one fuel category — a recognized property of partial proportional-odds models once some predictors are freed across cut-points, most likely arising here in small governorate-by-dwelling cells such as Aqaba and Villa, and not evidence of a coding error.

4. Results

4.1. Descriptive Statistics

The weighted analysis sample of 18,434 households is heavily concentrated at the top of the energy ladder: 79.3% rely on a modern heating fuel (electricity, solar air heater, or LPG), 15.0% on a transitional fuel (kerosene, gasoline/diesel, or alcohol/ethanol), and 5.7% on a traditional fuel (wood, charcoal, peat, or another solid biomass source). This weighted distribution differs materially from the unweighted sample shares (10.0%, 11.4%, and 78.6%, respectively): the realized DHS sample over-represents traditional-fuel-reliant households relative to their true population weight, and the weighted figures are used throughout the remainder of this paper.

The sample's socio-demographic profile reflects Jordan's predominantly urban, settled population: 89.6% of households are urban and 10.4% rural; 85.7% are headed by a man and 14.3% by a woman; the mean household size is 4.88 (SD = 2.06), and the mean age of the household head is 49.8 years (SD = 13.8).

The wealth-index quintiles are close to evenly distributed (19–21% each), as designed. Geographically, Amman accounts for 43.1% of the weighted sample, followed by Irbid (18.5%) and Zarqa (12.3%); the remaining nine governorates each contribute under 7%. Most households live in apartments (70.0%) or detached houses (“dar”, 27.6%), with villas and informal/other dwellings each at roughly 1.2%. Just under a third of household heads (29.3%) have completed higher education, while 6.1% have no formal education. Full weighted descriptive statistics are reported in Table 1.

Table 1
Weighted descriptive statistics, analysis sample (N = 18,434).

Variable / category	Unweighted N	Weighted %
Continuous variables (weighted mean $\pm$ SD)		
Household size	18,434	4.88 $\pm$ 2.06
Age of household head (years)	18,434	49.77 $\pm$ 13.83
Heating-fuel category (dependent variable)		
Traditional	1,846	5.73%
Transitional	2,107	14.99%
Modern	14,481	79.27%
Area of residence (ref. Urban)		
Urban	14,693	89.62%
Rural	3,741	10.38%
Sex of household head (ref. Male)		
Male	15,292	85.68%
Female	3,142	14.32%
Wealth quintile		
Poorest	5,433	19.24%
Poorer	4,019	20.13%
Middle	3,676	20.57%
Richer	3,265	20.04%
Richest	2,041	20.01%
Governorate (ref. Amman)		
Amman	2,579	43.07%
Irbid	2,058	18.52%
Zarqa	1,869	12.28%
Balqa	1,409	6.33%
Mafrq	1,890	5.45%
Karak	1,339	3.25%
Jarash	1,390	2.68%

Variable / category	Unweighted N	Weighted %
Madaba	1,352	2.49%
Ajloun	1,356	2.05%
Ma'an	1,255	1.78%
Tafiela	1,355	1.19%
Aqaba	582	0.92%
Dwelling type (ref. Apartment)		
Apartment	9,388	70.01%
Dar (detached house)	7,701	27.58%
Villa	150	1.21%
Other / Informal	1,195	1.21%
Education of household head (ref. No education)		
No education	1,854	6.10%
Primary	2,564	11.52%
Secondary	10,061	53.06%
Higher	3,955	29.33%

4.2. Bivariate Analysis

Design-corrected Pearson chi-square tests were conducted for each categorical predictor to assess bivariate associations with the three-tier fuel-category variable before entering the predictors into the multivariate model. Five of the six predictors show a statistically significant association with fuel choice (all $p < 0.001$); only the sex of the household head fails to reach significance ($p = 0.160$). The patterns described below provide the descriptive foundation for the regression analysis that follows.

The wealth gradient provides the most direct descriptive support for the energy-ladder hypothesis (Fig. 2). Among households in the poorest quintile, 13.6% rely on traditional fuel and 74.4% on modern fuel; in the richest quintile, reliance on traditional fuel drops to 1.2% while modern fuel use rises to 84.0%. The steepest decline in traditional-fuel use occurs between the poorest and poorer quintiles (from 13.6% to 7.4%), suggesting that even a modest improvement in household wealth is associated with a substantial reduction in solid-fuel dependence. By contrast, the share of households using modern fuel increases more gradually across the upper quintiles, consistent with a ceiling effect as the majority of Jordanian households already use LPG, electricity, or solar heating.

Geographic disparities are equally pronounced. The urban-rural divide is sharp: only 4.0% of urban households rely on traditional fuels, compared with 20.9% in rural households, while modern fuel use

stands at 80.4% in urban areas and 69.2% in rural areas. Across governorates, the variation is wider still. Ajloun leads with 32.2% reliance on traditional fuels and only 63.4% on modern fuels, followed by Mafrq (24.8% reliance on traditional fuels) and Jarash (22.0% reliance on traditional fuels). At the opposite extreme, 93.8% of households in Aqaba use modern fuel, with Karak (86.2%) and Irbid (83.8%) also substantially exceeding the national average. These bivariate patterns foreshadow the multivariate finding that geography constitutes the single most powerful predictor block in the regression model.

Dwelling type shows a striking bivariate pattern. Detached houses (“dar”) have by far the highest traditional-fuel share (14.4%) and the lowest modern-fuel share (74.0%) among dwelling categories, consistent with the interpretation that free-standing structures in peri-urban and rural settings afford easier access to solid fuel. Informal or non-permanent dwellings, by contrast, report 92.5% modern-fuel use, the highest of any category, a pattern that likely reflects LPG cylinder distribution to refugee shelters and temporary structures. Education follows a clear gradient: traditional-fuel use declines from 11.8% among households headed by a person with no formal education to 1.4% among those with higher education, while modern-fuel use rises correspondingly from 75.4% to 86.3%. The sex of the household head is the only predictor that does not reach statistical significance at the bivariate level ($p = 0.160$); male-headed and female-headed households show broadly similar fuel distributions (5.9% and 5.0% traditional-fuel reliance, respectively). This bivariate non-significance is noteworthy because the multivariate model reveals a significant female-head effect once rurality and wealth are controlled, suggesting that the bivariate null result reflects confounding rather than a genuine absence of association.

4.3. Multivariate Results

The partial proportional-odds model fits the data well (design-based Wald $F(36, 904) = 37.76$, $p < 0.001$; McFadden pseudo- $R^2 = 0.100$), and a final test of the imposed constraints found no remaining evidence of a proportional-odds violation ($\chi^2(8) = 12.70$, $p = 0.122$). Full coefficient estimates are reported in Table 2; the discussion below organizes the findings by thematic domain, emphasizing the implications of the statistically significant results for household energy transitions in Jordan.

Household wealth emerges as a significant but asymmetric driver of fuel choice, consistent with the energy-ladder hypothesis. Each increase in wealth quintile raises the odds of escaping traditional fuel use by roughly one-third but improves the odds of reaching the modern tier by only about 9% (Table 2). In average marginal effect terms, each quintile increase lowers the predicted probability of traditional-fuel use by 1.3 percentage points and raises the predicted probability of modern-fuel use by 1.4 percentage points. This pattern suggests that the first step on the ladder, moving away from wood and charcoal, is the most income-sensitive transition, while the final step to electricity or LPG is shaped by factors beyond purchasing power alone. Education shows a parallel threshold effect: only higher education (university-level) is significantly associated with climbing the ladder, while primary and secondary education show no meaningful effect. The finding implies that the informational and attitudinal advantages that the capabilities literature links to energy-related decision-making (Day et al., 2016) require a substantial stock of human capital before they translate into fuel-choice behavior.

Larger households face compounding disadvantages at every step of the energy ladder; each additional member significantly reduces both the odds of escaping traditional fuels and the odds of reaching the modern tier, indicating that the economic strain of a larger household constrains fuel transitions throughout the ladder. The age of the household head shows only a borderline association ($p = 0.054$), suggesting that generational differences in fuel preference are largely accounted for by other socioeconomic controls. Female-headed households present an instructive asymmetry: they are significantly more likely than male-headed households to have moved beyond traditional fuel but show no additional advantage at the modern-fuel threshold. This may reflect the concentration of female-headed households in urban areas, where access to transitional fuels such as kerosene is more readily available, rather than an independent gender effect on the final step to LPG or electricity.

Rural residence constitutes one of the strongest predictors in the model. Rural households face more than halved odds of escaping reliance on traditional fuels compared with their urban counterparts and significantly lower odds of reaching the modern tier. In average marginal effect terms, rural residence raises the predicted probability of relying on traditional fuel by 3.5 percentage points and lowers the predicted probability of using modern fuel by 7.2 percentage points. These results indicate that infrastructure deficits, supply-chain constraints, and the cultural embeddedness of solid-fuel use in rural Jordan remain formidable barriers that wealth alone cannot overcome.

Governorate produces the largest and most heterogeneous effect sizes in the model. Relative to Amman, three broad patterns emerge from the partial proportional-odds structure. First, the northern highland governorates of Ajloun, Jarash, and Mafrq show lower odds of escaping traditional fuel dramatically, indicating that wood and charcoal burning remains entrenched in these areas, likely reflecting local biomass availability and the cooler climate that increases heating demand. Notably, these governorates show no significant disadvantage at the transitional-to-modern threshold, suggesting that once households move beyond solid fuels, the subsequent transition to modern energy proceeds as elsewhere. Second, Aqaba, Karak, and Madaba are significantly more likely than Amman to use cleaner fuel at both thresholds, with Aqaba's nearly fivefold advantage plausibly linked to its warmer climate and urban port economy. Third, the two largest non-capital governorates exhibit divergent patterns: Zarqa's advantage dissipates and reverses at the modern-fuel threshold, while Irbid's advantage appears only at that same threshold. These heterogeneous geographic effects underscore that a uniform national energy transition policy is unlikely to be equally effective across Jordan's diverse subnational contexts.

Dwelling type further differentiates fuel-choice pathways. Detached houses ("dar") are significantly associated with lower odds of clean fuel use at both thresholds relative to apartments, consistent with the interpretation that free-standing homes in peri-urban and rural settings have greater access to, and storage capacity for, solid and transitional fuels. The most striking finding concerns informal or non-permanent dwellings, which show no disadvantage in escaping reliance on traditional fuel but exhibit the largest positive effect in the entire model at the modern-fuel transition. This counterintuitive result likely reflects the category's composition in Jordan, which includes refugee shelters and temporary structures that are typically served by LPG distribution networks provided by humanitarian organizations. Villas

show a borderline negative association, likely reflecting the small cell size rather than a substantive effect.

Table 2
Partial proportional-odds regression results (odds ratios), survey-corrected.

Predictor	Cut 1: Traditional vs. Transitional+Modern			Cut 2: Traditional+Transitional vs. Modern			PO
	OR	95% CI	p	OR	95% CI	p	
Continuous predictors							
Household size	0.890	0.860–0.921	< 0.001***	0.931	0.906–0.957	< 0.001***	Free
Age of head	0.995	0.991–1.000	0.054†	0.995	0.991–1.000	0.054†	Held
Rural, sex, and wealth							
Rural (vs. Urban)	0.462	0.314–0.680	< 0.001***	0.633	0.462–0.867	0.004**	Free
Female head (vs. Male)	1.320	1.084–1.607	0.006**	1.102	0.921–1.317	0.288	Free
Wealth quintile	1.327	1.186–1.483	< 0.001***	1.093	1.032–1.159	0.003**	Free
Governorate (reference: Amman)							
Ajloun	0.128	0.071–0.230	< 0.001***	0.495	0.373–0.657	< 0.001***	Free
Aqaba	4.956	2.985–8.226	< 0.001***	4.956	2.985–8.226	< 0.001***	Held
Balqa	0.963	0.750–1.238	0.769	0.963	0.750–1.238	0.769	Held
Irbid	0.801	0.397–1.617	0.536	1.535	1.162–2.029	0.003**	Free
Jarash	0.344	0.178–0.667	0.002**	0.875	0.627–1.219	0.429	Free
Karak	2.252	1.553–3.266	< 0.001***	2.252	1.553–3.266	< 0.001***	Held
Ma'an	0.551	0.279–1.089	0.086†	1.220	0.831–1.791	0.310	Free
Madaba	1.588	1.220–2.067	0.001**	1.588	1.220–2.067	0.001**	Held

Note: † $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. "PO" records whether proportional odds held for that predictor: "Held" predictors are constrained to one coefficient applying to both cut-points (the figure is repeated in both columns); "Free" predictors have two distinct coefficients. Standard errors are linearized and adjusted for the DHS's 26 strata and 965 primary sampling units. Weights: DHS household sample weight (HV005/1,000,000), normalized.

Predictor	Cut 1: Traditional vs. Transitional+Modern			Cut 2: Traditional+Transitional vs. Modern			PO
	OR	95% CI	p	OR	95% CI	p	
Mafraq	0.318	0.163–0.621	0.001**	0.852	0.602–1.205	0.365	Free
Tafiela	0.501	0.281–0.892	0.019*	0.989	0.760–1.288	0.936	Free
Zarqa	2.019	0.915–4.455	0.082†	0.768	0.628–0.939	0.010*	Free
Dwelling type (reference: Apartment)							
Dar (detached house)	0.433	0.305–0.615	< 0.001***	0.771	0.665–0.895	0.001**	Free
Other / Informal	1.711	0.890–3.290	0.107	4.610	2.787–7.625	< 0.001***	Free
Villa	0.585	0.331–1.035	0.065†	0.585	0.331–1.035	0.065†	Held
Education of household head (reference: No education)							
Primary	0.946	0.713–1.256	0.701	0.946	0.713–1.256	0.701	Held
Secondary	1.093	0.832–1.436	0.525	0.999	0.769–1.299	0.996	Free
Higher	1.650	1.221–2.230	0.001**	1.650	1.221–2.230	0.001**	Held
Threshold (intercept)	33.992	14.120–81.827	< 0.001***	4.940	3.006–8.119	< 0.001***	—
<i>Note: † p < 0.10, * p < 0.05, ** p < 0.01, *** p < 0.001. “PO” records whether proportional odds held for that predictor: “Held” predictors are constrained to one coefficient applying to both cut-points (the figure is repeated in both columns); “Free” predictors have two distinct coefficients. Standard errors are linearized and adjusted for the DHS’s 26 strata and 965 primary sampling units. Weights: DHS household sample weight (HV005/1,000,000), normalized.</i>							

5. Discussion

These results support the central energy-ladder claim that household fuel choice tracks socioeconomic position (Hosier & Dowd, 1987; Leach, 1992), but the proportional-odds violations across fourteen of the twenty-two predictor levels reveal that this is not a single ladder with a uniform slope. Two structurally distinct transitions operate in Jordan’s heating-fuel market: an escape from solid, biomass-based fuel that is strongly and predictably governed by wealth, household size, geography, and rurality; and a further move into electricity, solar heating, or LPG once a household has already left traditional fuel behind. The

model's modest overall explanatory power is itself consistent with (Masera et al., 2000)'s critique of the strictly linear energy ladder: a meaningful share of the variation in fuel choice, particularly in the second transition, is shaped by factors not captured here, plausibly including local LPG-cylinder distribution logistics, electricity-grid connection quality, or seasonal price fluctuations in kerosene.

Geography dominates the model. The northern highland governorates — Ajloun, Jarash, and Ma'raq — exhibit dramatic entrenchment in traditional fuel, a pattern consistent not with income poverty per se but with energy-infrastructure poverty: populations falling back on locally available biomass for reasons of supply rather than preference, echoing the geographic concentration of multidimensional energy poverty already documented in Ma'raq (M. M. Jaber, 2023; M. M. Jaber et al., 2025). Tafiela and Ma'an show a weaker version of the same dynamic. At the opposite extreme, Aqaba's uniformly strong advantage across both transitions is consistent with its commercially developed coastal economy, well-established electricity and LPG supply chains, and hospitality-driven demand for reliable heating year-round. Madaba and Karak show a similar, if more modest, pattern.

The Zarqa and Irbid findings illustrate why testing proportional odds matters for policy. Zarqa's pattern — an advantage that dissipates and reverses at the modern-fuel threshold — points to fuel lock-in at the transitional rung: households that leave biomass behind disproportionately settle on kerosene or gasoline rather than progressing to LPG or electricity, plausibly reflecting the cheap, locally accessible liquid fuel associated with the governorate's industrial and refinery presence. Irbid shows the mirror image: no meaningful difference from Amman in escaping reliance on traditional fuel, but a significant advantage at the modern-fuel threshold, consistent with a bimodal population that combines an underserved rural fringe with a well-connected urban core. In both cases, the more robust finding sits at the modern-fuel transition — a distinction that a standard ordinal model, forcing a single coefficient across both thresholds, would conceal entirely, and is itself a methodological argument for testing, rather than assuming, proportional odds in energy-choice models.

The asymmetric wealth effect has direct policy implications. Because each quintile increase is strongly associated with escaping traditional fuel but only weakly with reaching the modern tier, income-targeted subsidies are the right instrument for the first transition but a comparatively blunt one for the second. Reaching modern fuel appears to depend more on infrastructure and supply availability than on household income. Once a non-traditional fuel is affordable, this argues for governorate-targeted investment in electricity grid reliability and LPG distribution networks rather than relying solely on further income transfers. Education shows a parallel threshold as only higher education is significantly associated with fuel choice, consistent with education functioning here less as a direct information channel — basic fuel use is not specialized knowledge — than as a marker correlated with the income, occupational stability, and urban residence that university completion in Jordan tends to confer (Biswas & Das, 2022; Kyeremeh et al., 2024). Female household headship raises the odds of escaping traditional fuel but confers no further advantage at the modern-fuel transition, a pattern plausibly linked to lower capacity for physical firewood collection rather than to systematic income or preference differences.

The informal-dwelling finding represents the clearest distributional success story in the data. Households in non-permanent structures who have left traditional fuels behind overwhelmingly reach the modern tier, almost certainly via LPG cylinders, which require no fixed electrical infrastructure and can serve housing stock that formal grid connections cannot reach. Jordan's LPG subsidy and cylinder-distribution system, therefore, appears to function as a genuinely inclusive instrument, reaching even the housing segment most excluded from formal infrastructure investment. The corresponding policy gap is narrower than is sometimes assumed and lies specifically with households — geographically concentrated, including Zarqa — that still rely on kerosene or gasoline.

These conclusions are subject to the data limitations noted in the Methodology. The cross-sectional design and the survey's inability to observe fuel stacking are the most consequential. The latter is especially relevant to the Zarqa finding, since some households recorded as relying on kerosene or gasoline as their main fuel may also possess a secondary electric or LPG appliance that the survey's single-dominant-fuel question cannot capture, meaning the transitional-fuel lock-in described here is an upper-bound estimate. The small share of out-of-range predicted probabilities noted in the Methodology is concentrated in the smallest governorate and dwelling-type cells and does not undermine the larger, well-populated comparisons that anchor this discussion.

6. Conclusion

This analysis demonstrates that household heating-fuel choice in Jordan is governed by two distinct transitions rather than a single energy ladder, and that the second of these — the move from a transitional to a fully modern fuel — is both statistically harder to explain and policy-relevant in its own right. Treating the two transitions as a single proportional-odds process, as a conventional ordinal model would, conceals this structure entirely; testing the proportional-odds assumption explicitly and reporting both cut-points where it fails is the paper's principal methodological contribution.

The findings point to three policy priorities. First, geographic targeting should prioritize Ajloun, Jarash, Mafrq, Ma'an, and Tafiela, where the odds of remaining on traditional, biomass-based fuels are highest, and the underlying driver—local fuel availability rather than household preference—calls for energy-access rather than purely income-based interventions. Second, because wealth's effect is concentrated almost entirely at the first transition, income-targeted subsidies and wealth transfers are the appropriate instruments for moving households off solid fuel, but a comparatively weak lever for the further move into the fully modern tier; that second transition appears to depend on local infrastructure and fuel-supply reliability more than on household income. Third, Jordan's LPG-cylinder distribution system already functions as a remarkably inclusive policy success, reaching even informal and non-permanent dwellings; the corresponding policy gap is narrower than is sometimes assumed and lies specifically with the households — geographically concentrated, including in Zarqa — still relying on kerosene or gasoline rather than electricity, solar heating, or LPG.

Future research should prioritize three extensions summarized as panel or repeated cross-sectional data to establish whether the patterns identified here represent stable structural features of Jordan's fuel market or a transitional snapshot; survey instruments capable of capturing fuel stacking, which the current DHS module cannot detect; and an impact evaluation of Jordan's LPG subsidy and distribution reforms, using the governorate-level variation identified here as a natural starting point for identifying which delivery mechanisms are driving the second, harder transition into fully modern fuel.

Declarations

Author Contribution

M.M.J. conceived the study, harmonized survey data previously reported in the author's original publications, performed the analysis, and wrote the manuscript.

Data Availability

This study is based entirely on secondary analysis of publicly available, anonymized data from the 2023 Jordan Demographic and Health Survey (DHS), which was collected under its own ethical approval.

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Figures

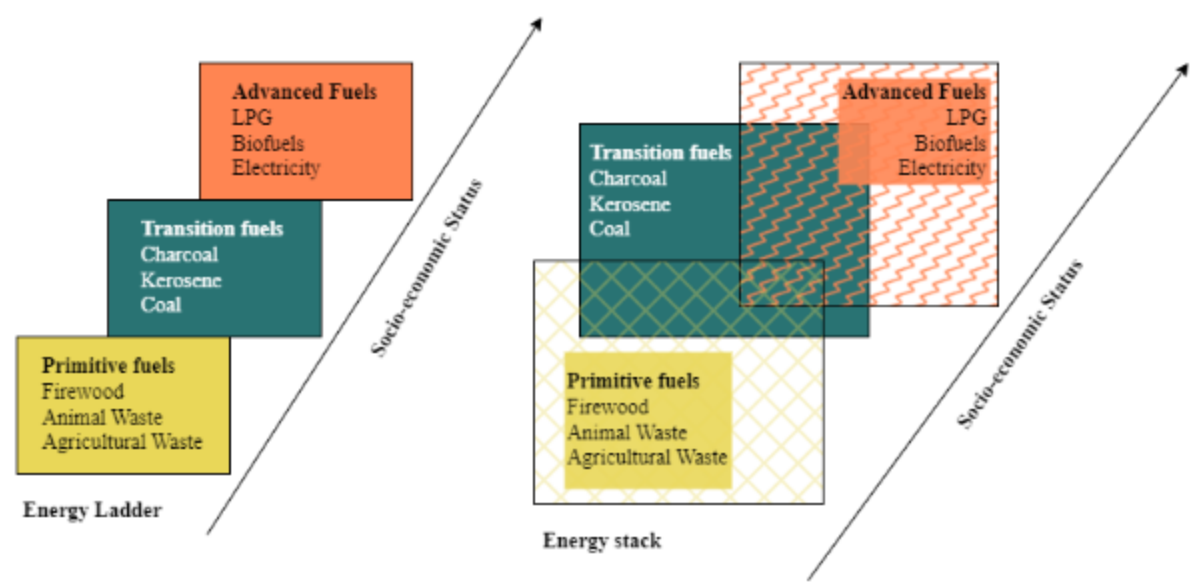


Figure 1

The energy-ladder model and the fuel-stacking model.

Source: prepared by the author, based on Schlag and Zuzarte (2008).

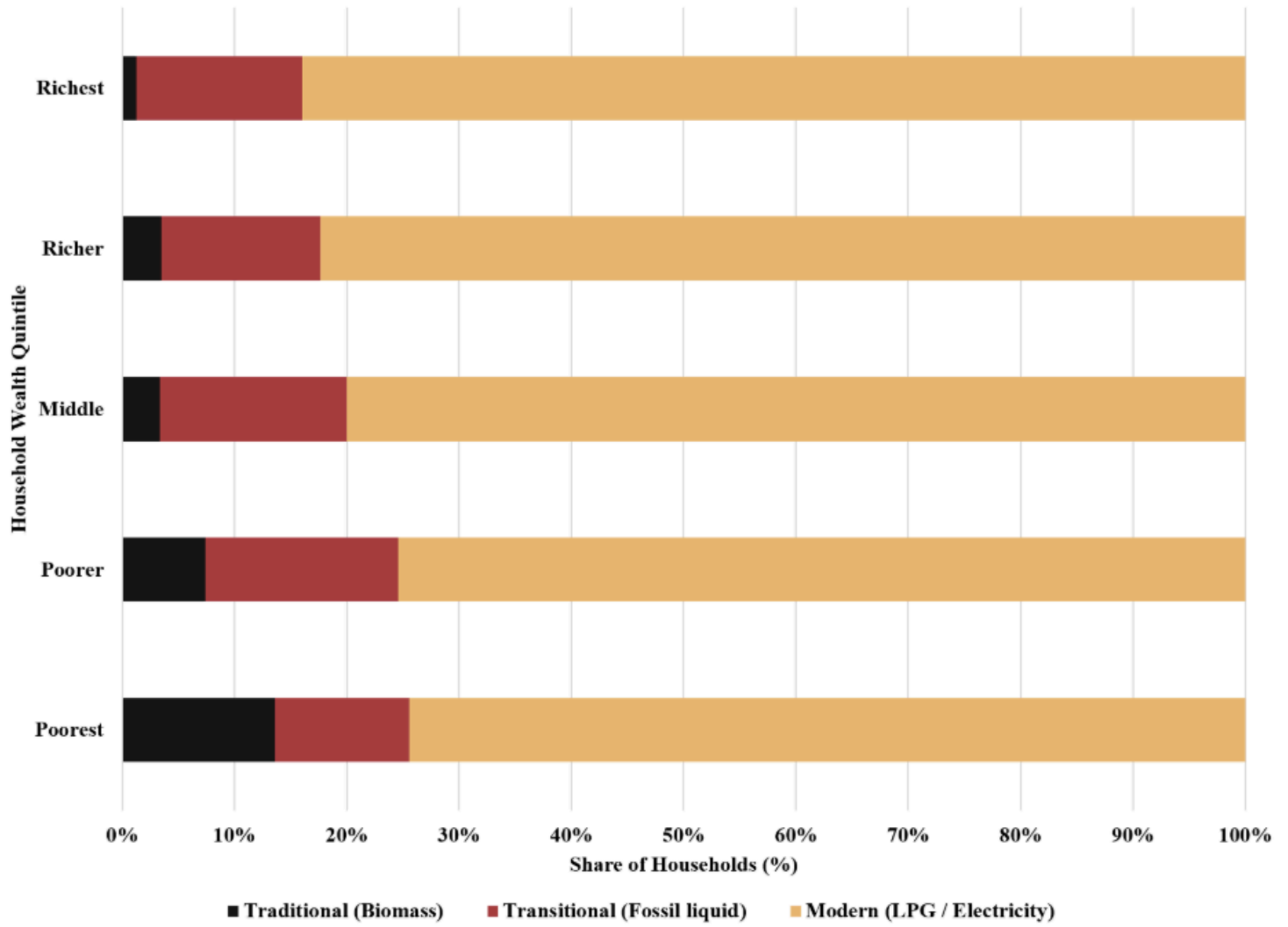


Figure 2

Energy Ladder: Heating Fuel by Household Wealth Quintile (N = 18,434).