Vitošević, J. (2025). Energy insecurity and its health impacts: A multi-dimensional analysis, *SCIENCE International journal, 4*(2), 19-25.
doi: 10.35120/sciencej0402019v UDK: 620.9-338.23-021.388]:613.1

ENERGY INSECURITY AND ITS HEALTH IMPACTS: A MULTI-DIMENSIONAL ANALYSIS

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Abstract: Energy insecurity, the lack of reliable, affordable, and safe energy, represents a growing but underexamined determinant of public health. This paper offers a multi-dimensional analysis of how energy insecurity affects health outcomes through interrelated physical, economic, and behavioral pathways. Drawing on interdisciplinary theoretical frameworks and a narrative synthesis of literature from both high-income and low- and middle-income countries, the study reveals that energy insecurity contributes to a wide spectrum of adverse outcomes, including respiratory illnesses, mental health issues, increased hospitalization rates, and social isolation. These impacts disproportionately affect vulnerable populations, reinforcing structural inequalities in health and energy access. By applying a systems thinking perspective, the paper highlights the cyclical nature of energy-related deprivation and its entanglement with housing conditions, economic hardship, and psychosocial stress. The findings underscore the need to reframe energy access as a critical component of health equity and advocate for integrated, justice-centered policies that bridge the divide between the energy and health sectors. The study concludes by calling for greater empirical research, particularly in underrepresented regions, and the incorporation of health-focused strategies into energy transition planning.

Keywords: *energy insecurity, health, environmental justice.*
Field: Social sciences; Law.

1. INTRODUCTION

The global energy landscape is undergoing a profound transformation marked by shifting geopolitical dynamics, increasing reliance on renewable resources, and heightened awareness of climate-related risks. In the 21st century, access to reliable, affordable, and clean energy is increasingly recognized as a critical determinant of health and human development. While much of the discourse around energy security focuses on economic and environmental dimensions, its implications for human health are often underexplored. Conversely, energy insecurity, the lack of reliable access to sufficient, affordable, and clean energy, poses significant direct and indirect threats to health, ranging from respiratory diseases caused by indoor air pollution to broader social vulnerabilities exacerbated by power instability. Despite global advances in energy technologies and infrastructure, millions of people around the world continue to live in conditions of energy insecurity, a state defined by insufficient, unstable, or unaffordable energy access. This condition is not only a marker of social and economic deprivation but also a potent contributor to a wide range of health challenges. The link between energy and health is complex, multifactorial, and mediated by both direct and indirect mechanisms, many of which remain underexplored in mainstream health and energy policy discourse.

At the household level, energy insecurity compels families to rely on polluting and unsafe fuels such as wood, charcoal, coal, or kerosene. The resulting indoor air pollution is a leading cause of respiratory infections, chronic obstructive pulmonary disease, and cardiovascular problems, particularly in women and children. Inadequate energy access also disrupts the provision of essential health services. Hospitals and clinics in energy-insecure regions frequently experience power outages that jeopardize emergency care, refrigeration of vaccines, surgical procedures, and the operation of life-saving equipment. Furthermore, energy poverty exacerbates social stress, erodes community resilience, and contributes to mental health problems, especially among vulnerable groups facing compounding socioeconomic pressures. Importantly, the impacts of energy insecurity are unevenly distributed. Low-income populations marginalized ethnic groups, displaced persons, and residents of informal settlements bear the heaviest burden. Gender dynamics further compound these disparities, as women and girls often face disproportionate exposure to hazardous energy environments due to domestic roles in cooking and caregiving. In many contexts, energy insecurity also reinforces structural inequities in access to education, employment, and healthcare, perpetuating a cycle of disadvantages.

This paper presents a multi-dimensional analysis of energy insecurity and its health consequences. Drawing on theoretical insights from environmental health, social epidemiology, and systems thinking, it

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explores the interdependent pathways through which energy insecurity affects physical, mental, and social well-being. It also highlights feedback loops and long-term effects, including how poor health reduces household productivity and limits the capacity to invest in cleaner energy sources, creating a vicious cycle.

2. THEORETHICAL FRAMEWORK

Access to energy services is widely recognized as a fundamental prerequisite for human well-being. However, energy insecurity, defined as the lack of consistent, affordable, and clean access to energy, serves as a crucial mediating factor linking health, development, sustainability, and prosperity (Ang et al., 2015). Energy insecurity exists at both macro and micro levels. At the system level, it manifests when national or regional infrastructures fail to provide reliable and sustainable energy access. At the household level, it becomes evident through inadequate service delivery, unaffordable energy costs, or reliance on unsafe fuel sources, all of which have profound consequences for physical and mental health. Although some energy systems appear secure at the national level, this macro-level security often obscures stark inequities in energy distribution. Many communities and households, particularly those in low-income settings, experience persistent energy deprivation despite living in seemingly well-resourced countries. The term “fuel poverty” has historically been used to describe this condition, but more recent literature favors “energy insecurity” for its broader analytical scope, encompassing not only affordability but also physical infrastructure and behavioral adaptation strategies (Hernández, 2016). Drawing on ecological health, social determinants of health, systems thinking and environmental justice, key conceptual frameworks posit energy insecurity as a complex, context-dependent phenomenon with cascading effects on physical, mental and social well-being.

2.1. *Energy Insecurity as a Social Determinant of Health*

Energy insecurity functions as a social determinant of health, mediating the relationship between socioeconomic status and a wide array of health outcomes (Marmot & Wilkinson, 2005; Marmot et al., 2008). Studies have shown that in low-income neighborhoods, energy insecurity is associated with respiratory illnesses, depression, asthma, sleep disturbances, and increased hospitalization rates among children, particularly during extreme weather seasons (Cook et al., 2008; Hernández & Siegel, 2019). Medical vulnerability, stemming from chronic conditions such as asthma, diabetes, or disabilities, has been shown not to protect against, but to exacerbate the scope of energy insecurity (Hernández, 2016). He outlines three dimensions of energy insecurity: physical, including inadequate housing and poor infrastructure; economic, referring to the disproportionate financial burden of energy costs on low-income households; and behavioral, involving coping mechanisms such as reducing energy use, rationing heat, or using dangerous alternatives. Behavioral energy insecurity can include both positive strategies, like resourcefulness and energy conservation, and negative ones, such as burning hazardous materials indoors, decisions that may place health, safety, and household stability at risk.

2.2. *Environmental Justice and Energy Equity*

The concept of energy justice provides an overarching normative framework for understanding how energy insecurity affects health and well-being across populations. Energy justice addresses the distributive, procedural, and recognitional dimensions of inequality in energy systems (Sovacool et al., 2016). Distributive injustice is particularly evident in the existence of “sacrifice zones”, regions that bear the environmental and health burdens of fossil fuel extraction and combustion, while receiving few direct benefits (Healy & Barry, 2017). The notion that some communities disproportionately suffer the health and ecological consequences of energy systems reflects a critical ethical and political failure in the design of modern energy policy. Moreover, energy insecurity is increasingly recognized as a barrier to human development in low- and middle-income countries. A paradox emerges in resource-rich nations, where the abundance of natural assets such as oil does not necessarily translate into development gains, a phenomenon known as the “resource curse” (Auty, 2007). These nations often suffer from commodity price volatility, governance deficits, and external influence over extraction industries, all of which impede their ability to invest in domestic energy security (Busse & Gröning, 2013).

2.3. *Systems Thinking and Complex Interactions*

We adopts a systems thinking perspective to explore the nonlinear and dynamic interactions between energy insecurity and health. Rather than viewing energy as an isolated input, this approach recognizes it as embedded within a broader social-ecological system characterized by feedback loops, time delays, and emergent properties (Meadows, 2008). For instance, poor health may reduce economic productivity, limiting household income and constraining the ability to purchase energy, thereby perpetuating a self-reinforcing cycle of deprivation.

Systems thinking also emphasizes the interdependence of sectors: health outcomes are shaped

not only by healthcare delivery but also by energy policy, urban planning, and climate resilience strategies. Identifying leverage points within this complex system is key to designing interventions that can yield broad, sustained improvements in both energy access and health equity (Rutter et al., 2017).

3. METHODOLOGY

This paper selects a qualitative, theory-informed analytical approach to investigate the health implications of energy insecurity through a multi-dimensional lens. Given the complex, intersectional nature of the topic, spanning health, energy policy, infrastructure, and social justice, a narrative literature, based synthesis was selected as the most suitable methodological framework. This design allows for the integration of diverse sources of evidence and conceptual models, enabling a nuanced analysis of both direct and indirect health impacts across various global contexts. Analytical Framework and Design is grounded in three intersecting frameworks: the three-dimensional model of energy insecurity (physical, economic, behavioral) as conceptualized by Hernández (2016); the social determinants of health framework, which highlights the broader socioeconomic conditions that shape health outcomes (Marmot & Wilkinson, 2005) and the energy justice perspective, which addresses the equitable distribution of energy services and the ethical considerations of energy production and consumption (Sovacool et al., 2016). These frameworks are further synthesized through a systems thinking perspective, which helps identify feedback loops, non-linear interactions, and emergent patterns that connect energy access, health outcomes, and resilience (Meadows, 2008; Rutter et al., 2017).

This study draws on secondary data from a wide range of peer-reviewed journal articles, policy documents, and organizational reports published between 2010 and 2024. Primary sources were identified through academic databases such as: Scopus, PubMed, Google Scholar, Web of Science. Key search terms included combinations of: energy insecurity, fuel poverty, health outcomes, mental health, public health, resilience, climate vulnerability, and energy justice.

The literature was selected based on the following inclusion criteria: focus on the relationship between energy (in)security and health outcomes; empirical or theoretical studies involving low-, middle-, or high-income countries; discussion of one or more dimensions of energy insecurity (physical, economic, behavioral); studies involving health system functioning, vulnerable populations, or household-level impacts. Studies focused solely on energy economics or technical system performance were excluded unless they included health-relevant components.

Findings were synthesized using thematic analysis, allowing for the identification of patterns across different dimensions of energy insecurity. Themes were mapped onto the analytical framework outlined above, with particular attention to: How physical infrastructure (e.g., housing quality, grid access) affects respiratory and cardiovascular health; How economic constraints on energy access lead to trade-offs in nutrition, heating, and healthcare usage; How behavioral coping mechanisms contribute to stress, injury, or disease exposure.

Several limitations must be acknowledged. First, this study does not include original fieldwork or quantitative meta-analysis; its strength lies in conceptual integration rather than statistical generalization. Second, the quality and regional specificity of available literature vary, potentially limiting comparability. Finally, while a systems perspective allows for holistic insight, it may obscure finer causal mechanisms that require further empirical investigation.

Despite these limitations, this methodology offers a rigorous and interdisciplinary foundation for understanding the health consequences of energy insecurity and identifying avenues for policy innovation and social change.

4. RESULTS AND DISCUSSIONS

Research on energy insecurity and its effects on health has grown steadily over the past two decades, reflecting a shift toward interdisciplinary inquiry at the intersection of energy policy, social inequality, and public health. Although early studies focused primarily on energy access in developing countries, recent work emphasizes the widespread nature of energy insecurity, even in high-income nations, and its multifaceted consequences for physical, mental, and institutional health outcomes. This literature review is organized around three primary themes aligned with the analytical framework of this paper: (1) physical infrastructure and housing quality, (2) economic vulnerability and affordability, and (3) behavioral adaptation and psychosocial stress.

4.1. Physical Infrastructure, Housing, and Health Risks

A significant body of literature highlights the direct health effects of inadequate energy-related

infrastructure, particularly in the context of housing. Poor insulation, unreliable electricity, and dependence on polluting fuels have been strongly associated with respiratory illnesses, cardiovascular problems, and excess winter mortality (Liddell & Morris, 2010; Thomson et al., 2017). In low-income settings, energy insecurity often results in exposure to indoor air pollution from biomass or kerosene stoves, contributing to the global burden of disease, especially among women and children (Bonjour et al., 2013). Energy-insecure households frequently live in substandard housing that lacks adequate ventilation, heating, or cooling systems. These conditions exacerbate chronic illness, reduce immune system function, and increase vulnerability to climate extremes (Siegel et al., 2024).

4.2. Economic Energy Burden and Trade-offs in Health

The economic dimension of energy insecurity has received increasing attention in recent studies, particularly through the concept of "energy burden", the proportion of household income spent on energy. High energy burden is associated with difficult trade-offs in household budgeting, including reduced spending on food, healthcare, and medications (Hernández, 2016; Drehobl & Ross, 2016). Households facing high energy costs often resort to energy rationing, limiting heating or lighting to unsafe levels, or relying on dangerous alternatives such as open flames or faulty heaters, increasing risks of fire, burns, or carbon monoxide poisoning. These coping strategies disproportionately affect low-income, elderly, and chronically ill individuals, contributing to cumulative health risks (Mould & Baker, 2017). Furthermore, studies have shown that high energy costs contribute to energy-related stress, which correlates with mental health issues such as anxiety, depression, and social isolation (Hernández et al., 2016; Jessel, Sawyer, & Hernández, 2019).

4.3. Behavioral Adaptation, Resilience, and Mental Health

The behavioral dimension of energy insecurity includes both adaptive and maladaptive coping strategies employed by individuals and households to manage constrained energy access. Positive responses, such as conserving energy or engaging in community-based sharing practices, reflect household resilience and resourcefulness. However, negative responses, including unsafe heating practices or avoiding healthcare visits to save energy costs, often result in direct harm to health and safety (Hernández, 2016). Studies have increasingly emphasized the psychosocial toll of energy insecurity. Living without consistent or adequate energy can induce a loss of control, diminished self-worth, and ongoing fear of disconnection. In vulnerable populations, this stress can have profound long-term mental health consequences, especially among children and caregivers (Hernández & Siegel, 2019; Cook et al., 2008). Furthermore, energy insecurity is shown to undermine social cohesion by isolating families and increasing stigma.

4.4. Emerging Topics: Climate Change, Health Systems, and Energy Justice

Recent literature has expanded the discussion to include climate vulnerability, emphasizing that climate change intensifies energy insecurity through extreme weather events, disrupted infrastructure, and shifting energy demand (Baker et al., 2018). This has implications not only for household health, but also for health system preparedness, as hospitals and clinics increasingly depend on reliable energy for cold chains, life support, and data systems. The literature also reflects a growing interest in energy justice, a framework that situates energy insecurity within larger questions of equity, recognition, and procedural fairness (Sovacool et al., 2019). Studies argue that energy transitions must be planned with justice in mind, avoiding the reproduction of existing health disparities or the creation of new "sacrifice zones" (Healy & Barry, 2017).

Table 1. Literature review organized around primary themes

Theme	Key Findings	Authors and year
Physical Infrastructure & Housing	Inadequate housing linked to increased winter mortality and poor respiratory outcomes	Liddell & Morris (2010)
Physical Infrastructure & Housing	Indoor air pollution from biomass fuels is a major global health risk, especially for women and children	Bonjour et al. (2013)
Economic Burden & Trade-offs	High energy burden forces households to choose between heating and essential needs like food and medicine	Drehobl & Ross (2016)
Economic Burden & Trade-offs	Energy insecurity contributes to material hardship and limits healthcare utilization.	Hernández (2016)
Behavioral Adaptation & Mental Health	Energy-related stress correlates with anxiety, depression, and isolation	Jessel et al. (2019)
Behavioral Adaptation & Mental Health	Behavioral coping strategies often place health and safety at risk	Cook et al. (2008)
Climate Vulnerability & Health Systems	Extreme weather events exacerbate grid instability and reduce healthcare system capacity	Baker et al. (2018)
Climate Vulnerability & Health Systems	Health system resilience depends on energy reliability for cold chains, equipment, and communications	Blanchet et al. (2017)
Energy Justice & Equity	Energy injustice results in disproportionate burdens for marginalized communities	Healy & Barry (2017)
Energy Justice & Equity	A just energy transition must consider equity, recognition, and fair distribution of costs and benefits	Sovacool et al. (2019)

Source: Authors' research

The findings demonstrate that energy insecurity not only reflects material deprivation but also reproduces cycles of vulnerability that manifest in poor physical and mental health outcomes. Importantly, these effects are not merely additive, they interact in nonlinear and reinforcing ways that exacerbate existing social inequalities, particularly among already marginalized populations. A major insight emerging from the reviewed literature is the circular nature of energy-health deprivation. Poor housing and unreliable infrastructure not only expose individuals to environmental hazards but also increase long-term health expenditures, which in turn reduce disposable income and the ability to invest in safer energy options. This cycle is further intensified when behavioral adaptations, intended to preserve energy or finances, inadvertently introduce new health risks, such as the use of open flames or the restriction of heating in cold months.

When assessing the health impacts of energy insecurity, scholars distinguish between direct and indirect effects. Direct health outcomes include cardiovascular and respiratory illnesses, arthritis, cancer, anxiety, and depression (Liddell & Morris, 2010), while indirect pathways involve mediators such as food insecurity, social stress, and reduced healthcare access (Graff et al., 2021). Jessel et al. (2019) offer an important heuristic model that categorizes energy insecurity as either chronic, a persistent inability to meet basic energy needs, or acute, which results from temporary disruptions such as fuel shortages or power outages. Their model identifies predictors, mediators, and outcomes, revealing how energy insecurity functions as a systemic feedback loop in which certain factors can act as both cause and consequence, worsening over time and increasing health risks. The COVID-19 pandemic exemplified how external crises can intensify energy insecurity (Boateng et al., 2021). Prior to 2020, energy vulnerability in the United States was already projected to rise due to infrastructure costs and policy shifts. The pandemic introduced new stressors: stay-at-home orders elevated residential energy demand, while hygiene protocols and healthcare costs strained household budgets. Despite this, energy insecurity was largely absent from emergency policy frameworks, highlighting a critical gap in government responses (Graff & Carley, 2020). The concept of energy insecurity as a social determinant of health underscores the need for health policy frameworks to move beyond clinical settings and incorporate broader infrastructural and environmental conditions. Similarly, the energy justice perspective reveals that technical solutions alone, such as grid expansion or fuel subsidies, are insufficient unless they are accompanied by policies that address procedural fairness and distributive equity. Without a justice-centered approach, energy

transitions risk reinforcing rather than resolving health disparities.

In addition, the growing relevance of climate change as a stressor on energy systems further complicates the health-energy nexus. Extreme weather events, grid instability, and rising energy prices will likely intensify both system-level and household-level energy insecurity in the coming decades. Health systems, therefore, must be treated not only as responders but as stakeholders in energy resilience planning. Climate-related disruptions disproportionately impact those already experiencing chronic energy insecurity, reducing their ability to adapt and recover. As such, climate change compounds the health consequences of energy insecurity and reinforces the structural barriers that prevent equitable access to essential services. In this context, exploring the energy-health-justice nexus offers a promising analytical lens for policy innovation. It shifts the conversation from short-term interventions to systemic change, calling for governance models that prioritize social equity, resilience, and long-term sustainability.

5. CONCLUSIONS

Energy insecurity is more than a technical or economic issue, it is a public health concern with profound social, physical, and psychological implications. Through this multi-dimensional analysis, it is clear that energy insecurity affects health outcomes through intersecting pathways that include inadequate housing, high economic burden, and risky behavioral adaptations. These effects are unevenly distributed, with low-income, marginalized, and medically vulnerable populations facing the greatest risks. Policymakers must begin to treat energy as a determinant of health and incorporate energy access considerations into health equity agendas. This includes funding for infrastructure improvements, targeted subsidies for vulnerable populations, and integrated resilience planning between the energy and health sectors. Moreover, energy transitions must be designed not only for sustainability but for justice, ensuring that no population bears a disproportionate burden of energy deprivation or environmental harm.

Future research should focus on generating robust, regionally sensitive data and developing interdisciplinary frameworks that inform both policy and practice. By embracing a systems perspective and recognizing the health consequences of energy insecurity, societies can move toward more equitable, resilient, and humane models of development.

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