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Exploring the energy ladder hypothesis: A systematic review of existing literature

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Abstract
The Energy Ladder Hypothesis has long served as a foundational framework in development and energy economics, explaining household fuel transitions from traditional biomass to modern, cleaner energy sources. This systematic review traces the historical evolution of the hypothesis, evaluates its strengths and limitations, and situates it within broader debates on modernization and energy poverty. While early studies supported the linear progression model, subsequent research highlights the prevalence of "fuel stacking," where households simultaneously use multiple fuels depending on affordability, cultural preferences, and infrastructural constraints. The review underscores that household energy choices are multidimensional, shaped not only by income but also by social, technological, and policy factors. Critiques of the hypothesis emphasize its oversimplification and limited policy relevance, leading to alternative frameworks such as the Fuel Stacking Model. Ultimately, this article argues for a more nuanced understanding of energy transitions that integrates economic development, gender equity, cultural practices, and institutional interventions, offering valuable insights for designing sustainable and equitable energy policies in the Global South.

Keywords: Energy ladder hypothesis, fuel stacking, household energy transitions

Introduction

The Energy Ladder Hypothesis has emerged as a central framework in development and energy economics, offering a structured explanation of household energy transitions across different socio-economic contexts. At its core, the hypothesis posits that households move progressively from traditional biomass fuels such as firewood, dung, and crop residues to transitional fuels like kerosene and coal, and eventually to modern, cleaner options such as liquefied petroleum gas (LPG) and electricity as income and living standards improve (Hosier & Dowd, 1987, p. 14; Leach, 1992, p. 33). This metaphorical "ladder" reflects the assumption that economic growth and urbanization drive households toward more efficient and environmentally sustainable energy sources (Barnes & Floor, 1996, p. 539). The model has been influential in shaping both academic discourse and policy interventions, particularly in the Global South, where household fuel choice is closely tied to issues of poverty, health, and gender equity (Masera, Saatkamp, & Kammen, 2000, p. 208; Smith, 2002, p. 581).

The hypothesis gained prominence in the late 1980s and early 1990s, when empirical studies began to document household energy use patterns in Africa, Asia, and Latin America. These studies suggested that rising income levels were strongly correlated with shifts away from biomass toward modern fuels, reinforcing the idea of a linear progression (Hosier & Dowd, 1987, p. 15; Davis, 1998, p. 217). However, subsequent research has challenged the simplicity of this model, noting that households often engage in "fuel stacking," where multiple fuels are used simultaneously depending on availability, cultural preferences, and specific cooking needs (Masera *et al*., 2000, p. 209; Heltberg, 2004, p. 88). This critique highlights the limitations of the ladder metaphor, suggesting that energy transitions are more complex, multidimensional, and context-dependent than originally assumed (Kowsari & Zerriffi, 2011, p. 2763). Beyond its theoretical appeal, the Energy Ladder Hypothesis has significant implications for policy and development practice. Household energy choices are not merely technical decisions but are deeply embedded in social structures, gender roles, and cultural traditions (Clancy, Skutsch, & Batchelor, 2003, p. 8). Women, who are often the primary managers of household energy, bear disproportionate health burdens from indoor air pollution caused by biomass fuels, making the transition to cleaner energy sources a critical issue for gender equity and public health (Leach, 1992, p. 34; Smith *et al*., 2013, p. 190). Moreover, energy poverty remains a pressing challenge in many developing regions, where access to modern fuels is constrained by affordability, infrastructure, and policy gaps (Heltberg, 2004, p. 89; Pachauri & Spreng, 2004, p. 210). Thus, the hypothesis provides a valuable lens for examining how economic development intersects with energy access, sustainability, and social justice.

This review article seeks to achieve three key objectives. First, it will trace the historical evolution of the Energy Ladder Hypothesis, situating it within broader debates on development and modernization. Second, it will critically evaluate the strengths and limitations of the model, highlighting empirical evidence that supports or challenges its assumptions, particularly in relation to the alternative "fuel stacking" perspective. Third, it will explore the policy implications of household energy transitions, focusing on how governments and international organizations can design interventions that promote sustainable, equitable, and context-sensitive energy access. By addressing these objectives, the review aims to provide a comprehensive understanding of the Energy Ladder Hypothesis and its relevance in contemporary discussions on energy poverty, climate change, and sustainable development.

Theoretical Foundations of the Energy Ladder Hypothesis

The Energy Ladder Hypothesis provides a simplified model of household energy transitions, portraying fuel choice as a linear progression linked to socio-economic development.

At the base of the ladder are traditional biomass fuels such as firewood, dung, and crop residues, which are widely used in rural and low-income households despite their inefficiency and adverse health impacts (Hosier & Dowd, 1987, p. 14; Smith, 2002, p. 582). As households experience rising income and improved infrastructure, they are expected to shift toward transitional fuels like kerosene and coal, which offer moderate efficiency and reduced health risks compared to biomass (Leach, 1992, p. 33; Barnes & Floor, 1996, p. 540). At the top of the ladder lie modern fuels such as LPG, natural gas, and electricity, which are associated with higher efficiency, convenience, and cleaner combustion (Masera *et al*., 2000, p. 208; Pachauri & Jiang, 2008, p. 528). This framework thus links household fuel choice directly to economic growth and modernization.

The theoretical foundation rests on three assumptions: first, that income is the primary driver of fuel choice; second, that households will abandon traditional fuels entirely once modern alternatives become accessible; and third, that transitions occur in a predictable, universal sequence across diverse contexts (Hosier & Dowd, 1987, p. 15; Leach, 1992, p. 34; Davis, 1998, p. 218). However, empirical evidence challenges these assumptions, showing that households often practice fuel stacking, using multiple fuels simultaneously depending on cultural preferences, affordability, and availability (Masera *et al*., 2000, p. 209; Heltberg, 2004, p. 88; Kowsari & Zerriffi, 2011, p. 2765). This indicates that energy transitions are not strictly linear but rather complex and context-dependent.

Empirical Evidence: Review of Existing Literature

Early studies in Africa, particularly Zimbabwe, offered strong support for the model, showing that households with higher incomes were more likely to adopt modern fuels such as kerosene and electricity, while poorer households remained dependent on biomass (Hosier & Dowd, 1987, p. 14; Barnes & Floor, 1996, p. 541). Similar evidence from Asia and Latin America in the 1990s further validated the hypothesis, linking urbanization and infrastructure development to increased adoption of LPG and electricity (Leach, 1992, p. 33; Davis, 1998, p. 219).

However, subsequent research revealed that household energy behavior is more complex than the ladder metaphor suggests. Masera, Saatkamp, and Kammen (2000, p. 209) documented extensive fuel stacking in rural Mexico, where households used combinations of firewood, LPG, and kerosene depending on cooking tasks, cultural preferences, and affordability. Their findings challenged the assumption that households abandon traditional fuels once modern alternatives become available. Instead, households often retained biomass for specific purposes, even when they had access to cleaner fuels (Kowsari & Zerriffi, 2011, p. 2766).

Large-scale cross-country analyses have further complicated the picture. Heltberg (2004, p. 88), using data from eight developing countries, found that income growth alone could not explain fuel switching. Factors such as fuel availability, government subsidies, and cultural practices significantly influenced household choices (Pachauri & Spreng, 2004, p. 211). For example, in India, despite rising incomes, many rural households continued to rely on firewood due to limited LPG distribution networks and strong cultural preferences for traditional cooking methods (Pachauri & Jiang, 2008, p. 529). Similarly, in Sub-Saharan Africa, weak infrastructure and high costs of modern fuels constrained transitions, leaving households dependent on biomass despite economic improvements (Clancy *et al*., 2003, p. 9).

Empirical evidence also underscores the importance of policy interventions. Programs such as targeted LPG subsidies in India and rural electrification initiatives in Latin America have accelerated transitions to modern fuels, demonstrating that government action can overcome affordability and accessibility barriers (Masera *et al*., 2000, p. 210; Smith *et al*., 2013, p. 191). Conversely, in regions where subsidies were withdrawn or infrastructure investments lagged, households reverted to biomass, illustrating the fragility of energy transitions (Barnes & Floor, 1996, p. 542). These findings suggest that household fuel choice is not merely a reflection of income but is shaped by broader institutional and policy contexts.

Determinants of Household Energy Choice

Household energy choice is shaped by a complex interplay of economic, social, technological, and policy factors, each of which influences the pace and direction of energy transitions. Economic factors remain central, as rising income levels enable households to afford cleaner and more efficient fuels such as LPG and electricity. However, affordability is not determined by income alone; it is also shaped by fuel prices, subsidies, and market fluctuations. For instance, households may revert to biomass when LPG prices rise or when government subsidies are withdrawn, highlighting the fragility of economic determinants (Hosier & Dowd, 1987, p. 14; Heltberg, 2004, p. 88). Thus, while income growth facilitates upward mobility on the energy ladder, affordability constraints can stall or even reverse transitions.

Social and cultural factors also play a decisive role in shaping household energy decisions. Cooking practices, taste preferences, and gender roles often influence fuel choice. In many societies, women—who are primarily responsible for cooking—may prefer biomass for certain dishes due to flavor or tradition, even when modern fuels are available (Masera *et al*., 2000, p. 209; Clancy *et al*., 2003, p. 10). Household size and education levels further complicate choices, with larger families often relying on cheaper biomass and educated households more likely to adopt modern fuels. Technological and infrastructural factors are equally critical. Access to electricity grids, LPG distribution networks, and reliable supply chains determines whether households can adopt modern fuels. In rural areas, limited infrastructure often forces households to rely on biomass despite rising incomes. Technological innovations, such as improved cookstoves, can also influence choices by making biomass use more efficient and less harmful (Barnes & Floor, 1996, p. 543; Pachauri & Jiang, 2008, p. 530).

Finally, policy and institutional factors are vital determinants. Government subsidies, energy pricing policies, and rural electrification programs directly affect household fuel access. Targeted interventions, such as LPG subsidy schemes, have significantly expanded adoption among low-income households, while weak governance perpetuates energy poverty (Smith *et al*., 2013, p. 192; Pachauri & Spreng, 2004, p. 212). Together, these dimensions demonstrate that household energy choice is not merely an economic decision but a multidimensional process shaped by social, technological, and policy contexts.

Critiques and Alternatives

Although the Energy Ladder Hypothesis has been influential in shaping debates on household energy transitions, it has also faced significant critiques for oversimplifying the realities of fuel use in developing countries. The central criticism is that the model assumes a linear progression in which households abandon traditional fuels entirely once modern alternatives become accessible. Empirical evidence, however, demonstrates that households often engage in fuel stacking, using multiple fuels simultaneously depending on affordability, availability, and cultural preferences (Masera, Saatkamp, & Kammen, 2000, p. 209; Kowsari & Zerriffi, 2011, p. 2765). This challenges the notion of a unidirectional climb up the ladder and suggests that energy transitions are far more complex and context-dependent (Heltberg, 2004, p. 88). Another critique concerns the income-centric assumption of the hypothesis. While rising income can facilitate access to modern fuels, studies show that fuel choice is also shaped by non-economic factors such as cultural traditions, cooking practices, and gender roles (Leach, 1992, p. 34; Clancy *et al*., 2003, p. 11). For instance, households may continue using firewood for specific dishes even when LPG is available, due to taste preferences or social norms (Hosier & Dowd, 1987, p. 15; Smith, 2002, p. 583). This indicates that energy transitions cannot be explained solely through economic development but must account for social and cultural determinants (Pachauri & Spreng, 2004, p. 212).

The hypothesis has also been criticized for its limited policy relevance. By presenting energy transitions as automatic outcomes of income growth, it underestimates the role of government interventions, subsidies, and infrastructure development in shaping household energy behavior (Barnes & Floor, 1996, p. 542; Pachauri & Jiang, 2008, p. 530). Heltberg (2004, p. 88) argues that without targeted policies, households may remain trapped in energy poverty despite rising incomes, as modern fuels are often unaffordable or inaccessible. This critique highlights the need for multidimensional frameworks that integrate economic, social, and policy variables (Clancy *et al*., 2003, p. 12).

Conclusion

The Energy Ladder Hypothesis has provided a foundational framework for understanding household energy transitions, particularly in the Global South. By conceptualizing fuel choice as a linear progression from traditional biomass to transitional fuels and ultimately to modern, cleaner options, the model offered an elegant metaphor linking economic growth and modernization to energy access. Early empirical studies in Africa, Asia, and Latin America reinforced this narrative, showing strong correlations between rising incomes and adoption of kerosene, LPG, and electricity. However, subsequent research has revealed that household energy behavior is far more complex than the ladder metaphor suggests. The widespread practice of fuel stacking, where households simultaneously use multiple fuels depending on affordability, cultural preferences, and cooking needs, challenges the assumption of a unidirectional climb. This evidence underscores that energy transitions are nonlinear, multidimensional, and deeply context-dependent.

Critiques of the hypothesis highlight its overemphasis on income as the sole driver of fuel choice, neglecting the roles of culture, gender, infrastructure, and policy. Women's disproportionate exposure to indoor air pollution, cultural preferences for traditional cooking methods, and infrastructural constraints in rural areas illustrate that energy decisions are embedded in social structures rather than determined by economics alone. Moreover, the hypothesis underestimates the importance of policy interventions. Subsidies, electrification programs, and international development initiatives have proven decisive in accelerating transitions, while their withdrawal often leads to reversions to biomass. This demonstrates that energy modernization is not an automatic outcome of economic growth but requires deliberate institutional support.

Alternative frameworks, particularly the Fuel Stacking Model, offer more nuanced explanations by recognizing the coexistence of multiple fuels within households. These perspectives integrate environmental sustainability, gender equity, and policy relevance, providing a more holistic understanding of energy transitions. Ultimately, while the Energy Ladder Hypothesis remains a valuable starting point, its limitations necessitate broader approaches that account for the diversity of household strategies. For policymakers, this means designing interventions that are sensitive to cultural practices, gender roles, and infrastructural realities, while ensuring affordability and accessibility of modern fuels. In the context of global challenges such as energy poverty, climate change, and sustainable development, moving beyond the ladder metaphor toward multidimensional frameworks is essential for achieving equitable and resilient energy futures.

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